Alaska Department of Environmental Conservation

Amendments to:
State Air Quality Control Plan

Vol. II: Analysis of Problems, Control Actions
Section III. K: Areawide Pollutant Control Program for Regional Haze

Public Review Draft

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Alaska Department of Environmental Conservation

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State Air Quality Control Plan

Volume II: Analysis of Problems, Control Actions
Section III. K: Areawide Pollutant Control Program for Regional Haze

Table of Contents

Page

SECTION III.K AREAWIDE POLLUTANT CONTROL PROGRAM FOR REGIONAL HAZE 1-1

III.K.1 PURPOSE AND SCOPE OF THE ALASKA REGIONAL HAZE STATE IMPLEMENTATION PLAN 1-1

A. Overview 1-1

B. Why Visibility? 1-2

C. EPA's Visibility Regulations and the Regional Haze Rule 1-3

1. History of the Visibility Program 1-3
2. Summary of the 1999 Federal Regional Haze Rule 1-6
3. Elements of the Regional Haze Plan 1-7

III.K.2 VISIBILITY AND REGIONAL HAZE 2-1

A. Overview 2-1

B. Sources of Visibility Impairment 2-2

1. Natural Sources 2-2
2. Anthropogenic Sources 2-2

C. Measuring or Quantifying Visibility Impairment 2-3

D. Monitoring Visibility 2-4

1. Overview of the IMPROVE Program 2-4
2. IMPROVE Algorithms 2-7

III.K.3 OVERVIEW OF ALASKA AND AIR QUALITY 3-1

A. Overview of Alaska 3-1

1. Geography 3-1
2. Topography 3-3
3. Economy 3-3

B. Sources of Pollution 3-3
1. International Long-Range Transport of Aerosols to Alaska 3-4
2. Biogenic Aerosols 3-6
3. Sources of Visibility Impairment Summary 3-8
C. Monitoring Strategy and Air Quality Data 3-9
1. Statewide Pollutant Monitoring 3-9
2. Regional Haze Monitoring 3-10
III.K.4 CHARACTERIZATION OF MONITORED IMPACTS AT ALASKA CLASS I AREAS 4-1
A. Natural Conditions and Visibility Baselines 4-1
1. Determining Natural Conditions 4-1
2. Determining Baselines 4-2
3. Rates of Progress and Glideslopes 4-3
4. Alaska Class I Area Natural Conditions 4-3
5. Baseline 4-6
6. Change: Natural Conditions, Baselines, and Glideslopes for Alaska's Class I Areas 4-6
7. Choice of IMPROVE II Algorithm 4-18
8. Choice of Baseline Years 4-18
B. Simeonof Wilderness Area 4-20
1. Baseline Conditions 4-20
2. Origins of Aerosol Species Influencing Regional Haze at Simeonof Class I Area 4-20
3. Best Days and Worst Days, 2002-2004 4-22
4. Correlations Among Aerosol Species at Simeonof 4-40
5. Effects of Volcanism on Visibility at Simeonof 4-43
6. Evaluation of the Effects of Uncontrollable Processes on Species at Simeonof Class I Area 4-45
C. Denali National Park 4-47
1. Baseline Conditions 4-47
2. Origins of Aerosol Species Influencing Regional Haze at Denali Class I Area 4-49
3. Best Days and Worst Days, Baseline Years 4-50
4. Correlations Among IMPROVE Aerosols Monitored at DENA1 and TRCR1 4-65
5. Wildfire Impacts Within Denali National Park 4-68
6. Correlations Between the TRCR1 and DENA1 Air Monitoring Sites 4-77

7. Light Extinction of Individual Species, Best/Worst Days, Seasonal Patterns 4-80
8. Evaluation of the Effects of Uncontrollable Processes on Species of Pollutants at Denali 4-94
D. Tuxedni (TUXE) 4-96
1. Baseline Conditions 4-96
2. Origins of Aerosol Species Influencing Regional Haze at Tuxedni Class I Area 4-97
3. Best Days and Worst Days, Baseline Years 4-99
4. Correlations Among IMPROVE Aerosols Monitored at TUXE1 4-109
5. Light Extinction of Individual Species: Best/Worst Days, Seasonal Patterns 4-112
6. Fire Impacts at Tuxedni 4-118
7. Evaluation of the Effects of Uncontrollable Processes 4-119
E. Bering Sea Wilderness Area 4-120
1. Origins of Aerosol Species Influencing Regional Haze at Bering Sea Class I Area 4-120
2. Influence of Wind and Weather on Visibility at the Bering Sea Class I Area 4-120
3. Potential for Oil Development 4-120
4. Future Visibility Impacts at Bering Sea Class I Area 4-121
III.K.5 EMISSION INVENTORY 5-1
A. Baseline and Future-Year Emissions Inventories for Modeling 5-1
B. 2002 Baseline Inventory 5-3
C. 2018 Future-Year Inventory 5-4
D. Inventories for Specific Source Categories 5-4
1. 2002-2018 Growth Revisions 5-6
2. Revisions to Anchorage, Fairbanks, and Juneau Emission Estimates 5-6
3. Revisions to the Mat-Su and Kenai Emission Estimates 5-7
4. Stationary Point Sources 5-8
5. Stationary Area Sources 5-9
6. Non-Road Mobile Sources 5-9
7. On-Road Mobile Sources 5-10
8. Biogenic Emissions Sources 5-10
9. Geogenic Emissions Sources 5-10
10. Wild and Other Fires 5-11
11. International Transported Emissions 5-11
E. Inventory Processing and Gridding 5-11

1. Grid Domain 5-11
2. Spatial Allocation 5-12
3. Gridded Emissions by Source Sector 5-13
F. Summary of Emission Inventories 5-23
III.K.6 BEST AVAILABLE RETROFIT TECHNOLOGY CONTROL PROGRAM (BART) 6-1
A. Alaska BART Regulations Overview and Public Process 6-1
1. Public Process for BART Determinations 6-1
2. BART Process in Regulations: 18A AAC 50.260 6-1
3. Identification of BART-Eligible Sources 6-3
4. Identification of BART Eligible Emission Units 6-3
B. BART Determination Process 6-4
1. Chugach Electric Association, Beluga River Power Plant 6-5
2. Alyeska Pipeline Service Company, Valdez Marine Terminal 6-5
3. Tesoro, Kenai Refinery 6-5
4. Anchorage Municipal Light & Power, Sullivan Plant 6-6
5. ConocoPhillips Alaska, Inc. Kenai LNG Plant 6-7
6. Agrium, Chem-Urea Plant 6-8
7. Golden Valley Electric Association, Healy Power Plant (GVEA) 6-9
C. BART Determination Summary 6-11
III.K.7 AIR QUALITY MODELING OF SOURCE REGIONS 7-1
A. Overview 7-1
B. Back Trajectory Analysis 7-2
C. Weighted Emissions Potential Analysis 7-7
1. Denali 7-11
2. Simeonof 7-11
3. Trapper Creek 7-11
4. Tuxedni 7-12
III.K.8 LONG-TERM STRATEGY 8-1
A. Overview of the Long-Term Strategy Development Process 8-1
1. Summary of Manmade Sources of Visibility Impairment Considered in the Long-Term Strategy 8-2
2. Technical Documentation 8-2
B. Long-Term Strategy Measures 8-3
1. Emission Reductions Due to Ongoing Air Pollution Programs 8-3

2. Measures to Mitigate Impacts of Construction Activities 8-9
3. Emission Limitations and Schedules for Compliance 8-9
4. Source Retirement and Replacement Schedules 8-9
5. Smoke Management Techniques for Agricultural and Forestry Burning 8-10
6. Enforceability of Emission Limitations and Control Measures 8-11
7. Anticipated Net Effect on Visibility Over the Period of the Long-Term Strategy 8-11

III.K.9 REASONABLE PROGRESS GOALS 9-1

A. Overview 9-1
B. Steps in Demonstrating Reasonable Progress 9-1
C. Summary of Four-Factor Analysis 9-2
1. Rationale and Scope of the Four-Factor Analysis 9-3
2. Identification of Sources for Four-Factor Analysis 9-4
D. Review of Additional Emission Reductions 9-33
E. Determination of Reasonable Progress Goals 9-36
F. Affirmative Demonstration of RPGs for 20% Worst Days 9-42

III.K.10 COMMITMENT TO FUTURE 308 PLAN REVISIONS 10-1

III.K.11 CONSULTATION 11-1

A. FLM Consultation 11-1
B. Tribal Consultation 11-2
C. Inter-State Consultation/Coordination 11-2
D. Regional Planning Coordination 11-2
E. Public Participation and Review Process 11-3

III.K.12 REFERENCES 1

List of Figures

Page

Figure III.K.1-1 Mandatory Class I Areas 1-4
Figure III.K.1-2 Alaska Class I Areas 1-4
Figure III.K.2-3 Visibility Measurement Scale 2-3
Figure III.K.3-1 Climate Regions of Alaska 3-1
Figure III.K.3-2 Improve Visibility Data for Denali National Park 3-4
Figure III.K.3-3 Map of Denali National Park and Preserve 3-12

Figure III.K.3-4 Map of Simeonof Wilderness Area 3-13

Figure III.K.3-5 Map of Tuxedni National Wildlife Refuge and Surrounding Area 3-15

Figure III.K.3-6 Map of Bering Sea Wilderness Area 3-16

Figure III.K.4-1 Natural Haze Levels II 4-5

Figure III.K.4-2 Glideslopes 4-9

Figure III.K.4-3 Baseline and Glideslope for Visibility at Simeonof, in Extinction (Mm^{-1}) 4-11

Figure III.K.4-4 Baseline and Glideslope for Visibility at Denali in Extinction (Mm^{-1}) 4-13

Figure III.K.4-5 Baseline and Glideslope for Visibility at Denali, Trapper Creek, in Extinction (Mm^{-1}) 4-15

Figure III.K.4-6 Baseline and Glideslope for Visibility at Tuxedni, in Extinction (Mm^{-1}) 4-17

Figure III.K.4-7 Proportional Representation of IMPROVE Aerosols at Simeonof, Average of 2002-2004 4-21

Figure III.K.4-8 Proportional Representation of IMPROVE Aerosols at Simeonof, Best and Worst Days, 2002-2004 4-23

Figure III.K.4-9 Relative Contributions of Rayleigh Scattering to Visibility Impairment at Simeonof (SIME1), Best (56%) and Worst Days (18%) 4-24

Figure III.K.4-10 Proportional Representation of IMPROVE Aerosols at Simeonof for Each Calendar Quarter of Baseline Years 4-26

Figure III.K.4-11 2002-2005 Proportional Representation of Aerosol Species at Simeonof 4-28

Figure III.K.4-12 2002-2005 Proportional Representation of Aerosol Species Excluding Sea Salt, at Simeonof 4-29

Figure III.K.4-13 2002 IMPROVE Species Contributions to Visibility Impairment by Sampling Day, at Simeonof 4-31

Figure III.K.4-14 2002 IMPROVE Species Contributions to Visibility Impairment by Sampling Day, at Simeonof 4-32

Figure III.K.4-15 Sea Salt Contribution to Visibility Impairment by Sampling Day, at Simeonof 4-33

Figure III.K.4-16 Sulfate Contribution to Visibility Impairment at Simeonof, by Sampling Day 4-34

Figure III.K.4-17 Soil Contribution to Visibility Impairment by Sampling Day, at Simeonof 4-35

Figure III.K.4-18 Nitrate Contribution to Visibility Impairment by Sampling Day, at Simeonof 4-36

Figure III.K.4-19 Coarse Matter Contribution to Visibility Impairment by Sampling Day, at Simeonof 4-37

Figure III.K.4-20 Elemental Carbon Contribution to Visibility Impairment by Sampling Day, at Simeonof 4-38

Figure III.K.4-21 Organic Matter Contribution to Visibility Impairment by Sampling Day, at Simeonof 4-39

Figure III.K.4-22 Wind Speed and Direction Frequency at Cold Bay Airport, Alaska Energy Authority 42

Figure III.K.4-23 Monitoring Status of Active Volcanoes in Alaska (Alaska Volcano Observatory) 4-44

Figure III.K.4-24 Contrasting Natural Visibility Conditions at Simeonof with Baseline Impairment from Probable Anthropogenic and Non-Anthropogenic Aerosols 4-46

Figure III.K.4-25 Proportional Representation of IMPROVE Aerosols at Denali, Baseline Years 4-48

Figure III.K.4-26 Proportional Representation of IMPROVE Aerosols on Best and Worst Days at Denali, Baseline Years 4-52

Figure III.K.4-27 Relative Contributions of Rayleigh Scattering to Visibility Impairment at Denali on Best and Worst Days 4-53

Figure III.K.4-28 Proportional Representation of IMPROVE Aerosols for Days of Each Calendar Quarter at Denali, Baseline Years 4-55

Figure III.K.4-29 2002-2006 Proportional Representation of IMPROVE Aerosols on Best and Worst Days at Denali, Directly Comparable Years 4-57

Figure III.K.4-30 2002 Proportional Representation of IMPROVE Aerosols at Denali on Best and Worst Days 4-58

Figure III.K.4-31 2005 Proportional Representation of IMPROVE Aerosols at Denali on Best and Worst Days 4-59

Figure III.K.4-32 2002-2006 Contribution of Aerosol Species to Light Extinction at Denali on Best and Worst Days 4-60

Figure III.K.4-33 Contribution of Aerosol Species to Light Extinction on Best and Worst Days at Denali IMPROVE Sites, Individual Years 2000-2006 4-61

Figure III.K.4-34 Interannual Visibility Impairment by Nitrate and Sulfate at Denali, 2002-2006 4-67

Figure III.K.4-35 2002 Visibility Impairment by Nitrate and Sulfate at Denali 4-68

Figure III.K.4-36 2000-2006 Extinction Due to Organic Matter Carbon and Elemental Carbon Aerosols at Denali (Mm^{-1}) 4-69

Figure III.K.4-37 2002-2006 Yearly Histograms of Extinction Due to Organic Matter Carbon and Elemental Carbon Aerosols at Denali 4-70

Figure III.K.4-38 Best and Worst Days, Relative Contributions of Organic Matter Carbon and Elemental Carbon at Denali for 2000-2006, 2002-2006, 2002, 2006 4-72

Figure III.K.4-39 Typical Yearly Maps of Wildfires Surrounding Denali for 2002, 2004 4-73

Figure III.K.4-40 Compilation Map of Wildfires Surrounding Denali for 1990-2009 4-74

Figure III.K.4-41 Compilation Map of Wildfires Surrounding Denali for 2000-2006 4-75

Figure III.K.4-42 Seasonal Differences in the OMC/EC Ratios of Aerosols at Denali IMPROVE Sites 4-76

Figure III.K.4-43 2002-2006 Contribution of Sea Salt to Light Extinction at Denali 4-80

Figure III.K.4-44 2004 Contribution of Sea Salt to Light Extinction on Best and Worst Days at Denali 4-81

Figure III.K.4-45 2000-2006 Contributions of Sulfate at Denali 4-82

Figure III.K.4-46 2002 and 2005 Contributions of Sulfate at Denali 4-83

Figure III.K.4-47 2000-2006 contributions of Soil at Denali 4-85

Figure III.K.4-48 2002 Contributions of Soil at Denali 4-86

Figure III.K.4-49 2000-2006 Contributions of Nitrate at Denali 4-87

Figure III.K.4-50 2002 and 2004 Contributions of Nitrate at Denali 4-88

Figure III.K.4-51 2000-2006 Contributions of Coarse Mass at Denali 4-89

Figure III.K.4-52 2002 Contributions of Coarse Mass at Denali 4-90

Figure III.K.4-53 2000-2006 Contributions of Elemental Carbon at Denali 4-91

Figure III.K.4-54 2002 Contributions of Elemental Carbon at Denali 4-92

Figure III.K.4-55 2002-2004 Contributions of Organic Matter Carbon at Denali (TRCR1 Site) 4-93

Figure III.K.4-56 2002 Contributions of Organic Matter Carbon at Denali 4-94

Figure III.K.4-57 Contrasting Light Extinction of Alaskan Anthropogenic Aerosols at Denali with Extinction Due to Non-Anthropogenic and Overseas Aerosol Sources with Natural Conditions 4-95

Figure III.K.4-58 Proportional Representation of IMPROVE Aerosols at Tuxedni, 2002-2004 Average 4-97

Figure III.K.4-59 Proportional Representation of IMPROVE Aerosols on Best and Worst Days at Tuxedni, 2002-2004 4-100

Figure III.K.4-60 Relative Contributions of Rayleigh Scattering to Visibility Impairment at Tuxedni on Best (80%) and Worst days (28%) 4-100

Figure III.K.4-61 Proportional Representation of IMPROVE Aerosols at Tuxedni for Best and Worst Days of Each Calendar Quarter, 2002-2004 4-102

Figure III.K.4-62 Proportional Representation of Aerosol Species at Tuxedni, Yearly Summaries Best and Worst Days, 2002-2006 4-104

Figure III.K.4-63 2002-2004 Proportional Representation of Aerosol Species at Tuxedni, Excluding Sea Salt, Organic Matter, Coarse Matter, and Elemental Carbon 4-105

Figure III.K.4-64 Contribution of Aerosol Species to Light Extinction at Tuxedni on Best and Worst Days, 2002-2006 4-106

Figure III.K.4-64 (continued) Contribution of Aerosol Species to Light Extinction at Tuxedni on Best and Worst Days, 2002-2006 4-108

Figure III.K.4-65 2005 IMPROVE Species Contribution to Visibility Impairment at Tuxedni Sampling Day 4-109

Figure III.K.4-66 Sea Salt at Tuxedni for 2004, 2005 4-112

Figure III.K.4-67 Organic Matter Carbon at Tuxedni for 2002-2006 4-113

Figure III.K.4-68 Organic Matter Carbon at Tuxedni for 2005, 2006 4-113

Figure III.K.4-69 Elemental Carbon at Tuxedni for 2002-2006 4-114

Figure III.K.4-70 Elemental Carbon at Tuxedni for 2005 4-114

Figure III.K.4-71 Sulfate at Tuxedni for 2002-2006 4-115

Figure III.K.4-72 Sulfate at Tuxedni for 2005 4-115

Figure III.K.4-73 Nitrate at Tuxedni for 2002-2006 4-116

Figure III.K.4-74 Nitrate at Tuxedni for 2003 4-116

Figure III.K.4-75 Soil at Tuxedni for 2002-2005 4-117

Figure III.K.4-76 Coarse Mass at Tuxedni for 2002-2005 4-118

Figure III.K.4-77 Contrasting Natural Visibility Conditions at Tuxedni with Baseline Impairment from Probable Anthropogenic and Non-Anthropogenic Aerosols 4-119

Figure III.K.4-78 Alaska Program Areas Outer Continental Shelf Oil and Gas Leasing Program 4-121

Figure III.K.5-1 Areal Extent of Alaska Regional Haze Modeling Domain 5-2

Figure III.K.5-2 Alaska Regional Haze Inventory 45 Km Grid Structure 5-12

Figure III.K.5-3 Baseline 2002 $PM_{2.5}$ Gridded Area Source Emissions (tons/year) 5-15

Figure III.K.5-4 Baseline 2002 $PM_{2.5}$ Gridded Non-Road Mobile Source (tons/year) 5-16

Figure III.K.5-5 Baseline 2002 $PM_{2.5}$ Gridded On-Road Mobile Source Emissions (tons/year) 5-17

Figure III.K.5-6 Baseline 2002 $PM_{2.5}$ Gridded Point Source Emissions (tons/year) 5-18

Figure III.K.5-7 Baseline 2002 $PM_{2.5}$ Gridded Commercial Marine Vessel Emissions (tons/year) 5-19

Figure III.K.5-8 Baseline 2002 $PM_{2.5}$ Gridded Aviation Source Emissions (tons/year) 5-20

Figure III.K.5-9 Baseline 2002 $PM_{2.5}$ Gridded Anthropogenic Fire Emissions (tons/year) 5-21

Figure III.K.5-10 5-22

Baseline 2002 $PM_{2.5}$ Gridded Natural Fire Emissions (tons/year) 5-22

Figure III.K.7-1 Denali National Park, AK – Normalized Back-Trajectory Residence Time 20% Worst Visibility Days 7-3

Figure III.K.7-2 Denali National Park, AK – 20% Best Visibility Days 7-3

Figure III.K.7-3 Trapper Creek Wilderness, AK – Normalized Back-Trajectory Residence Time 20% Worst Visibility Days 7-4

Figure III.K.7-4 Trapper Creek Wilderness, AK – Normalized Back-Trajectory Residence Time 20% Best Visibility Days 7-4

Figure III.K.7-5 Simeonof Wilderness, AK – Normalized Back-Trajectory Residence Time 20% Worst Visibility Days 7-5

Figure III.K.7-6 Simeonof Wilderness, AK – Normalized Back-Trajectory Residence Time 20% Best Visibility Days 7-5

Figure III.K.7-7 Tuxedni – Normalized Back-Trajectory Residence Time 20% Worst Visibility Days 7-6

Figure III.K.7-8 Tuxedni – Normalized Back-Trajectory Residence Time 20% Best Visibility Days 7-6

Figure III.K.7-9 Denali National Park, AK – Normalized Weighted Emission Potential (WEP) for Fine Particulate Matter ($PM_{2.5}$) 2002-04 Baseline, 20% Worst Visibility Days 7-10

Figure III.K.7-10 Denali National Park, AK – Normalized Weighted Emission Potential (WEP) for Fine Particulate Matter ($PM_{2.5}$) 2018 Base Case, 20% Worst Visibility Days 7-10

Figure III.K.9-1 Review of URP Glide path and WEP Trend, Baseline to 2018 for 20% Worst Days, Denali 9-38

Figure III.K.9-2 Review of URP Glide path and WEP Trend, Baseline to 2018 for 20% Worst Days, Simeonof 9-38

Figure III.K.9-3 Review of URP Glide path and WEP Trend, Baseline to 2018 for 20% Worst Days, Trapper Creek 9-39

Figure III.K.9-4 Review of URP Glide path and WEP Trend, Baseline to 2018 for 20% Worst Days, Tuxedni 9-39

List of Tables

Page

Table III.K.2-1 IMPROVE Parameters Contributing to Regional Haze, Algorithms and Descriptions 2-5

Table III.K.2-2 Key to Haze Pollutant Species and Their Abbreviations 2-7

As Used Throughout This Document 2-7

Table III.K.4-1 Natural Condition Estimates by Aerosol Species for Alaska's Four Class I Areas Using the IMPROVE II Algorithm 4-4

Table III.K.4-2 Baseline Estimates, by aerosol species for Alaska's Four Class I Areas Using the IMPROVE II Algorithm 4-7

Table III.K.4-3 Worst Day Visibilities for Natural Conditions and Baseline Estimates Using the IMPROVE II Algorithm, and the Resulting 10-Year Glide Slope Estimates 4-8

Table III.K.4-4 Baseline, Natural Conditions, Interim Glideslope, and Yearly Summaries at Simeonof, in Extinction (Mm^{-1}) 4-10

Table III.K.4-5 Baseline, Natural Conditions, Interim Glideslope, and Yearly Summaries at Denali in Extinction (Mm^{-1}) 4-12

Table III.K.4-6 Baseline, Natural Conditions, Interim Glideslope, and Yearly Summaries at Denali, Trapper Creek, in Extinction (Mm^{-1}) 4-14

Table III.K.4-7 Baseline, Natural Conditions, Interim Glideslope, and Yearly Summaries at Tuxedni, in Extinction (Mm^{-1}) 4-16

Table III.K.4-8 Algorithm Comparison, Worst Days Natural Conditions and Glide Slopes from Baseline to Natural Conditions in 2064 4-18

Table III.K.4-9 Three- and Five-Year Baseline Averages for Best and Worst Days, in Deciviews 4-19

Table III.K.4-10 Average Light Extinctions at Simeonof on Best and Worst Days, 2002-2004 4-23

Table III.K.4-11 Incidence of Best Days and Worst Days for Simeonof, Totaled by Month, 2002-2004 4-25

Table III.K.4-12 Pearson Correlation Coefficients Between Aerosol Species Mass at Simeonof 4-41

Table III.K.4-13 Average Light Extinctions on Best and Worst Days for Baseline Years at Denali 4-51

Table III.K.4-14 Incidence of Best Days and Worst Days, Totaled by Month at Denali, Baseline Years 4-54

Table III.K.4-15 Pearson Correlation Coefficients Between Aerosol Species at Denali 4-65

Table III.K.4-16 Aerosol Species' Pearson Correlations Between Denali Monitoring Sites for 2002-2006 4-77

Table III.K.4-17 Correspondence of Worst Days at Denali IMPROVE Monitoring Sites 4-78

Table III.K.4-18 Aerosol Compositions at Denali of 2003 Days for Which Only One Monitoring Site Recorded a Worst Day 4-79

Table III.K.4-19 Annual Variability in Sulfate Aerosols at Denali, Peak Months and Light Extinction 4-84

Table III.K.4-20 Annual Variability in Soil Aerosols at Denali, Peak Months and Light Extinction 4-86

Table III.K.4-21 Average Light Extinctions on Best and Worst Days, for 2002-2004 Baseline Years at Tuxedni, in Mm^{-1} 4-99

Table III.K.4-22 Incidence of Best Days and Worst Days, Totaled by Month at Tuxedni, 2002-2004 Baseline Years 4-101

Table III.K.4-23 Contrasting Extinctions in Years with Different Relative Proportions of Aerosol Species at Tuxedni, 2002-2005 vs. 2006 4-103

Table III.K.4-24 Patterns of Extinction Among Worst Days at Tuxedni, Seasons and Aerosol Species 4-108

Table III.K.4-25 Pearson Correlation Coefficients Between Aerosol Species at Tuxedni for All Days and for Worst Days 4-110

Table III.K.5-1 Summary of Regional Haze Emission Inventory Components 5-5

Table III.K.5-2 Changes in 2005 Population Estimates and 2018 Forecasts 5-6

Table III.K.5-3 Changes in 2003 Population Estimates and 2018 Forecasts 5-7

Table III.K.5-4 2002 Alaska Statewide Regional Haze Inventory Summary 5-23

Table III.K.5-5 2018 Alaska Statewide Regional Haze Inventory Summary 5-24

Table III.K.5-6 Relative Change in Alaska Regional Haze Emissions from 2002 to 2018 5-24

Table III.K.6-1 Summary of BART-Eligible Facility Analysis 6-12

Table III.K.6-2 Summary of BART Determination Findings, 98th Percentile Delta-Deciview, 2002-2004 6-12

Table III.K.7-1 Summary of Boroughs With Highest Weighted Emission Potential, Impacting Denali Monitoring Site on 20% Worst Days 7-13

Table III.K.7-2 Summary of Boroughs With Highest Weighted Emission Potential, Impacting Simeonof Monitoring Site on 20% Worst Days 7-14

Table III.K.7-3 Summary of Boroughs With Highest Weighted Emission Potential, Impacting Trapper Creek Monitoring Site on 20% Worst Days 7-15

Table III.K.7-4 Summary of Boroughs With Highest Weighted Emission Potential, Impacting Tuxedni Monitoring Site on 20% Worst Days 7-16

Table III.K.7-5 Summary of Total Weighted Emission Potential From All Boroughs Impacting Each Site on 20% Worst Days 7-17

Table III.K.9-1 Total Change in WEP Values for NOx, SOx, and $PM_{2.5}$ at Each Class I Area Monitoring Site 9-6

Table III.K.9-2 Distribution of WEP Values for Point Source Categories With the Potential to Significantly Impact Each Class I Area 9-6

Table III.K.9-3 Distribution of WEP Values for Area Source Categories With the Potential to Significantly Impact Each Class I Area 9-8

Table III.K.9-4 Alaska Industrial Boiler Emissions 9-9

Table III.K.9-5 Control Options for Coal-Fired Industrial Boilers 9-10

Table III.K.9-6 Control Options for Natural Gas-Fired Industrial Boilers 9-10

Table III.K.9-7 Control Options for Oil-Fired Industrial Boilers 9-11

Table III.K.9-8 Estimated Costs for Control of Coal-Fired Industrial Boilers 9-12

Table III.K.9-9 Estimated Costs for Control of Natural Gas-Fired Industrial Boilers 9-12

Table III.K.9-10 Estimated Costs for Control of Oil-Fired Industrial Boilers 9-13

Table III.K.9-11 Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures for Coal-Fired Industrial Boilers 9-14

Table III.K.9-12 Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Natural Gas-Fired Industrial Boilers 9-15

Table III.K.9-13 Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures for Oil-Fired Industrial Boilers 9-15

Table III.K.9-14 Alaska Petroleum Refinery Emissions 9-17

Table III.K.9-15 Alaska Petroleum Refinery Emissions 9-17

Table III.K.9-16 Control Options for Petroleum Refineries 9-18

Table III.K.9-17 Estimated Costs for Control of Petroleum Refineries 9-19

Table III.K.9-18 Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Petroleum Refineries 9-21

Table III.K.9-19 Alaska Industrial Boiler Emissions 9-24

Table III.K.9-20 Control Options for Turbines 9-24

Table III.K.9-21 Control Options for Reciprocating Engines with Gaseous Fuels 9-25

Table III.K.9-22 Control Options for Reciprocating Engines with Diesel and Other Liquid Fuels 9-25

Table III.K.9-23 Estimated Costs for Control of Turbines 9-26

Table III.K.9-24 Estimated Costs for Control of Reciprocating Engines with Gaseous Fuels 9-26

Table III.K.9-25 Estimated Costs for Control of Reciprocating Engines with Diesel and Other Liquid Fuel 9-27

Table III.K.9-26 Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Turbines 9-29

Table III.K.9-27 Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Reciprocating Engines with Gaseous Fuels 9-30

Table III.K.9-28 Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Reciprocating Engines with Diesel and Other Liquid Fuels 9-32

Table III.K.9-29 Change in Anthropogenic Share of WEP Forecast of Individual Pollutants for Each Class I Area Between Baseline and 2018 for 20% Worst Days (% Share of All Anthropogenic and Nonanthropogenic Sources) 9-34

Table III.K.9-30 Calculation of Uniform Rate of Progress Target Reduction for 2018, 20% Worst Days (deciview) 9-36

Table III.K.9-31 Comparison Between % Change in WEP Forecast of Individual Pollutants and..... 9-36

Glide Path Reduction Targets Between Baseline and 2018 for 20% Worst Days As Indicator of "Reasonable Progress" (all sources) 9-36

List of Appendices

APPENDIX III.K.2
IMPROVE Algorithms

APPENDIX III.K.3
Overview of Alaska and Air Quality

APPENDIX III.K.4.a
Volcanic Activity Reports for Baseline Years

APPENDIX III.K.4.b
Maps of Wildfires affecting Alaska's Class 1 Areas

APPENDIX III.K.5
Emission Inventory

APPENDIX III.K.6
BART Documentation

APPENDIX III.K.7
Air Quality Modeling of Source Regions

APPENDIX III.K.8
Alaska Enhanced Smoke Management Plan

APPENDIX III.K.9
Reasonable Progress Goals

APPENDIX III.K.11.a
Consultation: Regional Planning, WRAP Meetings and Conference Calls

APPENDIX III.K.11.b
Consultation: Federal Land Manager Review

APPENDIX III.K.11.c
Consultation: Public Participation and Review

Introductory Note: In this document each reference to "CAAA" means the Clean Air Act Amendments of 1990, P.L. 101-549.

SECTION III.K AREAWIDE POLLUTANT CONTROL PROGRAM FOR REGIONAL HAZE

III.K.1 PURPOSE AND SCOPE OF THE ALASKA REGIONAL HAZE STATE IMPLEMENTATION PLAN

A. Overview

A State Implementation Plan (SIP) is developed and implemented by states as required by the federal Clean Air Act (CAA), with formal approval and administration by the U.S. Environmental Protection Agency. A SIP consists of narrative overviews, background information, strategy plans, technical data, data analyses, and implementation plans for complying with CAA requirements. In Alaska, the Air Quality Control Plan, which contains the required SIPs for Alaska, is incorporated by reference into state regulations at 18 AAC 50.030.

This chapter of the Alaska Air Quality Control Plan addresses the federal rules for protection of visibility specifically related to regional haze. These federal rules were adopted to fulfill requirements of Section 169B of the Clean Air Act, which has as its purpose to protect and improve visibility at specified federal land units identified as Class I Areas. Class I Areas include national parks greater than 6,000 acres, wilderness areas and national memorial parks greater than 5,000 acres, and international parks that existed as of August 1977.

Despite Alaska's many national parks, forests, wildlife refuges, and wilderness areas, Alaska has only four such mandatory areas because most of these areas were set aside after the inclusion of the Class I areas in the 1977 Clean Air Act. Table III.K.1-1 lists the four Class I federal areas located within the state; as also shown in the table, no Class I federal areas located outside of the state are affected by emissions produced within Alaska.

Table III.K.1-1
Class I Federal Areas Located Inside and Outside of Alaska
Impacted by Emissions Produced Within Alaska

Class I Federal Area	Located in Alaska	Located Outside of Alaska
Denali National Park	Yes	-
Tuxedni Wilderness Area	Yes	-
Simeonof Wilderness Area	Yes	-
Bering Sea Wilderness Area	Yes	-
None	-	Yes

The United States Environmental Protection Agency (U.S. EPA) adopted the Regional Haze Rule in 1999 to protect visibility in Class I areas. The rule lays out specific requirements to ensure improvements in visibility at 156 of the largest national parks and wilderness areas across

the United States through the mitigation of human-caused air pollution impacts. The Regional Haze Rule sets out a long-term path of visibility improvement towards natural visibility conditions, to be attained by 2064. The Regional Haze Rule requires states to establish interim goals toward the final 2064 visibility goals.

This Regional Haze Plan* describes how the State of Alaska will meet federal requirements to measure and monitor visibility, aerosols, and air pollution at Alaska's four Class I Areas, how Alaska will evaluate the factors reducing visibility at each site, and how Alaska plans to identify and implement air pollution control measures to reach natural visibility conditions by the 2064 Regional Haze Rule target date. This plan includes both the characterizations of the baseline air quality at each of Alaska's Class I Areas and Alaska's strategy toward meeting the interim goals to be attained by 2018. It also presents Alaska's visibility status and goals, and represents Alaska's element of the national effort to assess visibility and visibility improvement through 2018. The SIP demonstrates specifically how 2018 visibility goals will be attained. All pollutants and aerosols affecting visibility are considered by this plan, including those entering Alaska at its borders. Air pollution sources, transport, and atmospheric precursors of aerosols originating within Alaska and entering Alaska from Asia, Europe, and Canada are considered by the SIP.

Each of the 50 states is required to address the Regional Haze Rule, but haze is inherently a regional, and frequently even international, phenomenon. Coordinated technical services, modeling, data management, and consulting have been provided by regional planning organizations. For Alaska, the Western Regional Air Partnership (WRAP) has served this function. Technical tool development, emission inventories, and air quality modeling have been conducted on a regional basis by the WRAP to support the efforts of all of the western states. Alaska has participated actively in WRAP projects, and uses WRAP technical products extensively in this plan.

The Regional Haze Rule of the Clean Air Act specifically regulates visibility, but the aerosols and pollutants that reduce visibility also impact human health and ecosystems in Alaska. Consequently, the implementation of this plan will impact Alaska's people and ecosystems in a broader manner. Alaska receives air pollutants across all its boundaries, from many international sources subject to different environmental regulations. The analysis of Alaska's air for the development of this plan gives us greater understanding of how our air quality is affected by international sources, and of where Arctic and Sub-arctic Alaska fits in the global picture of air quality.

B. Why Visibility?

Without the effects of air pollution, natural visual range is approximately 140 miles in the western United States and 90 miles in the eastern states. However, over the years, air pollution in many parts of the United States has significantly reduced the range that people can see. In the West, the current range is 35-90 miles, and in the East, only 15-25 miles. In Alaska in 2002, standard visual range at Denali National Park was approximately 133 miles. Reductions in

* The term "Regional Haze Plan" is used to refer specifically to this plan to address the requirements of the Regional Haze Rule; however, the term "Plan" and "SIP" may be used interchangeably.

Denali's visual range from existing and increasing air pollution will be evaluated as part of this SIP.

Visibility is reduced, or impaired, when particles and gases in the atmosphere reflect, scatter or absorb light. The visual range, or distance that we can see, is limited by very small particles in the air. The particles absorb and scatter sunlight, creating haze. Haze affects the color, contrast, and clarity of the vistas, wildlife, forests, seascapes, and ecosystems we can see. Good visibility is important to the enjoyment of national parks and scenic areas.

Many different types of particles and gases are released into the atmosphere through human activities. Not only do the pollutants released directly reduce visibility, but also the pollutants can react chemically with each other to create new types of pollutants which also affect visibility. The individual pollutants that create haze are measurable, for instance as sulfates, nitrates, organic carbon, elemental carbon, soil dust, or sea salt. But while many different types of pollutants contribute to impaired visibility, visibility is a single measure that includes the effects of many pollutants.

C. EPA's Visibility Regulations and the Regional Haze Rule

1. History of the Visibility Program

In 1977, Congress amended the Clean Air Act to include provisions to protect the scenic vistas of the nation's national parks and wilderness areas. In these amendments, Congress declared as a national visibility goal:

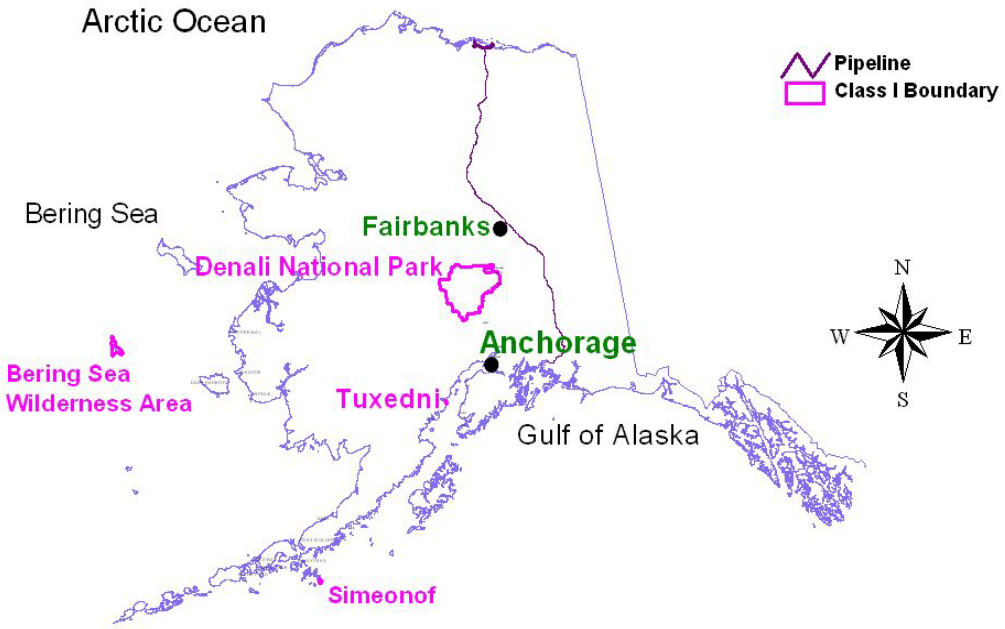
> *The prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution.* (Section 169A)

At that time, Congress designated all wilderness areas over 5,000 acres and all national parks over 6,000 acres as "mandatory federal Class I areas" ("Class I areas"). These Class I areas receive special visibility protection under the Clean Air Act. Figure III.K.1-1 shows the 156 national parks and wilderness areas designated as the Class I areas. The four Class I Areas in Alaska are shown in Figure III.K.1-2.

The 1977 Clean Air Act amendments charged Federal Land Managers (FLMs) with direct responsibility to protect the air quality and related values (including visibility) in areas of great scenic importance (that is, Class I areas) and to consider, in consultation with EPA, whether proposed industrial facilities will have an adverse impact on these values. The States were required to determine whether existing industrial sources of air pollution must be retrofitted to reduce impacts on Class I areas to acceptable levels. The EPA was tasked to report to Congress regarding methods for achieving greater visibility and to issue regulations towards that objective.

Figure III.K.1-1
Mandatory Class I Areas

Figure III.K.1-2
Alaska Class I Areas



Part C of the 1977 Clean Air Act amendments stipulated requirements to prevent significant deterioration of air quality and, in particular, to preserve air quality in national parks, national wilderness areas, national monuments and national seashores. The Prevention of Significant Deterioration (PSD) program includes area-specific (Class I, II, and III) increments or limits on the maximum allowable increase in air pollutants (particulate matter or sulfur dioxide) and a preconstruction permit review process for new or modifying major sources that allows for careful consideration of control technology, consultation with FLMs on visibility impacts, and public participation in permitting decisions.

Under Clean Air Act Section 169A(b), Congress established new requirements on major stationary sources in operation within a 15-year period prior to enactment of the 1977 amendments. Such sources to which visibility impairment can be reasonably attributed must install best available retrofit technology (BART) as determined by the State. In determining BART, the State must take into consideration the costs of compliance, the energy and non-air quality environmental impacts of compliance, any existing pollution control technology in use at the source, the remaining useful life of the source, and the degree of improvement in visibility which may reasonably be anticipated to result from the use of such technology.

On December 2, 1980, the EPA outlined a phased visibility program to ensure progress in achieving the national goal set forth by Congress. Regulations promulgated for Phase I of the program (under 40 CFR §51.300 through 307) required Alaska, 34 other states and 1 territory with mandatory Class I areas to revise their State Implementation Plans (SIPs) to include visibility protection.

Research conducted by EPA identified two general types of visibility impairment in Class I areas:

- Impairment due to smoke, dust, colored gas plumes, or layered haze emitted from stacks which obscure the sky or horizon and are relatable to a single stationary source or a small group of stationary sources.

- Impairment due to widespread, regionally homogeneous haze from a multitude for sources which impairs visibility in every direction over a large area, commonly referred to as regional haze.

EPA adopted a phased approach because it concluded that monitoring and regional scale modeling techniques, as well as knowledge concerning effectiveness of controls, were not fully developed for use in a regional haze regulatory program. EPA indicated regulations concerning more complex problems such as regional haze and urban plumes would be addressed in later phases.

Phase I of the visibility regulations focused on “reasonably attributable visibility impairment” (RAVI) and required states to:

- Coordinate SIP development with the appropriate FLMs.
- Develop programs to assess and remedy Phase I visibility impairment from existing major sources and to prevent visibility impairment from new sources.
- Develop a long-term strategy to address reasonable progress toward the national visibility goal.
- Develop a visibility monitoring strategy to collect information on visibility conditions.
- Consider in all aspects of visibility protection any "integral vistas" (important views of landmarks or panoramas that extend outside of the boundaries of the Class I area) identified by the FLMs or states as critical to the visitors' enjoyment of the Class I areas. (An integral vista that is adopted into regulation can be afforded the same level of protection from visibility impairment as the Class I area itself or any lesser level of protection, as determined by a state on a case-by-case basis.)

The EPA required affected states to submit revised SIPs satisfying these provisions by September 2, 1981.

In response to EPA's Phase I visibility rules, the Alaska Department of Environmental Conservation (ADEC) adopted regulations and State Implementation Plan revisions in 1982 that identified visibility special protection areas including the mandatory Class I areas and two integral vistas within Denali National Park and a visibility protection program for mandatory Class I areas through ADEC's PSD permitting program. This SIP was approved by EPA in the Federal Register on July 5, 1983.

2. Summary of the 1999 Federal Regional Haze Rule

The 1990 amendments to the Clean Air Act established a new Section 169(B) to address regional haze. Since regional haze and visibility problems do not respect state and tribal boundaries, the amendments also authorized EPA to establish visibility transport regions as a way to combat regional haze. The 1990 amendments also established a visibility transport commission to investigate and report on regional haze visibility impairment in the Grand Canyon National Park and nearby Class I areas. To address the 1990 Clean Air Act amendments, the problem of long-range transport of pollutants causing regional haze, and to meet the national goal of reducing man-made visibility impairment in Class I areas, EPA adopted "Phase II" visibility rules in 1999, the Regional Haze Rule. These rules can be found at 40 CFR 51.300-309 and were published in the Federal Register, Volume 64, July 1, 1999, pages 35714-35774. This regional haze SIP meets the "Section 308" requirements in 40 CFR 51.308. (The "Section 309" (40 CFR 51.309) option is available only for nine western states [Arizona, California, Colorado, Idaho, Nevada, New Mexico, Oregon, Utah, and Wyoming].)

The Regional Haze Rule requires states to adopt regional haze SIPs that focus on improving the haziest days (the worst 20%) and protecting the clearest days (the best 20%). The Rule lays out

the mechanisms by which states define long-term paths to improve visibility, with the goal of achieving visibility that reflects natural conditions by 2064. Unlike criteria pollutant SIPs, which require specific targets and attainment dates, the Regional Haze Rule requires states to establish a series of interim goals to ensure continued progress. The first planning period specifies setting reasonable progress goals for improving visibility in Class I Areas by the year 2018.

Each regional haze SIP must provide a comprehensive analysis of natural and human-caused sources of haze for each Class I area, and must contain strategies to control the sources and reduce the emissions that contribute to haze. The intent is to focus on reducing anthropogenic emissions, while achieving a better understanding and quantification of the natural causes of haze.

The Regional Haze Rule lays out specific requirements to ensure improvements in the anthropogenic components of visibility:

- The Best Available Retrofit Technology (BART) requirements address certain larger industrial sources that began operation before the adoption of the 1977 PSD Rules. Section III.K.6 of this Plan describes the BART review and evaluation in detail.

- The reasonable progress demonstration requires setting goals for the 20% worst and best days in each Class I area, based on an evaluation of how BART and other regional haze strategies will reduce emissions and improve or protect visibility. Section III.K.9 of this Plan describes the reasonable progress demonstration in detail.

3. Elements of the Regional Haze Plan

The Regional Haze Rule sets forth the goal of achieving natural visibility conditions by 2064 in all Class I Areas. Along that path, states must establish a series of interim goals to ensure continued progress. The first planning period specifies setting reasonable progress goals for improving visibility in Class I Areas by the year 2018. Specifically, the interim goals must provide for improved visibility on the 20 percent of days with the worst visibility, and ensure that there is no further degradation on the 20 percent of days with the best visibility.

A Regional Haze State Implementation Plan must contain many technical elements and analyses, as well as background information. The required elements of the plan are explained briefly in this section, and then detailed in the sections outlined below.

- Determining baseline and natural visibility conditions – Section III.K.4
- Presenting base year and future year emission inventories – Section III.K.5
- Setting reasonable progress goals for 2018 – Section III.K.9
- Documenting the strategy to attain these goals – Section III.K.8
- Determining best available retrofit technologies – Section III.K.6
- Consultation with states, tribes, and federal land managers – Section III.K.11
- Committing to a monitoring strategy – Section III.K.3
- Specifying a timeline for future Plan revisions – Section III.K.10

a. Determining Baseline and Natural Visibility Conditions

For each Class I Area in Alaska and for the baseline years of 2000-2004, the State must describe existing (current) visibility conditions on the suite of days with the best and worst visibility. The state must also establish what the best and the worst visibility would be like on days when only natural sources affect visibility, without any human-caused impairment. Achieving natural conditions for visibility on the worst days by the year 2064 is the overall goal of the Regional Haze Program.

Baseline or current visibility includes haze pollutant contributions from anthropogenic sources as well as those from natural sources, using the actual pollutant concentrations measured at IMPROVE (Interagency Monitoring of Protected Visual Environments) monitors every three days during the period of 2000-2004. The 20 percent highest days (roughly corresponding to the 24 days having the worst visibility) are averaged each year. These five yearly values are then averaged to determine the worst day visibility for the 2000-2004 baseline period. The same process is used to establish the best day baseline visibility value from the annual 20 percent best days over the baseline years.

Natural visibility conditions represent the long-term degree of visibility estimated to exist in the absence of anthropogenic impairment. Natural events such as wind storms, wildfires, volcanic activity, biogenic emissions, and even sea salt from sea breezes introduce particles from natural sources that contribute to haze in the atmosphere. Individual natural events can lead to high short-term concentrations of visibility-impairing pollutants.

Establishing the link between haze species (chemical form) and visibility impairment is the key to understanding regional haze. The haze species reflect (scatter) and absorb light in the atmosphere, thereby extinguishing light. The amount of light extinction affects visibility or the clarity of objects viewed at a distance by the human eye. The amount and type of haze species in the air can be measured, and the amount of light extinction caused by each one can be calculated, for any location or day, as visibility conditions change from good to poor throughout the year. The specific visibility measurement unit, the deciview (dv), is the natural logarithm of light extinction. The deciview is used in the Regional Haze Rule to track visibility conditions. While the deciview value describes overall visibility levels, light extinction describes the contribution of particular haze species to measured visibility. The haze species concentrations are measured as part of the IMPROVE monitoring network deployed throughout the United States.

The U.S EPA initially calculated default natural visibility conditions for all Class I areas but allowed states to develop more refined calculations. The Regional Planning Organizations nationwide funded research to refine the methods used to calculate visibility, the results of which were used to calculate the deciview values presented in this Plan. Additional research is ongoing to continue to better define natural visibility conditions in the western United States. New research is examining the increasing prevalence of wildfires in the western United States. The frequency of dust storms and their impact on areas disturbed by human vs. wildlife activities are

being investigated, as well as global transport of dust from natural desert storms in Africa and Asia. There is also increased awareness of the biogenic contributions to haze.

Section III.K.4 describes current visibility conditions in each Class I area as well as the nature of the pollutant species that contribute to the observed levels. Section III.K.9 provides further information on the role of natural versus anthropogenic contributions and how that affects the progress that can be expected by 2018.

b. Statewide Emissions Inventory of Haze-Causing Pollutants

As with any air quality analysis, a good understanding of the sources of haze pollutants is critical. The Plan includes emissions for the base year 2002, which represents the midpoint of the 2000-2004 baseline planning period, as well as future projected emissions to the year 2018. This emissions inventory was developed by the WRAP and ADEC. Alaska has developed inventories specific to Alaska conditions for urban, rural, aviation, rail, and marine sectors. Section III.K.5 provides information on emissions within Alaska, including both natural and anthropogenic source categories.

c. Reasonable Progress Goals for 2018

Reasonable progress goals are established by each state for each Class I Area as a deciview level to be achieved by 2018, the end of the first planning period. The reasonable progress goals must assure that the worst haze days get less hazy and that visibility does not deteriorate on the best days, when compared with the baseline period. WRAP and ADEC have prepared technical analyses to assess future visibility and provide the context to establish reasonable progress goals for the Class I Areas.

States must also compare their reasonable progress goals to the level of visibility improvement that would be achieved if perfectly linear progress between the current period and expected natural conditions in 2064 were to occur. This linear rate of progress is known as the uniform glide path. The uniform glide path is not a fixed standard that must be met; instead it simply provides a basis for evaluating the selected 2018 goals. Many factors come into play in determining whether the uniform glide path can be achieved in the initial progress period, including the cost and feasibility of controls as well as the appropriateness of the level set for natural conditions in 2064. The analysis of control measures leading to Alaska's selection of the reasonable progress goals is described in Section III.K.8. Section III.K.9 provides information on the WRAP and Alaska technical analyses used to establish the goals and discussion of natural versus human-caused source contributions.

d. 2018 Progress Strategy

The Plan also describes the long-term strategy that provides the necessary emission reductions to achieve the reasonable progress goals established for each Class I Area within Alaska. The Long-Term Strategy (LTS) is that portion of the Visibility SIP containing the state's 10-15 year strategy for making reasonable progress toward remedying existing and preventing future

visibility impairment. Federal law mandates a periodic review and, if necessary, revision of the Long-Term Strategy section of the plan at least every five years.

The EPA regulations require the State to (1) develop a long-term strategy; (2) coordinate its LTS with existing plans and goals, including those of federal land managers, that may affect impairment in any Class I area; (3) demonstrate why the LTS is adequate for making reasonable progress toward the national goal and state why the minimum factors were or were not addressed in developing the LTS; (4) consider the time necessary for compliance as well as the economic, energy and non-air quality environmental impacts of compliance, the remaining useful life of any affected existing source, as well as the effect of new sources; (5) review its strategy no less frequently than every 5 years and consult with federal land managers during this process; and (6) report to EPA and the public on the progress in achieving the national visibility goal.

During development of the LTS the State must consider, at a minimum, the six factors listed below.

- *Emission reductions due to ongoing air pollution control programs*. For example, the attainment and maintenance of National Ambient Air Quality Standards in the Anchorage and Fairbanks areas may reduce visibility impairment in a number of Class I areas in the state. If this is the case, the state should explain how this would contribute to reasonable progress.

- *Additional emission limitations and schedules for compliance*. States may have to control minor sources causing impairment not covered by BART to make reasonable progress toward the national goal.

- *Measures to mitigate the impacts of construction activities*. This recognizes that nearby construction activities can contribute to impairment in Class I areas. If this appears to be a problem in Alaska, the State should explain in its LTS what measures it will take to mitigate these impacts.

- *Source retirement and replacement schedules*. The construction of new sources, which will ensure the early or scheduled retirement of older, less well-controlled sources, can greatly aid progress toward the national visibility goal over the long term.

- *Smoke management techniques for agricultural and forestry management purposes including such plans as currently exist within the State for this purpose*. While EPA does not believe this is a significant cause of impairment in most states, the LTS should discuss measures that would constitute reasonable progress in relation to this issue.

- *Enforceability of emission limitations and control measures*. It is recognized that in some situations the enforceability of proposed or actual emission limitations and control measures on sources causing existing impairment may be an issue.

Section III.K.8 describes the measures included in Alaska's 2018 Long Term Progress Strategy.

e. Best Available Retrofit Technology (BART) Requirement

The BART requirement implements a federal mandate to retrofit certain very old sources that pre-date the 1977 amendments to the Clean Air Act by up to 15 years. The Plan must identify facilities that fall into any one of 26 specific source categories and contain emission units from the 1962-1977 time period having the potential to emit more than 250 tons per year of any haze pollutant. These emission units are known as BART-eligible sources. If it is demonstrated that the emissions from these sources cause or contribute to visibility impairment in any Class I Area, then the best available retrofit technology must be installed.

The determination of BART must take into consideration the costs of compliance, the energy and non-air quality environmental impacts of compliance, any existing pollution control technology in use at the source, the remaining useful life of the source, and the degree of improvement in visibility which may reasonably be anticipated to result from the use of such technology. In Alaska, there were seven facilities that fit the initial BART-eligible criteria. The systematic BART analysis carried out by ADEC is detailed in Section III.K.6.

f. Required Consultation

Preparation of the Plan and selection of reasonable progress goals requires consultation between states, FLMs, and affected tribes since haze pollutants can be transported across state lines, as well as international and tribal borders. In Alaska, Class I Areas are managed by the National Park Service (NPS) and the U.S. Fish and Wildlife Service (USFWS.) The draft Plan must be available to the FLMs at least 60 days before the public hearing on the final Plan. This allows time to identify and address any comments from the FLMs in the final Plan in advance of the public hearing.

Participation in the WRAP has helped to foster a regionally consistent approach to haze planning in the western states and provided a sound mechanism for consultation. The consultation process is explained in detail in Section III.K.11.

g. Monitoring Strategy

The Regional Haze SIP includes a monitoring plan for measuring, estimating and characterizing air quality and visibility impairment at Alaska's four Class I areas. The haze species concentrations are measured as part of the IMPROVE monitoring network deployed throughout the United States. Alaska uses four IMPROVE monitoring stations representing three of the four Class I Areas. Three of these stations were initiated specifically in response to Regional Haze rule requirements. There is no air monitoring being conducted for the Bering Sea Wilderness Area due to its remote location. Monitoring and additional research addressing transboundary sources of pollution in Denali Park are described in Section III.K.3 and Appendix III.K.3.

h. Mid-Course Review of Progress, Revisions, and Timelines

Following submittal of the initial Plan, and every ten years after that, a revised plan must be submitted for the following ten-year period. In the interim, each state is required to submit a five-year progress report to the EPA. Inventory and monitoring data updates, as well as a progress report on emission reductions, are prepared for the mid-course review. As in this initial plan, at the mid-course review Alaska will work and consult with other states through a regional planning process, as funding allows.

The mid-course review also allows each state to assess progress towards its reasonable progress goals. As explained in Section III.K.8, Alaska's strategy for improving visibility is related to ongoing activities to reduce emissions of criteria pollutants. The current control measures and incentive programs for stationary, area, and mobile sources contribute measurably to reductions in haze. The first mid-course review, anticipated to occur in 2013, will provide an opportunity to reassess progress in light of these and future programs. Section III.K.10 describes Alaska's commitment to periodic review.

III.K.2 VISIBILITY AND REGIONAL HAZE

A. Overview

Visibility refers to the visual quality of a vista with respect to detail, color rendition and contrast. It can refer to the maximum distance at which an object can be seen under prevailing conditions, and is sometimes known as "visual range." When molecules and small particles in the air reflect (scatter) and absorb light in the atmosphere, this extinguishes light and prevents it from reaching a viewer's eye; this "light extinction" affects visibility. Haze is the reduction in visibility caused when sunlight encounters tiny particles in the air, with the term "regional haze" referring to the air pollution, whether local or from a long distance, that reduces visibility in specific national parks and wilderness areas identified as Class I areas. Regional haze is caused by particles released by human activities or natural sources, and is regulated under the Regional Haze Rule (40 CFR 51.300-309). The pollutants, also called haze species, that create regional haze and impair visibility are measurable, for instance as sulfates, nitrates, organic carbon, elemental carbon, fine soil, sea salt, and coarse mass. (In regional haze analyses, the terms aerosol, particulates, particles, and pollutants may be used interchangeably.)

The particles that cause haze may be naturally occurring (e.g., from windstorms, wildfire, or volcanic activity) or may be released directly or indirectly as the result by human activities (referred to as anthropogenic sources). Natural sources contribute to visibility impairment, but natural emissions cannot be realistically controlled or prevented by the states. Anthropogenic emissions can be generated or originate within the boundaries of the state (referred to as "state-origin"), or can be generated outside the boundaries of the United States and then transported into a state. Although they contribute to visibility impairment, international-origin emissions cannot be regulated, controlled, or prevented by the states. Nevertheless, their impact on visibility can be significant so it is important to assess their contribution to impairment.

Haze-causing particles are also be classified by whether they were released directly, or were formed in the atmosphere. Particulate matter emitted directly into the atmosphere is referred to as primary particulate, which includes crustal materials and elemental carbon; particulate matter produced in the atmosphere from photochemical reactions of gas-phase precursors and subsequent condensation to form secondary particulates is referred to as secondary particulate, which includes ammonium nitrate, ammonium sulfates, and secondary organic aerosols. Secondary $PM_{2.5}$ is generally smaller than primary $PM_{2.5}$, and because the ability of $PM_{2.5}$ to scatter light depends on particle size, with light scattering for fine particles being greater than for coarse particles, secondary $PM_{2.5}$ plays an especially important role in visibility impairment. Moreover, the smaller secondary $PM_{2.5}$ can remain suspended in the atmosphere for longer periods and is transported long distances, thereby contributing to regional-scale impacts of pollutant emissions on visibility.

B. Sources of Visibility Impairment

EPA has identified two general causes of visibility impairment in Class I areas:

- Impairment due to smoke, dust, colored gas plumes, or layered haze emitted from stacks which obscure the sky or horizon and are relatable to a single stationary source or a small group of stationary sources; and

- Impairment due to widespread, regionally homogeneous haze from a multitude for sources that impairs visibility in every direction over a large area

While this Plan may address visibility impacts associated with visible plumes, its primary focus is to reduce regional, homogeneous haze coming from a variety of sources. Alaska's Class I areas are more typically subject to the latter cause of visibility impairment, both as natural and anthropogenic. Emissions impacts from within Alaska are seasonally driven with wildfire smoke in the summer and windblown dust in the spring/summer. International emission impacts are also seasonally driven with impacts in the winter (Eurasian arctic haze), spring (Asian dust), and summer (fires).

1. Natural Sources

Natural sources of visibility impairment are those not directly attributed to human activities. Natural events (for example, biological activities, ocean spray, windstorms, wildfire, volcanic activity) create aerosols that contribute to haze in the atmosphere. Natural visibility conditions are not constant; they vary with changing natural processes throughout the year. Specific natural events can lead to high short-term concentrations of visibility-impairing particulate matter and its precursors. Therefore, natural visibility conditions, for the purpose of Alaska's regional haze program, are represented by a long-term average of conditions expected to occur in the absence of emissions normally attributed to human activities. Natural visibility conditions reflect the contemporary vegetated landscape, land-use patterns, and meteorological/climatic conditions. Current methods of analyzing monitoring data do not distinguish between natural and anthropogenic emissions, but seasonal patterns and event timelines can provide insight into the relative contributions of natural sources of visibility impairment.

2. Anthropogenic Sources

Anthropogenic or human-caused sources of visibility impairment include anything directly attributable to human activities that produce emissions of visibility-impairing pollutants. Some examples include transportation, power generation, agricultural activities, mining operations, fires for land management, industrial fuel combustion and dust from soils disturbed by human activities. Anthropogenic effects on visibility are not constant; they vary with changing human activities throughout the year. As noted previously, international-origin emissions cannot be regulated, controlled, or prevented by the states and therefore are beyond the scope of this planning document. Any reductions in international origin anthropogenic emissions would likely fall under the purview of the U.S. EPA through international diplomatic activities.

C. Measuring or Quantifying Visibility Impairment

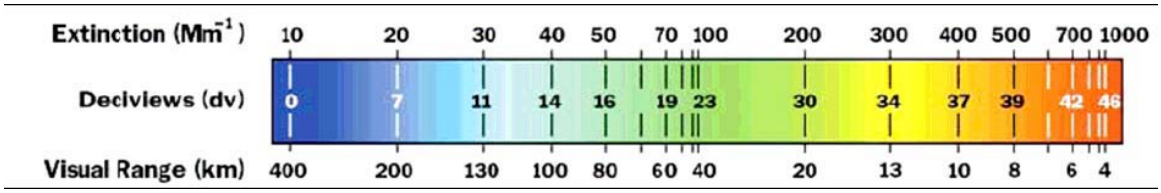
Visibility-impairing pollutants reflect, scatter, and absorb light in the atmosphere. "Light extinction" is the term used to describe light that is prevented from reaching a viewer's eyes by pollutants in the atmosphere. Light extinction can be measured by passing a light beam of known strength through a chamber of air and measuring the light attenuation by the gases and particles. Light that is scattered or absorbed by pollutants does not reach the other side of the chamber. Each haze species, or atmospheric pollutant, has a different light extinction capability, characterized by the extinction coefficient. Extinction coefficients are typically measured in the laboratory for each known species.

Molecules naturally found in the atmosphere also reflect, scatter, and absorb light. The interaction of light with very small molecules in the atmosphere causes "Rayleigh scattering," which also affects visibility.

Establishing the link between individual haze species and visibility impairment is the key to understanding regional haze. Light extinction caused by haze species can be calculated using the extinction coefficient and the measured concentration of the pollutant in the air. Light extinction is measured in inverse Megameters (Mm^{-1}). The specific visibility measurement unit used in the Regional Haze Rule to track visibility levels is the deciview (dv). The deciview is the natural logarithm of light extinction and is unitless. While the deciview value describes overall visibility levels, light extinction calculations can describe the contribution of each component haze species to measured visibility.

The relationship between units of light extinction (Mm^{-1}), haze index (dv), and visual range (km) is indicated by the scale below (Figure III.K.2-3). Visual range is the distance at which a given object can be seen with the unaided eye. The deciview scale is zero for pristine conditions and increases as visibility degrades. Each deciview change represents a perceptible change in visual air quality to the average person. Generally, a one deciview change in the haze index is likely perceptible by a person regardless of background visibility conditions.

Figure III.K.2-3
Visibility Measurement Scale



As the scale indicates, the deciview value gets higher as the amount of light extinction increases. The ultimate goal of the regional haze program is to reduce the amount of light extinction caused by haze species from anthropogenic emissions, until the deciview level for natural conditions is

reached. That level is the deciview level corresponding to emission levels from natural sources only. The haze species concentrations are measured as part of the IMPROVE monitoring network deployed throughout the United States. Four sites are operated in Alaska: Denali Headquarters, Trapper Creek, Tuxedni and Simeonof.

D. Monitoring Visibility

1. Overview of the IMPROVE Program

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program was established in the mid-1980s to measure visibility impairment in Class I areas throughout the United States. The monitoring sites are operated and maintained through a formal cooperative relationship between the EPA, National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Forest Service. In 1991, several additional organizations joined the effort: State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials, Western States Air Resources Council, Mid-Atlantic Regional Air Management Association, and Northeast States for Coordinated Air Use Management. The primary monitoring data available within Alaska's Class I areas are from the IMPROVE program.

The objectives of IMPROVE are to establish current visibility and aerosol conditions in mandatory Class I areas, to identify chemical species and emission sources responsible for existing man-made visibility impairment, to document long-term trends for assessing progress towards the national visibility goal, and to provide regional haze monitoring representing all visibility-protected federal Class I areas where practical. The data collected at the IMPROVE monitoring sites are used by land managers, industry planners, scientists, public interest groups, and air quality regulators to better understand and protect the visual air quality resource in Class I areas. Most importantly, the IMPROVE Program scientifically documents for American citizens the visual air quality of their wilderness areas and national parks.

The IMPROVE program has used three monitoring approaches: scene monitoring with automated cameras (discontinued, but still a reference to range of conditions), measurement of optical extinction with transmissometers, and the measurement of the composition and concentration of the particles that produce the extinction with aerosol monitors. The IMPROVE monitoring network consists of aerosol, light scatter, light extinction and scene samplers in a large number of national parks and wilderness areas. The IMPROVE monitor sample filters are analyzed for 47 different compounds including fine mass ($PM_{2.5}$), total mass (PM_{10}), optical absorption, elements, ions (chloride, nitrate, nitrite, sulfate), and organics. The parameters used in regional haze analysis are described in Table III.K.2-1, in terms of both mass and extinction. Table III.K.2-2 is a color key, or legend, to the different haze pollutant species and their abbreviations, as they appear in figures throughout this document. References to sulfate and nitrate in this document are intended to reflect ammonium sulfate and ammonium nitrate, respectively.

Table III.K.2-1
IMPROVE Parameters Contributing to Regional Haze, Algorithms and Descriptions

Parameter	Name	Algorithm	Description
MF	$PM_{2.5}$: Mass	Measured quantity	Gravimetric measurement of aerosol fine mass ($PM_{2.5}$)
MT	PM_{10}: Mass	Measured quantity	Gravimetric measurement of aerosol total mass (PM_{10})
aerosol_bext	Aerosol extinction	ammSO4f_bext + ammNO3f_bext + OMCf_bext + ECf_bext + SOILf_bext + CM_bext	Sum of major aerosol species mass extinction
ammNO3f	Ammonium nitrate	1.29*NO3f	Ammonium nitrate from nitrate ion
ammNO3f_bext	Ammonium nitrate extinction	3*fRH*ammNO3f	Use mass extinction efficiency of 3m2/g for ammonium nitrate and fRH
ammSO4f	Ammonium sulfate	4.125*Sf	Ammonium sulfate from sulfur element
ammSO4f_bext	Ammonium sulfate extinction	3*fRH*ammSO4f	Use mass extinction efficiency of 3m2/g for ammonium sulfate and fRH
CM	$PM_{2.5-10}$: mass	MT-MF	Fine mass ($PM_{2.5}$) subtracted from PM_{10}
CM_bext	Coarse mass extinction	0.6*CM	Use mass extinction efficiency of 0.6 m2/g for coarse mass
dv	Deciview	10*ln((aerosol_bext+10)/10)	Perception based visibility metric
ECf	Carbon: total elemental	E1+E2+E3-OP	Sum of elemental carbon fractions from TOR - OP
ECf_bext	Elemental carbon extinction	10*ECf	Use mass extinction efficiency of 10m2/g for elemental carbon
F_CM_bext	Coarse mass extinction fraction	100*CM_bext/aerosol_bext	Contribution of coarse mass extinction to aerosol extinction
F_EC	Elemental carbon fraction	100*ECf/RCFM	Contribution of fine elemental carbon to reconstructed fine mass
F_EC_bext	Elemental carbon extinction fraction	100*ECf_bext/aerosol_bext	Contribution of fine elemental carbon extinction to aerosol extinction

Table III.K.2-1
IMPROVE Parameters Contributing to Regional Haze, Algorithms and Descriptions

Parameter	Name	Algorithm	Description
F_NO3	Nitrate fraction	100*ammNO3f/RCFM	Contribution of fine ammonium nitrate to reconstructed fine mass
F_NO3_bext	Nitrate extinction fraction	100*ammNO3f_bext/aerosol_bext	Contribution of fine ammonium nitrate extinction to aerosol extinction
F_OMC	Organic carbon mass fraction	100*OMCf/RCFM	Contribution of fine organic mass to reconstructed fine mass
F_OMC_bext	Organic carbon mass ext. fraction	100*OMCf_bext/aerosol_bext	Contribution of fine organic mass extinction to aerosol extinction
F_SO4	Sulfate fraction	100*ammSO4f/RCFM	Contribution of fine ammonium sulfate to reconstructed fine mass
F_SO4_bext	Sulfate extinction fraction	100*ammSO4f_bext/aerosol_bext	Contribution of fine ammonium sulfate extinction to aerosol extinction
F_SOIL	Soil	100*SOILf/RCFM	Contribution of fine soil to reconstructed fine mass
F_SOIL_bext	Soil extinction fraction	100*SOILf_bext/aerosol_bext	Contribution of fine soil extinction to aerosol extinction
fRHgrid	Relative humidity factor	gridded value	Gridded value
OMCf	Organic mass by carbon	1.4*(O1+O2+O3+O4+OP)	Organic carbon mass from OC
OMCf_bext	Organic carbon extinction	4*1.4*OCf	Use mass extinction efficiency of 4 m2/g for organic carbon
RCFM	Reconstructed fine mass	ammSO4f + ammNO3f + ECf + OMCf + SOILf	Fine mass reconstructed from major component species concentrations
RCTM	Reconstructed total mass	ammSO4f + ammNO3f + ECf + OMCf + SOILf + CM	Sum of major fine and coarse aerosol mass concentrations
SOILf	Fine Soil	2.2*Al+2.49*Si+1.63*Ca+2.42*Fe+1.94*Ti	Sum of common oxides of soil elements

Table III.K.2-1
IMPROVE Parameters Contributing to Regional Haze, Algorithms and Descriptions

Parameter	Name	Algorithm	Description
SOILf_bext	Fine soil extinction	1*SOILf	Use mass extinction efficiency of 1m2/g for fine soil
SVR	Standard visual range	3910/(aerosol_bext+Rayleigh)	Standard visual range in kilometers

Table III.K.2-2
Key to Haze Pollutant Species and Their Abbreviations
As Used Throughout This Document

	Pollutant	IMPROVE Abbreviation
	Ammonium Nitrate	ammno3f_bext
	Ammonium Sulfate	ammso4f_bext
	EC (Elemental Carbon)	ecf_bext
	OMC (Organic Mass Carbon)	omcf_bext
	CM (Coarse Mass)	cm_bext
	Soil (fine Soil)	soilf_bext
	Sea Salt	seasalt_bext

Source: Table 7-1 IMPROVE Monitor Aerosol Composition

Detailed information regarding the IMPROVE program, including history, sampling protocols, standard operating procedures, and data availability can be found on the IMPROVE web site (http://vista.cira.colostate.edu/improve/) and the Visibility Information Exchange Web System (VIEWS) Web site (http://vista.cira.colostate.edu/views/).

The IMPROVE website provides access to raw data and data products, and tools for data processing and aggregating. Also available are online are databases, publications, analysis tools, a graphic viewer, and photographs selected to capture the range of visual conditions at each site. IMPROVE has also been a key participant in visibility-related research, including the advancement of monitoring instrumentation, analysis techniques, visibility modeling, policy formulation and source attribution field studies.

2. IMPROVE Algorithms

The IMPROVE program has developed two algorithms for computing visibility from the mass concentrations provided by the monitoring program. Each first multiplies mass concentrations by light extinction efficiencies per unit mass for each aerosol species. Then, light extinction by

all aerosol species is combined to estimate natural visibility, and converted to deciviews for purposes of regional haze analysis. Limitations of the original IMPROVE algorithm led to the development of the IMPROVE II algorithm, which has been used for all analyses in this document. A description of the two IMPROVE algorithms, and the estimates they produce, is found in Appendix III.K.2.

Use of the IMPROVE II algorithm also leads to revised estimates of natural conditions. A complete description of the default (original) approach for estimating natural haze levels is available in the Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule, at http://vista.cira.colostate.edu/improve/Publications/GuidanceDocs/guidancedocs.htm, as are the results of applying it all the IMPROVE monitoring sites. A description of the second IMPROVE algorithm may be found at http://vista.cira.colostate.edu/improve/Publications/GrayLit/019_RevisedIMPROVEeq/RevisedIMPROVEAlgorithm3.doc

III.K.3 OVERVIEW OF ALASKA AND AIR QUALITY

A. Overview of Alaska

The size, scale, and diversity of Alaska have an influence on air quality and regional haze. This section discusses important features of the state and its air quality.

Alaska is a large state (572,000 square miles) with a small population (686,300). The largest population centers in Alaska are the Municipality of Anchorage (population 279,240), the City of Fairbanks (34,500), the Matanuska-Susitna Borough (76,006), and City & Borough of Juneau (30,700). There are no other communities with populations over 10,000. Several towns have populations between 1,000 and 10,000, and there are many communities with fewer than 1,000 people.

1. Geography

Alaska comprises one-sixth of the United States' landmass, spanning 20 degrees of latitude (51°N – 71°N). Alaska contains 65% of the U.S. continental shelf, more shoreline than the rest of the 49 states combined, 17,000 square mile of glaciers, 3,000,000 lakes that are over 20 acres in size, and receives 40 % of the U.S. fresh water runoff. Figure III.K.3-1 shows a map of Alaska and the diverse climate regions described below.

Figure III.K.3-1
Climate Regions of Alaska

Note: The majority of the Aleutian Islands (west) are omitted.

The Panhandle is a temperate rain forest in the southeastern part of Alaska that is mainly comprised of mountainous islands and protected marine waterways. Rainfall exceeds 100 inches per year in many areas. Most communities are small and have fewer than 5,000 year-round residents. Juneau, the State's capital, is the largest city in the region with a population of approximately 30,700.

The South Gulf Coast is one of the wettest regions in the world: Yakutat receives over 150 inches of non-thunderstorm rain per year and Thompson Pass averages over 700 inches of snow annually. The area is covered with rugged mountains and barren shoreline and is the target of many Gulf of Alaska storms. This coastline contains only a handful of small fishing communities.

South-central Alaska is fairly temperate in comparison to the rest of Alaska. Rainfall varies widely across the region, averaging between 15 inches per year in the Matanuska-Susitna (Mat-Su) Valley and 60 inches per year in Seward. This region contains 60% to 70% of the state's population, with Anchorage, the state's largest city, home to 279,240 people. Bounded by active volcanoes on the southwest and glacial river plains to the northeast, this sector of the state has experienced 24-hour dust levels in excess of 1,000 ug/m^3.

The Alaska Peninsula and its westward extension, the Aleutian Chain, form the southwestern extension of the mountainous Aleutian Range. This region is comprised of remote islands and small, isolated fishing villages. This area is one of the world's most economically important fishing areas, as well as a vital migratory route and nesting destination for birds.

Southwest Alaska encompasses the vast Yukon-Kuskokwim River Delta, a wide low-lying area formed by two of the state's major river systems and dotted with hundreds of small lakes and streams. This region is heavily impacted by storm systems which rotate northward into the Bering Sea. Communities in this region receive between 40 and 70 inches of precipitation each year. This portion of the state is quite windy, experiencing winds between 15–25 miles per hour throughout the year. These winds, coupled with fine delta silt, help to create dust problems for some southwestern communities. Rural villages normally contain fewer than 500 people and are located along the major rivers and coastline. Regional hub communities, such as Galena and Bethel, have up to 6,300 residents.

Interior Alaska describes the vast expanse of land north of the Alaska Range and south of the Brooks Range. This region contains Fairbanks, Alaska's second largest city, with a population of 32,000 people (84,000 in the borough). The climate varies greatly with clear, windless, -50°F winter weather giving way to summer days with 90°F temperatures and afternoon thunderstorms. Sectors of this region also experience blustery winds and high concentrations of re-entrained particulates from open riverbeds.

The Seward Peninsula is the section of Alaska that extends westward into the Bering Sea between Norton Sound and Kotzebue Sound. This hilly region is barren and windswept with 15-25 mile per hour winds common. Rainfall in this region averages between 15 and 24 inches per year. Villages in this region are small except for Nome, which has over 3,000 people.

The North Slope region, located north of the Brooks Range, is an arctic desert receiving less than ten inches of precipitation annually. Wind flow is bimodal, with the easterlies dominating the meteorological patterns. Winter wind speeds average 15-25 mile per hour, dropping off slightly during the summer. The North Slope is extremely flat and supports huge summertime populations of bears, caribou, and migratory birds.

2. Topography

Alaska is topographically varied. The state contains seven major mountain ranges, which influence the majority of all regional wind flow patterns. The mountains channel flow, create rotor winds, cause up slope and down slope flow, initiate drainage winds, produce wind shear and extreme mechanical turbulence. For air quality impact analyses, Alaska's rugged mountains can only be described as complex; complex terrain makes most air quality models unsuited for use in the state. The complexity of most local meteorology renders the use of site specific meteorological data inadequate for control strategy development.

3. Economy

The oil and gas industry dominates the Alaskan economy, with more than 80% of the state's revenues derived from petroleum extraction. Alaska's main export product (excluding oil and natural gas) is seafood, primarily salmon, cod, pollock and crab. Agriculture represents only a fraction of the Alaskan economy. Agricultural production is primarily for consumption within the state and includes nursery stock, dairy products, vegetables, and livestock. Manufacturing is limited, with most foodstuffs and general goods imported from elsewhere. The state's industrial outputs are crude petroleum, natural gas, coal, gold, precious metals, zinc and other mining, seafood processing, timber and wood products.

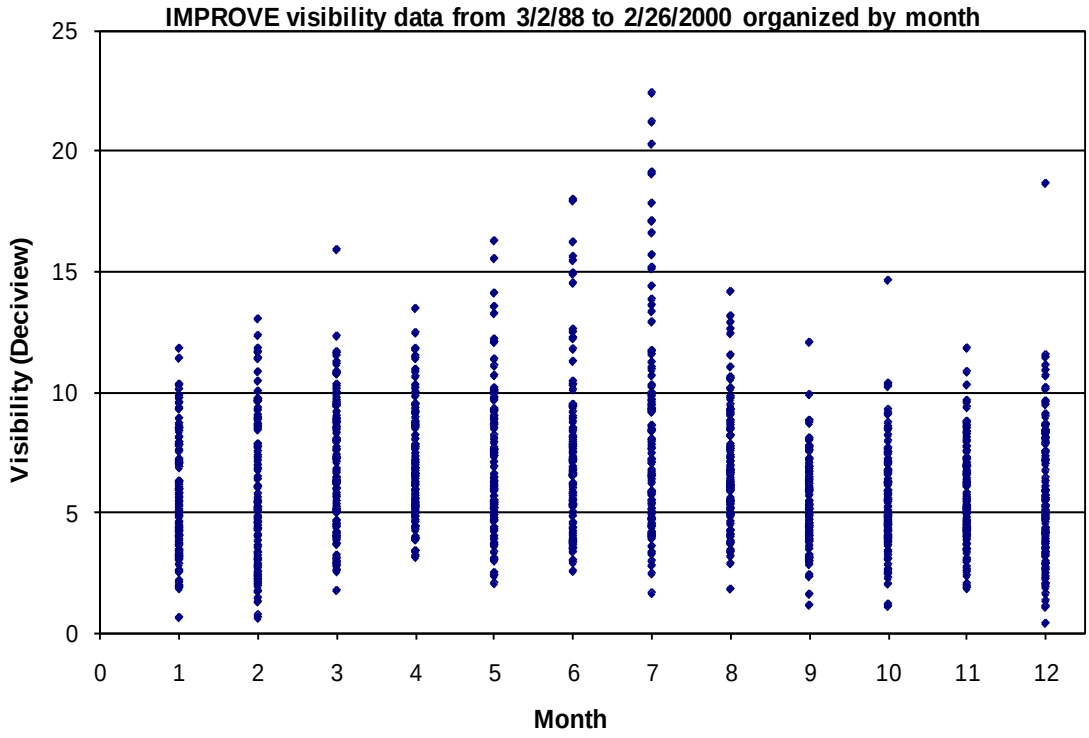
Employment is primarily in government and industries such as natural resource extraction, shipping, and transportation. Military bases are a significant component of the economy in both Fairbanks and Anchorage. Federal subsidies are also an important part of the economy, allowing the state to keep taxes low. There is also a growing service and tourism sector. Tourism via cruise ships and air travel has expanded considerably in recent years, providing additional support to the economy.

B. Sources of Pollution

The primary sources of visibility degradation in Alaska's Class I areas are dust and anthropogenic emissions originating in Asia (referred to as "Asian dust") and blowing across the Pacific Ocean from March to May; the "Arctic haze," which occurs from October to March; and regional wildfires, which typically start when the snow melts, usually in April, and continue until mid-August.

The seasonal nature of long-range transport and regional pollution leads to a bimodal trend of low visibility that peaks once in summer and once in winter; this can be seen in Figure III.K.3-2, which shows the IMPROVE visibility data collected at the headquarters of the Denali National Park from March 1988 to February 2000.

Figure III.K.3-2
Improve Visibility Data for Denali National Park



1. International Long-Range Transport of Aerosols to Alaska

A primary issue that has been identified is the international transport of air pollutants into the state.[1] Unlike the states in the contiguous United States, Alaska borders no other state. Instead, Alaska has direct impacts from Russia, China, other parts of Asia, Europe, and Canada. Alaska is particularly affected by transport from Asia and Russia/Eastern Europe. Due to the winter conditions at high latitudes (like at Denali National Park), namely a lack of sunlight and liquid water, expected atmospheric chemical reactions do not occur. This can cause emissions that have been transported hundreds or thousands of miles to appear in analyses as though from a local source. International transport of pollutants into Alaska has been documented through a variety of research studies. In particular, the research has focused on Arctic haze and Asian dust events.

The Alaskan airshed contains a complex array of aerosols that vary seasonally and geographically. Forest fires are the largest source of aerosols in central ("Interior") Alaska,[2] followed by "Arctic haze," anthropogenic aerosols from Northern Europe and Russia that reach Alaska in the winter and early spring. Asian deserts and cities are the source of some of the aerosols, collectively known as Asian dust, that arrive in spring and summer. Oceans are another, generally less significant, source of aerosol.

The two major international aerosol transport phenomena that affect Alaska are Arctic haze and Asian dust.[3] Arctic haze refers to pollution transported to Alaska over the Pole during the winter and early spring from Europe and Russia; Asian dust refers to wind-blown dust originating primarily from the arid deserts of Mongolia and China and transported across the Pacific and into Alaska during late spring. A brief summary of each of these phenomena is provided below; further details are provided in Appendix III.K.3.

a. Arctic Haze

During the winter, the Arctic atmosphere becomes contaminated with anthropogenic pollution transported primarily from sources in Europe and Russia.[4] This unusual form of regional air pollution is commonly referred to as "Arctic haze". Sulfur oxides and soot are its main ingredients, although many metal and organic compounds can be found in Arctic haze samples.[5] Arctic haze is absent during summer, but begins to appear in the early winter. Photochemical oxidation of sulfur dioxide into sulfate aerosols after polar sunrise and seasonal meteorological conditions cause Arctic haze to reach its peak intensity in March, after which levels sharply decline.

The haze is composed of particles no larger than 2 μm because these particles have low settling velocities and are capable of remaining suspended in the atmosphere for weeks. This allows the particles to travel into the Arctic, which has few local aerosol sources.[6] The size of the Arctic haze aerosols is approximately the same as the wavelength of visible light (0.39-0.76 μm), allowing the aerosol to scatter light and therefore diminish visibility very effectively.

Arctic haze is often layered, a consequence of the small thermal lapse rate of the Arctic atmosphere in the winter. The shallow lapse rate dampens vertical mixing and therefore allows pollution to spread horizontally much faster than vertically.[7] Arctic haze occurs throughout the height of the Arctic troposphere as a result of the tendency of air parcels to move along surfaces of constant potential temperature causing pollution from lower latitudes to enter the Arctic at higher altitudes.[8]

Episodes of high concentrations of aerosol pollution are not always coincident with high concentrations of gaseous pollution. In fact, the two have a slightly offset seasonality, with the gases tending to reach their highest concentrations in January-February due to decreased photochemistry and mixing in the Arctic, while aerosol pollution reaches its maximum in March-April due to increased airflow from central Eurasia and increased gas-to-particle conversion.

In the absence of Arctic haze, visibility in the Arctic is quite high. Barrow averages 271 km visual range in June. The average value for March is reduced to 143 km, and episodes of Arctic haze drive the range much lower.[9] Arctic haze often reduces visibility to approximately 30 km in the high Arctic.[10] Barrie also notes that suspended ice crystals frequently accompanied the haze, which further reduces visibility to about 10 km. These ice crystals are probably formed by the nucleation of ice onto acidic aerosols at temperatures below –25° C.

b. Asian Dust

Generally, long-range transport must occur at high altitudes (above 5 km) over an ocean in order to avoid scavenging.[11] Therefore, while the Pacific Ocean usually serves as a barrier to pollution transport, pollution can undergo long-range transport over it if lofted high enough. The transport of desert dust from the Orient is a well-documented phenomenon,[12] and so, increasingly, is the transport of pollution.

One of the first attempts to characterize the origin of Arctic haze found that a large haze incident in early May 1976 was caused by desert dust.[13] This conclusion was based on the morphology of the aerosols and their chemical composition, along with consideration of the meteorological situation preceding the appearance of the haze. The dust was almost certainly transported from the Gobi and Taklimakan deserts in Mongolia and northern China. Nearly every spring, high winds loft so much dust that it falls on Japan and Korea like yellow snow. The Japanese refer to the massive dust fall as the "kosa", the Koreans call it the "whangsa". Spring is not only the most active period for dust storms in the Gobi and Taklimakan, but also the period of most active atmospheric transport between the Orient and the Arctic.

Geological evidence suggests that global scale transport of Asian dust has been a long-running natural phenomenon.[14] Chemical analysis of Greenlandic ice cores[15] and Hawaiian soil studies[16,17,18,19] have shown that the chemical and radiological fingerprints of deposited dust were consistent with the composition of the Asian dust sources.

Rahn et al. [1977] detected little pollution in the 1976 dust plume, but Chinese sulfur dioxide emissions have since tripled. Unsurprisingly, more recent studies have shown an increase in anthropogenic pollution concurrent with the transport of Asian air during the spring over the Pacific Ocean[20,21,22] and North America.[23] The concentration of sulfate, nitrate, soot, and heavy metal aerosols accompanying these dust plumes will almost certainly increase as China's coal-fired economy rapidly expands over the coming decades.

Since human activities have been contributing to the expansion of the Gobi Desert, it is likely that the amount of Asian dust transported over to the Arctic will increase over time. Chinese records indicate an increase in the severity of dust storms impacting Beijing, which lies directly in the path of storms coming off the desert.

2. Biogenic Aerosols

Alaska's landscape is dominated by natural ecosystems rather than human dominated systems. Consequently, air quality in the state is strongly affected by natural biogenic emissions as well as human activities. Biogenic emissions, or emissions from (non-human) living things, are produced by the organisms of forests, tundra, wetlands, and sea. The effects of biogenics on air quality are determined by vegetation, animal and microbial species composition, climate and meteorology, soil and permafrost processes, and secondary atmospheric reactions.

Forest and tundra ecosystems produce a wide variety of volatile organic hydrocarbons, with common groups being isoprenes and monoterpenes. Production of biogenic volatile organic

compounds (VOCs) varies by latitude, plant species, diurnal cycles, temperatures, meteorology, and even browsing pressure. Under the right conditions, biogenic VOCs act as nucleation centers, forming nanoparticles which impair visibility and alter climate.[24,25,26,27,28]

Wetland and lake ecosystems release VOCs from microbial activity in inundated and seasonally inundated soils. These ecosystems release VOCs as perennially frozen soils thaw, releasing to decomposition organic matter produced and trapped long ago by freezing. Common emissions from lakes and wetlands are methane and methane hydrates.[29,30]

The term "biogenic" is used inconsistently in the scientific literature, sometimes including emissions from wildfire, sometimes not. In this document wildfire emissions are treated separately. Recent research on biogenic emissions has focused on sources, transport, vertical stratification, chemical composition, modeling from meteorology, variation in emissions factors, and specific processes producing ozone, NO_x, black carbon, CO, and VOCs. Most of the research is aimed at understanding formation of climatically relevant, or climate altering, particles. Included here within the category of biogenic emissions are sea salt and volcanic emissions.

a. Formation of Biogenic Aerosols

Under some conditions biogenic VOCs become nucleation centers, resulting in the formation of nanoparticles up to 80 nm.[31] Much current research examines the conditions under which this happens. Relevant conditions include concentrations of condensable vapor[32] and concentrations of other atmospheric constituents such as H_2SO_4 and ammonia.[33] Some researchers have noted, based on correlations, the likely importance of sulfuric acid, sulfur dioxide, and ammonia concentrations to particle formation.[,,34,35] Increasing probabilities of nucleation mode aerosols have been seen with increasing heat flux, temperature variability, and vertical wind speed variance.[36]

Biogenic emissions vary seasonally, both qualitatively and quantitatively, even at a single location. Local meteorology influences secondary particle formation as well. In the Canadian high Arctic, variation in the composition of primary biogenic emissions has been reported, with monoterpenes and B-caryophyllene making major contributions to secondary OC in late winter to early summer, and isoprenes making major contributions to secondary OC in early June.[37]

One comprehensive study in Scandinavia concludes that boreal forest is a major source of climate-relevant aerosols, most likely at levels capable of competing with the anthropogenic aerosol releases. It demonstrates that conversion of terpenes to secondary organic aerosols does take place over boreal forests, with the highest concentrations of very small particles formed when emissions are low. As terpene emissions increased, particle mass increased, with the consequence that nucleation quenches itself. Boreal forest typically sustains 1K-2K/cm^3 particles in 40-100 nm size range, and these concentrations are established rapidly across marine-terrestrial boundaries. Across boreal and arctic regions, particle formation varies seasonally, latitudinally, and with temperature.[38]

b. Sea Salt

Sea salt, a major component of marine aerosols, is formed by the evaporation of water ejected from wind whipped whitecaps and breaking waves. The production of sea salt aerosol and its size distribution is very sensitive to wind speed and surface conditions. Although most of the sea salt aerosol mass is in the size fraction above 1 μm diameter, a small but significant fraction of the sea salt aerosol is in the submicrometre fraction.[39] The large particles have high settling velocities, resulting in relatively short residence times. The remaining particles are smaller, have a longer residence time, transport over longer distances and impact visibility. Sea salt has been identified as a significant contributor to visibility impairment at all of the Class I sites in Alaska.

c. Geogenic Emissions

Alaska is home to many active and dormant volcanoes. Volcanoes located on the Aleutian Islands, the Alaska Peninsula, and in the Wrangell Mountains are part of the "Ring of Fire" that surrounds the Pacific Ocean basin. The state contains 52 historically active volcanoes, 14 of which have had at least one major eruptive event since 1990. During the 50-year period between 1945 and 1995, 90 eruptions have been reported from 23 volcanoes, for a frequency of about 2 (1.8) eruptions per year. Additional volcanic sources impacting Alaska are located across the Bering Sea on Russia's Kamchatka Peninsula. The 29 active volcanoes in Kamchatka typically have three or four explosive eruptions per year that emit volcanic ash and gases high enough into the atmosphere to impact air travel between Asia and North America.

The most abundant gas typically released into the atmosphere from volcanic systems is water vapor, followed by carbon dioxide and sulfur dioxide. Volcanoes also release smaller amounts of others gases, including hydrogen sulfide, hydrogen, carbon monoxide, hydrogen chloride, hydrogen fluoride, and helium. Large explosive eruptions inject a tremendous volume of sulfur aerosols into the stratosphere, which depending on wind speed and direction can significantly impact any of the Class I sites located in Alaska.

3. Sources of Visibility Impairment Summary

The initial mischaracterization of arctic haze as dust from Asian dust storms rather than industrial activity foreshadowed the more complex picture of Arctic haze seen today. International transport of pollutants into Alaska is indeed crucial to the impairment of visibility in the sparsely populated, less-industrialized Alaska, but the pollutants seen today derive from a variety of sources, not solely industrial.

International transport of pollutants affecting visibility in Alaska is associated with human activities in many places and at multiple scales. Carbon particulates arise from both local human activities and regional phenomena. Important long-distance sources of atmospheric carbon include land clearing fires, wildfires, and coal burning for power generation. Dust particulates are affected by local land use and management, local weather systems, and intercontinental air masses. Biogenic emissions from vegetation, soils, and oceanic plankton also affect visibility, and are of increasing interest to researchers. Biogenic emissions can arise locally or can be transported long distances before entering Alaska. Geogenic emissions from volcanoes and river

geomorphic processes contribute to degradation of visibility within Alaska. Geogenic sources also may be local or international.

C. Monitoring Strategy and Air Quality Data

1. Statewide Pollutant Monitoring

ADEC operates or oversees a network of ambient air monitors in a variety of locations throughout Alaska. The purpose of the state ambient air-monitoring network has been to determine whether levels of pollutants are exceeding the national ambient air quality standards. For this reason, sites have typically been located to evaluate impacts from local emission sources, such as motor vehicles, wood-burning stoves, unpaved roads, windblown dust, and industrial facilities. Air quality data are easily available for the major population centers but data are sparse for the vast majority of the state. It is not possible to monitor the air quality in every community, so ADEC has taken a three-pronged approach to the monitoring network design:

- Monitoring larger communities to cover the largest possible population exposure.
- Monitoring designated smaller towns that are representative of multiple communities in a region.
- Monitoring in response to air quality complaints.
- Additional monitoring data are available when industries applying for air quality permits conduct background monitoring.

Alaska's air monitoring program focuses on five of the seven criteria pollutants regulated through the National Ambient Air Quality Standards (NAAQS): carbon monoxide (CO), coarse particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), ozone (O3) and lead (Pb). There are eight separate and distinct monitoring objectives associated with these pollutants:

1. CO – seasonal monitoring in Anchorage and Fairbanks (October through March);
2. PM_{10} – monitoring in the major communities of Juneau, Anchorage and the central Matanuska-Susitna Valley (Mat-Su);
3. $PM_{2.5}$ – monitoring in Juneau, Fairbanks, Anchorage and the Mat-Su Valley;
4. Wildland Fire ($PM_{2.5}$) - statewide monitoring during the summer fire season (May – September);
5. Slash Burning ($PM_{2.5}$) for agricultural and beetle kill (August – May);
6. Rural Community/Tribal Village Dust Monitoring (May-September), Residential Wood Smoke (September-March) – selected communities statewide;
7. Ozone – Denali National Park (operated by NPS) and Anchorage; and
8. Source oriented lead monitoring.

The state's primary air monitoring network evaluates the level of these criteria air pollutants, following guidance provided in EPA's National Monitoring Strategy, and focuses Alaska's monitoring on our largest communities. Citizen complaints from rural villages have been addressed on an "as available" basis in the past.

In addition to the primary network of criteria pollutant monitors, there are several mercury deposition monitoring sites in Alaska. Two state-sponsored sites for collecting ambient mercury in precipitation are located in Kodiak and Unalaska. The sites are part of the mercury deposition network (MDN). Additionally there is a site established in Bettles and a short term site in Glacier Bay in southeast Alaska both managed by the National Park Service.

Atmospheric wet deposition monitoring was initiated in 1980 at Denali National Park in Denali Borough, Alaska, as part of the National Atmospheric Deposition Program (NADP)/National Trends Network. Monitoring at the Poker Creek site northeast of Fairbanks began in 1992. Monitoring in Juneau began in 2004. Ambler was an NADP site from 1994-1995. Precipitation at National Trends Network sites is measured for pH, specific conductance, then analyzed for the following chemical species: Ca, Mg, K, Na, NH_4, NO_3, Cl, SO_4, and PO_4.

Because ADEC's core ambient air monitoring network has been concentrated on urban areas, which are far from Alaska's Class I areas, the ambient air monitoring data are not representative of impacts within Alaska's Class I areas and are of limited usefulness for analysis of regional haze pollutants around Alaska's Class I areas.

2. Regional Haze Monitoring

EPA's regional haze rule has several monitoring requirements. This plan must include a monitoring strategy for measuring, characterizing, and reporting regional haze visibility impairment that is representative of all Class I areas within the State. Alaska complies with this requirement through participation in the IMPROVE network.

Alaska is working with EPA and the FLMs to ensure that monitoring networks provide data that are representative of visibility conditions in each affected Class I area within the State. Along with monitoring strategies for the Class I areas, the SIP must include a determination of whether additional monitoring sites or equipment are needed to establish if progress goals are being achieved. The State of Alaska needs to address many issues in its comprehensive regional haze monitoring strategy.

A description of Alaska's Class I areas and the monitoring network within each is provided below. This is followed by a brief discussion of monitoring considerations particularly relevant to Alaska's Class I areas and conditions.

a. Description of Class I Areas and Monitoring Network

Alaska has four Class I areas subject to the Regional Haze Rule: Denali National Park, Tuxedni National Wildlife Refuge, Simeonof Wilderness Area, and Bering Sea Wilderness Area. They were designated Class I areas in August 1977. Figure III.K.1-2 shows their locations, with Denali National Park in the Interior, Tuxedni and Simeonof Wilderness Areas as coastal, and the Bering Sea Wilderness Area.

Denali National Park and Preserve

Denali National Park and Preserve is a large park in the interior of Alaska. It has kept its integrity as an ecosystem because it was set aside for protection fairly early in Alaska's history. Denali National Park headquarters lies 240 miles north of Anchorage and 125 miles southwest of Fairbanks, in the center of the Alaska Range. The park area totals more than 6 million acres. Denali, at elevation 20,320-feet the highest mountain in North America, is a prominent feature in the park and throughout Alaska. Denali National Park and Preserve accommodates a wide variety of visitor uses. The Alaska Range divides the park into two geographic zones by blocking the warm moist air from the Gulf of Alaska from getting to the interior inland side of the park. The park has many vegetation types associated with the variety of aspects and elevations within the park; elevations range from 2000 feet to over 20,000 feet above sea level. The park contains numerous glaciers, permafrost and high mountains. Treeline in Denali is typically around 3,000' above sea level. Much of the 92 mile Park Road is near or above treeline, making for many spectacular views. Denali is the only Class I site in Alaska that is easily accessible and connected to the road system. Denali has the most extensive air monitoring of Alaska's Class I areas, so more detailed examinations of long-term and seasonal air quality trends are possible for this site.

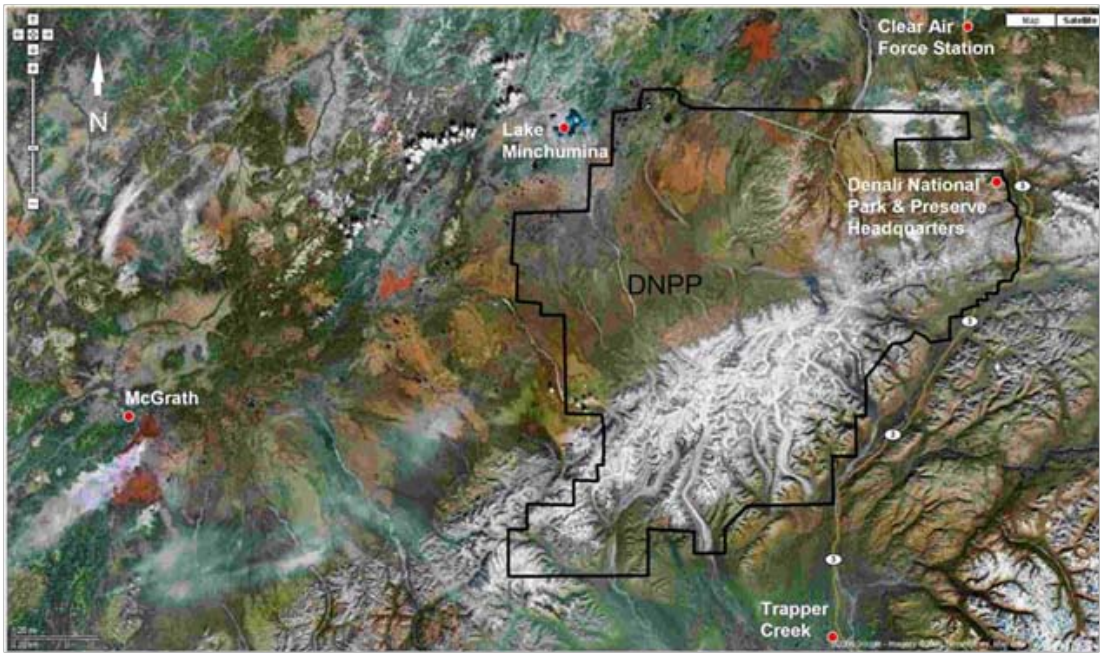
IMPROVE monitoring data are available from the Denali site from March 1988 to the present. Air quality at Denali National Park is monitored as part of several other national air and visibility monitoring networks, described below, as well as many stand-alone atmospheric science research projects.

Aside from visitor services concentrated around park headquarters, there is a single park road, extending 92 miles into the park from the northeastern boundary. The road is paved for its first 15 miles. One air monitoring site is located near the eastern end of the park road. A second, newer site, known as "Trapper Creek", is located to the south of the Park at another site with reliable year-round access and electrical power (see Figure III.K.3-3).

The Denali Headquarters monitoring site, an IMPROVE protocol site (DENA1), is across the Park Road from park headquarters, approximately 250 yards from headquarters area buildings. The site (elevation of 2,125 feet) sits above the main road (elevation 2,088 feet). The side road to the monitoring site winds uphill for 130 yards, providing access to the monitoring site and a water treatment facility. The hill is moderately wooded, but the monitoring site sits in a half-acre clearing.

During the park season, mid-May to mid-September, 70 buses and approximately 560 private vehicles per day traverse the road loaded with park visitors. During the off season, approximately100 passenger and maintenance vehicles pass within 0.3 miles of the monitoring site. Private vehicles are only allowed on the first 14.8 miles of the Park Road.

Figure III.K.3-3
Map of Denali National Park and Preserve



The monitoring site is 2 miles west of the Nenana River and 3.2 miles south of the Healy Ridge, which rises to 6,000 feet at its highest point. It is located in an east-west valley, between the Healy Ridge and the main Alaska Range, which is about two miles wide at the monitoring station and gets wider to the west towards the Sanctuary and Savage Rivers.

The Trapper Creek IMPROVE monitoring site (TRCR1) is located 100 yards east of the Trapper Creek Elementary School. It is the official IMPROVE site for the Denali Class I area. The site is located west of Trapper Creek, Alaska and a quarter mile south of Petersville Road. The site is the official IMPROVE site for Denali National Park and Preserve and was established in September 2001 to evaluate the long-range transport of pollution into the Park from the south. The elementary school experiences relatively little traffic during the day, about 4 buses and 50 automobiles. The school is closed June through August. This site was selected because it has year-round access to power, is relatively open and is not directly impacted by local sources.

IMPROVE monitoring data have been recorded at the Denali Headquarters IMPROVE site from March of 1988 to present. The IMPROVE monitor near the park's headquarters was originally the IMPROVE site. Due to topographical barriers, such as the Alaska Range, it was determined that the headquarters site was not adequately representative of the entire Class I area. Therefore, Trapper Creek, just outside of the park's southern boundary, was chosen as a second site for an IMPROVE monitor and is the official Denali IMPROVE site as of September 10, 2001. The headquarters site is now the protocol site. A CASTNet (Clean Air Status and Trends Network) monitor is located near the Denali Headquarters IMPROVE site.

A DELTA-DRUM sampler was installed at the Denali National Park headquarters site for the period July 30 –September 7, 2001. (A Poker Flat research range site north of Fairbanks also had a DELTA-DRUM sampler September 1 – 29, 2000, March 25 – April 22, 2001, and July 26 – September 7, 2001.) DRUM samplers were installed for both the Denali and Trapper Creek sites in February 2008. They ran through April of 2009.

A CASTNet (Clean Air Status and Trends Network) style monitor was located near the Trapper Creek IMPROVE site. Another CASTNet style monitor is co-located with the Denali National Park headquarters IMPROVE monitor. A third was located at Poker Flat Research Range.

In addition to the IMPROVE network, many other monitoring networks have sites at the Denali headquarters monitoring site , including the National Atmospheric Deposition Program, NPS's meteorological monitoring equipment, and several research projects from the University of Alaska, Fairbanks.

Simeonof Wilderness Area

Simeonof Wilderness Area consists of 25,141 acres located in the Aleutian Chain 58 miles from the mainland (see Figure III.K.3-4). It is one of 30 islands that make up the Shumagin Group on the western edge of the Gulf of Alaska. Access to Simeonof is difficult due to its remoteness and

Figure III.K.3-4
Map of Simeonof Wilderness Area

the unpredictable weather. It is home to greater than 55 species of birds as well as sea otters, hair seals, walruses, Arctic foxes, ground squirrels and at least 17 species of whales. The vegetation is naturally treeless with wetlands mixed in with coastal cliff, meadow and dune environments. There are 188 taxa of lichens in the park. Winds are mostly from the north and northwest as part of the midlatitude westerlies. Occasionally winds from Asia blow in from the west.

The island is isolated and the closest air pollution sources are from marine traffic in the Gulf of Alaska and the community of Sand Point.

The Fish and Wildlife Service has placed an IMPROVE air monitor in the community of Sand Point to represent the wilderness area. The community is on a nearby more accessible island approximately 60 miles north west of the Simeonof Wilderness Area. The monitor has been on line since September 2001. The location was selected to provide representative data for regional haze conditions at the wilderness area.

Tuxedni National Wildlife Refuge

Tuxedni National Wildlife Refuge is located on a fairly isolated pair of islands in Tuxedni Bay off of Cook Inlet in Southcentral Alaska. There is little human use of Tuxedni except for a few kayakers and some backpackers. There is an old cannery built near Snug Harbor on Chisik Island which is not part of the wilderness area; however it is a jumping off point for ecotourists staying at Snug Harbor arriving by boat or plane. The owners of the land have a commercial fishing permit as do many Cook Inlet fishermen. Set nets are installed around the perimeter of the island and in Tuxedni Bay during fishing season.

Along with commercial fishing, Cook Inlet has reserves of gas and oil that are currently under development. Gas fields are located at the Kenai area and farther north. The inlet produces 30,000 barrels of oil a day and 485 million cubic feet of gas per day. Pipelines run from Kenai to the northeast and northeast along the western shore of Cook Inlet starting in Redoubt Bay. The offshore drilling is located north of Nikiski and the West McArthur River. All of the oil is refined at the Nikiski refinery and the Kenai Tesoro refinery for use in Alaska and overseas.

The Fish and Wildlife Service has installed an IMPROVE monitor near Lake Clark National Park to represent conditions at Tuxedni Wilderness Area. This site is on the west side of Cook Inlet, approximately 5 miles from the Tuxedni Wilderness Area. The site was operational as of December 18, 2001, and represents regional haze conditions for the wilderness area. Figure III.K.3-5 shows a map of Tuxedni and the surrounding area.

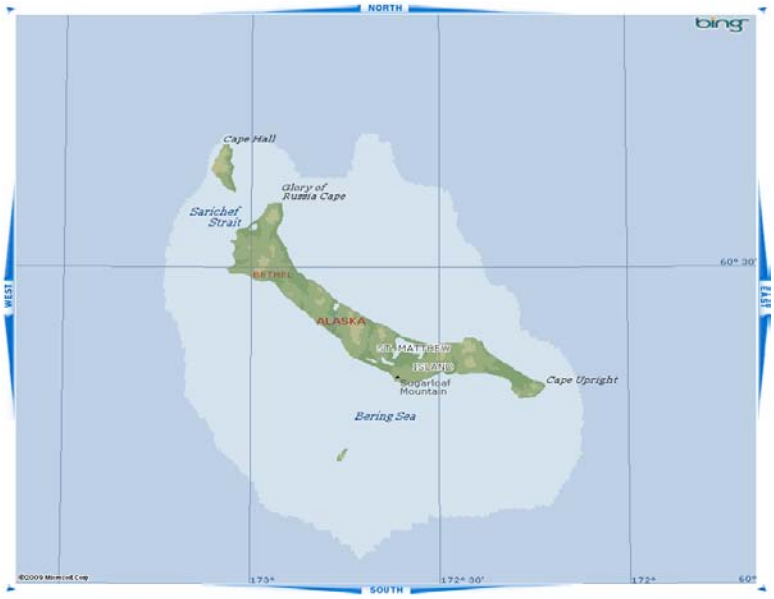
Figure III.K.3-5
Map of Tuxedni National Wildlife Refuge and Surrounding Area

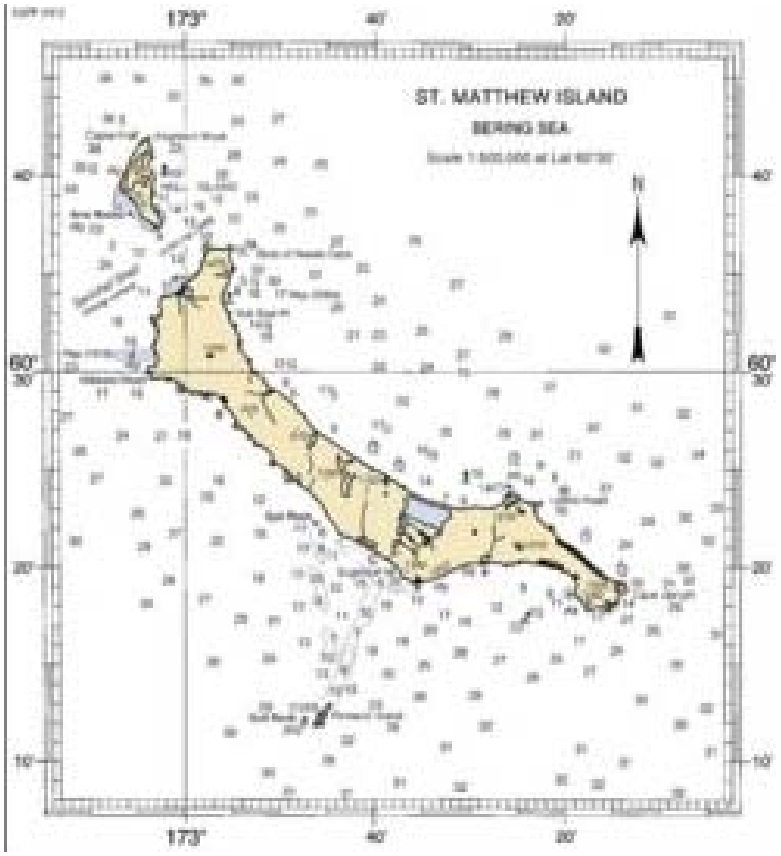
Bering Sea Wilderness Area

The Bering Sea Wilderness is located off the coast of Alaska about 350 miles southwest of Nome. Hall Island is at the northern tip of the larger St Matthew Island. St Matthew Island is remote with arctic foxes and insular voles joined by the occasional polar bear that comes in off the pack ice. Ringed seals and stellar sea lions haul themselves up on the shore. 125 species of birds are present on the tundra and rock covered island. There is trawling for king crab offshore. Lichen species were heavily overgrazed when the Coast Guard introduced reindeer to the island in 1944; mosses, forbs and shrubs took over leaving about 10% of the lichen cover. The reindeer are gone, but 22 years later the lichens are only very slowly growing back. Figure III.K.3-6 shows a map of the Bering Sea Wilderness Area.

The Bering Sea Wilderness Area had a DELTA-DRUM sampler placed on it during a field visit in 2002**.** However, difficulties were encountered with the power supply for the sampler and no viable data is available from that effort. No IMPROVE monitoring is currently planned for Bering Sea Wilderness Area because of its inaccessibility.

Figure III.K.3-6
Map of Bering Sea Wilderness Area





b. Additional Monitoring Considerations

One of the monitoring issues that Alaska has identified is the logistical difficulty of monitoring at remote locations. Remote locations make it challenging to provide power for instrumentation. If a monitor is located at the nearest power source, such as a town, it is also near local sources of emissions, and therefore less likely to be representative of the Class I area. Remote sampling in Class I areas may be needed to verify that data from an off-site IMPROVE monitor are representative. DRUM aerosol impactor sampling may provide an opportunity to verify impacts at remote Class I areas like Simeonof and Tuxedni. The challenges for ongoing air and visibility monitoring in Alaska are transportation and site maintenance. Sites are remote, access may be only by air or water, and electrical power may be lacking. In many places winter temperatures are extreme, often dipping well below zero Fahrenheit for weeks at a time.

DELTA-DRUM Samplers have been used at several sites in Alaska for relatively short periods. Researchers have unsuccessfully modified these samplers for remote winter use in Denali Park. Drum samplers were set up at the Denali and Trapper Creek sites as well as in McGrath and Lake Minchumina in February and March 2008. They proved to be quite problematic with mechanical and pump issues in winter conditions. They ran intermittently between February/March 2006 and April 2009.

Alaska will continue to evaluate as resources allow their portable sampling platforms for use in remote environments.

III.K.4 CHARACTERIZATION OF MONITORED IMPACTS AT ALASKA CLASS I AREAS

A. Natural Conditions and Visibility Baselines

The Regional Haze Rule requires that states improve visibility at Class I areas to the visibility levels defined as "natural conditions," which are defined as the conditions that would prevail in the absence of any human impacts on visibility. The specific requirement is that states improve the worst 20% of days while maintaining visibility of the best days. To address the requirements of the Rule, states must determine natural conditions as defined by the Rule; natural conditions are the endpoint, or goal. States must also measure initial, baseline visibility conditions; this defines the starting point from which improvement is measured.

For each Class I area, Alaska must describe the visibility conditions that existed in the baseline years of 2000–2004 for the 20% of days with the best visibility and the 20% of days with the worst visibility.

For each Class I area, Alaska must describe the visibility conditions on the 20% best and the 20% worst days which would have existed if natural conditions had existed for the baseline period. Natural conditions are the conditions that would prevail in the absence of any human impacts on visibility.

Achieving natural conditions for visibility on the worst days by the year 2064, at the same time not diminishing visibility on the best days, is the overall goal of the Regional Haze Program.

1. Determining Natural Conditions

Conceptually, there are four steps to determining natural conditions: 1) defining visibility and how it will be measured, 2) defining algorithms to calculate visibility from the amounts of naturally occurring aerosols in the air, 3) estimating the typical natural concentrations of each aerosol species in the absence of human impacts, and 4) calculating natural conditions from the typical natural concentrations of each aerosol species in the absence of human impacts, using the algorithm developed in step 2.

Visibility impairment as defined by the Regional Haze Rule means "any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions." Atmospheric aerosols scatter and absorb light, reducing visibility. Light extinction is the loss, or attenuation, of light passing through the atmosphere**.** Extinction is estimated from air monitoring data by adding the extinctions by each type of aerosol. Light extinction is influenced by the numbers, sizes, and chemistry of atmospheric aerosols.

Visibility impairment is measured in deciviews. Deciviews are derived from calculations of light extinction, "such that uniform changes in haziness correspond to uniform incremental changes in perception across the entire range of conditions, from pristine to highly impaired."

The IMPROVE air monitoring network provides data for the Class I area sites during baseline years and into the future. It provides measurements of aerosols at sites and, more importantly here, algorithms to estimate the contribution of each type of aerosol to overall light extinction. Two IMPROVE algorithms have been developed to estimate the light extinction from different aerosol species concentrations.

EPA's 2003 RHR guidance on tracking progress and estimating natural conditions was based on the first IMPROVE algorithm. Limitations of the original IMPROVE algorithm led to the development of a second IMPROVE algorithm which has been used for all analyses in this document. A description of the original approach for estimating natural haze levels is available in the Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule, at http://vista.cira.colostate.edu/improve/Publications/GuidanceDocs/guidancedocs.htm, as are the results of applying it all of the IMPROVE monitoring sites. A description of the second IMPROVE algorithm may be found at http://vista.cira.colostate.edu/improve/Publications/GrayLit/019_RevisedIMPROVEeq/RevisedIMPROVEAlgorithm3.doc. The two IMPROVE algorithms are further discussed in APPENDIX III.K.2.

The second IMPROVE algorithm has been used for all Alaska Regional Haze analyses. The limitations of the original IMPROVE algorithm are especially relevant to Alaska's remote and coastal Class I areas. The original IMPROVE algorithm tended to underestimate light extinction for the highest haze conditions and overestimate it for the lowest haze conditions. Alaska has very low haze levels compared to the rest of the United States. The original IMPROVE algorithm used a ratio of organic compound mass to total carbon mass of 1.4, though the literature indicated that the ratio is higher especially in remote areas, such as Alaska. The original algorithm also didn't include a term for sea salt, which is important for sites near the sea coasts. Other limitations include use of a single Rayleigh scattering estimate for all sites, and flawed assumptions used to estimate 20% best and worst conditions. The second IMPROVE algorithm addressed these limitations, so is used here.

2. Determining Baselines

Conceptually, there are five steps to determining baselines: 1) define visibility and how it will be measured, 2) use an existing air monitoring network to provide consistent aerosol measurements, 3) monitor (measure) the concentrations of aerosol species over the baseline years 2000-2004, 4) define algorithms to calculate visibility from the amounts of naturally occurring aerosols and pollutants in the air, 5) calculate baseline conditions from the monitored concentrations of each aerosol species using the algorithm developed in Step 4.

For several Alaska Class I area sites, monitoring began in late 2001; therefore, only three complete years of monitoring data, 2002-2004, define their baselines. Baseline or current visibility includes haze pollutant contributions from anthropogenic sources as well as those from natural sources.

Baseline visibility is calculated using the actual pollutant concentrations measured at the IMPROVE monitors every three days during the period of 2000-2004. The 20% highest

deciview days (roughly corresponding to the 24 days having the worst visibility) are averaged each year. These five yearly values are then averaged to determine the worst days' visibility in deciviews for the 2000-2004 baseline period. The same process is used to get the best day baseline visibility value in deciviews from the annual 20% best days over the baseline years.

Due to the remote location of the Class I area in the Bering Sea and the severe meteorology, problems were encountered in operating monitors. For this reason, insufficient data are available to calculate baseline values for this site.

3. Rates of Progress and Glideslopes

Baseline visibility conditions can be compared to natural visibility conditions to assess reductions needed to achieve 2064 goals. The difference between the baseline and natural visibility levels for the 20% worst days can be used to compute a uniform rate of progress glide slope. Glide slopes provide a reference against which progress toward uniform natural conditions can be measured. The slope of the line from baseline to natural conditions indicates the severity of change necessary to reach natural condition by 2064. States are required to use this information to establish goals that provide for an improvement in visibility for the 20% worst days while ensuring no degradation in visibility occurs on the 20% best days.

4. Alaska Class I Area Natural Conditions

Natural condition estimates for the Alaska Class I areas are presented in Table III.K.4-1, which includes site totals and both mass and extinction estimates for individual aerosol species. Light extinction due to sea salt dominates worst day and annual estimates for the coastal sites, Tuxedni and Simeonof. At both Denali sites, DENA1 and TRCR1, the greatest light extinction on worst day and annual estimates comes from organic mass from carbon (OMC) and coarse mass (CM), with lesser contributions from SO4. In Alaska, large quantities of sea salt and OMC typically derive from ocean and wildfires, respectively. Sulfate extinction on the worst days ranges from 10-15% of the total at the Denali sites, to 5% at Simeonof and 9% at Tuxedni. Worst day extinction due to nitrates is estimated at 5-9% of the total for Denali sites, 4% at Simeonof, and 8% at Tuxedni.

The worst day natural condition estimates for Alaska Class I areas fall within the range described by the contiguous (i.e., lower-48) states (Figure III.K.4-1), with the Denali sites falling at the high visibility extreme, Simeonof toward the lower visibility end, and Tuxedni in between. The deciview values correspond to sight distances from roughly 210 km at DENA1 to 101 km at SIME, with TUXE1 and TRCR1 in between.

Table III.K.4-1
Natural Condition Estimates by Aerosol Species for Alaska's Four Class I Areas Using the IMPROVE II Algorithm

From: Alaska naturallevelsII.xls

Column codes:
- Annual Natural Conditions: estimate
- Best Day Natural Conditions: Best 20% estimate
- Worst Day Natural Conditions: Worst 20% estimate

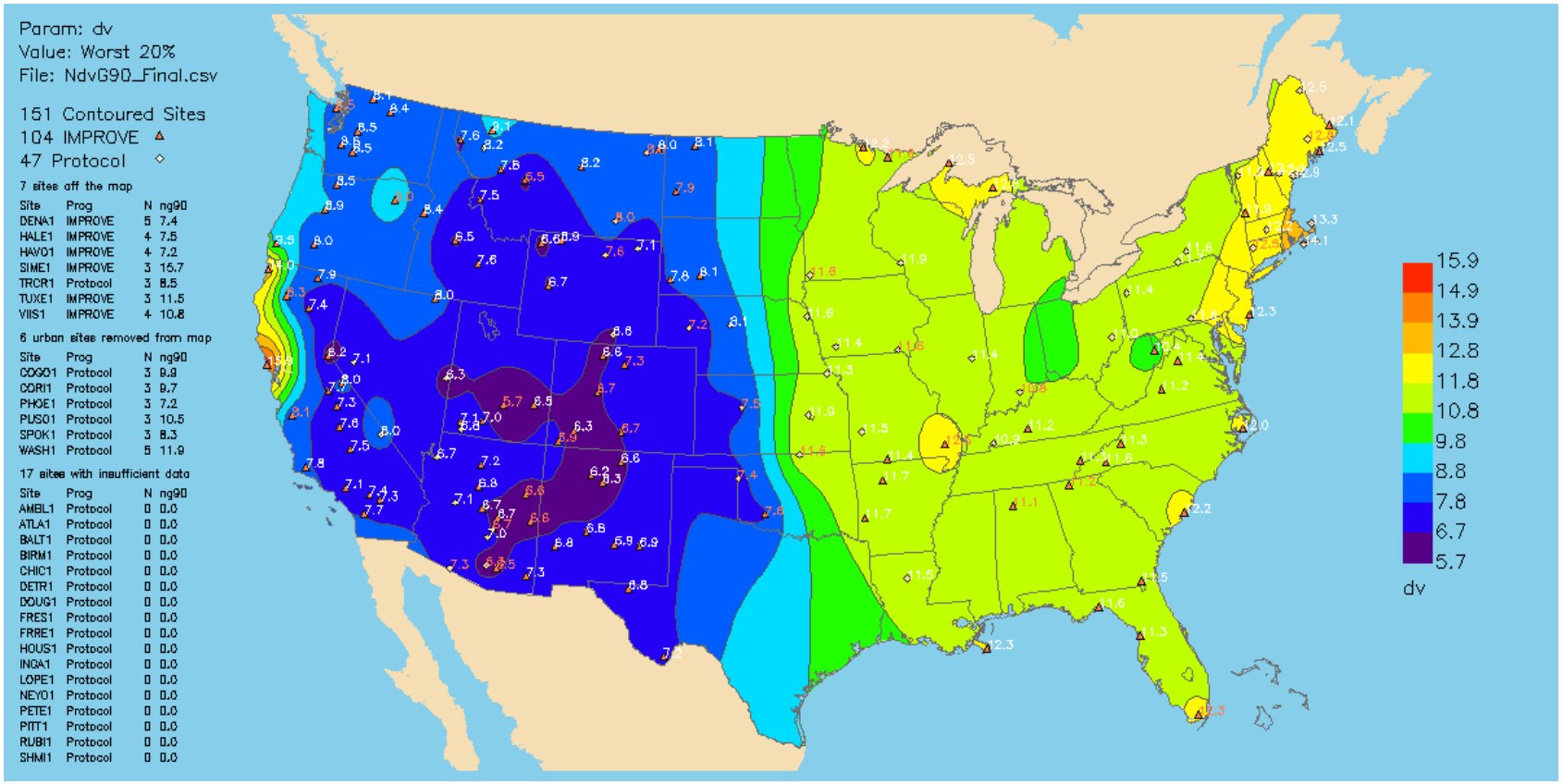
Species codes:

aBext	total aerosol extinction	bSoil	fine soil extinction	OMC	organic mass from carbon
bCM	coarse mass extinction	bSs	sea salt extinction	SO4	ammonium sulfate mass
bEC	elemental carbon extinction	dv	deciview	Soil	fine soil mass
bNO3	ammonium nitrate extinction	CM	coarse mass	Ss	sea salt mass
bOMC	organic extinction	EC	elemental carbon mass		
bSO4	ammonium sulfate extinction	NO3	ammonium nitrate mass		

	Annual Natural Conditions	Best Day Natural Conditions	Worst Day Natural Conditions	Units		Annual Natural Conditions	Best Day Natural Conditions	Worst Day Natural Conditions	Units
DENA									
aBext	4.31	0.94	11.81	Mm^{-1}	dv	3.79	1.77	7.32	
bCM	0.67	0.19	1.4	Mm^{-1}	CM	1.12	0.18	2.61	ug/m^3
bEC	0.2	0.06	0.48	Mm^{-1}	EC	0.02	0.01	0.05	ug/m^3
bNO3	0.35	0.13	0.6	Mm^{-1}	NO3	0.06	0.03	0.09	ug/m^3
bOMC	2.07	0.24	7.29	Mm^{-1}	OMC	0.6	0.1	1.9	ug/m^3
bSO4	0.65	0.24	1.13	Mm^{-1}	SO4	0.12	0.04	0.2	ug/m^3
bSoil	0.14	0.04	0.3	Mm^{-1}	Soil	0.14	0.04	0.33	ug/m^3
bSs	0.23	0.05	0.6	Mm^{-1}	Ss	0.04	0.02	0.07	ug/m^3
TRCR									
aBext	4.88	1.12	11.81	Mm^{-1}	dv	4.94	2.71	8.4	
bCM	0.91	0.24	1.72	Mm^{-1}	CM	1.53	0.27	3.39	ug/m^3
bEC	0.2	0.09	0.4	Mm^{-1}	EC	0.02	0.01	0.04	ug/m^3
bNO3	0.54	0.17	1.11	Mm^{-1}	NO3	0.06	0.03	0.1	ug/m^3
bOMC	1.89	0.23	5.95	Mm^{-1}	OMC	0.6	0.1	1.7	ug/m^3
bSO4	0.89	0.28	1.79	Mm^{-1}	SO4	0.12	0.04	0.2	ug/m^3
bSoil	0.15	0.05	0.3	Mm^{-1}	Soil	0.15	0.05	0.32	ug/m^3
bSs	0.29	0.06	0.54	Mm^{-1}	Ss	0.05	0.02	0.05	ug/m^3
SIME									
aBext	16.31	5.03	37.18	Mm^{-1}	dv	9.6	5.28	15.6	
bCM	1.8	0.71	3.15	Mm^{-1}	CM	3	0.9	6.66	ug/m^3
bEC	0.2	0.15	0.24	Mm^{-1}	EC	0.02	0.01	0.02	ug/m^3
bNO3	1.2	0.6	1.67	Mm^{-1}	NO3	0.1	0.05	0.14	ug/m^3
bOMC	1.46	0.72	2.65	Mm^{-1}	OMC	0.46	0.27	0.64	ug/m^3
bSO4	1.28	0.76	1.76	Mm^{-1}	SO4	0.12	0.07	0.16	ug/m^3
bSoil	0.13	0.04	0.21	Mm^{-1}	Soil	0.13	0.04	0.31	ug/m^3
bSs	10.23	2.04	27.5	Mm^{-1}	Ss	1.26	0.3	3.06	ug/m^3
TUXE									
aBext	8.02	1.71	20.71	Mm^{-1}	dv	6.32	3.15	11.32	
bCM	1.24	0.31	2.48	Mm^{-1}	CM	2.06	0.42	4.69	ug/m^3
bEC	0.2	0.07	0.34	Mm^{-1}	EC	0.02	0.01	0.03	ug/m^3
bNO3	0.87	0.36	1.58	Mm^{-1}	NO3	0.09	0.05	0.16	ug/m^3
bOMC	1.98	0.26	5.49	Mm^{-1}	OMC	0.6	0.08	1.47	ug/m^3
bSO4	0.96	0.3	1.79	Mm^{-1}	SO4	0.12	0.04	0.2	ug/m^3
bSoil	0.1	0.03	0.14	Mm^{-1}	Soil	0.1	0.04	0.16	ug/m^3
bSs	2.67	0.38	8.89	Mm^{-1}	Ss	0.38	0.06	1.13	ug/m^3

Figure III.K.4-1
Natural Haze Levels II

The map of the contiguous states shows worst days natural conditions haze levels calculated using the IMPROVE II approach. Class I area deciview estimates and contours between sites are mapped. Deciview values for Alaska sites are not mapped, but are both to the left and below the map. Numeric values based on fewer than 3 years of valid baseline data are shown in red. *Map is taken from the final report Natural Haze Levels II committee to the RPO Monitoring/Data Analysis Workgroup. Alaska data listing at left differs slightly from tabular data in the final report. Color blocks below the map are consistent with elsewhere in this SIP.*



DENA1 7.3 --- TRCR1 8.4 --- TUXE1 11.3 --- SIME1 15.6 ---

5. Baseline

Baseline measurements for the Alaska Class I areas are presented in Table III.K.4-2, which includes site totals and both mass and extinction estimates for individual aerosol species. Light extinction due to nearly equal amounts of sea salt and sulfate dominates annual baselines for the coastal sites, Tuxedni and Simeonof. On worst days at Tuxedni, sea salt and sulfate are still equivalent. However, on worst days at Simeonof, sea salt extinction (25.16 Mm^{-1}) far exceeds sulfate extinction (15.3 Mm^{-1}). At both Denali sites, DENA1 and TRCR1, the greatest light extinction on annual baselines comes from organic mass carbon and sulfate, with sulfate higher at TRCR1 and OMC higher at DENA1. On worst days at DENA1, OMC extinction far exceeds sulfate extinction; however the two extinctions are more nearly equal at TRCR1.

In Alaska, large quantities of sea salt and OMC typically derive from ocean and wildfires, respectively. Sulfate extinction on the worst days ranges from 10-15% of the total at the Denali sites, to 5% at Simeonof and 9% at Tuxedni. Worst day extinction due to nitrates is estimated at 5-10% of the total for Denali sites, 4% at Simeonof, and 8% at Tuxedni.

6. Change: Natural Conditions, Baselines, and Glideslopes for Alaska's Class I Areas

Baseline measurements and Natural conditions estimates, summed across all IMPROVE species, are presented in Table III.K.4-3. This information was provided by the WRAP Technical Support System (TSS).[*] This table contrasts worst day baseline conditions with natural conditions estimates for Alaska's Four Class I areas, and presents the resulting 10-year glideslopes.

Figure III.K.4-2 displays the rate of progress (deciview reduction per decade) required to reach natural levels in 60 years for each site, using contours determined with the IMPROVE II algorithm and the natural haze levels II approach. For the Alaska Class I areas, small rates of progress are needed to attain natural condition by 2064. DENA1 falls below the ranges for the rest of the country.

[*] http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx

Table III.K.4-2
Baseline Estimates, by aerosol species for Alaska's Four Class I Areas Using the IMPROVE II Algorithm

From: Alaska naturallevelsII.xls

Column codes:
- Annual Baseline: mean
- Best Day Baseline: Best 20% mean
- Worst Day Baseline: Worst 20% mean

Species codes:

aBext	total aerosol extinction	bSoil	fine soil extinction	OMC	organic mass from carbon
bCM	coarse mass extinction	bSs	sea salt extinction	SO4	ammonium sulfate mass
bEC	elemental carbon extinction	dv	deciview	Soil	fine soil mass
bNO3	ammonium nitrate extinction	CM	coarse mass	Ss	sea salt mass
bOMC	organic extinction	EC	elemental carbon mass		
bSO4	ammonium sulfate extinction	NO3	ammonium nitrate mass		

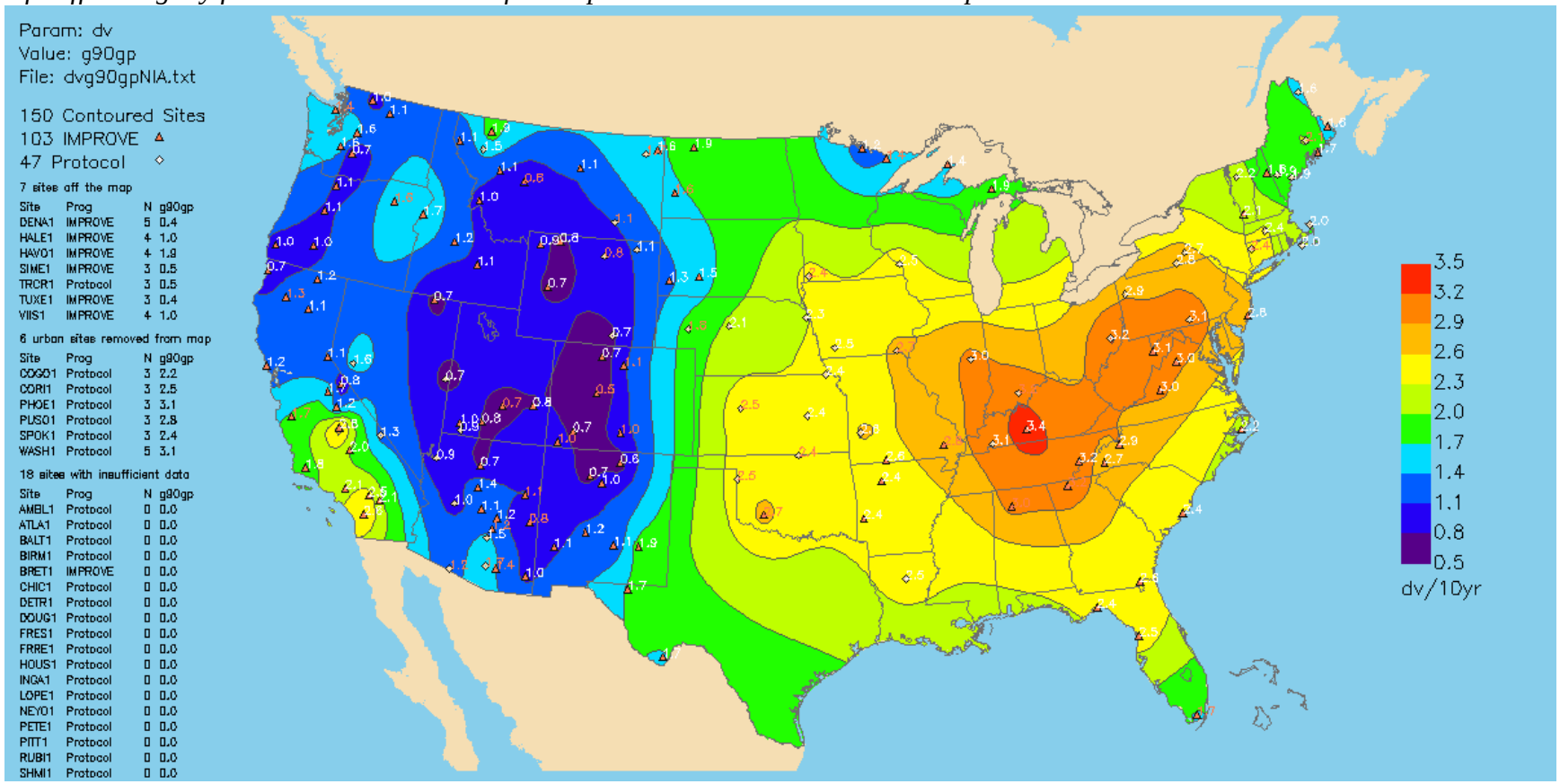
	Annual Baseline	Best Day Baseline	Worst Day Baseline	Units		Annual Baseline	Best Day Baseline	Worst Day Baseline	Units
DENA									
aBext	7.56	1.75	20	Mm^{-1}	dv	5.34	2.42	9.86	
bCM	0.67	0.21	1.37	Mm^{-1}	CM	1.12	0.35	2.29	ug/m^3
bEC	0.65	0.17	1.58	Mm^{-1}	EC	0.06	0.02	0.16	ug/m^3
bNO3	0.34	0.13	0.6	Mm^{-1}	NO3	0.05	0.02	0.1	ug/m^3
bOMC	3.03	0.32	10.83	Mm^{-1}	OMC	0.81	0.11	2.6	ug/m^3
bSO4	2.49	0.81	4.85	Mm^{-1}	SO4	0.43	0.13	0.87	ug/m^3
bSoil	0.14	0.05	0.31	Mm^{-1}	Soil	0.14	0.05	0.31	ug/m^3
bSs	0.23	0.07	0.45	Mm^{-1}	Ss	0.04	0.01	0.08	ug/m^3
TRCR									
aBext	8.81	2.14	21.37	Mm^{-1}	dv	6.75	3.45	11.61	
bCM	0.91	0.26	1.63	Mm^{-1}	CM	1.52	0.43	2.72	ug/m^3
bEC	0.65	0.3	1.31	Mm^{-1}	EC	0.06	0.03	0.13	ug/m^3
bNO3	0.54	0.17	1.09	Mm^{-1}	NO3	0.06	0.02	0.12	ug/m^3
bOMC	2.83	0.36	9.06	Mm^{-1}	OMC	0.85	0.13	2.53	ug/m^3
bSO4	3.43	0.93	7.54	Mm^{-1}	SO4	0.44	0.12	0.94	ug/m^3
bSoil	0.15	0.05	0.27	Mm^{-1}	Soil	0.15	0.05	0.27	ug/m^3
bSs	0.29	0.08	0.47	Mm^{-1}	Ss	0.05	0.01	0.08	ug/m^3
SIME									
aBext	26.65	9.59	53.44	Mm^{-1}	dv	12.72	7.6	18.56	
bCM	2.57	1.08	4.39	Mm^{-1}	CM	4.29	1.81	7.31	ug/m^3
bEC	1	0.43	1.94	Mm^{-1}	EC	0.1	0.04	0.19	ug/m^3
bNO3	1.27	0.53	1.91	Mm^{-1}	NO3	0.1	0.04	0.16	ug/m^3
bOMC	1.9	0.59	4.56	Mm^{-1}	OMC	0.58	0.2	1.24	ug/m^3
bSO4	9.63	3.72	15.3	Mm^{-1}	SO4	0.84	0.33	1.37	ug/m^3
bSoil	0.13	0.03	0.18	Mm^{-1}	Soil	0.13	0.03	0.18	ug/m^3
bSs	10.15	3.21	25.16	Mm^{-1}	Ss	1.25	0.39	3.12	ug/m^3
TUXE									
aBext	12.95	2.94	31.46	Mm^{-1}	dv	8.26	3.99	14.11	
bCM	1.23	0.33	2.49	Mm^{-1}	CM	2.06	0.55	4.15	ug/m^3
bEC	0.66	0.2	1.18	Mm^{-1}	EC	0.07	0.02	0.12	ug/m^3
bNO3	0.95	0.39	1.78	Mm^{-1}	NO3	0.1	0.04	0.18	ug/m^3
bOMC	3.04	0.39	8.88	Mm^{-1}	OMC	0.87	0.14	2.24	ug/m^3
bSO4	4.3	1.06	8.74	Mm^{-1}	SO4	0.5	0.12	0.99	ug/m^3
bSoil	0.1	0.03	0.15	Mm^{-1}	Soil	0.1	0.03	0.15	ug/m^3
bSs	2.66	0.53	8.24	Mm^{-1}	Ss	0.38	0.08	1.18	ug/m^3

Table III.K.4-3
Worst Day Visibilities for Natural Conditions and Baseline Estimates Using the IMPROVE II Algorithm, and the Resulting 10-Year Glide Slope Estimates

Site	Class I Area(s)	Years of Complete Data	Worst Haze Natural Conditions (dv)	Worst Haze Baseline Conditions (dv)	10-year Glide Slope (dv)
DENA1	Denali	5	7.3	9.9	0.4
TRCR1	Denali	3	8.4	11.6	0.5
SIME1	Simeonof	3	15.6	18.6	0.5
TUXE1	Tuxedni	3	11.3	14.1	0.5

Figure III.K.4-2
Glideslopes

The map shows the rates of progress (deciview reduction per decade) required for sites to attain natural conditions in 60 years. Class I area rates of progress and contours between sites are mapped. Values were determined using the new IMPROVE II algorithm and the Natural Conditions II approach. Values for Alaska sites are not mapped, but are both to the left of the map and below. *Ref. Map is taken from the final report Natural Haze Levels II committee to the RPO Monitoring/Data Analysis Workgroup. Alaska data listing at left differs slightly from tabular data in the final report. Color blocks below the map are consistent with elsewhere in this SIP.*



DENA1 0.4 --- TRCR1 0.5 --- SIME1 0.5 --- TUXE1 0.5 ---

Simeonof Class I Area Baselines, Natural Conditions, Glideslope, and Interim Visibility Targets:

The Simeonof baselines and natural conditions for best and worst days are presented in Table III.K.4-4. With baseline and target goals calculated, the glideslope was defined, and five-year target visibilities calculated (Table III.K.4-4). Figure III.K.4-3 presents the baseline, glideslope, and natural conditions graphically for units of particulate extinction (Mm^{-1}).

Table III.K.4-4
Baseline, Natural Conditions, Interim Glideslope, and Yearly Summaries at Simeonof, in Extinction (Mm^{-1})

Worst 20% Visibility Days

Site	Year	aBext|Base	aBext|Inc	aBext|NCII	Particle Extinction|NIA
SIME1	2000	53.44			
SIME1	2001	53.44			
SIME1	2002	53.44			55.18
SIME1	2003	53.44			51.22
SIME1	2004	53.44	53.44		53.93
SIME1	2008		52.2		
SIME1	2013		50.69		
SIME1	2018		49.21		
SIME1	2023		47.76		
SIME1	2028		46.36		
SIME1	2033		44.98		
SIME1	2038		43.64		
SIME1	2043		42.33		
SIME1	2048		41.06		
SIME1	2053		39.81		
SIME1	2058		38.6		
SIME1	2064		37.18	37.2	
SIME1	2005				46.88
SIME1	2006				56.3

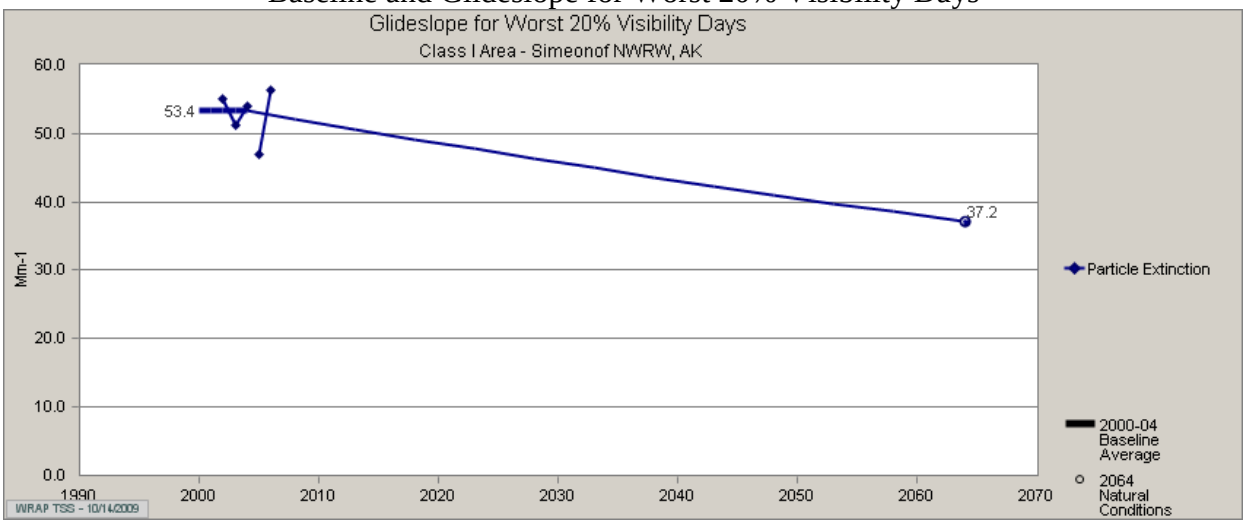
Best 20% Visibility Days

Site	Year	aBext|Base	aBext|NCII	Particle Extinction|NIA
SIME1	2000	9.59		
SIME1	2001	9.59		
SIME1	2002	9.59		9.86
SIME1	2003	9.59		7.86
SIME1	2004	9.59		11.04
SIME1	2064		5.0323	
SIME1	2005			9.96
SIME1	2006			11.15

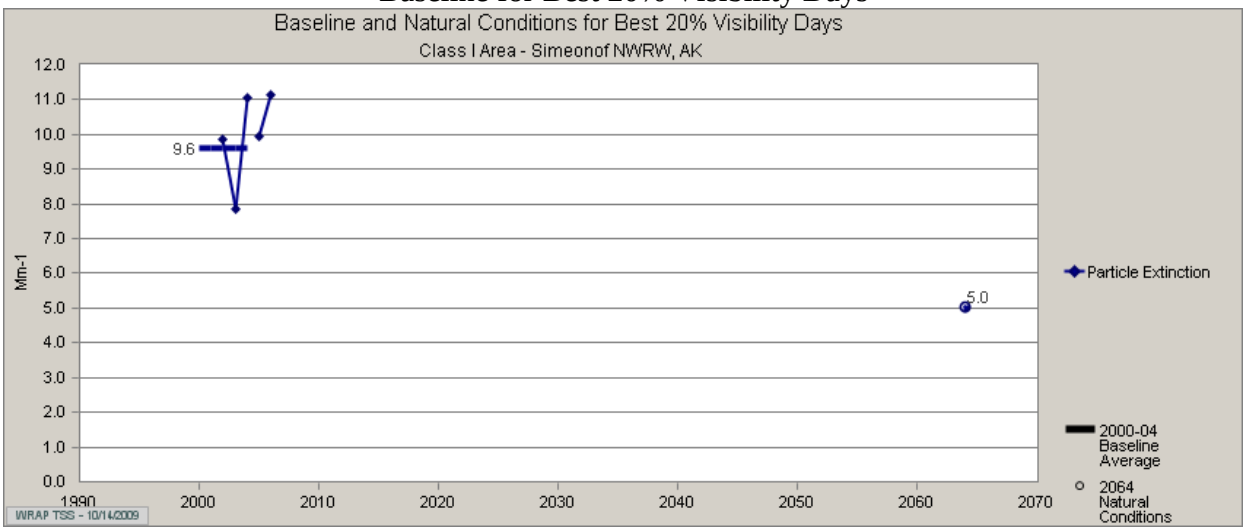
Note: 2005-2006 visibility summaries are included as they are discussed individually in the text.

Figure III.K.4-3
Baseline and Glideslope for Visibility at Simeonof, in Extinction (Mm^{-1})

Baseline and Glideslope for Worst 20% Visibility Days



Baseline for Best 20% Visibility Days



Denali Class I Area Baselines, Natural Conditions, Glideslope, and Interim Visibility Targets:

The DENA1 (Denali) Baselines and Natural Conditions for best and worst days are presented in Table III.K.4-5. With baseline and target goals calculated, the glideslope was defined, and five-year target visibilities calculated (Table III.K.4-5). Figure III.K.4-4 presents the baseline, glideslope, and natural conditions graphically for units of particulate extinction (Mm^{-1}).

Table III.K.4-5
Baseline, Natural Conditions, Interim Glideslope, and Yearly Summaries at Denali in Extinction (Mm^{-1})

Worst 20% Visibility Days

Site	Year	aBext|Base	aBext|Inc	aBext|NCII	Particle Extinction|NIA
DENA1	2000	20			32.97
DENA1	2001	20			16.07
DENA1	2002	20			18.66
DENA1	2003	20			16.26
DENA1	2004	20	20		16.02
DENA1	2008		19.37		
DENA1	2013		18.59		
DENA1	2018		17.84		
DENA1	2023		17.11		
DENA1	2028		16.4		
DENA1	2033		15.71		
DENA1	2038		15.03		
DENA1	2043		14.38		
DENA1	2048		13.74		
DENA1	2053		13.11		
DENA1	2058		12.51		
DENA1	2064		11.8	11.8	
DENA1	2005				21.26
DENA1	2006				16.45

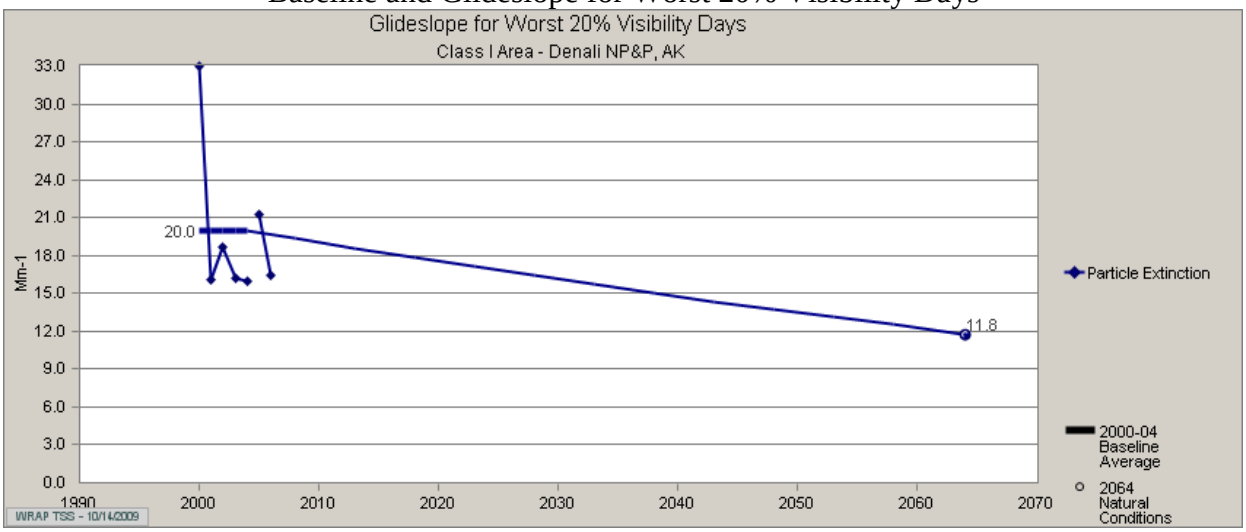
Best 20% Visibility Days

Site	Year	aBext|Base	aBext|NCII	Particle Extinction|NIA
DENA1	2000	1.75		2.05
DENA1	2001	1.75		1.87
DENA1	2002	1.75		1.64
DENA1	2003	1.75		1.44
DENA1	2004	1.75		1.76
DENA1	2064		0.9393	
DENA1	2005			1.25
DENA1	2006			1.94

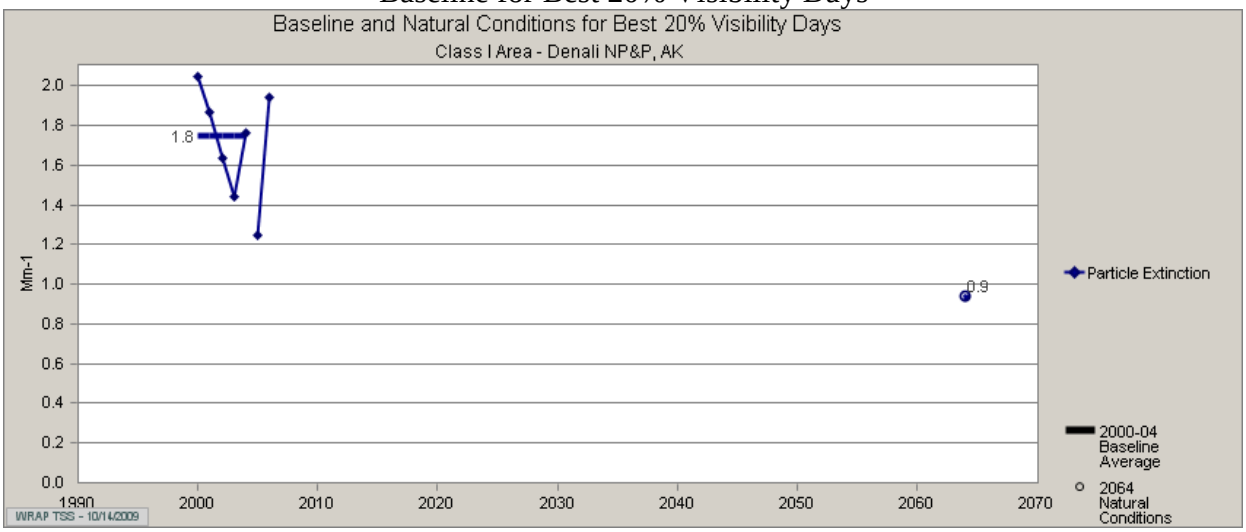
Note: 2005-2006 visibility summaries are included as they are discussed individually in the text.

Figure III.K.4-4
Baseline and Glideslope for Visibility at Denali in Extinction (Mm^{-1})

Baseline and Glideslope for Worst 20% Visibility Days



Baseline for Best 20% Visibility Days



The TRCR1 (Denali) baselines and natural conditions for best and worst days are presented in Table III.K.4-6. With baseline and target goals calculated, the glideslope was defined, and five-year target visibilities calculated (Table III.K.4-6). Figure III.K.4-5 presents the baseline, glideslope, and natural conditions graphically for units of particulate extinction (Mm^{-1}).

Table III.K.4-6
Baseline, Natural Conditions, Interim Glideslope, and Yearly Summaries at Denali, Trapper Creek, in Extinction (Mm^{-1})

Worst 20% Visibility Days

Site	Year	Averaged Baseline	Interim Target	NCII Estimate	Measured Particle Extinction
TRCR1	2000	21.37			
TRCR1	2001	21.37			
TRCR1	2002	21.37			20.96
TRCR1	2003	21.37			18.75
TRCR1	2004	21.37	21.37		24.39
TRCR1	2008		20.62		
TRCR1	2013		19.7		
TRCR1	2018		18.81		
TRCR1	2023		17.95		
TRCR1	2028		17.12		
TRCR1	2033		16.31		
TRCR1	2038		15.52		
TRCR1	2043		14.76		
TRCR1	2048		14.02		
TRCR1	2053		13.31		
TRCR1	2058		12.61		
TRCR1	2064		11.8	11.8	
TRCR1	2005				33.54
TRCR1	2006				20.39

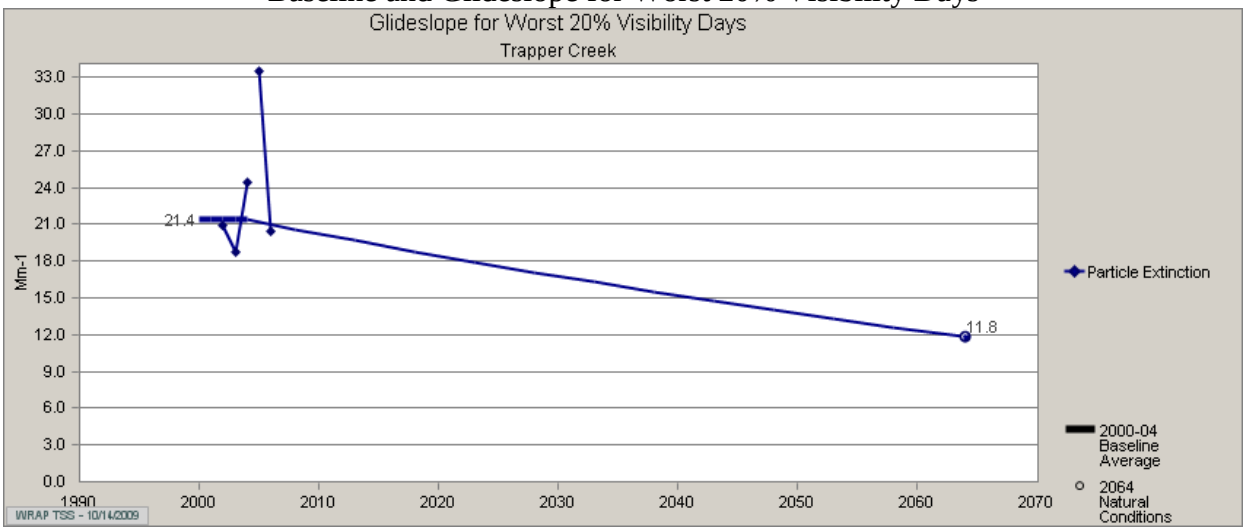
Best 20% Visibility Days

Site	Year	Averaged Baseline	|NCII Estimate	Measured Particle Extinction
TRCR1	2000	2.14		
TRCR1	2001	2.14		
TRCR1	2002	2.14		2.11
TRCR1	2003	2.14		1.82
TRCR1	2004	2.14		2.5
TRCR1	2064		1.12	
TRCR1	2005			1.78
TRCR1	2006			2.95

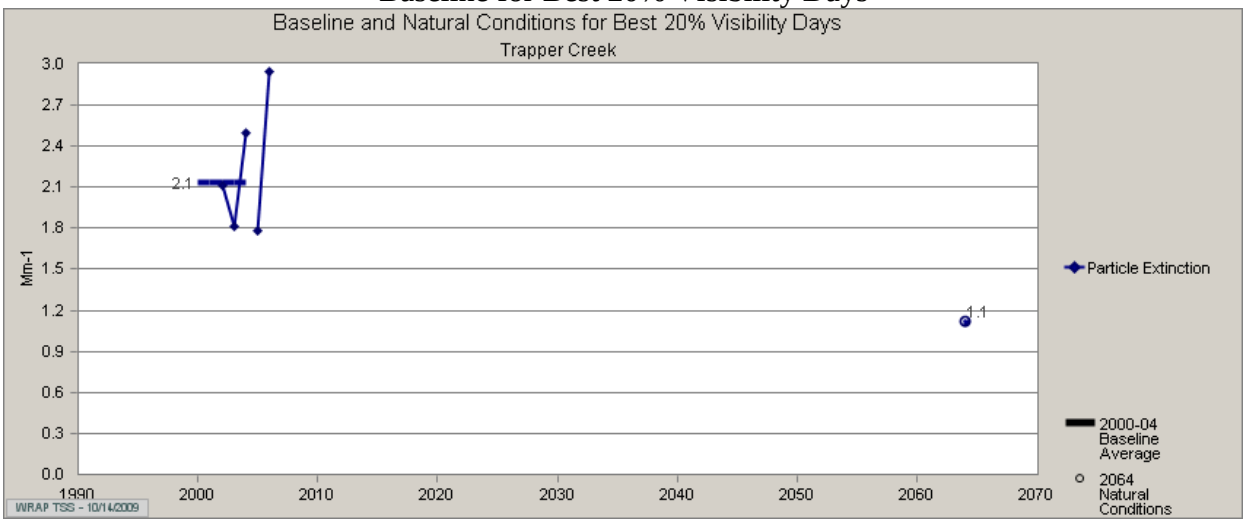
Note: 2005-2006 visibility summaries are included as they are discussed individually in the text.

Figure III.K.4-5
Baseline and Glideslope for Visibility at Denali, Trapper Creek, in Extinction (Mm^{-1})

Baseline and Glideslope for Worst 20% Visibility Days



Baseline for Best 20% Visibility Days



Tuxedni Class I Area Baselines, Natural Conditions, Glideslope, and Interim Visibility Targets:

The Tuxedni visibility baselines and natural conditions for best and worst days are presented in Table III.K.4-7. With baseline and target goals calculated, the glideslope was defined, and five-year target visibilities calculated (Table III.K.4-7). Figure III.K.4-6 presents the baseline, glideslope, and natural conditions graphically for units of particulate extinction (Mm^{-1}).

Table III.K.4-7
Baseline, Natural Conditions, Interim Glideslope, and Yearly Summaries at Tuxedni, in Extinction (Mm^{-1})

Worst 20% Visibility Days

Site	Year	aBext|Base	aBext|Inc	aBext|NCII	Particle Extinction|NIA
TUXE1	2000	31.46			
TUXE1	2001	31.46			
TUXE1	2002	31.46			39.33
TUXE1	2003	31.46			24.17
TUXE1	2004	31.46	31.46		30.87
TUXE1	2008		30.64		
TUXE1	2013		29.63		
TUXE1	2018		28.65		
TUXE1	2023		27.7		
TUXE1	2028		26.76		
TUXE1	2033		25.86		
TUXE1	2038		24.97		
TUXE1	2043		24.1		
TUXE1	2048		23.26		
TUXE1	2053		22.44		
TUXE1	2058		21.64		
TUXE1	2064		20.7	20.7	
TUXE1	2005				32.19
TUXE1	2006				30.1

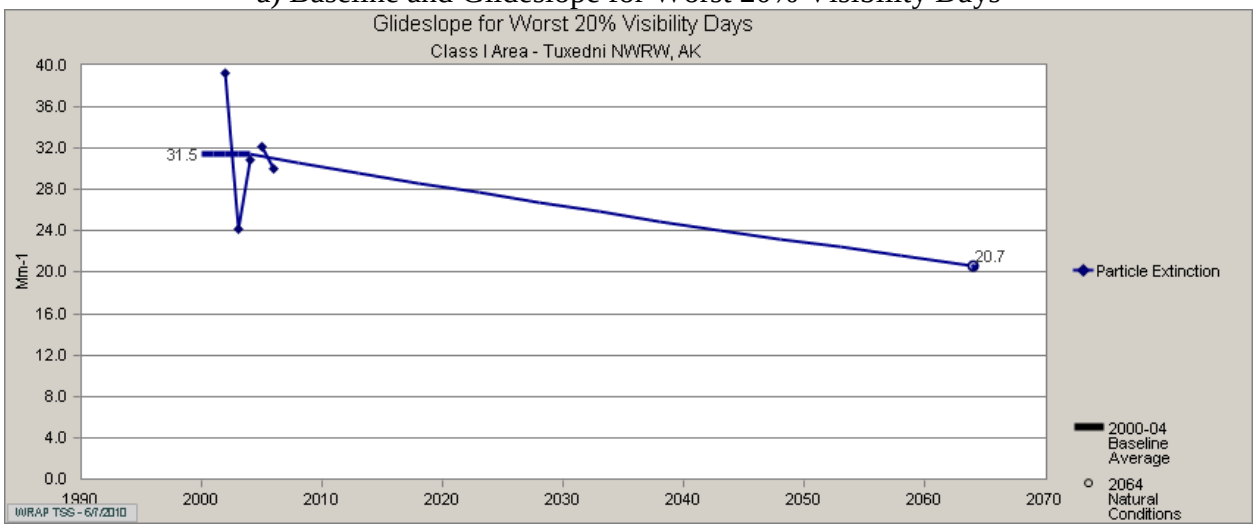
Best 20% Visibility Days

Site	Year	aBext|Base	aBext|NCII	Particle Extinction|NIA
TUXE1	2000	2.94		
TUXE1	2001	2.94		
TUXE1	2002	2.94		3.26
TUXE1	2003	2.94		2.62
TUXE1	2004	2.94		2.93
TUXE1	2064		1.7138	
TUXE1	2005			2.74
TUXE1	2006			3.62

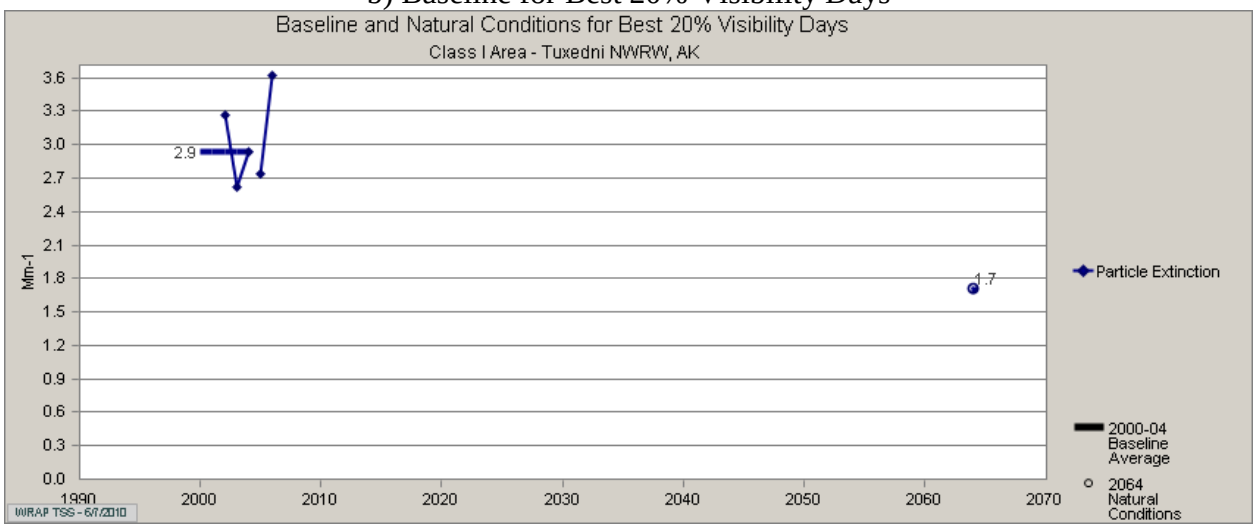
Note: 2005-2006 visibility summaries are included as they are discussed individually in the text.

Figure III.K.4-6
Baseline and Glideslope for Visibility at Tuxedni, in Extinction (Mm^{-1})

a) Baseline and Glideslope for Worst 20% Visibility Days



b) Baseline for Best 20% Visibility Days



7. Choice of IMPROVE II Algorithm

As stated previously, the second IMPROVE algorithm is more applicable to Alaska regional haze conditions and analyses. Natural condition and glide slope estimates from each available IMPROVE algorithm are contrasted in Table III.K.4-8. The IMPROVE II algorithm shows much higher natural haze levels for the two coastal Class I areas and decreases the slope of haze improvement (deciview reduction/decade) necessary to attain natural conditions by 2064. With the IMPROVE II algorithm, the estimated decadal improvement is not perceptible to the naked eye at any of the Class I areas. The glide path slopes at coastal sites are among the lowest anywhere in the country; slopes at the Denali sites fall outside the national range depicted in Figure III.K.4-2.

Table III.K.4-8
Algorithm Comparison, Worst Days Natural Conditions and Glide Slopes from Baseline to Natural Conditions in 2064

	Natural Haze II dv Worst Days	Natural Haze Default dv Worst Days	Glide Path, IMPROVE II deciview reduction /decade Slope	Glide Path, Default deciview reduction /decade Slope
SIME	15.7	7.9	0.5	1.1
TUXE	11.3	7.6	0.5	0.7
DEN1	7.4	7.2	0.4	0.4

Note: Final report Natural Haze Levels II Committee

The natural values presented in Table III.K.4-8 are slightly different from values now available from the WRAP TSS website and used elsewhere in this document. Since the report producing these values did not address Trapper Creek, a decision was made to use the TSS values, which employ the IMPROVE II algorithm, in glide slope calculations elsewhere in this document to ensure consistency across all of the sites.

8. Choice of Baseline Years

The regional haze rule requires that years 2000-2004 be used to characterize the Baseline Conditions at each Class I area. For three of Alaska's IMPROVE sites, monitoring data are only available for years 2002-2004. Baselines for these three sites are calculated from three years of data in order to keep methods consistent with other states in the WRAP region. ADEC assessed the potential impact on glideslopes of using five years of baseline data, 2002-2006, by calculating three- and five-year baseline conditions for best and worst days (Table III.K.4-9). Trapper Creek had the greatest difference in worst days baseline (0.3 deciview). The greatest difference corresponds to a change in five-year glideslope of only 0.02, so 2002-2004 baselines were retained.

Table III.K.4-9
Three- and Five-Year Baseline Averages for Best and Worst Days, in Deciviews

Site		Years	Baseline Average (dv)	Number of Years
Simeonof	Worst Days	2002-2006	18.4	5 years
		2000-2004	18.6	3 years
	Best Days	2002-2006	7.8	5 years
		2000-2004	7.6	3 years
Tuxedni	Worst Days	2002-2006	14.1	5 years
		2000-2004	14.1	3 years
	Best Days	2002-2006	4.1	5 years
		2000-2004	4.0	3 years
Denali, Trapper Creek	Worst Days	2002-2006	11.9	5 years
		2000-2004	11.6	3 years
	Best Days	2002-2006	3.5	5 years
		2000-2004	3.5	3 years
Denali, Denali Park	Worst Days	2002-2006	10.0	5 years
		2000-2004	9.9	
	Best Days	2002-2006	2.3	
		2000-2004	2.4	

B. Simeonof Wilderness Area

1. Baseline Conditions

The regional haze rule requires that baseline visibility conditions be characterized for each Class I area. The goal of the rule is to improve visibility on worst days from baseline to natural conditions while maintaining baseline visibility on best days. The baseline and natural conditions visibilities together determine an approximate glideslope for visibility improvements and emission reductions toward 2064 goals. Strict adherence to such a glideslope is not necessary, as emission reductions and controls have varied timetables and consequences; however, the glideslope gives a general trend against which reasonable progress may be evaluated.

a. Available Baseline Data

At the Simeonof Class I area, IMPROVE monitoring began late in 2001. The years 2002-2004 were used as baseline. Monitoring results for those years are described in detail in this section. To better understand seasonal and annual influences on Alaska's Class I areas, close examination is also made of annual patterns through 2005.

b. Annual summary for the 2002-2004 Baseline Period

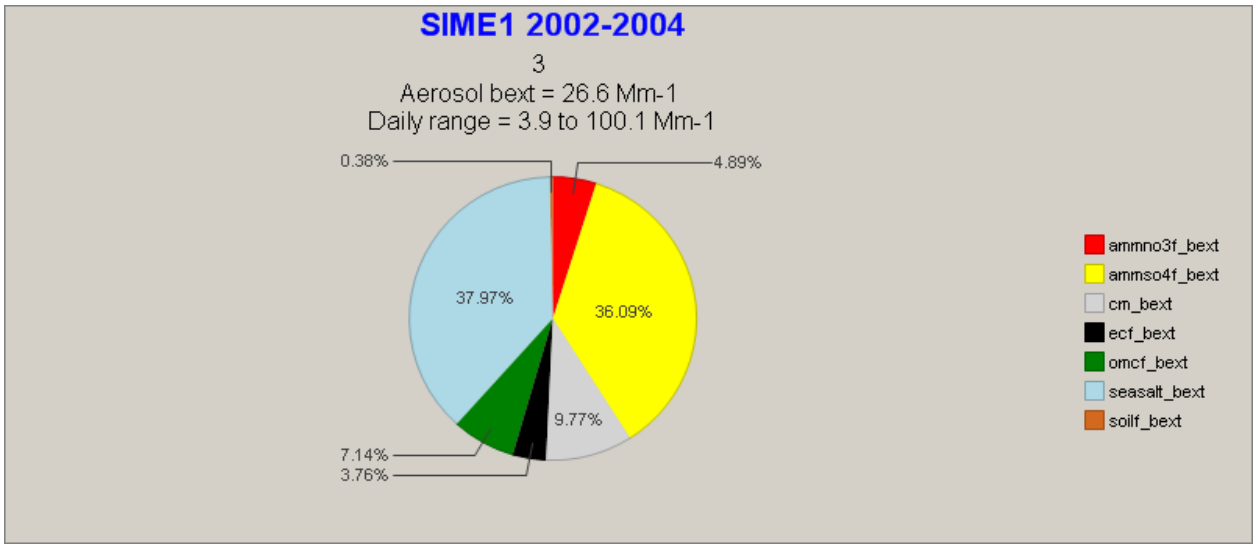
The overall average total light extinction coefficient (B_{ext}) at Simeonof was 26.6 Mm^{-1}. The visual range was approximately 101 km, which corresponds to a deciview of approximately 12.7. In comparison, the Alaska Class I area sites at Denali National Park and Tuxedni National Wildlife Refuge had average B_{ext} of 8.8 and 12.9 Mm^{-1}. Point Reyes National Seashore, a coastal site outside Alaska and away from major population centers, had an average B_{ext} of 46 Mm^{-1}.

The largest components of baseline light extinction at Simeonof are sea salt and sulfate, with organic matter carbon and coarse mass contributing to a lesser extent. The average contributions of the major aerosol components to Simeonof Wilderness Area haze were sea salt 38.0%, sulfate 36.1%, coarse mass 9.8%, organic matter carbon matter 7.1%, nitrate 4.9%, elemental carbon 3.8%, and soil 0.4% (Figure III.K.4-7).

2. Origins of Aerosol Species Influencing Regional Haze at Simeonof Class I Area

Sea Salt at Alaska's coastal Class I areas is primarily of oceanic origin. Sea salt aerosols dramatically affect visibility at both of the coastal Class I area sites, Simeonof and Tuxedni. However, sea salt reaches as far as the Denali Class I area in Alaska's Interior at times.

Figure III.K.4-7
Proportional Representation of IMPROVE Aerosols at Simeonof, Average of 2002-2004



Note: Constituent aerosols are ammonium nitrate (red), ammonium sulfate (yellow), coarse mass (gray), elemental carbon (black), organic matter carbon (green), sea salt (blue), soil (orange). The chart summarizes three years of data. Total aerosol extinction (aerosol_bext) is 26.6 Mm^{-1}. Average daily range is also indicated. (Chart format and abbreviations apply throughout document.)

Organic Matter Carbon (OMC) aerosols originate in both anthropogenic and natural events. In Alaska, the major sources of organic matter carbon are wildland fires (forest, wetland, and tundra) and biogenic aerosols produced by natural vegetation. Wildfires in Alaska occur mostly during the May-August fire season. Controlled burns take place more often in April and May, and in September and October when fires are more easily controlled. Alaska's Interior, between the Alaska Range and the Brooks Range, is most prone to wildfire, but air in all parts of the state is affected. Wildland and agricultural fires in Siberia and Northern Europe also contribute organic matter carbon to Alaska's air. Anthropogenic sources of organic matter carbon are varied, but relatively few, in this sparsely populated region of the state.

Elemental Carbon (EC) is typically the product of incomplete combustion of fossil fuels, vegetation and soils (wildfires and agricultural fires). Levels of elemental carbon are highly correlated with organic matter carbon in Alaska. In spite of that, the relative proportions of the two vary widely. Elemental carbon particles are typically smaller than organic matter carbon particles, and are expected to travel further. This is significant for aerosols reaching the state from Asia and Northern Europe. Inside Alaska, severe wildfires burn vegetation and soils more completely, creating relatively more elemental carbon than from cooler burning fires. The severity of a fire changes as rapidly as wind and weather, with changing relative emissions of elemental carbon and organic matter carbon. A change in wind direction can instantly redirect fire emissions from a nearby monitoring site to one further away, thus changing the relative emissions of elemental carbon and organic matter carbon. Simeonof Wilderness Area is impacted by fires in Interior Alaska, in Asia and Europe, and nearby on the Alaska Peninsula.

Ammonium Sulfate (SO_4) aerosols in Alaska originate from both anthropogenic and natural events. Near Simeonof, volcanoes produce sulfur compounds as ash and volcanic gases. In winter, arctic haze from Northern Europe and Russia contributes sulfur compounds including sulfur dioxide to Alaskan air. These compounds are converted to sulfates in the increasing light levels of spring. Arctic haze also contains particulate sulfur originating from coal burning and metal smelting in Asia and northern Europe. Within Alaska, sulfate aerosols are produced by coal and diesel powered generators, home heating, and mobile sources. It is possible, but not yet known, that biogenic sulfate from ocean plankton contributes sulfate to the Simeonof Class I area site. Another potential source for sulfate is fuel use associated with oceanic shipping.

Ammonium Nitrate (NO_3) is created from several species of NOx. In Alaska, NOx is typically generated by anthropogenic activities, primarily high temperature combustion of fossil fuels. Few such anthropogenic sources exist near Simeonof Class I area. Potential sources for nitrate emissions are oceanic biogenics and fuel use associated with oceanic shipping.

Soil aerosols in Alaska originate from local sources of erosion and in Asian dust storms. At Simeonof, erosion of unvegetated surfaces along the sea coast, rivers, glaciers, and volcanoes may contribute to soil aerosols. The international origin of soil aerosols can frequently be determined because they arrive in discrete meteorological events, often when Alaskan soils are snow covered. Some spring aerosols have been traced chemically and morphologically to sources in Mongolia and northern China. Other long distance aerosols have been traced to agricultural burning in Russia and cooking fires in Asia. None of these sources are controllable for purposes of regional haze.

Coarse Mass (CM) aerosols arise from many different sources and processes. At other Class I areas, important contributors to this category include crustal minerals, organic mass and inorganic salts such as calcium nitrate and sodium nitrate. Within Alaska, typical sources of coarse mass include erosion of coasts and river floodplains, traffic on unpaved roads, and windborne glacial deposits.

3. Best Days and Worst Days, 2002-2004

The average light extinction coefficient (Bext – Rayleigh Scattering (12 Mm^{-1})) during the 20% worst days was 53.4 Mm^{-1}. This is nearly 5.5 times of the value of 9.6 Mm^{-1} during the 20% best days and 2.4 times of the value of 22.5 Mm^{-1} during the middle 60% days. Relative proportions of both sulfate and sea salt changed markedly between best and worst days.
In 2002-2004 sea salt was the largest aerosol contributor to haze during the 20% worst days. Sulfate was the largest aerosol contributor of those susceptible to human control. The contribution of sulfate to light extinction varied both seasonally and year to year.

a. Average and Relative Contributions of Aerosol Species to Visibility on the Best and Worst Days

At Simeonof, the average worst days were characterized by greater extinction in all species measured (Table III.K.4-10). Total light extinction varied dramatically between the best and

worst days, with average non-Rayleigh extinctions from 9.6-53.4 Mm^{-1}. Extinction due to sulfate varied from 3.7-15.3 Mm^{-1}.

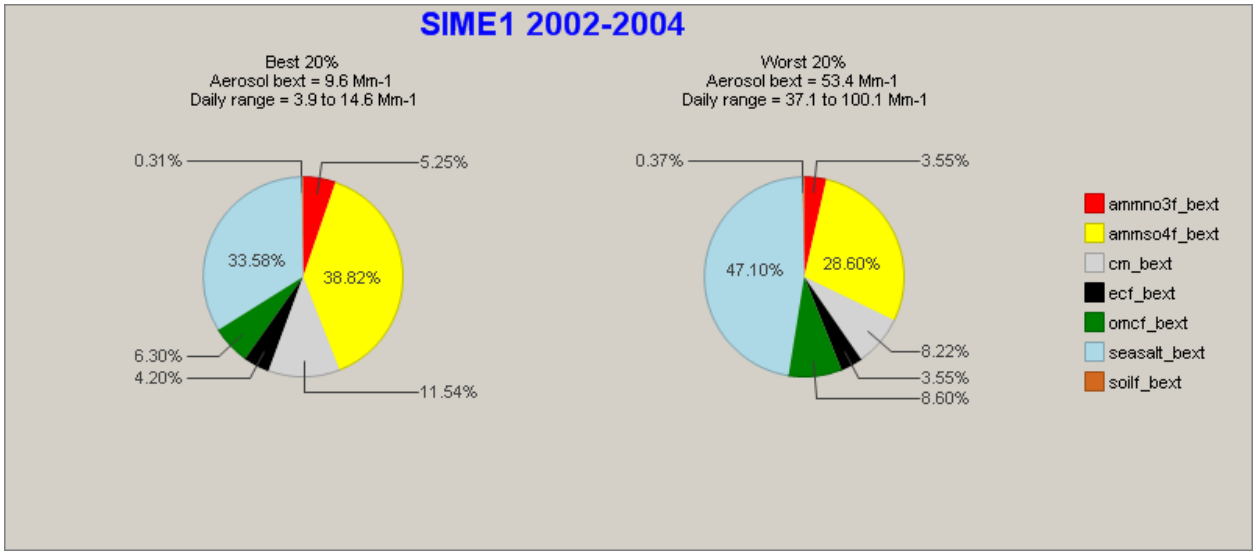
Table III.K.4-10
Average Light Extinctions at Simeonof on Best and Worst Days, 2002-2004

Parameter	Best 20%: Average	Best 20%: Minimum	Best 20%: Maximum	Worst 20%: Average	Worst 20%: Minimum	Worst 20%: Maximum
ammno3f_bext	0.5	0	1.3	1.9	0.5	6.9
ammso4f_bext	3.7	0.01	10.2	15.3	5.5	40.2
cm_bext	1.1	0.1	2.4	4.4	0.3	9.1
ecf_bext	0.4	0	3	1.9	0	15.5
omcf_bext	0.6	0	5.1	4.6	0	46.8
seasalt_bext	3.2	0	8.8	25.2	0	70
soilf_bext	0.03	0.01	0.1	0.2	0.04	0.9
Total extinction	9.6	3.9	14.6	53.4	37.1	100.1
Total extinction including Rayleigh	21.6	15.9	26.6	65.4	49.1	112.1

Note: Extinctions due to each aerosol species are in separate rows. Total extinctions including and without and including Rayleigh scattering comprise the last two rows of the table.

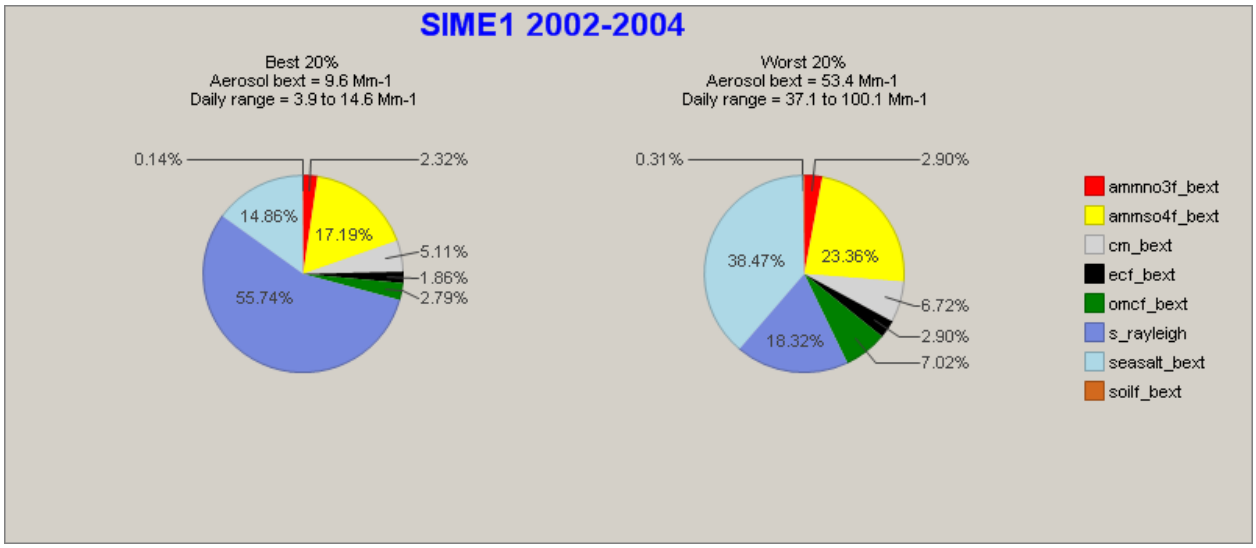
The relative proportions of both sulfate and sea salt changed markedly between best and worst days (Figure III.K.4-8). Sea salt rose from 34 to 47% of extinction on worst days, as sulfate fell from 39 to 29%. The relative contributions of nitrate, elemental carbon, and coarse mass fell slightly on worst days, and organic matter carbon rose slightly (Figure III.K.4-8).

Figure III.K.4-8
Proportional Representation of IMPROVE Aerosols at Simeonof, Best and Worst Days, 2002-2004



With Rayleigh scattering of 12 Mm^{-1} included, total light extinction on the best and worst days varied from 21.6 Mm^{-1}, with visual range of 181 km and 7.6 deciview, to an extinction of 65.4, with a range of 60 km and 18.6 deciview (Table III.K.4-10). The high relative contributions of Rayleigh scattering to best (56%) and worst days (18%) (Figure III.K.4-9) underscore the relatively low aerosol concentrations monitored at Simeonof.

Figure III.K.4-9
Relative Contributions of Rayleigh Scattering to Visibility Impairment at Simeonof (SIME1), Best (56%) and Worst Days (18%)



b. Seasonality, 2002-2004

At Simeonof, the days with worst visibility are not evenly scattered throughout the year. The highest occurrence of the 20% worst days was in February, with March, April, October, and November having intermediate counts (Table III.K.4-11). January and December had the most best days. Data from individual years show a substantial amount of interannual variability.

Table III.K.4-11
Incidence of Best Days and Worst Days for Simeonof, Totaled by Month, 2002-2004

Months, 2002-2004	Number of Best Days (Group 10)	Number of Worst Days (Group 90)
1	10	4
2	7	14
3	1	9
4	3	9
5	7	5
6	1	4
7	8	1
8	4	4
9	5	4
10	8	8
11	6	8
12	11	3

The best days and worst days seen in Table III.K.4-11 represent visibility extremes. Average visibilities change seasonally as well. Average light extinctions, computed for each calendar quarter, summarize seasonal changes in air quality at Simeonof (Figure III.K.4-10). For Quarter 4 and Quarter 1 (October through March), the relative proportions of aerosol species are close to the annual average for worst days (Figures III.K.4-10a & 10b, Figure III.K.4-8). In Quarter 2 and Quarter 3 (April through September) the proportions were quite different from the annual average, with much higher proportions of sulfate.

c. Proportional Representation of Pollutant Species: Best Days/Worst Days, by Year

The poorest visibility days (worst days) at Simeonof are caused by very large increases in some aerosols, and only small increases in others. Comparing the proportions of individual pollutants on best/worst days and for each year can highlight the important species separating best and worst days. In 2002, for instance, light extinction for each species differed between best and worst days (Figure III.K.4-11). Extinction due to sulfate was a greater percent of total extinction on best days (43.3%) than on worst days (27.5%). Extinction due to sea salt was a greater percentage on worst days (40.4 %) than best days (29.2%). Organic matter carbon increased from 7 to 14 percent on worst days.

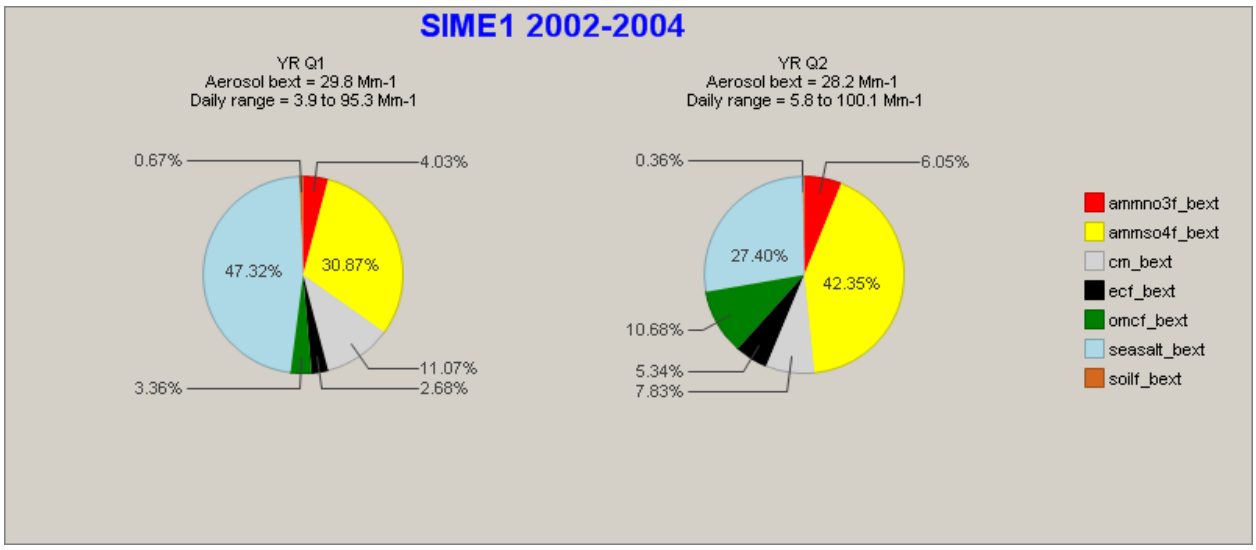
Consistent differences exist between best and worst days at Simeonof. Each year sulfate, nitrate, and coarse mass are less important on worst days than on best days. Each year sea salt is more important on worst days. These differences are sometimes slight, but are consistent. Organic matter carbon and elemental carbon do not differ consistently between best and worst days.

Sea salt is crucial to visibility at the coastal Simeonof Class I area. It is the only aerosol species that always increases in importance on worst days (Figure III.K.4-11). It is episodic (occurring in short events) and highly dependent on local meteorology. It varies significantly from year-to-year in timing and impacts. It is also not subject to human control.

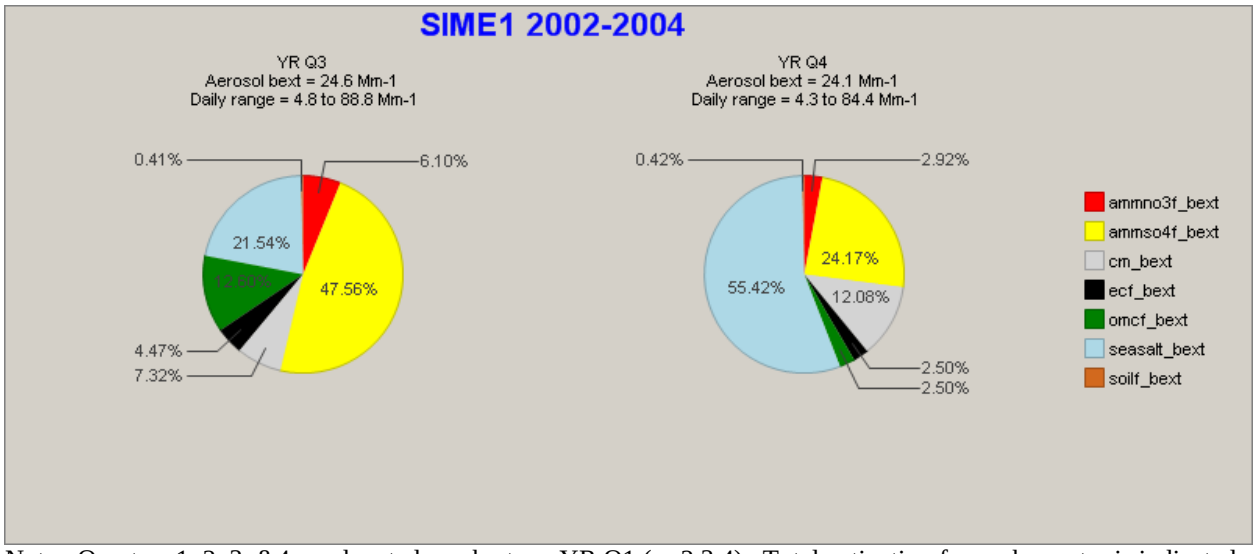
Subtraction of the light extinction caused by sea salt from analyses leaves a simplified picture of aerosol extinction on best and worst days, a picture that highlights sources of visibility impairment that might be amenable to state control (Figure III.K.4-12). With sea salt removed, the proportions of aerosol species become more similar on best and worst days. In 2002 and 2003, worst days then differ in having higher proportions of elemental carbon and organic matter carbon, two largely uncontrollable, wildfire-related aerosols. The proportions of elemental carbon and organic matter carbon relative to each other vary, as occurs with fires of different severities and at different distances. In 2005, a year with fewer wildfires, the proportions of aerosols are similar on best and worst days. With subtraction of all aerosol sources largely independent of human activities, sulfate (at close to 80%) and nitrate (at close to 10%) contribute most to visibility impairment.

Figure III.K.4-10
Proportional Representation of IMPROVE Aerosols at Simeonof
for Each Calendar Quarter of Baseline Years

a) Calendar Quarter 1 (January-March) & Quarter 2 (April-June)



b) Calendar Quarter 3 (July-September) & Quarter 4 (October-December)



Note: Quarters 1, 2, 3, &4 are denoted on charts as YR Q1 (or 2,3,4). Total extinction for each quarter is indicated as Aerosol bext. Although aerosol proportions vary with calendar quarter, total extinction and average daily ranges vary less.

Figure III.K.4-11
2002-2005 Proportional Representation of Aerosol Species at Simeonof

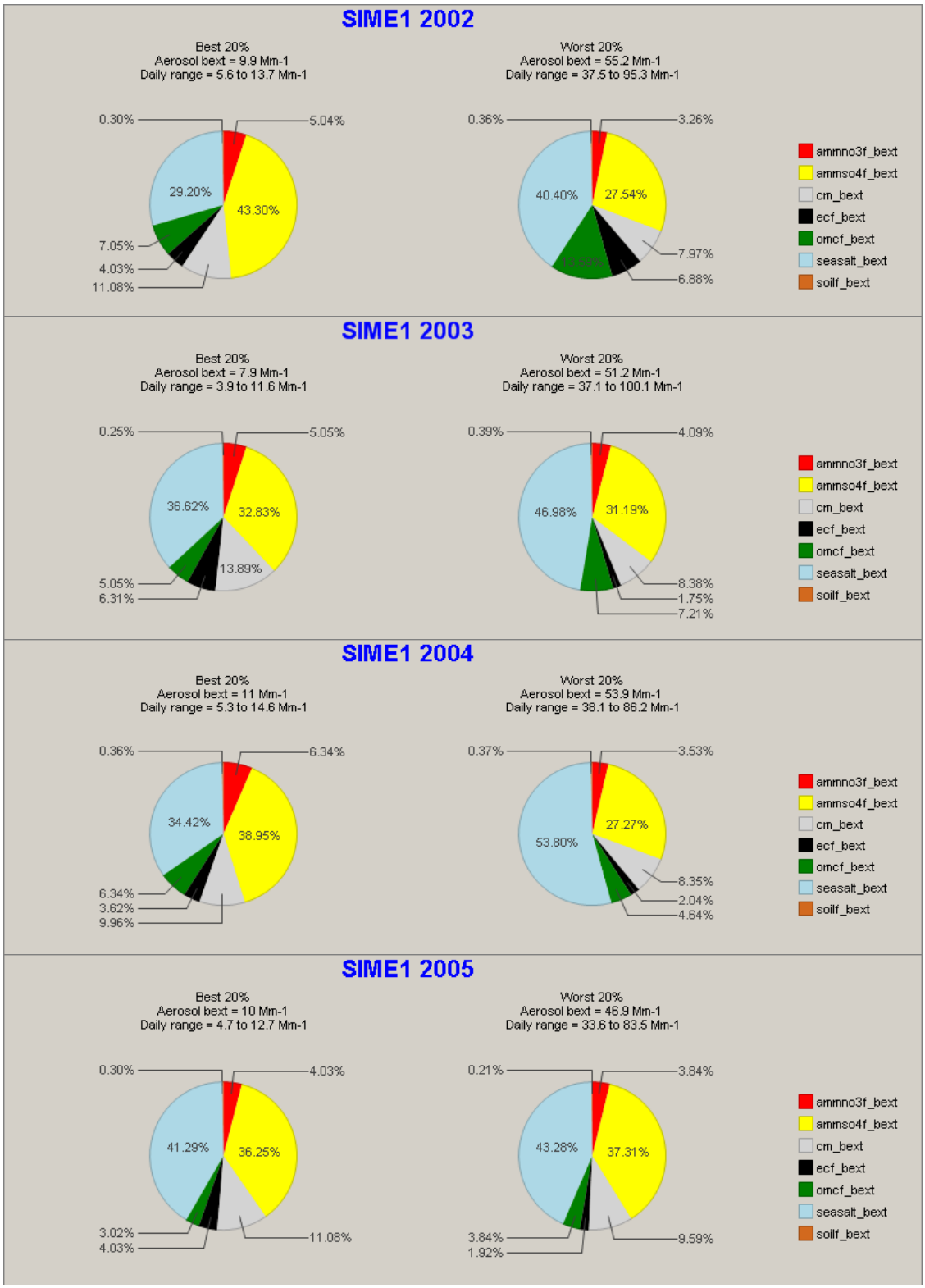
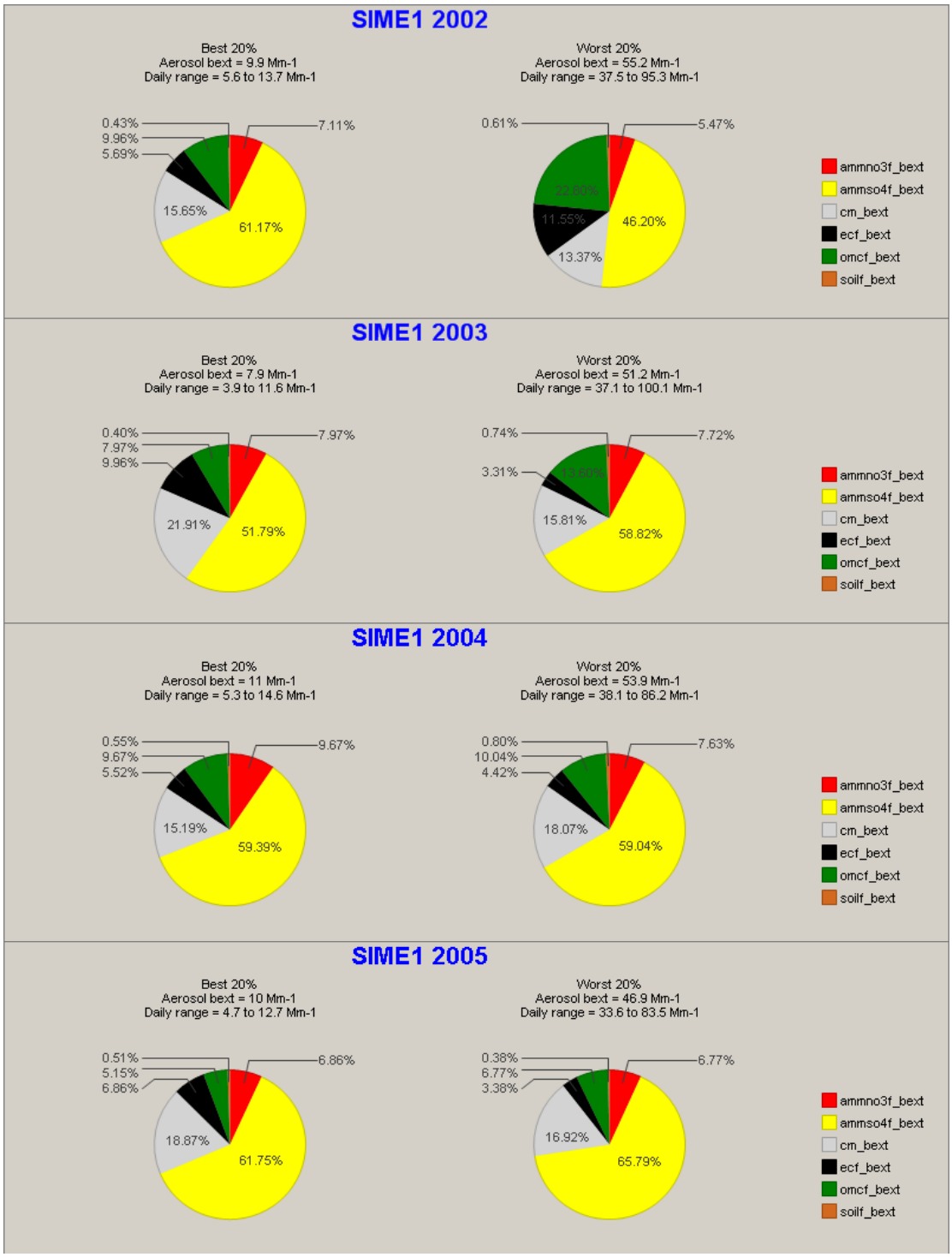


Figure III.K.4-12
2002-2005 Proportional Representation of Aerosol Species Excluding Sea Salt, at Simeonof



d. Daily and Seasonal Variation in Light Extinction Due to IMPROVE Aerosol Species

On each air sampling day, visibility is determined by the combined extinctions of all aerosol species measured. Stacked histograms represent the contributions of each aerosol species on each sampling day (Figure III.K.4-13). The sampling days determined to be best days and worst days are labeled **B** and **W** on the histograms. Figure III.K.4-13 shows histograms from 2002, with stepwise subtraction of sea salt, organic matter carbon, and coarse mass. These are subtracted because they are least likely to be of human origin, and least likely to be controllable by the State of Alaska. At Simeonof, the separation of worst and best days is much greater in the histogram of all aerosol species (Figure III.K.4-13a) than in the histogram containing aerosols more amenable to control (Figure III.K.4-13c).

Sea salt and sulfate have the greatest effect on visibility at Simeonof. Worst days had much more sea salt than best days. The relative contribution of sea salt to extinction differed dramatically on best and worst days in 2002 (Figure III.K.4-11). That is, worst days usually had proportionately more sea salt that best days. In other years, the relative contributions of sea salt to extinction were similar (2004) or differed only slightly (2003).

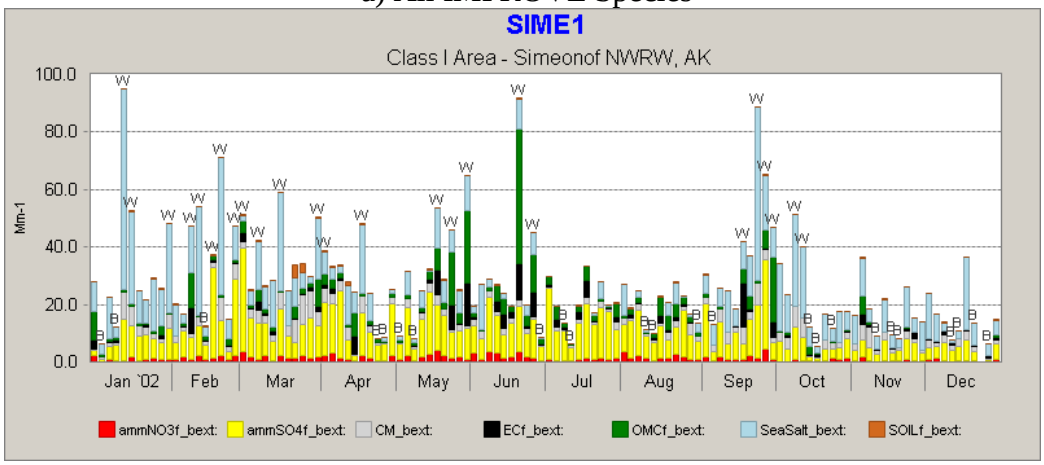
With sea salt extinction removed (Figure III.K.4-13b), it becomes clear that organic matter carbon peaks in summer, resulting in worst days. Coarse mass particulates are greater in spring and fall, contributing to worst days then. The peaks of OMC and elemental carbon extinction show that fire is important to summer worst days, and can be also in spring and fall. Wildfire distribution, timing, and severity differ year to year within Alaska. Wildfires from Northern Europe and Asia also affect Alaska's air. The resulting peaks in OMC and EC extinction differ in size, dates, and relative proportions.

With uncontrollable aerosols removed, nitrate, sulfate and soil remain (Figure III.K.4-13c). Soil has a small and episodic influence on visibility. Nitrate affects visibility only slightly, with a slight dip in mid-winter effects. Sulfate does not clearly separate the best and worst days. Most worst days do have sulfate values above 10 Mm^{-1}, but the range of extinction on 2002 worst days is much greater, from 37-95 Mm^{-1}. Sulfate is usually less than half of total extinction on worst days, but it is the greatest fraction of anthropogenic aerosols at Simeonof.

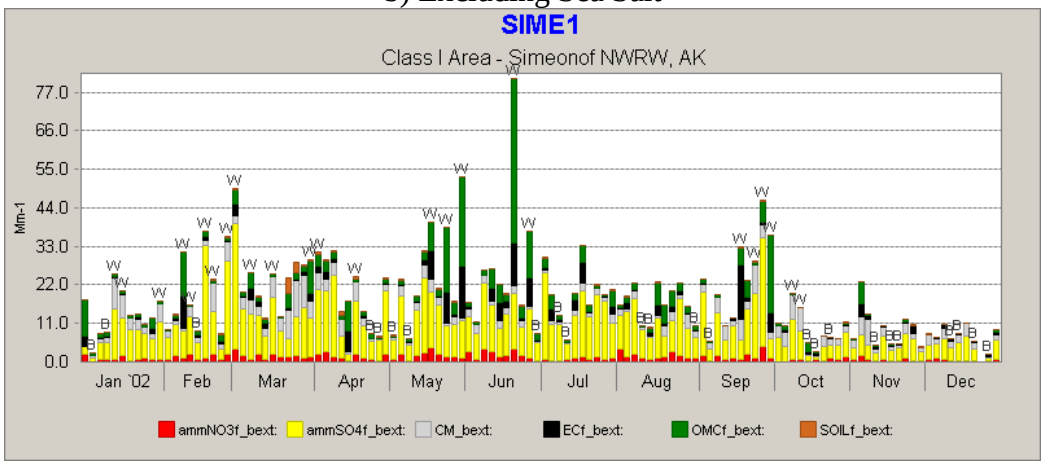
The contrast between the 2002 histogram of anthropogenic aerosols (Figure III.K.4-13c) and aerosols largely out of human control (Figure III.K.4-14) is cause for concern. Best days and worst days are most clearly delineated by the aerosols least likely to be controllable by state regulation.

Figure III.K.4-13
2002 IMPROVE Species Contributions to Visibility Impairment by Sampling Day, at Simeonof

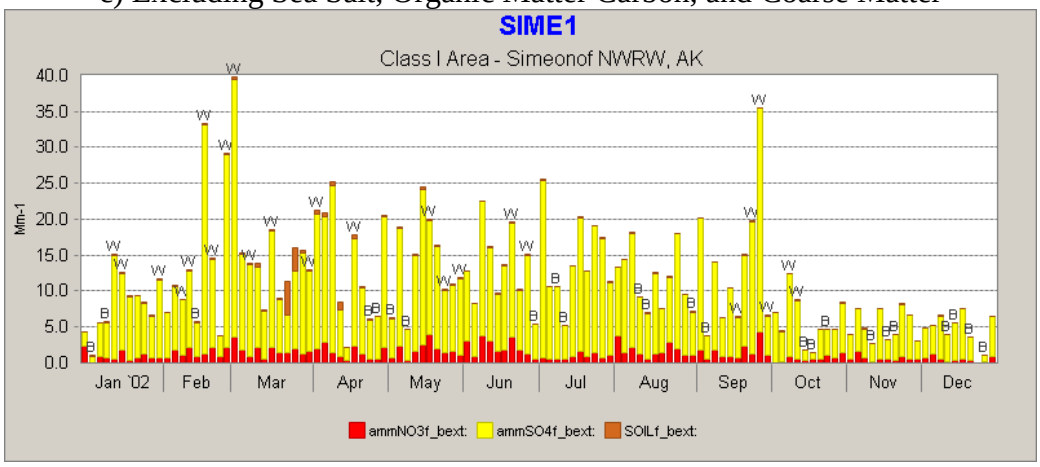
a) All IMPROVE Species



b) Excluding Sea Salt

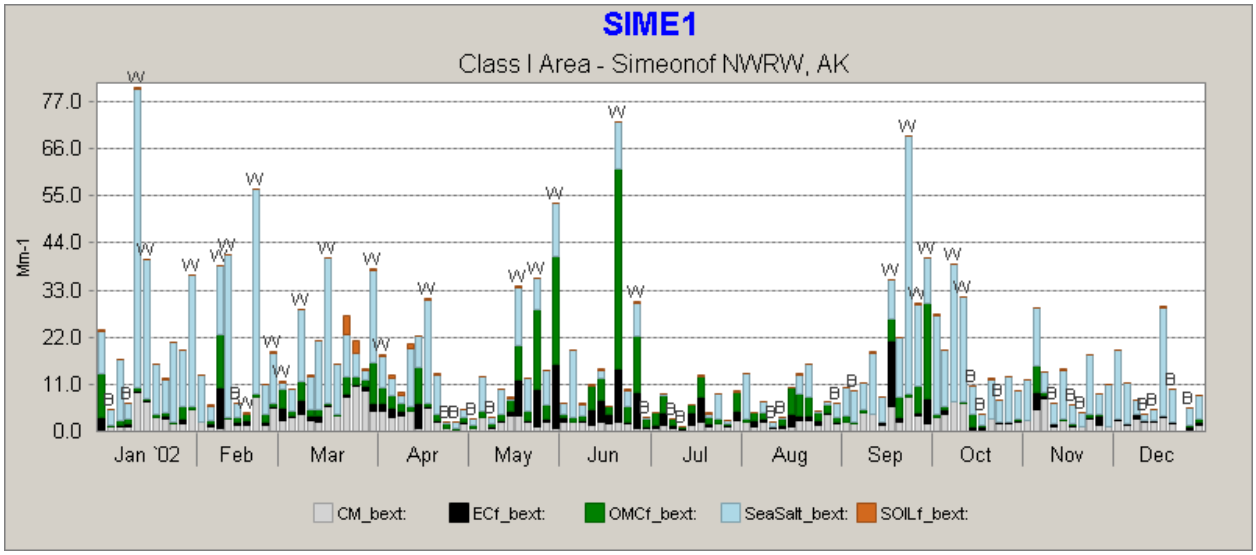


c) Excluding Sea Salt, Organic Matter Carbon, and Coarse Matter



Note: Stepwise removal of species not under human control in Alaska.

Figure III.K.4-14
2002 IMPROVE Species Contributions to Visibility Impairment by Sampling Day, at Simeonof



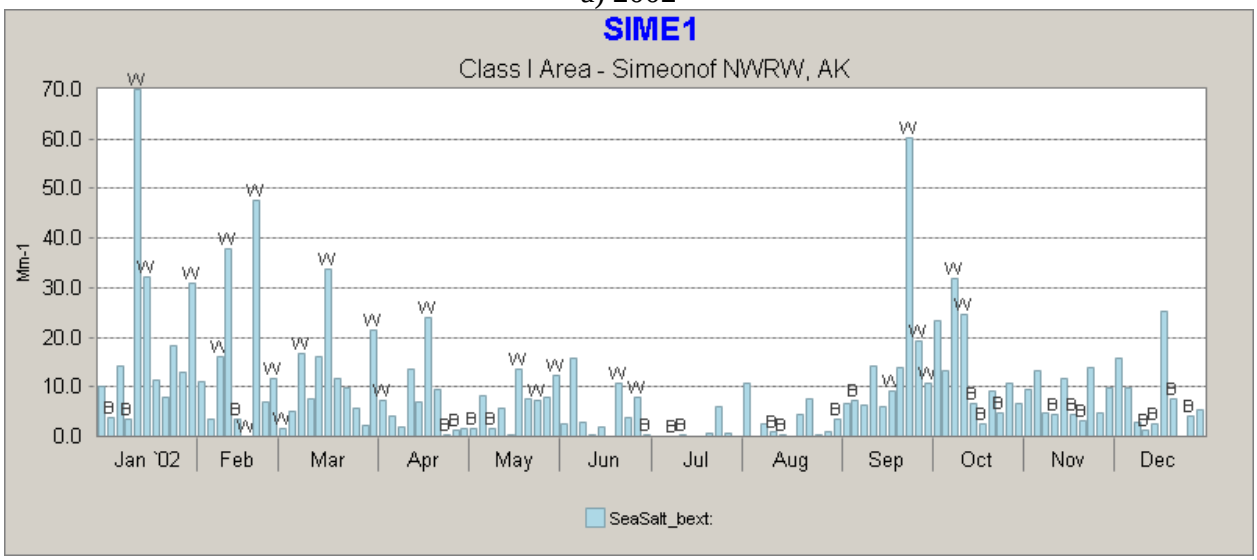
Note: Only aerosol species largely out of human control are included: Coarse mass, Elemental carbon, organic matter carbon, and sea salt.

e. Variation in Individual Species Between Best and Worst Days

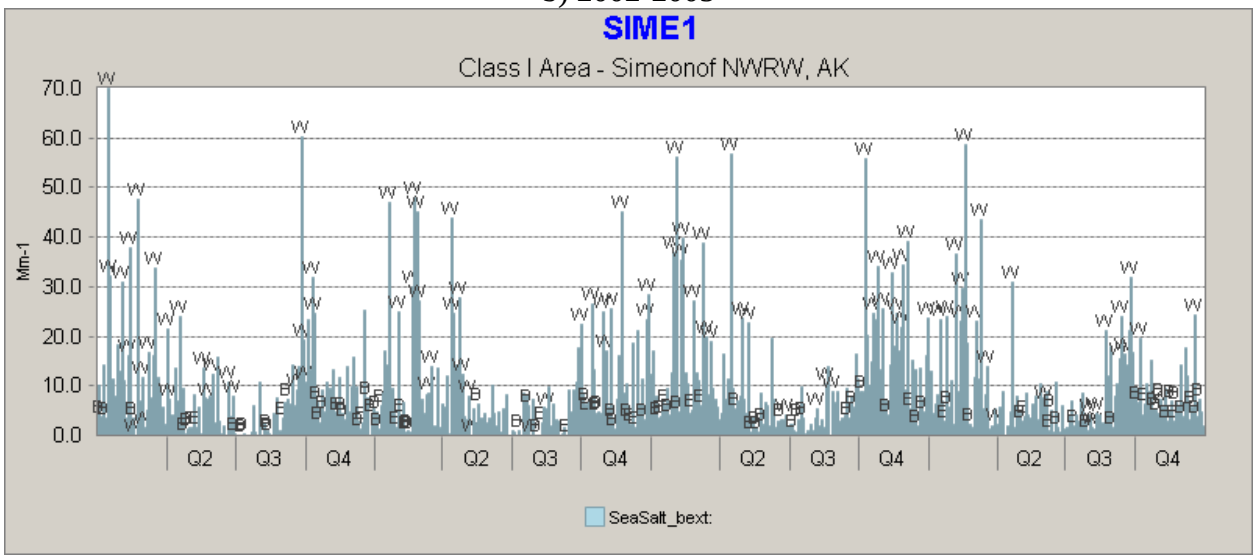
Sea Salt: Sea salt is clearly correlated with impaired visibility at Simeonof (Figure III.K.4-15a & 15b). Few worst days have low sea salt, and no best days occur when sea salt is high (r=0.78). Sea salt peaks are very episodic, and may be seasonal, with values in Quarter 3 and the latter half of Quarter 2 being lowest. It may be possible to characterize specific weather systems, wind speeds, and wind directions generating sea salt peaks, but it will not be possible to control them.

Figure III.K.4-15
Sea Salt Contribution to Visibility Impairment by Sampling Day, at Simeonof

a) 2002



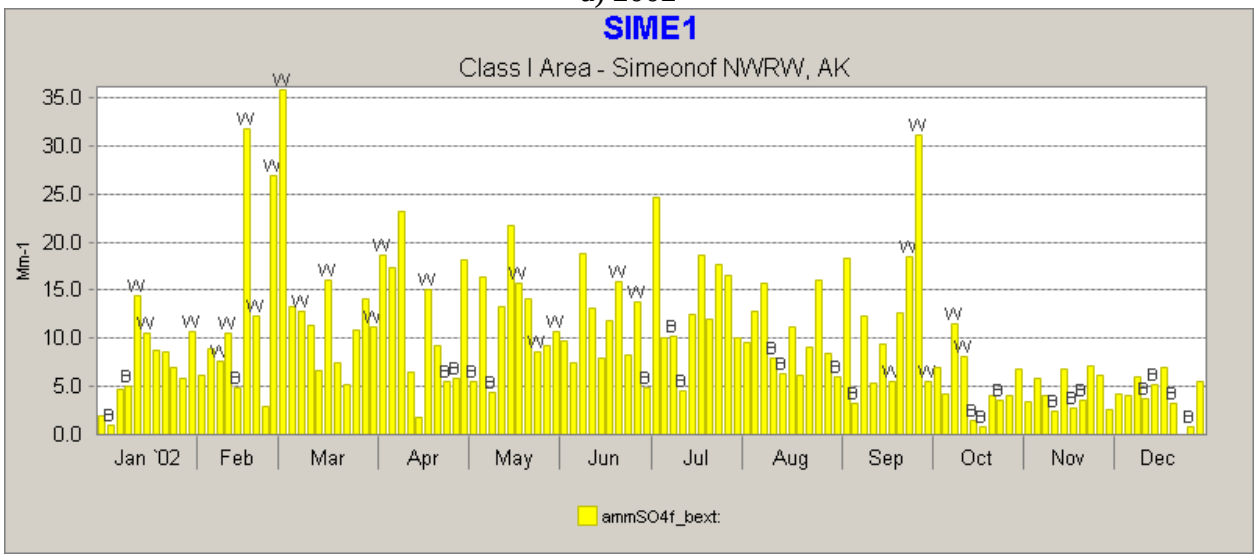
b) 2002-2005



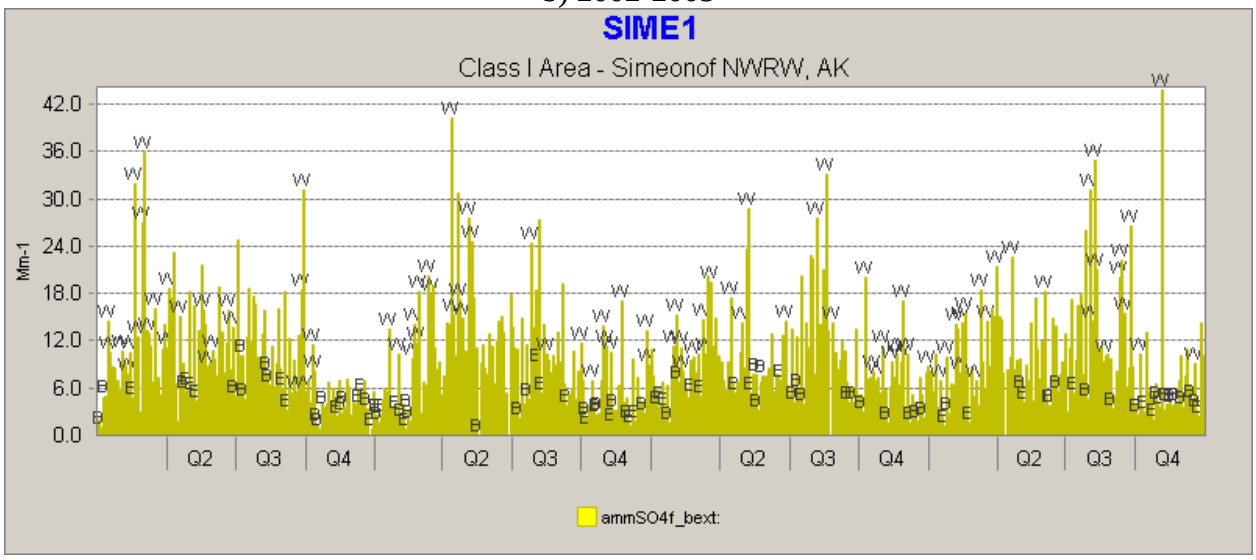
Sulfate: Sulfate is clearly correlated with impaired visibility at Simeonof (r=.65; Figure III.K.4-16). However, there is considerable variability, and sulfate is not the only factor affecting the worst days. Sulfate episodes may be tied to oceanic emissions; if so, correlations with sea surface temperatures may be detectable. Other potential sources for sulfate are fuel use associated with marine shipping and human activities on shore. There is some evidence for lower sulfate values during the fourth quarter, which may correlate with offshore shipping or oceanic emissions.

Figure III.K.4-16
Sulfate Contribution to Visibility Impairment at Simeonof, by Sampling Day

a) 2002



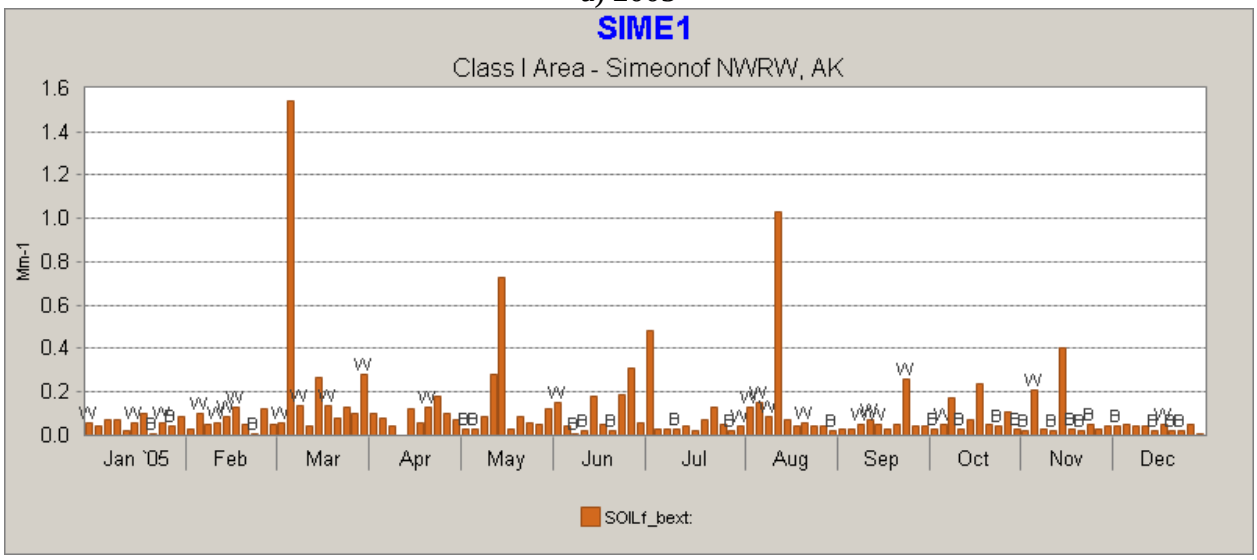
b) 2002-2005



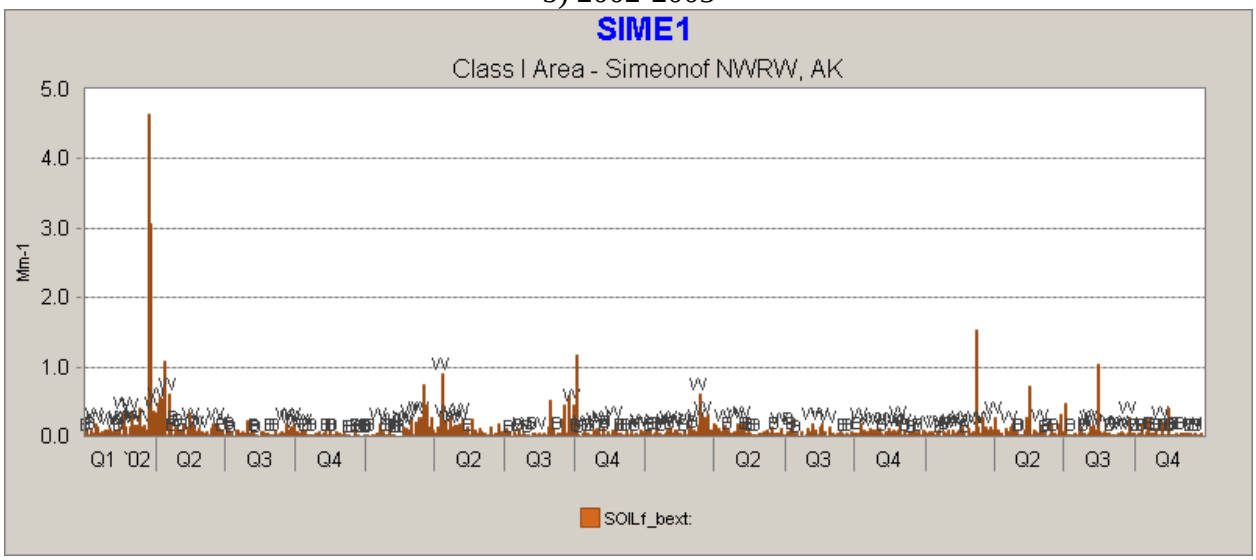
Soil: No correlation between Soil aerosols and overall scene visibility exists at Simeonof (r=.18). Soil is a very small contributor to visibility impairment. Soil aerosols are distinctly episodic, with 9 discrete peaks in 2002-2005 (Figure III.K.4-17). Soil during Quarter 4 is low in all these years. Soil origins may differ at different times of year, from locally generated aerosols in summer to Asian dust events in April and May.

Figure III.K.4-17
Soil Contribution to Visibility Impairment by Sampling Day, at Simeonof

a) 2005



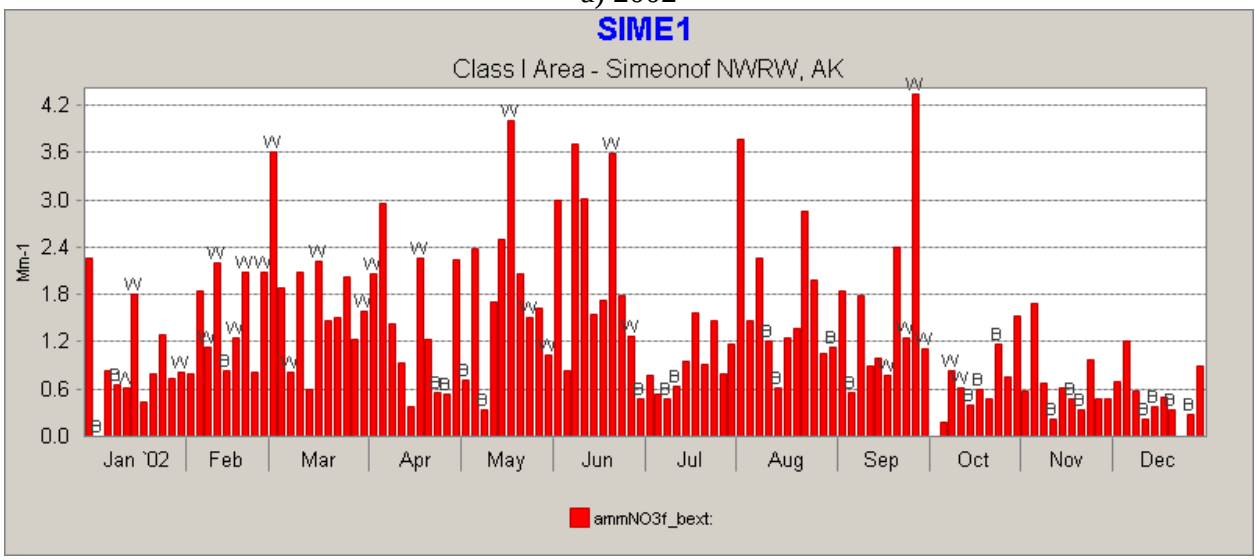
b) 2002-2005



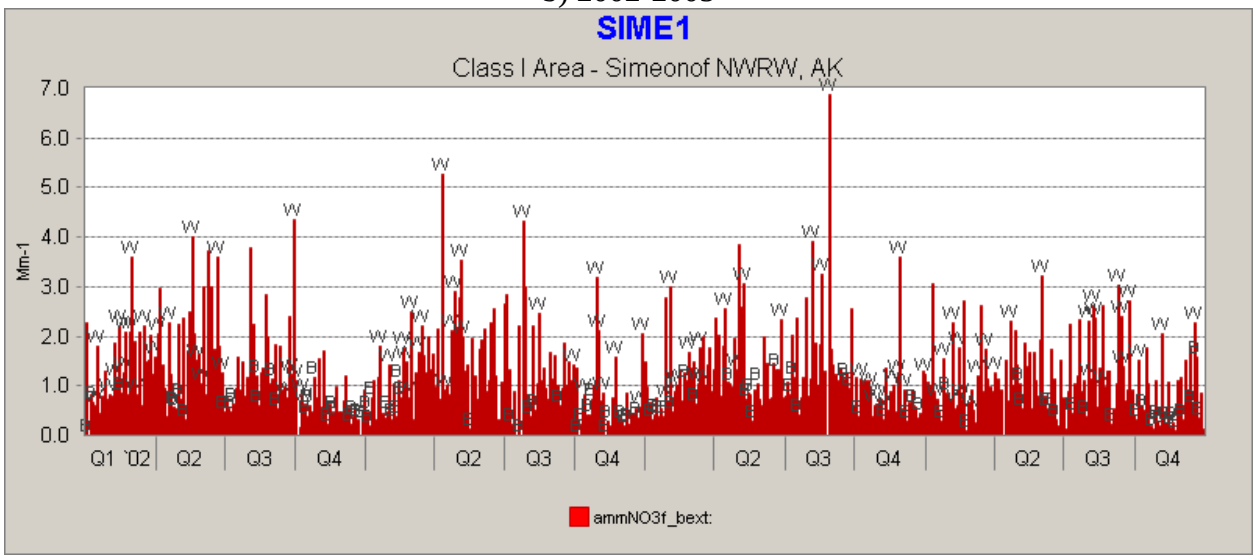
Nitrate: At Simeonof, most worst days have higher nitrate extinction (r=.55). However, extinctions due to nitrate rarely exceed 5 Mm^{-1}, while on most worst days extinction exceeds 40 Mm^{-1}. Quarter 4 may be lower statistically but not in all years (Figure III.K.4-18). Nitrates in Alaska are typically of human origin.

Figure III.K.4-18
Nitrate Contribution to Visibility Impairment by Sampling Day, at Simeonof

a) 2002



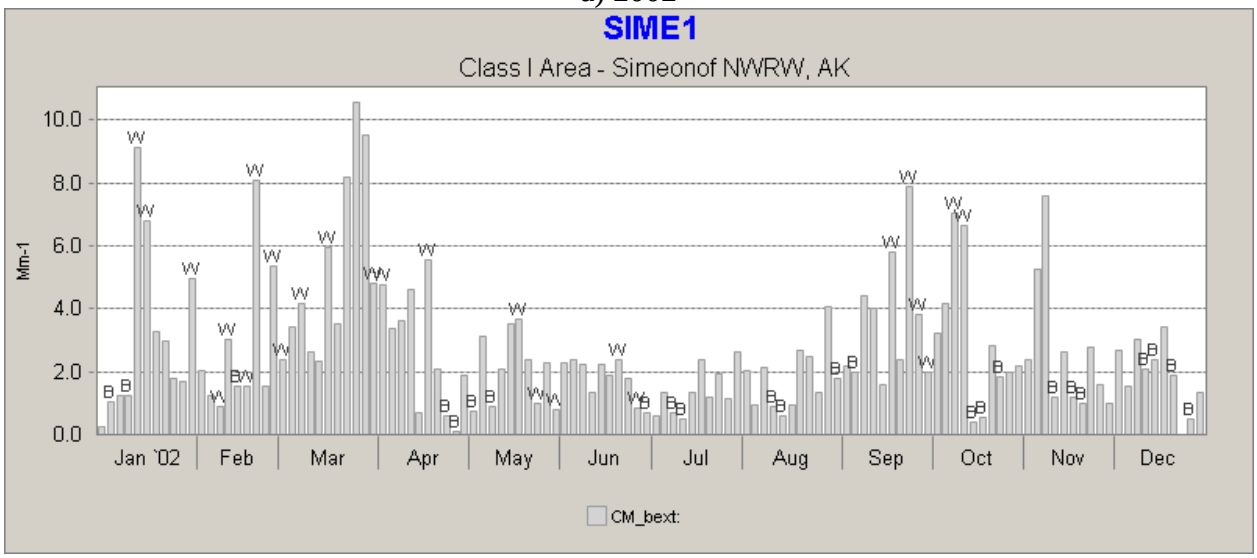
b) 2002-2005



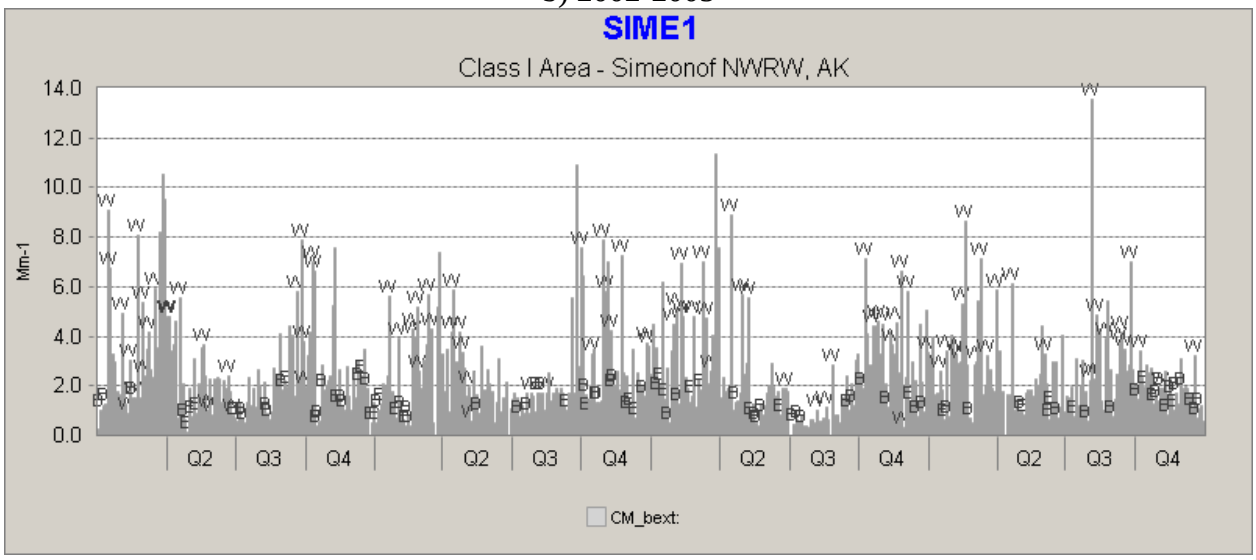
Coarse Mass: At Simeonof, most worst days have higher coarse mass (r=.60). Seasonal patterns vary, but Quarters 2&3 are typically lower (Figure III.K.4-19). Coarse mass histograms do not clearly separate best and worst days.

Figure III.K.4-19
Coarse Matter Contribution to Visibility Impairment by Sampling Day, at Simeonof

a) 2002



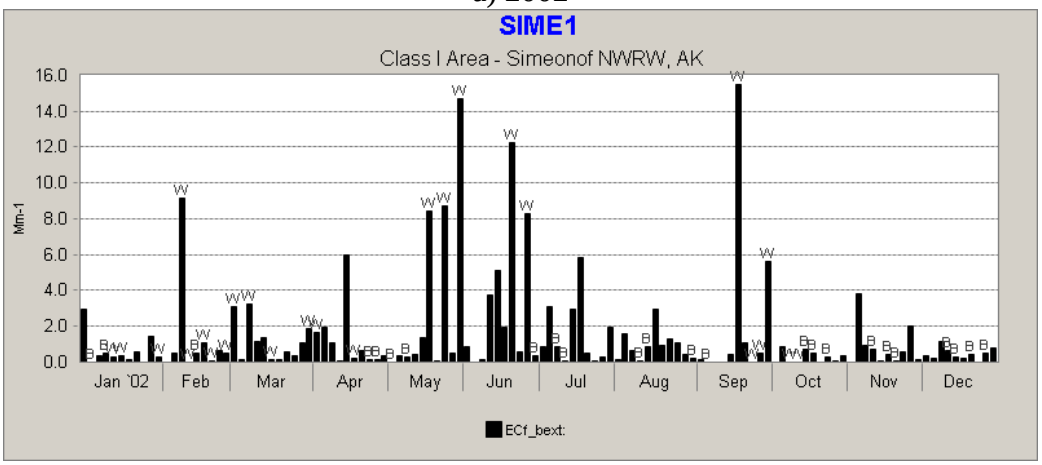
b) 2002-2005



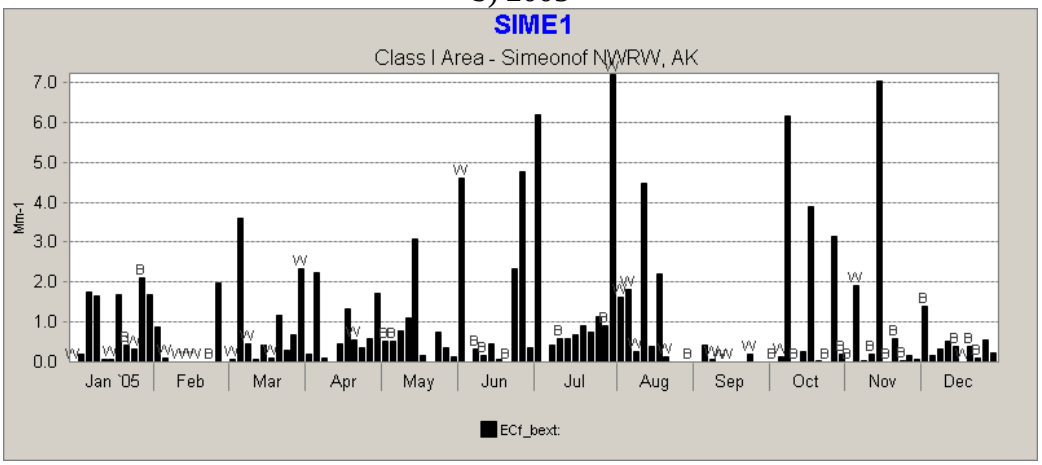
Elemental Carbon: Elemental carbon is highly episodic and highly variable from year to year. It is not correlated with overall extinction (r=.22) (Figure III.K.4-20). Elemental carbon tends to be higher during growing seasons, but does not occur only then. Many worst days lack elemental carbon. Both elemental carbon and organic matter carbon are associated with wildfires in Alaska, but their ratio varies, perhaps with distance, fire severity, and weather. The years 2002 and 2005 had contrasting fire activity, with 2002 activity in May, June, and September, and 2005 activity peaking in July and August. The strong contrasts between years are visible in Figure III.K.4-20c.

Figure III.K.4-20
Elemental Carbon Contribution to Visibility Impairment by Sampling Day, at Simeonof

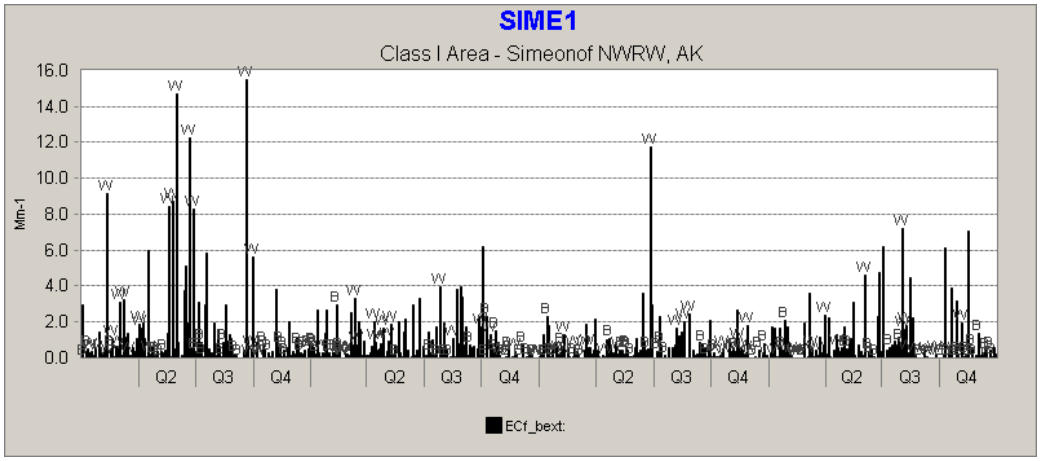
a) 2002



b) 2005



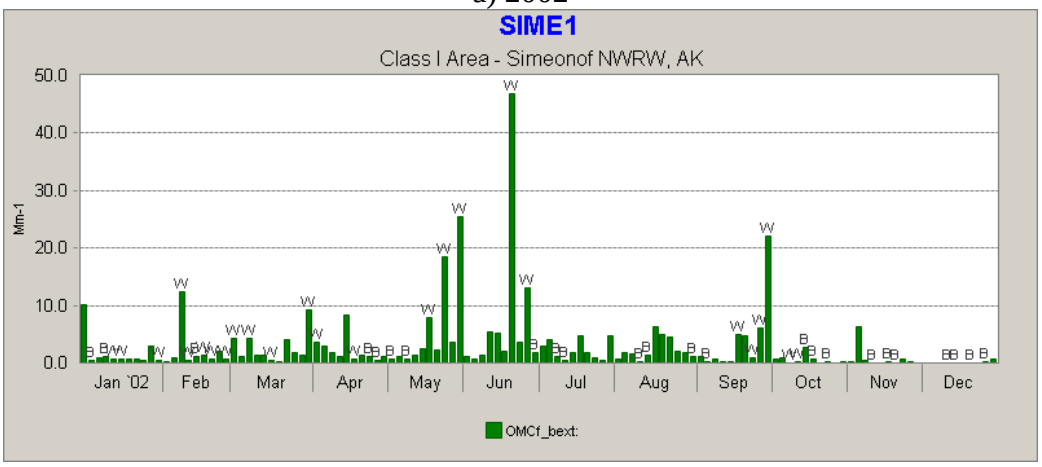
c) 2002-2005



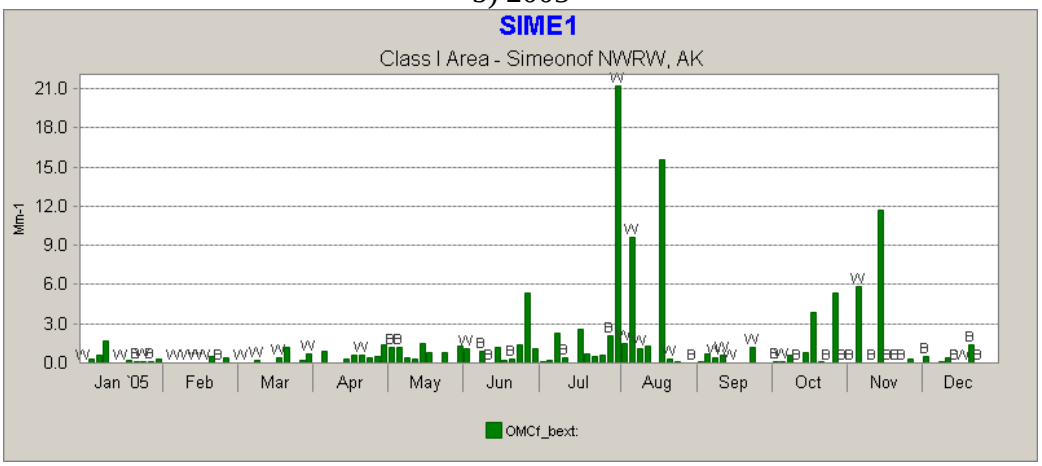
Organic Matter: Organic matter carbon is highly episodic, highly variable from year to year, and not strongly correlated with overall extinction (r=.36). It tends to be higher during growing seasons and lower in Quarters 4 and 1 (Figure III.K.4-21). Organic matter carbon sometimes drastically affects visibility in Alaska, but many worst days at Simeonof lack it. Fires that generate organic matter carbon are both local and overseas, with much overseas burning happening outside of Alaska's wildfire season. Stationary sources burning fish oil may also contribute. Oceanic biogenic emissions may contribute. Years 2002 and 2005 (Figure III.K.4-21a & 21b) differ in timing of wildfire emissions, and Figure III.K.4-21c shows the typical extent of year to year variation.

Figure III.K.4-21
Organic Matter Contribution to Visibility Impairment by Sampling Day, at Simeonof

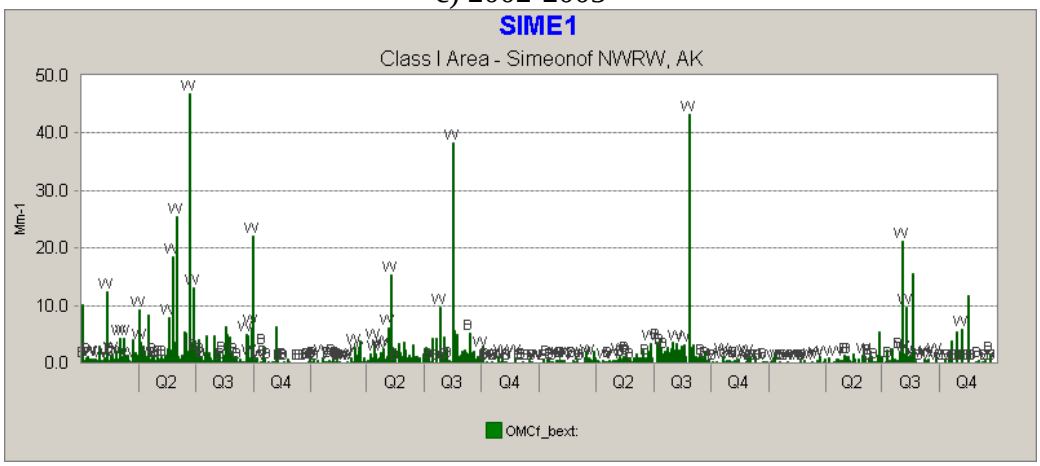
a) 2002



b) 2005



c) 2002-2005



4. Correlations Among Aerosol Species at Simeonof

Pearson correlations among the aerosol species monitored at Simeonof give information about their potential origins and about potential controls. (Pearson's correlations between aerosol species and total extinction as previously discussed in Section III.K.4.4.D *Variation in Individual Species* indicate the visual impairment due to each species.) Correlations between species pairs were computed using aerosol mass values rather than extinctions. Table III.K.4-12 summarizes the correlations between aerosol species pairs for 2002-2004 sampling dates and for 2002-2004 worst day sampling dates. Correlations between aerosol species during months representing the Alaska fire season are discussed in text below.

Four distinct patterns of correlation appear among Simeonof aerosols. Three species pairs are positively correlated both on worst days and on all days. These positively correlated species pairs are nitrate and sulfate, elemental carbon and organic matter carbon, and sea salt and coarse mass. Two species pairs show only slight positive correlations on worst days and on all days: sulfate and sea salt, and nitrate and sea salt. Coarse matter and organic matter carbon are

negatively correlated on worst days, but not for all days. Two species pairs show a slight shift to negative correlation on worst days: sulfate and coarse matter, and nitrate and coarse matter.

As shown in the table, sea salt and coarse matter aerosols are positively correlated both on worst days and on all days. Sea salt and coarse matter aerosols arrive on the same coastal weather systems. Both species are typically associated with shoreline and offshore winds, and are usually lower in summer. Cold Bay, the closest weather monitoring site, records lower mean wind speeds in summer (June-August). During most of the year at Cold Bay prevailing winds are southeasterly, but during the summer, winds are more frequently westerly and northerly (Figure III.K.4-22). Thus yearly weather patterns are associated with measurable changes in aerosol extinction.

Table III.K.4-12
Pearson Correlation Coefficients Between Aerosol Species Mass at Simeonof
2002-2004

Correlations on all days:

0.66	**NO3 SO4**
-0.03	CM EC
0.60	**EC OMC**
-0.08	CM OMC
0.27	SO4 CM
0.24	NO3 CM
0.61	**SS CM**
0.18	SS NO3
0.26	SS SO4

Correlations on Worst Days:

0.58	**NO3 SO4**
-0.43	CM EC
0.58	**EC OMC**
-0.50	**CM OMC**
-0.12	SO4 CM
-0.23	NO3 CM
0.66	**SS CM**
0.21	SS NO3
0.13	SS SO4

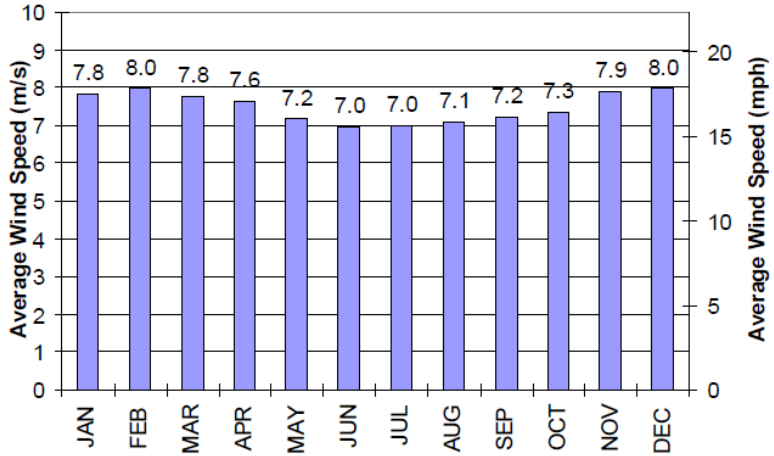
Note: Correlations above +/- 0.5 are shown in bold.
SS - Sea Salt

Elemental carbon and organic matter carbon are positively correlated both on worst days and on all days. Elemental carbon and organic matter carbon also arrive with the same weather systems, but different systems than those carrying sea salt and coarse matter to Simeonof. Elemental carbon and organic matter carbon are usually associated with fire, so the responsible weather systems in summer are expected to arrive via interior Alaska, where most fires in Alaska occur. However, effects of wildfires and agricultural fires overseas cannot be discounted. Elemental carbon and organic matter carbon peaks do also occur outside the Alaska growing season. In fact, the correlation between elemental carbon and organic matter carbon on October through April worst days is even greater (0.84) than during the Alaska growing season (0.58).

Nitrate and sulfate aerosols are not strongly correlated to other IMPROVE aerosols. They occur throughout the year, but may drop slightly in the fourth quarter, a time of shifting winds. Nitrate and sulfate may share a common source, most likely of human origin.

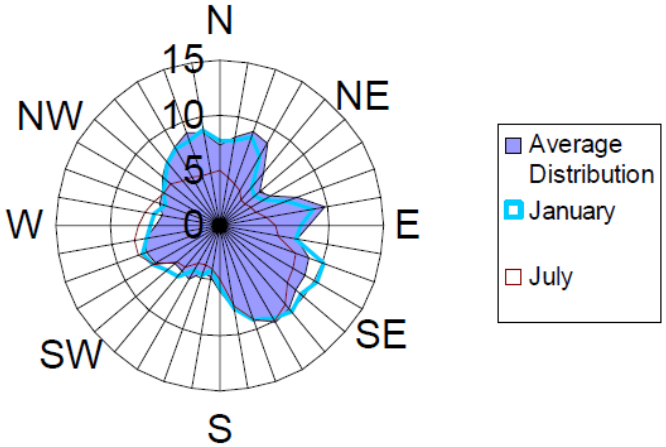
Figure III.K.4-22
Wind Speed and Direction Frequency at
Cold Bay Airport, Alaska Energy Authority

a) Monthly Average Wind Speed



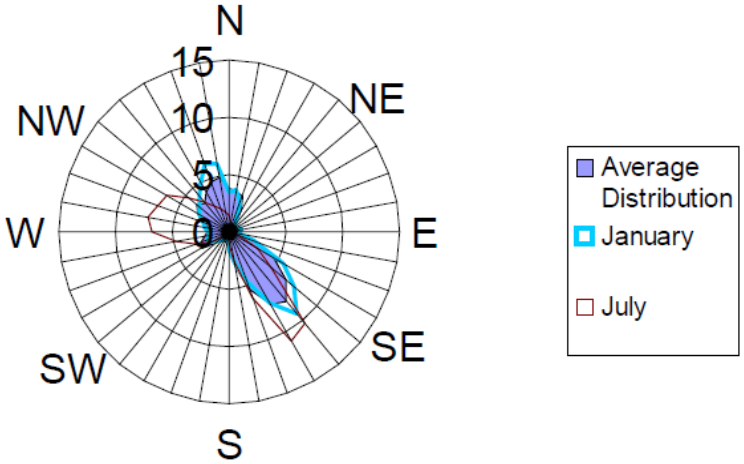
Note: Monthly average wind speeds. Summer months have lower average wind speeds.

b) Wind Speed Distribution Rose (m/s)



Note: Annual patterns of wind direction and speed. Northerly and easterly winds are typically milder in summer months.

c) Wind Frequency Distribution Rose (% of Time)



Note: Annual frequencies of wind direction. Northwesterly winds are more frequent in summer

5. Effects of Volcanism on Visibility at Simeonof

According to the Alaska Volcano Observatory (AVO), Alaska contains over 130 volcanoes and volcanic fields. More than 50 of these have been active within historical time (since about 1760 in Alaska). Depending on weather patterns, eruptions may influence large or small areas, on land or offshore. Volcanic ash in the atmosphere is a serious hazard to jet aircraft. The AVO assists the Federal Aviation Administration in warning aircraft of areas to avoid by analyzing satellite imagery and working with the National Weather Service to predict where winds will carry the ash.

AVO monitoring includes networks of continuously recording seismometers installed at more than 20 volcanoes. Volcanic unrest, caused by the migration of magma and other fluids through the earth's crust, is heralded by increased seismicity, often months to weeks before eruption. At volcanoes without seismic networks, satellite imagery is the source of routine monitoring information. AVO analyzes satellite data for thermal anomalies and ash plumes at about 80 volcanoes in the north Pacific. Thermal anomalies at volcanic vents have been detected up to several weeks before large eruptions. Other AVO monitoring includes deformation monitoring with satellite radar interferometry and periodic field-based GPS surveys.

The monitoring status of Alaska's volcanoes is shown in Figure III.K.4-23. These volcanoes are monitored by the Alaska Volcano Observatory. During eruptions, reports that include the location, time, size of the eruption, and narrative descriptions of projected plume paths are distributed by AVO to federal, state, and local government agencies, directly affected private parties, the media, and commercial airlines. These reports are available on the AVO website: http://www.avo.alaska.edu/ and in Appendix III.K.4.

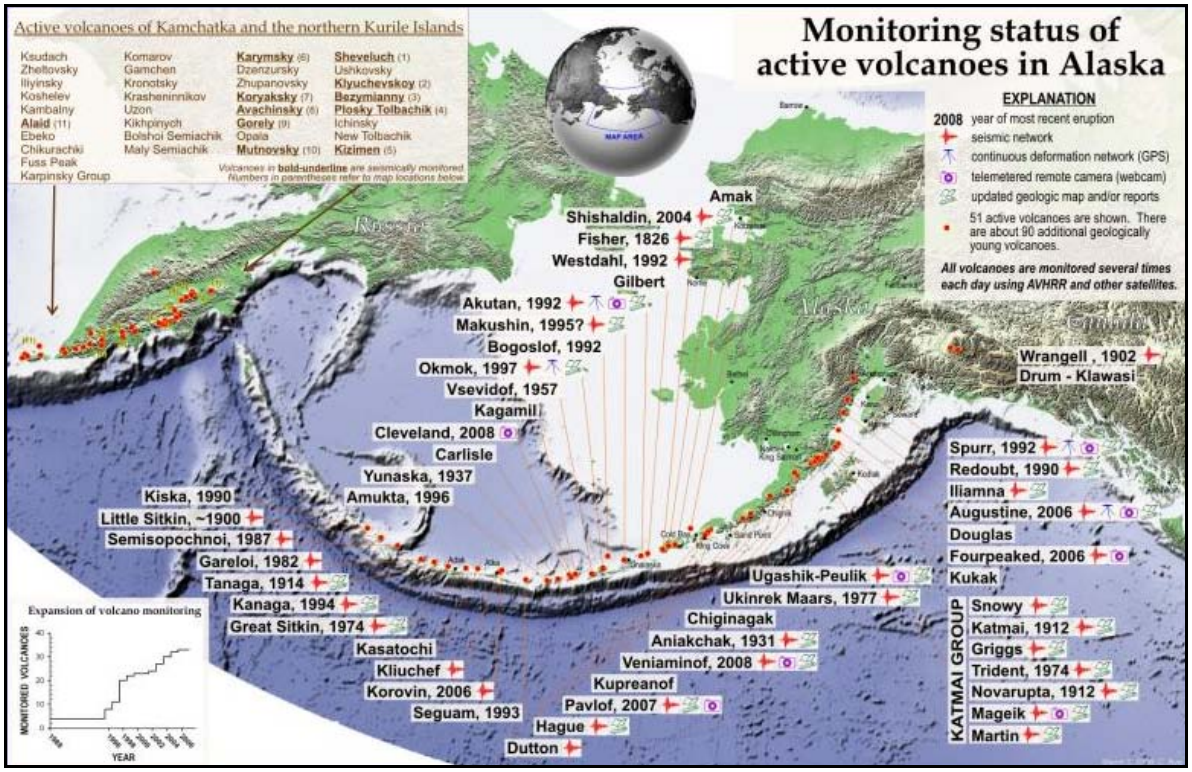
Outlined below are several important points that must be considered in attempting to correlate volcanic activity with air sampling data:

- Volcanic eruptions typically last for weeks to months. Specific events within eruptions can sometimes be identified but they are not usually accompanied by corresponding details about emissions.

- Between eruptions, many specific events are reported by the public, pilots, offshore shipping personnel, and researchers. This is not systematic sampling, so it is not known how many actual events are missed. All reports are investigated by AVO.

- Volcanic eruptions and events are highly episodic, so emissions of gases and aerosols are likely to be episodic as well. While USGS has efforts underway to compile gas emission-rate data for Cook Inlet and Alaska Peninsula volcanoes, these data are dependent on plume traverses rather than continuous measurement, and are not available for the volcanoes near Simeonof Class I area.[40]

Figure III.K.4-23
Monitoring Status of Active Volcanoes in Alaska (Alaska Volcano Observatory)



To determine whether elevated sulfate levels at Simeonof are related to volcanic activity, the following were examined:

- Eruption history and all reported non-eruption events were examined for correspondence with IMPROVE data. Particular attention was related to dates showing spikes in sulfate above 20 Mm^{-1}.

- The available puff modeling was examined to identify specific plume events over Class I areas. The corresponding dates were examined for spikes in sulfate.

- The entire record for 2003, when no eruptions occurred, was contrasted with 2004 and 2005, when Veniaminof, Shishaldin, Augustine, Cleveland, and Korovin erupted.

- For Veniaminof, which is the closest to the Simeonof Class I area, eruptions and events from 2002 through 2008 were examined to identify discrete events that might show up in IMPROVE air monitoring.

a. Eruptions and Events

Nine eruptions were monitored in the years 2002-2008. Typically, eruptions last weeks to months, with activity during eruptions being monitored by seismometer, thermal imaging, deformation tracking by remote sensing, aircraft overflights, visible activity reports, modeling of volcanic plumes using puff models, and, less frequently, on-site visits.

Many non-eruptive events were also recorded and investigated during these years. Such events include seismic activity, plume reports, misinterpreted normal meteorology, ash flows, landslides, dome collapses, lake building or draining. The influence of these events on air quality was not known in most cases. All were examined and interpreted with the data available, which was typically sparse.

Volcanic Eruptions 2002-2008:

Veniaminof	2002, 2004, 2005, 2006, 2008
Shishaldin	2004
Augustine	2005
Cleveland	2005
Korovin	2005

None of the eruptions monitored between 2002 and 2005 showed episodic activity corresponding with high sulfate days at Simeonof Class I area. Eruption reports are found in Appendix III.K.4.

Ten non-eruptive events were investigated, including steaming fumaroles, clouds, landslides, and re-entrained ash. A few typical reports are found in Appendix III.K.4. During one 2003 event, fumarolic or hydrothermal activity at Emmons Lake caldera, high sulfur values occurred on July 26 and August 4. However, sulfur values during the entire reported event (July 7-August 16) do not stand out from other time periods. When sulfur levels from adjacent sampling dates during volcano activity are unremarkable, it is difficult to conclude that a few days of high sulfur is due to the volcanism.

In spite of active monitoring of Alaska's volcanoes, the State does not know the specific timing of emission bursts, even during eruptions. The presence of ongoing active fumaroles muddies the water further. However, the entire annual record for 2003, when no eruptions occurred, can be contrasted with 2004 and 2005, when Veniaminof, Shishaldin, Augustine, Cleveland, and Korovin erupted. No correspondence between eruption and monitored sulfate aerosols is seen, with comparisons on daily and annual bases. (Figures and numerical data are found in Appendix III.K.4).

6. Evaluation of the Effects of Uncontrollable Processes on Species at Simeonof Class I Area

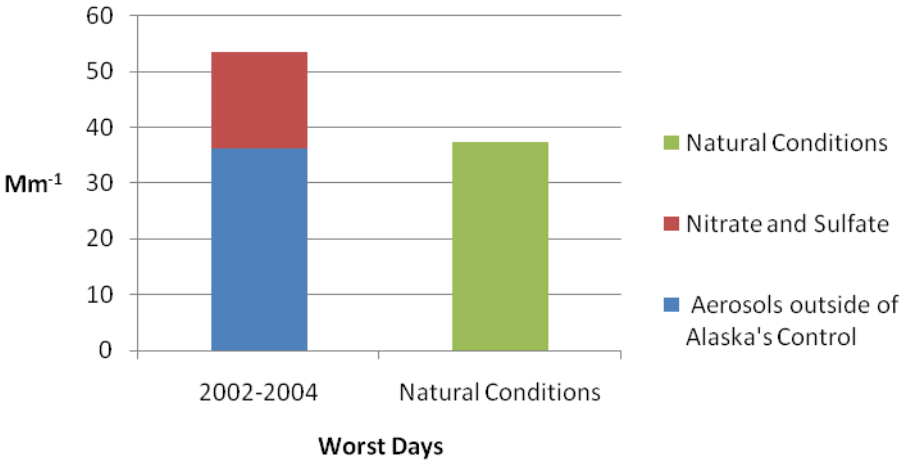
Sea salt and sulfate make the strongest contributions to worst days at Simeonof. Other aerosols, such as soil, elemental carbon, and organic matter carbon, are highly episodic and derive

primarily from sources outside of Alaska's control. Nitrate and sulfate aerosols at Simeonof are always present, and sulfate aerosol levels are always significant. The sources of sulfate and nitrate have not currently been identified.

Sea salt, sulfate, coarse mass particulates, elemental carbon, and organic matter carbon all contribute significantly to visibility impairment. Sea salt varies widely year to year, both seasonally and in short-tem events. It may be possible to identify specific weather events causing high sea salt levels. Potential sources for sulfate at Simoenof include onshore activities, marine shipping, local marine based industries, and oceanic biogenic emissions. Volcanic eruptions do occur in the Aleutians, but the sulfate signal at Simeonof is strong all year, much more frequently than volcanic activity is observed. Elemental and organic matter carbon are associated with wildfires which vary spatially (location and area) and temporally (during growing seasons, depending on weather). Wildfires occur anytime within the Alaskan wildfire season and within fire seasons in Siberia, Northern Europe and Asia. Soil aerosols are episodic and at times can be linked to Asian dust events. They have only small effects on visibility. Coarse mass is seasonal, lower in summer, and correlated with sea salt. Probable sources for coarse mass at Simeonof are coastal erosion (crustal minerals), carbonaceous materials and inorganic salts. Nitrate aerosols have relatively small effects on visibility at Simeonof. Nitrate levels are somewhat correlated with visibility, frequently contribute 1-4 Mm^{-1} of extinction on worst days, and are somewhat correlated with sulfates. Nitrates in Alaska are typically of human origin.

At Simeonof Class I area, the baseline visibility impairment due to non-anthropogenic aerosol species or from outside the state is very close to natural conditions goals under the Regional Haze Rule (Figure III.K.4-24).

Figure III.K.4-24
Contrasting Natural Visibility Conditions at Simeonof with Baseline Impairment from Probable Anthropogenic and Non-Anthropogenic Aerosols



C. Denali National Park

1. Baseline Conditions

The regional haze rule requires that baseline visibility conditions be characterized for each Class I area. The goal of the Rule is to improve visibility on worst days from baseline to natural conditions while maintaining baseline visibility on best days. The baseline and natural conditions visibilities together determine an approximate glideslope for visibility improvements and emission reductions toward 2064 goals. Strict adherence to such a glideslope is not necessary, as emission reductions and controls have varied timetables and consequences; however, the glideslope gives a general trend against which reasonable progress may be evaluated.

a. Available Baseline Data

Two IMPROVE monitoring sites represent the Denali Class I area. The first, DENA1, is an IMPROVE protocol site located near the Denali National Park entrance, not far from the main Park visitor facilities. It is on the east end of the Park and on the north side of the Alaska Range. Air monitoring at this location began before 1990. The second site, TRCR1, was placed near the southern border of the Park to better characterize air masses entering the park from the south and west. Air monitoring at the TRCR1 (Trapper Creek) site began in 2001. TRCR1 is the official site representing the Denali Class I area.

At the Denali Class I area, IMPROVE monitoring began well before the 2000-2004 Regional Haze Baseline period. Unlike other Alaska Class I areas, DENA1 has monitoring data for the entire 2000-2004 baseline years. Monitoring results for those years are described in detail in this section. To better understand seasonal and annual influences, and to facilitate direct comparison of DENA1 with TRCR1, the other Denali Park monitoring site, close examination is also made of annual patterns through 2006.

b. Annual Summaries for the Baseline Periods (DENA1 2000-2004, TRCR1 2002-2004)

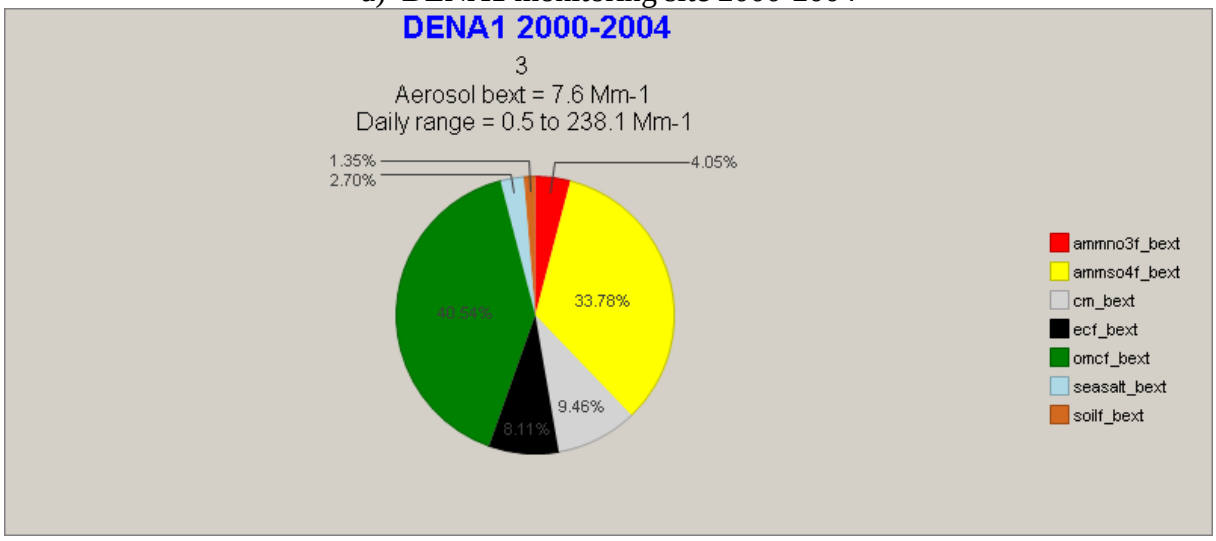
The average total light extinction coefficient (B_{ext}) at DENA1 was 7.6 Mm^{-1}. At TRCR1, the overall average total light extinction coefficient (B_{ext}) at was 8.8 Mm^{-1}. The 2000-2004 DENA1 baseline visual range was 210 km, equivalent to an extinction of 7.6 Mm^{-1}, with Rayleigh scattering of 11. At TRCR1, the 2002-2004 TRCR1 Baseline Visual range was 188 km, equivalent to an extinction of 8.8 Mm^{-1} with Rayleigh scattering of 12. As comparisons, the Alaska Class I area sites at Simeonof Wilderness Area and Tuxedni National Wildlife Refuge had average B_{ext} of 26.6 and 12.9 Mm^{-1}. From outside Alaska, Point Reyes National Seashore, a coastal site away from major population centers, had an average B_{ext} of 46 Mm^{-1}. Glacier National Park had an average B_{ext} of 28.7 Mm^{-1}.

The largest fractions of total baseline light extinction at DENA1 are organic matter carbon and sulfate, with coarse mass and elemental carbon contributing to a lesser extent. TRCR1 has similar annual proportions (Figure III.K.4-25).

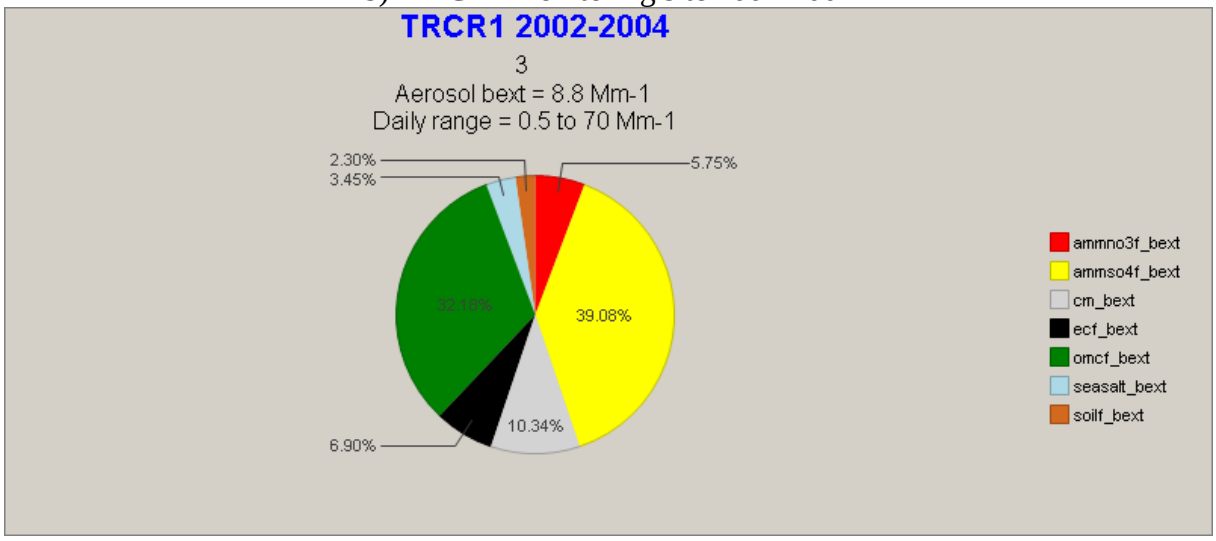
Visibility at DENA1 is more strongly influenced by organic matter carbon and elemental carbon than at TRCR1. Haze at TRCR1is more influenced by sulfates and nitrates. The average contribution of each IMPROVE aerosol to haze at the DENA1 site was 40% for organic matter carbon, sulfate 33.8%, coarse mass 9.5%, elemental carbon 8.1%, nitrate 4.1%, sea salt 2.7%, and soil 1.4%. At TRCR1 the average contribution of IMPROVE aerosols was 32.2% for organic matter carbon, sulfate 39.1%, coarse mass 10.3%, elemental carbon 6.9%, nitrate 5.75%, sea salt 3.4%, and soil 2.3%.

Figure III.K.4-25
Proportional Representation of IMPROVE Aerosols at Denali, Baseline Years

a) DENA1 monitoring site 2000-2004



b) TRCR1 monitoring site 2002-2004



Note: Constituent aerosols are ammonium nitrate (red), ammonium sulfate (yellow), coarse mass (gray), elemental carbon (black), organic matter carbon (green), sea salt (blue), soil (orange). Total aerosol extinction (aerosol_bext) is 7.6 Mm^{-1}. Average daily range is also indicated. (Chart format and abbreviations apply throughout document.)

2. Origins of Aerosol Species Influencing Regional Haze at Denali Class I Area

Sea Salt at Alaska's coastal Class I areas is primarily of oceanic origin. Sea salt aerosols dramatically affect visibility at both of the coastal Class I area sites, Simeonof and Tuxedni. However, sea salt reaches as far as the Denali Class I area in Alaska's Interior at times. Distinct spikes in sea salt aerosols at the DENA1 and TRCR1 IMPROVE monitoring sites suggest that sea salt incursions can arrive from several directions. Desert saltpans and floodplain salt-encrusted soils contribute to sea salt aerosols elsewhere, and potentially do in Alaska as well. Other WRAP states report sea salt incursions from the Arctic reaching as far south as the lower 48.

Organic Matter Carbon (OMC) aerosols originate in both anthropogenic and natural events. In Alaska, the major sources of organic matter carbon are wildland fires (forest, wetland, and tundra) and biogenic aerosols produced by natural vegetation. Wildfires in Alaska occur mostly during the May-August fire season, although controlled burns take place more often in April and May, and September and October when fires are more easily controlled. Alaska's Interior, between the Alaska Range and the Brooks Range, is most prone to wildfire, as can be seen in fire history maps (Appendix III.K.4.b). Different regions of the state have slightly differing fire seasons. Wildland and agricultural fires in Siberiaand Northern Europe also contribute organic matter carbon to Alaska's air. Other anthropogenic sources of organic matter carbon include cooking, road dust, mobile sources, industry, biomass burning, and burning of fossil fuels, particularly coal. Anthropogenic, secondary organic matter carbon forms from VOCs released into the atmosphere.

Elemental Carbon (EC) is typically the product of incomplete combustion of fossil fuels, vegetation, and soils (wildfires and agricultural fires). Levels of elemental carbon are highly correlated with organic matter carbon in Alaska. In spite of that, the relative proportions of the two vary widely. Elemental carbon particles are typically smaller than organic matter carbon particles, and are expected to travel further. This is significant for aerosols reaching the state from Asia and Europe. Inside Alaska, severe wildfires burn vegetation and soils more completely, creating relatively more elemental carbon than from cooler burning fires. The severity of a fire changes as rapidly as wind and weather, changing relative emissions of elemental carbon and organic matter carbon. A change in wind direction can instantly redirect fire emissions from a nearby monitoring site to one further away, thus changing the relative emissions of elemental carbon and organic matter carbon.

Ammonium Sulfate (SO_4) aerosols in Alaska originate from both anthropogenic and natural events. Volcanoes produce sulfur compounds as ash and volcanic gases. In winter, arctic haze from Northern Europe and Russia contributes sulfur compounds including sulfur dioxide to Alaskan air. These compounds are converted to sulfates in the increasing light levels of spring. Arctic haze also contains particulate sulfur originating from coal burning and metal smelting in Asia and northern Europe. Within Alaska, sulfate aerosols are produced by coal and diesel powered generators, home heating, and mobile sources. It is possible, but not yet known, that biogenic sulfate from ocean plankton contributes to sulfate at the coastal Class I area sites.

Ammonium Nitrate (NO_3) is created from several species of NOx. In Alaska, NOx is typically generated by anthropogenic activities, primarily high temperature combustion of fossil fuels. Sources include power generation, home heating, mobile sources, and arctic haze. The chemistry of ammonium nitrate formation is dependent on sunlight and atmospheric moisture, so atmospheric precursors may build up through the winter and produce ammonium nitrate in spring.

Soil aerosols in Alaska originate in Asian dust storms and from more local sources of erosion. The origin of soil aerosols can be determined because they usually arrive in discrete meteorological events, and often when Alaskan soils are snow covered. Spring aerosols can be traced chemically and morphologically to their sources in Mongolia and northern China. Other long distance aerosols have been traced to agricultural burning in Russia and cooking fires in Asia. Locally, erosion of unvegetated surfaces along major rivers and glaciers may contribute to soil aerosols. None of these sources are controllable for purposes of regional haze.

Coarse Mass (CM) aerosols arise from many different sources and processes. At other Class I areas, important contributors to this category include crustal minerals, organic mass, and inorganic salts such as calcium nitrate and sodium nitrate. Within Alaska, typical sources of coarse mass include erosion of coasts and river floodplains, traffic on unpaved roads, and windborne glacial deposits.

3. Best Days and Worst Days, Baseline Years

DENA1: The 2000-2004 DENA1 baseline visual range for best and worst days was 307 km (1.8 $Mm^{-1)}$ and 126 km (20 Mm^{-1}), respectively. The average aerosol light extinction coefficient (Bext – Rayleigh Scattering (10 Mm^{-1})) during the 20% worst days is 20.0 Mm^{-1}, which is about 11 times of the value of 1.8 Mm^{-1} during the 20% best days. Relative proportions of both sulfate and organic mass change markedly between best and worst days. In 2000-2004, organic matter carbon was the largest aerosol contributor to haze during the 20% worst days, but more complicated patterns emerge with analysis of individual years.

TRCR1: The 2002-2004 TRCR1 baseline visual range for best and worst days was 277 km (2.1 $Mm^{-1)}$ and 117 km (21.4 Mm^{-1}) respectively. The average aerosol light extinction coefficient (Bext – Rayleigh Scattering (10 Mm^{-1})) during the 20% worst days is 21.4 Mm^{-1}, which is about 10 times of the value of 2.1 Mm^{-1} during the 20% best days. The relative proportions of both sulfate and organic mass change markedly between best and worst days, but more complicated patterns emerge with analysis of individual years.

For both monitoring sites during the baseline period organic matter was the largest contributor to haze during the 20% worst days. Sulfate was the largest aerosol contributor of those amenable to human control.

a. Average and Relative Contributions of Aerosol Species to Visibility on the Best and Worst Days

At both monitoring sites, the average worst days are characterized by greater extinction due to all species measured (Table III.K.4-13). Total light extinction varies dramatically between the best and worst days, with average non-Rayleigh extinctions at DENA1 from 1.8 to 20.0 and from 2.1 to 21.4 Mm^{-1} for TRCR1. By far the greatest relative change was for organic matter which was 36 times higher than on best days for DENA1 and 23 times higher than on best days for TRCR1. Extinction due to organic matter carbon varies from 0.3-10.8Mm^{-1}. Extinction due to sulfate varies only from 0.8-4.9Mm^{-1}. Clearly, wildfire-related organic matter carbon is the strongest determinant of worst days at the Denali IMPROVE sites.

Table III.K.4-13
Average Light Extinctions on Best and Worst Days for Baseline Years at Denali in Mm^{-1}

a) DENA1 monitoring site 2000-2004

Parameter	Best 20%: Average	Best 20%: Minimum	Best 20%: Maximum	Worst 20%: Average	Worst 20%: Minimum	Worst 20%: Maximum
ammno3f_bext	0.1	0	0.5	0.6	0.1	4.3
ammso4f_bext	0.8	0.1	1.6	4.9	0.8	15.9
cm_bext	0.2	0	1	1.4	0	5.7
ecf_bext	0.2	0	1.1	1.6	0.03	13.5
omcf_bext	0.3	0	1.4	10.8	0.3	211
seasalt_bext	0.1	0	1.2	0.4	0	13
soilf_bext	0.05	0.01	0.2	0.3	0.02	2.2
Total Extinction	1.8	0.5	2.8	20	8.8	238.1
Total Extinction including Rayleigh	12.8	11.5	13.8	31	19.8	249.1

Note: Extinctions due to each aerosol species are in separate rows. Total extinctions without and including Rayleigh scattering comprise the last two rows of the table.

b) TRCR1 monitoring site 2002-2004

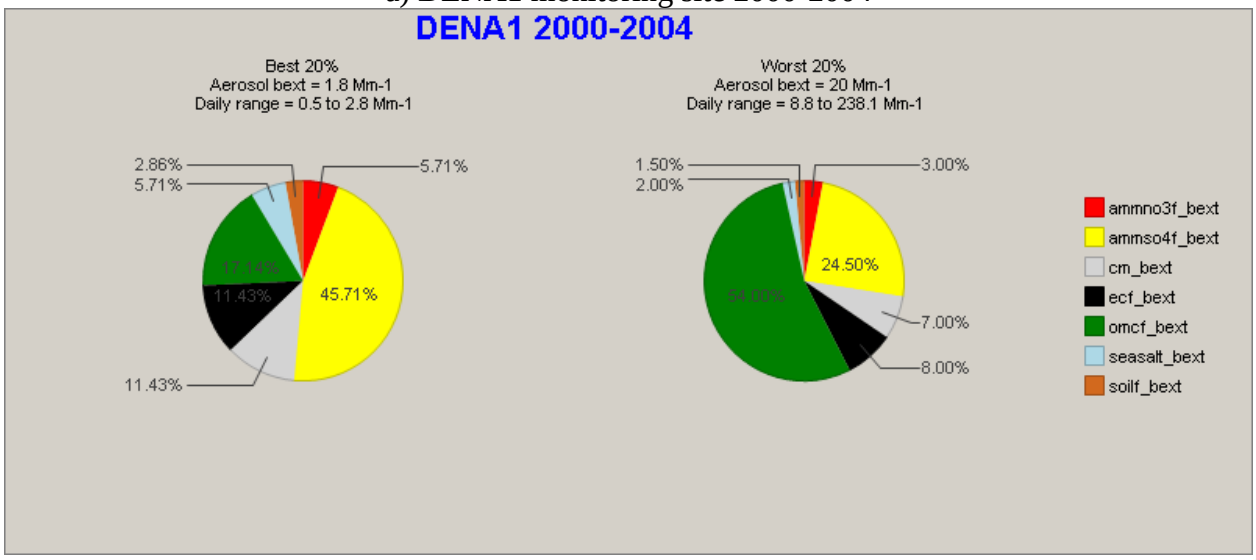
Parameter	Best 20%: Average	Best 20%: Minimum	Best 20%: Maximum	Worst 20%: Average	Worst 20%: Minimum	Worst 20%: Maximum
ammno3f_bext	0.2	0	0.7	1.1	0.2	3.2
ammso4f_bext	0.9	0.2	2.1	7.5	2.5	17.6
cm_bext	0.3	0	0.9	1.6	0.4	8.5
ecf_bext	0.3	0	1.1	1.3	0	3.6
omcf_bext	0.4	0	1.9	9.1	0.8	55.6
seasalt_bext	0.1	0	0.7	0.5	0	8.8
soilf_bext	0.05	0	0.2	0.3	0.01	1.3
Total Extinction	2.1	0.5	3.3	21.4	12.6	70
Total Extinction including Rayleigh	14.1	12.5	15.3	33.4	24.6	82

Note: Extinctions due to each aerosol species are in separate rows. Total extinctions without and including Rayleigh scattering comprise the last two rows of the table.

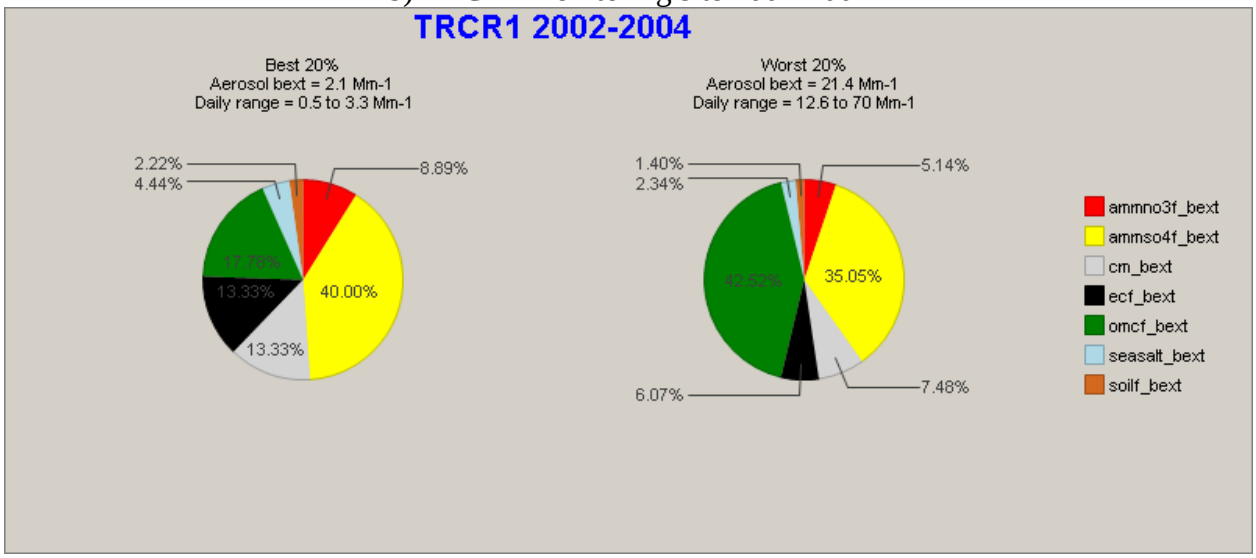
Relative proportions of both sulfate and organic matter change markedly between best and worst days (Figure III.K.4-26). Interannual variability, discussed later, provides more insight into how species proportions vary. Organic matter rose from 17% on best days to 54% of extinction on worst days at DENA1 (18-43% at TRCR1), as sulfate fell from 46% to 25% (40-35% at TRCR1). The relative contributions of nitrate, sea salt, soil, and coarse mass all fell slightly on worst days. Again, wildfire-related organic matter carbon is the strongest determinant of worst days at the Denali IMPROVE sites.

Figure III.K.4-26
Proportional Representation of IMPROVE Aerosols on Best and Worst Days at Denali, Baseline Years

a) DENA1 monitoring site 2000-2004



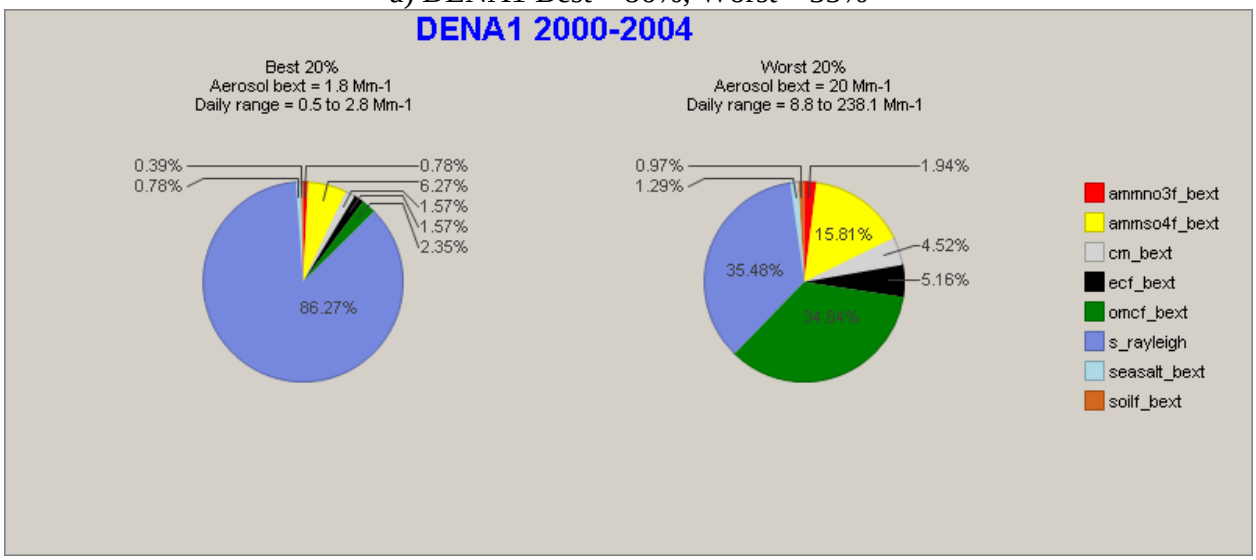
b) TRCR1 monitoring site 2002-2004



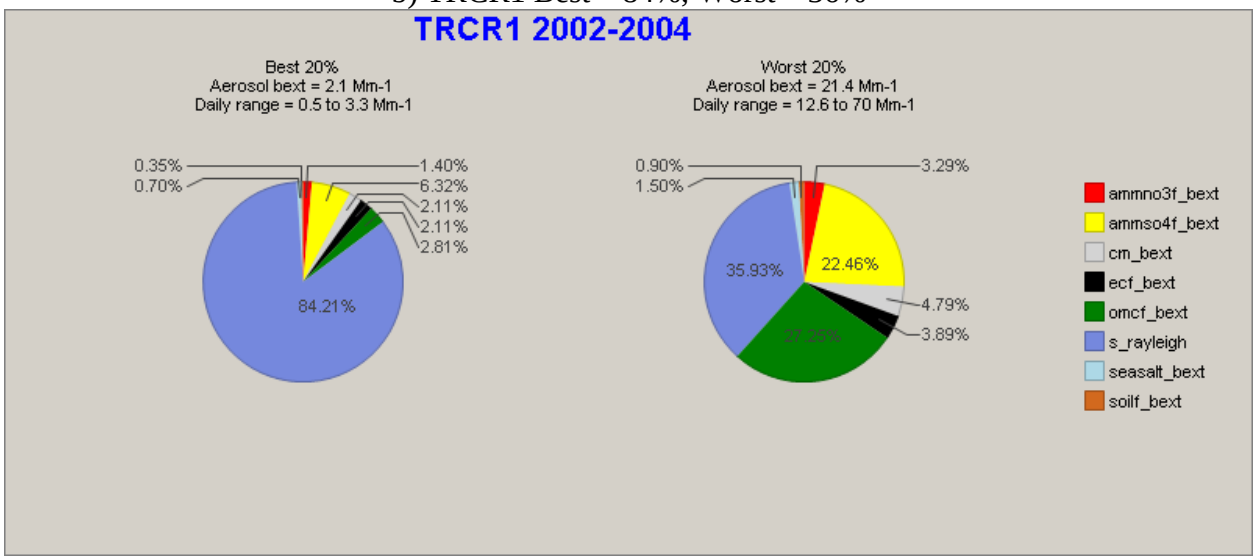
The high relative contributions of Rayleigh scattering to best and worst days (Figure III.K.4-27) underscore the low aerosol concentrations monitored at Denali.

Figure III.K.4-27
Relative Contributions of Rayleigh Scattering to Visibility Impairment at Denali on Best and Worst Days

a) DENA1 Best – 86%, Worst – 35%



b) TRCR1 Best – 84%, Worst – 36%



Note: Rayleigh scattering is 12 Mm-1.

b. Seasonality, Baseline Years

At Denali, the days with worst visibility are not evenly scattered throughout the year. The highest occurrence of the 20% worst days at DENA1 was in May through July, with March, April, and August having intermediate counts (Table III.K.4-14). November, December, January and February had the greatest number of best days. At TRCR1 the highest occurrence of the 20% worst days was in May through August. Data from individual years show a substantial amount of interannual variability.

Table III.K.4-14
Incidence of Best Days and Worst Days, Totaled by Month at Denali, Baseline Years

a) DENA1 site 2000-2004

Months, 2000-2004	Number of Best Days (Group 10)	Number of Worst Days (Group 90)
1	15	3
2	18	5
3	7	16
4	4	11
5	2	18
6	0	21
7	2	20
8	1	11
9	8	6
10	13	2
11	21	1
12	19	1

b) TRCR1 site 2002-2004

Months, 2000-2004	Number of Best Days (Group 10)	Number of Worst Days (Group 90)
1	11	0
2	13	1
3	3	4
4	4	4
5	1	15
6	0	11
7	0	15
8	1	14
9	1	6
10	10	2
11	15	0
12	11	0

The best days and worst days, seen in Table III.K.4-14, represent visibility extremes. Average visibilities change seasonally as well. Average light extinctions, computed for each calendar quarter, summarize seasonal changes in air quality at the Class I areas (Figure III.K.4-28). For October through March (yearly Quarters 4 and 1), the relative proportions of aerosol species are closer to that of average best days (Figures III.K.4.26 & III.K.4-28). The subset of winter days resembles best days more than worst days. In Quarters 2 and 3 (April through September), relative proportions were closer to those of average worst days, with much higher proportions of organic matter. The seasonal increase and interannual variability of organic matter carbon aerosols in Quarters 2 and 3 is further discussed below.

Figure III.K.4-28
Proportional Representation of IMPROVE Aerosols for Days of Each Calendar Quarter at Denali, Baseline Years

a) DENA1 Quarters 1, 2, 3, & 4

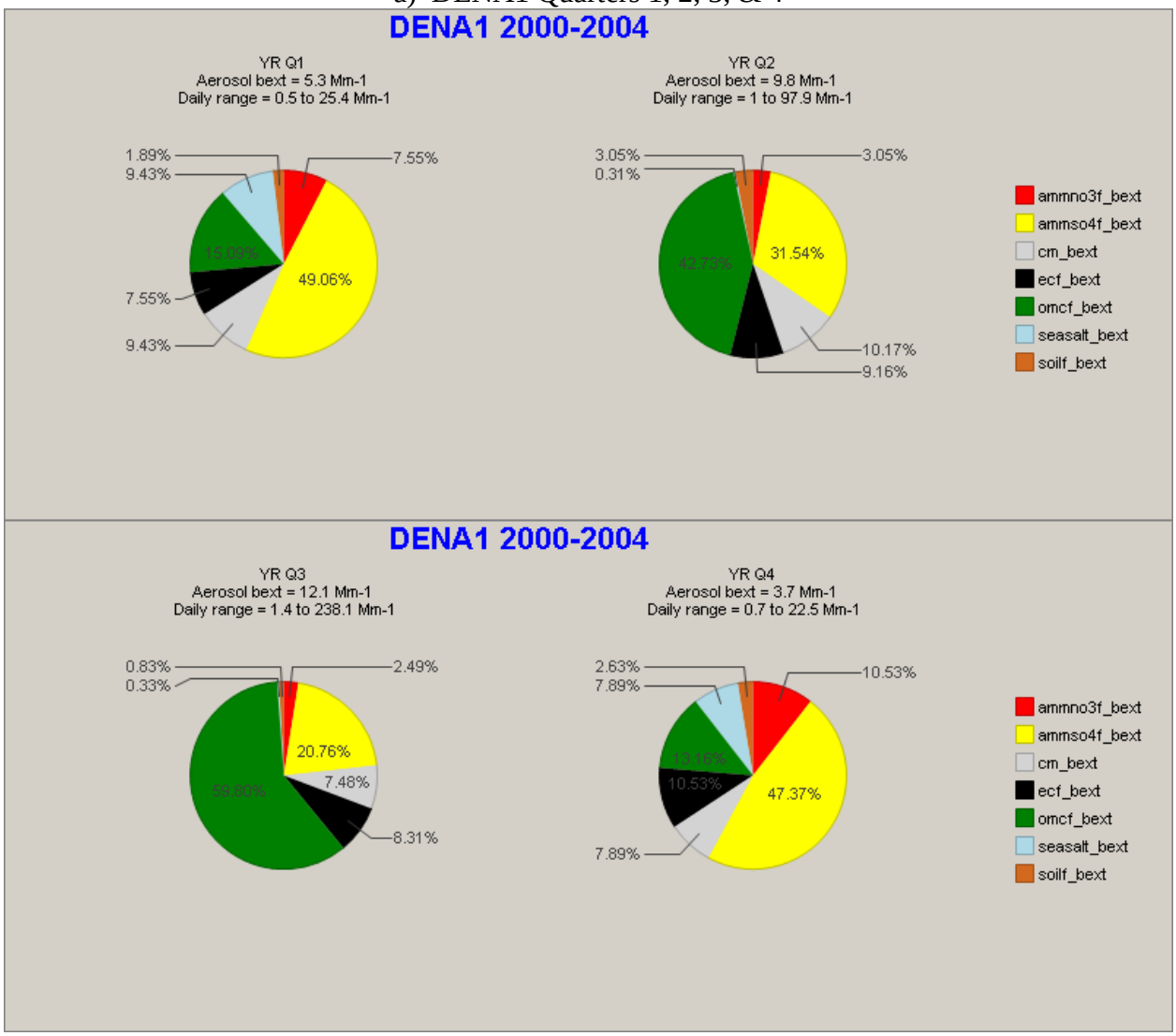
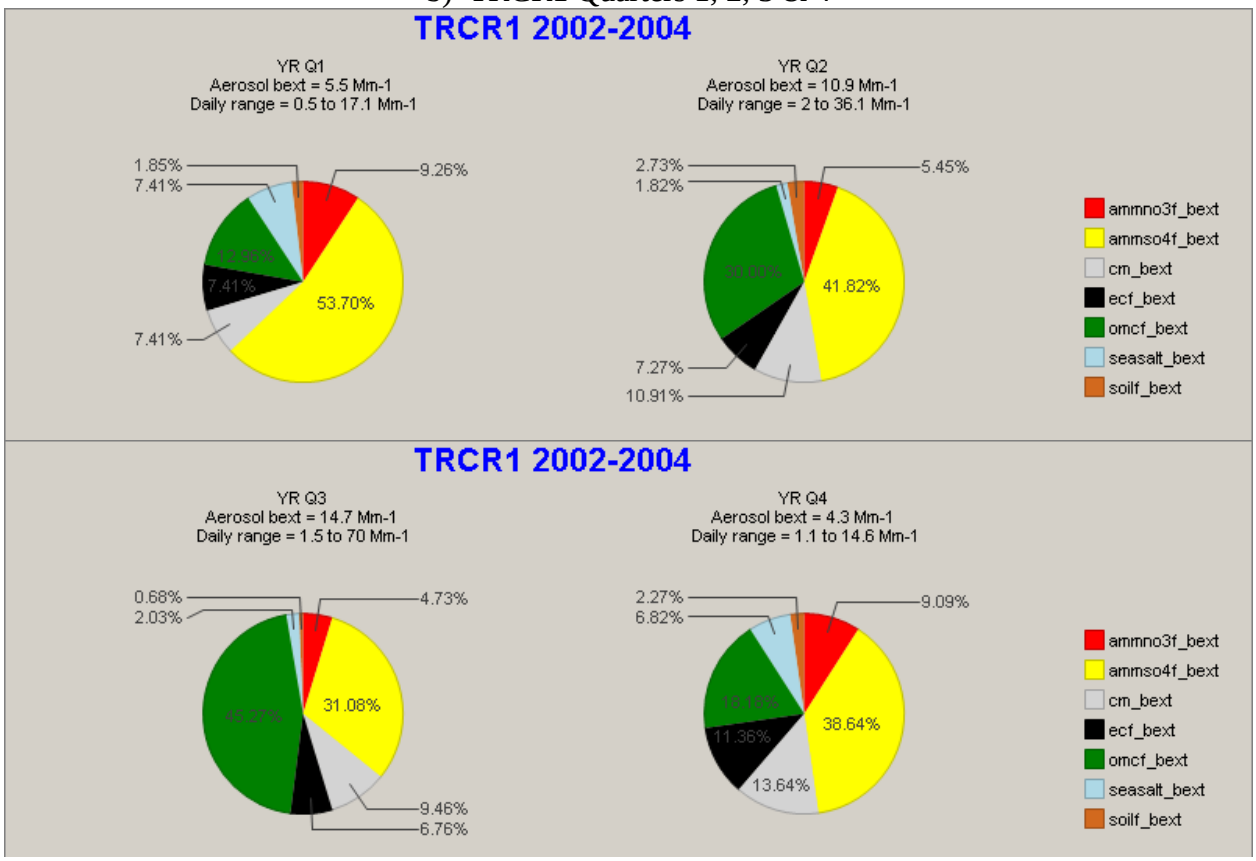


Figure III.K.4-28 (continued)
Proportional Representation of IMPROVE Aerosols for Days of Each Calendar Quarter at Denali, Baseline Years

b) TRCR1 Quarters 1, 2, 3 & 4



Note: Quarters 1, 2, 3, & 4 denoted on chart as YR Q1, YR Q2, YR Q3, or YR Q4.

c. Proportional Representation of Pollutant Species: Best Days/Worst Days, by Year

The poorest visibility days (worst days) at Denali are caused by very large increases in some aerosols, and only small increases in others. Comparing the proportions of individual pollutants on best and worst days and comparing them separately for each year can highlight the key species separating best and worst days. For instance, for the DENA1 baseline (2000-2004) light extinction due to organic matter carbon increased from 17.1 to 54 percent between best and worst days (Figure III.K.4-26a). Sulfate fell from 45.7 to 24.5 percent between best and worst days, and nitrate ranged from 5.7 to 3 percent. For 2002-2006, years with comparable data from both sites, the largest components of light extinction at both Denali and Trapper Creek are organic matter carbon and sulfate (Figure III.K.4-29).

Wildfire activity varies greatly year to year in Alaska. In six of the seven years from 2000-2006, organic matter carbon dominated the worst days. For individual years 2002 and 2005 (Figures

III.K.4-30, III.K.4-31), the worst days showed a proportion of organic matter carbon much higher than best days. In contrast, in a year with few fires (2006), the worst days showed a proportion of organic matter carbon quite similar to best days. DENA1 and TRCR1 IMPROVE sites are separated by much of the Alaska Range, and so are affected differently by wildfires. More detailed comparisons will show that even in years with identical summaries, the timing and origins of the organic matter carbon aerosols can differ widely. Nevertheless, changes in organic matter carbon aerosol at Denali clearly drive the differences in the relative contributions of aerosol species from year to year.

Figure III.K.4-29
2002-2006 Proportional Representation of IMPROVE Aerosols on Best and Worst Days at Denali, Directly Comparable Years

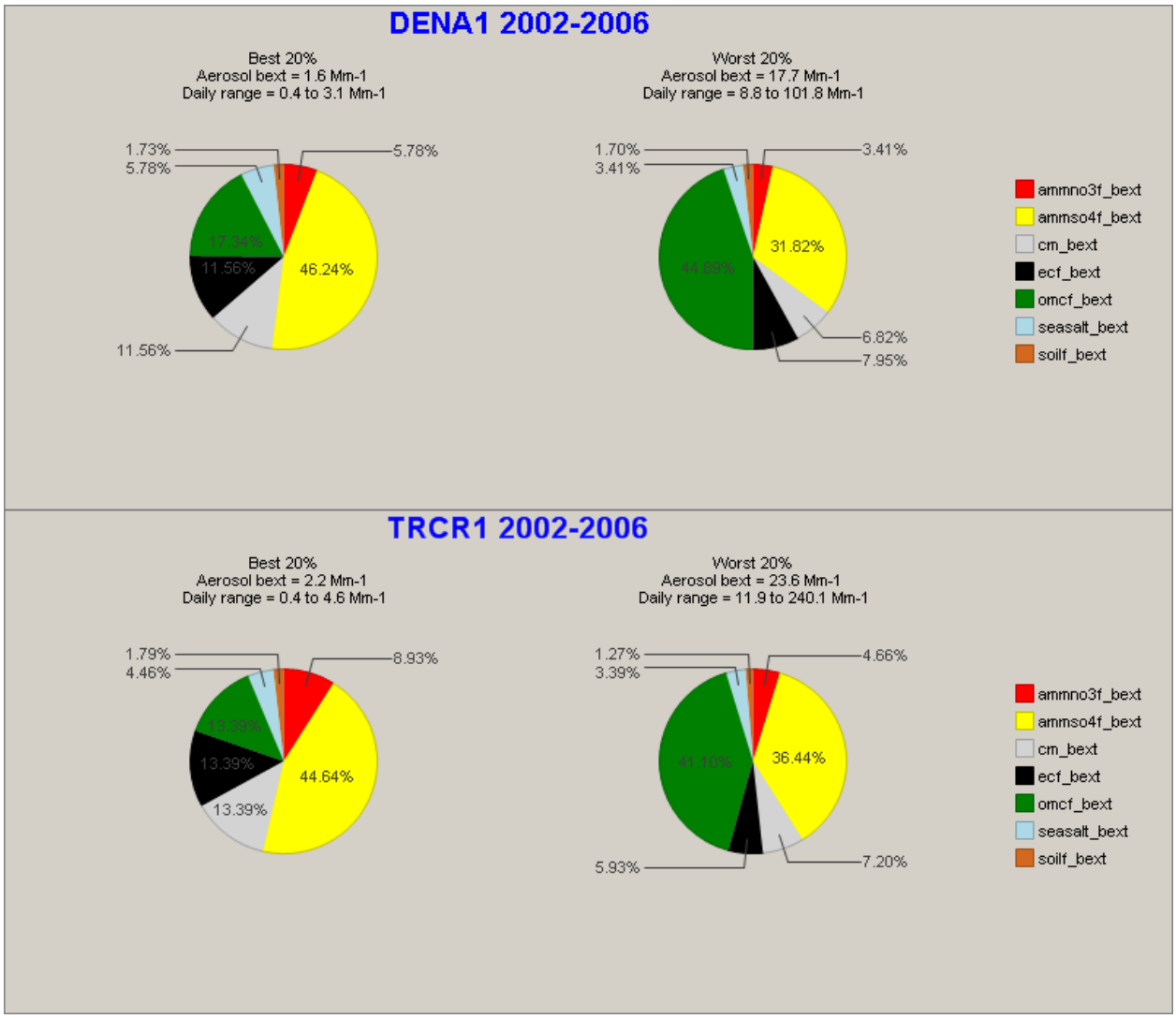


Figure III.K.4-30
2002 Proportional Representation of IMPROVE Aerosols at Denali on Best and Worst Days

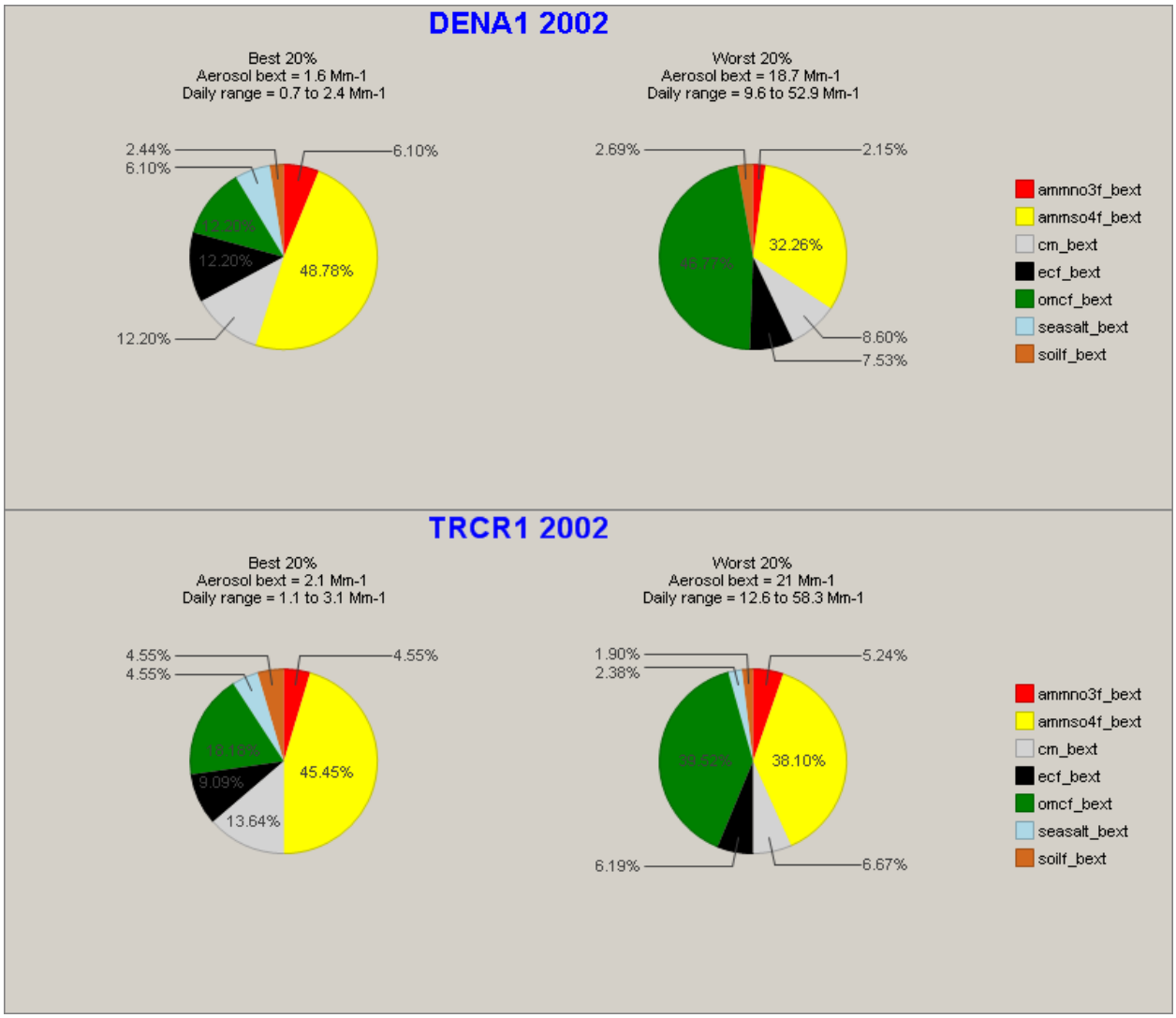
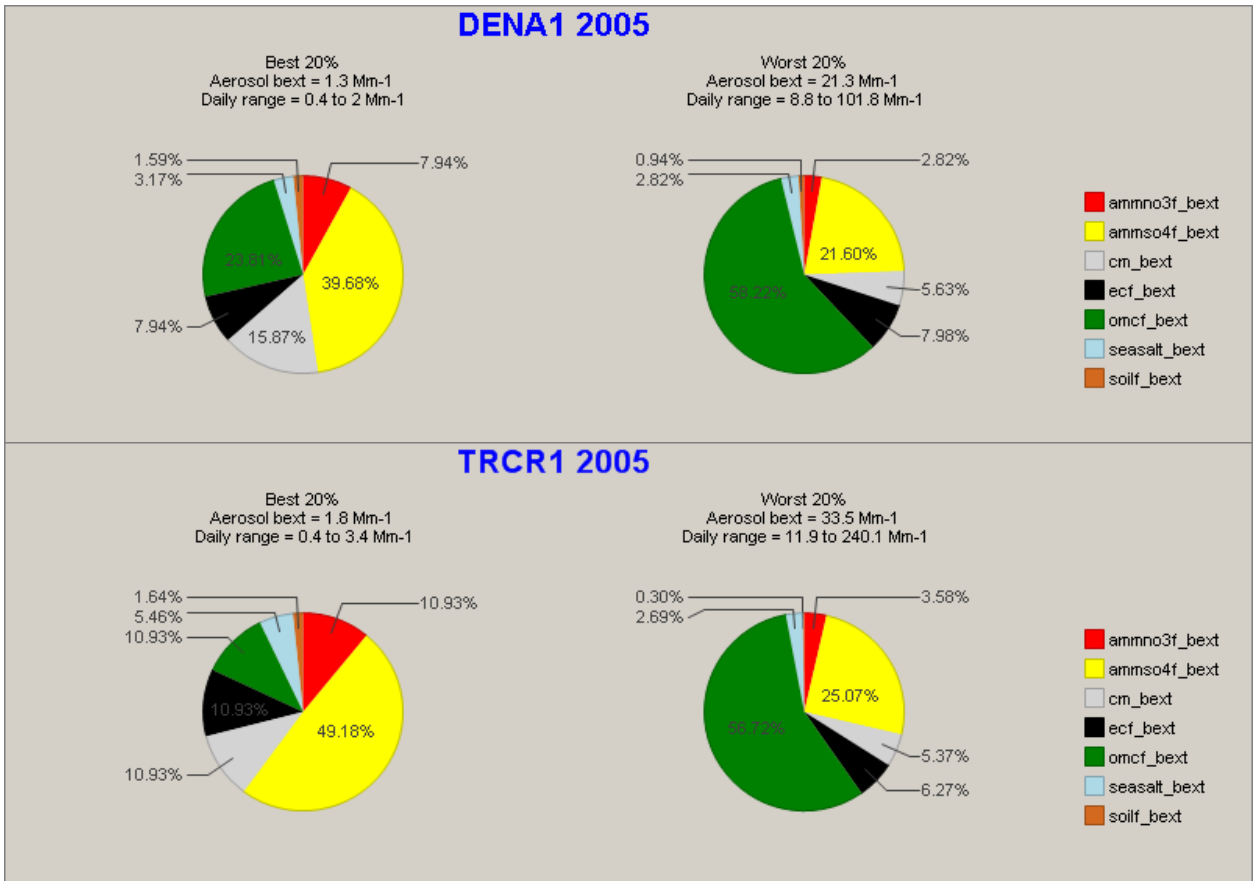


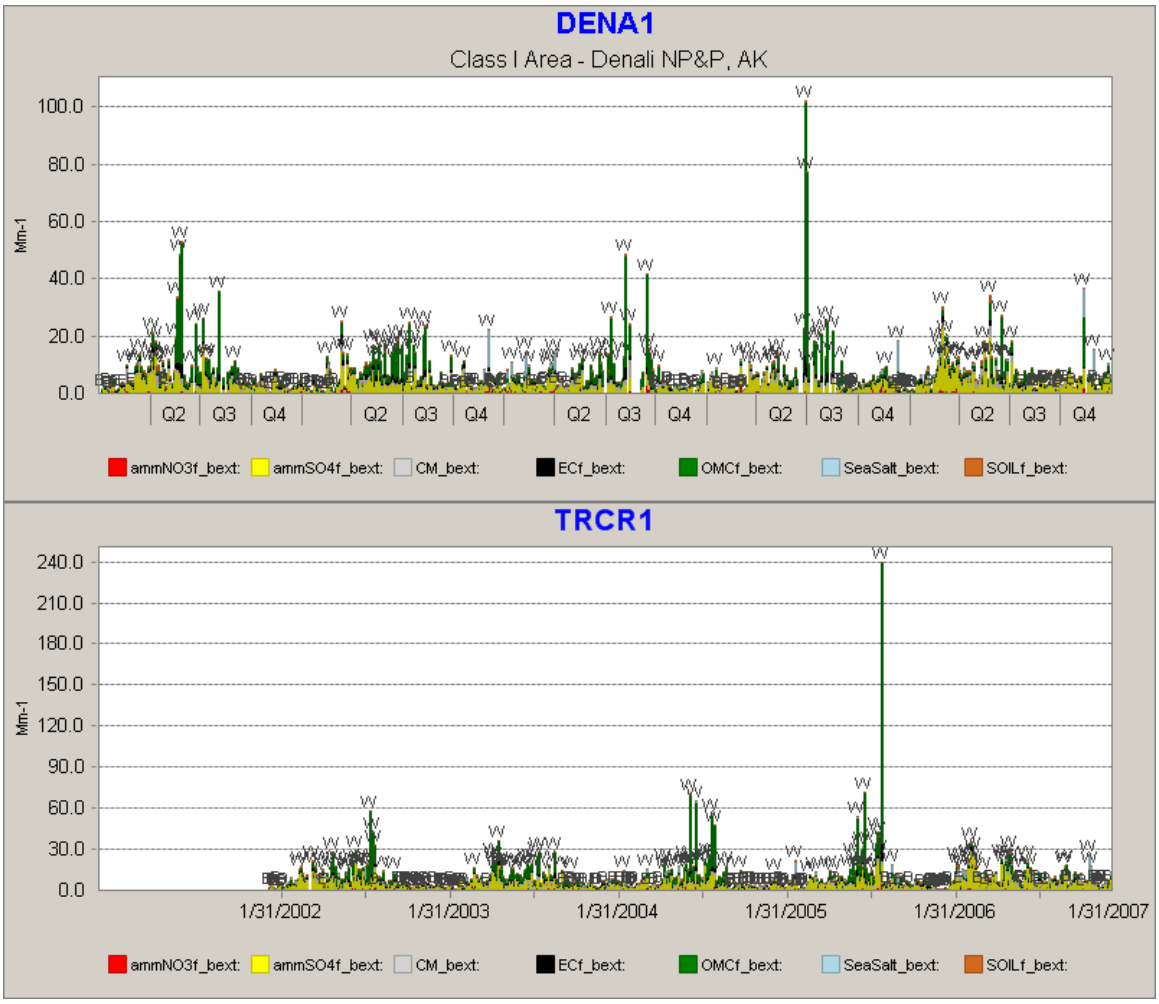
Figure III.K.4-31
2005 Proportional Representation of IMPROVE Aerosols at Denali on Best and Worst Days



d. Daily, Seasonal, and Annual Variation in Light Extinction Due to IMPROVE Aerosol Species

On each air sampling day, visibility is determined by the combined extinctions of all aerosol species measured. Stacked histograms represent the actual, rather than proportional contributions of each aerosol species on each sampling day. Figure III.K.4-32 displays the general annual patterns evident from 2002-2006. Figure III.K.4-33 displays histograms for individual years, with finer resolution, and with best and worst sampling days labeled **B** and **W**. Visibility at Denali was most impaired during the summer and spring (Figure III.K.4-32). The degree of impairment in February-May and in September varied year to year. The year 2006 differed in both timing and chemistry of worst days. The predominant differences among years are in the timing, locations, and severity of wildfires (OMC and EC) during the growing season.

Figure III.K.4-32
2002-2006 Contribution of Aerosol Species to Light Extinction at Denali on Best and Worst Days



Organic matter carbon contributes heavily to worst days each year (Figure III.K.4-33). The timing and behavior of Alaska wildfires producing organic matter carbon varies year to year. Fires also contribute to worst days in spring and winter. Alaska receives organic matter carbon and elemental carbon linked to fire activity in Asia and Europe. Transboundary pollutants from Asia and Europe in winter and spring are significant and predictable, but in most years local wildfire effects dominate. Sulfate and nitrate aerosols are present continuously, but other aerosols are episodic. Sea salt events contribute to worst days in winter and spring.

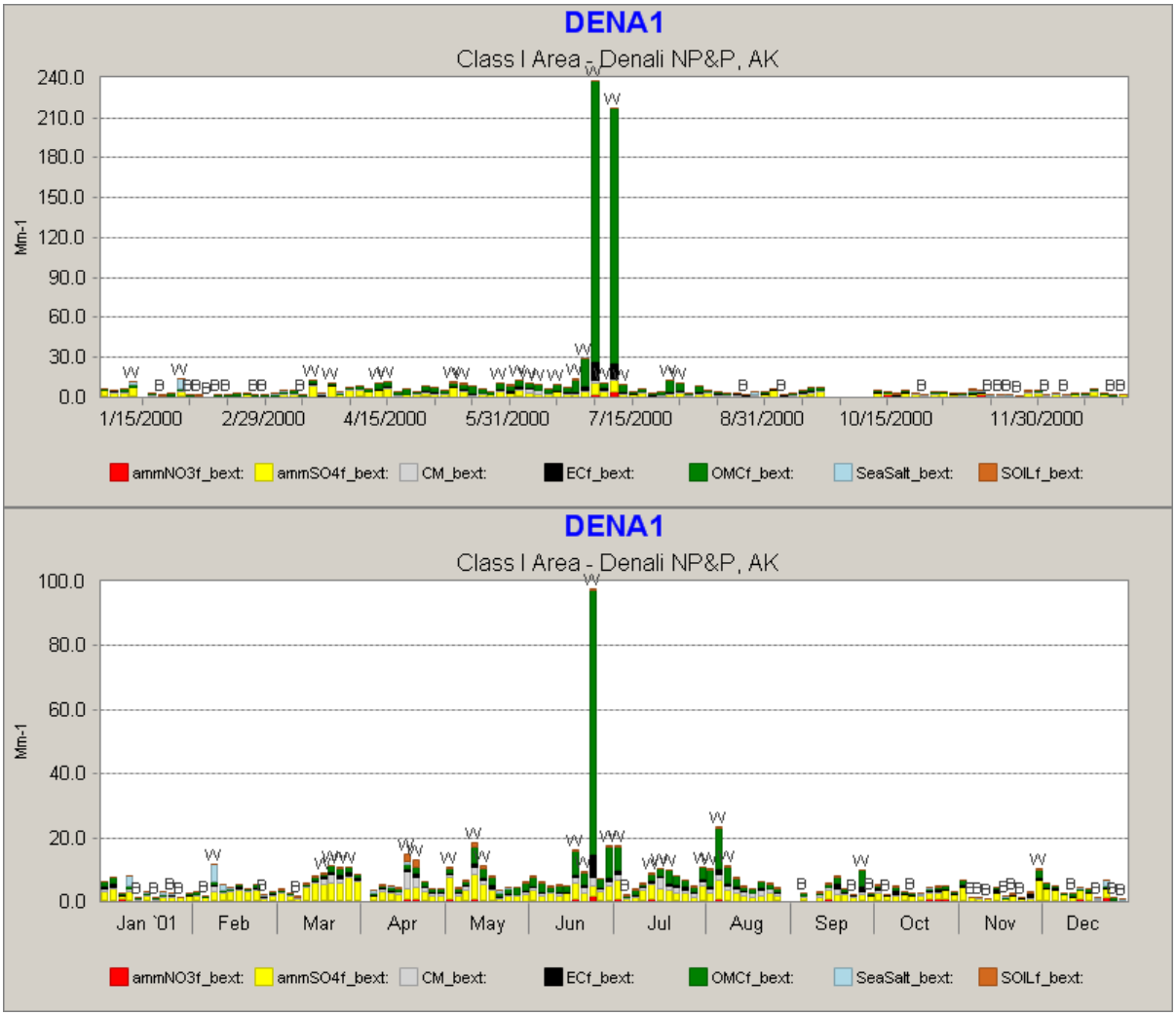
Sulfate and organic matter carbon contributed most to worst days during the spring and summer. Total Extinction on these worst days typically ranged from 10-20 Mm^{-1}, with occasional much higher peaks. During less impaired times of year, sea salt was the largest additional contributor

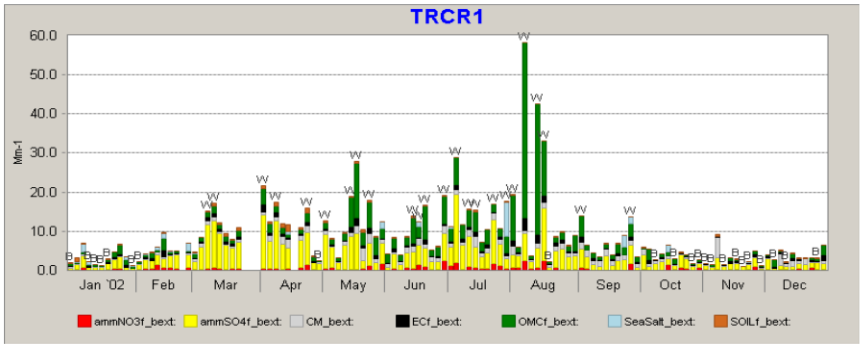
to visibility impairment. The largest organic matter carbon peaks occurred in summer, and are associated with Alaskan wildfires.

In spring and summer, worst days were frequently caused by one or a few species. During the rest of the year worst days were usually caused by a combination of species.

Sampling days missing one or more channels of IMPROVE data are omitted from stacked histograms. However, data that were reported for those days can be seen by examining individual aerosols. This situation is most striking for August 2004, where missing data for Coarse Matter correspond with extremely high Organic Matter Carbon from wildfires. (See Figure III.K.4-33, as well as Figure III.K.4-36, presented later.)

Figure III.K.4-33
Contribution of Aerosol Species to Light Extinction on Best and Worst Days at Denali IMPROVE Sites, Individual Years 2000-2006

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Mm-1
Jan '02
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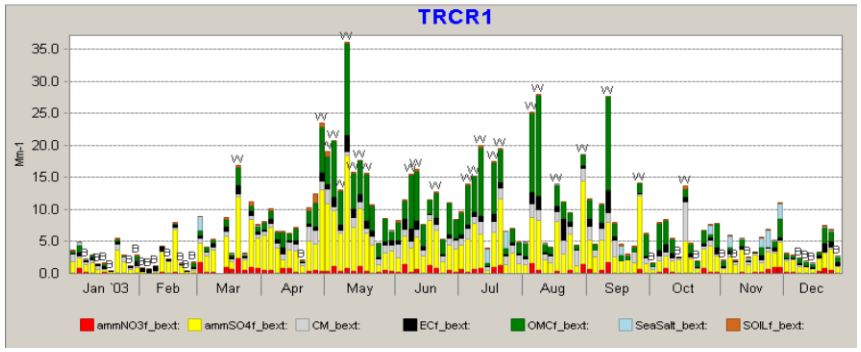
ammSO4f_bext:
CM_bext:
ECf_bext:
OMCf_bext:
SeaSalt_bext:
SOILf_bext: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Mm-1
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Dec
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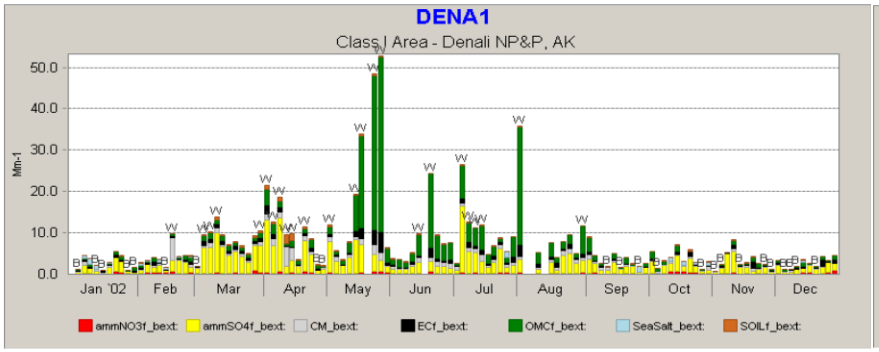
CM_bext:
ECf_bext:
OMCf_bext:
SeaSalt_bext:
SOILf_bext:


DENA1
Class I Area - Denali NP&P, AK
Mm-1
Jan '02
Feb
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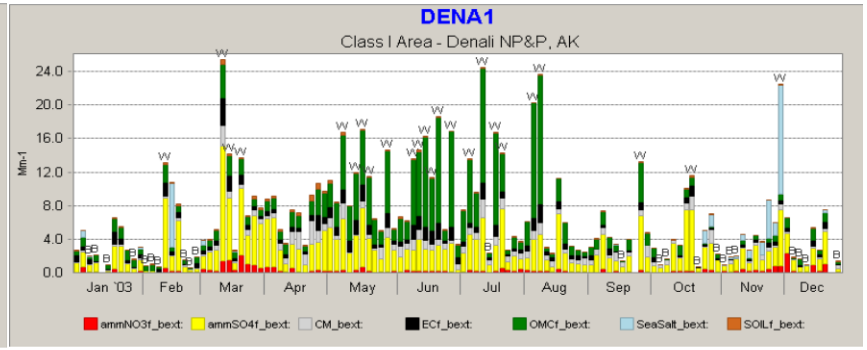
DENA1
Class I Area - Denali NP&P, AK
Mm-1
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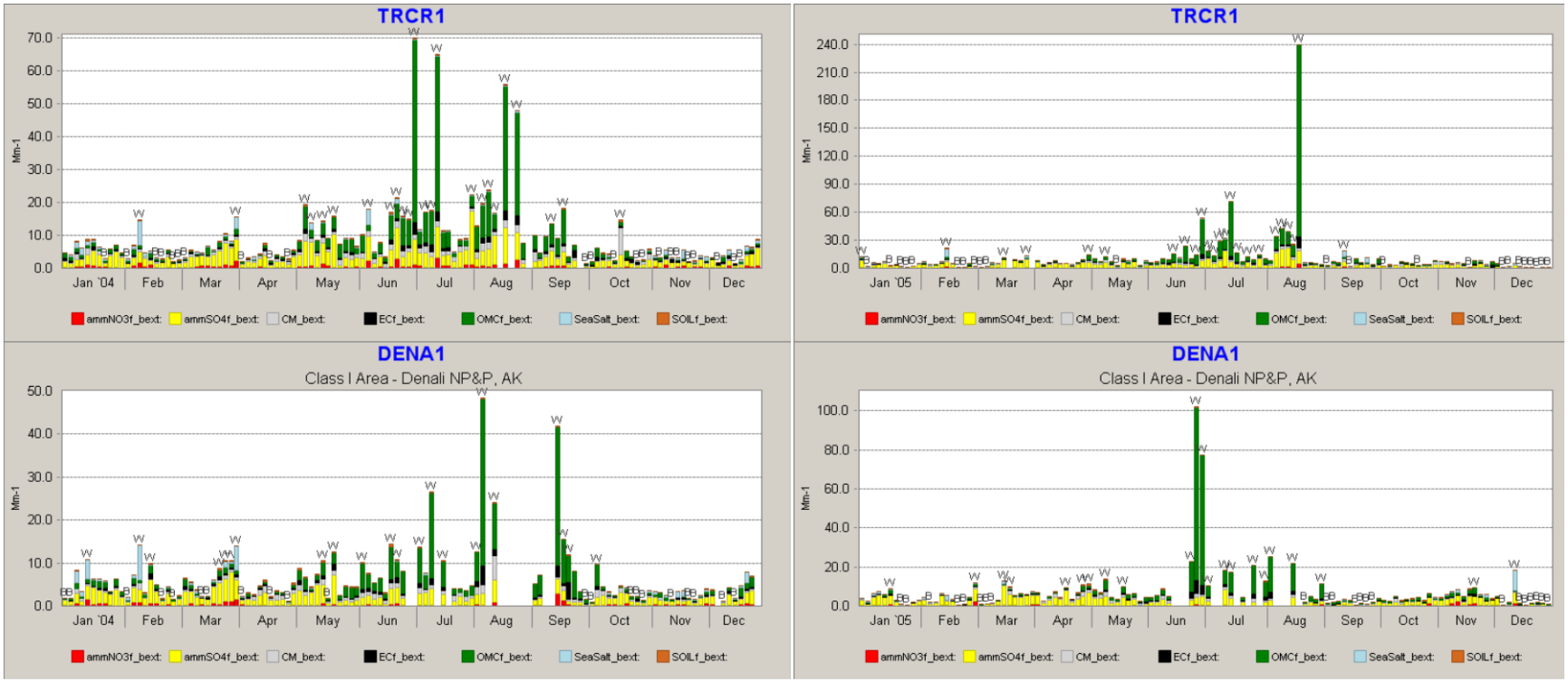
OMCf_bext:
SeaSalt_bext:
SOILf_bext:


TRCR1
Mm-1
Jan '04 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
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TRCR1
Mm-1
Jan '05 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
ammNO3f_bext: ammSO4f_bext: CM_bext: ECf_bext: OMCf_bext: SeaSalt_bext: SOILf_bext:
DENA1
Class I Area - Denali NP&P, AK
Mm-1
Jan '04 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
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DENA1
Class I Area - Denali NP&P, AK
Mm-1
Jan '05 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
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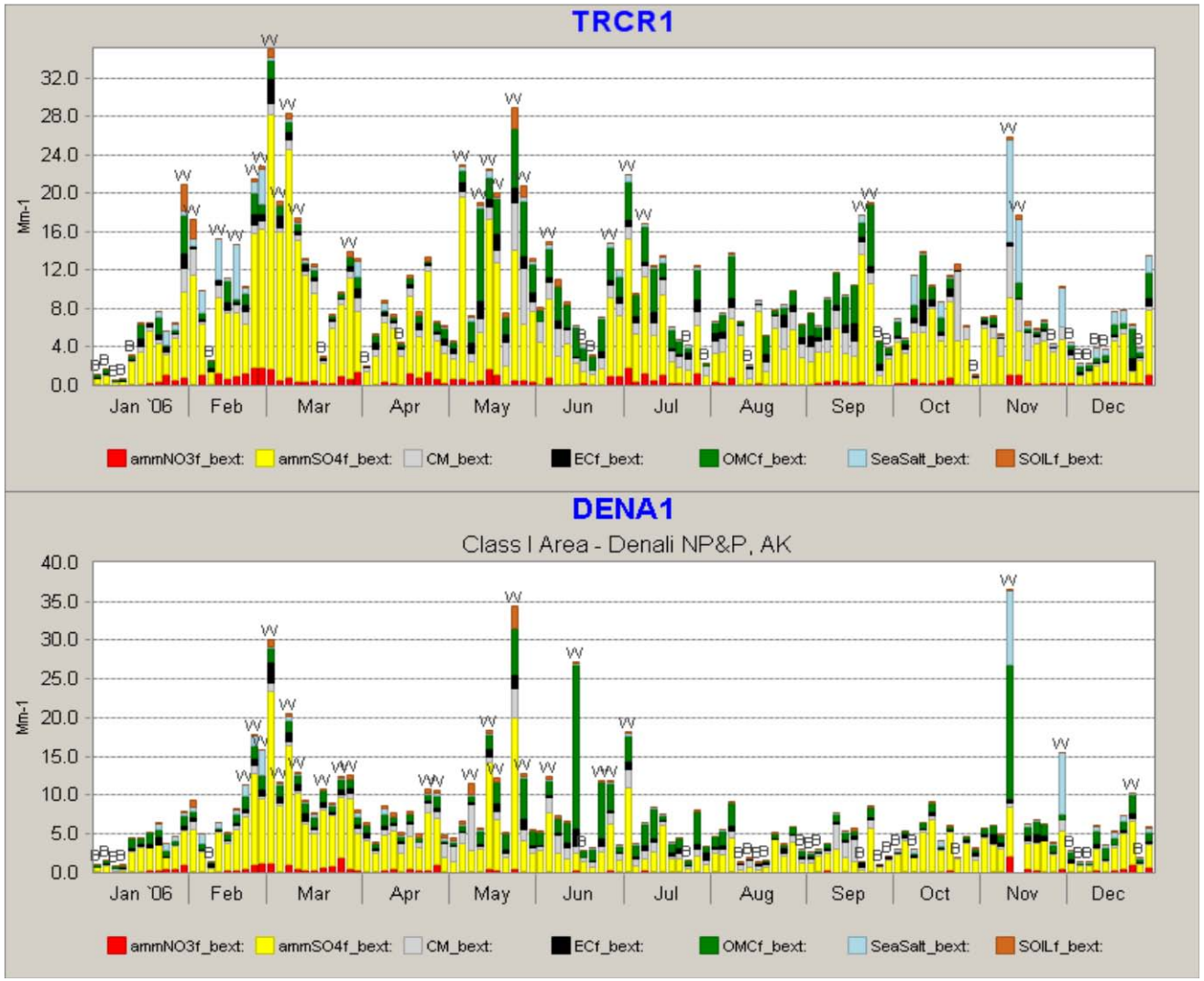
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Mm-1
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16.0
12.0
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4.0
0.0
Jan '06
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ammNO3f_bext:
ammSO4f_bext:
CM_bext:
ECf_bext:
OMCf_bext:
SeaSalt_bext:
SOILf_bext:
DENA1
Class I Area - Denali NP&P, AK
Mm-1
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35.0
30.0
25.0
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15.0
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OMCf_bext:
SeaSalt_bext:
SOILf_bext:

4. Correlations Among IMPROVE Aerosols Monitored at DENA1 and TRCR1

Aerosol species emitted from a common source, arriving on the same weather systems, or simply from the same direction will be correlated with each other. Correlations can be used to make inferences about aerosol origins.

The correlations among aerosols at Denali National Park show a more complex picture than at Simeonof Class I area (Table III.K.4-15). Organic matter carbon and elemental carbon are strongly correlated on worst days and all days, at both monitoring sites. They are most clearly associated with wildfire. The other species correlations are smaller. Soil and coarse matter are slightly correlated to each other, but not to the fire aerosols. Research has identified Asian dust events as important sources of soil and coarse matter in Alaska. For the worst days, almost every correlation decreases or becomes more negative. For instance, at DENA1 the correlation between nitrate and sulfate on worst days (0.25) is less than that on all days (0.50). At TRCR1, the correlation between nitrate and sulfate falls to 0.23 on worst days from 0.57 on all days.

Table III.K.4-15
Pearson Correlation Coefficients Between Aerosol Species at Denali

DENA1	MASS	TRCR1	MASS	DENA1	MASS	TRCR1	MASS
ALL DAYS	2002-2006	ALL DAYS	2002-2006	WORST DAYS	2002-2006	WORST DAYS	2002-2006
0.50	**N S**	**0.57**	**N S**	0.25	N S	0.23	N S
0.11	N CM	0.19	N CM	-0.17	N CM	-0.08	N CM
0.29	N EC	0.42	N EC	-0.02	N EC	0.31	N EC
0.22	N OMC	0.42	N OMC	-0.03	N OMC	0.33	N OMC
0.29	N SS	0.33	N SS	0.27	N SS	0.23	N SS
0.19	N SOIL	0.16	N SOIL	-0.04	N SOIL	-0.13	N SOIL
0.32	S CM	0.26	S CM	-0.03	S CM	-0.22	S CM
0.37	S EC	0.34	S EC	-0.09	S EC	0.00	S EC
0.16	S OMC	0.23	S OMC	-0.30	S OMC	-0.12	S OMC
0.07	S SS	0.08	S SS	-0.06	S SS	-0.14	S SS
0.59	**S SOIL**	0.46	S SOIL	0.46	S SOIL	0.28	S SOIL
0.31	CM EC	0.28	CM EC	0.02	CM EC	0.09	CM EC
0.29	CM OMC	0.29	CM OMC	0.05	CM OMC	0.11	CM OMC
-0.01	CM SS	0.12	CM SS	-0.12	CM SS	0.09	CM SS
0.61	**CM SOIL**	0.44	CM SOIL	**0.53**	**CM SOIL**	0.34	CM SOIL
0.84	**EC OMC**	**0.87**	**EC OMC**	**0.84**	**EC OMC**	**0.93**	**EC OMC**
-0.08	EC SS	-0.05	EC SS	-0.27	EC SS	-0.20	EC SS
0.24	EC SOIL	0.15	EC SOIL	-0.06	EC SOIL	-0.03	EC SOIL
-0.02	OMC SS	-0.04	OMC SS	-0.14	OMC SS	-0.18	OMC SS
0.12	OMC SOIL	0.07	OMC SOIL	-0.15	OMC SOIL	-0.12	OMC SOIL
-0.05	SS SOIL	-0.02	SS SOIL	-0.15	SS SOIL	-0.12	SS SOIL

Note: Correlations above +/- 0.5 are shown in bold. Shaded pairs are mentioned in text.
SS - Sea Salt

This pattern—aerosol species less correlated on worst days—is consistent with one or a few stochastic processes dramatically influencing worst day visibility. In this case, impacts of wildfire are overwhelming, and are determined not only by wind and weather patterns but also by unpredictable ignition events (and subsequent weather). This is a very different pattern than one where stationary sources emit pollutants from a single location. It is not possible to identify specific weather patterns responsible for worst days because wildfires affect Denali from every direction.

Alternately, the relatively slight correlations among nitrate, sulfate, soil and coarse mass may depend on southerly air masses. The fewest fires impacting Denali occur southwest and due south.

a. Species Closely Associated with Human Activities

Sulfate and nitrate are the aerosols most closely associated with human activities in Alaska. In considering only these two species, sulfate ranges from 80-91% on best days and 82-94% on worst days. Nitrate ranges from 9-20% on best days and 6-18% on worst days. Time series histograms (Figure III.K.4-34) show the more seasonal nature of sulfate aerosols, higher in spring and summer, and the less seasonal nature of nitrate. The correlations between the sulfate and nitrate extinction are 0.50-0.57 for all days, but fall to 0.25-0.23 on worst days. Many days with sulfate peaks are not worst days.

Most worst days have sulfate peaks, even though sulfate provides only a small part of total extinction on those days (Figure III.K.4-34). Analyses suggest that the sulfate and nitrate affecting visibility at Denali National Park arise from multiple sources and weather systems. This conclusion is supported by patterns of correlation among aerosols, and comparisons of all and worst days at two IMPROVE monitoring sites (Figure III.K.4-35). The northern site (DENA1) and southern site (TRCR1) are not acting in concert: sometimes, such as in September 2002, the worst days differ at the two sites; sometimes, high levels of sulfate or nitrate contribute to worst days at one site but not both. Correlations frequently decrease on worst days.

b. Species Not Closely Associated with Human Activities

Sea salt epitomizes an aerosol highly dependent on meteorology and not subject to human control. Subtraction of sea salt results in little change in aerosol proportions of remaining aerosols between best and worst days. Soil aerosols are also not closely associated with human activities. Soil aerosols at the two Denali monitoring sites show the same early spring peaks associated with dust storms in Asia.

Wildfire is not closely tied to humans in Alaska, although it may result from Eurasian agricultural activities. Fine organic carbon (organic matter carbon) and elemental carbon at Denali are closely associated with wildfire, so are largely out of local human control.

Figure III.K.4-34
Interannual Visibility Impairment by Nitrate and Sulfate at Denali, 2002-2006

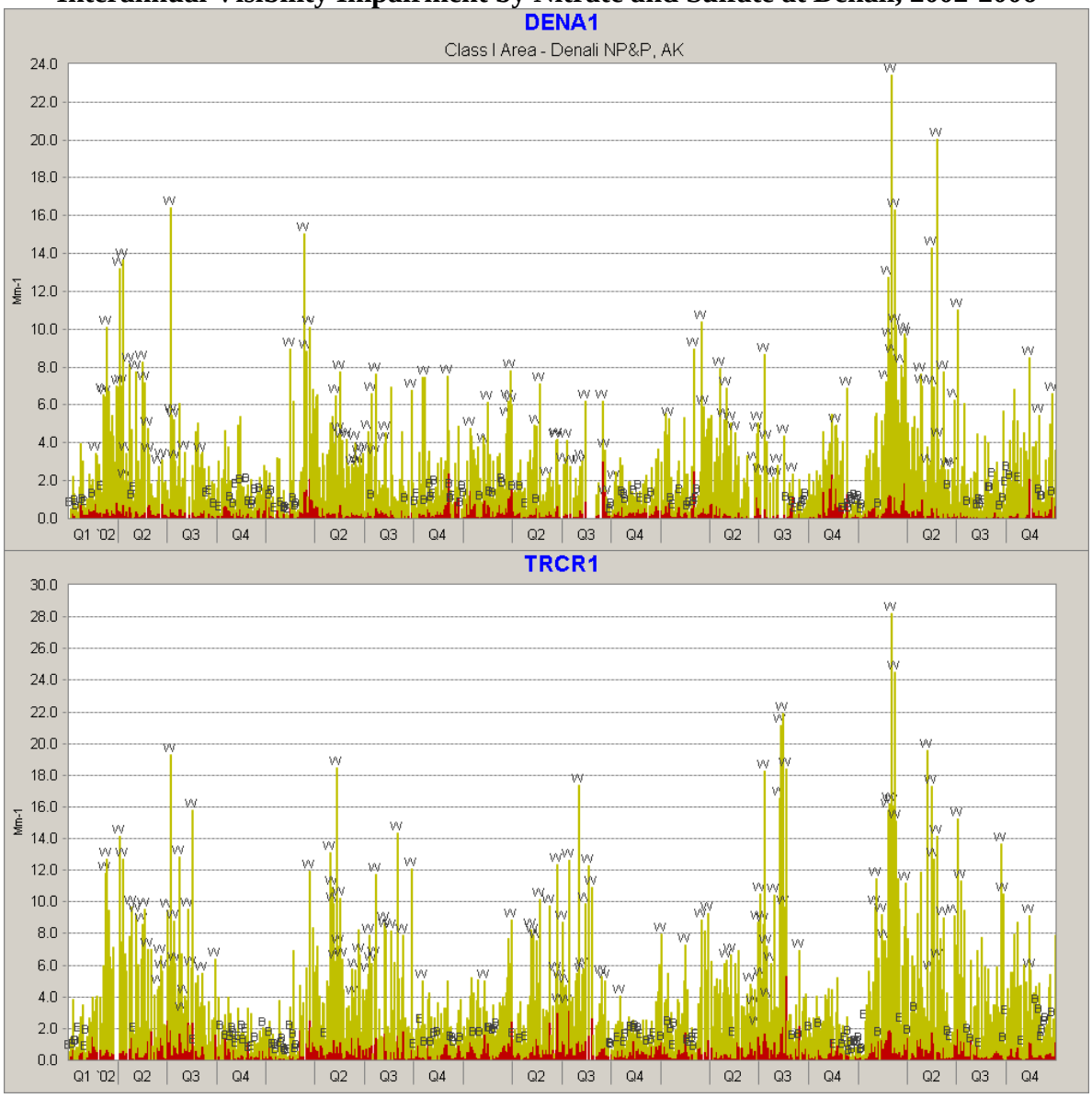
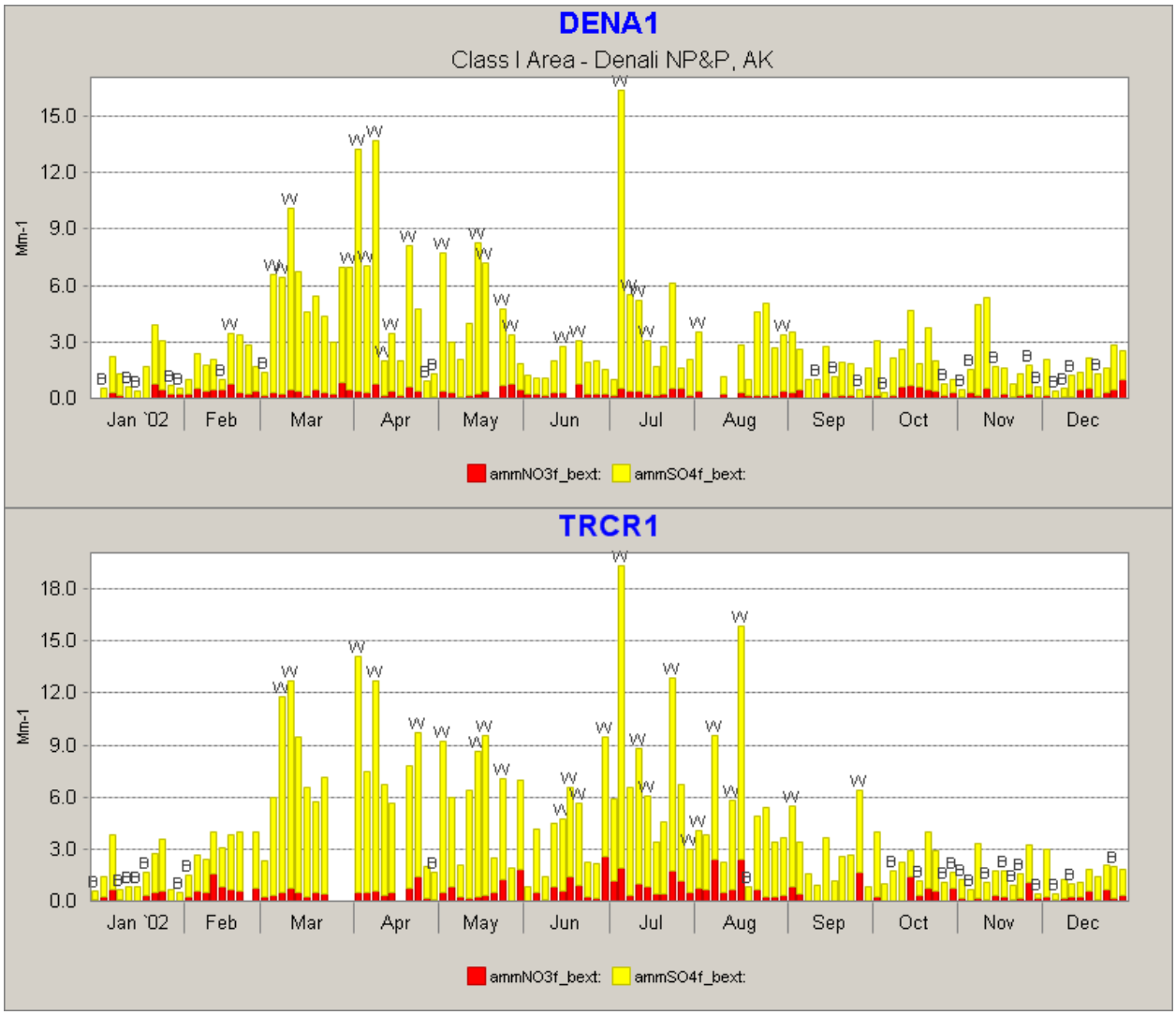


Figure III.K.4-35
2002 Visibility Impairment by Nitrate and Sulfate at Denali

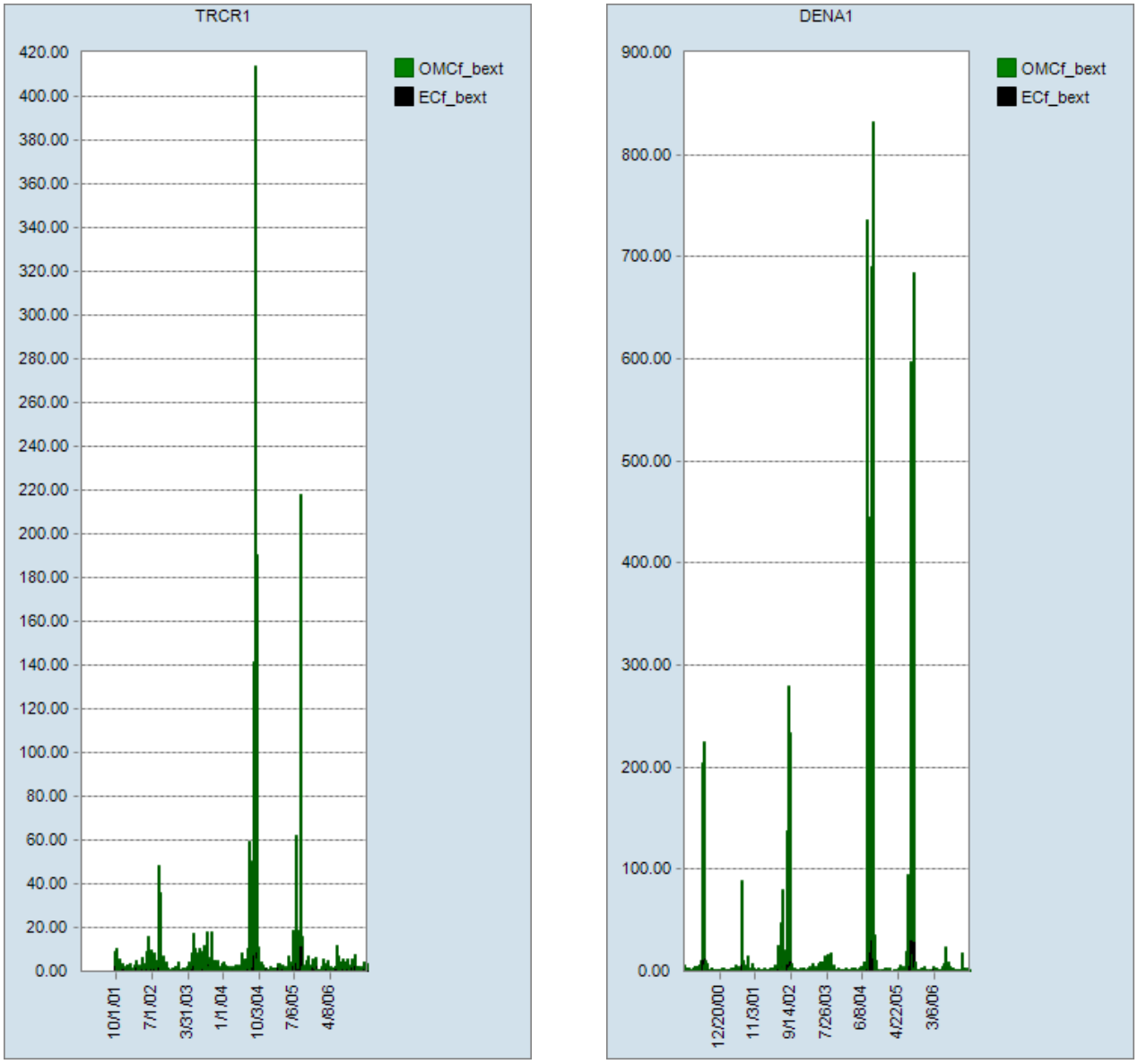


5. Wildfire Impacts Within Denali National Park

a. Species Associated with Wildfire

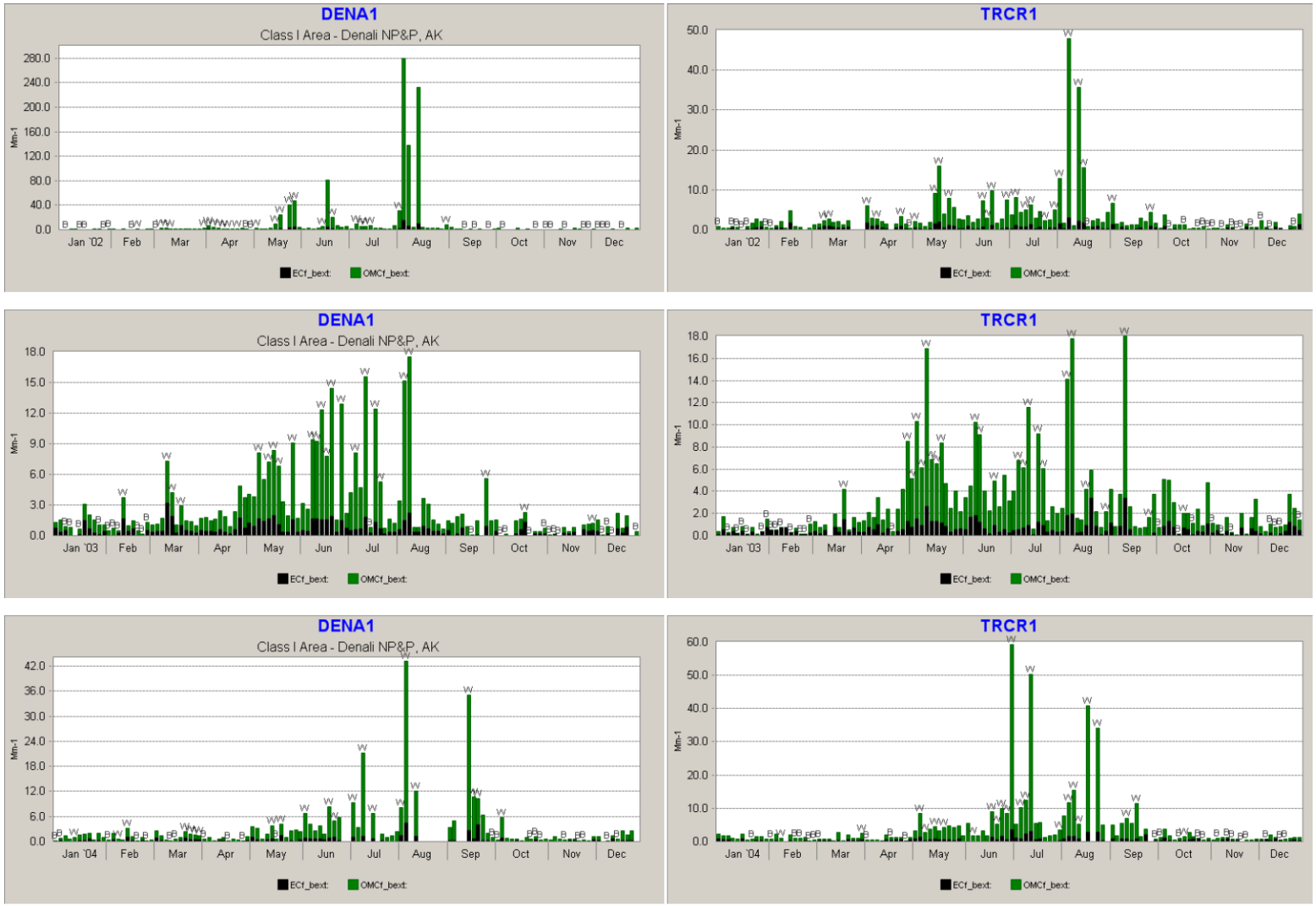
Organic matter carbon is the aerosol most clearly associated with wildfire. It is highly seasonal and highly variable year to year (Figure III.K.4-36). Elemental carbon is highly correlated with organic matter carbon (r= 0.9), but typically is a small fraction of OMC (Figure III.K.4-36). 2000-2006 seasonal patterns of OMC show the importance of both local (summer) and overseas fires (Figure III.K.4-37, March 2003, for instance).

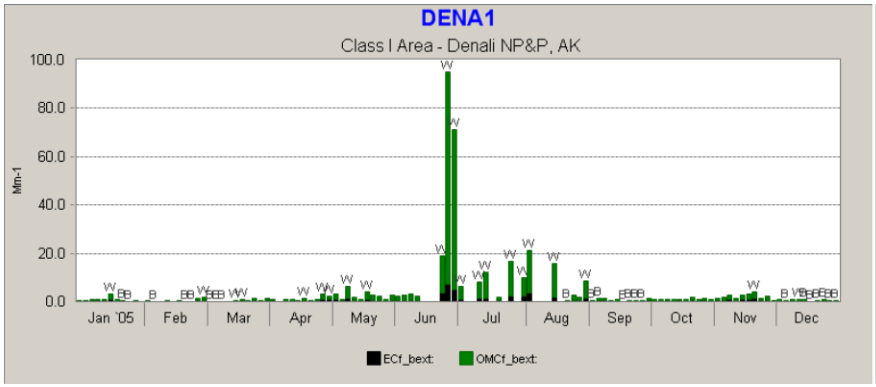
Figure III.K.4-36
2000-2006 Extinction Due to Organic Matter Carbon and Elemental Carbon Aerosols at Denali (Mm^{-1})



Close to a fire, organic matter carbon is the dominant aerosol. Specifically, worst days have higher average proportions of organic matter, and lower proportions of elemental carbon (Figure III.K.4-38). The proportional disparity between best and worst days is no greater in the years most affected by wildfire. Fires north and south of the Alaska Range influence IMPROVE sites differently. Clearly, organic matter carbon aerosols vary greatly both day to day and between the two sites representing Denali National Park (Figures III.K.4-37, III.K.4-39). Fire distribution, size, behavior, and emissions change rapidly during a typical Alaskan summer, as both daily histograms and yearly maps show.

Figure III.K.4-37
2002-2006 Yearly Histograms of Extinction Due to Organic Matter Carbon and Elemental Carbon Aerosols at Denali

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Class I Area - Denali NP&P, AK
Mm-1
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60.0
40.0
20.0
0.0
Jan '05
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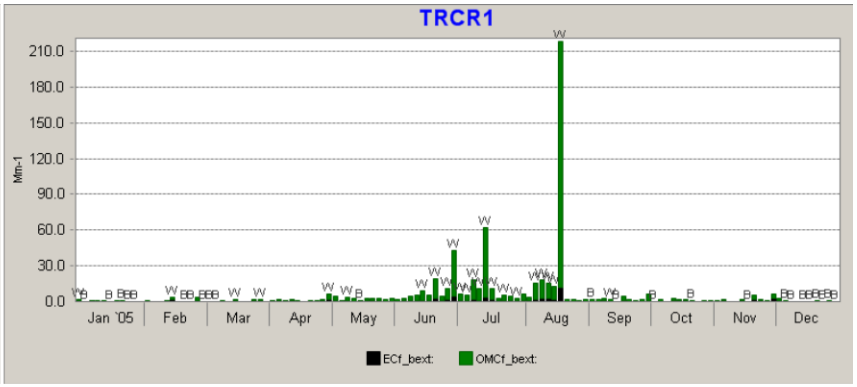
ECf_bext:
OMCf_bext:


TRCR1
Mm-1
210.0
180.0
150.0
120.0
90.0
60.0
30.0
0.0
Jan '05
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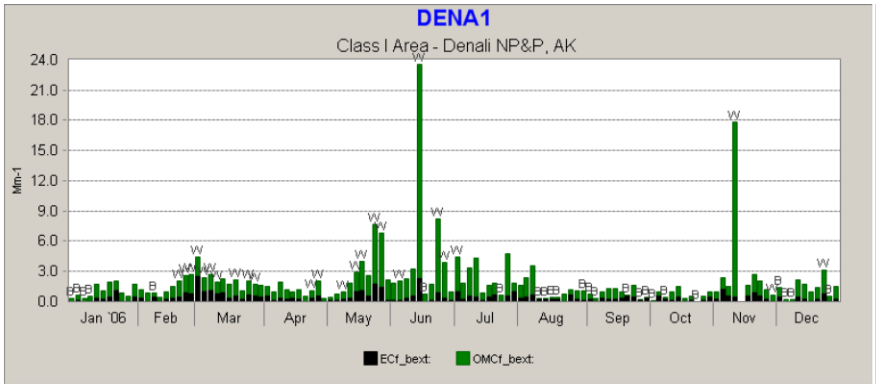
Nov
Dec
ECf_bext:
OMCf_bext:


DENA1
Class I Area - Denali NP&P, AK
Mm-1
24.0
21.0
18.0
15.0
12.0
9.0
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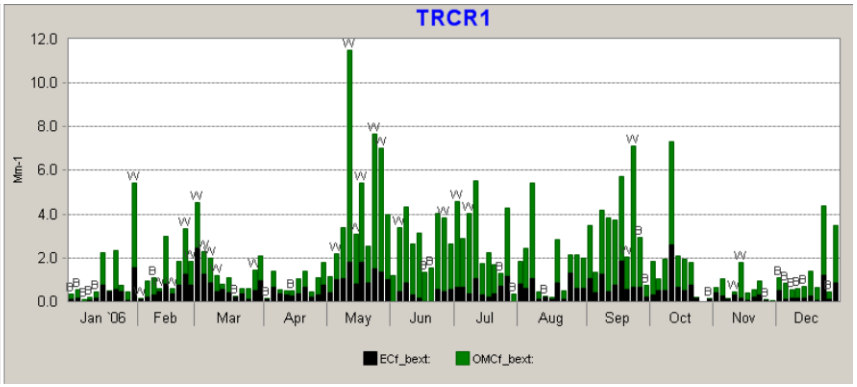
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OMCf_bext:

Figure III.K.4-38
Best and Worst Days, Relative Contributions of Organic Matter Carbon and Elemental Carbon at Denali for 2000-2006, 2002-2006, 2002, 2006

Figure III.K.4-39
Typical Yearly Maps of Wildfires Surrounding Denali for 2002, 2004

Additional, larger maps are found in Appendix III.K.4.

Figure III.K.4-40
Compilation Map of Wildfires Surrounding Denali for 1990-2009

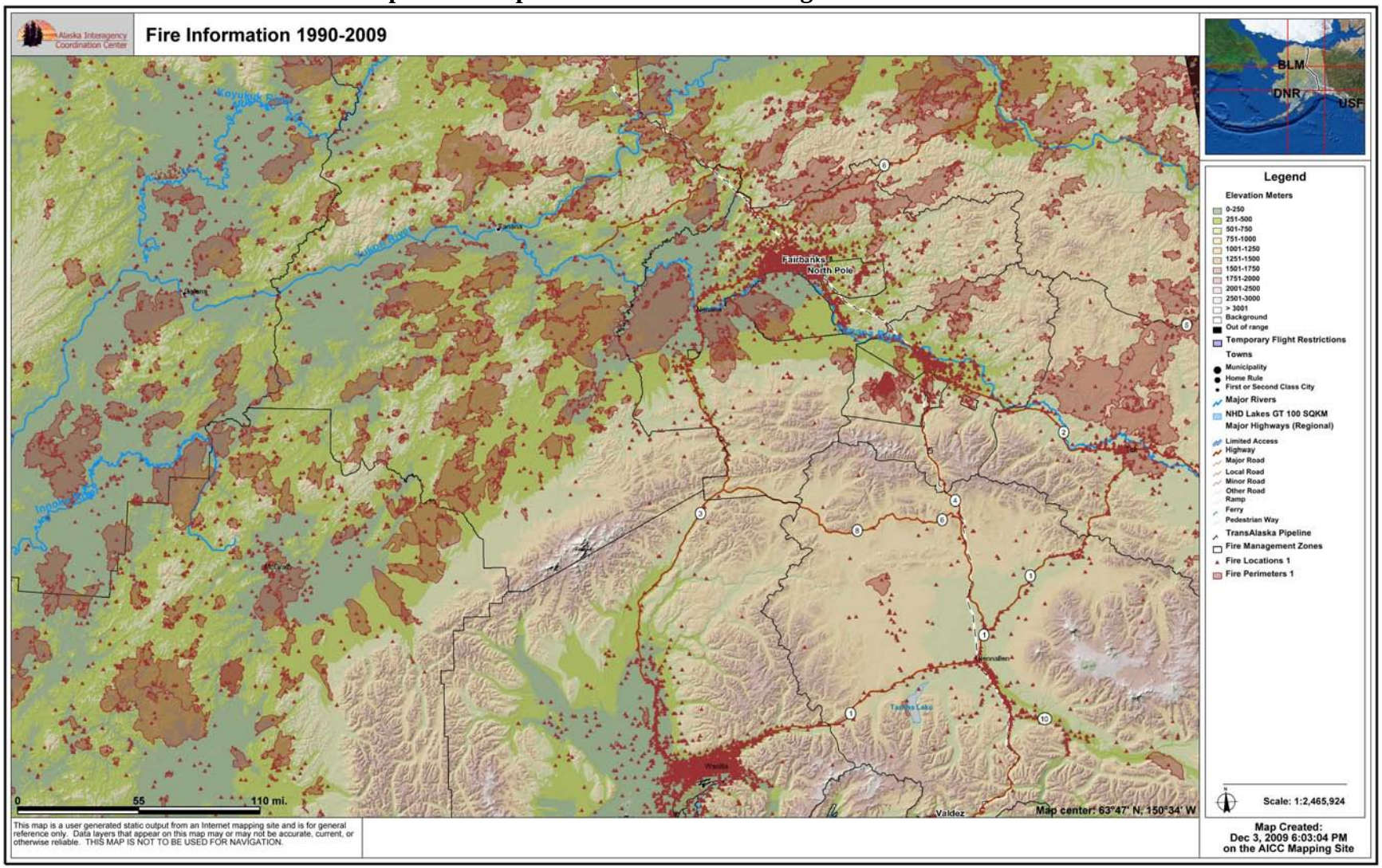
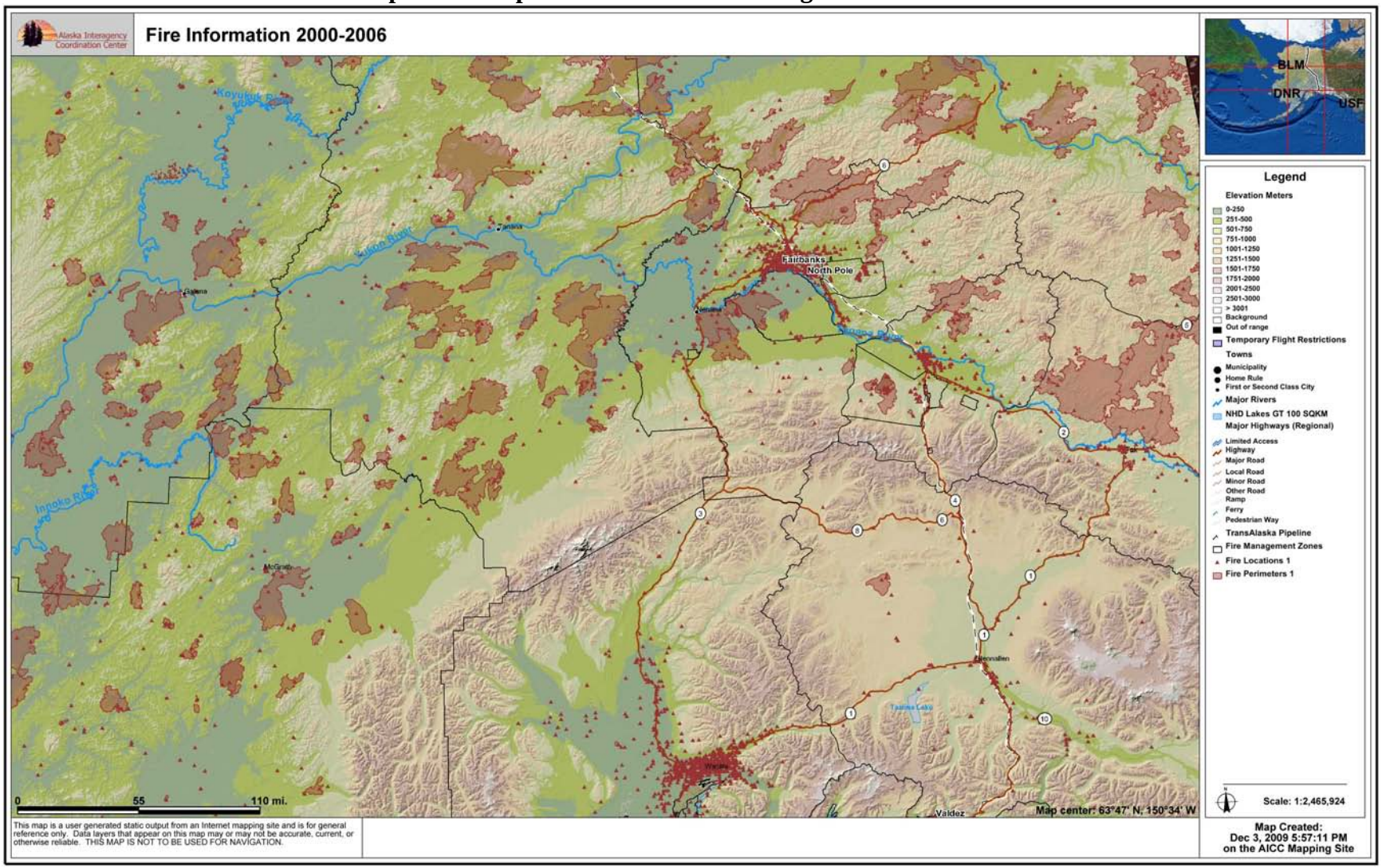


Figure III.K.4-41
Compilation Map of Wildfires Surrounding Denali for 2000-2006



b. Wildfire Variability

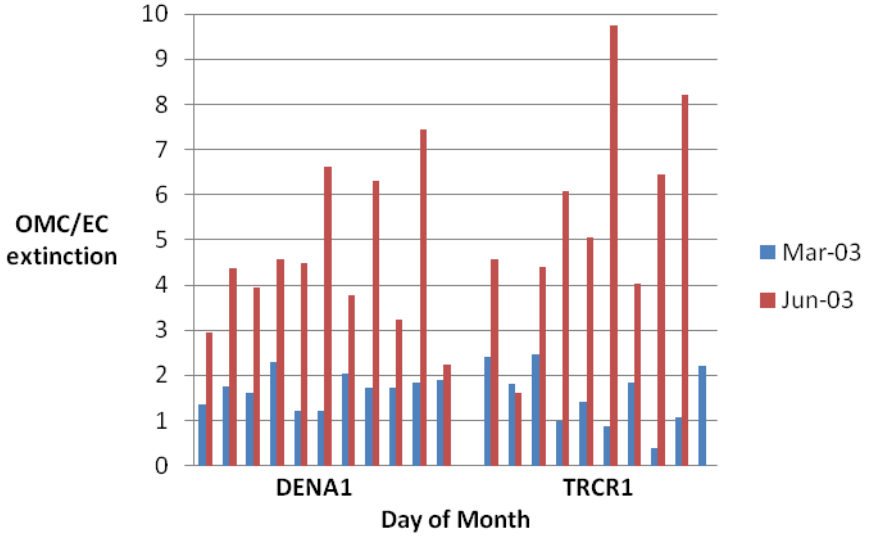
In a typical year, Denali National Park receives wildfire smoke from several directions (Figures III.K.4-38 to III.K.4-41). Any weather system may bring smoke into the Park, depending on locations of recent ignition events, land cover patterns of vegetation and hydrology, humidity, and rainfall. Sometimes, wildfires smolder and reemerge the following year. Fires may burn vegetation and soil down to mineral soil, scorch vegetation in complex spatial patterns, flare up repeatedly, and re-burn a site in subsequent years. Most of Interior Alaska burns regularly (Figures III.K.4-40, III.K.4-41 1990-2009, 2000-2006), but Alaska also receives smoke from wildfires and agricultural fires in Northern Europe and Asia. Impacts of fire on visibility vary greatly from year to year during the baseline period; fire maps for each year are in Appendix III.K.4.

c. Wildfire Seasonality

Examination of organic matter carbon and elemental carbon extinction for individual years shows that wildfires can influence visibility at any time, more frequently March to September (Figure III.K.4-37). The Alaska fire season is generally from June-August. Fire aerosols may affect either or both monitoring sites, and may shift rapidly with wind changes.

The ratio of organic matter carbon to elemental carbon (OMC/EC) varies from day to day, as fire severity and distance from a fire changes. Elemental carbon travels further, and more severe fires emit relatively more of it. In general, the ratio is lower in spring and fall when aerosols likely are travelling farther, but there is still great variability (Figure III.K.4-42). The OMC/EC ratio is also greater on worst days, which are frequently due to nearby fires.

Figure III.K.4-42
Seasonal Differences in the OMC/EC Ratios of Aerosols at Denali IMPROVE Sites



Note: March aerosols are assumed to originate outside the state, as Alaska landscapes are snow covered in March.

6. Correlations Between the TRCR1 and DENA1 Air Monitoring Sites

To understand visibility impairment at Denali Class I area, it is useful to know how different daily monitoring data are at the two IMPROVE sites. Some worst days at both sites are due to common weather systems. Other times, air movement is blocked by the expanse of the Alaska Range between the sites. Sometimes, aerosols arriving from overseas have dispersed enough to arrive at both sites simultaneously. Measurement of correlations between the sites helps to answer these questions (Table III.K.4-16).

For sulfate and coarse mass, the sites are less correlated on those days that turn out to be TRCR1 worst days. This suggests multiple sources of sulfate or coarse mass contributing to impairment at the two monitoring sites. For instance, sulfate arriving from the south may cause a worst day at TRCR1 without reaching DENA1. Other times sulfate arrives from the north, causing a worst day at DENA1. For sea salt, the correlation between the sites is greater on TRCR1 worst days, which is consistent with sea salt coming from the south. Soil aerosols at the two sites are highly correlated, with most soil arriving from overseas.

Table III.K.4-16
Aerosol Species' Pearson Correlations Between Denali Monitoring Sites for 2002-2006

	Strength of Correlations between sites	**All days μg/m^3**	**DENA1 Worst Days μg/m^3**	**TRCR1 Worst Days μg/m^3**
Nitrate	low	0.28	0.32	0.30
Sulfate	high, lower on TRCR1 worst days	0.77	0.83	0.64
Coarse mass	low, lower on TRCR1 worst days	0.34	0.24	0.16
Elemental carbon	intermediate	0.49	0.45	0.51
Organic matter carbon	intermediate	0.53	0.55	0.59
Soil	High	0.70	0.86	0.67
Sea salt	Intermediate, higher on worst days	0.53	0.79	0.68

Note: Correlations were calculated for all sampling days, the subset of days which were DENA1 worst days, and the subset of days which were TRCR1 worst days.

In 2002-2004, only 39% of worst days at the two sites are worst days at both sites (Table III.K.4-17). Sulfate, wildfire, sea salt, and coarse mass levels are sometimes quite different at the two sites. This results in dates on which only one site recorded a worst day (Table III.K.4-18). On these days, sulfate can be higher at either the northern or southern site. Sea salt may be higher at

the site further from the coast. Fires vary in time, location, and burn characteristics. These patterns suggest multiple sources and weather systems carrying each species.

Table III.K.4-17
Correspondence of Worst Days at Denali IMPROVE Monitoring Sites
(Between Denali and Trapper Creek)

	2002	2003	2004
Number of days which were worst days at both sites	15	14	10
Number of days which were worst days at either or both sites	34	32	35
Percentage of worst day correspondence between the sites	44	44	29
2002-2004 Percentage of worst day correspondence between sites	39%		

a. Worst Days at TRCR1 Alone (Table III.K.4-18)

In April and May, worst days occurred at TRCR1 alone on days when sulfate was much higher at TRCR1. This is consistent with a southerly sulfate source. From July-September, worst days occurred at TRCR1 alone on days when both sulfate and OMC were higher at TRCR1. Examination of specific fire histories may explain these, as both OMC and sulfate have been linked to wildfire. In October, much higher coarse mass at TRCR1 caused a worst day at TRCR1 alone.

b. Worst Days at DENA1 Alone (Table III.K.4-18)

In February and March, worst days occurred at DENA1 alone on days when sulfate levels were much higher at DENA1. Fire-related organic matter carbon and elemental carbon were also slightly higher on these days. In June, worst days occurred at DENA1 on days when fire-related organic matter carbon and elemental carbon were much higher at DENA1. On June 20, the totals were similar (with higher sulfate at TRCR1), but because air in general is cleaner at Denali, the day was designated a worst day. In October, a worst day at DENA1 alone was a day with much higher sulfate at DENA. One December worst day was attributable to a sea salt event.

Table III.K.4-18
Aerosol Compositions at Denali of 2003 Days for Which Only One Monitoring Site Recorded a Worst Day
(Worst Day is RHR Group 90)

a) TRCR1 Worst Days

		DENA1 Speciation Data									TRCR1 Speciation Data							
Date	**RHR Group**	**Total**	**NO_3**	**SO_4**	**CM**	**EC**	**OMC**	**Sea Salt**	**SOIL**	**RHR Group**	**Total**	**NO_3**	**SO_4**	**CM**	**EC**	**OMC**	**Sea Salt**	**SOIL**
4/30/03	70	9.76	0.24	4.82	0.77	0.8	2.88	.01	0.23	90	23.48	0.52	12.58	1.33	1.34	7.14	0	0.56
5/3/03	70	11.02	0.26	5.16	1.13	1.3	2.74	0	0.42	90	19.06	0.47	10.44	2.27	0.85	4.3	0	0.73
5/6/03	70	8.41	0.26	3.7	0.48	1	2.82	0	0.14	90	20.71	1.29	8.59	0.52	1.56	8.72	0	0.03
5/12/03	70	7.97	0.05	2.24	0.13	1.5	4.04	0	0.02	90	36.12	0.86	17.59	0.55	2.68	14.21	0	0.23
7/11/03	70	9.6	0.2	3.75	0.81	0.7	4.01	0	0.11	90	15.22	0.81	7.07	1.1	0.74	5.42	0	0.08
8/19/03	70	11.23	0.46	6.51	0.59	1	2.69	0	0.02	90	13.91	0.52	7.65	1.55	0.95	3.22	.01	0.01
8/31/03	30	2.51	0.07	0.86	0.88	0.2	0.45	0	0.03	90	18.55	1.6	12.77	2.03	0.44	1.7	0	0.02
9/12/03	50	4.21	0	1.74	0.34	0.8	1.25	0	0.04	90	27.65	1.82	6.09	1.66	3.41	14.59	0	0.08
10/18/03	70	10.04	0.25	7.21	0.89	0.7	0.94	0	0.08	90	13.62	0.22	4.8	6.15	0.74	1.24	0	0.47

b) DENA1 Worst Days

		DENA1 Speciation Data									TRCR1Speciation Data							
Date	**RHR Group**	**Total**	**NO_3**	**SO_4**	**CM**	**EC**	**OMC**	**Sea Salt**	**SOIL**	**RHR Group**	**Total**	**NO_3**	**SO_4**	**CM**	**EC**	**OMC**	**Sea Salt**	**SOIL**
2/14/03	90	13.07	0.56	8.39	0.19	1.7	2.02	0	0.24	30	4.27	0.32	3.03	0.15	0.74	0	0	0.04
3/16/03	90	14.19	1.54	7.31	0.89	1.9	2.3	0	0.24	70	8.67	1.08	4.78	0.71	0.8	1.13	0	0.18
6/17/03	90	16.32	0.21	2.61	1.01	1.6	10.74	0	0.12	50	7.7	0.2	2.63	0.78	0.66	3.34	0	0.08
6/20/03	90	11.36	0.2	2.49	0.73	1.6	6.15	0	0.15	70	11.51	1.41	6.86	0.95	0.21	2.01	0	0.09
6/29/03	90	16.9	0.1	3.36	0.46	1.5	11.37	0	0.08	70	11.1	0.66	3.81	1.11	0.59	4.83	0	0.09
10/21/03	90	11.59	0.23	7.25	1.6	1.4	0.94	0	0.22	30	4.7	0.15	2.09	0.36	0.58	1.47	0	0.04
12/2/03	90	22.52	0.85	6.66	0.63	0.6	0.65	13	0.15	70	11.04	1.02	3.96	0.27	0.45	2.83	2.37	0.15

7. Light Extinction of Individual Species, Best/Worst Days, Seasonal Patterns

a. Sea Salt

Sea salt aerosols are quite episodic at Denali Class I area (Figures III.K.4-43 and III.K.4-44), and are more frequent in Quarters 4 & 1. Fewer sea salt incursions reach Denali than reach Trapper Creek, which is not unexpected considering the mountain ridges between them. The figures suggest that the sea salt events at DENA1 only occasionally correspond to events at Trapper Creek (TRCR1).

Figure III.K.4-43
2002-2006 Contribution of Sea Salt to Light Extinction at Denali

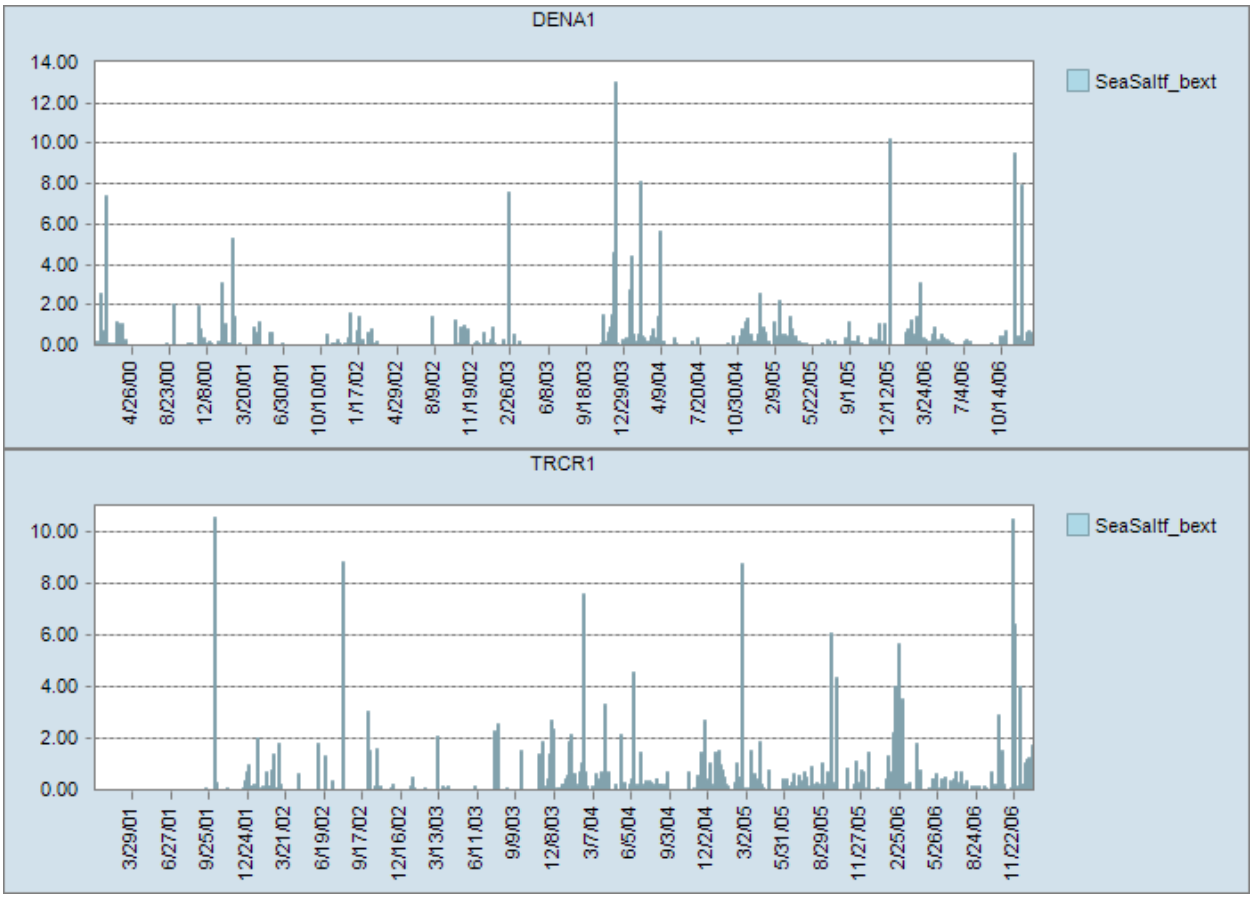
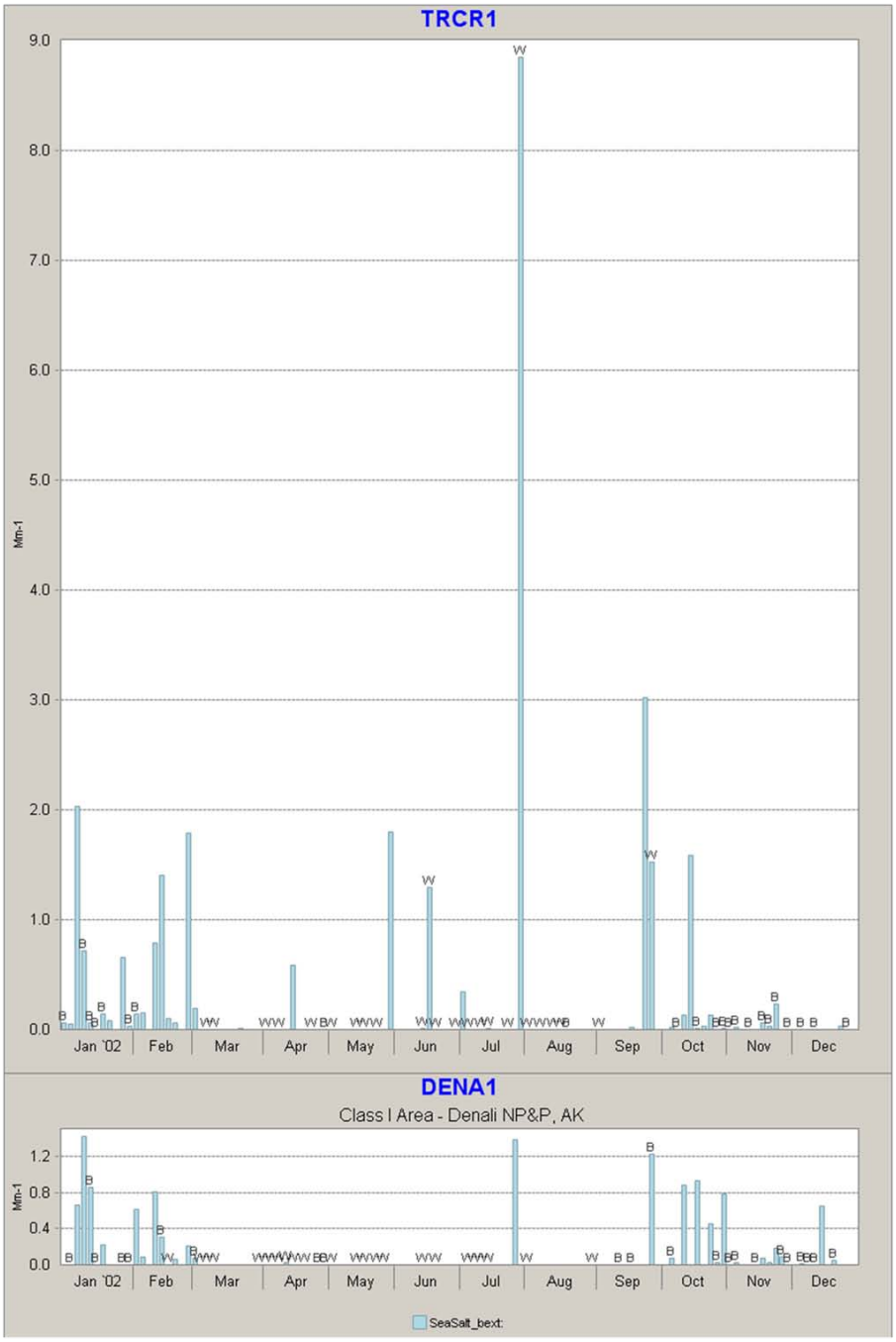


Figure III.K.4-44
2004 Contribution of Sea Salt to Light Extinction on Best and Worst Days at Denali



Note: Best days (B) and worst days (W) are identified on the histograms. When extinction is low, B, W, and E (for missing data) labels overlap at the base of the histogram.

b. Sulfate

Most worst days at Denali Class I area have sulfate extinctions greater than 3 Mm^{-1} (Figures III.K.4-45, III.K.4-46). Sulfate aerosols vary seasonally, typically being lower in Quarters 4 and 1, and higher in Quarter 2. Sulfate levels do vary between years (Table III.K.4-19). Spring peaks are associated with aging of air masses in higher light and humidity levels. Summer peaks at TRCR1 are frequently not mirrored at DENA1.

Figure III.K.4-45
2000-2006 Contributions of Sulfate at Denali

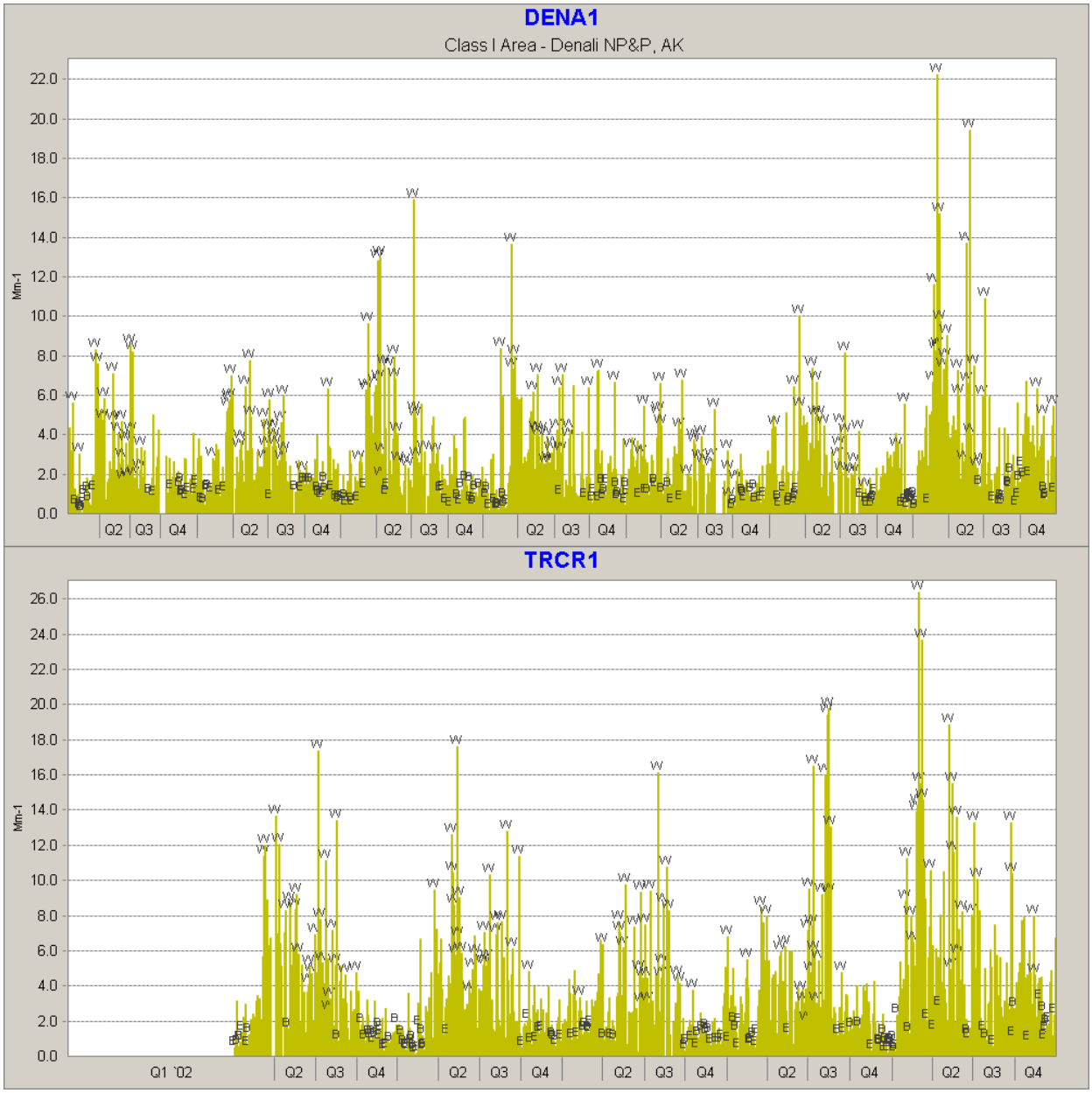


Figure III.K.4-46
2002 and 2005 Contributions of Sulfate at Denali

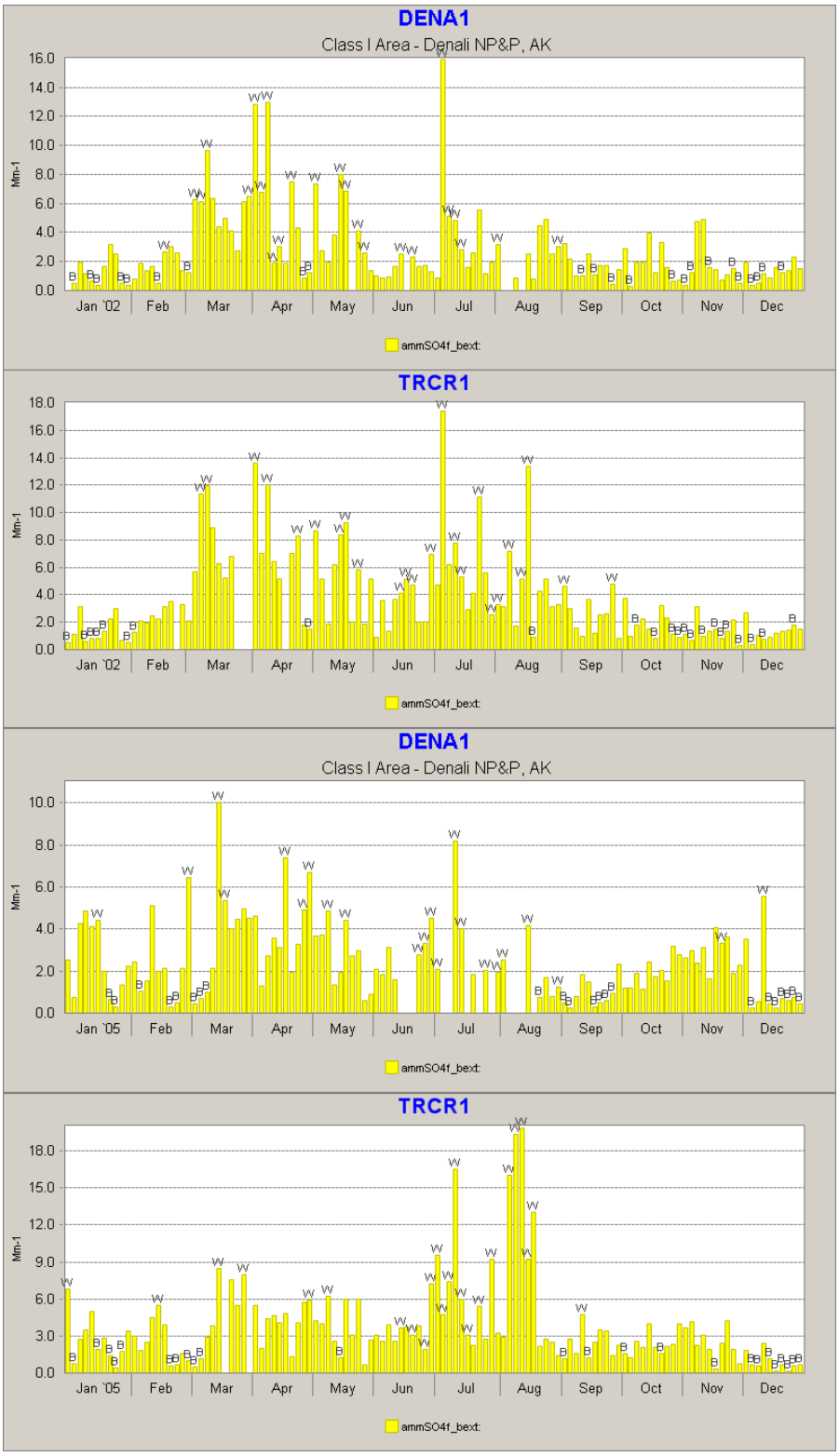


Table III.K.4-19
Annual Variability in Sulfate Aerosols at Denali, Peak Months and Light Extinction

Year	Peak Months	Typical Sulfate Extinction on Worst Days (peaks)
2000	3-7	1-9
2001	3-8	2-8
2002	3-7	2-14 (16)
2003	2-8	2-9 (14)
2004	1-9	2-7
2005	1, 3-8	2-10
2006	2-6	3-15 (22)

Note: Numbers within () denote peaks which exceed the typical values presented.

c. Soil

Extinction due to soil aerosols is quite episodic. It varies seasonally, but is usually lower than 0.4 Mm^{-1} (Figures III.K.4-47, III.K.4-48). The summary table (Table III.K.4-20) shows that soil contributes to worst days at extinctions over 0.2 units any time between February and August, with highest contributions in March to May from Asian dust storms. Some soil events affect both sites; others do not.

Figure III.K.4-47
2000-2006 contributions of Soil at Denali

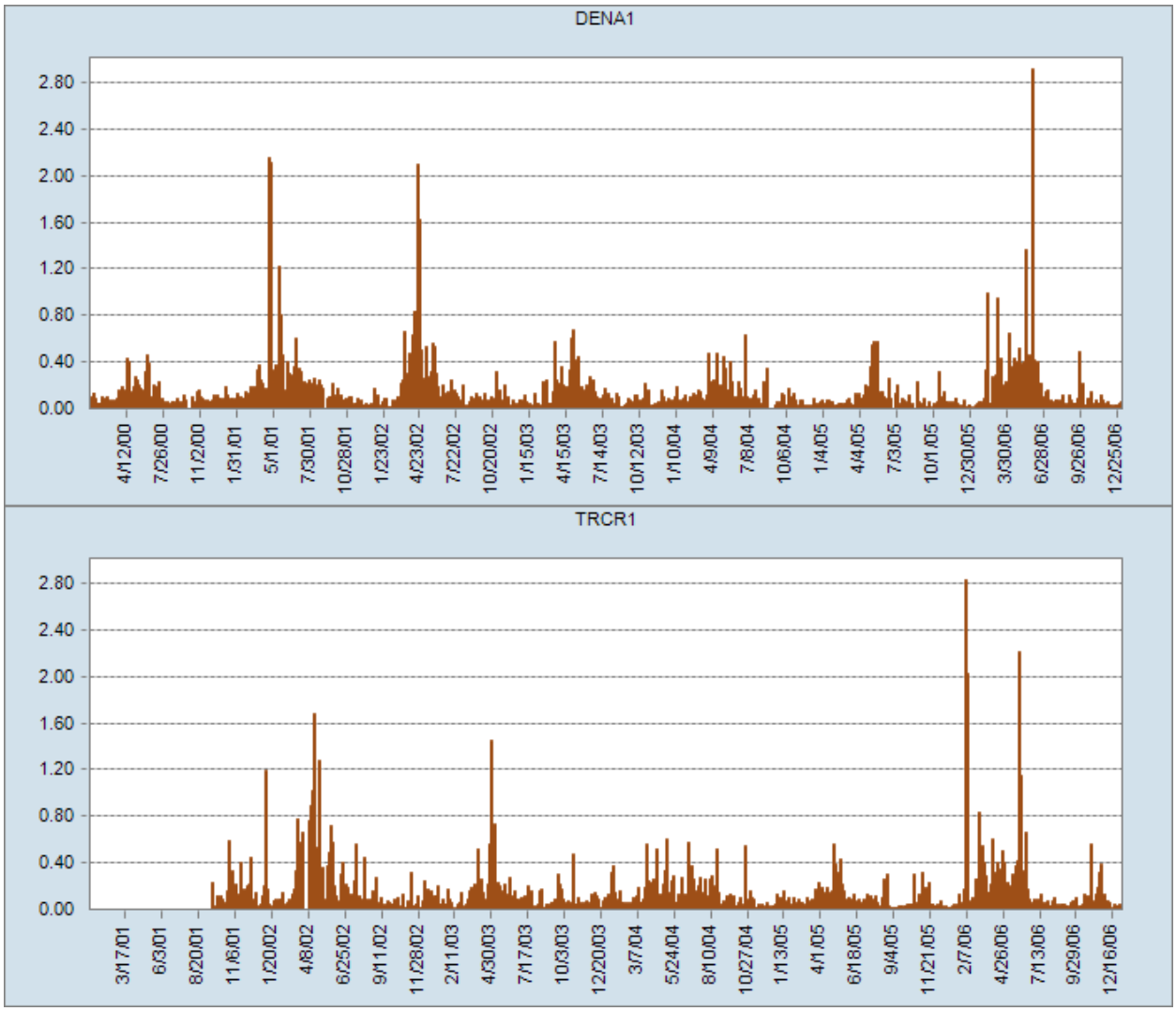
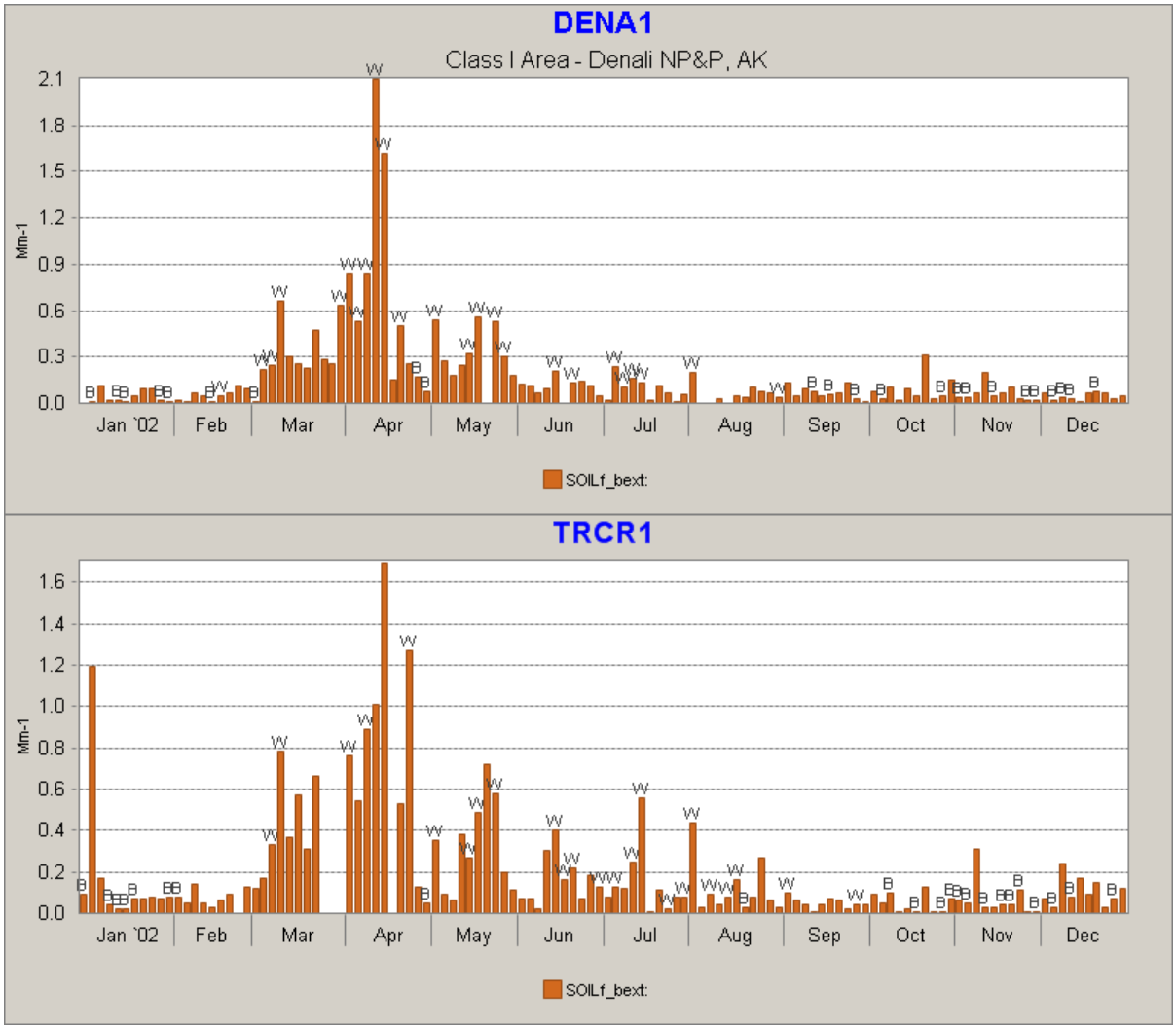


Table III.K.4-20
Annual Variability in Soil Aerosols at Denali, Peak Months and Light Extinction

Year	Months in Which Soil Peaks Contribute to Worst Days	Approximate Size of Peaks on Worst Days Mm^{-1}
2000	3-7	>0.2
2001	3-8	>0.2
2002	3-8	>0.2
2003	2-6, 10	>0.2
2004	3-8	>0.2
2005	4-6, 8	>0.2
2006	2-6	>0.2

Figure III.K.4-48
2002 Contributions of Soil at Denali



d. Nitrate

Nitrate aerosols are not obviously seasonal at Denali (Figures III.K.4-49, III.K.4-50). Relatively large nitrate peaks frequently occur on days which are not worst days. There is no specific range of nitrate values typically present on worst days. Typical nitrate values are below 1 Mm^{-1}, but spikes to between 2 and 4 Mm^{-1} do occur in most years. In summer and fall, TRCR1 nitrates exceed those at DENA1.

Figure III.K.4-49
2000-2006 Contributions of Nitrate at Denali

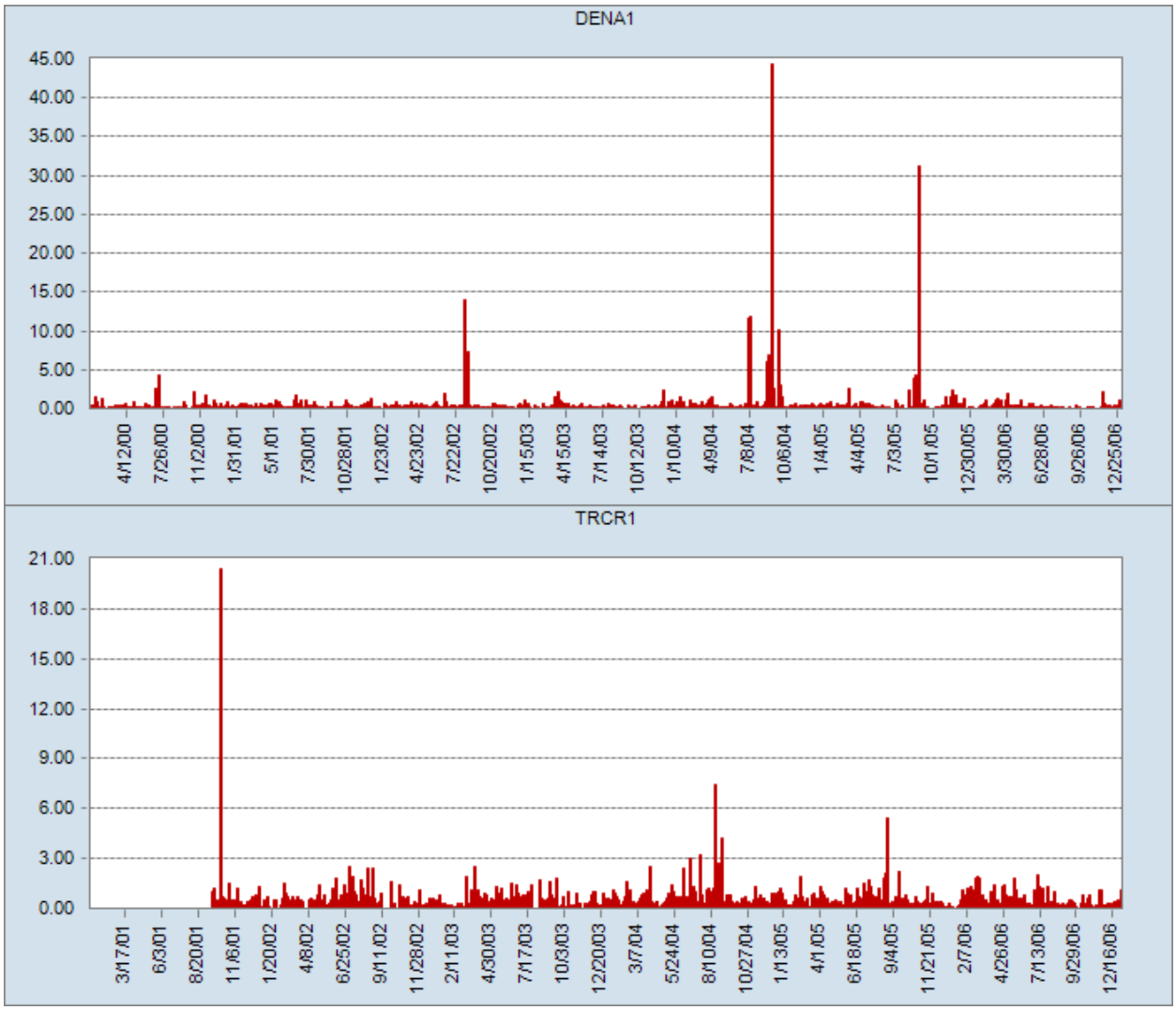
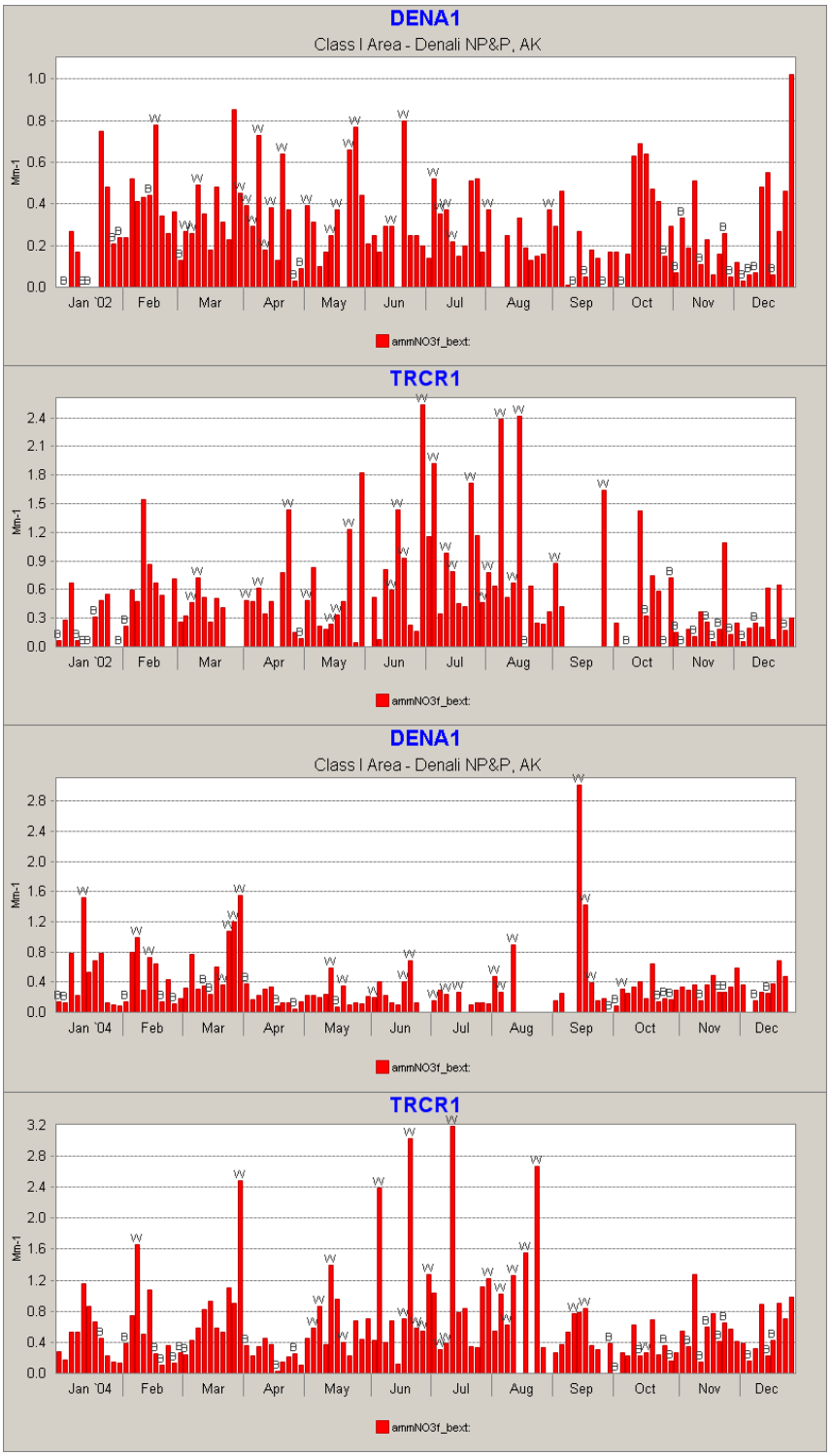


Figure III.K.4-50
2002 and 2004 Contributions of Nitrate at Denali



e. Coarse Mass

Coarse mass aerosols are seasonal, peaking in spring to summer months, usually between March and August (Figures III.K.4-51, III.K.4-52). Peaks also occur in February and October. Coarse mass peaks or events are not consistently worst days, although extinctions of 1-6 Mm^{-1} frequently occur on worst days. Since many worst days have low coarse mass extinction, it is concluded that coarse mass rarely drives the designation of worst days at Denali.

Figure III.K.4-51
2000-2006 Contributions of Coarse Mass at Denali

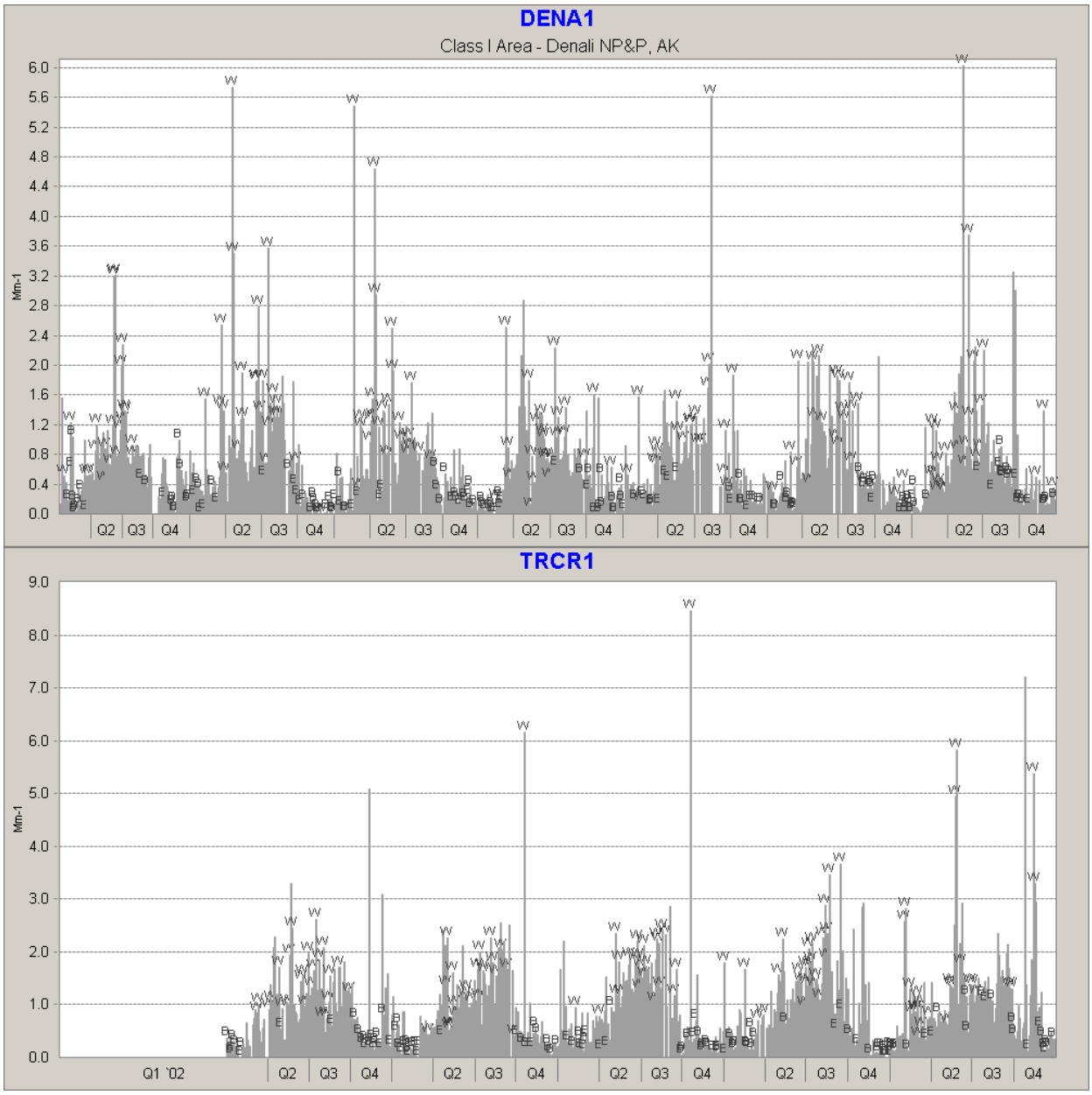
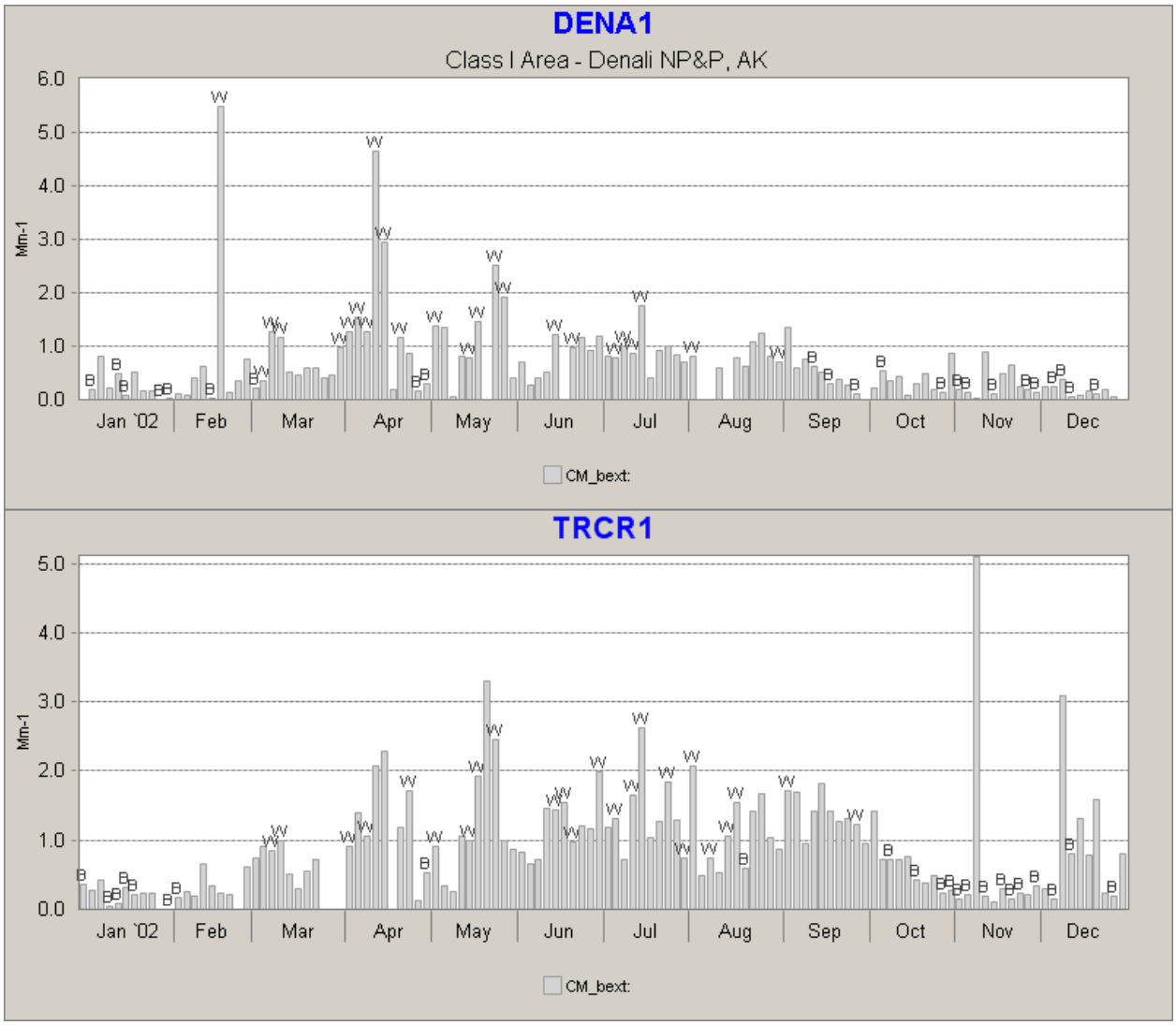


Figure III.K.4-52
2002 Contributions of Coarse Mass at Denali



f. Elemental Carbon

Elemental carbon is closely associated with fire in Alaska (Figure III.K.4-53, III.K.4-54). Typical extinctions fall below 1 Mm^{-1}. Almost every time elemental carbon extinction rises above 2 Mm^{-1} is a worst day. Peaks in elemental carbon from 2 to 14 Mm^{-1} do occur from March to August, so wildfires outside Alaska contribute.

Figure III.K.4-53
2000-2006 Contributions of Elemental Carbon at Denali

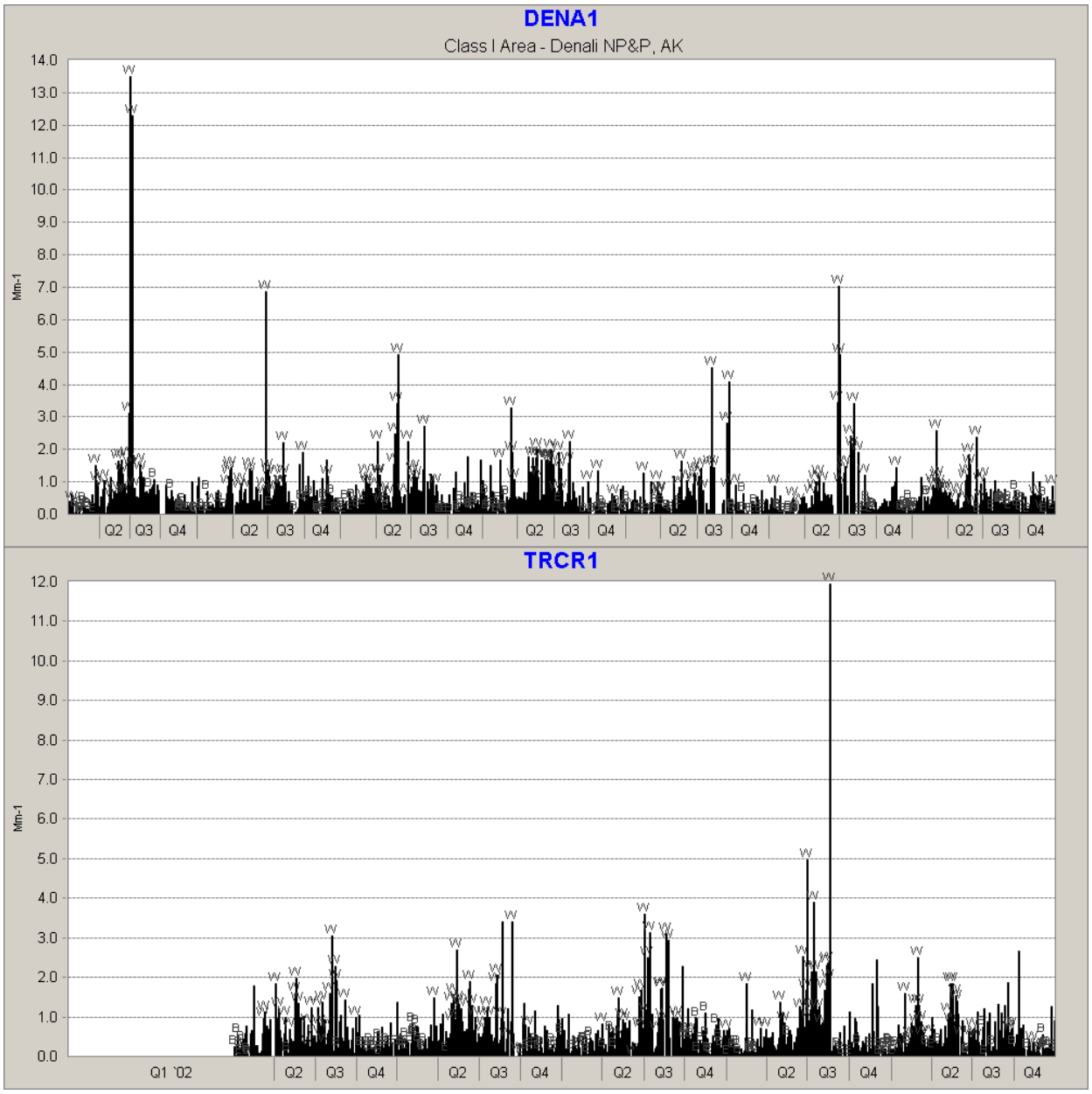
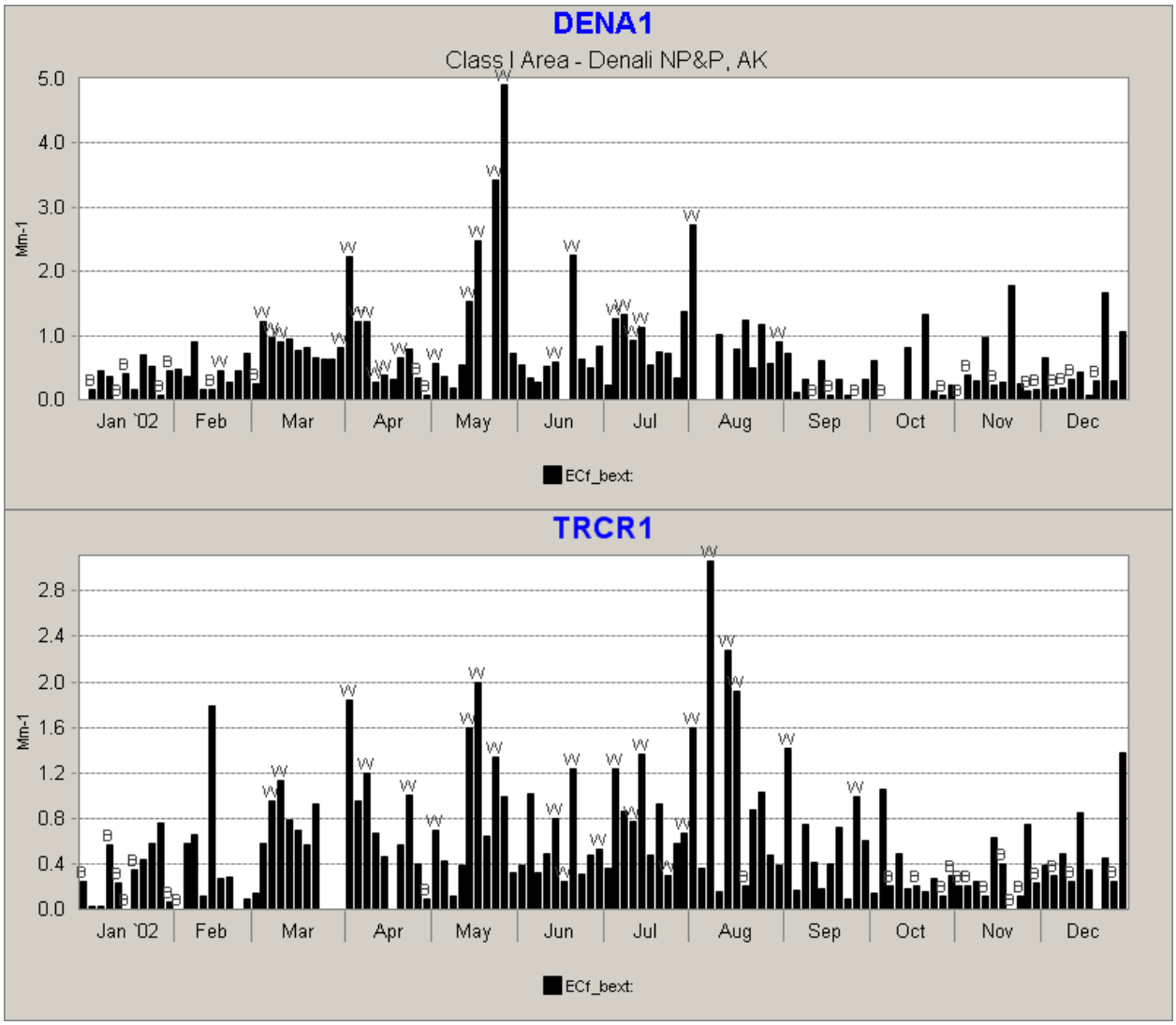


Figure III.K.4-54
2002 Contributions of Elemental Carbon at Denali



g. Organic Matter Carbon

Organic matter is the most seasonal aerosol affecting Denali, and is closely associated with wildfires. Distributions show spikes any time between May and September (Figure III.K.4-36). Years differ in terms of number and size of fires, fire severity, and fire distance from monitoring sites. These differences are reflected in the monitoring record. The highest organic matter carbon peaks occur in summer, but even in shoulder seasons such as March and April, organic matter is a large component of worst days (Figures III.K.4-55, III.K.4-56). Organic matter is the dominant cause of worst days at Denali, but it is not the only one.

Figure III.K.4-55
2002-2004 Contributions of Organic Matter Carbon at Denali (TRCR1 Site)

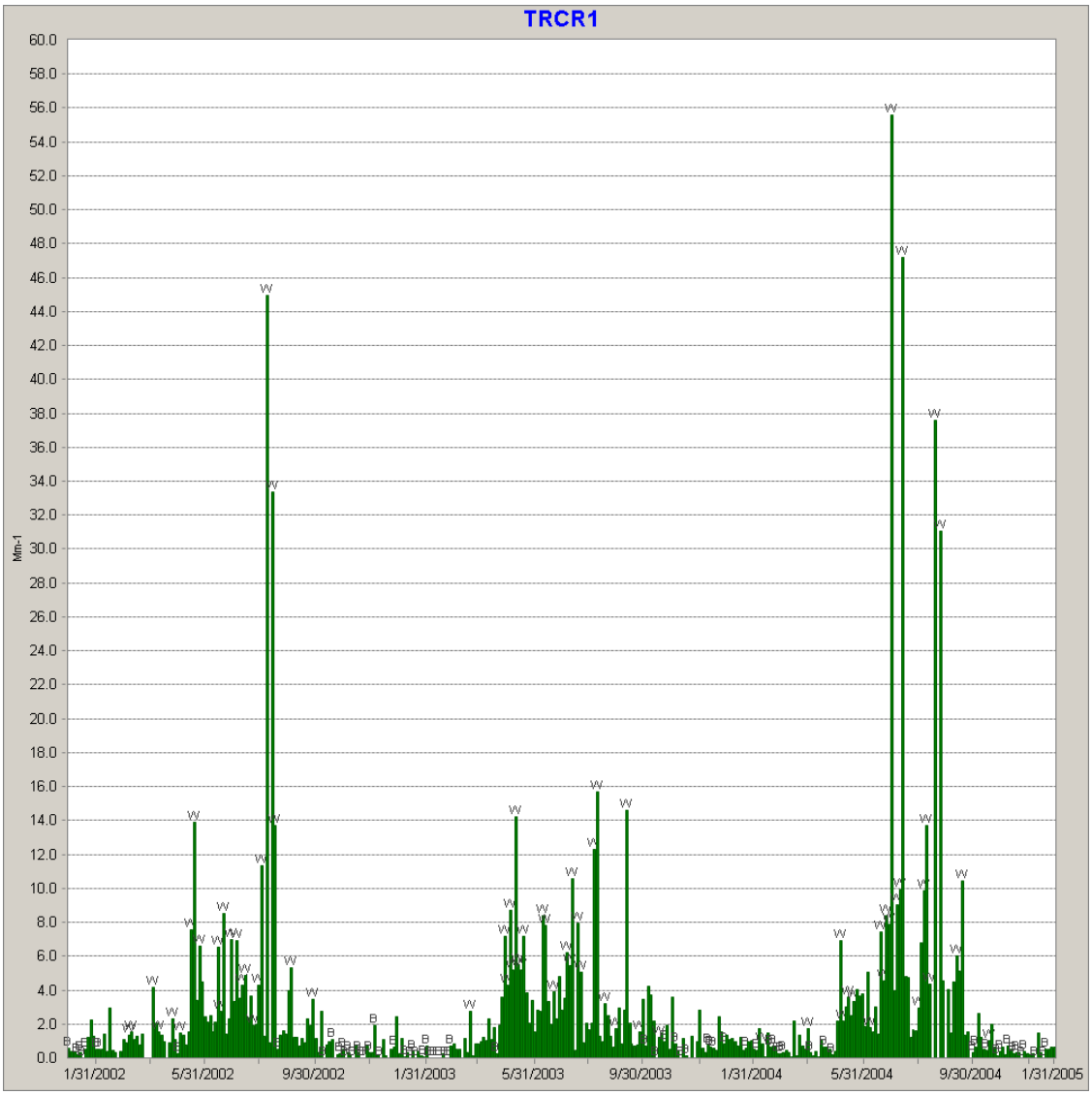
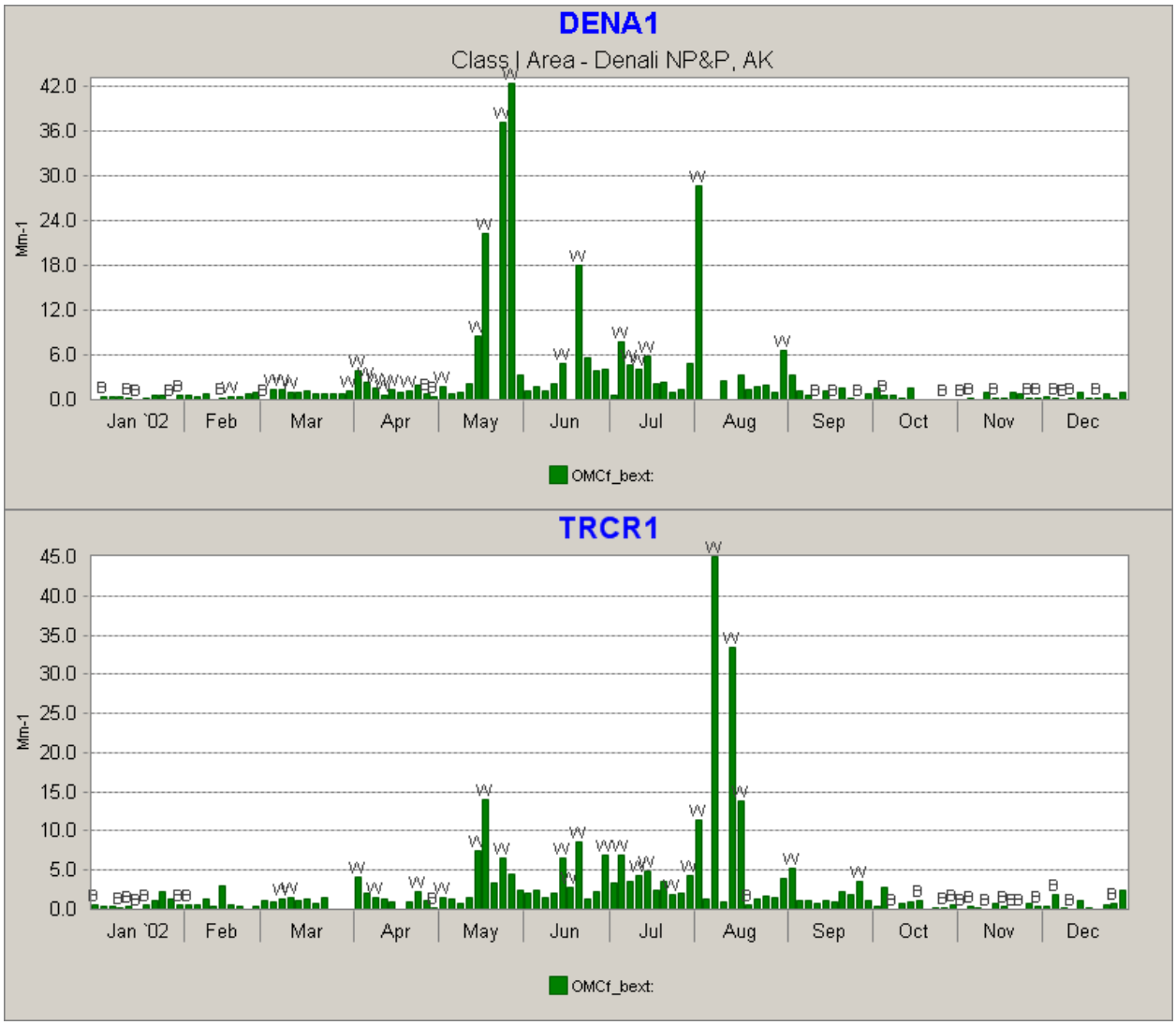


Figure III.K.4-56
2002 Contributions of Organic Matter Carbon at Denali

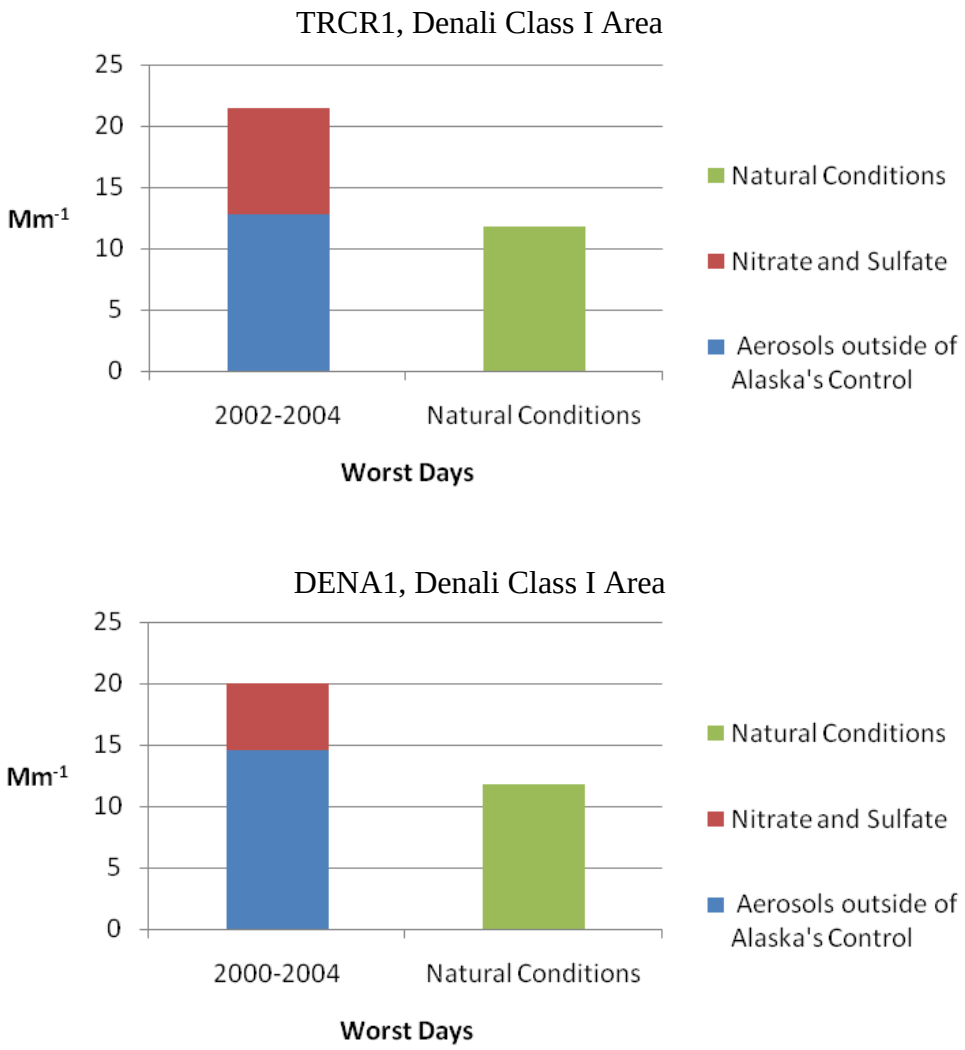


8. Evaluation of the Effects of Uncontrollable Processes on Species of Pollutants at Denali

Organic matter carbon and elemental carbon in Alaska are closely associated with wildfire, so are largely out of human control. Some anthropogenic fires in Asia and Northern Europe affect Alaska's air, but again, they are not controllable in Alaska. Sea salt is primarily oceanic in origin, and not controllable. Soil aerosols do not affect Alaska air severely, and most of the few large soil events can be traced to Asian winter dust storms. Soil and coarse matter are slightly correlated, which may indicate a common origin at times. Local processes such as winds sweeping along glacial rivers may entrain soil and silt, leading to a correlation between the aerosols.

Subtraction of the light extinction caused by organic matter carbon, elemental carbon, sea salt, coarse matter, and soil leaves a much simplified picture of aerosol extinction on best and worst days. The combined extinctions of those aerosols originating in not clearly controllable natural processes and those aerosols originating overseas are compared to light extinctions under natural conditions in Figure III.K.4-57.

Figure III.K.4-57
Contrasting Light Extinction of Alaskan Anthropogenic Aerosols at Denali with Extinction Due to Non-Anthropogenic and Overseas Aerosol Sources with Natural Conditions



D. Tuxedni (TUXE)

1. Baseline Conditions

The regional haze rule requires that baseline visibility conditions be characterized for each Class I area. The goal of the Rule is to improve visibility on worst days from baseline to natural conditions while maintaining baseline visibility on best days. The baseline and natural conditions visibilities together determine an approximate glideslope for visibility improvements and emission reductions toward 2064 goals. Strict adherence to such a glideslope is not necessary, as emission reductions and controls have varied timetables and consequences; however, the glideslope gives a general trend against which reasonable progress may be evaluated.

a. Available Baseline Data

IMPROVE monitoring at the Tuxedni Class I area began late in 2001. The years 2002-2004 were used as baseline. Monitoring results for those years are described in detail in this section. To better understand seasonal and annual influences on Alaska's Class I areas, close examination is also made of annual patterns through 2005.

b. Annual Summary for the Baseline Period 2002-2004

The overall average total light extinction coefficient (Bext) at TUXE1 was 12.9 Mm^{-1}.

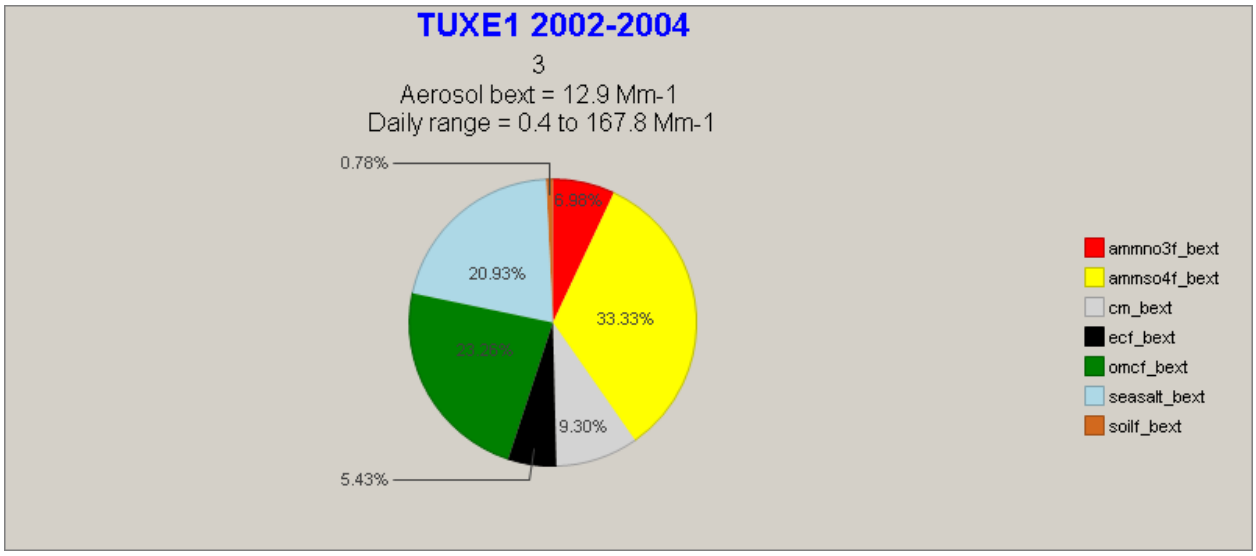
The Visual Range was approximately 157 km, which corresponds to a deciview of approximately 8.3.

As comparisons, the Alaska Class I area sites Denali National Park and Simeonof Wilderness Area had average B_{ext} of 8.8 and 26.6 Mm^{-1}. From outside Alaska, Point Reyes NS, a coastal site away from major population centers had an average B_{ext} of 46 Mm^{-1}.

The largest component of baseline light extinction at Tuxedni is sulfate, with sea salt and organic matter carbon contributing to a lesser extent. The average contributions of the major aerosol components to Tuxedni haze were sulfate 33.3%, sea salt 20.9%, organic matter carbon 23.2%, nitrate 7.0%, elemental carbon 5.4%, soil 0.8% and coarse mass 9.3% (Figure III.K.4-58).

Figure III.K.4-58
Proportional Representation of IMPROVE Aerosols at Tuxedni, 2002-2004 Average

Constituent aerosols are ammonium nitrate (red), ammonium sulfate (yellow), coarse mass (gray), elemental carbon (black), organic matter carbon (green), sea salt (blue), soil (orange). Total aerosol extinction (aerosol_bext) is 12.9 Mm^{-1}. Average daily range is also indicated.



2. Origins of Aerosol Species Influencing Regional Haze at Tuxedni Class I Area

Sea Salt at Alaska's coastal Class I areas is primarily of oceanic origin. Sea salt aerosols dramatically affect visibility at both of the coast Class I area sites, Simeonof and Tuxedni. However, sea salt reaches as far as the Denali Class I area in Alaska's Interior. Episodic spikes in sea salt aerosols at Tuxedni suggest that sea salt is caused by specific meteorological conditions. Desert saltpans and floodplain salt-encrusted soils contribute to sea salt aerosols elsewhere, and potentially do in Alaska as well. However, along Alaska's coastline even sea salt aerosols entrained on land can reasonably be attributed to oceanic salts.

Organic Matter Carbon (OMC) aerosols originate in both anthropogenic and natural events. In Alaska, the major sources of organic matter carbon are wildland fires (forest, wetland, and tundra) and biogenic aerosols produced by natural vegetation. Wildfires in Alaska occur mostly during the May-August fire season, although controlled burns take place more often in April and May, and September and October when fires are more easily controlled. Alaska's Interior, between the Alaska Range and the Brooks Range, is most prone to wildfire, as can be seen in fire history maps. Different regions of the state have slightly differing fire seasons. Wildland and agricultural fires in Siberia and Northern Europe also contribute organic matter carbon to Alaska's air. Other anthropogenic sources of organic matter carbon include cooking, road dust, mobile sources, industry, biomass burning, and burning of fossil fuels, particularly coal. Anthropogenic, secondary organic matter carbon forms from VOCs released into the atmosphere.

Elemental Carbon (EC) is typically the product of incomplete combustion of fossil fuels, vegetation and soils (wildfires and agricultural fires). Levels of elemental carbon are highly correlated with organic matter carbon in Alaska. In spite of that, the relative proportions of the two vary widely. Elemental carbon particles are typically smaller than organic matter carbon particles, and are expected to travel further. This is significant for aerosols reaching the state from Asia and Europe. Inside Alaska, severe wildfires burn vegetation and soils more completely, creating relatively more elemental carbon than from cooler burning fires. The severity of a fire changes as rapidly as wind and weather, changing relative emissions of elemental carbon and organic matter carbon. A change in wind direction can instantly redirect fire emissions from a nearby monitoring site to one further away, thus changing the relative emissions of elemental carbon and organic matter carbon.

Ammonium Sulfate (SO_4) aerosols in Alaska originate from both anthropogenic and natural events. Volcanoes produce sulfur compounds as ash and volcanic gases. In winter, arctic haze from Northern Europe and Russia contributes sulfur compounds including sulfur dioxide to Alaskan air. These compounds are converted to sulfates in the increasing light levels of spring. Arctic Haze also contains particulate sulfur originating from coal burning and metal smelting in Asia and northern Europe. Within Alaska, sulfate aerosols are produced by coal and diesel powered generators, home heating, and mobile sources. It is possible, but not yet known, that biogenic sulfate from ocean plankton contributes to sulfate at the coastal Class I area sites.

Ammonium Nitrate (NO_3) is created from several species of NOx. In Alaska, NOx is typically generated by anthropogenic activities, primarily high temperature combustion of fossil fuels. Sources include power generation, home heating, mobile sources, and arctic haze. The chemistry of ammonium nitrate formation is dependent on sunlight and atmospheric moisture, so atmospheric precursors may build up through the winter and produce ammonium nitrate in spring.

Soil aerosols in Alaska originate in coastal erosion and in Asian dust storms. The origin of soil aerosols can be determined because they usually arrive in discrete meteorological events, and often when Alaskan soils are snow covered. Spring aerosols can be traced chemically and morphologically to their sources in Mongolia and northern China. Other long distance aerosols have been traced to agricultural burning in Russia and cooking fires in Asia. Locally, erosion of unvegetated surfaces along major rivers and glaciers may contribute to soil aerosols. None of these sources are controllable for purposes of Regional Haze, and soil aerosols contribute very little to worst days.

Coarse Mass (CM) aerosols arise from many different sources and processes. At other Class I areas, important contributors to this category include crustal minerals, organic mass, and inorganic salts such as calcium nitrate and sodium nitrate. Within Alaska, typical sources of coarse mass include erosion of coasts and river floodplains, traffic on unpaved roads, and windborne glacial deposits.

3. Best Days and Worst Days, Baseline Years

The 2002-2004 TUXE1 baseline visual range for best and worst days was 262 km (2.9 Mm^{-1}) and 90 km (31.5 Mm^{-1}). The average aerosol light extinction coefficient (Bext – Rayleigh Scattering) during the 20% worst days is 31.5 Mm^{-1}, which is about 10.9 times of the value during the 20% best days. The relative proportions of all components differ between best and worst days in a 2002-2004 summary, but summaries over different timespans show considerable variability. However, in each summary, sulfate, sea salt, and organic matter carbon are the major contributors to worst days. Further analysis will address whether they appear in combination, or in different worst day scenarios.

a. Average and Relative Contributions of Aerosol Species to Visibility on the Best and Worst Days

At Tuxedni, the average worst days are characterized by greater extinction due to every species measured (Table III.K.4-21), although the relative contributions of sulfate, nitrate, and coarse mass fall slightly on worst days (Figure III.K.4-59). On worst days, the relative contributions of organic matter carbon and sea salt rise. Total light extinction varies dramatically between the best and worst days, with average non-Rayleigh extinctions at TUXE1 from 2.9 to 31.5 Mm^{-1}. By far the greatest relative changes were for organic matter, which was 22 times higher that on best days, and sea salt, which was 16 times higher on worst days. Extinction due to organic matter carbon varied from 0.4-8.9Mm^{-1}. Extinction due to sea salt varied from 0.5-8.2Mm^{-1}.

Table III.K.4-21
Average Light Extinctions on Best and Worst Days, for 2002-2004 Baseline Years at Tuxedni, in Mm^{-1}

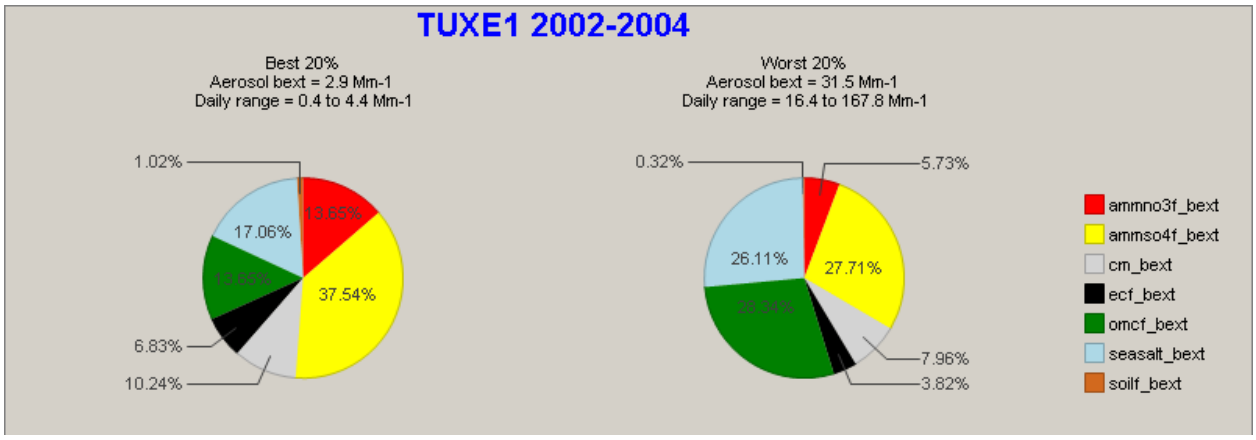
Parameter	Best 20%: Average	Best 20%: Minimum	Best 20%: Maximum	Worst 20%: Average	Worst 20%: Minimum	Worst 20%: Maximum
ammno3f_bext	0.4	0	2.2	1.8	0	27.2
ammso4f_bext	1.1	0.1	2.8	8.7	1.2	18.4
cm_bext	0.3	0	0.9	2.5	0.2	8
ecf_bext	0.2	0	1.2	1.2	0	6.3
omcf_bext	0.4	0	2	8.9	0.2	162.4
seasalt_bext	0.5	0	2.3	8.2	0	37.9
soilf_bext	0.03	0	0.3	0.1	0.02	0.9
Total Extinction	2.9	0.4	4.4	31.5	16.4	167.8
Total Extinction incl. Rayleigh	14.9	12.4	16.4	43.5	28.4	179.8

Note: Extinctions due to each aerosol species are in separate rows. Total extinctions including and without Rayleigh scattering comprise the last two rows of the table.

For 2002-2004 worst days, sea salt, organic matter carbon, and sulfate had roughly equivalent contributions to haze. (Figure III.K.4-59). However, the contribution of all three aerosols varies

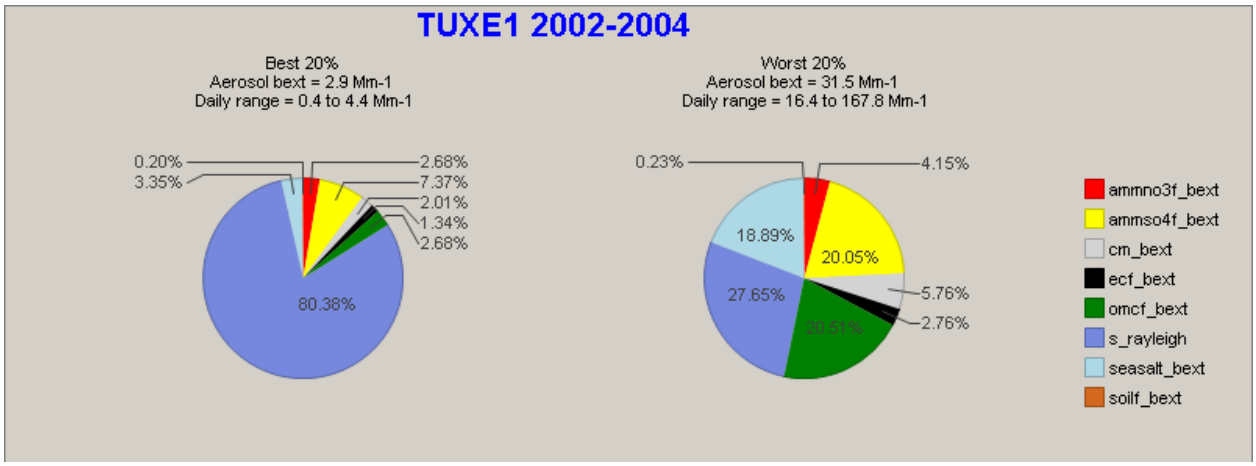
both seasonally and year to year. In years with few wildfires, sulfate increases to the largest component of worst-day aerosols. Organic matter carbon and sea salt are the

Figure III.K.4-59
Proportional Representation of IMPROVE Aerosols on Best and Worst Days at Tuxedni, 2002-2004



strongest determinants of worst days at the Tuxedni IMPROVE site, but they are highly variable and not amenable to control. The high relative contributions of Rayleigh scattering to best and worst days (Figure III.K.4-60) underscore the low aerosol concentrations monitored at Tuxedni.

Figure III.K.4-60
Relative Contributions of Rayleigh Scattering to Visibility Impairment at Tuxedni on Best (80%) and Worst days (28%)



b. Seasonality, 2002-2004

At Tuxedni, the days with worst visibility are not evenly scattered throughout the year. The highest occurrence of the 20% worst days was in summer (July and August), with May and June having intermediate counts (Table III.K.4-22). October, November, and February had the greatest number of best days. Data from individual years show a substantial amount of interannual variability.

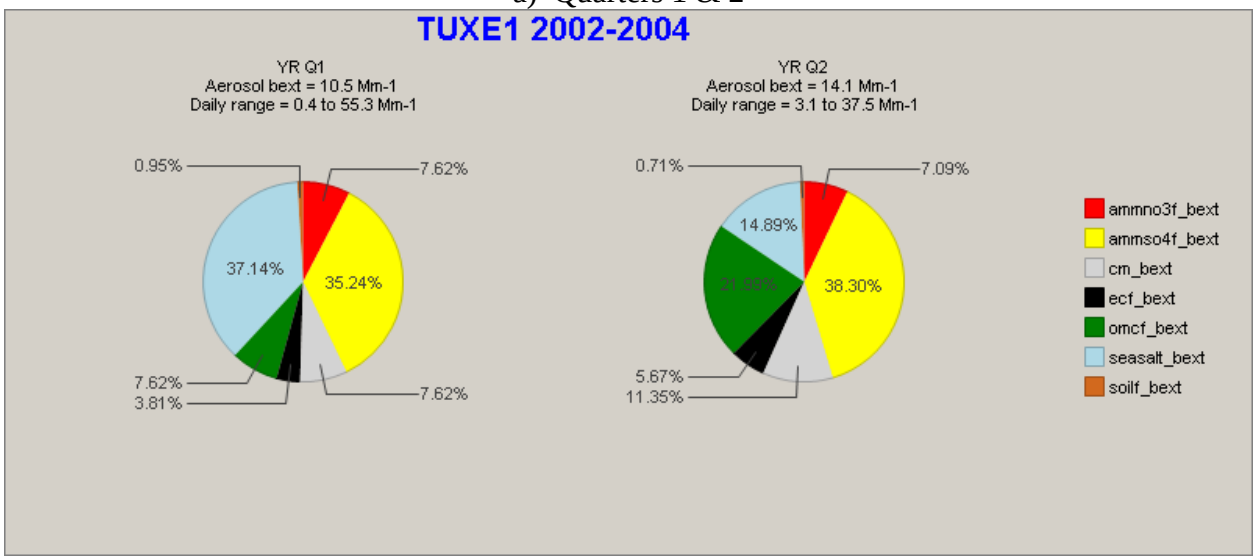
Table III.K.4-22
Incidence of Best Days and Worst Days, Totaled by Month at Tuxedni, 2002-2004 Baseline Years

Months, 2002-2004	Number of Best Days (Group 10)	Number of Worst Days (Group 90)
1	5	6
2	11	4
3	6	1
4	1	3
5	1	8
6	0	9
7	0	12
8	0	15
9	2	4
10	11	2
11	10	3
12	8	0

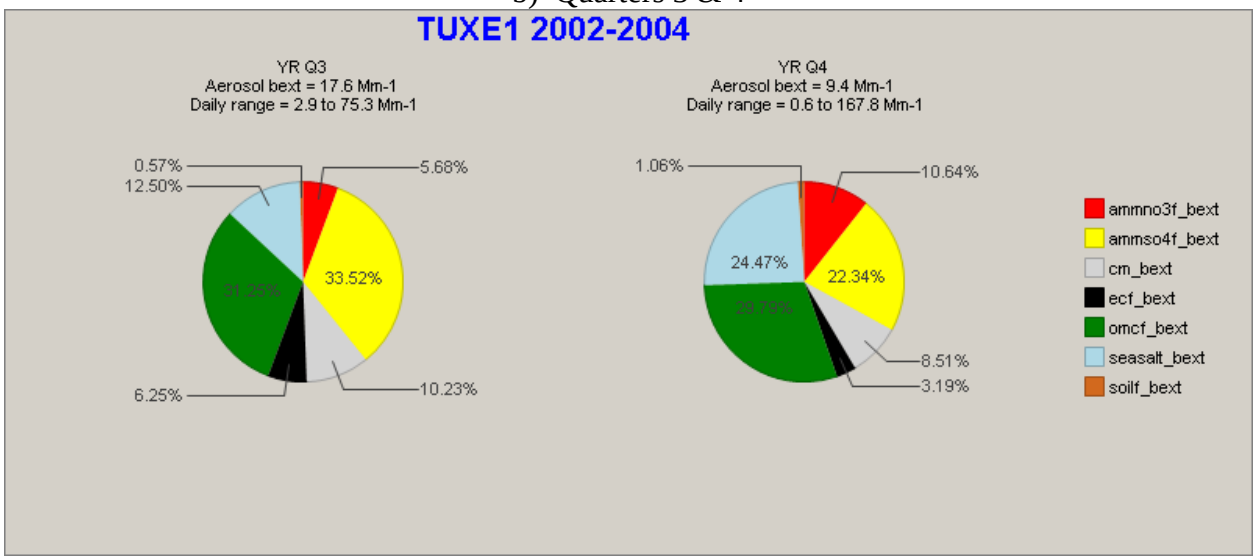
The best days and worst days seen in Table III.K.4-22 represent visibility extremes. Average visibilities change seasonally as well. Average light extinctions, computed for each calendar quarter, summarize seasonal changes in air quality at the Class I areas (Figure III.K.4-61). Yearly Quarters 4&1 (October through March), show increased importance of sea salt. Relative contributions of organic matter carbon were much lower in Quarter 1 (January –March).

Figure III.K.4-61
Proportional Representation of IMPROVE Aerosols at Tuxedni for Best and Worst Days of Each Calendar Quarter, 2002-2004

a) Quarters 1 & 2



b) Quarters 3 & 4



c. Proportional Representation of Pollutant Species: Best Days/Worst Days, by Year

The poorest visibility days (worst days) at Tuxedni are caused by very large increases in some aerosols, and only small increases in others. Comparing the proportions of individual pollutants on best and worst days and comparing them separately for each year can highlight the key species separating best and worst days (Figure III.K.4-61).

The largest components of baseline light extinction at Tuxedni are sulfur, sea salt, and organic matter carbon (Figure III.K.4-62). Coarse matter contributes less. For best days each year, sulfate extinction was the greatest component, at between 35% and 40%. On best days, nitrate is as much as 15% of the whole. On worst days in 2004 and 2005, extinction due to sea salt was distinctly higher than on best days. For 2002 and 2005, proportional contributions of organic matter carbon were greater on worst days. The year 2006 was quite different proportionately, although average extinctions on best and worst days were equivalent (Table III.K.4-23). 2006 had fewer fires, resulting in much less organic matter carbon on to worst days (Table III.K.4-23). Sulfate contributed much more to worst days in 2006.

Table III.K.4-23
Contrasting Extinctions in Years with Different Relative Proportions of Aerosol Species at Tuxedni, 2002-2005 vs. 2006

a) Average Best and Worst Day Total Aerosol Extinction for Years 2002-2006

b)

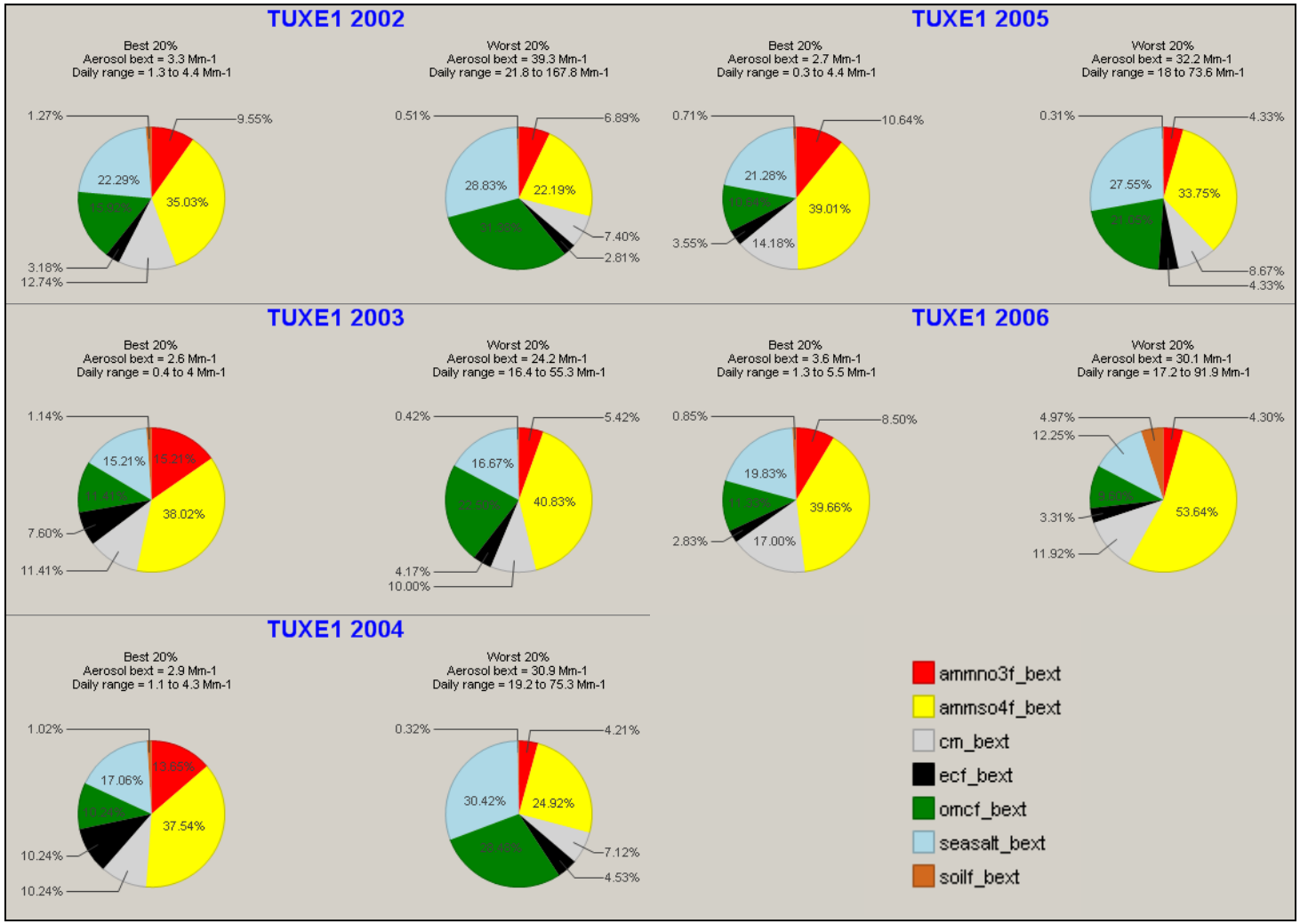
Year	Best Days, Average Extinction (Mm^{-1})	Worst Days, Average Extinction (Mm^{-1})
2002	3.3	39.3
2003	2.6	24.2
2004	2.9	30.9
2005	2.7	32.2
2006	3.6	30.1

c) Contrasting Sulfate and OMC Extinctions in years with different aerosol proportions

d)

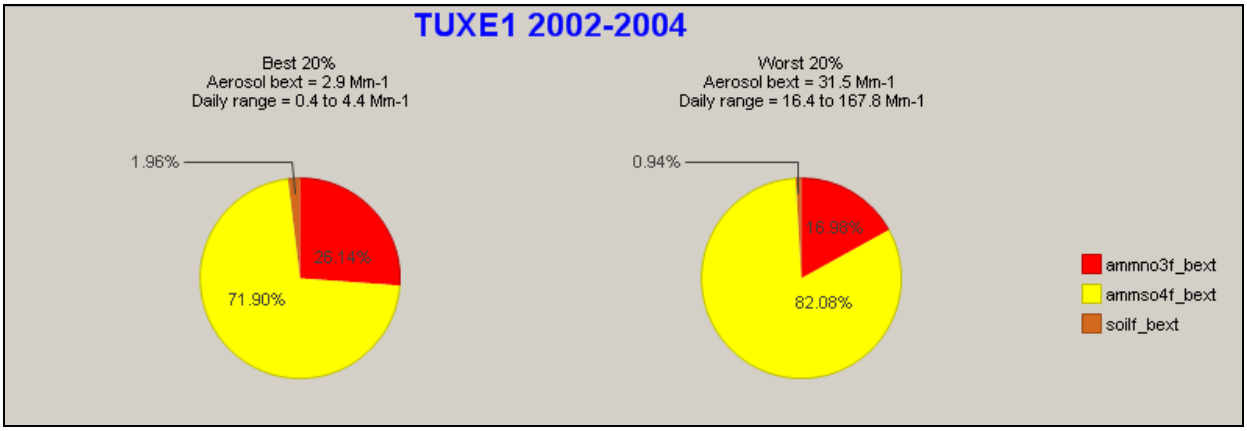
TUXE1	2002-2005	Best Days	1.1 Mm^{-1} Sulfate	.4 Mm^{-1} Organic Matter Carbon
TUXE1	2006	Best Days	1.4 Mm^{-1} Sulfate	.4 Mm^{-1} Organic Matter Carbon
TUXE1	2002-2005	Worst Days	9.3 Mm^{-1} Sulfate	8.3Mm^{-1} Organic Matter Carbon
TUXE1	2006	Worst Days	16.2 Mm^{-1} Sulfate	2.9 Mm^{-1} Organic Matter Carbon

Figure III.K.4-62
Proportional Representation of Aerosol Species at Tuxedni, Yearly Summaries Best and Worst Days, 2002-2006



Removal of those components of haze least correlated with human activities can reveal the underlying processes (Figure III.K.4-63). Sea salt is highly dependent on local meteorology and is crucial at this coastal site, varying year to year and seasonally. Organic matter carbon and elemental carbon are closely associated with wildfire. Coarse mass particulate matter in Alaska is associated with coastal erosional processes. All of these are largely out of human control. Subtraction of the light extinction caused by them leaves a much simplified picture of aerosol extinction on best and worst days, with sulfate the component of consistently greater importance on worst days.

Figure III.K.4-63
2002-2004 Proportional Representation of Aerosol Species at Tuxedni, Excluding Sea Salt, Organic Matter, Coarse Matter, and Elemental Carbon



d. Daily, Seasonal, and Annual Variation in Light Extinction Due to IMPROVE Aerosol Species

On each air sampling day, visibility is determined by the combined extinctions of all aerosol species measured. Stacked histograms represent the actual, rather than proportional, contributions of each aerosol species on each sampling day. Figure III.K.4-64 displays histograms for years 2002-2006, by sampling day, with best and worst sampling days labeled **B** and **W**. Table III.K.4-24 presents average extinctions for best and worst days of each year. Table III.K.4-25 summarizes worst-day characteristics for each year, with extinction ranges, dominant aerosol species, and seasonal effects.

Extinction on best days was typically less than 5 Mm^{-1}. Extinction on worst days typically ranged from 15-40 Mm^{-1}, with occasional much higher peaks. The predominant differences between years are in sea salt events, which occur at any time of year, and in wildfire impacts, which occur primarily during the growing season. Fires do also contribute to worst days in spring and fall. Transboundary pollutants from Asia and Europe in winter and spring are seen in soil and sulfate peaks, but the effects of sea salt and organic matter carbon are greater.

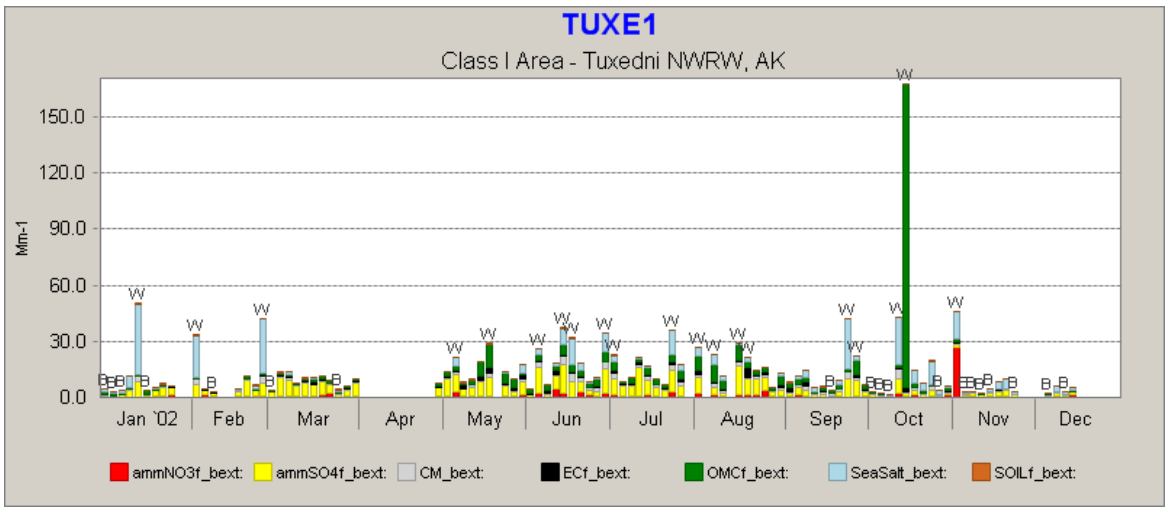
Visibility at Tuxedni was most impaired during the summer and the "shoulder" seasons of spring and fall. The degree of impairment in March, April, May, and September varied year to year. The impacts of sea salt varied greatly year to year. Most worst days were caused by a combination of aerosol species, but in winter, sea salt, soil, or coarse mass alone can cause worst days (for example January and November of 2004). The year 2006 differed in both timing and chemistry of worst days, with a decrease in fire and January peak in soil and coarse matter.

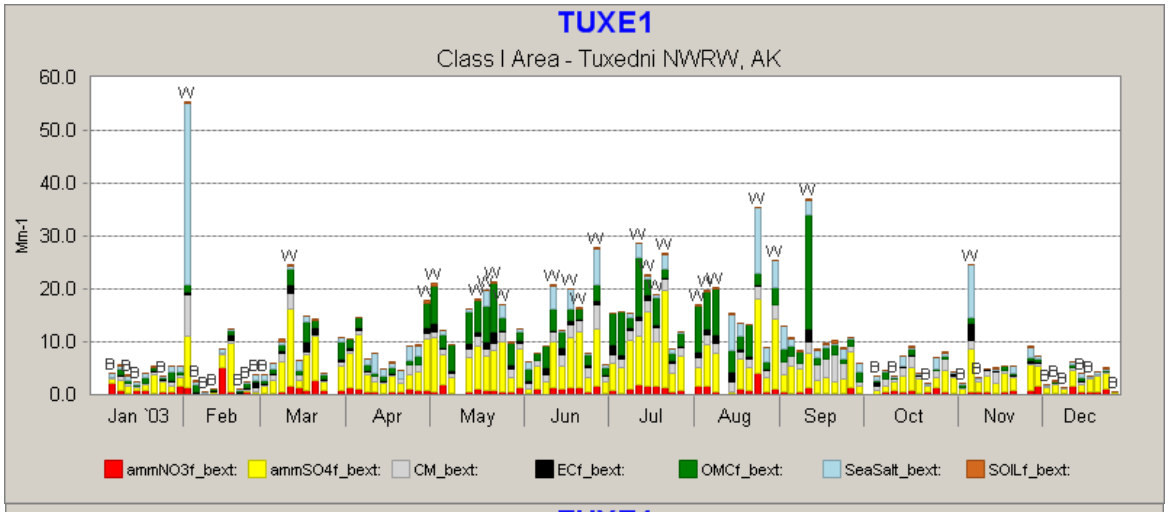
Sulfate, organic matter carbon, and sea salt contributed to worst days during the seasons of most frequent impairment at Tuxedni. Extinction on these worst days typically ranged from 15-60 Mm^{-1}, with substantially higher peaks. During less impaired seasons, sea salt was the most frequent contributor to worst days.

Sea salt and soil aerosols were quite episodic, rather than having high or low seasons. A few distinct nitrate peaks were seen. While the largest organic matter carbon peaks occurred in summer, organic matter carbon also was present earlier and later than the typical Alaskan fire season, for instance in October 2002 and spring 2003.

Removal of those components of those haze least correlated with human activities can provide insight into realistic options to control regional haze (Figure III.K.4-65).

Figure III.K.4-64
Contribution of Aerosol Species to Light Extinction at Tuxedni on Best and Worst Days, 2002-2006




TUXE1
Class I Area - Tuxedni NWRW, AK
Mm-1
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jan `03
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
ammNO3f_bext:
ammSO4f_bext:
CM_bext:
ECf_bext:
OMCf_bext:
SeaSalt_bext:
SOILf_bext:

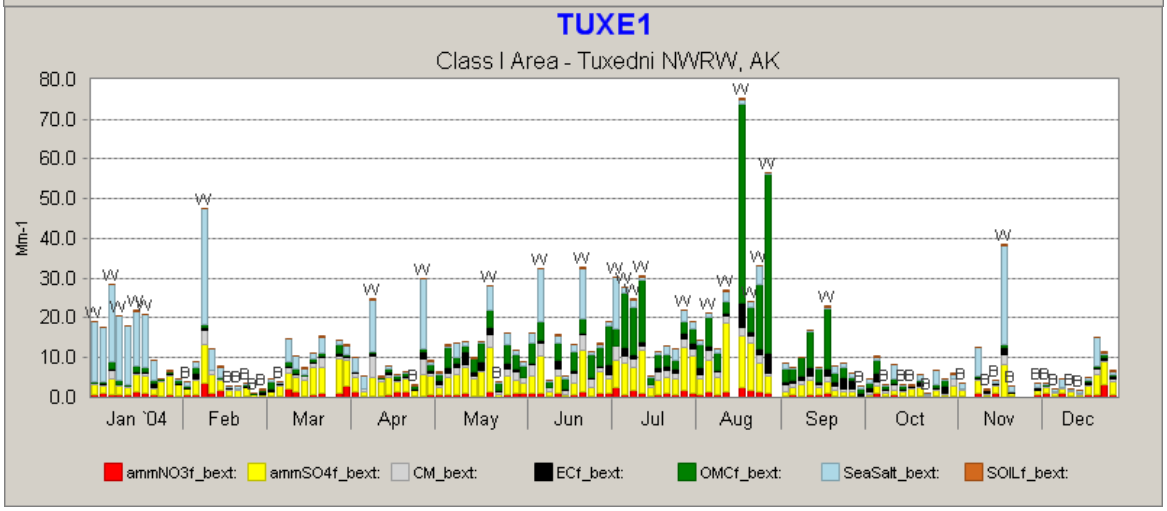

TUXE1
Class I Area - Tuxedni NWRW, AK
Mm-1
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Jan `04
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
ammNO3f_bext:
ammSO4f_bext:
CM_bext:
ECf_bext:
OMCf_bext:
SeaSalt_bext:
SOILf_bext:

Figure III.K.4-64 (continued)
Contribution of Aerosol Species to Light Extinction at Tuxedni on Best and Worst Days, 2002-2006

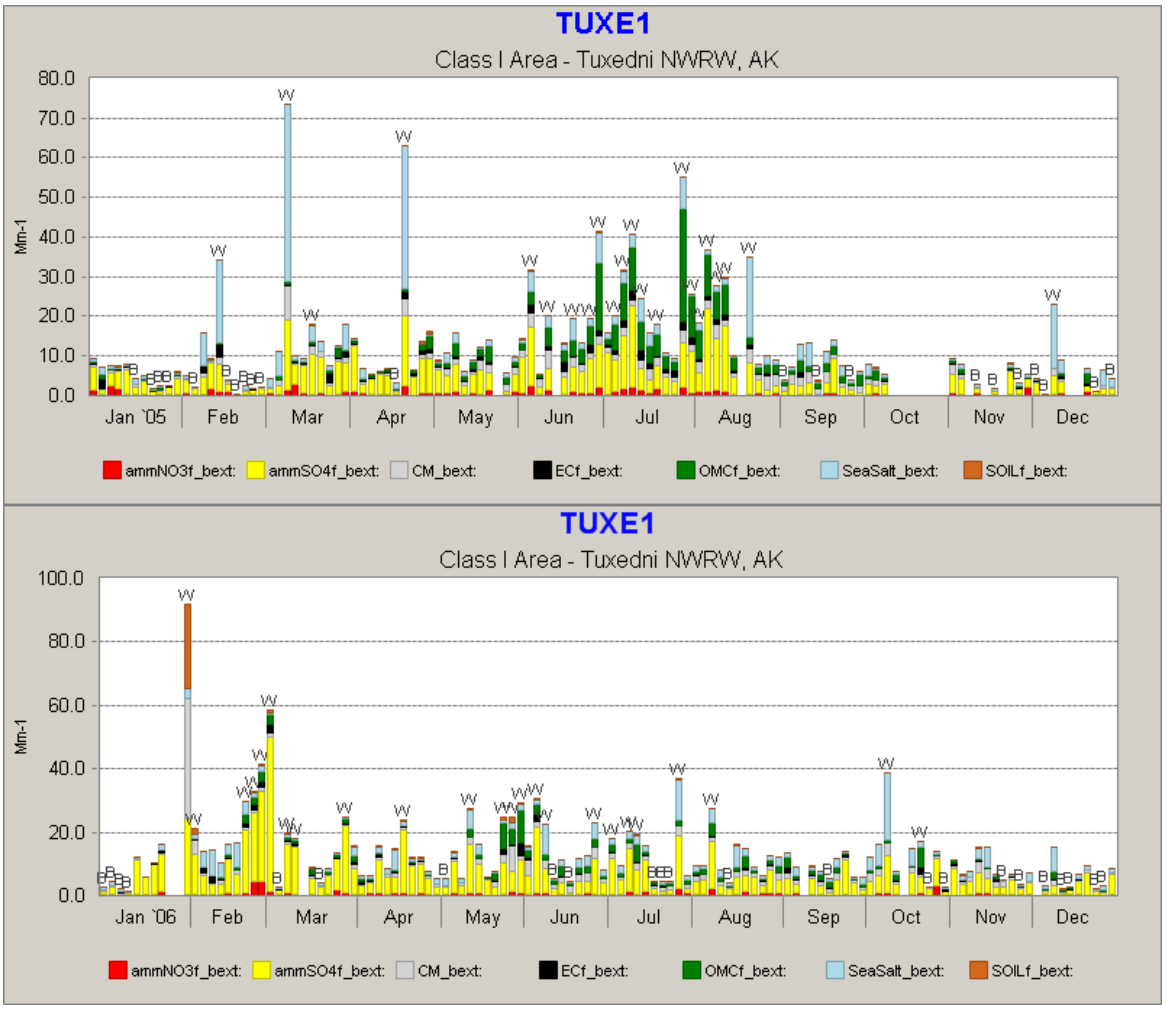


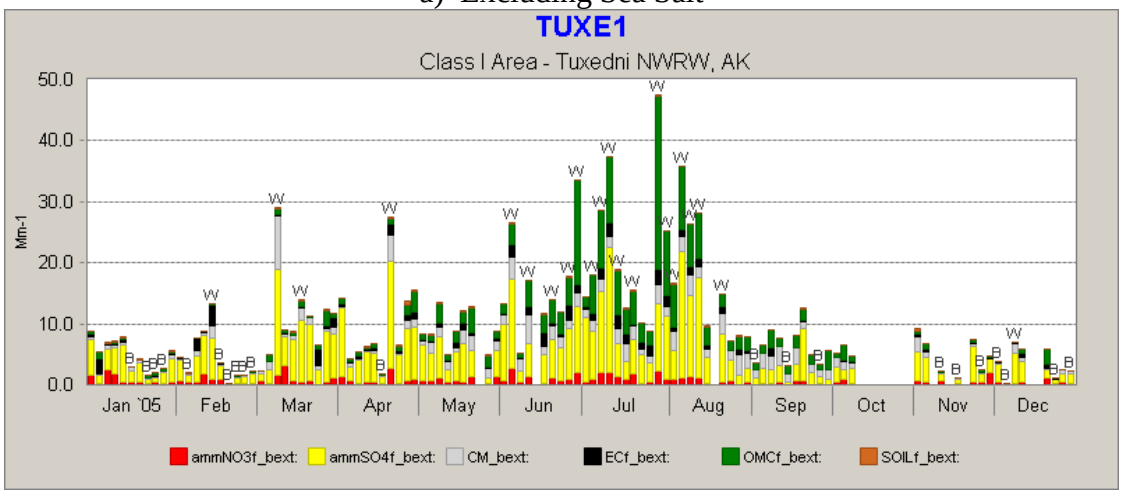
Table III.K.4-24
Patterns of Extinction Among Worst Days at Tuxedni, Seasons and Aerosol Species

Year	Worst Days Extinction Range	Worst Day Peaks	Season of Greatest Impairment	Contributing Species in Worst Season	Species Causing Worst Days in Other seasons
2002	20-60	170	May-Oct	S, OM, SS, N	SS
2003	20-40	60	Mar-Sept	S, OM	SS
2004	15-40	75	May- Sept	S,OM,SS	SS
2005	18-50	75	Jun-Aug	S, OM, SS	SS
2006	18-50	95	Feb-Aug	S, less OM,SS	S, one Soil and CM event

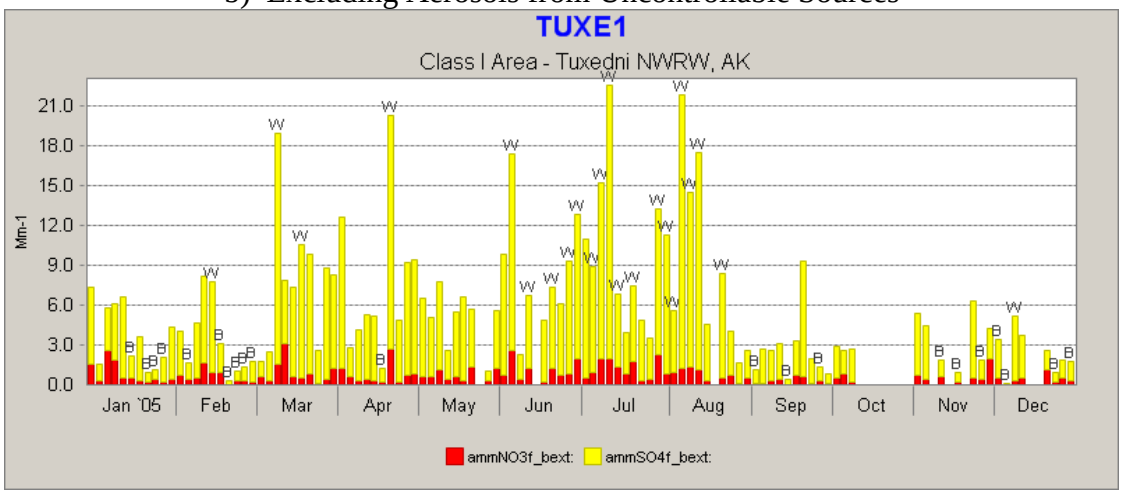
Note: SS - Sea Salt

Figure III.K.4-65
2005 IMPROVE Species Contribution to Visibility Impairment at Tuxedni Sampling Day

a) Excluding Sea Salt



b) Excluding Aerosols from Uncontrollable Sources



4. Correlations Among IMPROVE Aerosols Monitored at TUXE1

Aerosol species emitted from a common source, arriving on the same weather systems, or simply from the same direction will be correlated with each other. Correlations can be used to make inferences about aerosol origins. Correlations among species for all sampling days and worst sampling days are presented in Table III.K.4-25, as are the degrees by which correlations change between the two.

Coarse mass and sea salt show the strongest correlation between aerosol species, for all days and worst days. Elemental carbon and organic matter carbon also are positively correlated both on all days and worst days. Overall, coarse mass is not correlated with either elemental carbon or

Table III.K.4-25
Pearson Correlation Coefficients Between Aerosol Species at Tuxedni for All Days and for Worst Days

Aerosol Species	All Days	Worst Days	Change
N S	0.21	-0.13	-0.34
N CM	0.12	-0.09	-0.20
N EC	0.06	-0.11	-0.16
N OMC	0.05	-0.07	-0.12
N SS	0.18	0.05	-0.13
N Soil	0.05	-0.07	-0.12
S CM	**0.54**	**0.32**	-0.21
S EC	0.31	-0.07	-0.39
S OMC	0.17	-0.26	-0.43
S SS	0.25	-0.18	-0.42
S SOIL	**0.49**	**0.36**	-0.13
CM EC	0.14	-0.28	-0.43
CM OMC	0.15	-0.29	-0.43
CM SS	**0.59**	**0.56**	-0.03
CM SOIL	0.36	0.11	-0.25
EC OMC	**0.50**	**0.46**	-0.04
EC SS	-0.03	-0.36	-0.33
EC Soil	0.14	0.12	-0.02
OMC SS	-0.05	-0.34	-0.29
OMC SOIL	0.10	-0.01	-0.11
SS SOIL	0.04	-0.12	-0.16

Magnitude of Change

> -0.4
> -0.3
> -0.2

Note: Species pairs with correlations above +/- 0.45 are shown in bold. Shading represents the change in correlations between All days and worst days.
SS - Sea Salt

organic matter carbon, but on worst days it is negatively correlated with both. Sea salt is also negatively correlated with both fire aerosols on worst days. These correlations are consistent with two types of worst days: one with the fire aerosols organic matter carbon and elemental carbon, the other with coarse mass and sea salt aerosols associated with coastal processes. The two types of worst days are even more distinct in summer (May-August), when correlations between EC-OMC (0.73) and CM-SS (0.71) strengthen, and between CM-EC becomes more negative (-0.43).

For all days, sulfate is positively correlated with other aerosols, especially coarse mass and soil, but all correlations with sulfate decreased or become negative on worst days. Correlations with organic matter carbon and sea salt decrease dramatically. Nitrate is not strongly correlated with other aerosols, but on worst days its correlations also decreased or become negative. Sulfate and nitrate aerosols are not correlated with wildfire aerosols, coastal aerosols, or each other on worst days.

a. Species Closely Associated with Human Activities

Sulfate and nitrate are the aerosols most closely associated with human activities in Alaska, and so are most amenable to management. Both species are important at Tuxedni, but they become less important on worst days, acting more as background than as drivers of worst days. Average sulfate extinction at Tuxedni is one-third of total extinction, rising to 37.5% on best days, falling to 27.7 on worst days. Nitrate is a much smaller fraction. Most days with sulfate peaks above 12 Mm^{-1} are worst days, but since worst days average 31.5 Mm^{-1} extinction, sulfate alone is not responsible.

The correlations of sulfur with all other aerosols decreased or became more negative on worst days. The correlations between sulfate and nitrate extinction are also low, 0.21 for all days, falling to -0.13 on worst days. The primary weather patterns causing worst days at Tuxedni apparently differ from those carrying the most sulfate aerosols to the site. Potential sources for sulfate at Tuxedni include permitted stationary sources, as well as onshore activities, marine traffic, local marine based industries, and oceanic biogenics. Volcanic eruptions do occasionally occur near Tuxedni, but did not during the baseline years 2002-2004.

b. Species Not Closely Associated with Human Activities

The three aerosols most important to worst days at Tuxedni are sulfate, sea salt, and organic matter carbon. The latter two, sea salt and organic matter carbon, are not closely linked to human activities and are not amenable to human management**.** Sea salt epitomizes an aerosol dependent on meteorology and oceanic processes. Sea salt aerosols vary greatly year to year, occur episodically in short or lengthy events, and may peak at any time of year (Figure III.K.4-66). It may be possible to identify specific weather events causing high sea salt levels. OMC and EC aerosols are strongly linked to wildfires which occur throughout the state, most commonly in the Interior. Eurasian agricultural activities also contribute organic matter carbon and elemental carbon aerosols to Alaskan Class I area sites.

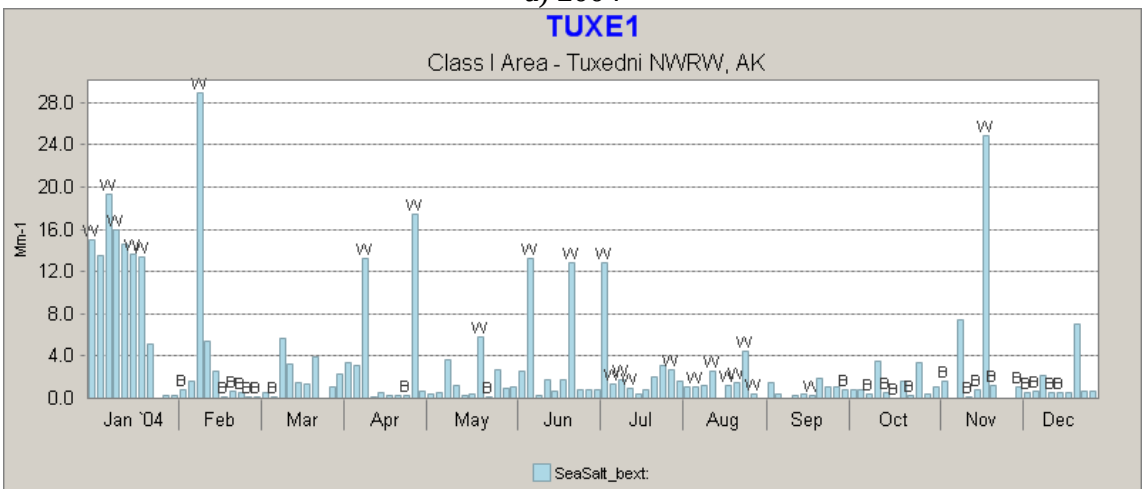
Soil aerosols and coarse mass at Tuxedni are also not closely associated with human activities. Soil aerosols show some early spring peaks associated with dust storms in Asia. Coarse mass at Tuxedni is strongly seasonal higher in summer—although brief episodes occur at almost any time of year. At seasonal sites such as Tuxedni shoreline erosion and winds influence coarse mass deposition.

5. Light Extinction of Individual Species: Best/Worst Days, Seasonal Patterns

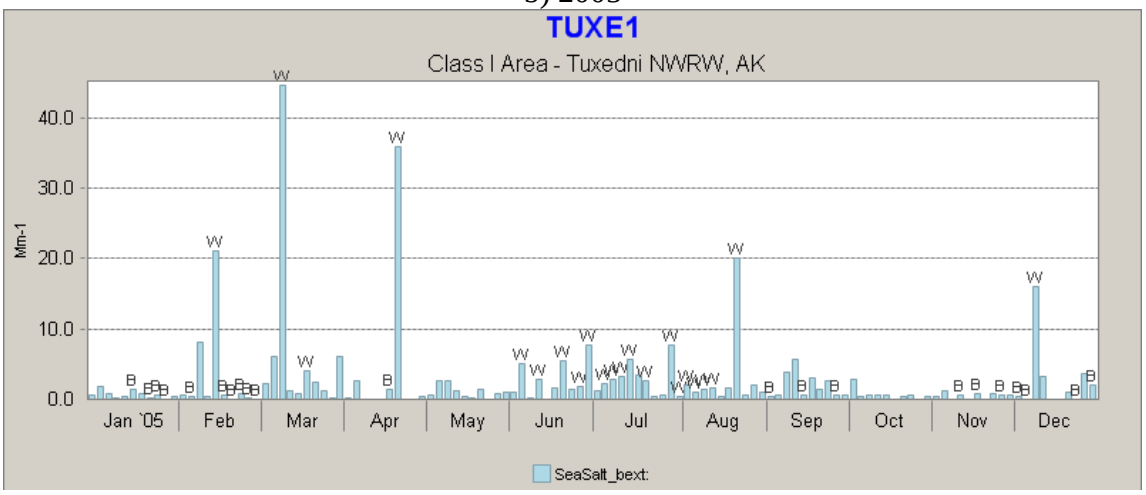
Sea salt: Sea salt extinction is highly episodic, and is expected to depend on local meteorology at this coastal site (Figure III.K.4-66). Spikes in sea salt contribute to worst days in all months.

Figure III.K.4-66
Sea Salt at Tuxedni for 2004, 2005

a) 2004



b) 2005



Organic Matter Carbon: Organic matter carbon at Tuxedni is quite seasonal, and may be episodic or continuous. Organic matter carbon increases during the Alaska growing (and wildfire) season, June through September in most years (Figure III.K.4-67, III.K.4-68a). Organic matter carbon is relatively high some Octobers, and in February to May of some years (see 2006, Figure III.K.4-68b).

Figure III.K.4-67
Organic Matter Carbon at Tuxedni for 2002-2006

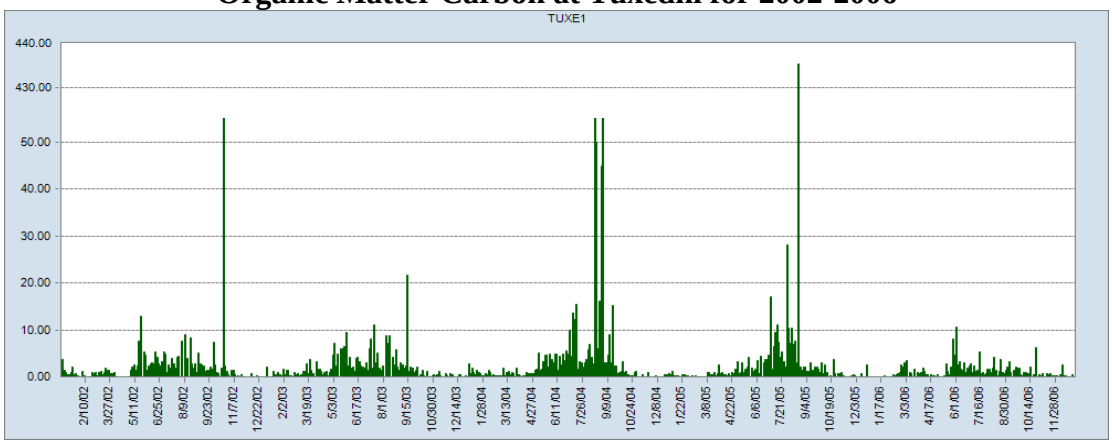
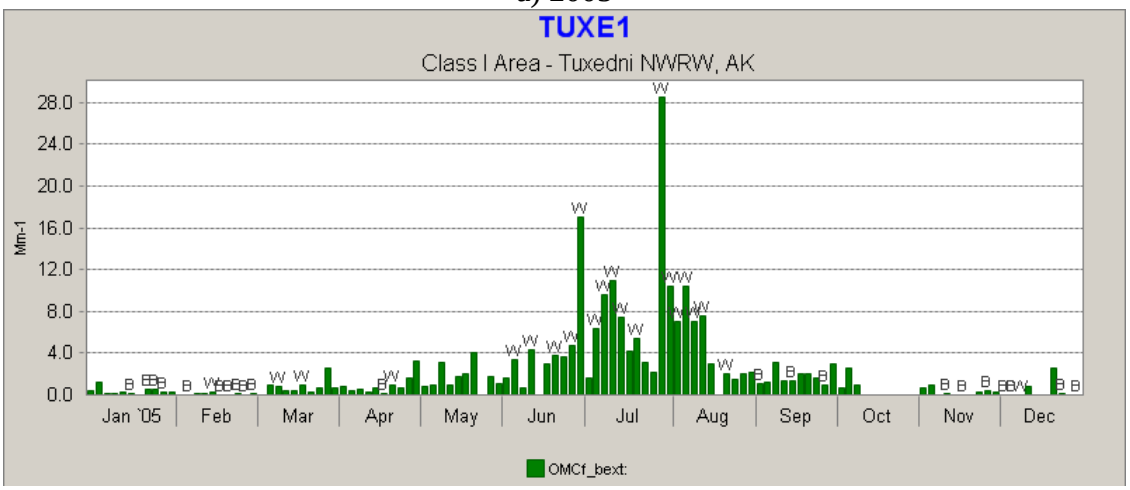
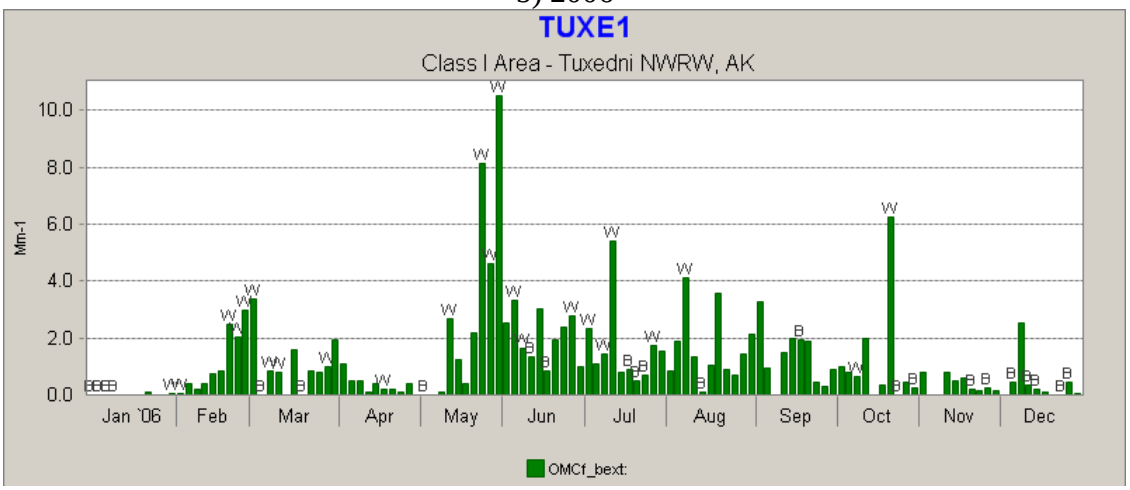


Figure III.K.4-68
Organic Matter Carbon at Tuxedni for 2005, 2006

a) 2005



b) 2006



Elemental Carbon at Tuxedni may be episodic or continuous, and is typically seasonal. Figure III.K.4-69 shows the variability of elemental carbon from year to year. Figure III.K.4-70 shows a typical year.

Figure III.K.4-69
Elemental Carbon at Tuxedni for 2002-2006

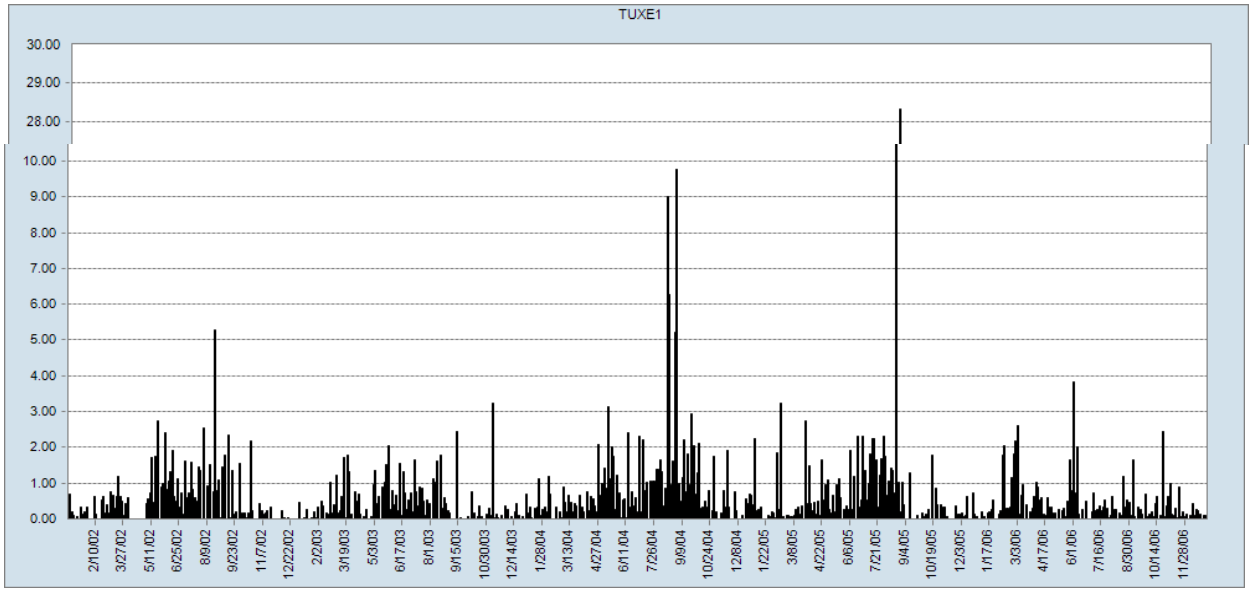
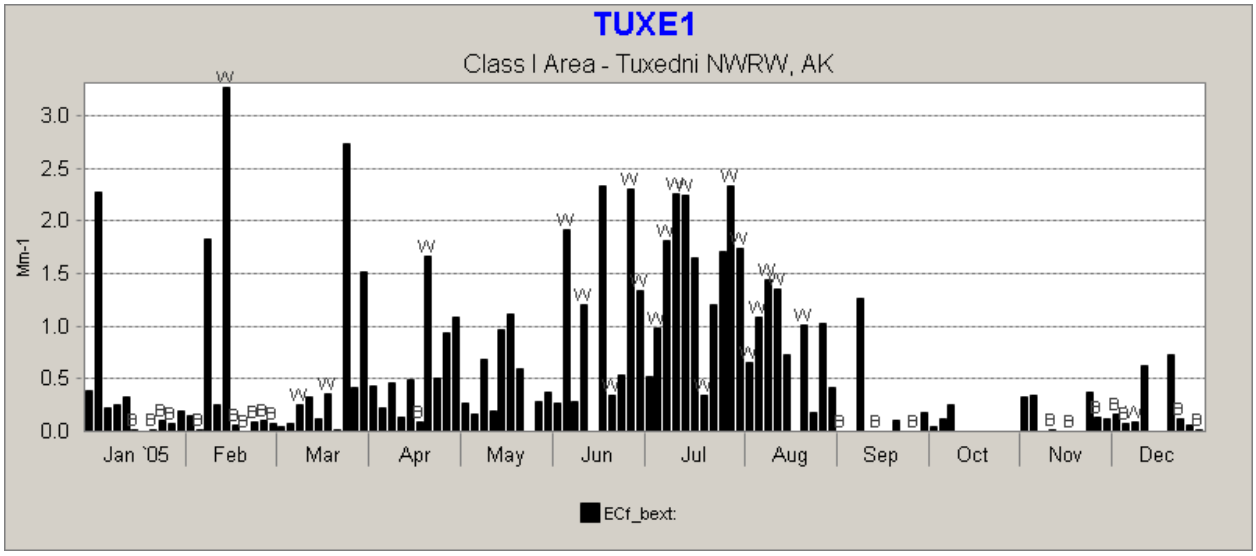


Figure III.K.4-70
Elemental Carbon at Tuxedni for 2005



Sulfate at Tuxedni is present continuously, and is typically seasonal, increasing in May through August. Figure III.K.4-71 shows the variability of sulfate from year to year; 2006 is quite different from 2002-2005. Figure III.K.4-72 shows a typical year, with increased summer levels and suggestions of springtime increases as well. On almost every worst day, sulfate extinctions exceed 3 Mm^{-1}, although sulfate also exceeds 3 Mm^{-1} at many other times. On best days, sulfate extinctions fall below 3 Mm^{-1}.

Figure III.K.4-71
Sulfate at Tuxedni for 2002-2006

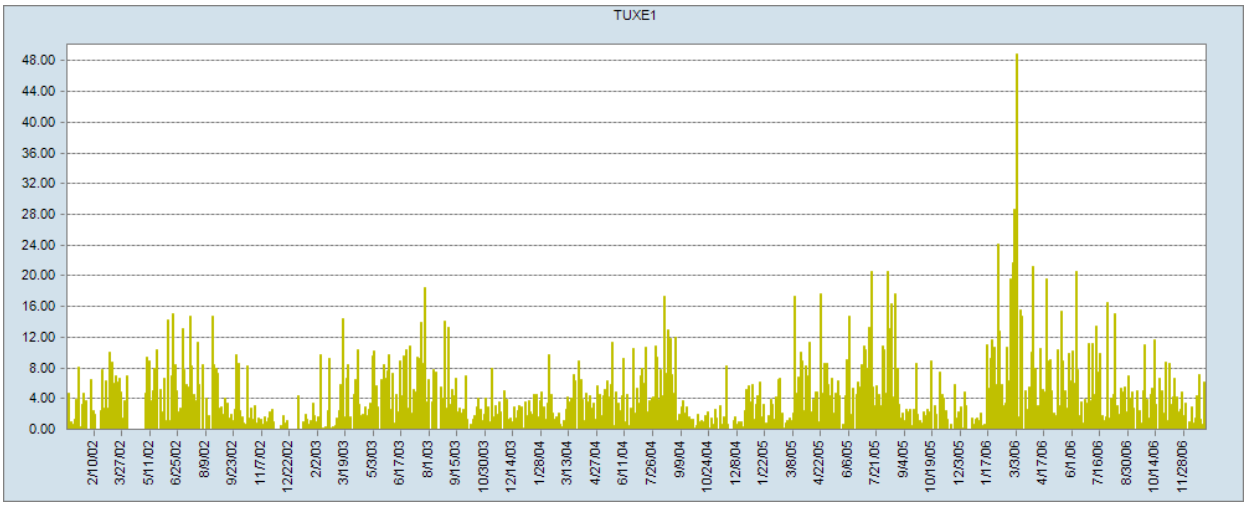
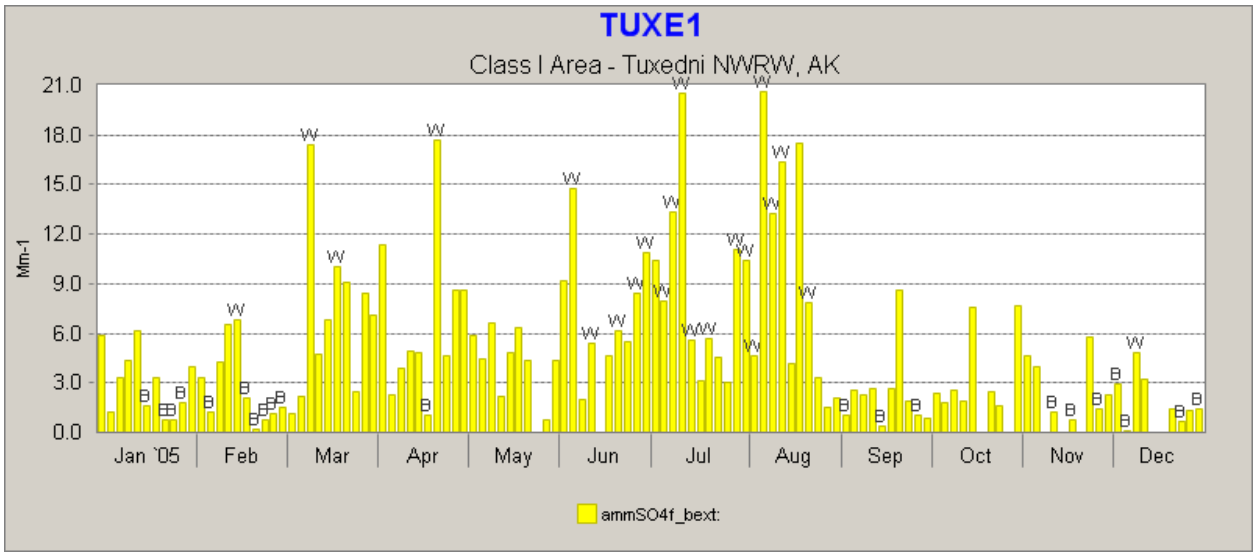


Figure III.K.4-72
Sulfate at Tuxedni for 2005



Nitrate extinction is highly variable, so does not show a clear seasonal pattern (Figure III.K.4-73). However, nitrate aerosols may be statistically higher in summer. Nitrate extinction is typically below 3 Mm^{-1}, although peaks above as high as 27 Mm^{-1} do occur (Figure III.K.4-74).

Figure III.K.4-73
Nitrate at Tuxedni for 2002-2006

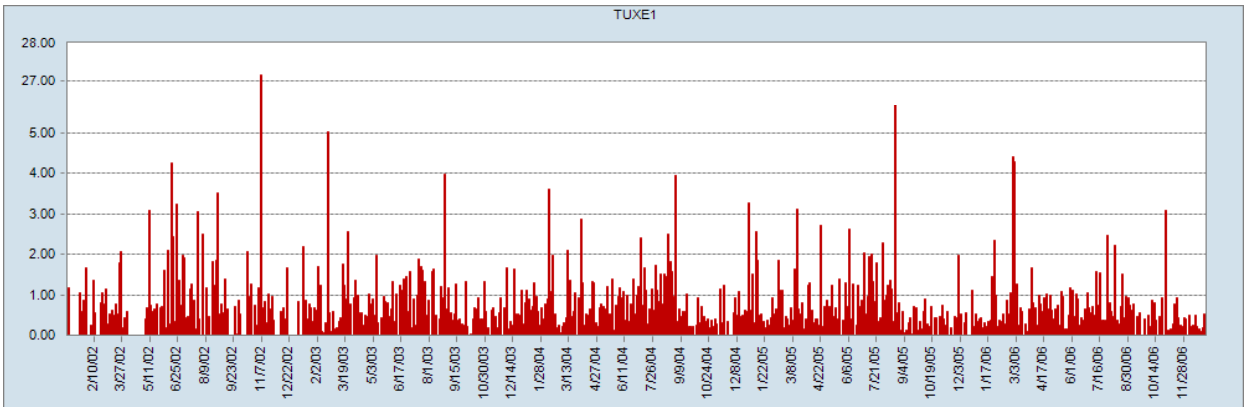
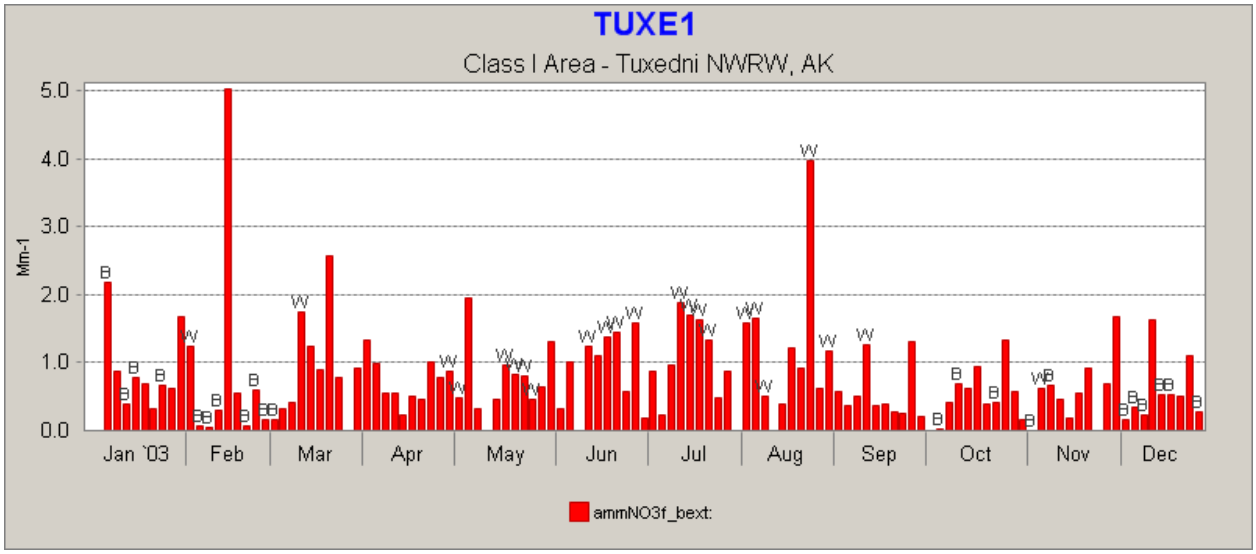
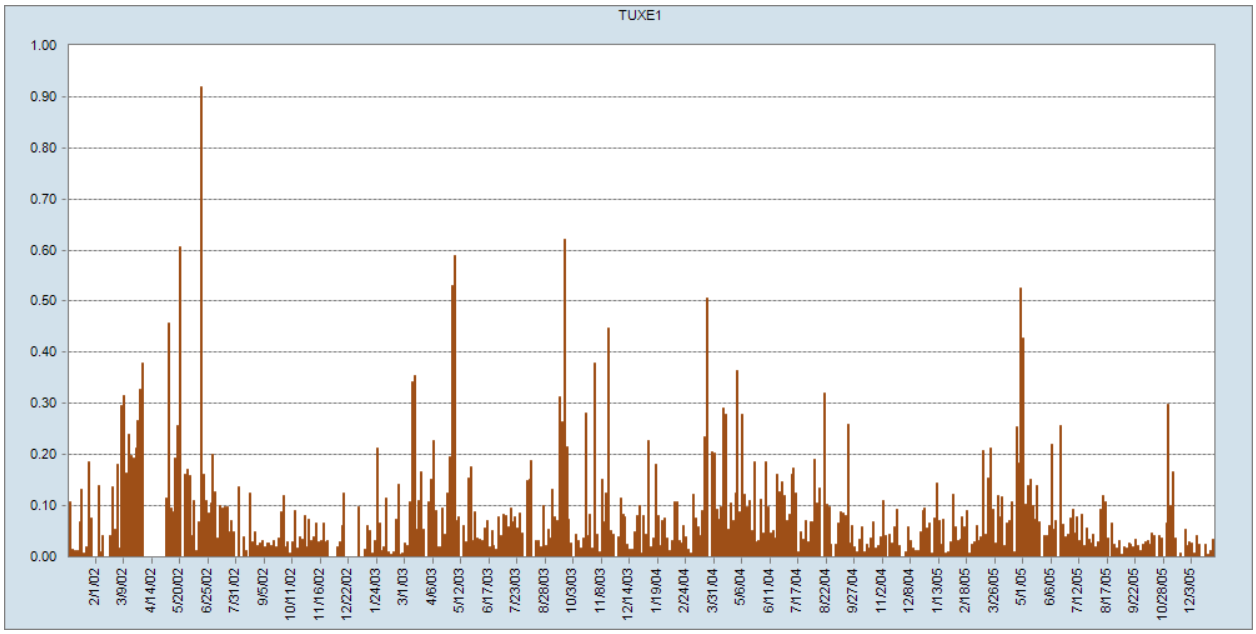


Figure III.K.4-74
Nitrate at Tuxedni for 2003



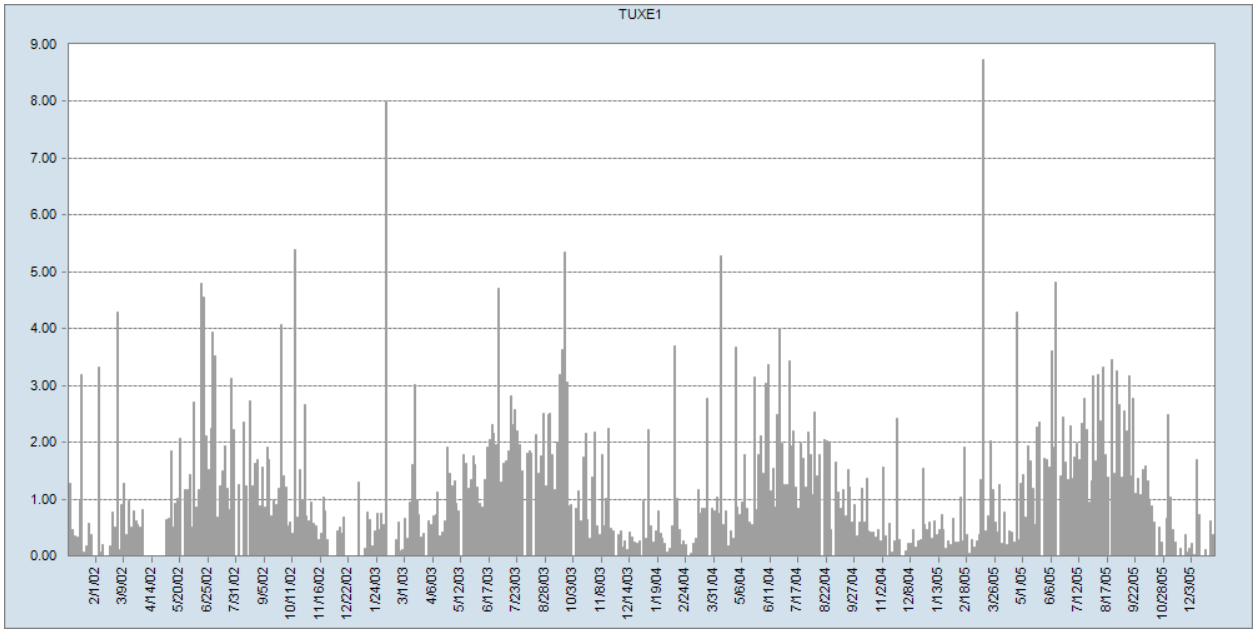
Soil aerosols have quite episodic effects at Tuxedni (Figure III.K.4-75). Soil extinction remained low, below 2 Mm^{-1}, for the entire baseline period. However, it reached 26 Mm^{-1} on one occasion in January 2006.

Figure III.K.4-75
Soil at Tuxedni for 2002-2005



Coarse Mass: Coarse mass at Tuxedni is strongly seasonal, typically lower from November to January (Figure III.K.4-76**)**. Brief episodes of high coarse mass extinction occur at almost any time of year. Coarse mass extinction stayed below 9 Mm^{-1} during the baseline period, but it reached 38 Mm^{-1} on February 1 2006, when soil extinction reached 26 Mm^{-1}.

Figure III.K.4-76
Coarse Mass at Tuxedni for 2002-2005



6. Fire Impacts at Tuxedni

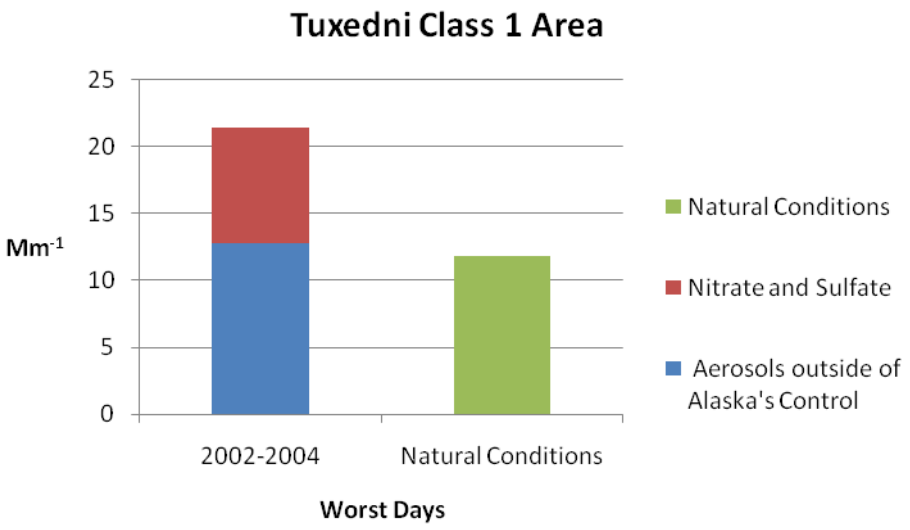
Tuxedni is far from Alaska's Interior, where most wildfires occur. Nevertheless, it does receive aerosols from fires both inside and outside the state. Organic matter carbon is the aerosol most clearly associated with wildfire. It is highly seasonal and highly variable year to year (Figure III.K.4-67). Organic matter carbon causes many worst days at Tuxedni, most of them during summer months (Table III.K.4-24). Elemental carbon is correlated with organic matter carbon, but much less than at Denali, which is affected by nearby fires. The fires affecting Tuxedni are mostly distant, with sorting of aerosols by size likely before reaching Tuxedni. The distance aerosols travel from the Yukon-Kuskokwim Delta and Eurasia underscores the difficulty of managing these aerosols at Tuxedni.

7. Evaluation of the Effects of Uncontrollable Processes

Sulfate, sea salt and organic matter carbon make the strongest contributions to worst days at Tuxedni. Of these, only sulfate may be amenable to human control. Sea salt and organic matter carbon together make up 54% of light extinction on worst days but are caused by wildfire, wind, erosion, and coastal weather. Elemental carbon, coarse mass and soil arise from similar natural processes. Human activities in northern Europe and Asia contribute soil, elemental carbon, organic matter carbon, and sulfates to Alaska's Class 1 areas, including Tuxedni.

At Tuxedni Class I area, the baseline visibility impairment due to non-anthropogenic aerosol species and aerosols from outside the state exceeds the natural conditions goals under the Regional Haze Rule (Figure III.K.4-77).

Figure III.K.4-77
Contrasting Natural Visibility Conditions at Tuxedni with Baseline Impairment from Probable Anthropogenic and Non-Anthropogenic Aerosols



E. Bering Sea Wilderness Area

As noted previously, due to the remote location of the Class I area in the Bering Sea and the severe meteorology, problems were encountered in installing and operating monitors at, or in proximity to, the Bering Sea Class I area. For this reason, no nearby monitoring site exists and insufficient data are available to calculate baseline values for this site.

1. Origins of Aerosol Species Influencing Regional Haze at Bering Sea Class I Area

As is true elsewhere in Alaska, the Bering Sea Class I area receives air pollutants from Asia, Northern Europe, and North America. Sources that may impact the island likely include dust, agricultural burning, industrial emissions, and wildfire. Local aerosols arise from coastal weather processes.

2. Influence of Wind and Weather on Visibility at the Bering Sea Class I Area.

The Bering Sea Wilderness Area consists of three islands 375 km off the coast of western Alaska. The closest and most representative long-term NWS meteorological monitoring station is at St Paul Island, 365 km south-southeast in the Pribilof Islands of the Bering Sea. The Bering Sea Wilderness is within the global circulation zone of midlatitude westerlies. Synoptic wind patterns of the Bering Sea are modified by the Pacific High Pressure Center in the summer and by the Aleutian Low in the winter. At times, especially in the spring, the Pacific High over the eastern Pacific Ocean intensifies and creates a ridge that diverts midlatitude westerly flow from Asia northwards towards Alaska. This can result in transport of Asian dust to the region. Towards the end of summer, this ridge weakens and midlatitude flow becomes more zonal (westerly). Monthly St Paul Island Alaska wind roses (http://www.coha.dri.edu/web/state_analysis/Alaska/BeringSeaWA_metsfcwind_stpaulisland.html) show monthly and seasonal wind patterns at that southern Bering Sea island location. Wind speeds are generally strong and wind directions predominantly northerly to easterly in the winter. A wide range of southerly flow is dominant in the summer. Emissions may reach the Bering Sea Class I area from almost any direction, depending on the time of year, but emission sources are distant. (Causes of Haze Assessment, http://www.coha.dri.edu/)

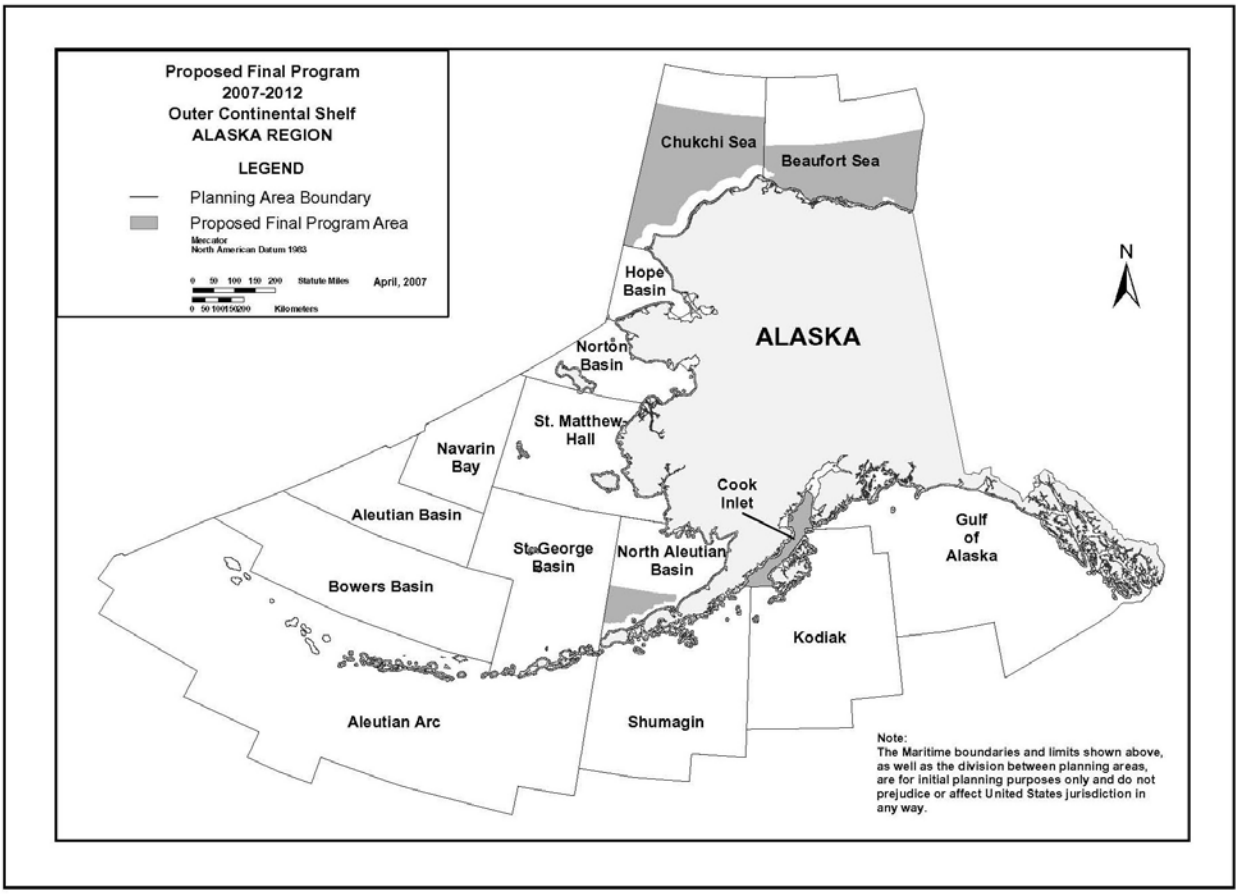
3. Potential for Oil Development

Given the islands location in the Bering Sea, industrial, commercial, or community development near the Class I area is unlikely except for potential offshore oil and gas development. Current offshore oil development is distant, with no lease sales held or planned in the St. Matthew-Hall and adjoining program areas of Aleutian Basin, Bowers Basin, and Aleutian Arc (Figure III.K.4-78). There was no industry interest expressed in response to an August 2005, Request for Comments. For Hope Basin, no lease sales have been held. This area has been included in recent programs in conjunction with the Chukchi Sea Planning Area as a special interest sale. No industry interest was expressed for the Hope Basin area. For Norton Basin, Navarin Basin, and St. George Basin, one sale was held in each area in 1983. Exploration wells were drilled, with no commercial discoveries. There was no industry interest expressed in response to the August 2005, Request for Comments (Draft Proposed Program Outer Continental Shelf Oil and Gas Leasing Program, 2007-2012. February 2006. U.S. Department of the Interior Minerals Management Service).

Within the Alaska Region, lease sales have been scheduled for the Beaufort Sea, Chukchi Sea, North Aleutian Basin, and Cook Inlet planning areas. While the status of these sales is in flux, industry interest exists for these areas at some distance from the Bering Sea Class I area.

All offshore oil development is, and will be, under the purview of EPA.

Figure III.K.4-78
Alaska Program Areas Outer Continental Shelf Oil and Gas Leasing Program



Proposed Final Program Outer Continental Shelf Oil and Gas Leasing Program 2007-2012.
U.S. Department of the Interior, Minerals Management Service April 2007

4. Future Visibility Impacts at Bering Sea Class I Area

As is true elsewhere in Alaska, the Bering Sea Class I area will continue to receive air pollutants from Asia, Northern Europe, and North America. From overseas, increases in coal-fired power generation, changing patterns in agricultural burning, erosion-fueled dust storms, wildfires, and changes in northern European industrial activity all have the potential to affect visibility at the Alaskan Class I areas. Changes in the U.S. Outer Continental Shelf (OCS) Oil and Gas Leasing Programs could affect Alaska Class I areas, as could changes in Russian OCS lease sales.

III.K.5 EMISSION INVENTORY

Given the characterizations of existing regional haze levels at each of the Class I monitors, a series of emission inventories were developed for the entire state of Alaska upon which to base the regional haze air quality modeling and reasonable further progress demonstration.

This section discusses the development of these Alaska Regional Haze emission inventories. It addresses selection of the analysis years and scenarios to support the subsequent modeling and reasonable further progress demonstration, the pollutants included in the inventories, the scope and extent of included sources, the data sources and methods used to develop individual emission estimates, and the processing/formatting that was performed to configure the inventories into useful modeling datasets.

A. Baseline and Future-Year Emissions Inventories for Modeling

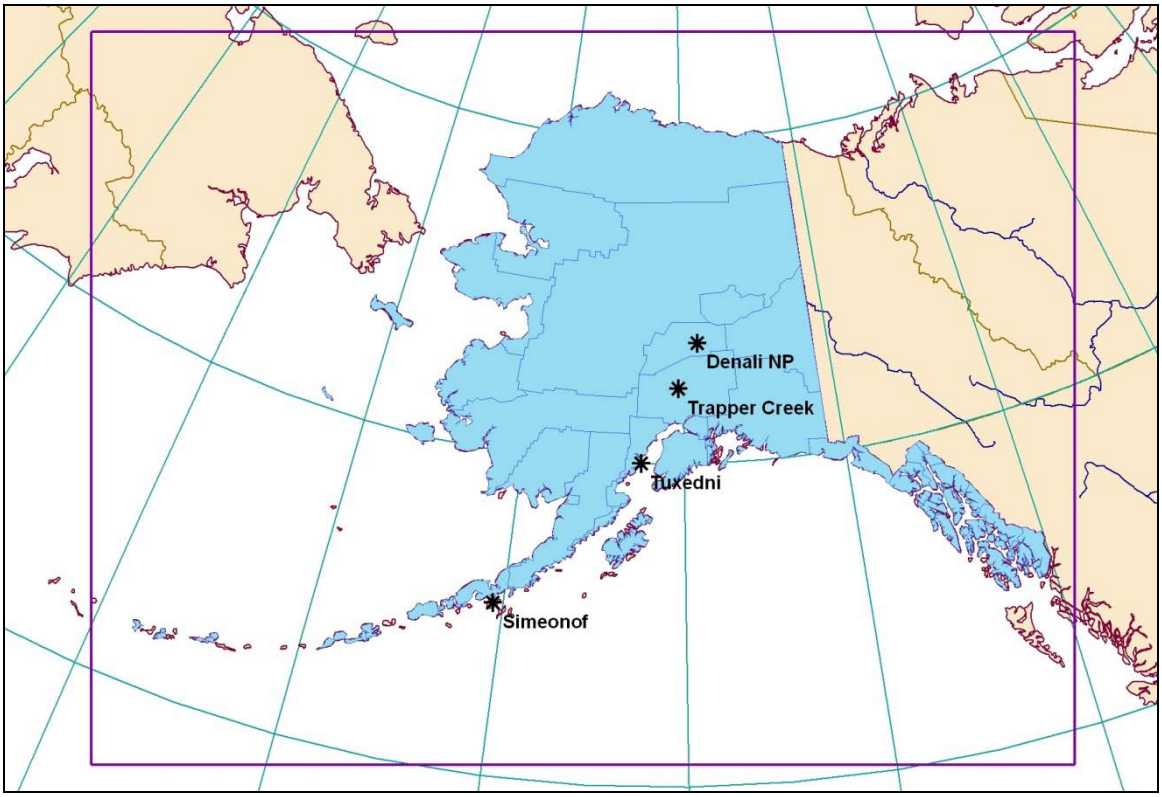
A series of pollutant emission inventories were developed to support the modeling analysis conducted for the SIP. Key issues that were considered in the development of these region haze emission inventories are outlined below.

- *Pollutants* – Inventories were developed for the following pollutants: hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), sulfur oxides (SOx), ammonia (NH_3), and coarse and fine particulate matter (PM_{10} and $PM_{2.5}$, respectively). Although CO is not considered a pollutant that affects regional haze, it was included in the inventories developed to support this effort because it was contained in supporting inventory datasets from previous Alaska inventory studies. It was generally simpler to retain it in these inventories, but not include it in subsequent products (e.g., the Weighted Emissions Potential analysis described in Section III.K.7).

- *Areal Extent* – The inventories represent sources within the entire state of Alaska, encompassing a total of 27 boroughs/counties.[*] Figure III.K.5-1 shows the extent of the rectangular modeling domain for which the inventories were developed, along with the locations of the four Class I monitoring sites in Alaska. Even though this rectangular domain extends into portions of Canada, emissions from Canadian sources were not included. In addition, as discussed in Section III.K.5.D, emissions that are potentially transported to Alaska from other areas such as Asia and Russia were also excluded.

[*] What are referred to as "counties" in the contiguous states within the U.S. are termed "boroughs," "municipalities" or "census areas" in Alaska. From this point forward, they are referred to interchangeably.

Figure III.K.5-1
Areal Extent of Alaska Regional Haze Modeling Domain



- *Included Sources* – Emission sources included all known* stationary point and area sources including fugitive dust and both anthropogenic and natural fires and on-road and non-road mobile sources. As discussed later in this section, biogenic and geogenic sources were not included.

- *Calendar Years* – Emission inventories were developed for two calendar years: 2002 and 2018. As explained in Section III.K.5.B, the 2002 inventory is intended to represent emissions during the 2000-2004 five-year average baseline period defined in the Regional Haze Rule. The calendar year 2018 forecasted inventory represents the end of the implementation period for the initial SIP.

- *Temporal Resolution* – The inventories were expressed in the form of annual emissions for the two calendar years listed. However, for all source sectors except stationary point

* All known point area and mobile sources were included with one exception: non-road locomotives. Locomotive emissions in Alaska were obtained from the WRAP in the form of summarized calendar year 2002 and 2018 totals for the entire state. Emissions from locomotives represented less than 0.7% of total statewide emissions for all pollutants, including NOx. Given their relatively minor emission levels and lack of a spatial dataset other than a railroad track centerline layer to distribute locomotive activity and emissions, they were not included in these inventories.

sources and fires, they were developed by summing separate six-month winter and summer season emissions. In many cases, these underlying winter and summer seasonal inventories were developed based on season-specific activity levels and ambient conditions. (Seasonal representation is especially important in Alaska where ambient conditions and activity levels for particular source categories vary significantly over a yearly period.)

- *Spatial Resolution* – Emissions throughout the state were allocated into individual 45-kilometer square grid cells over the rectangular domain shown in Figure III.K.5-1. Depending on the source sector, techniques differed in how emissions were spatially resolved and allocated to grid cells as explained later under Section III.K.5.E.

Given this overview, specific elements of the 2002 baseline and 2018 forecasted inventories are described below.

B. 2002 Baseline Inventory

As described in the Regional Haze Rule,[41] the baseline inventory (and baseline visibility characterizations) should be developed in a manner that, to the extent feasible, represents an average of annual emissions over the period from 2000-2004. The intent is to account for emission sources or events with potentially large variations from year to year that can affect visibility and regional haze. For certain source categories, significant variations in activity (and emissions) can occur. This is especially true in Alaska, where differences in annual emissions from sources such as wildfires or geogenic activity from one year to the next can be substantial, and significantly affect regional haze characterizations depending on how the irregular annual activity from such sources are accounted for.

Therefore, the fire sector of the baseline inventory was developed using 2000-2004 average data obtained from the WRAP Fire Inventory efforts.[42] These data reflect fire activity (from wildfires, wildland fires, and prescribed burns) averaged over this five-year period and likely reflect a less biased estimate of baseline fire emissions than activity in a given individual year. Prescribed fire acreage is typically less that five percent of the entire burned acreage.

For the remaining source categories, the baseline inventory was represented using calendar year 2002 annual activity and emission estimates. For these remaining categories, there is much less "random" variation in source activity from year to year, although in most cases, there are consistent trends in activity for sources related to population, employment or travel (e.g., vehicle miles). For these categories, activity levels that reflect the year 2002 midpoint of the 2000-2004 baseline provide a good estimate of average annual activity over that period. These 2002 activity levels were either directly estimated for specific sources or backcasted from calendar year 2005 levels using trends in county-wide population from 2002 to 2005.

C. 2018 Future-Year Inventory

The 2018 inventory was developed to reflect emission levels projected to calendar year 2018, accounting for forecasted changes in source activity and emission factors. Population projections[43] compiled by the Alaska Department of Labor and Workforce Development (DOLWD) at five-year intervals through 2030 by individual borough and census area were used to grow 2002 baseline activity to 2018 for most of the source categories, with a couple of exceptions.

First, fire sector emissions for wildfires were held constant, reflecting the fact that one cannot reasonable forecast any change in wildfire activity through the state between 2002 and 2018. (As explained later, modest reductions in prescribed burn emissions were assumed, consistent with WRAP 2018b Phase III Fire Inventory forecast.) Second, activity from small port commercial marine vessel activity in 2002 was assumed to be identical to that obtained for calendar year 2005.

Emission factors specific to calendar year 2018 were also developed for source sectors affected by regulatory control programs and technology improvements. These source sectors included on-road and non-road mobile sources (except commercial marine vessels and aviation) and stationary point sources.

While the methodology adopted to forecast the 2018 inventory ensures that there is continuity in the emission sources and activity levels represented, it fails to account for structural changes that will occur. For example, within the stationary source sector, some of the point sources operating in 2002 have already shut down; nevertheless their emissions are forecast to grow in proportion to the population growth rate. Similarly, new and or permitted sources that are not currently operating may be in operation in 2018 and their emissions are not included in the 2018 forecast. An example of a source that has shut down is the Agrium facility located in the Kenai. An example of a permitted source that did not operate in 2002, is not currently operating, but could operate in future years is the Healy Clean Coal Project (HCCP). To the extent that the status of these and other facilities are known their impact on forecasted emissions and visibility will be discussed to provide a more accurate view of potential impacts.

D. Inventories for Specific Source Categories

The regional haze emission inventories were developed largely by integrating emission estimates from a series of earlier inventory efforts[44,45,46,47,48] prepared for specific source sectors and areas within Alaska. These inventory studies were commissioned by ADEC or developed in conjunction with WRAP for criteria pollutant SIP planning and routine reporting purposes, but also with an eye toward representing 2002 and 2018 emissions for all key source sectors statewide for this Regional Haze SIP. Thus, a key component of this effort consisted of assembling these separate inventory datasets into a complete, unified structure that properly accounted for emissions across the entire state for all included source sectors.

Table III.K.5-1 shows the coverage of each of these earlier inventory "components" by source sector and area of the state. For the purpose of combining these earlier study datasets together and as indicated in Table III.K.5-1, the state is represented in three geographic regions:

1. "Big 3" boroughs/counties of Anchorage, Fairbanks and Juneau;
2. Remaining 24 borough/counties; and
3. Large Ports (which is not mutually exclusive and spans both county groups).

As indicated at the bottom left of Table III.K.5-1, fire emissions were represented using the Phase III Fire Inventories obtained from the WRAP and were categorized by fire type (e.g., wildfire, wildland fire, prescribed burn) and an indication of whether it was anthropogenic or natural in origin/cause. As seen in the resulting inventory tabulations, it was critical both to distinguish between anthropogenic and natural fires and to account for the sizable contribution of natural fires within the Alaska Regional Haze inventories.

Table III.K.5-1
Summary of Regional Haze Emission Inventory Components

<table>
<tr><th rowspan="2">Source Sector</th><th colspan="3">Geographic Area in Alaska</th></tr>
<tr><th>Anchorage, Fairbanks, Juneau</th><th>Remaining 24 Boroughs & Census Areas</th><th>Nine Major Ports</th></tr>
<tr><td>Area (excl. wildfires)</td><td rowspan="3">DEC "Big 3"Criteria Pollutant Inventories</td><td rowspan="4">WRAP 2005, 2018 Representative Communities Inventories</td><td>n/a</td></tr>
<tr><td>Non-Road Mobile (excl. Commercial Marine Vessels & Aviation)</td><td>n/a</td></tr>
<tr><td>On-Road Mobile</td><td>n/a</td></tr>
<tr><td>Commercial Marine Vessels</td><td>Anchorage & Juneau from Pechan inventories</td><td>Pechan Alaskan Port 2002, 2005, 2018 Commerical Marine Vessels Inventories</td></tr>
<tr><td>Aviation (aircraft, ground support equipment)</td><td colspan="2">WRAP 2002 Aviation Inventory</td><td>n/a</td></tr>
<tr><td>Point</td><td colspan="2">WRAP 2002 and 2018 Point Source Inventories</td><td>n/a</td></tr>
<tr><td>Fires, Anthro & Natural</td><td colspan="2">WRAP 2002, 2018 Phase III Fire Inventories</td><td>n/a</td></tr>
</table>

n/a – not applicable

Once the inventory data from these earlier studies were assembled into a series of unified datasets covering both the 2002 baseline and 2018 forecast calendar years, initial tabulations were developed to examine emissions by pollutant, county, and source sector. Review of these initial tabulations revealed the need to re-examine some of the growth assumptions that were used to project 2018 emissions in the original studies, ensure specific sources were not double-counted, and refine assumptions that were used to extrapolate county-wide emissions from small community emission surveys for specific counties.

A series of revisions/updates to the originally developed inventory datasets were applied to address these issues and are described in detail as follows.

1. 2002-2018 Growth Revisions

The population forecast employed in the Representative Community Emission Inventory was based on a 2005 forecast from the Alaska Department of Commerce.[*] More recent estimates of the 2005 base year population levels and 2018 forecasts show surprising differences. This discussion focuses on the two boroughs identified in the WEP (weight emission potential) analysis as having the greatest anthropogenic impact on Class I areas: Mat-Su and Kenai. Table III.K.5-2 compares the 2005 estimates and 2018 forecasts available at the time of the Representative Community analysis and more recent estimates. It shows that Mat-Su grew more rapidly in 2005 than originally estimated and that the forecast for 2018 has diminished considerably. The Kenai, on the other hand, shows little change in the 2005 population estimate,

Table III.K.5-2
Changes in 2005 Population Estimates and 2018 Forecasts

Borough	Projection Source	2005	2018	Rate
Mat-Su	Dept. Commerce – 2005	67,210	123,616	1.84
	Dept. Labor – 2007/2008	73,984	105,823	1.43
Kenai	Dept. Commerce – 2005	51,133	62,487	1.22
	Dept. Labor – 2007/2008	51,172	57,102	1.12

but a substantial change in 2018 forecast. Overall, the current forecasts of growth are roughly half the values used in the Representative Community analysis. Since similar reductions were observed for other boroughs, the population forecasts used to drive the 2018 emission estimates for all communities and boroughs were updated with the more current estimates.

Two separate reports from the Department of Labor were used to update the population estimates: the first provides population values by borough between 1990 and 2008;[49] the second provides an updated forecast of population by borough between 2007 and 2030.[50] Three separate forecasts are available: low, middle, and high. The middle values were used to update the emission inventory forecasts.

2. Revisions to Anchorage, Fairbanks, and Juneau Emission Estimates

Emission estimates for Anchorage, Fairbanks, and Juneau included in the Regional Haze emissions inventory came from the Criteria Pollutant Inventory.[51] That effort produced estimates of on-road, non-road and area source emissions. A review of the study found that

[*] 2000 Census Population and 2005 State Demographer Estimated Population, Alaska Department of Commerce, Community, and Economic Development, Community Database Online *http://www.dced.state.ak.us/dca/commdb/CF_COMDB.htm*, September 2006.

wildfire emissions were included for summer months only in the area source estimates. Since wildfire emissions are addressed separately in the Regional Haze inventory, these values were netted out of the emission estimates for Anchorage, Fairbanks, and Juneau.

The previously cited population forecasts used to project growth for the boroughs addressed in the Representative Community analysis were used to update the forecasts for Anchorage, Fairbanks, and Juneau. Table III.K.5-3 compares the values used in the Criteria Pollutant Inventory and the updated values. As can be seen, the growth rates for Anchorage and Fairbanks have increased, while the Juneau growth declined.

Table III.K.5-3
Changes in 2003 Population Estimates and 2018 Forecasts

Borough	Projection Source	2003	2018	Rate
Anchorage	Dept. Labor 1998 - 2018	269,567	298,875	1.11
	Dept. Labor – 2007/2008	271,031	315,925	1.17
Fairbanks	Dept. Labor 1998 – 2018	88,012	98,585	1.12
	Dept. Labor – 2007/2008	85,652	100,244	1.17
Juneau	Dept. Labor 1998 – 2018	31,388	34,447	1.10
	Dept. Labor – 2007/2008	31,047	32,182	1.04

3. Revisions to the Mat-Su and Kenai Emission Estimates

The emission estimates for these boroughs were examined in detail and found to be substantially greater (5-20 times) than the estimates for Anchorage, the most populated borough in the state. The reason is that surrogate communities selected to represent communities in these boroughs, from the Representative Community study, do not well represent the infrastructure available to these boroughs.[*] Key differences are outlined below.

- Most Mat-Su and Kenai communities have access to natural gas from Enstar for space heat. The surrogate communities did not and burned a mixture of distillate fuel oil and wood for space heat, which significantly overstated emissions from space heating.

- All of the representative and surrogate communities include significant levels of fugitive dust from vehicle operations on unpaved roads, whereas most of the roads in the Mat-Su and Kenai communities are paved.

- All the representative and surrogate communities include significant amounts of utility emissions from Diesel generators. Almost all of the communities within Mat-Su and Kenai Boroughs are on the grid from:

[*] That study conducted a detailed survey of activity and fuel use in 13 communities stratified to represent all areas outside of Anchorage, Fairbanks, and Juneau (communities with the largest populations). The results from the surveyed communities were then extrapolated to all communities outside of the three major population centers.

- Chugach Electric,
- Mat-Su Electric,
- Homer Electric,
- Seward Electric, or
- Combinations of the above

Most of the power for these grids, which are interconnected, come from natural gas and hydro power plants. Most, but not all, are located in Anchorage and qualify as major point sources; emissions from these facilities have already been addressed in the Regional Haze inventory. The remaining facilities in Mat-Su and Kenai do not qualify as major point sources.

To address the overestimation of the emissions from communities located within Mat-Su and Kenai Boroughs, new surrogates were identified for most, but not all, communities. Those communities with access to natural gas for space heating, which were identified through discussions with Enstar staff, had Anchorage assigned as their representative community. Those communities identified as on the road system, but without access to natural gas, had Fairbanks assigned as their representative community (as it has no indigenous supply of natural gas). Remaining communities off the road system with their own electricity generation were assigned, depending on their location, either Northway Village or Port Graham as surrogates (the former represents activity on communities connected to the highway system and the latter represents a coastal community with marine activity).

The approach used to prepare emission estimates for these communities was to take the Anchorage and Fairbanks inventories, with the wildfire values netted out, and compute per capita emission estimates in 2002 and 2018 using the population estimates used to prepare each of these inventories. The year/pollutant-specific per capita values were then multiplied by the appropriate population estimates for each of the relevant communities.

A comparison of the results from this effort with the original estimates found a huge reduction in the estimated emissions for each borough. This represents the combination of lower population projections, and the use of more representative emission rates (lower levels of space heating, power generation, and fugitive dust emissions).

Given these revisions, the following sub-sections summarize sources that were represented within individual sectors, as well as provide an indication of which sectors were not included in the Regional Haze inventories and the rationale behind their exclusion.

4. Stationary Point Sources

Stationary point source emissions were based on the 2002 (Inv. 13, Version 4) and 2018 (Inv. 24, Preliminary Reasonable Further Progress, Version 2) Alaska point source inventories obtained from the WRAP.

These point source emissions were used "as is" without any adjustments. Latitude and longitude coordinates provided in the inventory datasets for each facility/source were used to spatially grid the point source emissions.

The Alaska point source inventories contained over 1,800 individual facility/device records encompassing over 130 unique source types as defined by the Source Classification Code (SCC).

a. Electric Generating Units

The point source inventory included emissions from electric generation units (EGU). Both external combustion boilers and internal combustion (IC) engines (turbines and reciprocating IC engines) were represented. Fuel types represented included subbituminous coal, distillate oil, and natural gas.

b. Non-EGU Point Sources

The remaining point sources included fuel combustion from external boilers and IC engines used in non-electricity generation industrial, commercial/institutional, and space heating applications. They also included major point source facility emissions from various industrial processes (e.g., chemical manufacturing, metal production, petroleum industry, oil and gas production), petroleum and solvent evaporation, and waste disposal.

5. Stationary Area Sources

Stationary area sources essentially included those stationary sources not directly represented as major facility point sources within the WRAP Point Source inventory, as well as other source categories for which emissions occur over areas rather than individual locations (e.g., fugitive dust).

Area source emissions were based on the area source components of the Big 3 and Representative Communities inventories. They included the following source types:

- Residential space heating (from fireplaces, wood stoves, fuel oil and natural gas);
- Fugitive dust;
- Surface coatings;
- Used oil combustion;
- Asphalt production and paving;
- Gasoline distribution; and
- Structural fires.

As noted earlier, wildfires were not included within the stationary area source inventories but were treated separately.

6. Non-Road Mobile Sources

Non-road mobile sources were generally developed within the Big 3 and Representative Communities studies using non-road equipment population and activity estimates compiled under those estimates combined with emission factors from EPA's NONROAD model. Source categories represented included the following:

- Off-road vehicles and equipment (loaders, excavators, tractors/dozers, forklifts, scrapers, graders, etc.);
- Lawn and garden tractors;
- Agricultural equipment;
- Pleasure craft;
- Snowmobiles and snowblowers;
- All terrain vehicles; and
- Off-road motorcycles.

Commercial marine vessels and aviation emissions (from both aircraft and ground support equipment) were also included but were treated separately for reporting and tabulation purposes within the Regional Haze inventory.

7. On-Road Mobile Sources

On-road mobile source emissions were based on combinations of on-road vehicle travel activity (i.e., vehicle miles traveled, VMT) combined with vehicle emission factors from EPA's MOBILE6.2 model. Emissions were calculated separately for each of the on-road vehicle types (passenger cars, light-duty trucks, heavy-duty trucks, buses, and motorcycles) defined in MOBILE.

For the Big 3 counties, county-wide travel activity was based on outputs from regional travel demand models or estimates based on traffic counts and road centerline miles as described in the Big 3 Inventory study report. For the remainder of the state, travel activity based on extrapolations from travel estimated within individual survey communities as documented in the Representative Communities study.

8. Biogenic Emissions Sources

Biogenic emissions (from trees and plant vegetation) were not included in these regional haze inventories because no biogenic inventories have been developed for Alaska. (Although biogenic emissions have been estimated for a number of states within the WRAP region, Alaska is not one of them.) Given its northerly location, preponderance of snow and ice cover, and short growing season, it would be problematic to extrapolate "lower 48" biogenic emission factors and activity to Alaska.

9. Geogenic Emissions Sources

Similarly, geogenic emissions (gas/oil seeps, wind erosion, and geothermal and volcanic activity) were also excluded due to lack of available data.

10. Wild and Other Fires

Fire emissions (except from structural fires) were based on the Phase III Fire Inventories obtained from the WRAP. The 2002 inventory came from the baseline 2000-2004 average fire inventory developed by the WRAP. The 2018 inventory was based on WRAP's 2018b projected inventory, which applied estimated emission reductions from the application of fire emission reduction techniques[52] to controllable emissions from prescribed and agricultural fires.

Fire sources included wildfires, wildland and range fires and prescribed burns. Latitude and longitude coordinates of the centroids of each individual fire contained within the WRAP datasets were used to spatially grid these fire emissions, as described later in Section III.K.5.E. Over 1,000 individual fires were represented in these inventories for Alaska.

11. International Transported Emissions

Internationally transported emissions were not included in these inventories. A number of studies such as Pollisar, et al. (2001)[53] have been conducted that have attributed atmospheric aerosols measured in Alaska to contributions from upwind regions as far away as portions of Asia and Russia based on back trajectory analysis and identification of unique chemical source signatures; however, robust emission estimates from these source areas are not available. Thus, no attempt was made to account for these international, long-range transported sources.

It is also noted that emission reductions developed to comply with the "glide path" requirements of the Regional Haze Rule that exclude contributions from other known sources, such as internationally transported sources will be directionally conservative (i.e., overstate the required reductions for in-state sources that were included).

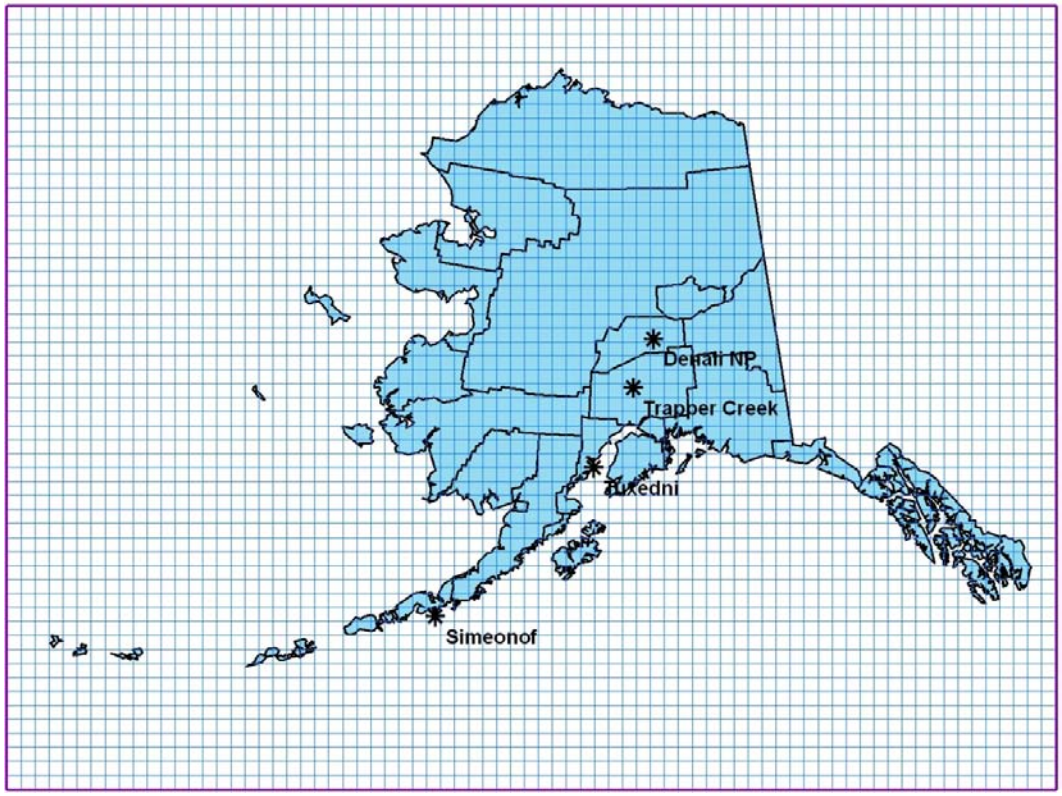
E. Inventory Processing and Gridding

1. Grid Domain

Once the inventory datasets were assembled and updated as described in Section III.K.5.D, the emissions data were spatially allocated into a modeling grid domain. The grid domain was based on one developed under an earlier WRAP study[54] for which a modeling protocol was developed and MM5-based meteorological datasets were prepared. This Alaska Grid domain is shown below in Figure III.K.5-2. It is defined on a polar stereographic projection, with central latitude 59°N and central longitude 101°W and a datum that assumes a perfectly spherical earth with a radius of 6370.997 km. This grid consists of 45 km square cells, with 75 cells (76 dot points) in the east-west direction and 56 cells (57 points) running north-south.

(This domain is smaller than the original domain developed under the earlier WRAP study. Once it was determined that only in-state emissions would be considered under for this effort, the original 45 km domain, which encompassed 108 east-west cells and 89 north-south cells and extended into Russia as well as western Canada, Washington and Oregon, was downsized to that depicted in Figure III.K.5-2.)

Figure III.K.5-2
Alaska Regional Haze Inventory 45 Km Grid Structure



2. Spatial Allocation

Emissions by source category were allocated into individual cells in the Alaska Grid domain using a more simplified approach than typically applied in gridded inventory development. Given the size of the grid cells (45 km square) as well as the size of populated areas within Alaska (and relative isolation from one area to the next), emissions for most of the source categories were geo-located into individual cells based on the city or town to which they were attributed. These spatial allocation methods are described below.

As described earlier, emissions from the following source sectors in all counties except Anchorage, Fairbanks, and Juneau were determined based largely on population-based extrapolations:

- Area sources (excluding fires);
- Non-road mobile sources (excluding commercial marine and aviation); and
- On-road sources.

Given the large size of the grid cells in relation to the size of all but the largest cities in the state (i.e., Anchorage, Fairbanks, and Juneau), emissions from these source categories were allocated to individual cities and towns based on populations and then allocated into a grid cell treating each city/town as a "point" source. U.S. census-based latitude and longitude coordinates for each of over 400 individual cities, towns, or tribal villages were used to assign emissions from the source sectors above to the appropriate grid cell.

For the three counties/boroughs containing the largest cities—Anchorage, Fairbanks, and Juneau—spatial emission allocations were more refined. A 2000 U.S. Census-based census block-level GIS shapefile layer was used to allocate county-wide emissions compiled for these three counties from the "Big-3" criteria pollutant inventories to specific grid cells. (Census "blocks" are the smallest and most spatially-resolved entity represented in the Census.) Cell allocations were based on the centroid location of each census block and were performed within ArcGIS.

Spatial allocation of emissions from commercial marine vessels, aviation, and fires was performed similarly, but not identically, to that described above for area, non-road, and on-road sources outside the Big-3 counties. First, commercial marine vessels emissions from the large ports represented in the Pechan study were allocated to the grid cell where each of the nine ports was located. Commercial marine vessels emissions for the roughly 160 small ports/harbors from the Representative Communities study were also "point" allocated to grid cells based on a single latitude/longitude coordinate set for each point. Second, aviation emissions (from aircraft and ground support equipment operation) were allocated using latitude/longitude coordinates for each of the over 1,200 airports, airfields, or airstrips obtained from the Federal Aviation Administration (FAA) or Alaska Department of Transportation and Public Facilities (DOT&PF) databases used to develop the emission estimates. Finally, fire emissions were also allocated as "point" sources based on the latitude/longitude coordinates assigned to each separate fire (wildfire, wildland fire or prescribed burn) in the Phase III WRAP Fire baseline database. (The largest individual fires represented in this database were still less than one-third the size of an individual grid cell, thus allocation accuracy using this "point" approach was not substantially affected.) Note that the commercial marine vessels, aviation, and fire source allocations were identical to those for area, non-road, and on-road sources except the allocations were based on directly represented activity and emissions for each source entity, rather than population-based allocations.

Finally, stationary point sources were allocated to grid cells in the "traditional" manner, based on the coordinates of each emitting device represented in the WRAP Point Source database for Alaska.

3. Gridded Emissions by Source Sector

Using the methods described above, emissions by county were allocated into cells within the modeling domain. To provide a better understanding of emission contributions impacting each Class I monitor, the data were gridded into separate layers by source sector as follows:

- Area (stationary area sources excluding fires);
- Non-Road (excluding commercial marine vessels and aviation);
- On-Road;
- Point;
- Commercial Marine Vessels;
- Aviation (aircraft and ground support equipment);
- Anthropogenic Fires (prescribed burns); and
- Natural Fires (wildfires, wildland fires and some prescribed burns).

Figures III.K.5-3 through III.K.5-10 present samples of these sector-specific gridded inventories, showing 2002 $PM_{2.5}$ emissions shaded density plots (in tons/year) for each individual sector in the order listed above. Note that the density intervals are not fixed, but increase geometrically. Thus, cells with medium or dark brown shading represent emission densities several orders of magnitude greater than the lightest shading. The geometric interval widths were necessary to keep the same set of intervals across all source sectors.

Although $PM_{2.5}$ area and non-road sources are more widespread throughout the state (with a larger number of shaded cells as seen in Figures III.K.5-3 and III.K.5-4), natural fires exhibit much greater emissions (and emission densities) than any other sector as seen in Figure III.K.5-10.

Similar plots to these were prepared for each of the other pollutants, for both the 2002 and 2018 inventories and provided to the WRAP's contractor ENVIRON as the basis for preparing Weighted Emission Potential (WEP) inventories described later in Section III.K.7.

Figure III.K.5-3
Baseline 2002 $PM_{2.5}$ Gridded Area Source Emissions (tons/year)

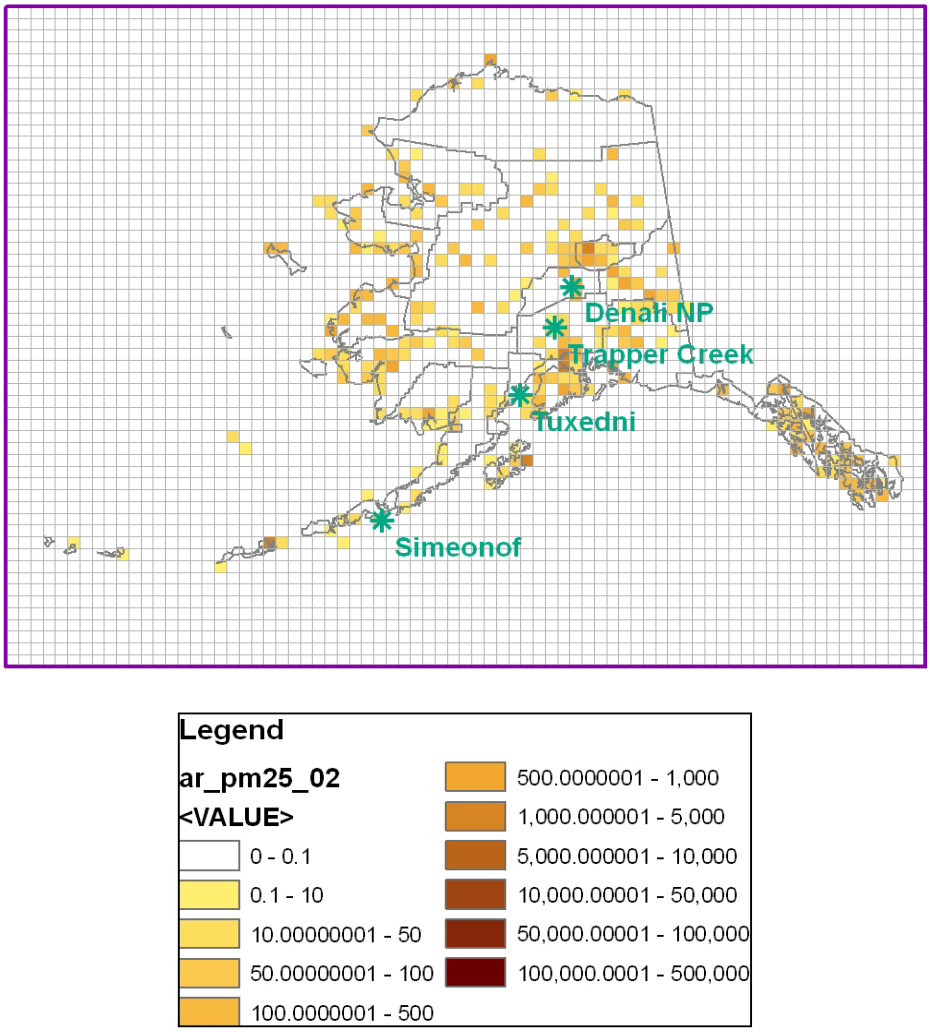
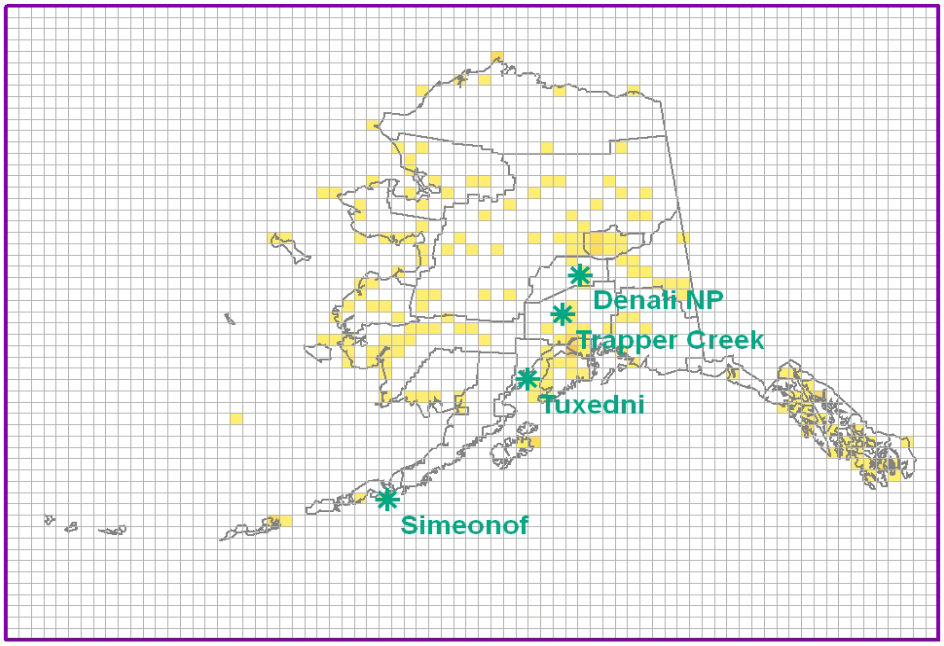


Figure III.K.5-4
Baseline 2002 $PM_{2.5}$ Gridded Non-Road Mobile Source (tons/year)



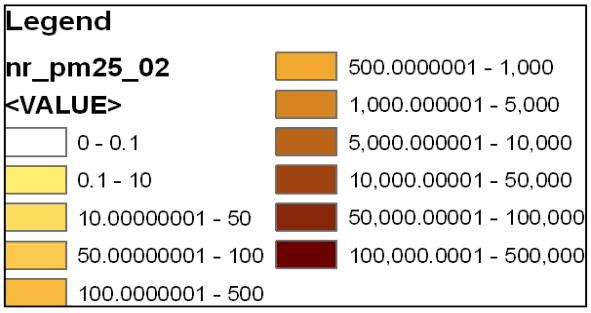


Figure III.K.5-5
Baseline 2002 $PM_{2.5}$ Gridded On-Road Mobile Source Emissions (tons/year)

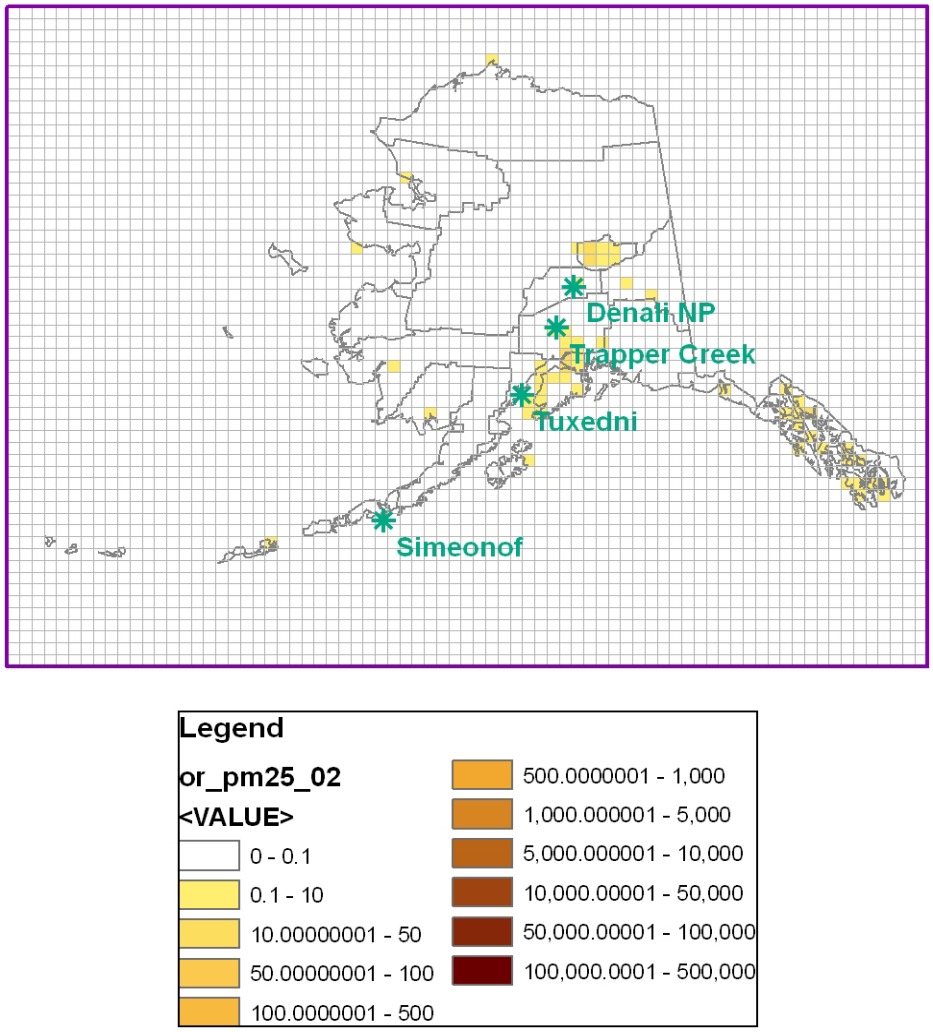
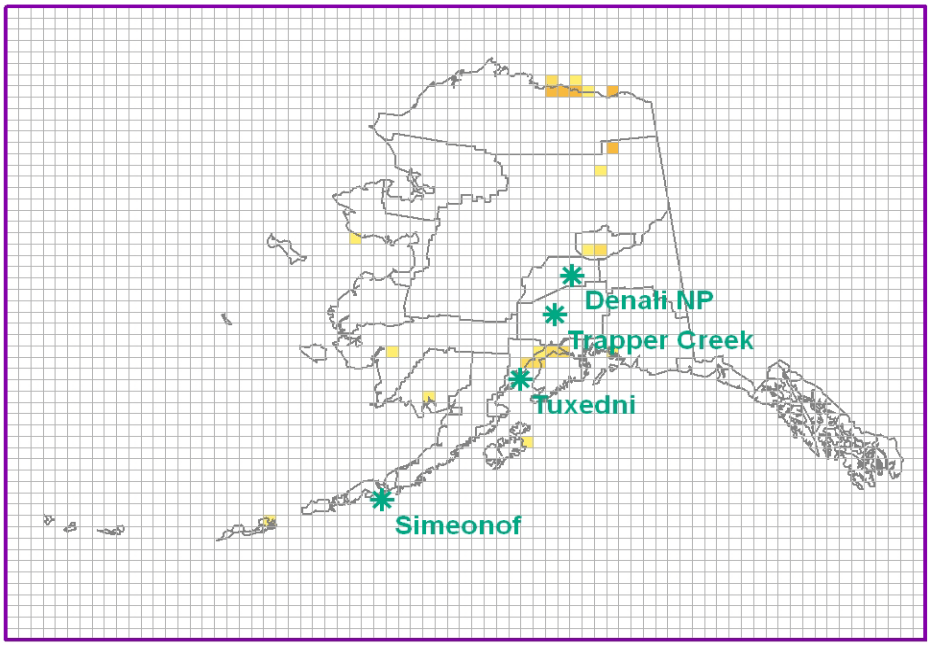


Figure III.K.5-6
Baseline 2002 $PM_{2.5}$ Gridded Point Source Emissions (tons/year)



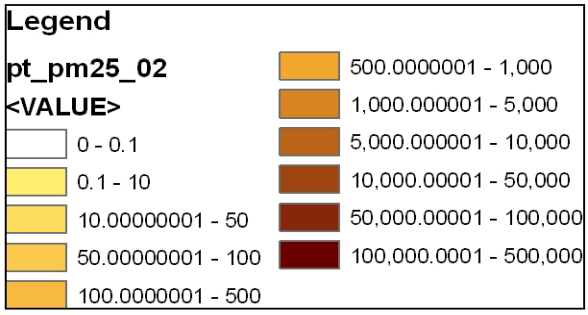


Figure III.K.5-7
Baseline 2002 $PM_{2.5}$ Gridded Commercial Marine Vessel Emissions (tons/year)

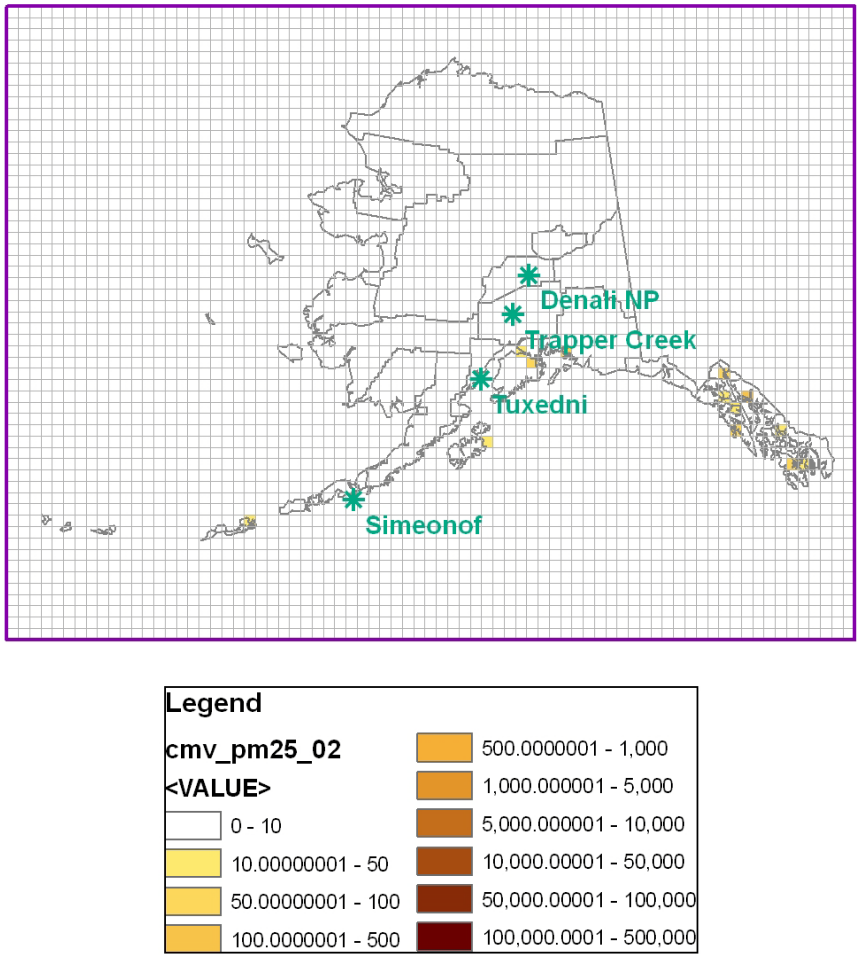
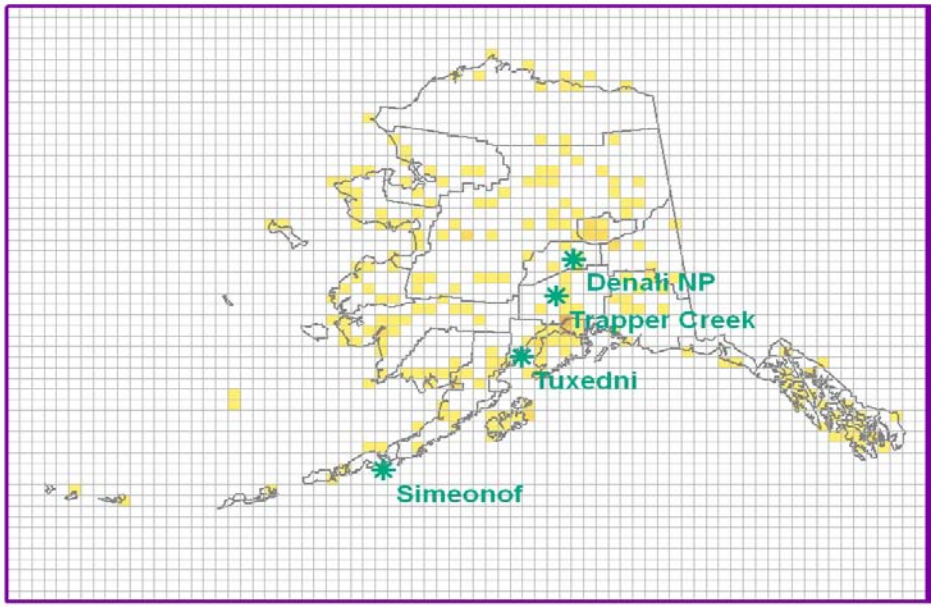


Figure III.K.5-8
Baseline 2002 $PM_{2.5}$ Gridded Aviation Source Emissions (tons/year)



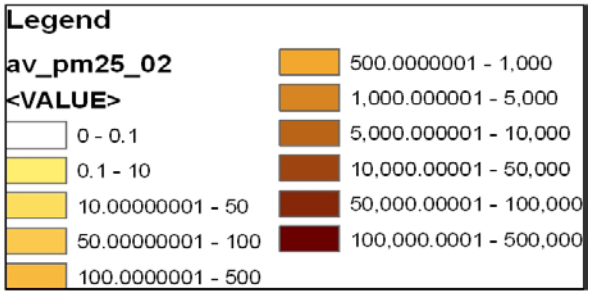
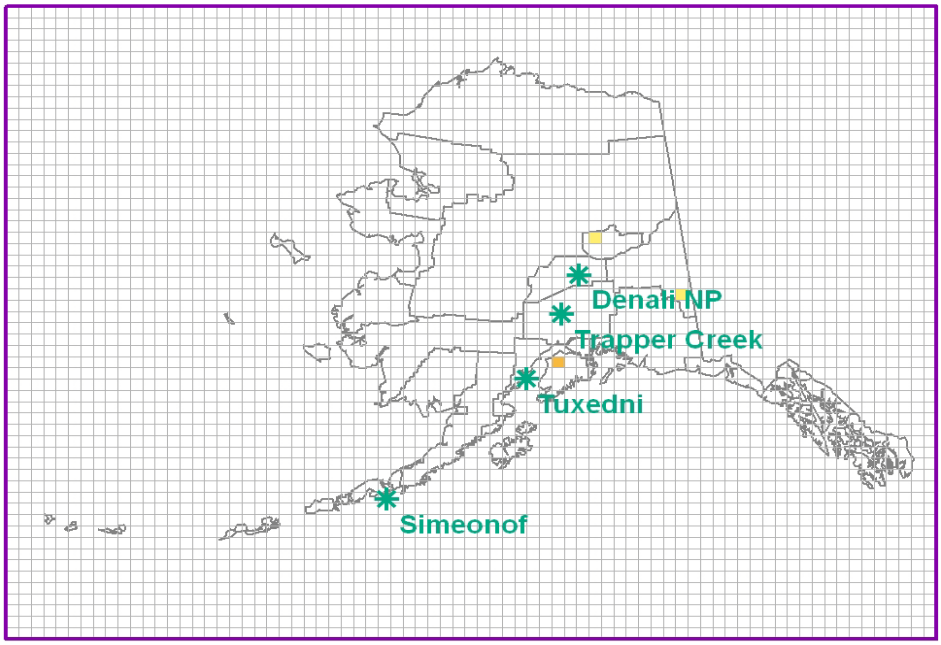


Figure III.K.5-9
Baseline 2002 $PM_{2.5}$ Gridded Anthropogenic Fire Emissions (tons/year)



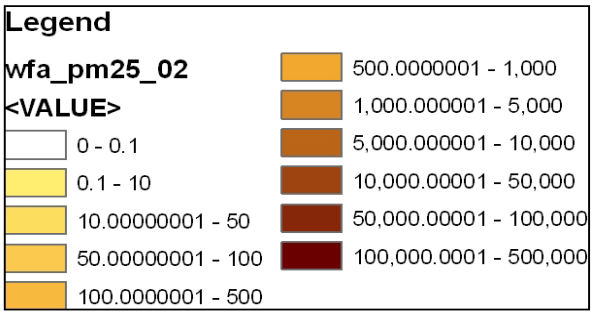
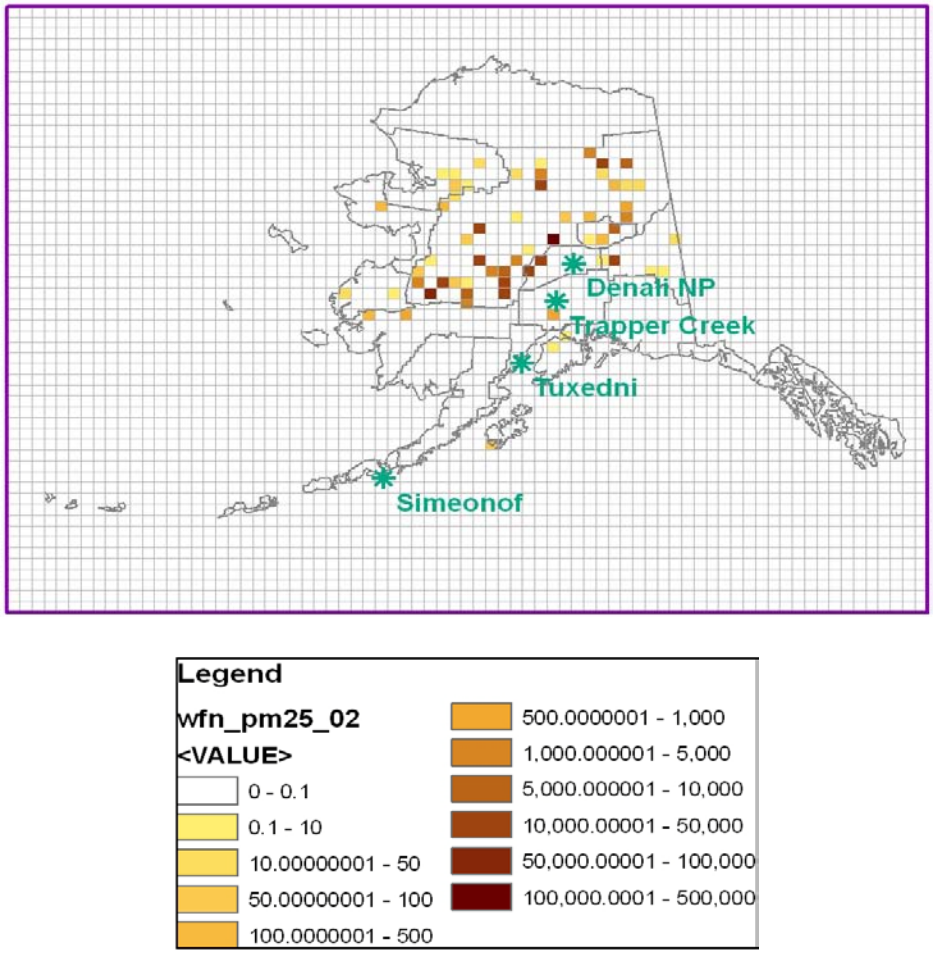


Figure III.K.5-10
Baseline 2002 $PM_{2.5}$ Gridded Natural Fire Emissions (tons/year)



F. Summary of Emission Inventories

In addition to the sector-specific 2002 and 2018 gridded emission inventory datasets described in the preceding sub-section, tabular emission summaries of total statewide and county-by-county emissions by source sector were also prepared.

Tables III.K.5-4 and III.K.5-5 show total statewide emissions (in tons/year) by source sector and pollutant for the calendar year 2002 and 2018 inventories, respectively. In addition to the totals across all source sectors, anthropogenic emission fractions (defined as all sectors except natural fires divided by total emissions) are also shown at the bottom of each table.

Table III.K.5-4
2002 Alaska Statewide Regional Haze Inventory Summary

Source Sector	Annual Emissions (tons/year)						
	HC	**CO**	**NOx**	**PM_{10}**	**$PM_{2.5}$**	**SOx**	**NH_3**
Area, Excluding Wildfires	128,271	81,978	14,742	106,985	30,636	1,872	0
Non-Road	7,585	52,223	4,111	416	392	49	8
On-Road	7,173	80,400	7,077	204	158	324	307
Commercial Marine Vessels	356	2,880	11,258	663	643	4,979	5
Aviation (Aircraft & GSE)	1,566	21,440	3,265	699	667	335	6
Point	5,697	27,910	74,471	5,933	1,237	6,813	580
Wildfires, Anthropogenic	98	2,048	46	200	172	13	9
Wildfires, Natural	274,436	5,831,755	125,110	557,403	478,057	34,304	26,233
TOTAL - All Sources	**425,181**	**6,100,633**	**240,080**	**672,502**	**511,962**	**48,689**	**27,149**
Anthropogenic Fraction	**35.5%**	**4.4%**	**47.9%**	**17.1%**	**6.6%**	**29.5%**	**3.4%**

As Tables III.K.5-4 and III.K.5-5 clearly show, natural wildfires represent an overwhelming majority of emissions for all pollutants except NOx, for which they still contribute nearly half of all emissions statewide.

Table III.K.5-5
2018 Alaska Statewide Regional Haze Inventory Summary

Source Sector	Annual Emissions (tons/year)						
	HC	CO	NOx	PM_{10}	$PM_{2.5}$	SOx	NH_3
Area, Excluding Wildfires	137,696	88,030	15,683	116,629	33,329	2,068	0
Non-Road	7,766	65,900	3,332	337	313	47	9
On-Road	2,946	44,881	2,881	138	74	39	340
Commercial Marine Vessels	616	4,751	16,205	1,031	1,192	1,129	9
Aviation (Aircraft & GSE)	1,799	24,387	3,810	794	757	386	7
Point	6,612	24,406	65,230	1,783	358	8,587	1,106
Fires, Anthropogenic	53	1,100	26	107	93	7	5
Fires, Natural	274,436	5,831,755	125,110	557,403	478,057	34,304	26,233
TOTAL - All Sources	**431,925**	**6,085,210**	**232,277**	**678,223**	**514,173**	**46,568**	**27,709**
Anthropogenic Fraction	**36.5%**	**4.2%**	**46.1%**	**17.8%**	**7.0%**	**26.3%**	**5.3%**

Table III.K.5-6 summarizes the relative changes in statewide emissions by source sector and pollutant from 2002 to 2018. Emission increases (positive changes) are shown in black; emission decreases (negative changes) are shown in red.

Table III.K.5-6
Relative Change in Alaska Regional Haze Emissions from 2002 to 2018

Source Sector	Percentage Emissions Change 2002-2018						
	HC	CO	NOx	PM_{10}	$PM_{2.5}$	SOx	NH_3
Area, Excluding Wildfires	+7.3%	+7.4%	+6.4%	+9.0%	+8.8%	+10.4%	+20.7%
Non-Road	+2.4%	+26.2%	-18.9%	-19.1%	-20.2%	-4.2%	+14.9%
On-Road	-58.9%	-44.2%	-59.3%	-32.3%	-53.2%	-87.9%	+10.7%
Commercial Marine Vessels	+73.0%	+65.0%	+43.9%	+55.5%	+85.3%	-77.3%	+68.6%
Aviation (Aircraft & GSE)	+14.9%	+13.7%	+16.7%	+13.6%	+13.5%	+15.5%	+15.5%
Point	+16.1%	-12.6%	-12.4%	-69.9%	-71.1%	+26.0%	+90.8%
Fires, Anthropogenic	-45.5%	-46.3%	-43.8%	-46.2%	-46.0%	-43.8%	-45.8%
Fires, Natural	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
TOTAL - All Sources	**+1.6%**	**-0.3%**	**-3.3%**	**+0.9%**	**+0.4%**	**-4.4%**	**+2.1%**

As seen in Table III.K.5-6, relative changes in pollutant emissions from 2002 to 2018 are very modest due to the large emissions contribution from natural fires, which were assumed to remain constant over this period. Even so, decreases in total NOx and SOx emissions of 3.3% and 4.4%

are projected on a statewide basis. However, these emission decreases are partially offset by lesser relative increases in statewide VOC, PM, and NH_3 emissions.

Appendix III.K.5 presents more detailed versions of these statewide emission summary tabulations, broken down county-by-county.

In addition to providing summaries of the 2002 and 2018 inventories, these tabulations were also used to independently cross-check the gridded emission allocations to ensure there were no lost or double-counted sources resulting from the spatial allocations. These cross-checks were performed by comparing the tabular summary data in Tables III.K.5-4 and III.K.5-5 to exported versions of the grid plots that were then totaled across all grid cells in the modeling domain. These cross-checks were performed by individual source sector.

III.K.6 BEST AVAILABLE RETROFIT TECHNOLOGY CONTROL PROGRAM (BART)

EPA released the Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations; Final Rule, on July 6, 2005. The rule set out how states are to address the visibility impacts of certain stationary source (source) categories on federally designated Class I areas and to establish emission limits for sources. ADEC followed the federal BART rule and conducted an extensive BART process. This section provides an overview of ADEC's regulation and public process, followed by a review of the process and determination for each BART-eligible facility. It is important to note that the BART sources started following the 18 AAC 260 regulations in advance (beginning in May 2007) and adhered to the regulations prior to their promulgation in December 2007. One facility completed the BART process prior to the regulations being in effect and an additional initially identified source did not have to complete the process at all.

A. Alaska BART Regulations Overview and Public Process

1. Public Process for BART Determinations

An essential element of the BART process is an open public examination for the BART determinations for the affected sources to ensure that the process protects the visibility of Class I areas based on available scientific analysis.

This public process included identification of BART eligible sources and units; WRAP modeling to determine which identified sources were subject to BART; inclusion of regulations that allowed sources to apply for an enforceable Owner Requested Limit (ORL); and regulations requiring BART subject sources to analyze control technologies to enable ADEC to determine final enforceable emission limits and compliance.

To ensure that the BART process was clearly followed by sources, the BART guidelines were promulgated in Alaska Regulation 18 AAC 50.260. These regulations established the procedures sources would need to follow. Sources determined to be subject to BART were therefore required to implement emission controls unless they could verify through the process delineated in 18 AAC 50.260 that its emission units were not subject to BART.

2. BART Process in Regulations: 18A AAC 50.260

In April 2007, ADEC proposed regulations to adopt the federal BART rules into 18 AAC 50.260 to establish the process and specific steps for the BART eligible sources to follow to provide the analysis necessary for ADEC to make BART determinations. ADEC's regulations adopting the federal BART rules were promulgated on December 30, 2007. Those regulations clearly outlined the BART process, with required elements addressed in the regulation subsections summarized below.

In 18 AAC 50.260(a), ADEC adopts the federal BART guidelines and some revised definitions from 40 C.F.R. 51.301 applicable to the BART process.

18 AAC 50.260(b) specifies that sources subject to BART be identified in accordance with Section III of the BART guideline and sets the date by which ADEC will notify subject sources of their status.

18 AAC 50.260(c) establishes the procedures by which a source can request an exemption from BART by submitting a visibility impact analysis showing that the source is not reasonably anticipated to cause or contribute to any impairment of visibility in a Class I area. 18 AAC 50.260(c) also provides the procedure by which, if a source is denied an exemption, it can apply for an ORL under 18 AAC 50.225 that limits emissions to a level below which the source is not reasonably anticipated to cause or contribute to any impairment of visibility in a Class I area.

18 AAC 50.260(d)-(*l*) establish the process that sources that did not request or receive an exemption or an ORL must undertake to conduct control technology visibility impact analysis modeling.

- Subsection (d) establishes the procedure for the submittal and approval of a BART assessment modeling protocol.
- Subsection (e) establishes the timeline for submittal of an analysis that is consistent with Section IV of the BART guidelines.
- Subsection (f) identifies the pollutants of concern.
- Subsection (g) establishes that if an owner or operator applies the most stringent controls available that are consistent with the analysis conducted under (e), they will not be required to conduct a visibility impact analysis.
- Subsection (h) addresses the requirements that the visibility impact analysis must meet.
- Subsection (i) allows ADEC to request any additional information needed to complete the review of the analysis.
- Subsection (j) establishes the method ADEC will use to make a preliminary BART determination.
- Subsection (k) sets out the public notice procedures for a preliminary BART determination.
- Subsection (l) establishes how a final BART determination will be made after the public notice period.

18 AAC 50.260(m) establishes how a final BART determination may be appealed.

18 AAC 50.260(n) establishes the deadline by which a source must implement a final BART determination.

18 AAC 50.260(o) requires the owner or operator of a source required to install control technology to maintain the equipment and conduct monitoring, recordkeeping, and reporting in accordance with the final BART determination.

18 AAC 50.260(p) sets out how ADEC work on BART determinations would be billed.

18 AAC 50.260(q) sets out the definitions used in the section that are not found in 18 AAC 50.990.

3. Identification of BART-Eligible Sources

ADEC conducted a preliminary review of Title V permits to identify sources that could potentially be eligible for BART under the federal rule. ADEC then worked in conjunction with WRAP to identify BART eligible sources from this preliminary BART source list. WRAP contracted with Eastern Research Group, Inc. (ERG) to determine BART eligibility of the sources from the federal rule criteria based on age of emission units, size of source emissions, and the CAA list of stationary source categories. ERG produced its report in April 2005, which found that the following seven sources were determined to be eligible for BART:

- Chugach Electric, Beluga River Power Plant;
- Alyeska Pipeline Service Company, Valdez Marine Terminal (Alyeska);
- Tesoro, Kenai Refinery;
- Anchorage Municipal Light and Power, George Sullivan Plant 2;
- ConocoPhillips Alaska Inc., Kenai LNG Plant (CPAI);
- Agrium, Chemical-Urea Plant; and
- Golden Valley Electric Association, Healy Power Plant (GVEA).

4. Identification of BART Eligible Emission Units

ADEC conducted three workshops with the seven BART-eligible sources from January to March 2007. In the workshops, ADEC presented the federal BART Rule, explained what the rule would mean for the sources, and explained how it was determined which sources had BART eligible emission units and would be subject to BART. As part of this process, ADEC also established BART determination and compliance regulations.

In the first workshop, there were concerns from sources that the WRAP list of BART eligible emission units included units that should not be BART eligible. ADEC further examined the Title V permits of the seven sources to establish emission unit lists for each source that was BART eligible. Based on the analysis, ADEC contacted the sources in April 2007, with the list of emission units that were considered BART eligible. The facilities provided additional information on the emission units to ADEC. After review and analysis by ADEC and EPA of

the additional information, a final list of BART eligible emission units was established. Sources were notified in May 2007 of the final list of eligible emission units. One source, Chugach Electric Association, Beluga River Power Plant was determined to not be BART eligible due to the replacement of the BART-eligible emission units with ones that were not BART eligible (Documentation is provided in Appendix III.K.6.). The remaining six sources listed above were determined to have BART eligible emission units and followed 18 AAC 50.260.

a. Preliminary Determination of Which BART-Eligible Sources are Subject to BART

Under 18 AAC 50.260 and the BART guidelines, BART status is determined by conducting a visibility impact analysis using emissions from the BART eligible emission units (at the identified source) to determine if they impact visibility at a Class I area. ADEC provided the results of WRAP and ERG's research and known emission rates to WRAP in 2005. WRAP conducted preliminary visibility impact analysis modeling to determine which sources could be reasonable anticipated to be causing or contributing to visibility impairment at two Class I areas in Alaska: Denali National Park and Tuxedni National Wildlife Refuge.

WRAP's preliminary modeling indicated that the seven facilities initially identified as BART-eligible sources could be reasonably anticipated to cause or contribute to visibility impacts at Denali, Tuxedni, or both. Based on the visibility impact modeling, all seven sources were determined to be subject to BART. A 0.5 deciview threshold was used to determine if a source was causing or contributing to visibility impairment.

b. Analysis of Visibility Impacts from Subject to BART Sources

The preliminary visibility impact modeling was conducted using potential to emit (PTE) emission data, rather than a more refined data set based on actual emission rate data that were available. As a result, the facilities were concerned that the WRAP modeling results showing that they all caused or contributed to visibility impairment at either or both of the Class I areas might not be accurate. ADEC reviewed the WRAP modeling data set methodology to ensure accuracy and provided more precise emission data for a revised impact modeling assessment.

A second visible impact modeling review of the data sets was conducted in conjunction with the FLMs of the federal agencies responsible for the Class I area, EPA staff, the sources, and their consultants. All parties agreed to develop a refined meteorological data set and the use of actual emission rates. Improvements to the meteorological data set and modeling protocols included an additional three-year meteorological data set (MM5). Additionally, the sources, ADEC, EPA, and the FLMs worked together to develop a more detailed CALMET modeling protocol using the additional meteorological data. The sources also used actual emission levels when they conducted the additional modeling.

A description of the outcome of the revised modeling for each facility is presented below. Generally, the use of the refined meteorology led to lower visibility impacts.

B. BART Determination Process

1. Chugach Electric Association, Beluga River Power Plant

Under the BART guidelines and 18 AAC 50.260(b), Chugach Electric, Beluga River Power Plant (Chugach) was not a stationary source that was BART eligible. Chugach was determined to not be BART eligible due to the replacement of the BART-eligible emission units with ones that were not BART eligible.

In April 2007, ADEC sent a letter to Chugach officials regarding the status of its BART eligible emission units. Chugach responded in April 2007 with information that the BART-eligible emission units had been replaced and the plant had become a "steam electric plant" after the BART timeframe. EPA concurred with ADEC on the reclassification of the source as having occurred after the BART timeframe.

DEC notified Chugach on May 7, 2007, that the facility was not subject to the BART Rule and would not need to do any further work relating to the rule (see correspondence in Appendix III.K.6).

2. Alyeska Pipeline Service Company, Valdez Marine Terminal

DEC determined that Alyeska Pipeline Service Company, Valdez Marine Terminal (Alyeska) met the requirements to be exempted from BART under 18 AAC 50.260(c)(4).

Alyeska participated in the extensive efforts in the spring and summer of 2007 to develop the MM5 data set which could be used to run more refined modeling analyses.

In accordance with the notification requirements in 18 AAC 50.260(b), ADEC notified Alyeska on December 28, 2007, that the facility was a BART eligible facility and would need to comply with 18 AAC 50.260. On July 13, 2007, Alyeska submitted to ADEC its draft Assessment of Potential Visibility Impacts in compliance with a request for exemption from BART under 18 AAC 50.260(c)(4). ADEC reviewed the submittal and requested some revisions to the analysis in October 2007. The revised analysis report was submitted on November 7, 2007. ADEC reviewed the revised modeling analysis and concluded that it showed that Alyeska did not cause or contribute to visibility impairment at either Tuxedni or Denali at or above 0.5 deciview.

ADEC notified the company of its BART exempt status on November 23, 2007 (see correspondence in Appendix III.K.6).

3. Tesoro, Kenai Refinery

DEC determined that Tesoro, Kenai Refinery (Tesoro) met the requirements to be exempted from BART under 18 AAC 50.260(c)(4).

Tesoro participated in the extensive efforts in the spring and summer of 2007 to develop the MM5 data set that could be used to run more refined modeling analyses. Tesoro also participated in the development of the revised CALMET modeling protocol, which it then used to run additional modeling.

In accordance with the notification requirements in 18 AAC 50.260(b), ADEC notified Tesoro on December 28, 2007, that the facility was a BART eligible facility and would need to comply with 18 AAC 50.260. Tesoro submitted its modeling protocol to ADEC on January 22, 2008, and submitted additional information on January 25, 2008. ADEC reviewed the protocol, and it was approved on April 17, 2008.

Tesoro completed its modeling analysis and submitted the data in compliance with a request for exemption from BART under 18 AAC 50.260(c)(4) on May 16, 2008. ADEC contracted the review of the modeling analysis on July 1, 2008. The review and recommendation from the contractor was completed on August 12, 2008. ADEC reviewed the report and concluded that Tesoro's Kenai Refinery did not cause or contribute to visibility impairment at either Tuxedni or Denali at or above 0.5 deciview.

DEC notified the company of its BART exempt status on August 18, 2008 (see correspondence in Appendix III.K.6).

4. Anchorage Municipal Light & Power, Sullivan Plant

DEC determined that Anchorage Municipal Light & Power (Anchorage MLP) met the requirements to be exempted from BART under 18 AAC 50.260(c)(4).

Anchorage MLP participated in the extensive efforts in the spring and summer of 2007 to develop the MM5 data set which could be used to run more refined modeling analyses. Anchorage MLP also participated in the development of the revised CALMET modeling protocol, which it then used to run additional modeling.

In accordance with the notification requirements in 18 AAC 50.260(b), ADEC notified Anchorage MLP on December 28, 2007, that the facility was a BART eligible facility and would need to comply with 18 AAC 50.260. Anchorage MLP submitted its modeling protocol to ADEC on October 12, 2007. ADEC reviewed the protocol, and it was approved on January 8, 2008.

Anchorage MLP completed its modeling analysis and submitted the data in compliance with a request for exemption from BART under 18 AAC 50.260(c)(4) on March 10, 2008, and submitted additional information on March 22, 2008. ADEC contracted the review of the modeling analysis on July 1, 2008. The contractor found problems with the exemption modeling, and ADEC requested additional information from Anchorage MLP on August 7, 2008. The additional information was provided on August 27, 2008. The review and recommendation from the contractor was completed on October 2, 2008. ADEC reviewed the report and concluded that Anchorage MLP's Sullivan Plant did not cause or contribute to visibility impairment at either Tuxedni or Denali at or above 0.5 deciview.

DEC notified the company of its BART exempt status on October 3, 2008 (see correspondence in Appendix III.K.6).

5. ConocoPhillips Alaska, Inc. Kenai LNG Plant

ConocoPhillips Alaska, Inc. Kenai LNG Plant (CPAI) signed a Compliance Order By Consent (COBC) with ADEC. The COBC limits the hours of operation of the BART eligible units and requires the monitoring and recording of emissions from them to ensure NOx emissions remain at or below a maximum daily rate of 5,467 lbs.

CPAI contributed to the efforts in the spring and summer of 2007 to develop the MM5 data set which could be used to run more refined modeling analyses. CPAI also contributed to the development of the revised CALMET modeling protocol, which it then used to run additional modeling. However, from April 3, 2007, on, CPAI has disputed that the Kenai LNG Plant is a "fuel conversion plant" as defined in the Clean Air Act (CAA) and therefore holds that it should not be a BART-subject source. As a result of the position that the Kenai LNG Plant should not be defined as a "fuel conversion plant," CPAI submitted nearly all of its requests and applications under protest. ADEC and EPA conferred and agreed that, according to federal guidance, the Kenai LNG Plant is a fuel conversion plant and is therefore subject to BART (see EPA letter of November 14, 2007, provided in Appendix III.K.6). CPAI continues to maintain that it is not a "fuel conversion plant."

In accordance with the notification requirements in 18 AAC 50.260(b), ADEC notified CPAI on January 4, 2008, that the facility was a BART eligible facility and would need to comply with 18 AAC 50.260. CPAI submitted its modeling protocol to ADEC on February 1, 2008. ADEC reviewed the protocol, and it was approved on February 28, 2008.

CPAI completed their modeling analysis and submitted the data in compliance with a request for exemption from BART under 18 AAC 50.260(c)(4) on April 25, 2008. ADEC reviewed the analysis and denied the exemption request because the analysis showed that the maximum 24-hour change in visibility in at least one Class I area was greater than the 0.5 deciview threshold.

On May 14, 2008, ADEC notified CPAI of the denial of the exemption and of its option under 18 AAC 50.260(c)(5) to submit either a BART control analysis or an application for an ORL in accordance with 18 AAC 50.225.

CPAI submitted an application for an ORL on June 18, 2008. The required public notice was published on August 26, 2008. The public notice and public comment period were suspended on September 19, 2008, when CPAI concluded that it would be unable to meet the conditions of the ORL and requested that ADEC suspend the notice so that CPAI and ADEC could discuss establishing an appropriate schedule for reducing emissions. CPAI submitted a revised ORL application on November 17, 2008, along with revised modeling analysis. The ORL was publicly noticed on January 15, 2009, and the public notice was extended on both February 16, 2009, and March 2, 2009. Upon the conclusion of the public comment period on March 23, 2009, ADEC received comments solely from CPAI, on March 23, 2009. CPAI stated that it still would be unable to comply with the schedule established in the ORL. It was determined that ADEC and CPAI would be unable to reach a satisfactory conclusion for issuing an ORL.

Prior to the end of the public comment period, ADEC and CPAI had begun discussing whether a COBC would be a more logical resolution to ensuring emission reductions from the Kenai LNG Plant given CPAI's position that it is not a "fuel conversion plant" and ADEC's desire to meet the requirements of the BART Rule. CPAI agreed to provide its control technology analysis to ADEC so that all options could be evaluated, including an ORL and the reductions that would result from a COBC.

DEC contracted to have the analysis reviewed and evaluated to determine whether the reductions that would be achieved by the proposed ORL would be at least equal to those that could be reasonably achieved by any of the other control options. The Department of Law (DOL), ADEC, and CPAI worked together to write a COBC that ensures that after December 31, 2013, the emissions from the identified BART eligible units at the Kenai LNG Plant will be limited to a level that would keep the plant from causing or contributing to visibility impairment in at least one Class I area at equal to or greater than the 0.5 deciview threshold.

The COBC was signed by all concerned parties and became effective on August 7, 2009 (see correspondence in Appendix III.K.6).

6. Agrium, Chem-Urea Plant

Under 18 AAC 50.260(e)-(*l*), Agrium, Chem-Urea Plant (Agrium) will have a zero emission limit for its BART eligible units.

Agrium participated in the extensive efforts in the spring and summer of 2007 to develop the MM5 data set which could be used to run more refined modeling analyses. Agrium also participated in the development of the revised CALMET modeling protocol, which they then used to run additional modeling.

In accordance with the notification requirements in 18 AAC 50.260(b), ADEC notified Agrium on December 28, 2007, that the facility was a BART eligible facility and would need to comply with 18 AAC 50.260. Agrium submitted its modeling protocol to ADEC on January 29, 2008, and submitted additional requested information on March 11, 2008. ADEC reviewed the protocol, and it was conditionally approved on April 18, 2008, with conditions requiring that the protocol be adjusted before running the model and analysis.

Agrium completed its modeling analysis and submitted the data in support of the requirement to submit control technology visibility impact analysis modeling under 18 AAC 50.260(d)-(e) on July 28, 2008. ADEC contracted the review of the modeling analysis on September 2, 2008. The contractor reviewed the analysis and asked that ADEC request additional information from Agrium on September 19, 2008. The additional information was received on October 9, 2008. However, because the plant was not operating and it was unknown when it might reopen, full control technology data was not available. Using the available data and analysis, the contractor provided a report on November 25, 2008. It was recommended at that time that it be determined that the current controls would constitute BART and if the plant reopened in the future and reactivated BART-eligible units, a full BART Control Analysis would be done at that time. ADEC was unable to public notice the decision in late 2008 and when it prepared to public

notice the preliminary BART determination in 2009, consultation with EPA revealed that the proposed determination would not be acceptable under the federal BART rules and that an alternative would have to be selected. A suggested alternative was to set the BART emission limits at zero and incorporate them into a future Title V permit. However, Agrium was in the process of having its Title V permit renewed and would be unable to operate any of the BART units after the BART deadline, even with a Title V permit, if that was the determination.

Extensive consultation among ADEC, EPA, and Agrium about alternatives resulted in Agrium notifying that ADEC that it would be requesting the suspension of the renewal of its Title V permit as well as the termination of its current Title V permit, as soon as permitting of an associated facility was complete. If Agrium later decides to reopen the Chem-Urea Plant, it will pursue applying for new air permits at that time.

Application for new air permits would require that all units to be in use at the facility be included in the PSD application process. As a result, all BART-eligible units at the facility would be reclassified as PSD units and therefore would not be considered BART units. The preliminary BART determination for Agrium was public noticed on August 17, 2009. That determination stated that Agrium will have a zero emission limit for its BART eligible units and will pursue new air permits if and when it plans to restart its facility. The public comment period ended on September 17, 2009. ADEC received comments supportive of the proposed determination from the U.S. Fish and Wildlife Service. The final determination was not changed from the preliminary determination. Therefore, Agrium will have a zero emission limit for its BART eligible units and will pursue new air permits if it plans to restart its facility.

In accordance with 18 AAC 50.260(*l*), ADEC notified Agrium and other concerned parties of the final BART determination on October 6, 2009 (See correspondence in Appendix III.K.6).

7. Golden Valley Electric Association, Healy Power Plant (GVEA)

ADEC has determined that the BART emission limits for GVEA will be 0.20 lb/MMBtu for NOx, the current limit of 0.30 lb/MMBtu for SO_2, and the current limit of 0.015 lb/MMBtu for PM.

In accordance with the notification requirements in 18 AAC 50.260(b), ADEC notified GVEA on December 28, 2007, that the facility was a BART eligible facility and would need to comply with 18 AAC 50.260. The BART eligible units at the source consist of one primary power generating unit, the 25-MW Foster-Wheeler Unit No. 1 (Healy 1), and one Cleaver Brooks standby building heater. GVEA undertook a full assessment of control options under 18 AAC 50.260(d)-(e) and used the WRAP modeling protocol. GVEA submitted its BART control analysis report on July 28, 2008.

ADEC contracted with Enviroplan to conduct a technical review of the GVEA BART control analysis on September 3, 2008. The contractor reviewed the analysis, and additional information was requested from GVEA. GVEA submitted supplemental information on October 3, 2008; November 11, 2008; and December 10, 2008. The July 2008 GVEA analysis report was revised and resubmitted by GVEA on January 2, 2009, as a revised final BART control analysis report.

GVEA provided additional relevant supplemental information on March 18, 24, and 30, 2009; and June 19, 2009.

Enviroplan recommended preliminary BART determinations for each BART-eligible source at this facility, consistent with 18 AAC 50.260(j). These proposed determinations were described in an April 27, 2009 "Findings" report, which concluded that the GVEA BART control analysis complied with 18 AAC 50.260(e) through (h); and it proposed BART for Healy 1 as the existing dry sorbent injection system (SO_2); the addition of a SCR system (NO_x); and the existing reverse gas baghouse system (PM_{10}). For Auxiliary Boiler #1, the existing configuration, which is no air pollution control systems, was determined as BART.

ADEC reviewed, accepted, and public noticed Enviroplan's recommended preliminary BART determinations, as described in its April 27 Findings report. In accordance with 18 AAC 50.260, ADEC public noticed a proposed preliminary April 27, 2009 BART determination findings report for Golden Valley Electric Association's (GVEA) Healy Power Plant on May 12, 2009. ADEC accepted public comments from May 12, 2009 until June 15, 2009. Comments were received from the following:

- Frank Abegg, Fairbanks;
- Alaska State Representative Mike Kelly, Fairbanks;
- Don Shepherd, National Park Service;
- Sanjay Narayan, Sierra Club; and
- Kristen DuBois, GVEA.

In response to the public comments, the final BART determination differed from the preliminary determination. It found that BART for Healy 1 is the existing dry sorbent injection system (SO_2), the addition of a selective non-catalytic reduction (SNCR) system to the existing low NOx burner with overfire air (NOx) and the existing reverse gas baghouse system (PM_{10}). Final emission limits were established for SO_2, NOx and PM_{10}. The modeling analysis for Healy 1 indicated the SNCR system will provide a 0.62 deciview reduction for 51 days per year (3.359 to 2.739 deciview). The analysis of the Auxiliary Boiler showed the visibility impact was less than 0.5 deciview.

ADEC asked Enviroplan to incorporate the decisions in this Response to Comment document into its BART Determination Report regarding Golden Valley Electric Association's Healy Power Plant. This allows for consistency between the final decision documents. ADEC therefore considers Enviroplan's BART Determination Report as a valid description of the technical basis for the BART emission limits established under 18 AAC 50.260(l) for Healy #1 and Auxiliary Boiler # 1.

In accordance with 18 AAC 50.260(*l*), ADEC notified GVEA and other concerned parties of the final BART determination on February 9, 2010. (See correspondence in Appendix III.K.6.) On February 24, 2010, GVEA sent a letter to ADEC requesting an informal review of the final BART determination. The informal review did not result in any substantial changes to the final BART determination, and the emission limits did not change. However, while conducting the

informal review, ADEC staff discovered that there were some errors in the emission rates listed in the Final BART Determination Report as well as in emission rates used in the modeling for Auxiliary Boiler #1. The inaccurate rates in the report were corrected. Enviroplan reran modeling using the corrected emission rates for Auxiliary Boiler #1, and the visibility impact was still less than 0.5 deciview. The final report contains the revised modeling analysis. An unnecessary footnote was removed from the final report as a result of the informal review. GVEA challenged the shutdown statement in the final determination report. ADEC revised and clarified the statement in the report. From the informal review letter:

> *The Department fully expects the useful life of Healy Unit 1 will end in 2024, based on GVEA's representations in their BART submittals. If circumstances change and it makes sense to operate Healy Unit 1 beyond 2024, the Department will evaluate the situation at that time. The Regional Haze SIP provides additional opportunities to evaluate visible impacts of Healy Unit 1 under the reasonable progress process. In regards to a shutdown under the BART rules, GVEA should be aware that the BART guidelines (BART Guidelines 40 CFR 51, Appendix Y, Section IV.D.4.k.2) do provide for the implementation of BART of the shutdown of a BART eligible unit should that unit operate beyond the useful life presumed in the BART determination.*

ADEC did not change any of the other issues that GVEA requested be reviewed.

C. BART Determination Summary

As described above, ADEC worked in conjunction with WRAP to determine which sources were eligible for BART determinations, and then assessed whether a BART determination would be required for each facility. The results of this process are summarized in Table III.K.6-1, which lists each of the facilities initially identified as being BART-eligible, and whether a BART determination was required for each, based on a review of the emission units at those facilities. Table III.K.6-2 then summarizes the BART determination findings (i.e., the average of 2002-2004 98th percentile delta deciview) for each facility, based on modeling analyses assessing the visibility impacts of those BART-eligible sources on Alaska's Class I areas. As the table shows, with the exception of the GVEA facility at Healy, none of the facilities exceeded the 0.5 delta deciview significance threshold. As described earlier and summarized in the table, a number of paths led to this conclusion. In the case of Chugach Electric, it was the finding that the facility was not subject to the BART rule. In the case of Agrium, it was the finding that the facility had closed and that it will have a zero emission limit for the BART eligible units if a decision is made to reopen the facility. For the remaining facilities, it was the result of agreements to limit emissions or the use of actual emission levels. As noted earlier, the application of BART at the Healy Power Plant results in a reduction in the predicted number of days over the 0.5 deciview by an additional 51 days per year. Copies of the individual facility modeling analyses and agreements are contained in Appendix III.K.6.

Table III.K.6-1
Summary of BART-Eligible Facility Analysis

Facility	Subject to BART Analysis	BART Determination
Chugach	No: Originally identified units replaced	N/A
Alyeska, Valdez Marine Terminal	No: Modeled visibility impacts less than 0.5 deciview	N/A
Tesoro, Kenai Refinery	No: Modeled visibility impacts less than 0.5 deciview	N/A
Anchorage ML&P	No: Modeled visibility impacts less than 0.5 deciview	N/A
CPAI	No: COBC limits emissions from units to levels that would have modeled visibility impacts less than 0.5 deciview	N/A – Handled by COBC
Agrium	Yes	Facility is currently shutdown – zero emission limit for BART eligible units
GVEA, Healy Power Plant	Yes	NOx: 0.20 lbs/MMBtu SO_2: 0.30 lb/MMBtu PM: 0.015 lb/MMBtu

Table III.K.6-2
Summary of BART Determination Findings, 98th Percentile Delta-Deciview, 2002-2004

BART Sources	Tuxedni	Denali
Chugach	NA	NA
Alyeska,Valdez Marine Terminal	0.065	0.08
Tesoro, Kenai Refinery	0.425	0.041
Anchorage ML&P	0.23	0.36
CPAI	<0.50	<0.50
Agrium	-	-

III.K.7 AIR QUALITY MODELING OF SOURCE REGIONS

A. Overview

While modeling is only explicitly referenced in two sections of the regional haze rule (i.e., Section 501.308(c)(ii) and 308(d)(3)(iii)), it is a critical technical step in many of the planning requirements of the rule. Models are needed for source apportionment, control strategy development and optimization, quantification of incremental impacts of individual source categories, and analysis of cumulate impacts. Air quality and visibility modeling in support of regional haze planning in the WRAP region was the responsibility of the WRAP Modeling Forum's Regional Modeling Center (RMC). The RMC used the air pollution emissions data provided by member states to simulate historic air quality conditions and estimate the benefit of emissions reductions programs in the future. Regional gridded dispersion models were used for these simulations.

Due to delays in emission inventory development for state sources, lack of information on emission inventories for international sources impacting the state, and funding constraints, it was not possible for the WRAP to perform photochemical grid modeling for Alaska. In lieu of photochemical modeling and as a first step toward future modeling, the WRAP evaluated alternate meteorological modeling techniques to simulate the unique and complex meteorological conditions of Alaska. This resulted in the use of the modeling techniques described below to gain insight into which emission sources within the State are impacting the four Class I areas.

- *Back Trajectory Modeling* was conducted to determine the path of air parcels impacting each site. Back trajectories account for the impact of wind direction and wind speed on the delivery of emissions to a site, but do not account for chemical transformation, dispersion and deposition.

- *Weighted Emissions Potential (WEP) Analysis* was used to assess the relative emissions contribution from in-state sources impacting each site. WEP analysis integrates gridded emissions estimates, back trajectory residence time estimates, and the effect of distance to approximate deposition.

- *CALPUFF* was used to assess the impact of emissions from BART-eligible sources on visibility at Denali and Tuxedni. CALPUFF used MM5 data, surface meteorological measurements, and major source specific emission estimates to calculate visibility impacts due to emissions of SO_2, NOx and primary PM emissions. A summary of source specific modeling results and deciview impacts was presented in Section III.K.6. Copies of the source-specific modeling analyses are presented in Appendix III.K.6.

Presented below is brief description of the back trajectory modeling and WEP analysis methodologies, a summary of the results, and an assessment of significance from in-state emission sources.

B. Back Trajectory Analysis

A WRAP contractor—Air Resource Specialists, Inc. (ARS)—generated meteorological back trajectories for IMPROVE monitoring sites. Back trajectory analyses use interpolated measured or modeled meteorological fields to estimate the most likely central path over geographical areas that provided air to a receptor at a given time. The method essentially follows a parcel of air backward in hourly steps for a specified period of time. Back trajectories account for the impact of wind direction and wind speed on delivery of emissions to the receptor, but do not account for chemical transformation, dispersion, and deposition of samples.

Trajectories were generated using the Hybrid-Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model developed by the National Oceanic and Atmospheric Administration's (NOAA) Air Resources Laboratory. HYSPLIT uses archived three-dimensional meteorological fields generated from observations and short-term forecasts. HYSPLIT can be run to generate forward or backward trajectories using several available meteorological data archives.

ARS could not use the National Weather Service's National Center's for Environmental Prediction Eta Data Assimilation System (EDAS) to represent meteorology in Alaska, since it contains data for the continental U.S only. Therefore ARS used the FNL data from the National Weather Service's National Centers for Environmental Prediction (NCEP). The FNL data consist of meteorological model output at 191 km resolution and include late-arriving conventional and satellite data observations that are not available in the EDAS data set. The principal difference the EDAS and FNL datasets is the resolution: EDAS has a horizontal resolution of 80 km before 2004 and a 40 km resolution beginning in 2004. As noted above, the FNL data have a horizontal resolution of 191 km.

Using the FNL data, HYSPLIT prepared back trajectory analyses for each of the four Class I sites in Alaska for the annual 20% worst and 20% best visibility days. The duration of the trajectory was set to 8 days (192 hours backward in time); this value was chosen to represent a compromise between higher certainty (shorter duration) and the expected atmospheric life of sulfate aerosols (one-two weeks.). Residence time maps were constructed to display where air parcels impacting the Class I sites spent the most time before reaching the monitors. The values associated with each color in the map legend are normalized to the maximum percentage value observed, which is generally the grid cell where the receptor site is located. Residence time over an area is indicative of general flow patterns, but does not necessarily imply the area contributed significantly to haze compounds since it does not account for the emissions and removal process.

The results are presented in Figures III.K.7-1 through III.K.7-8, with a 20% worst and 20% best visibility sequence for each Class I area. Starting with Denali (Figures III.K.7-1 and III.K.7-2), the pattern for the 20% worst days shows a relatively dense, almost bull's-eye pattern with nearby locations having the maximum residence time, which diminishes with distance. The pattern is stretched, however, from the southwest to the northeast, suggesting that sources in Anchorage, Mat-Su, and Fairbanks are principal contributors. The pattern for the 20% best days is considerably different and shows significant air flow from the Gulf of Alaska (i.e., the southeast). It is important to remember that the colors are normalized to the maximum residence

Figure III.K.7-1
Denali National Park, AK – Normalized Back-Trajectory Residence Time 20% Worst Visibility Days

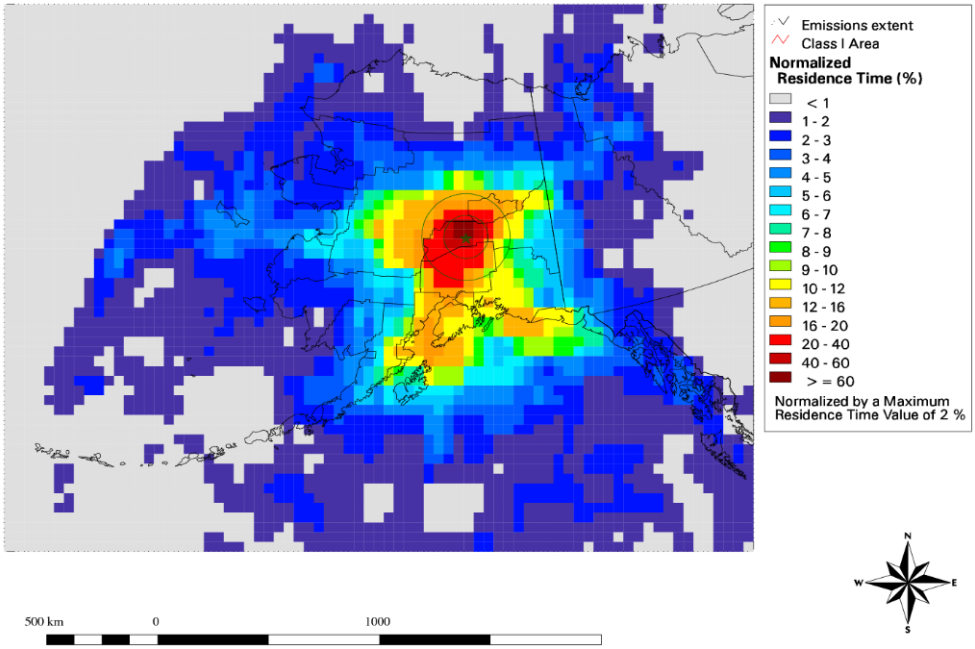


Figure III.K.7-2
Denali National Park, AK – 20% Best Visibility Days

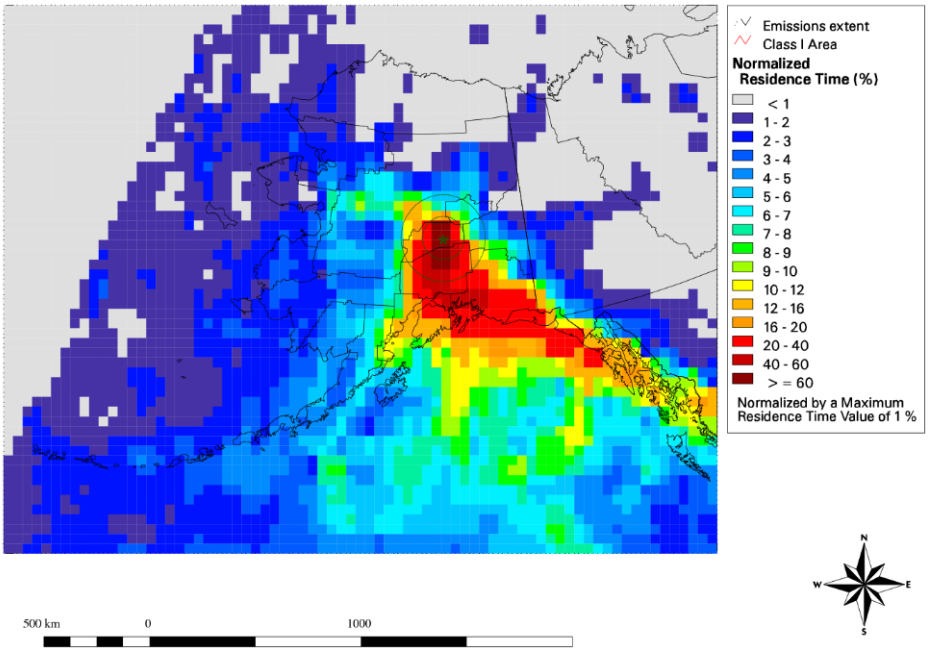


Figure III.K.7-3
Trapper Creek Wilderness, AK – Normalized Back-Trajectory Residence Time 20% Worst Visibility Days

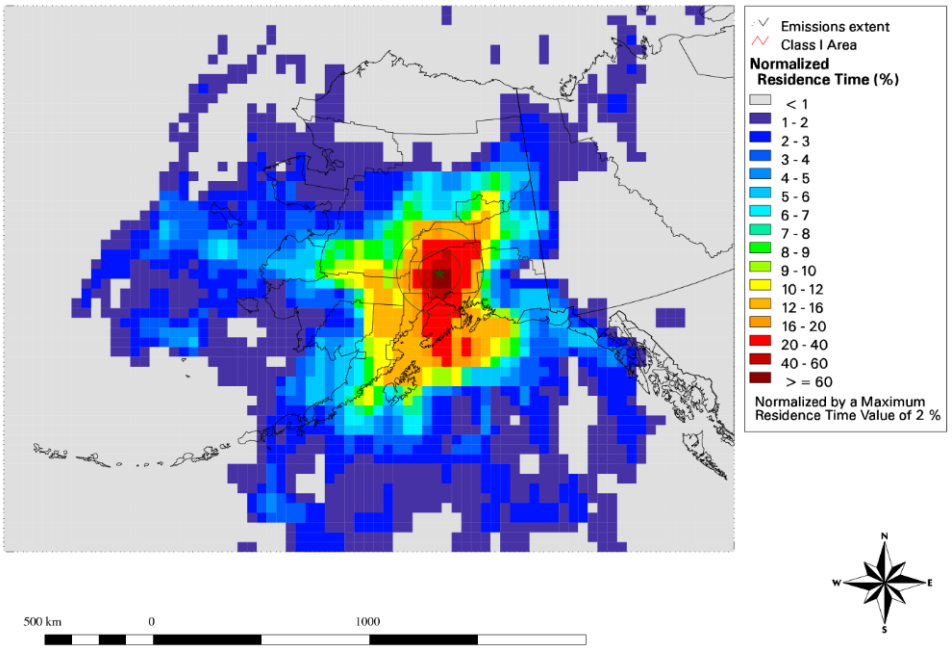


Figure III.K.7-4
Trapper Creek Wilderness, AK – Normalized Back-Trajectory Residence Time 20% Best Visibility Days

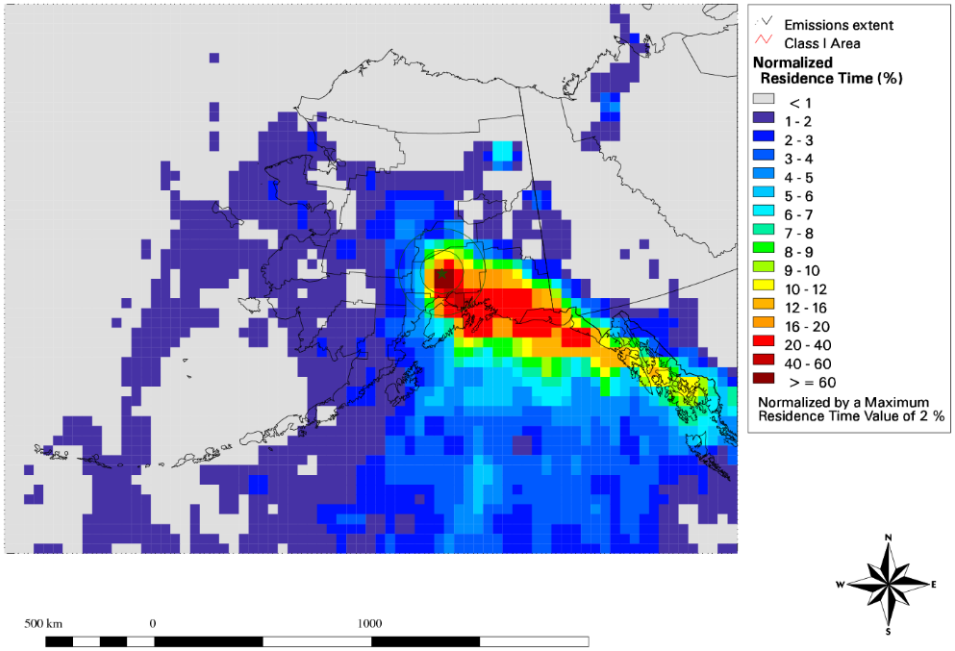


Figure III.K.7-5
Simeonof Wilderness, AK – Normalized Back-Trajectory Residence Time 20% Worst Visibility Days

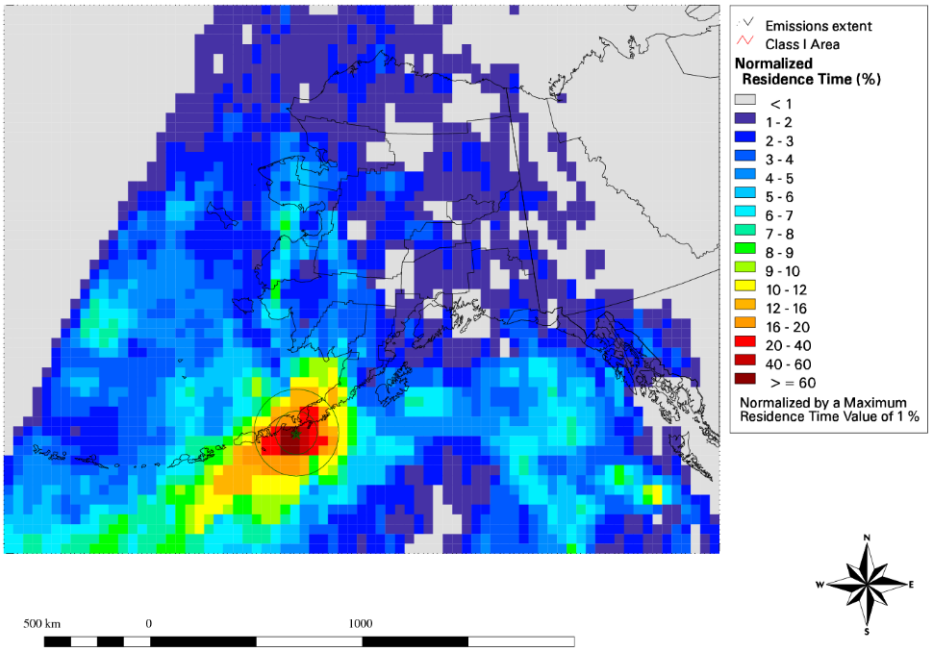


Figure III.K.7-6
Simeonof Wilderness, AK – Normalized Back-Trajectory Residence Time 20% Best Visibility Days

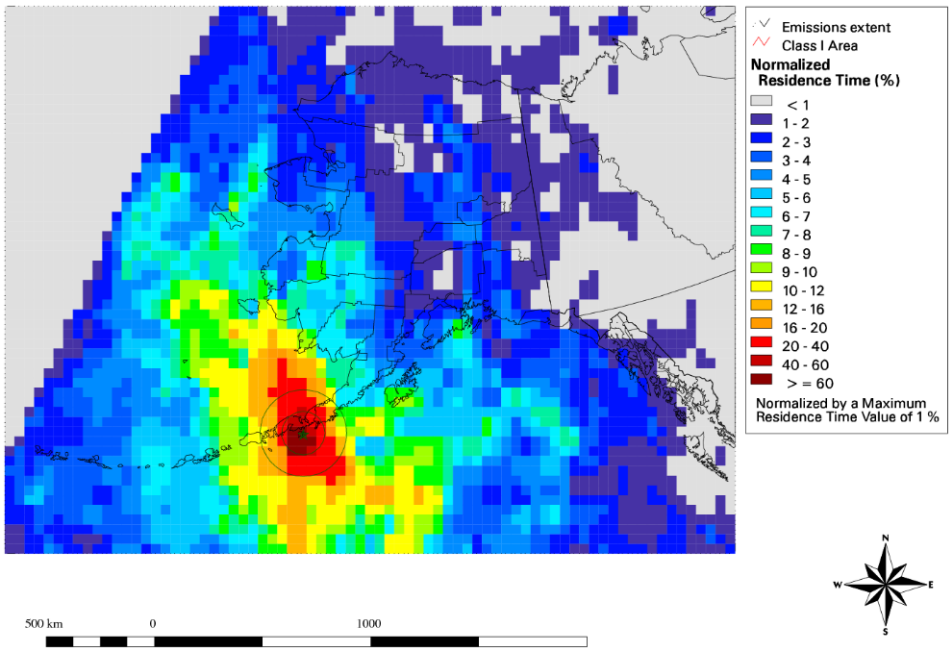


Figure III.K.7-7
Tuxedni – Normalized Back-Trajectory Residence Time 20% Worst Visibility Days

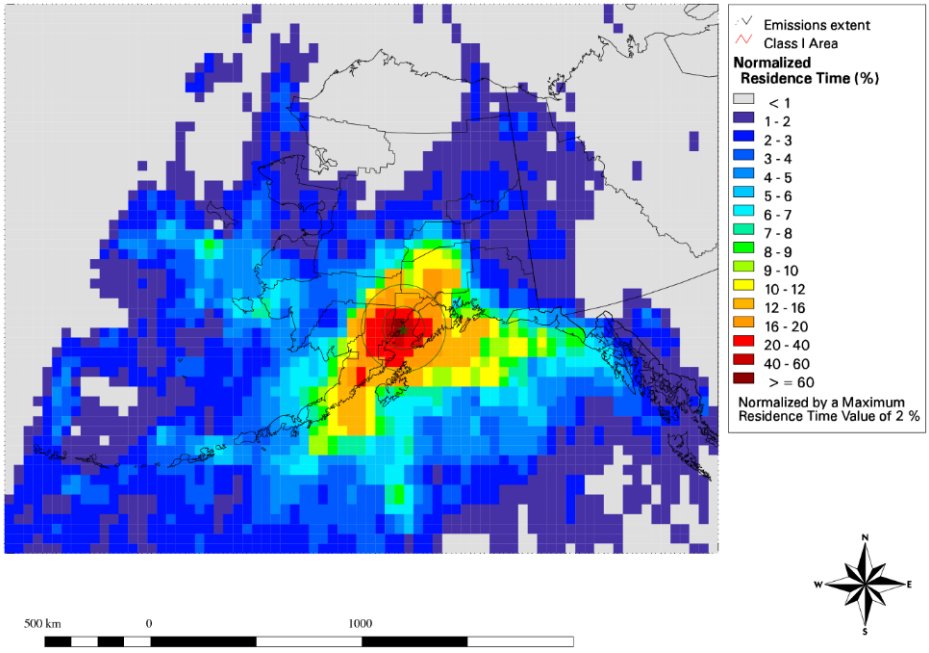
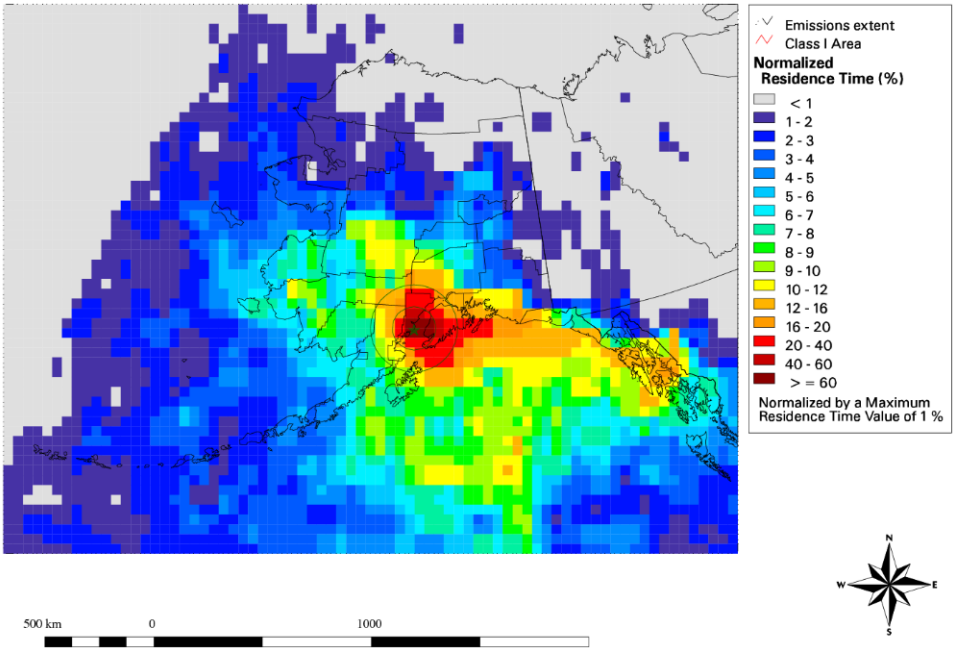


Figure III.K.7-8
Tuxedni – Normalized Back-Trajectory Residence Time 20% Best Visibility Days



time value observed, which is 2% for the 20% worst days at Denali. A similar, but a less symmetrical, pattern is seen in Figure III.K.7-3 for the 20% worst visibility days at Trapper Creek. It shows the area of maximum impact ranges in a more north south direction and suggests the Kenai could be a significant contributor in addition to Anchorage, Mat-Su, and Fairbanks. The influence of air from the Gulf of Alaska is also evident in Figure III.K.7-4 for the 20% best visibility days at Trapper Creek.

The pattern for the 20% worst visibility days at Simeonof displayed in Figure III.K.7-5 shows the area of maximum impact stretches toward the southwest, which is primarily open water. The residence time of locations in the central part of the state is shown to be much less. However, since the density of emissions within the Aleutian Islands is significantly lower than from the areas within the mainland, it will be important to account for the effect of residence time, distance, and emissions density when determining which sources are having the largest impact at Simeonof (and each of the other sites). Figure III.K.7-6 shows the 20% best days pattern of air impacting Simeonof is more from the northwest and southeast, with air from open water in both the Bering Sea and the Gulf of Alaska having significant residence time.

Figure III.K.7-7 shows that the pattern on the 20% worst days for Tuxedni is more symmetrical for the areas with the greatest residence time, and areas to the east have greater influence than those to the west. Clearly, sources located in the Kenai, Anchorage, and Mat-Su are likely to have a significant impact on this site. The pattern for the 20% best visibility days displayed in Figure III.K.7-8 is less symmetrical and shows again the influence of air parcels coming from the Gulf of Alaska.

It should be clear that residence time information by itself provides limited insight into assessing source significance. For this reason, as explained in the following section, it was combined with gridded emissions inventory estimates and distance to provide a more informed assessment of source apportionment.

C. Weighted Emissions Potential Analysis

The WEP analysis was developed as a screening tool for states to decide which source regions have the potential to contribute to haze formation at specific Class I areas, based on both the baseline 2002 and 2018 emissions inventories. Unlike the SOx/NOx Tracer analysis, this method does not account for chemistry and removal processes. Instead, the WEP analysis relies on an integration of gridded emissions data, meteorological back trajectory residence time data, a one-over-distance factor to approximate deposition and dispersion, and a normalization of the final results. Residence time over an area is indicative of general flow patterns, but does not necessarily imply the area contributed significantly to haze at a given receptor. Therefore, where possible it is important to use WEP analysis as one piece of a larger, more comprehensive weight of evidence analysis. For Alaska, however, no additional evidence is available from modeling to provide additional insight. For this reason, the results of the WEP analysis provide the principal insight into location and source significance and how that significance is forecast to change over time.

A description of the emissions data and source categories used in the WEP analysis was presented in Section III.K.5. Annual estimates from the statewide emissions inventory were processed into 45-km grid cells for six pollutants:

- $PM_{2.5}$
- VOC
- SOx
- NOx
- NH_3
- PM_{10}

As described earlier in this Section III.K.7.B, back trajectory residence time estimates were prepared using NOAA's HYSPLIT model. ENVIRON prepared the WEP analysis for Alaska, which consisted of weighting the annual gridded emissions (by pollutant and source category) by the worst and best extinction days' residence times for the five-year baseline period. To account for the effect of deposition along the trajectories, the result was further weighted by a one-over-distance factor, measured as the distance in km between the centroid of each emissions grid cell and the centroid of the grid cell containing the Class I area monitoring site.

The home grid cell was weighted by one-fourth of the 45-km grid cell difference to avoid an overly large response in that grid cell. The resulting weighted emissions field was normalized by the highest grid cell to ease interpreting the results. The WEP results were also normalized to baseline calendar year 2002 emissions. In other words, for each site and pollutant, WEP values total 100 (or 100%) across all source sectors and grid cells. The 2018 results were then scaled relative to the normalized 2002 baseline so that actual changes in weighted emissions between calendar years are evident.

ENVIRON prepared a series of maps to display the results of the Alaska analysis. Figures III.K.7-9 and III.K.7-10 display the results for the 20% worst days in 2002-2004 and 2018 for $PM_{2.5}$ impacting Denali. As with the back trajectory plots, color is used to identify differences in that magnitude of WEP values calculated for each location. They show areas with the highest values are located nearby to the north, east, and west of the site. Areas with lower impacts are more broadly scattered throughout the state. A comparison between the 2002-2004 and 2018 displays shows that higher values were calculated for some nearby locations in 2018. The problem with these maps is that it is difficult to determine the identity of the areas impacting the sites and they provide no insight into individual sources. Thus, a different method was needed to organize the data so it would be easier to determine which locations and sources are most significant and how they change over time.

This was accomplished by aggregating the WEP results for each grid cell into counties (i.e., boroughs) in which the emission sources are located. These values were organized by Class I site, year, pollutant, source category, and county, and the WEP values for the top three boroughs[*]

[*] After examining the data, it was determined that the top 3-Boroughs, with a few exceptions, accounted for 97+% of pollutant specific WEP values impacting each monitor.

Figure III.K.7-9
Denali National Park, AK – Normalized Weighted Emission Potential (WEP) for Fine Particulate Matter ($PM_{2.5}$) 2002-04 Baseline, 20% Worst Visibility Days

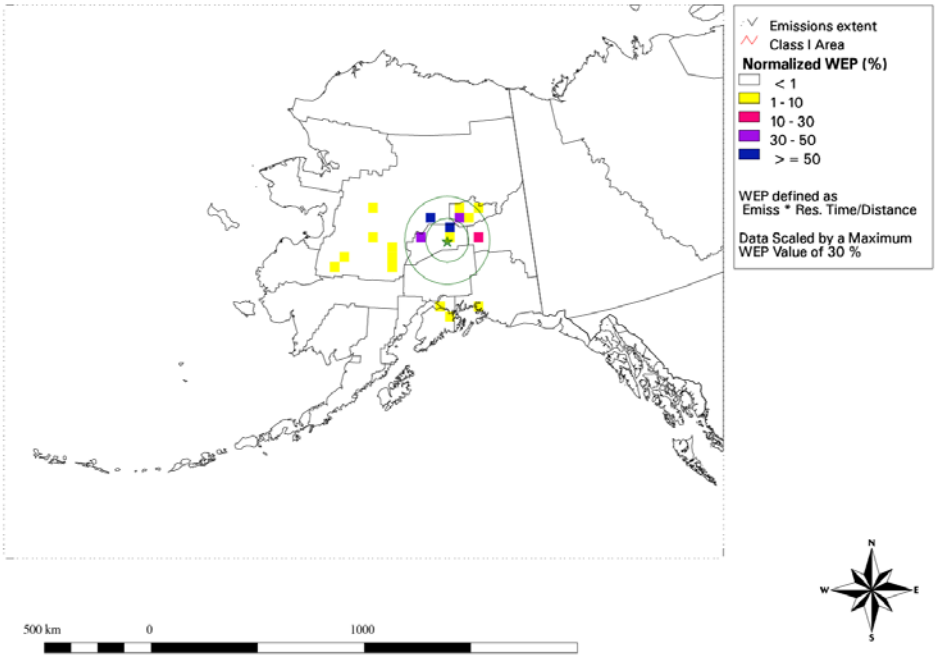
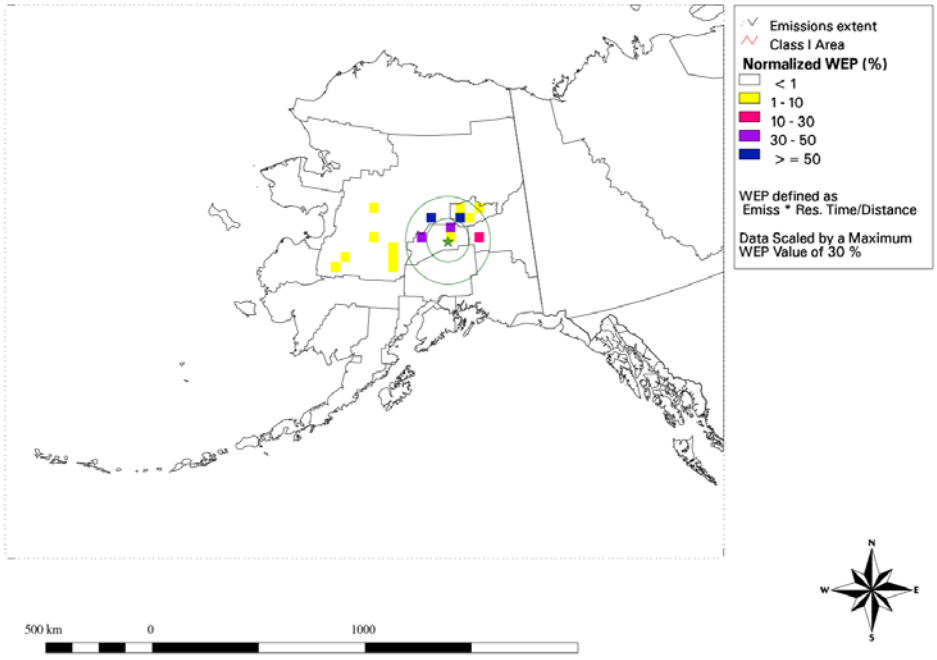


Figure III.K.7-10
Denali National Park, AK – Normalized Weighted Emission Potential (WEP) for Fine Particulate Matter ($PM_{2.5}$) 2018 Base Case, 20% Worst Visibility Days



impacting each site were extracted. Those values are displayed in Tables III.K.7-1 through III.K.7-4 for sources impacting each Class I area. Color is used to direct attention to the most significant WEP values, a legend for the values represented by each color is located at the bottom of each table. Red is the most significant and "clear" (i.e., no shading) is the least (values less than 10).

1. Denali

Table III.K.7-1 summarizes the WEP values from the top three boroughs for each pollutant on the 20% worst days. The right-most column presents the total normalized WEP value for each pollutant, year, and borough across all source types.[*] As can be seen for $PM_{2.5}$, the total WEP value for the three boroughs is 95.5 in 2002 and 95.9 in 2018, an increase of 0.4. Changes in the total values across the boroughs provide insight into which pollutants are being impacted by anthropogenic activity since the values from the natural fires and anthropogenic fires are held constant. The most striking feature of the table is that natural fires are the dominant source for all of the pollutants displayed—no other source is significant for $PM_{2.5}$. For VOC, the stationary area source is the second largest source, but the forecast shows that its share is declining as is the total predicted WEP. For NOx, the Fairbanks point sources are shown to have a WEP increase of roughly 3. Offsetting reductions in the other boroughs and sources, however, limit the overall increase in NOx to 1.5. More significantly, Fairbanks point sources are forecast to have a SOx WEP increase of 11.6.

Overall, the information presented in Table III.K.7-1 demonstrates that the only anthropogenic source of concern impacting Denali is Fairbanks point source SOx emissions.

2. Simeonof

A summary of the WEP values from the top three boroughs impacting Simeonof is presented in Table III.K.7-2. It shows that the natural fires in Yukon-Koyukuk are the dominant source of all pollutants impacting the site. The totals for each pollutant demonstrate that there is little change forecast, either up or down, which means that none of the anthropogenic sources is forecast to have a significant change in activity or emissions impacting the site.

Overall, the information presented in Table III.K.7-2 shows that natural fires are the dominant source of emissions impacting the site and that no anthropogenic source is identified as having a significant impact on the site.

3. Trapper Creek

The information presented in Table III.K.7-3 also shows that natural fires are the largest source of emissions impacting that site. WEP values, however, are highlighted for several other source

[*] Anthropogenic fires are prescribed fires and are not displayed because their WEP values are barely detectible (i.e., 4th decimal place) or zero for all boroughs impacting the Class I sites. Similarly, values for aviation were not displayed because their values, with a few exceptions, that will be discussed when relevant, are well less than and not a significant contributor to the WEP. The totals displayed in Tables III.K.7-1 – III.K.7-.4, however, include the contribution of anthropogenic fires and aviation for the boroughs displayed.

categories. On-road mobile sources are shown to have a VOC value of greater than 10. However, they are also shown to have a declining impact over the 2002-2018 period reflecting the benefits of fleet turnover and increasingly stringent federal motor vehicle emissions standards. Point source NOx emissions are also shown to have WEP values exceeding 10; however, they are forecast to have a declining impact over the forecast period. Stationary area sources in Mat-Su are shown to have WEP values above 10 and to be increasing for $PM_{2.5}$, VOC, and SOx over the forecast period. Reductions from other anthropogenic sources, however, reduce the increase in the total VOC WEP to 1.6.

Overall, the information presented in Table III.K.7-3 shows that while natural fires are the largest source of emissions, stationary area sources from Mat-Su are forecast to experience a WEP increase of 5.5 for $PM_{2.5}$ and 9.2 for SOx. The 4.1 increase forecast for Mat-Su VOC is largely offset by reductions in other sources.

4. Tuxedni

The information presented in Table III.K.7-4 shows a more complex mixture of source contributions than seen for the previous sites. While natural fires are still a significant source for many of the pollutants, several other source categories show a large and even greater contribution for some of the pollutants. Point sources located in the Kenai Peninsula are shown to be the largest source of NOx emissions, but they are forecast to decline substantially. They are also shown to be the largest source of NH_3 emissions in 2018; the WEP is forecast to almost double from 2002 to 2018. While VOC levels from point sources in the Kenai are shown to increase by 5.2 from 2002 to 2018, that increase is largely offset by decreases in other sources since the overall value from the three boroughs is predicted to increase by 0.5. Stationary area sources in the Kenai are shown to have slight increases for $PM_{2.5}$, VOC, and SOx emissions. Again, the increase in overall VOC is shown to be only 0.5, so the impact of the area source increase is not significant. Similarly, the WEP increase of 3.2 forecast for Kenai area SOx sources is dramatically offset by the reduction in commercial marine vessels values so that the overall forecast for SOx values drops by more than 12.

Overall, the information presented for Tuxedni shows that the only concern is the very large increase in NH_3 emissions coming from point sources in the Kenai Peninsula.

Before reaching conclusions from the WEP values displayed in Tables III.K.7-1 – III.K.7-4, it is important to review the trends in total WEP values forecast for all boroughs impacting each site. A summary of those values is presented in Table III.K.7-5. Overall, it shows a mixed picture for each site, with some values decreasing and some increasing. Denali and Simeonof are shown to have no significant change in emissions. Trapper Creek is shown to have WEP increases of 6.0 and 7.7 for $PM_{2.5}$ and for NH_3 respectively. Tuxedni is shown to have a very large increase in NH_3 with either declines or modest increases in the other pollutants.

Table III.K.7-1
Summary of Boroughs With Highest Weighted Emission Potential, Impacting Denali Monitoring Site on 20% Worst Days

Borough	Year	Commercial Marine Vessels	Natural Fires	Non-Road Mobile	On-Road Mobile	Point	Stationary Area	Total
				$PM_{2.5}$				
Yukon-Koyukuk CA	2002	0.0	61.6	0.0	0.0	0.0	0.3	61.9
	2018	0.0	61.6	0.0	0.0	0.0	0.3	61.9
Southeast Fairbanks	2002	0.0	28.7	0.0	0.0	0.0	1.1	29.8
	2018	0.0	28.7	0.0	0.0	0.0	1.4	30.1
Fairbanks North Star	2002	0.0	2.3	0.0	0.0	0.0	1.3	3.7
	2018	0.0	2.3	0.0	0.0	0.0	1.5	3.9
Total	2002	0.0	92.6	0.0	0.0	0.0	2.7	95.5
	2018	0.0	92.6	0.0	0.0	0.0	3.2	95.9
				VOC				
Yukon-Koyukuk CA	2002	0.0	43.6	0.1	0.0	0.0	1.7	45.3
	2018	0.0	43.6	0.0	0.0	0.0	1.5	45.2
Southeast Fairbanks	2002	0.0	19.3	0.1	0.0	0.0	6.4	25.9
	2018	0.0	19.3	0.2	0.0	0.0	8.2	27.8
Denali Borough	2002	0.0	0.0	0.4	0.0	0.0	21.3	21.8
	2018	0.0	0.0	0.4	0.0	0.0	19.2	19.7
Total	2002	0.0	62.9	0.6	0.1	0.0	29.3	93.1
	2018	0.0	62.9	0.6	0.1	0.0	28.9	92.6
				NOx				
Yukon-Koyukuk CA	2002	0.0	44.1	0.0	0.1	0.0	0.2	44.4
	2018	0.0	44.1	0.0	0.0	0.0	0.1	44.3
Southeast Fairbanks	2002	0.0	19.6	0.0	0.0	1.0	1.5	22.2
	2018	0.0	19.6	0.0	0.0	0.8	1.9	22.5
Fairbanks North Star	2002	0.0	1.6	0.5	2.5	10.8	0.4	16.3
	2018	0.0	1.6	0.2	0.8	13.7	0.4	17.5
Total	2002	0.0	65.3	0.6	2.6	11.8	2.0	82.9
	2018	0.0	65.3	0.3	0.9	14.5	2.5	84.4
				SOx				
Fairbanks North Star	2002	0.0	1.3	0.0	0.3	23.7	2.6	28.0
	2018	0.0	1.3	0.0	0.0	35.3	3.0	39.8
Yukon-Koyukuk CA	2002	0.0	35.8	0.0	0.0	0.0	0.1	35.9
	2018	0.0	35.8	0.0	0.0	0.0	0.1	35.9
Southeast Fairbanks	2002	0.0	15.9	0.0	0.0	1.3	0.1	17.4
	2018	0.0	15.9	0.0	0.0	0.8	0.2	16.9
Total	2002	0.0	52.9	0.0	0.4	25.0	2.8	81.3
	2018	0.0	52.9	0.0	0.0	36.1	3.3	92.6
				NH_3				
Yukon-Koyukuk CA	2002	0.0	65.9	0.0	0.0	0.0	0.0	65.9
	2018	0.0	65.9	0.0	0.0	0.0	0.0	65.9
Southeast Fairbanks	2002	0.0	29.2	0.0	0.0	0.0	0.0	29.2
	2018	0.0	29.2	0.0	0.0	0.0	0.0	29.2
Fairbanks North Star	2002	0.0	2.4	0.0	0.7	0.1	0.0	3.2
	2018	0.0	2.4	0.0	0.7	0.1	0.0	3.3
Total	2002	0.0	97.5	0.0	0.7	0.1	0.0	98.3
	2018	0.0	97.5	0.0	0.8	0.1	0.0	98.4

Shading: clear (0-9.9), yellow (10-24.9), orange (25-49.9), red (50+), gray (totals)

Table III.K.7-2
Summary of Boroughs With Highest Weighted Emission Potential, Impacting Simeonof Monitoring Site on 20% Worst Days

Borough	Year	Commercial Marine Vessels	Natural Fires	Non-Road Mobile	On-Road Mobile	Point	Stationary Area	Total
$PM_{2.5}$								
Yukon-Koyukuk CA	2002	0.0	88.0	0.0	0.0	0.0	0.2	88.3
	2018	0.0	88.0	0.0	0.0	0.0	0.2	88.3
Southeast Fairbanks	2002	0.0	2.5	0.0	0.0	0.0	0.3	2.8
	2018	0.0	2.5	0.0	0.0	0.0	0.4	2.9
Fairbanks North Star	2002	0.0	0.7	0.0	0.0	0.0	0.2	0.9
	2018	0.0	0.7	0.0	0.0	0.0	0.2	0.9
Total	2002	0.0	91.3	0.0	0.0	0.0	0.7	92.0
	2018	0.0	91.3	0.0	0.0	0.0	0.8	92.1
VOC								
Yukon-Koyukuk CA	2002	0.0	67.5	0.0	0.0	0.0	1.1	68.7
	2018	0.0	67.5	0.0	0.0	0.0	1.0	68.5
Dillingham CA	2002	0.0	0.0	0.2	0.0	0.0	4.7	5.0
	2018	0.0	0.0	0.2	0.0	0.0	4.9	5.2
Southeast Fairbanks	2002	0.0	1.8	0.0	0.0	0.0	2.1	3.9
	2018	0.0	1.8	0.1	0.0	0.0	2.6	4.5
Total	2002	0.0	69.3	0.3	0.0	0.0	7.9	77.6
	2018	0.0	69.3	0.3	0.0	0.0	8.5	78.3
NOx								
Yukon-Koyukuk CA	2002	0.0	53.8	0.0	0.0	0.1	0.1	54.0
	2018	0.0	53.8	0.0	0.0	0.1	0.1	54.0
North Slope Borough	2002	0.0	0.0	0.0	0.0	9.6	0.0	9.6
	2018	0.0	0.0	0.0	0.0	7.4	0.0	7.5
Kenai Peninsula	2002	0.4	0.0	0.0	0.1	6.2	0.2	7.0
	2018	0.7	0.0	0.0	0.1	5.3	0.2	6.2
Total	2002	0.4	53.8	0.1	0.2	15.8	0.3	70.6
	2018	0.7	53.8	0.1	0.1	12.8	0.3	67.6
SOx								
Yukon-Koyukuk CA	2002	0.0	73.9	0.0	0.0	0.0	0.1	74.0
	2018	0.0	73.9	0.0	0.0	0.0	0.1	74.0
Fairbanks North Star	2002	0.0	0.6	0.0	0.1	3.2	0.4	4.3
	2018	0.0	0.6	0.0	0.0	4.4	0.5	5.5
Dillingham CA	2002	0.1	0.0	0.1	0.0	0.6	2.0	2.8
	2018	0.0	0.0	0.1	0.0	0.6	2.1	2.7
Total	2002	0.1	74.5	0.1	0.1	3.7	2.5	81.1
	2018	0.0	74.5	0.1	0.0	5.0	2.6	82.3
NH_3								
Yukon-Koyukuk CA	2002	0.0	91.0	0.0	0.0	0.0	0.0	91.0
	2018	0.0	91.0	0.0	0.0	0.0	0.0	91.0
Kenai Peninsula	2002	0.0	0.0	0.0	0.1	2.0	0.0	2.1
	2018	0.0	0.0	0.0	0.1	3.8	0.0	3.9
Southeast Fairbanks	2002	0.0	2.5	0.0	0.0	0.0	0.0	2.5
	2018	0.0	2.5	0.0	0.0	0.0	0.0	2.5
Total	2002	0.0	93.5	0.0	0.1	2.0	0.0	95.5
	2018	0.0	93.5	0.0	0.1	3.8	0.0	97.4

Shading: clear (0-9.9), yellow (10-24.9), orange (25-49.9), red (50+), gray (totals)

Table III.K.7-3
Summary of Boroughs With Highest Weighted Emission Potential, Impacting Trapper Creek Monitoring Site on 20% Worst Days

Borough	Year	Commercial Marine Vessels	Natural Fires	Non-Road Mobile	On-Road Mobile	Point	Stationary Area	Total
$PM_{2.5}$								
Yukon-Koyukuk CA	2002	0.0	63.7	0.0	0.0	0.0	0.2	63.8
	2018	0.0	63.7	0.0	0.0	0.0	0.1	63.8
Matanuska-Susitna	2002	0.0	4.0	0.3	0.2	0.0	10.9	16.3
	2018	0.0	4.0	0.2	0.1	0.0	16.4	22.0
Southeast Fairbanks	2002	0.0	14.8	0.0	0.0	0.0	0.8	15.6
	2018	0.0	14.8	0.0	0.0	0.0	1.0	15.8
Total	2002	0.0	82.4	0.3	0.2	0.0	11.8	95.7
	2018	0.0	82.4	0.2	0.1	0.0	17.5	101.6
VOC								
Yukon-Koyukuk CA	2002	0.0	43.7	0.0	0.0	0.0	0.7	44.4
	2018	0.0	43.7	0.0	0.0	0.0	0.6	44.3
Matanuska-Susitna	2002	0.0	2.6	5.0	10.2	0.2	8.5	28.0
	2018	0.0	2.6	6.2	4.6	0.3	12.6	28.4
Southeast Fairbanks	2002	0.0	9.6	0.1	0.0	0.0	4.5	14.3
	2018	0.0	9.6	0.1	0.0	0.0	5.8	15.6
Total	2002	0.0	56.0	5.1	10.2	0.2	13.7	86.7
	2018	0.0	56.0	6.3	4.6	0.3	19.0	88.3
NOx								
Matanuska-Susitna	2002	0.1	1.7	3.6	14.3	8.2	4.5	37.8
	2018	0.1	1.7	2.6	6.9	9.0	6.4	33.3
Yukon-Koyukuk CA	2002	0.0	28.3	0.0	0.0	0.0	0.0	28.4
	2018	0.0	28.3	0.0	0.0	0.0	0.0	28.4
Kenai Peninsula	2002	2.9	0.0	0.1	0.3	18.0	0.4	21.7
	2018	4.6	0.0	0.1	0.1	15.7	0.5	21.0
Total	2002	3.0	30.0	3.7	14.6	26.2	5.0	87.9
	2018	4.7	30.0	2.7	7.1	24.7	6.9	82.6
SOx								
Yukon-Koyukuk CA	2002	0.0	44.1	0.0	0.0	0.0	0.1	44.2
	2018	0.0	44.1	0.0	0.0	0.0	0.1	44.2
Matanuska-Susitna	2002	0.1	2.6	0.0	3.9	0.0	14.5	25.0
	2018	0.0	2.6	0.0	0.5	0.0	23.7	31.7
Fairbanks North Star	2002	0.0	0.8	0.0	0.1	6.3	0.8	8.1
	2018	0.0	0.8	0.0	0.0	8.8	1.0	10.6
Total	2002	0.1	47.5	0.0	4.0	6.3	15.4	77.2
	2018	0.0	47.5	0.0	0.5	8.9	24.7	86.5
NH_3								
Yukon-Koyukuk CA	2002	0.0	66.5	0.0	0.0	0.0	0.0	66.5
	2018	0.0	66.5	0.0	0.0	0.0	0.0	66.5
Southeast Fairbanks	2002	0.0	14.7	0.0	0.0	0.0	0.0	14.7
	2018	0.0	14.7	0.0	0.0	0.0	0.0	14.7
Matanuska-Susitna	2002	0.0	4.0	0.0	7.0	0.0	0.0	11.0
	2018	0.0	4.0	0.1	9.7	0.0	0.0	13.9
Total	2002	0.0	85.2	0.0	7.0	0.0	0.0	92.3
	2018	0.0	85.2	0.1	9.7	0.0	0.0	95.2

Shading: clear (0-9.9), yellow (10-24.9), orange (25-49.9), red (50+), gray (totals)

Table III.K.7-4
Summary of Boroughs With Highest Weighted Emission Potential, Impacting Tuxedni Monitoring Site on 20% Worst Days

Borough	Year	Commercial Marine Vessels	Natural Fires	Non-Road Mobile	On-Road Mobile	Point	Stationary Area	Total
$PM_{2.5}$								
Yukon-Koyukuk CA	2002	0.0	71.7	0.0	0.0	0.0	0.1	71.9
	2018	0.0	71.7	0.0	0.0	0.0	0.1	71.9
Kenai Peninsula	2002	0.2	0.0	0.3	0.2	0.6	16.3	17.8
	2018	0.4	0.0	0.2	0.1	0.0	17.9	18.8
Matanuska-Susitna	2002	0.0	0.8	0.1	0.0	0.0	2.4	3.6
	2018	0.0	0.8	0.1	0.0	0.0	3.3	4.5
Total	2002	0.2	72.5	0.4	0.3	0.6	18.8	93.2
	2018	0.4	72.5	0.3	0.1	0.0	21.4	95.2
VOC								
Kenai Peninsula	2002	0.1	0.0	5.7	8.9	16.9	15.4	47.1
	2018	0.2	0.0	5.0	3.0	22.1	17.2	47.7
Yukon-Koyukuk CA	2002	0.0	36.2	0.0	0.0	0.0	0.5	36.6
	2018	0.0	36.2	0.0	0.0	0.0	0.4	36.6
Matanuska-Susitna	2002	0.0	0.4	0.7	1.9	0.1	1.8	5.2
	2018	0.0	0.4	0.9	0.8	0.1	2.6	5.1
Total	2002	0.1	36.6	6.4	10.8	17.0	17.7	88.9
	2018	0.3	36.6	5.9	3.8	22.2	20.2	89.4
NOx								
Kenai Peninsula	2002	3.5	0.0	1.8	8.0	60.9	2.1	76.3
	2018	5.0	0.0	0.9	2.7	48.7	2.3	59.6
Yukon-Koyukuk CA	2002	0.0	13.9	0.0	0.0	0.0	0.0	13.9
	2018	0.0	13.9	0.0	0.0	0.0	0.0	13.9
Matanuska-Susitna	2002	0.0	0.2	0.4	1.5	1.6	0.6	5.3
	2018	0.0	0.2	0.3	0.7	1.8	0.8	4.9
Total	2002	3.5	14.0	2.2	9.5	62.6	2.7	95.6
	2018	5.1	14.0	1.2	3.4	50.5	3.1	78.5
SOx								
Yukon-Koyukuk CA	2002	0.0	39.3	0.0	0.0	0.0	0.0	39.3
	2018	0.0	39.3	0.0	0.0	0.0	0.0	39.3
Kenai Peninsula	2002	13.7	0.0	0.0	3.9	4.3	25.7	47.7
	2018	0.7	0.0	0.0	0.3	5.0	28.9	35.0
Matanuska-Susitna	2002	0.0	0.4	0.0	0.8	0.0	1.3	3.7
	2018	0.0	0.4	0.0	0.1	0.0	2.1	4.1
Total	2002	13.8	39.7	0.0	4.7	4.3	27.0	90.7
	2018	0.7	39.7	0.0	0.4	5.0	31.1	78.4
NH_3								
Kenai Peninsula	2002	0.0	0.0	0.0	5.3	37.9	0.0	43.3
	2018	0.0	0.0	0.0	5.7	72.4	0.0	78.1
Yukon-Koyukuk CA	2002	0.0	51.5	0.0	0.0	0.0	0.0	51.5
	2018	0.0	51.5	0.0	0.0	0.0	0.0	51.5
Matanuska-Susitna	2002	0.0	0.6	0.0	1.2	0.0	0.0	1.8
	2018	0.0	0.6	0.0	1.6	0.0	0.0	2.2
Total	2002	0.0	52.1	0.0	6.6	37.9	0.0	96.6
	2018	0.0	52.1	0.0	7.3	72.4	0.0	131.8

Shading: clear (0-9.9), yellow (10-24.9), orange (25-49.9), red (50+), gray (totals)

Table III.K.7-5
Summary of Total Weighted Emission Potential From All Boroughs Impacting Each Site on 20% Worst Days

Class I Site	Year	$PM_{2.5}$	VOC	NOx	SOx	NH_3
Denali	2002	100.0	100.0	100.0	100.0	100.0
	2018	100.2	99.1	99.5	100.8	101.1
	Change	0.2	-0.9	-0.5	0.8	1.1
Simeonof	2002	100.0	100.0	100.0	100.0	100.0
	2018	100.3	102.8	97.2	97.8	102.0
	Change	0.3	2.8	-2.8	-2.2	2.0
Trapper Creek	2002	100.0	100.0	100.0	100.0	100.0
	2018	106.0	102.2	94.9	100.9	107.7
	Change	6.0	2.2	-5.1	0.9	7.7
Tuxedni	2002	100.0	100.0	100.0	100.0	100.0
	2018	102.1	101.0	82.9	87.0	135.2
	Change	2.1	1.0	-17.1	-13.0	-35.2

It is useful to contrast the change in total WEP values with the summaries reached for the top three boroughs for each site to see if any revisions are needed:

- Denali – The large increase in point source SOx from the Kenai seen in Table III.K.7-1 is largely offset by reductions from other sources to a value of less than 1.0. All of the other anthropogenic sources show either a decline or a negligible increase. These forecasts do not account for the emissions from the HCCP at the GVEA facility in Healy (i.e., unit # 2). That facility did not operate in 2002 and is not currently operating, but is permitted to operate. If brought on line, the point source NOx emitted within the Denali Borough would increase by a factor of 4.0 and the SOx would increase by a factor of 2.8 (based on permitted not actual emissions). This increase would make the Denali Borough the largest sources of anthropogenic emissions and the second largest source of all emissions impacting the Denali monitors.

- Simeonof – Table III.K.7-2 showed that natural fires are the dominant source of pollutants impacting this site; no anthropogenic source was shown to have a significant impact. The totals displayed in Table III.K.7-5 show the addition of the other boroughs change that assessment since a small WEP increase in VOC and NH_3 is shown along with a small WEP decrease in NOx and SOx; the increase shown for $PM_{2.5}$ is negligible.

- Trapper Creek – The addition of the other boroughs significantly offsets the increase in SOx and VOC WEP values seen in Table III.K.7-3. SOx is reduced to a value of less than 1.0 and VOC is reduced to 2.2. On the other hand, the WEP increase seen for $PM_{2.5}$ increased slightly from 5.5 to 6.0 when all boroughs are considered, with most of the increase coming from Mat-Su area sources. The NH_3 WEP increase of 2.8 seen across the three boroughs increased to 7.7 when all of the boroughs are considered, with

2.7 of that increase being attributable to on-road vehicle activity in Mat-Su. The remainder comes from increased vehicle activity in other boroughs.

- Tuxedni – The principal finding that there is a large increase in NH_3 emissions coming from point sources in the Kenai Peninsula. The NH_3 emissions are primarily from a BART-eligible facility, the Agrium Chem-Urea plant, which was operational in 2002 and projected to 2018, but that is currently shut down. As discussed in Section III.K.6, these emissions effectively no longer exist and if the facility restarts would be subject to PSD permitting.

III.K.8 LONG-TERM STRATEGY

The Regional Haze Rule requires Alaska to submit a 10-15 year long-term strategy (LTS) to address regional haze visibility impairment in each Class I area in Alaska and for each Class I area outside Alaska that may be affected by emissions originating from within the Alaska. Due to the long distances from Alaska to the Lower 48 states, Alaska has not identified any Class I areas outside of Alaska that are impacted by Alaskan emissions and no states have notified Alaska through the regional planning process of Alaska source impacts on their Class I areas. As a result, Alaska's strategy focuses solely on addressing visibility impairment in Alaska's Class I areas. In addition, Alaska has found that international emissions transported into Alaska have an impact on visibility in the Class I areas. These international emissions cannot be controlled by local or state control measures and are factored into the reasonable progress goals discussed in Section III.K.9. The LTS must identify all manmade sources of visibility-impacting pollution that Alaska considered in developing the strategy as well as the measures needed to achieve Alaska's reasonable progress goals. The LTS presented in this section covers the first regional haze planning period, which spans from 2002 to 2018.

A. Overview of the Long-Term Strategy Development Process

Alaska is a participant in the Western Regional Air Partnership, which is a major source of technical and policy assistance for the western states in developing regional haze reduction strategies. While Alaska has differences from other states in some of the tools available for use in the regional haze planning process, the following list contains WRAP products that were used by ADEC in developing the LTS. For additional detail on WRAP products, please see the WRAP website at http://www.wrapair.org.

- Technical Support System (TSS) – This is a project that provides a single, one-stop shop for access, visualization, analysis, and retrieval of the technical data and regional analytical results prepared by WRAP Forums and Workgroups in support of regional haze planning in the West. The TSS specifically summarizes results and consolidates information about air quality monitoring, meteorological and receptor modeling analyses, and emission inventories and models. http://vista.cira.colostate.edu/wraptss/

- Regional Modeling Center (RMC) – The RMC conducted an MM5 Modeling Study and assisted with an Alaska Visibility Modeling Protocol. These reports are posted and available for download. http://pah.cert.ucr.edu/aqm/308/docs.shtml

- Visibility Information Exchange Web System (VIEWS) – This data system provides ongoing access to IMPROVE and other visibility monitoring data, research results, and special studies related to regional haze. Downloads of IMPROVE data, custom displays of spatial, chemical, and temporal patterns, as well as information about applying monitoring data for regional haze planning, are available. http://vista.cira.colostate.edu/views/

- Causes of Haze Assessment Project (CoHA) – This project provides detailed analyses of IMPROVE and meteorological monitoring data in the WRAP region. It includes multi-year

back trajectory wind plots for each monitored Class I area, trajectory regression analyses' results used in the Phase I attribution of haze project, and extensive descriptive information about the monitoring data and each Class I area. http://coha.dri.edu/index.html

- Emissions Data Management System (EDMS) – This data system provides emission inventory data and web-based GIS application with a consistent, complete, and regional approach to emissions data tracking for SIP development, periodic progress reviews, and data updates. The EDMS serves as a central emission inventory database for all types of emissions, and uses associated software to facilitate the data collection efforts for regional modeling, emissions tracking and associated data analyses. http://wrapedms.org/default_login.asp

1. Summary of Manmade Sources of Visibility Impairment Considered in the Long-Term Strategy

Regional Haze Rule Section 51.308(d)(3)(iv) requires the state to identify all anthropogenic, or manmade, sources of visibility impairment considered in developing the LTS. Section III.K.5 of this plan describes emissions within the state and projections of emission changes from manmade sources from 2002 to 2018; Sections III.K.4, III.K.7 and III.K.9 discuss the sources that may be impacting Class I areas in Alaska. Together, these sections show the major manmade source categories impacting Alaska's Class I areas, which are therefore the primary focus of the LTS. All manmade source categories considered are listed below.

- Stationary sources subject to BART requirements
- Non-BART stationary sources
- Smoke from planned burning for agricultural, land clearing, forestry, and habitat management
- On-road and non-road mobile sources
- Area sources
- Construction

2. Technical Documentation

Section 51.308(d)(3)(iii) of the Regional Haze rule requires documentation of the technical basis, including modeling, monitoring, and emission information, on which the State relied upon to determine the apportionment of emission reductions needed to achieve progress goals in each Class I area it affects. Alaska relied on technical information and analysis provided by the WRAP, through various projects and studies conducted by contractors, WRAP staff, and incorporated into the WRAP's TSS website. In addition, ADEC undertook additional analyses in the development of this plan.

Emissions Data – Section III.K.5 describes the emission inventory information for Alaska that was used in developing this plan.

Modeling Techniques – Section III.K.7 describes the source apportionment analysis and approach developed by Alaska, including the use of back trajectory modeling and a Weighted Emission Potential (WEP) tool, for the attribution of sources of sulfate, nitrate, organic carbon, elemental carbon, fine PM, and coarse PM.

Monitoring Data – Section III.K.3 describes the IMPROVE monitoring network and other monitoring data in Alaska. Section III.K.4 provides a summary of monitoring data, trends, and breakdown by pollutant for each of the site locations in Alaska.

B. Long-Term Strategy Measures

Regional Haze Rule Section 51.308(d)(3)(v) lists the following minimum factors that must be considered in development of the Long-Term Strategy:

- Emission reductions due to ongoing air pollution control programs;
- Measures to mitigate the impacts of construction activities;
- Emission limitations and schedules for compliance;
- Source retirement and replacement schedules;
- Smoke management techniques for agricultural and forestry burning;
- Enforceability of emission limitations and control measures; and
- Anticipated net effect on visibility over the period of the long-term strategy.

Consideration of each of these factors is discussed below. In addition, another requirement not specifically referenced in the above list is regional haze BART control. This program is relevant to ADEC's on-going air pollution control programs, and as such will be discussed with the first factor listed above.

1. Emission Reductions Due to Ongoing Air Pollution Programs

Alaska has a number of ongoing programs and regulations that directly protect visibility or provide for improved visibility by generally reducing emissions. This summary does not attempt to estimate the actual improvements in visibility at each Class I area that will occur between 2002 and 2018, because existing technical tools are inadequate to accurately do so. The visibility benefits from these programs are secondary to the primary health-based air pollution objectives of these programs and rules.

a. Prevention of Significant Deterioration/New Source Review Regulations

The two primary regulatory programs for addressing visibility impairment from industrial sources are BART and the Prevention of Significant Deterioration/New Source Review (PSD/NSR) rules. The PSD/NSR rules protect visibility in Class I areas from new industrial sources and major changes to existing sources. Alaska's regulations (18 AAC 50 Article 3) and SIP require visibility impact assessment and mitigation associated with emissions from new and modified major stationary sources through protection of air quality related values (AQRVs). AQRVs are scenic and environmentally related resources that may be adversely affected by a

change in air quality, including visibility, odor, noise, vegetation, and soils. These visibility requirements were approved by EPA in 1983.

Alaska's continued implementation of New Source Review and Prevention of Significant Deterioration requirements with Federal Land Manager involvement for Class I area impact review will assist in maintaining the least impaired days from further degradation and assure that no Class I area experiences degradation in visibility resulting from expansion or growth of stationary sources in the state.

b. Reasonably Attributable Visibility Impairment BART Requirements

Federal regulations at 40 CFR 51.305-51.306 contain requirements for the purposes of addressing "reasonably attributable" visibility impairment at each Class I area. These requirements included a three-step process to address visibility degradation from identifiable stationary sources:

1. Federal Land Manager (FLM) "certifies" impairment.

2. State makes a determination as to whether impairment can be "reasonably attributable" to one or a small group of stationary sources.

3. If the state determines that impairment is attributable to a source or small group of sources, the state undertakes a Best Available Retrofit Technology (BART) analysis to arrive at the appropriate control level.

It should be noted that the "reasonably attributable" BART requirements are separate and distinct from the Regional Haze BART requirements discussed in Section III.K.6. While both apply to existing industrial sources, the reasonably attributable BART requirements are triggered by a "certification" by the Federal Land Manager that visibility impairment exists in a federal Class I area. Upon such a certification, ADEC is required to make a determination of impairment attributable to a source and then analyze BART for the contributing source.

To date, ADEC has not made any determinations of "reasonably attributable" impairment for Alaska Class I areas. However, concerns related to a PSD permit issued to the Golden Valley Electric Association, Inc for the Healy Power Plant in 1994 resulted in evaluation and mitigation of potential impacts for that facility on the Denali Class I area.

ADEC issued Golden Valley Electric Association, Inc. (GVEA), a permit to operate the Healy Clean Coal Project (HCCP) in May 1994. The HCCP is located in Healy, Alaska, approximately 3.8 miles from the border of Denali National Park and Preserve. Through ADEC's PSD permit process, the Department of the Interior (DOI) and EPA offered recommendations and conducted independent modeling assessments. In the opinion of ADEC, modeling results demonstrated little potential for visibility impact from plumes and haze derived from proposed HCCP operations. The DOI appealed the issuance of a final permit in March 1993. Eventually, a Memorandum of Agreement was signed between the DOI, DOE, and GVEA to address visibility concerns and allow issuance of the permit.

ADEC issued a final permit to operate on May 6, 1994. GVEA agreed to retrofit its old generator, Unit #1, with low-NO_X burners, and use overfire air, if feasible. It was to inject sorbent (FCM or lime) into Unit #1 to control SO_2 emissions. GVEA accepted facility-wide emission levels of 1,439 tpy for NO_X and 721 tpy for SO_2. If a visible plume were detected, GVEA would reduce combined emissions from permitted levels to 200 lbs/hr for NO_X and 150 lbs/hr for SO_2, for 12 hours. It was to continue in 12-hour increments until the plume was no longer observed.

c. Regional Haze BART Control

Section 51.308(e) of the rule includes the requirements for states to implement Best Available Retrofit Technology for eligible sources within the State that may reasonably cause or contribute to any impairment of visibility in any mandatory Class I area. The installation of BART emission limits is an integral part of the state's LTS. ADEC established regulations in 18 AAC 50.260 establishing the guidelines for BART under the regional haze rule. ADEC has completed analysis of the identified BART-eligible sources in Alaska and has conducted four-factor analyses and established BART emission limits per the regulations. Each source subject to BART is required to install and operate BART as expeditiously as practical, but in no event later than January 1, 2015, or five years after the EPA approval of this implementation plan, whichever occurs first. Once controls are implemented, facilities subject to BART must ensure that control equipment is properly operated and maintained. Regional haze BART outcomes and emission limits are discussed in detail in Section 6 III.K.6 of this plan. The BART limitations will result in long-term visibility improvements to two of Alaska's Class I areas: Denali National Park and Tuxedni National Wildlife Refuge.

ADEC originally identified seven industrial facilities with units determined to be eligible for BART:

- Anchorage Municipal Light and Power, George Sullivan Plant 2;
- Golden Valley Electric Association, Healy Power Plant (GVEA);
- Agrium, Chemical-Urea Plant;
- Alyeska Pipeline Service Company, Valdez Marine Terminal;
- ConocoPhillips Alaska Inc., Kenai LNG Plant (CPAI);
- Tesoro, Kenai Refinery; and
- Chugach Electric, Beluga River Power Plant.

These facilities were notified of the eligible units in 2007. It was subsequently determined that the Chugach Electric Beluga River Power Plant was actually not BART-eligible due to replacement of the originally identified units. The six remaining facilities were determined to have BART eligible units and followed the requirements of 18 AAC 50.260.

Details on the full BART process and the BART determinations for each facility are included in Section III.K.6. The table below summarizes in general terms the outcome of the BART process for each facility.

Facility	Subject to BART Analysis	BART Determination
Alyeska, Valdez Marine Terminal	No: Modeled visibility impacts less than 0.5 deciview	N/A
Tesoro, Kenai Refinery	No: Modeled visibility impacts less than 0.5 deciview	N/A
Anchorage Municipal Light and Power, Sullivan Plant	No: Modeled visibility impacts less than 0.5 deciview	N/A
CPAI, Kenai LNG Plant	No: COBC limits emissions from units to levels that would have modeled visibility impacts less than 0.5 deciview	N/A – Handled by COBC
Agrium, Chem-Urea Plant	Yes	Facility is currently shutdown – zero emission limit for BART eligible units
GVEA, Healy Power Plant	Yes	NOx: 0.20 lbs/MMBtu SO_2: 0.30 lb/MMBtu PM: 0.015 lb/MMBtu

d. Operating Permit Program and Minor Source Permit Program

DEC implements a Title V operating permit program as well as a minor source permit program for stationary sources of air pollution. The Title V permits are consistent with the requirements of 40 CFR Part 71 and requirements are found in 18 AAC 50 Article 3, Major Stationary Source Permits. The requirements for minor source permits are found in 18 AAC 50 Article 5, Minor Permits. Sources that may be required to obtain minor permits include asphalt plants, thermal soil remediation units, rock crushers, incinerators, coal preparation plants, or a Port of Anchorage stationary source. Minor permits are required for new or existing sources with a potential to emit above specific thresholds before construction, before relocating a portable oil and gas operation, or before beginning a physical change or change in the method of operation. Details are included in the state regulation.

These permit programs, coupled with PSD/NSR requirements, serve to ensure that stationary industrial sources in Alaska are controlled, monitored, and tracked to prevent deleterious effects of air pollution. Given the level of visibility impairment at Alaska's Class I areas, the sources that have been found to be significant contributors to that impairment, and the uncertainty of the technical information and analyses, ADEC believes that at this time the existing stationary source controls, coupled with regional haze BART controls (described above), will be adequate for the purposes of reducing visibility impairment on the worst visibility days and maintaining visibility on the best visibility days in Alaska Class I areas. ADEC will continue to assess and evaluate the impacts of stationary sources on Class I area visibility in future SIP revisions and will consider whether additional controls are warranted for stationary sources to insure reasonable progress in the long term.

e. Alaska Open Burning Regulations

Smoke from wildland fires are a major contributor to visibility impairing air pollution in Alaska communities and mandatory federal Class I areas. Alaska has previously established open burning regulations in 18 AAC 50.065 and included open burning requirements in the State Implementation Plan (Volume II, Section III.F) to reduce and prevent particulate matter emissions from impacting public health. These requirements will now protect visibility impairment in Class I areas as well.

18 AAC 50.065 provides ADEC with the authority to require approvals for controlled burning to manage forest land, vegetative cover, fisheries, or wildlife habitat if the area to be burned exceeds 40 acres yearly. The regulations also provide for department approvals for open burns for firefighter training exercises. This existing program, coupled with the state's Enhanced Smoke Management Plan (described later in this subsection), provides for control of visibility impairing pollutants resulting from planned open burning. It should be noted that wildfire emissions typically dwarf planned burn emissions in any given year. Wildfires can occur in proximity to Class I areas or their smoke may be transported long distances resulting in visibility impacts. Section III.K.4 describes the impact from smoke emissions in Class I areas.

f. Local, State and Federal Mobile Source Control Programs

Mobile source emissions show descreases in NOx, SO_2, and VOCs in Alaska during the period 2002-2018. This decline in emissions is due to numerous rules already in place, most of which are federal regulations.

The State of Alaska has established regulations related to mobile sources that primarily impact the Fairbanks and Anchorage CO maintenance areas, Alaska's two largest cities. These regulations include local inspection and maintenance (I/M) programs (18 AAC 52), which have been in effect since the 1980s and that are described in Volume II, Sections III.A-C, of the Alaska Air Quality Control Plan. The local I/M programs may be suspended in the CO maintenance areas following approval by EPA of a revised SIP. The Fairbanks program was suspended in January 2010. The Anchorage program remains in effect, but may be suspended in the future pending local air quality planning decisions and federal approval. Alaska regulations (18 AAC 53) also provided for an oxygenated fuel program in Anchorage, which was suspended in 2004. These programs have resulted in NOx and hydrocarbon emission reductions from motor vehicles in Alaska's largest communities.

The Federal Motor Vehicle Control Program (FMVCP) is the federal certification program that requires all new cars sold in 49 states to meet specific emission standards. (California is excluded because it has its own state-mandated certification program.) As part of the FMVCP, all new cars must meet their applicable emission standards on a standard test cycle called the Federal Test Procedure (FTP). These standards vary according to vehicle age, with the newer vehicles required to be considerably cleaner than older models. The result of this decline over time in allowable emissions from newly manufactured vehicles has been a drop in overall emissions from the vehicle fleet, as older, dirtier vehicles are replaced with newer, cleaner vehicles.

EPA's Tier 2 emission standards for passenger cars, light trucks and larger passenger vehicles are focused on reducing emissions most responsible for ozone and particulate matter (i.e., nitrogen oxide or NOx and hydrocarbon or HC emissions). The control equipment introduced to meet these standards will result in reductions in visibility impairing pollutants. Mandated reductions in the sulfur content of gasoline will further enhance the performance of this equipment. This will also reduce emissions from the existing fleet of gasoline-powered vehicles by reducing the deterioration of catalytic converters.

Various federal rules establishing emission standards and fuel requirements for diesel onroad and nonroad equipment will significantly reduce emissions of particulate matter, nitrogen oxides, and sulfur oxides from emission sources over the first planning period. Prior to 2006, Alaska had fuel sulfur exemptions from the EPA for mobile sources. In June 2006, EPA finalized a rule in 40 CFR Part 69 for controlling air pollution from motor vehicles and nonroad diesel engines allowing an alternative low-sulfur diesel transition for Alaska (http://www.epa.gov/EPA-AIR/2006/June/Day-06/a5053.htm). This rule kept urban/road system portions of Alaska on the national rule's timeline but allowed for flexibility and some additional time for rural Alaska to fully comply. By 2010, all onroad and nonroad diesel engines in Alaska must meet EPA's national requirements for 15 ppm S diesel fuel. In addition to the regulatory programs, ADEC is also promoting voluntary projects to reduce diesel emission reductions throughout the state.

In addition to the federal and state programs described above, the two CO maintenance areas in Fairbanks and Anchorage have local programs to address mobile source emissions that will also reduce visibility impairing pollutants. Both communities have transit programs that assist in reducing vehicle emissions in their respective areas. In Anchorage, specific local programs included in the SIP are a vanpool/ridesharing program, which reduces overall vehicle miles travelled, and efforts to encourage the use of block heaters in the winter to reduce cold start emissions from motor vehicles. In Fairbanks, the local "plug-in" program for engine block-heater use and electrification of parking lots also assists with reducing mobile source emissions from cold starts.

g. Implementation of Programs to Meet PM_{10} NAAQS

The community of Eagle River and the Mendenhall Valley in Juneau are either currently or formerly nonattainment areas with respect to the NAAQS for coarse particulate matter (PM_{10}). These areas exceeded the standards due primarily to wood burning and road dust sources. Other communities in Alaska face similar problems, particularly with regards to road dust. Both wood burning and road dust sources can contribute to visibility impairment. While most of Alaska's communities are not in close proximity to Class I areas, improvements made through PM control programs—such as wood smoke control, road paving, or dust suppression—may assist in mitigating visibility impacts, depending on the proximity to Class I areas.

In addition to the ongoing emission reductions in PM_{10} nonattainment and maintenance areas, ADEC has a new $PM_{2.5}$ nonattainment area in the Fairbanks North Star Borough, which will require the adoption of new measures to reduce emissions.

2. Measures to Mitigate Impacts of Construction Activities

In developing this LTS, ADEC has considered the impact of construction activities on visibility in Alaska's Class I areas. Alaska's Class I areas are remote with little to no significant growth in close proximity to each area. Based on this general knowledge of growth and construction activity in Alaska, and without conducting extensive research on the contribution of emissions from construction activities on visibility, ADEC believes that current state and federal regulations already adequately address this emission source.

State regulations contained at 18 AAC 50.045(d) require that entities who cause or permit bulk materials to be handled, transported, or stored or who engage in industrial activities or construction projects shall take reasonable precautions to prevent particulate matter from being emitted into the ambient air. This regulation allows the state to take action on fugitive dust emissions from construction activities.

In addition to state regulation, federal rules establishing emission standards and fuel requirements for diesel non-road equipment will significantly reduce emissions of particulate matter, nitrogen oxides, and sulfur oxides from emission sources in the construction sector over the first planning period. Prior to 2006, Alaska had fuel sulfur exemptions from the EPA for mobile sources. In June 2006, EPA finalized a rule in 40 CFR Part 69 for controlling air pollution from motor vehicles and nonroad diesel engines allowing an alternative low-sulfur diesel transition for Alaska (http://www.epa.gov/EPA-AIR/2006/June/Day-06/a5053.htm). This rule kept urban/road system portions of Alaska on the national rule's timeline but allowed for flexibility and some additional time for rural Alaska to fully comply. By 2010, all onroad and nonroad diesel engines in Alaska must meet EPA's national requirements for 15 ppm S diesel fuel.

3. Emission Limitations and Schedules for Compliance

Promulgated state and federal regulations under the Clean Air Act have unique emission limits and compliance schedules specified for the affected sources. These limitations and schedules are identified in the specific rules. The schedules for compliance in implementing BART controls are described in Section III.K.6. ADEC's four-factor analysis did not identify any additional measures that were appropriate to implement during this first regional planning period. As a result, no other emission limitations or schedules of compliance are included in this plan. It is anticipated that further evaluation of control programs for future SIP updates may identify additional emission controls that could be implemented. Emission limitations and compliance schedules will be included as needed during the periodic plan updates.

4. Source Retirement and Replacement Schedules

The construction of new sources to replace older, less well-controlled sources can aid in progress toward achieving visibility goals. Alaska's continued implementation of NSR and PSD requirements with FLM involvement for Class I area impact review will assist in maintaining the least impaired days from further degradation and assure that no Class I area experiences degradation in visibility resulting from expansion or growth of stationary sources in the state.

ADEC will continue to track source retirement and replacement and include known schedules in periodic revisions to this plan.

5. Smoke Management Techniques for Agricultural and Forestry Burning

SIP requirements related to smoke management are found in Section 308(d)(3)(iv)(E) of the Regional Haze rule. Smoke from wildland fires is a major contributor to visibility impairing air pollution in Alaska, including in Class I areas. Alaska's implementation of effective smoke management techniques through regulation and an Enhanced Smoke Management Plan will mitigate impacts of planned burning on visibility in Class I areas.

As described previously, ADEC has regulations related to open burning in 18 AAC 50.065 and included open burning requirements in the SIP (Volume II, Section III.F). ADEC requires approvals for open burning or controlled burning to manage forest land, vegetative cover, fisheries, or wildlife habitat if the cumulative area to be burned exceeds 40 acres yearly. ADEC also requires approvals for open burns for firefighter training exercises. In addition to this ongoing regulation, ADEC has developed and implemented an Alaska Enhanced Smoke Management Plan (ESMP) and is including this plan as part of this long-term strategy. Open burn approvals require that entities conducting planned burns follow the provisions in the ESMP.

ADEC works cooperatively with the Alaska Wildland Fire Coordinating Group (AWFCG) to address air quality impacts from wildland fire through the ESMP. The AWFCG was formed in 1994 and provides a forum that fosters cooperation, coordination and communication for wildland fire and for planning and implementing interagency fire management statewide. The AWFCG membership includes state, federal and Native land management agencies/owners that have fire management responsibilities for the lands they manage/own.

One of the objectives of the AWFCG is to provide a forum for anticipating smoke intrusions into sensitive areas, including communities and Class I areas; resolving on-going smoke management issues; and improving smoke management techniques. Another objective is to ensure that prescribed fire, as a tool to reduce risk and/or future smoke emissions, is considered by ADEC when promulgating policy, procedures and regulations. Without the use of prescribed fire on the landscape, the state could see large, catastrophic fires whose smoke would create larger impacts on Alaskans and Class I areas than the smoke of controlled burns. The AWFCG Smoke Management/Air Quality Committee addresses the AWFCG smoke management objectives and assists ADEC with the development and revision of the ESMP for Prescribed Fire and propagation of policies, procedures and regulations related to smoke management.

The ESMP helps fulfill Alaska's responsibilities for protection of air quality and human health under federal and state law and reflects the Clean Air Act requirement to improve regional haze in Alaska's Class I areas. The ESMP outlines the process, practices and procedures to manage smoke from prescribed and other open burning and identifies issues that need to be addressed by ADEC and land management agencies or private landowners/corporations to help ensure that prescribed fire (e.g. controlled burn) activities minimize smoke and air quality problems. The ESMP provides accurate and reliable guidance and direction not only to and from the fire authorities who use prescribed fire as a resource management tool, but also to the private landowners and/or corporations who conduct agricultural or land-clearing burns. The ESMP

describes and clarifies the relationship between fire authorities and ADEC. These agencies must work together effectively to combine planned burning, resource management and development with smoke, public health and Class I area visibility goals.

Alaska's ESMP was last adopted by the AWFCG in June 2009 and is evaluated annually by the AWFCG and interested parties. The ESMP may be revised annually as needed, but will be revised at least every 5 years in accordance with EPA's Interim Policy on Wildland and Prescribed Fires. The ESMP dated June 2009 is included in Appendix III.K.8 (please note that this plan may be revised annually based on routine evaluation of its effectiveness).

6. Enforceability of Emission Limitations and Control Measures

Section 51.308(d)(3)(v)(F) of the Regional Haze Rule requires that emission limitations and control measures used to meet reasonable progress goals be enforceable. Enforceability of BART emission limits will occur through this SIP rule and Alaska regulations (18 AAC 50.260). Alaska has ensured that all emission limits and control measures used to meet reasonable progress goals are enforceable by embodying these in state regulation (18 AAC 50). ADEC has adopted this Regional Haze Plan into the Alaska Air Quality Control Plan (Alaska's State Implementation Plan) at 18 AAC 50.030, which ensures that all elements in the plan are enforceable.

7. Anticipated Net Effect on Visibility Over the Period of the Long-Term Strategy

The anticipated net effect on visibility from emission reductions by point, area, and mobile sources during the period of the LTS is estimated in Section III.K.9. The reasonable progress demonstration, based on monitoring, emission inventory, and modeling projections, indicates that measures included in the long term strategy provide for an improvement in visibility on the 20% worst days consistent with the uniform rate of progress target in 2018.

The results of the reasonable progress demonstration in Section III.K.9 show many anthropogenic emission sources declining significantly in Alaska through 2018. Overall visibility benefits of these reductions are somewhat offset, however, by emissions from natural sources such as wildfire and dust, and other uncontrollable sources. This includes international sources in Canada Asia, and Europe, global transport of emissions, and offshore shipping in the Pacific Ocean. Despite this, it is clear that visibility improvements will be made due to the control of BART sources, as well as numerous on-the-books regulations such as state and federal mobile source rules, the marine emission control area, smoke management, and other elements contained in the LTS that address $PM_{2.5}$ over the next five to ten years and may provide additional improvements by 2018.

As part of the requirement to submit five-year progress reports on this plan, ADEC will include in the five-year update any additional visibility improvements expected due to updated or new information related to the demonstration of reasonable progress in Section III.K.9 of this plan.

III.K.9 REASONABLE PROGRESS GOALS

A. Overview

The Regional Haze Rule established a 60-year timeline to improve visibility in Class I areas from the baseline conditions to natural conditions in 2064. The first step in the process is for States to provide a demonstration of "reasonable progress" between the baseline and 2018, the first milestone year. As part of this demonstration, States must establish a Reasonable Progress Goal (RPG) for each Class I area that identifies the visibility improvement for the worst 20 percent of monitored (i.e., most-impaired) days while ensuring no degradation of visibility for the best 20 percent of monitored (i.e., least-impaired) days. States have the flexibility to establish different RPGs for each Class I area.

The first step in establishing the RPG is to calculate the Uniform Rate of Progress (URP) for each Class I area. The URP is a straight line from the baseline conditions to the natural conditions in 2064. This line, known as the "glide path", establishes the URP for 2018 which is the target year for the first planning period. The URP for each Class I area is shown in Section III.K.4.

States must consider the projected emissions in 2018 along with the benefits of all regional haze control measures as well as the URP when selecting RPGs. The 2018 URP does not mandate a reduction target. States have the option to select RPGs with greater, equivalent or lesser visibility improvements than established by the URP; however, in those cases where an RPG provides less improvement than URP, states must document why it is not possible to achieve the URP levels and why the selected value is "reasonable."

B. Steps in Demonstrating Reasonable Progress

Many of the steps followed in establishing RPG values in 2018 have been presented in earlier sections of this Plan. Presented below is a brief summary of each of the key steps followed for each Class I area.

1. Establish Baseline and Natural Conditions – The 2000–2004 baseline and natural conditions, which establish the target in 2064, were calculated by the WRAP for the best and worst days. A discussion of these calculations is presented in Section III.K.4.

2. Calculate Uniform Rate of Progress (URP) – The URP glide path was calculated from the baseline to 2064 for the worst days. The glide path established the 2018 planning target in units of deciviews. These calculations were presented in Section III.K.4.

3. Identify Pollutants Impacting Visibility – Section III.K.4 details the pollutant species contributing to visibility impairment on the 20 percent worst and best days during the baseline period.

4. Characterize Emission Estimates for All State Sources Impacting Visibility – Alaska devoted considerable resources to preparing the first statewide emission inventory of

criteria pollutants for use in assessing trends between the baseline and 2018. A discussion of the inventory is presented in Section III.K.5.

5. Evaluate the Source Contributions Impacting Visibility – The WEP analysis, presented in Section III.K.7, documents the distribution of sources impacting each Class I site. It also highlights the differences in pollutant specific contributions from anthropogenic and nonathropogenic sources between the baseline and 2018.

6. Document Emission Reductions From BART – A description of the modeling analysis and emission reductions achieved by BART for each impacted source is presented in Section III.K.6.

7. Conduct Four-Factor Analysis – A description of the process used to identify key pollutants and source categories impacting each Class I area is presented in Section III.K.9.C along with the results of the analysis.

8. Review of Additional Emission Reductions – A discussion of source-specific BART reductions and their impact on the pollutant-specific WEP reductions forecast for each site on the 20 percent worst days is presented below in Section III.K.9.D.

9. Establish RPGs – The process used to establish separate 2018 RPGs for each Class I area for the 20% worst and best days is presented below in Section III.K.9.E.

10. Contrast RPG and URP Targets in 2018 – A comparison between the RPG target established in Step 9 and the URP target established in Step 2 along with an affirmative demonstration that reasonable further progress is being made from anthropogenic sources within the limits of the uncertainty of the URP glide path is presented in Section III.K.9.F for each Class I area. Also presented is a review of how issues in Step 8 are expected to support that finding.

C. Summary of Four-Factor Analysis

Section 308(d)(1)(i)(A) of the Regional Haze Rule requires that states consider the following factors and demonstrate how they were taken into consideration in selecting the reasonable progress goals:

- Costs of compliance;
- Time necessary for compliance;
- Energy and non-air quality environmental impacts of compliance; and
- Remaining useful life of any potentially affected sources.

In conducting this four-factor analysis, EPA guidance indicates that states have "considerable flexibility" in how these factors are taken into consideration, in terms of what sources or source categories should be included in the analysis, and what additional control measures are reasonable.[*]

1. Rationale and Scope of the Four-Factor Analysis

ADEC looked at key pollutants and certain source categories and the magnitude of their emissions in applying the four factors. Based on the flexibility in how to apply the statutory factors, the rationale outlined below was used in defining the scope of this analysis.

- Focus on 20% worst days: The Regional Haze rule primarily focuses on demonstrating reasonable progress for the 20% worst days so ADEC's four-factor analysis addresses only the worst days. It is a reasonable assumption that emission reductions benefiting the worst days also benefit the best days.

- Focus on anthropogenic sources: The purpose of this analysis is to evaluate certain sources or source categories for potential controls; therefore, the analysis should be of sources that are controllable. While wildfire, natural windblown dust, and sea salt may be important contributors to regional haze, ADEC does not see the value in applying a four factor analysis to these natural source categories. Therefore, ADEC considered point, area, and mobile sources, and planned burning in the analysis.

  For mobile sources, there are major emissions reductions projected by 2018, based on numerous "on-the-books" federal and state regulations, as described in detail in the state's Long Term Strategy in Section III.K.8. These controls and emission reductions should result in significant visibility improvements by 2018. Based on the above findings, ADEC did not believe applying the four-factor analysis to mobile sources was warranted or productive in developing this plan

  For fire sources, planned forestry burning can be a large anthropogenic source. As detailed in the Long Term Strategy, these activities are controlled under Alaska's open burning regulations Enhanced Smoke Management Program (ESMP). Given the current level of control through the ESMP and regulations, Alaska has a relatively advanced level of smoke management in place. The on-going re-evaluation of these programs also provides for improvements over time. As a result, ADEC did not believe applying the four-factor analysis to forestry burning was needed.

  Given the considerations above, ADEC has focused the four-factor analysis on point and area sources only. Further refinement of this approach is provided below.

- Focus on fine particulate matter, sulfate, and nitrate pollutants: ADEC has determined that the four-factor analysis should focus on fine particulate matter ($PM_{2.5}$), sulfate, and

[*]"Guidance for Setting Reasonable Progress Goals Under the Regional Haze Program," June 2007.

nitrate pollutants. Although there are six visibility-impairing pollutants of concern, sulfate and nitrate are typically associated with anthropogenic sources and tend to be more effective at degrading visibility than $PM_{2.5}$. $PM_{2.5}$ has been included, but is frequently associated with natural sources, such as wildfire and natural windblown dust; as a result the human-caused $PM_{2.5}$ emissions are often dwarfed by the natural sources.

2. Identification of Sources for Four-Factor Analysis

As EPA guidance indicates that states have "considerable flexibility" in terms of how the four factors are taken into consideration, what sources or source categories should be included in the analysis, and what additional control measures are reasonable, ADEC believes that focusing the application of the four-factor analysis to point and area sources, particularly of SO_2 and NOx, is consistent with the guidance and reasonable for the first planning period of the regional haze plan.

It is also useful to keep in perspective the sheer geographic scale of Alaska, the relative impacts of human-caused sources on regional haze impacts in Alaska's Class I areas and the anticipated reductions in pollutants from these sources. These impacts and trends were a consideration in determining which source categories to consider for this first analysis.

Natural wildfire emissions are by far the largest source of emissions within the state. Discussion of Alaska's emissions in Section III.K.5 indicates that human-caused SO_2 and NOx emissions represent 29.5% and 47.9%, respectively, of the total emissions for these pollutants in 2002. Statewide, however, both of these pollutant categories are estimated to have declining emissions between 2002 and 2018 based on existing control programs already in place. Two of the source categories showing increases in these pollutants are predominantly outside the state control: commercial marine vessels and aviation. Increases are expected across all pollutants in area source pollution due primarily to projected population growth between 2002 and 2018. Point sources are predicted to have declining NOx emissions, but increasing SO_2 emissions.

The Western Regional Air Partnership contracted with EC/R Incorporated for an analysis of the four regulatory factors for a number of source categories that are relevant to Alaska:

- Reciprocating Internal Combustion Engines and Turbines;
- Oil And Natural Gas Exploration and Productions Field Operations;
- Natural Gas Processing Plants;
- Industrial Boilers; and
- Petroleum Refineries.

ADEC's analysis described in this section relies on the report from this effort titled, "Supplementary Information for Four Factor Analyses by WRAP States," May 4, 2009, which is included in Appendix III.K.9. The Weighted Emission Potential (WEP) analysis for sources in Alaska provides information on these identified source categories, which can assist in determining whether these sources have the potential to significantly impact visibility in Class I areas and whether they are reasonable to control.

Section III.K.7 provided a detailed description of the development of WEP estimates for each source and pollutant for the three boroughs with the greatest potential impact at each of the Class I sites for 2002 and 2018. It also identified which source categories may be having a significant impact on those sites. The WEP values, however, provide no detail on the relative contribution of individual sources within each source category. Without this insight it is difficult to assess the potential benefits of control programs that are being implemented at the local, state or federal level. To provide this insight the percent distribution of emissions from individual sources was organized into common categories within the point and stationary area source categories (the two anthropogenic categories that may be significantly impacting the Class I sites). The percent distribution of their emissions within each source category, borough and year was applied to the corresponding WEP value for those boroughs shown as potentially having a significant impact at each site.

The following source categories were selected to represent the distribution of point sources:

- Industrial Boilers;
- Natural Gas Processing Plants;
- Oil & Natural Gas Exploration and Production Field Operations;
- Reciprocating IC Engines and Turbines; and
- Other.

Listed below are the source categories selected to represent the distribution of stationary area sources.

- Electric Utility – Distillate Oil
- Commercial – Distillate Oil
- Commercial – Natural Gas
- Residential – Distillate Oil
- Residential – Natural Gas
- Wood Burning
- Road Dust
- Other

The total change in WEP values for the pollutants with the greatest visibility impacts (i.e., NOx, SOx and $PM_{2.5}$) at each Class I area is presented in Table III.K.9-1. A similar presentation of area source WEP values potentially having a significant impact on Class I sites is presented in Table III.K.9-3. To be conservative, all boroughs/pollutants for these sources having a value above 5.0 are included in the tables. In some cases, however, these sources are shown to have a reduction. In other cases, as discussed in Section III.K.7, the overall increase in the WEP value shown is offset by reductions from other sources and boroughs impacting the site.

Table III.K.9-1
Total Change in WEP Values for NOx, SOx, and $PM_{2.5}$ at Each Class I Area Monitoring Site

Monitor Site	NOx	SOx	$PM_{2.5}$
Denali	-0.5	0.8	0.2
Trapper Creek	-5.1	0.9	6.0
Tuxedni	-17.1	-13.0	2.1
Simeonof	-2.8	-2.2	0.3

Table III.K.9-2
Distribution of WEP Values for Point Source Categories With the Potential to Significantly Impact Each Class I Area

Denali				
Source Categories	**Fairbanks - NOx**		**Fairbanks - SOx**	
	2002	**2018**	**2002**	**2018**
Industrial Boilers	4.9	4.5	11.0	9.2
Nat. Gas Process. Plants	0.0	0.0	0.0	0.0
Oil & Gas Field Operations	0.0	0.0	0.0	0.0
Petroleum Refineries	0.4	0.0	0.2	0.0
Recip. Engines & Turbines	5.5	8.4	12.4	25.7
Other	0.0	0.8	0.0	0.4
Total	10.8	13.7	23.7	35.3
Trapper Creek				
Source Categories	**Kenai - NOx**		**Fairbanks – SOx**	
	2002	**2018**	**2002**	**2018**
Industrial Boilers	0.7	0.5	2.9	2.3
Nat. Gas Process. Plants	0.0	0.0	0.0	0.0
Oil & Gas Field Operations	0.5	0.6	0.0	0.0
Petroleum Refineries	0.7	0.0	0.1	0.0
Recip. Engines & Turbines	7.5	5.7	3.3	6.4
Other	8.7	9.0	0.0	0.1
Total	18.0	15.7	6.3	8.8
Source Categories	**Mat-Su - NOx**			
	2002	**2018**		
Industrial Boilers	0.0	0.0		
Nat. Gas Process. Plants	0.0	0.0		
Oil & Gas Field Operations	0.0	0.0		
Petroleum Refineries	0.0	0.0		
Recip. Engines & Turbines	2.4	3.0		
Other	5.8	6.0		
Total	8.2	9.0		

Table III.K.9-2
Distribution of WEP Values for Point Source Categories With the Potential to Significantly Impact Each Class I Area

Tuxedni				
Source Categories	**Kenai - NOx**		**Kenai - SOx**	
	2002	**2018**	**2002**	**2018**
Industrial Boilers	2.3	1.6	0.3	0.2
Nat. Gas Process. Plants	0.0	0.0	0.0	0.0
Oil & Gas Field Operations	1.5	1.8	0.1	0.4
Petroleum Refineries	2.3	0.0	0.9	0.0
Recip. Engines & Turbines	25.4	17.5	2.6	2.9
Other	29.3	27.9	0.4	1.4
Total	60.9	48.7	4.3	5.0
Simeonof				
Source Categories	**North Slope - NOx**		**Kenai - NOx**	
	2002	**2018**	**2002**	**2018**
Industrial Boilers	0.0	0.0	0.2	0.2
Nat. Gas Process. Plants	0.0	0.0	0.0	0.0
Oil & Gas Field Operations	0.3	1.0	0.2	0.2
Petroleum Refineries	0.0	0.0	0.2	0.0
Recip. Engines & Turbines	9.2	6.3	2.6	1.9
Other	0.1	0.1	3.0	3.0
Total	9.6	7.4	6.2	5.3

Table III.K.9-3
Distribution of WEP Values for Area Source Categories With the Potential to Significantly Impact Each Class I Area

Trapper Creek				
Source Categories	**Mat-Su – PM2.5**		**Mat-Su – NOx**	
	2002	**2018**	**2002**	**2018**
Electric Utility - Dist. Oil	0.1	0.1	0.2	0.3
Commercial - Dist. Oil	0.0	0.0	0.2	0.3
Commercial - Nat. Gas	0.0	0.0	0.9	1.2
Residential - Dist. Oil	0.0	0.0	0.5	0.7
Residential - Nat. Gas	0.0	0.0	2.6	3.7
Wood Burning	5.3	7.9	0.1	0.1
Road Dust	4.1	6.2	0.0	0.0
Other	1.4	2.1	0.0	0.1
Total	10.9	16.4	4.5	6.4
Source Categories	**Mat-Su – SOx**			
	2002	**2018**		
Electric Utility - Dist. Oil	0.0	0.0		
Commercial - Dist. Oil	3.5	5.7		
Commercial - Nat. Gas	0.0	0.1		
Residential - Dist. Oil	10.4	17.0		
Residential - Nat. Gas	0.1	0.2		
Wood Burning	0.2	0.3		
Road Dust	0.0	0.0		
Other	0.3	0.4		
Total	14.5	23.7		
Tuxedni				
Source Categories	**Kenai – PM2.5**		**Kenai – SOx**	
	2002	**2018**	**2002**	**2018**
Electric Utility - Dist. Oil	0.0	0.0	0.0	0.0
Commercial - Dist. Oil	0.0	0.0	5.6	6.4
Commercial - Nat. Gas	0.0	0.0	0.1	0.1
Residential - Dist. Oil	0.0	0.0	16.9	19.1
Residential - Nat. Gas	0.1	0.1	0.3	0.3
Wood Burning	5.1	5.7	2.1	2.4
Road Dust	10.7	11.7	0.0	0.0
Other	0.3	0.3	0.7	0.7
Total	16.3	17.9	25.7	28.9

The WEP analysis (as shown in Table III.K.9-3) did not identify any of the Boroughs as having significant area source NOx, SOx or $PM_{2.5}$ impacts on either Denali or Simeonof. Increases in area source $PM_{2.5}$, NOx and SOx are, however, seen impacting Trapper Creek and Tuxedni. Table III.K.9-1 shows substantial reductions in aggregate NOx values at both Trapper Creek and Tuxedni, a large reduction in SOx at Tuxedni and a slight increase in SOx at Trapper Creek. Increases in area source $PM_{2.5}$ values however can be seen impacting both sites. A review of Table III.K.9-3 shows the principal sources of increasing $PM_{2.5}$ are wood burning and road dust. Since the statutory analysis factors established in section 169A(g) of the Clean Air Act are not readily applicable to these sources, they are not addressed in the four-factor analysis. Information presented in Table III.K.9-2, however suggests three categories of point sources that may be significant contributors to regional haze and warrant further analysis. These are industrial boilers, petroleum refineries and reciprocating engines and turbines.

3. Four-Factor Analysis

As noted above, three point source categories warrant further analysis based on the emission inventory trends and WEP results: Industrial Boilers, Petroleum Refineries, and Reciprocating Engines and Turbines. For this first Regional Haze Plan, ADEC believes that given the level of improvement needed to reach natural conditions and the level of technical tools available to demonstrate source specific impacts, it is reasonable to conduct the four-factor analysis on the general source categories rather than on individual sources. In future reviews and planning periods, ADEC can refine these analyses further, if needed, to address specific source impacts.

a. Industrial Boilers

The Industrial Boiler source category consists of point sources with industrial boilers that burn oil, natural gas, coal, and other fuels. These boilers are used in manufacturing, processing, mining, and refining, or any other industry to provide steam, hot water, and/or electricity. The WEP analysis indicates that Denali National Park monitoring sites have potential impacts for SOx and NOx from the industrial boilers in the Fairbanks North Star Borough and the Kenai Peninsula Borough. For the Tuxedni monitoring site, industrial boilers show potential impacts for VOC and NOx. The Simeonof monitoring site does not show significant impacts from industrial boilers.

Table III.K.9-4 shows the estimated statewide emissions for NOx, SO_2, PM_{10}, $PM_{2.5}$, and VOC from the WRAP emission inventory and four factor analyses for Alaska's industrial boilers.

The WRAP four-factor analysis identified control options for coal-fired, natural gas-fired, and oil-fired boilers as listed in Tables III.K.9-5- III.K.9-7. The age of a boiler impacts the amount of emission reduction that can be obtained through control. Older, pre-PSD boilers likely have more potential for emission reduction than newer boilers that have either been subject to PSD regulations or more recent BACT analyses.

Table III.K.9-4
Alaska Industrial Boiler Emissions

Emission Source	Pollutant Emissions, TPY				
	NOx	SO_2	PM_{10}	$PM_{2.5}$	VOC
Coal-fired Boilers	1823	1421	0	0	6
Natural gas-fired Boilers	260	7	11	10	11
Oil-fired Boilers	67	55	2	2	3
Total	2150	1483	13	12	21

Table III.K.9-5
Control Options for Coal-Fired Industrial Boilers

Pollutant Controlled	Control Technology[a]	Estimated Control Efficiency (%)
NOx	LNB	50
	LNB w/OFA	50-65
	SNCR	30-75
	SCR	40-90
SO_2	Physical coal cleaning	10-40
	Chemical coal cleaning	50-85
	Switch to lower sulfur fuel	20-90
	Dry sorbent injection	50-90
	Spray dryer absorber	90
	Wet FGD	90
$PM_{2.5}$, PM_{10}, Elemental Carbon	Fabric Filter	99.3
Organic Carbon	ESP	99.3

[a] Note: LNB=Low NOx Burner; OFA=Over Fire Air; SNCR=Selective NonCatalytic Reduction; SCR=Selective Catalytic Reduction; FGD=Flue Gas Desulfurization; ESP=Electrostatic Precipitator

Table III.K.9-6
Control Options for Natural Gas-Fired Industrial Boilers

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)
NOx	LNB	40
	LNB w/OFA	40-60
	LNB w/OFA and FGR	40-80
	SNCR	30-75
	SCR	70-90

Table III.K.9-7
Control Options for Oil-Fired Industrial Boilers

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)
NOx	LNB	40
	LNB w/OFA	30-50
	LNB w/OFA and FGR	30-50
	SNCR	30-75
	SCR	40-90
SO_2	Switch to lower sulfur fuel	20-90
	Spray dryer absorber	90
	Wet FGD	90
$PM_{2.5}$, PM_{10}, Elemental Carbon	Fabric Filter	95.8
Organic Carbon	ESP	95.8

Factor 1 – Cost of Compliance

The WRAP analyses provided a generalized range of cost estimates for the emission control options identified for each category of industrial boiler. These estimates are summarized in Table III.K.9-8 thru Table III.K.9-10.

Table III.K.9-8
Estimated Costs for Control of Coal-Fired Industrial Boilers

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)	Estimated Capital Cost ($/MMBtu/hr)	Estimated Annual Cost ($M)	Cost Effectiveness ($/ton)
NOx	LNB	50	3,435-6,856	0.175-0.317	344-4,080
	LNB w/OFA	50-65	4,908-9,764	NA	412-4,611
	SNCR	30-75	3,550-7,083	0.333-0.419	1,728-6,685
	SCR	40-90	9,817-19,587	0.738-1.32	1,178-7,968
SO_2	Physical coal cleaning	10-40	NA	NA	70-563
	Chemical coal cleaning	50-85	NA	NA	1,699-2,561
	Switch to lower sulfur fuel	20-90	NA	NA	
	Dry sorbent injection	50-90	11,633-36,096	NA	851-5,761
	Spray dryer absorber	90	27,272-73,549	7.93-9.26	3,885-8,317
	Wet FGD	90	40,203-86,410	10.10-11.71	4,687-10,040
$PM_{2.5}$, PM_{10}, Elemental Carbon	Fabric Filter	99.3	20,065-30,287	0.82-1.39	406-592
Organic Carbon	ESP	99.3	17,037-24,293	0.66-1.17	342-485

Table III.K.9-9
Estimated Costs for Control of Natural Gas-Fired Industrial Boilers

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)	Estimated Capital Cost ($/MMBtu/hr)	Estimated Annual Cost ($M)	Cost Effectiveness ($/ton)
NOx	LNB	40	1,205-2,405	0.190-0.346	412-7,075
	LNB w/OFA	40-60	1,722-3,435	NA	412-7,075
	LNB w/OFA and FGR	40-80	2,690-5,368	NA	439-6,689
	SNCR	30-75	2,840-5,666	0.206-0.355	1,997-9,952
	SCR	70-90	5,399-10,773	0.484-0.831	1,022-24,944

Table III.K.9-10
Estimated Costs for Control of Oil-Fired Industrial Boilers

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)	Estimated Capital Cost ($/MMBtu/hr)	Estimated Annual Cost ($M)	Cost Effectiveness ($/ton)
NOx	LNB	40	1,205-2,405	0.190-0.346	412-7,075
	LNB w/OFA	30-50	1,722-3,435	NA	412-7,075
	LNB w/OFA and FGR	30-50	2,690-5,368	NA	439-6,689
	SNCR	30-75	2,840-5,666	0.206-0.355	1,997-9,952
	SCR	40-90	5,339-10,773	0.484-0.831	1,022-24,944
SO_2	Switch to lower sulfur fuel	20-90	NA	NA	5611
	Spray dryer absorber	90	119,731-270,514	7.72-8.80	4,947-10,887
	Wet FGD	90	36,930-73,660	9.85-11.29	6,008-13,156
$PM_{2.5}$, PM_{10}, Elemental Carbon	Fabric Filter	95.8	17,205-26,291	0.72-1.20	7,298-10,889
Organic Carbon	ESP	95.8	14,302-21,243	0.58-0.98	5,983-8,844

Factor 2 – Time Necessary for Compliance

If controls were implemented, the overall time for compliance is expected to be five to six years. Up to two years would be needed to develop and adopt rules necessary to require these controls. The WRAP analyses indicated that a source may require:

- Up to a year to procure the necessary capital to purchase control equipment;
- Approximately 18 months to design, fabricate, and install SCR or SNCR technology for NOx control;
- Approximately 30 months to design, build, and install SO_2 scrubbing technology; and
- additional time, up to 12 months, for staging the installation process if multiple boilers are to be controlled.

Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

The WRAP four-factor analyses also evaluated the estimated energy and non-air pollution impacts of control measures for industrial boilers. These impacts are included in Tables III.K.9-11 through III.K.9-13. In general, the combustion modification technologies (LNB, OFA, FGR) do not require steam or generate solid waste, wastewater, or additional CO_2. They also do not require additional fuel to operate, and in some cases may decrease fuel usage because of the optimized combustion of the fuel.

Table III.K.9-11
Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures for Coal-Fired Industrial Boilers

Control Technology	Pollutant	Energy and non-air pollution impacts (per ton of emission reduced)				
		Electricity Requirement	Steam Requirement	Solid Waste Produced	Wastewater Produced	Additional CO_2 Emitted
LNB	NOx					
LNB w/OFA	NOx					
SNCR	NOx	1-2 kW/1000 acfm	0.25			
SCR	NOx	0.89	0.25	0.021		
Physical coal cleaning	SO_2					
Chemical coal cleaning	SO_2					
Switch to lower sulfur fuel	SO_2					
Dry sorbent injection	SO_2	2-4 kW/1000 acfm	0.25	0.021		
Spray dryer absorber	SO_2	0.4		3.7	0.69	
Wet FGD	SO_2	4-8 kW/1000 acfm				
Fabric Filter	$PM_{2.5}$, PM_{10}	1-2 kW/1000 acfm				
ESP	$PM_{2.5}$, PM_{10}	0.5-1.5kW/1000 acfm				

Table III.K.9-12
Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Natural Gas-Fired Industrial Boilers

Control Technology	Pollutant	Energy and Non-Air Pollution Impacts (per ton of emission reduced)				
		Electricity Requirement	Steam Requirement	Solid Waste Produced	Wastewater Produced	Additional CO_2 Emitted
LNB	NOx					
LNB w/OFA	NOx					
LNB w/OFA and FGR	NOx	6.4				
SNCR	NOx	1-2 kW/1000 acfm	0.25			
SCR	NOx	0.89	0.25	0.021		
Water Injection	NOx					

Table III.K.9-13
Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures for Oil-Fired Industrial Boilers

Control Technology	Pollutant	Energy and Non-Air Pollution Impacts (per ton of emission reduced)				
		Electricity Requirement	Steam Requirement	Solid Waste Produced	Wastewater Produced	Additional CO_2 Emitted
LNB	NOx					
LNB w/OFA	NOx					
LNB w/OFA and FGR	NOx	6.4				
SNCR	NOx	1-2 kW/1000 acfm	0.25			
SCR	NOx	0.89	0.25	0.021		
Switch to lower sulfur fuel	SO_2					
Spray dryer absorber	SO_2	0.4		3.7	0.69	
Wet FGD	SO_2	4-8 kW/1000 acfm				
Fabric Filter	$PM_{2.5}$, PM_{10}	1-2 kW/1000 acfm				
ESP	$PM_{2.5}$, PM_{10}	0.5-1.5kW/1000 acfm				

Retrofitting with SNCR requires energy for compressor power and steam for mixing. This would produce a small increase in CO_2 emissions to generate electricity; the technology itself, however,does not produce additional CO_2 emissions.

Installation of SCR on an industrial boiler is not expected to increase fuel consumption. However additional energy is required to operate the SCR, which will produce an increase in CO_2 emissions to generate the electricity. In addition, spent catalyst would have to be changed periodically, producing an increase in solid waste disposal.

For SO_2 control technologies, energy is required for material preparation (e.g., grinding), materials handling (e.g., pumps/blowers), flue gas pressure loss, and steam requirements. Power consumption is also affected by the reagent utilization of the control technology, which also affects the control efficiency of the control technology.

PM control technologies require energy to operate compressors, heaters, and ash handling. In addition, an additional fan may be required to reduce the flue gas pressure loss by the ESP or FF. The ESP also requires energy to operate the transformer-rectifier. These energy requirements will produce an increase in CO_2 emissions to generate the required electricity.

Factor 4 – Remaining Useful Life of Any Potentially Affected Sources

Industrial boilers do not have a set equipment life and it is difficult to estimate the remaining life of any potentially affected sources. Remaining useful life is specific to the facility for which controls are considered. The remaining life of an industrial boiler is not anticipated to affect the cost of control technologies for these sources.

b. Petroleum Refineries

The category of Petroleum Refineries consists of point sources at petroleum refineries, including process heaters, catalytic cracking units, coking units, and ancillary operations, flares, and incinerators. Reciprocating engines and turbines associated with refineries are handled within their separate categories. In Alaska, small petroleum refineries are found in the North Slope Borough (at the oil production facilities), in the Fairbanks North Star Borough (North Pole), in the Kenai Peninsula Borough (Nikiski), and in Valdez. The WEP analysis indicates that Denali National Park monitoring sites have small potential impacts for SOx and NOx from petroleum refineries in the Fairbanks North Star Borough and the Kenai Peninsula Borough. For the Tuxedni monitoring site, petroleum refineries show potential impacts for VOC and NOx. The Simeonof monitoring site does not show significant impacts from petroleum refineries.

Table III.K.9-14 and Table III.K.9-15 show the estimated statewide emissions for NOx, SO_2, PM_{10}, $PM_{2.5}$, and VOC from the WRAP 2002 emission inventory and four-factor analyses for Alaska's petroleum refineries.

Table III.K.9-14
Alaska Petroleum Refinery Emissions

Emission Source	Pollutant Emissions, TPY			
	NOx	SO_2	PM_{10}	$PM_{2.5}$
Process Heaters	573	62	30	2
Catalytic Cracking Units				
Flares	102	8	6	
Fluid Coking Units				
Coke Calcining				
Incinerators		41		
Other	122	41	7	0
Total	797	111	43	2

Table III.K.9-15
Alaska Petroleum Refinery Emissions

Emission Source	Pollutant Emissions, TPY VOC
Fugitive Emissions	
Wastewater Treatment	1018
Process Heaters	9
Flares	130
Other	11
Total	1167

The WRAP four-factor analysis identified control options for petroleum refineries as listed in Table III.K.9-16.

Table III.K.9-16
Control Options for Petroleum Refineries

Source Type	Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)
Process Heaters	NOx	LNB	40
	NOx	ULNB (Ultra Low NOx Burner)	75-85
	NOx	LNB and FGR	48
	NOx	SNCR	60
	NOx	SCR	70-90
	NOx	LNB and SCR	70-90
	SO_2	Fuel Treatment to remove sulfur	Up to 90
Fluid Catalytic Cracking Units	NOx	Catalyst additives for NOx reduction	46
	NOx	LoTOx™	85
	NOx	SNCR	40-80
	NOx	SCR	80-90
	SO_2	Catalyst additives for SO_2 absorbtion	20-60
	SO_2	Desulfurization of catalytic cracker feed	Up to 90
	SO_2	Wet scrubbing	70-99
	PM_{10}	ESP	95+
	$PM_{2.5}$	ESP	95+
	EC	ESP	95+
	OC	ESP	95+
Coking or coke calcining boilers	SO_2	Spray dry absorber	80-95
	SO_2	Wet FGD	90-99
Flares	SO_2	Improved process control and operator training	Varies
	SO_2	Expand sulfur recovery unit	Varies
	SO_2	Flare gas recovery system	Varies

Factor 1 – Cost of Compliance

The WRAP analyses provided a generalized range of cost estimates for the emission control options identified for petroleum refineries. These estimates are summarized in Table III.K.9-17.

Table III.K.9-17
Estimated Costs for Control of Petroleum Refineries

Source Type	Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)	Estimated Capital Cost ($1000/unit)	Estimated Annual Cost ($/year/unit)	Units	Cost Effectiveness ($/ton)
Process Heaters	NOx	LNB	40	2.7-7.6	290-810	MM-Btu/hr	650-2,800
	NOx	ULNB	75-85	2.8-13	300-1,300	MM-Btu/hr	400-2,000
	NOx	LNB and FGR	48	5.8-16	640-1,700	MM-Btu/hr	1,000-2,600
	NOx	SNCR	60	5.2-22	570-2,400	MM-Btu/hr	890-5,200
	NOx	SCR	70-90	33-48	3,700-5,600	MM-Btu/hr	2,900-6,700
	NOx	LNB and SCR	70-90	37-55	4,000-6,300	MM-Btu/hr	2,900-6,300
	SO_2	Fuel Treatment to remove Sulfur	Up to 90	3.4-10	28,000-36,000	Refinery capacity, 1000 barrels/day	1,300-1,700
Fluid Catalytic Cracking Units	NOx	Catalyst additives for NOx reduction	46	N/A	N/A	N/A	N/A
	NOx	LoTOx™	85	N/A	N/A	N/A	1,700-2,000
	NOx	SNCR	40-80	N/A	N/A	N/A	2,500
	NOx	SCR	80-90	N/A	N/A	N/A	2,500
	SO_2	Catalyst additives for SO_2 absorbtion	20-60	N/A	N/A	N/A	N/A
	SO_2	Desulfurization of catalytic cracker feed	Up to 90	23-54	190,000-250,000	Refinery capacity, 1000 barrels/day	6,200-8,000
	SO_2	Wet scrubbing	70-99	N/A	N/A	N/A	1,500-1,800
	PM_{10}	ESP	95+	N/A	N/A	N/A	>10,000
	$PM_{2.5}$	ESP	95+	N/A	N/A	N/A	>10,000
	EC	ESP	95+	N/A	N/A	N/A	>10,000
	OC	ESP	95+	N/A	N/A	N/A	>10,000
Coking or coke calcining boilers	SO_2	Spray dry absorber	80-95	N/A	N/A	N/A	1,500-1,900
	SO_2	Wet FGD	90-99	N/A	N/A	N/A	1,500-1,800
Flares	SO_2	Improved process control and operator training	Varies	N/A	N/A	N/A	N/A
	SO_2	Expand sulfur recovery unit	Varies	N/A	N/A	N/A	N/A
	SO_2	Flare gas recovery system	Varies	N/A	N/A	N/A	N/A

Factor 2 – Time Necessary for Compliance

If controls were implemented, the overall time for compliance is expected to be 6.5 years. Up to two years would be needed to develop and adopt rules necessary to require these controls. The WRAP analyses indicated that a source may require the following lead time:

- Up to a year to procure the necessary capital to purchase control equipment;
- Approximately 13-18 months to design, fabricate, and install SCR or SNCR technology for NOx control;
- Approximately 30 months to design, build, and install SO_2 scrubbing technology for a single emission source; and
- Additional time, up to 12 months, for staging the installation process if multiple sources are to be controlled at a single facility.

Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

The WRAP four-factor analyses also evaluated the estimated energy and non-air pollution impacts of control measures for petroleum refineries. These impacts are included in Table III.K.9-18. Process modifications to desulfurize process gases burned in process heaters would generally require increases in catalytic hydrotreatment processing. These modifications may increase the generation of spent catalyst, which would need to be treated as a solid waste or a hazardous waste. Low NO_X burners for process heaters are expected to improve overall fuel efficiency. FGR would require additional electricity to recirculate the fuel gas into the heater. In SCR systems for process heaters or other sources, fans would be required to overcome the pressure drop through the catalyst bed. The fans would require electricity, with resultant increases in CO_2 to generate the electricity. In addition, spent catalyst would have to be changed periodically, producing an increase in solid waste disposal.

Catalyst additives for reducing NOx and SO_2 emissions from fluid catalytic cracking units are likely to result in increased generation of spent catalyst, which would have to be disposed of as hazardous waste. These catalyst additives may also result in increases in fuel consumption, but information is not available to quantify these impacts. A LoTOx™ scrubbing system or wet scrubbing system applied to the fluidized catalytic cracking unit would require electricity to operate fans and other auxiliary equipment, and would produce a wastewater stream which would require treatment. In addition, sludge from the scrubber would require disposal as solid waste. SCR and SNCR systems would also require electricity for fans, and SCR systems would produce additional solid waste because of spent catalyst disposal. Dust captured by an ESP or fabric filter would also require disposal as a solid waste. The presence of catalyst fines in the dust may require treatment as a hazardous waste.

Sulfur recovery units require electricity and steam. Wet or dry scrubbers applied to incinerators and tail gas treatment units applied to sulfur recovery units would use electricity for the fan power needed to overcome the scrubber pressure drop. These systems would also produce solid waste, and wet scrubbers would produce wastewater which would require treatment.

Table III.K.9-18
Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Petroleum Refineries

Source Type	Pollutant	Control Technology	Additional Fuel Requirement (%)	Energy and Non-Air Pollution Impacts (per ton of emission reduced)				
				Electricity Requirement (kW-hr)	Steam Requirement (tons steam)	Solid Waste Produced (tons waste)	Wastewater Produced (1000 gallons)	Additional CO_2 Emitted (tons)
Process Heaters	NOx	LNB	a	e				
	NOx	ULNB	a	e				
	NOx	LNB and FGR		3,300				3.3
	NOx	SNCR	0.16	460				3.2
	NOx	SCR		8,400		0.073		8.4
	NOx	LNB and SCR		8,400		0.073		8.4
	SO_2	Fuel Treatment to remove Sulfur	b					b
Fluid Catalytic Cracking Units	NOx	Catalyst additives for NOx reduction	d			d		
	NOx	LoTOx™		d		d	d	
	NOx	SNCR		460				3.2
	NOx	SCR		8,400		0.073		8.4
	SO_2	Catalyst additives for SO_2 absorption	d			d		
	SO_2	Desulfurization of catalytic cracker feed	d		d	d		d
	SO_2	Wet scrubbing		1,100	3.1		3.7	2.6
	PM_{10}	ESP		97		1		0.1
	$PM_{2.5}$	ESP		97		1		0.1
	EC	ESP		97		1		0.1
	OC	ESP		97		1		0.1
Coking or coke calcining boiler offgas	SO_2	Spray dry absorber		400				1.1
	SO_2	Wet FGD		1,100	3.1		3.7	2.6

Table III.K.9-18
Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Petroleum Refineries

Source Type	Pollutant	Control Technology	Additional Fuel Requirement (%)	Energy and Non-Air Pollution Impacts (per ton of emission reduced)				
				Electricity Requirement (kW-hr)	Steam Requirement (tons steam)	Solid Waste Produced (tons waste)	Wastewater Produced (1000 gallons)	Additional CO_2 Emitted (tons)
Flares	SO_2	Improved process control and operator training						
	SO_2	Expand sulfur recovery unit	d	d	d			d
	SO_2	Flare gas recovery system	d	d	d			d

Notes: blank indicates no impact is expected.
[a] The measure is expected to improve fuel efficiency.
[b] CO_2 from the generation of electricity would be offset by avoided emissions due to replacing diesel engines,
[c] EPA has estimated that control measures used to meet Tier 4 standards will be integrated into the engine design so that sacrifices in fuel economy will be negligible.
[d] Some impact is expected but insufficient information is available to evaluate the impact.
[e] Some designs of low-NOx burners and ultralow-NOx burners require the use of pressurized air supplies. This would require additional electricity to pressurize the combustion.

Factor 4 - Remaining Useful Life of Any Potentially Affected Sources

Industrial processes are often refurbished to extend their lifetimes. Therefore, the remaining lifetime of most equipment is expected to be longer than the projected lifetime of pollution control technologies analyzed for this category. In the case of add-on technologies, the projected lifetime is 15 years. If the remaining life of an emission source is less than the projected lifetime of a pollution control device, then the capital cost of the control device would have to be amortized over a shorter period of time, corresponding to the remaining lifetime of the emission source. This would cause an increase in the amortized capital cost of the pollution control option, and a corresponding increase in the total annual cost of control. This increased cost can be quantified as follows:

$$A_1 = A_0 + C \times \frac{1-(1+r)^{-m}}{1-(1+r)^{-n}}$$

Where:

A_1 = the annual cost of control for the shorter equipment lifetime ($)
A_0 = the original annual cost estimate ($)
C = the capital cost of installing the control equipment ($)
r = the interest rate (0.07)
m = the expected remaining life of the emission source (years)
n = the projected lifetime of the pollution control equipment

c. Reciprocating Internal Combustion Engines and Turbines

The Reciprocating Internal Combustion Engine and Turbine source category consists of point sources with reciprocating engines and turbines typically located at industrial, commercial, and institutional facilities. Most of the turbines burn gaseous fuels including natural gas, liquefied petroleum gas, and industrial process gas. Reciprocating engines are divided between gaseous fuels and liquid fuels, like kerosene and diesel oil. The WEP analysis indicates that Denali National Park monitoring sites have potential impacts for SOx and NOx from the reciprocating engines and turbines in the Fairbanks North Star Borough and the Kenai Peninsula Borough. For the Tuxedni monitoring site, industrial boilers show potential impacts for VOC and NOx. The Simeonof monitoring site shows potential NOx impacts from North Slope Borough reciprocating engines and turbines.

Table III.K.9-19 shows the estimated statewide 2002 emissions for NOx, SO_2, PM_{10}, $PM_{2.5}$, and VOC from the WRAP emission inventory and four factor analyses for Alaska's reciprocating engines and turbines.

Table III.K.9-19
Alaska Industrial Boiler Emissions

Emission Source	Pollutant Emissions, TPY				
	NOx	SO_2	PM_{10}	$PM_{2.5}$	VOC
Turbines – gaseous fuel	44,293	705	167	66	665
Turbines – liquid fuel	4,446	2,539	140	127	2
Reciprocating Engines –gaseous fuel	50	0	0	0	1
Reciprocating Engines – liquid fuel	12,779	670	179	168	466
Total	61,569	3,915	486	361	1,133

The WRAP Four-Factor Analysis identified control options for reciprocating internal combustion engines and turbines as listed in Tables III.K.9-20-III.K.9-22.

Table III.K.9-20
Control Options for Turbines

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)
NOx	Water or steam injection	68-80
	Low-NOx burners	68-84
	SCR	90
	Water or steam injection with SCR	93-96

Table III.K.9-21
Control Options for Reciprocating Engines with Gaseous Fuels

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)
NOx	Air-Fuel ratio adjustment	10-40
	Ignition retarding technologies	15-30
	Low emission combustion (LEC) retrofit	80-90
	SCR	90
	NSCR	90-99
	Replacement with electric motors	100
VOC	NSCR	40-85
	Replacement with electric motors	100
SO_2	Replacement with electric motors	100
PM_{10}	Replacement with electric motors	100
$PM_{2.5}$	Replacement with electric motors	100
Elemental Carbon	Replacement with electric motors	100
Organic Carbon	Replacement with electric motors	100

Table III.K.9-22
Control Options for Reciprocating Engines with Diesel and Other Liquid Fuels

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)
NOx	Ignition timing retard	15-30
	EGR	40
	SCR	80-95
	Replacement of Tier 2 engines with Tier 4	87
PM_{10}	Replacement of Tier 2 engines with Tier 4	85
	Diesel Oxidation Catalyst	25
$PM_{2.5}$	Replacement of Tier 2 engines with Tier 4	85
	Diesel Oxidation Catalyst	25
Elemental Carbon	Replacement of Tier 2 engines with Tier 4	85
	Diesel Oxidation Catalyst	25
Organic Carbon	Replacement of Tier 2 engines with Tier 4	85
	Diesel Oxidation Catalyst	25
VOC	Replacement of Tier 2 engines with Tier 4	87
	Diesel Oxidation Catalyst	90

Factor 1 – Cost of Compliance

The WRAP analyses provided a generalized range of cost estimates for the emission control options identified for internal combustion reciprocating engines and turbines. These estimates are summarized in Tables III.K.9-23 through III.K.9-25.

Table III.K.9-23
Estimated Costs for Control of Turbines

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)	Estimated Capital Cost ($/1000 Btu)	Estimated Annual Cost ($/yr/1000Btu)	Cost Effectiveness ($/ton)
NOx	Water or steam injection	68-80	4.4-16	2-5	560-3,100
	Low-NOx burners	68-84	8-22	2.7-8.5	5,200-16,200
	SCR	90	8-22	2.7-8.5	2,000-10,000
	Water or steam injection with SCR	93-96	13-34	5.1-13	1,000-6,700

Table III.K.9-24
Estimated Costs for Control of Reciprocating Engines with Gaseous Fuels

Pollutant Controlled	Control Technology	Estimated Control Efficiency (%)	Estimated Capital Cost ($/hp/hr)	Estimated Annual Cost ($/yr/hp)	Cost Effectiveness ($/ton)
NOx	Air-fuel ratio adjustment	10-40	4.4-43	13-86	320-8,300
	Ignition retarding technologies	15-30	N/A	10-32	310-2,000
	LEC retrofit	80-90	120-820	30-210	320-2,500
	SCR	90	20-180	40-461	430-4,900
	NSCR	90-99	17-35	3-6	16-36
	Replacement with electric motors	100	120-140	38-44	100-4,700
VOC	NSCR	40-85			1,500-6,200
	Replacement with electric motors	100			1,000-60,000
SO_2	Replacement with electric motors	100			>13,000
PM_{10}	Replacement with electric motors	100			>13,000
$PM_{2.5}$	Replacement with electric motors	100			>13,000
EC	Replacement with electric motors	100			>33,000
OC	Replacement with electric motors	100			>50,000

Table III.K.9-25 Estimated Costs for Control of Reciprocating Engines with Diesel and Other Liquid Fuel					
Pollutant Controlled	**Control Technology**	**Estimated Control Efficiency (%)**	**Estimated Capital Cost ($/hp/hr)**	**Estimated Annual Cost ($/yr/hp)**	**Cost Effectiveness ($/ton)**
NOx	Ignition timing retard	15-30	16-120	14-66	1,000-2,200
	EGR	40	100	26-67	780-2,000
	SCR	80-95	100-2,000	40-1,200	3,000-7,700
	Replacement of Tier 2 engines with Tier 4	87	125	20	900-2,400
PM_{10}	Replacement of Tier 2 engines with Tier 4	85			25,000-68,000
	Diesel Oxidation Catalyst	25			1,400
$PM_{2.5}$	Replacement of Tier 2 engines with Tier 4	85			25,000-68,000
	Diesel Oxidation Catalyst	25			1,400
EC	Replacement of Tier 2 engines with Tier 4	85			>50,000
	Diesel Oxidation Catalyst	25			3,300
OC	Replacement of Tier 2 engines with Tier 4	85			>50,000
	Diesel Oxidation Catalyst	25			4,200
VOC	Replacement of Tier 2 engines with Tier 4	87			22,000-59,000
	Diesel Oxidation Catalyst	90			350

Factor 2 – Time Necessary for Compliance

If controls were implemented, the overall time for compliance is expected to be 5.5 years. Up to 2 years would be needed to develop and adopt rules necessary to require these controls. The WRAP analyses indicated that a source may require the following lead-time:

- Up to a year to procure the necessary capital to purchase control equipment;
- Approximately 18 months to design, fabricate, and install SCR or SNCR technology for NOx control; and
- Additional time, up to 12 months, for staging the installation process if multiple boilers are to be controlled at a single facility.

Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

Tables III.K.9-26 through III.K.9-28 shows the estimated energy and non-air pollution impacts of control measures for reciprocating engines and turbines derived in the WRAP analyses. In

general, air-to-fuel-ratio adjustments and ignition retarding technologies have been found to increase fuel consumption by up to 5%, with a typical value of about 2.5%. This increased fuel consumption would result in increased CO_2 emissions. LEC technology is not expected to increase fuel consumption and may provide some fuel economy.

Diesel oxidation catalyst and diesel filtration technologies would produce an increase in fuel consumption in order to overcome the pressure drop through the catalyst bed and the filter. This is assumed to be roughly the same as the increase in fuel consumption for SCR installations, about 0.5%. In the case of diesel oxidation catalysts, the catalyst would have to be changed periodically, producing an increase in solid waste disposal. If diesel reciprocating engines are replaced with electric motors, there would be an increase in electricity demand, but this would be offset by the fuel consumption that would be avoided by replacing the engine.

For turbines, water injection and steam injection would require electricity to operate pumps and ancillary equipment. Water injection would produce an increase in fuel consumption in order to evaporate the water, and steam injection would require energy to produce the steam. The increased electricity, steam, and fuel demands would produce additional CO_2 emissions.

Installation of SCR on any type of engine would cause a small increase in fuel consumption, about 0.5%, in order to force the exhaust gas through the catalyst bed. This would produce an increase in CO_2 emissions to generate the electricity. In addition, spent catalyst would have to be changed periodically, producing an increase in solid waste disposal.

Table III.K.9-26
Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Turbines

Control Technology	Pollutant	Additional Fuel Requirement (%)	Energy and Non-Air Pollution Impacts (per ton of emission reduced)				
			Electricity Requirement (kW-hr)	Steam Requirement (tons steam)	Solid Waste Produced (tons waste)	Wastewater Produced (1000 gal)	Additional CO_2 Emitted (tons)
Water or steam injection	NOx	a		31			8.1
Low-NOx burners	NOx	a					
SCR	NOx	a					
Water or steam injection with SCR	NOx	0.45			0.026		1.7

Notes: blank indicates no impact is expected.
[a] The measure is expected to improve fuel efficiency.

Table III.K.9-27
Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Reciprocating Engines with Gaseous Fuels

Control Technology	Pollutant	Additional Fuel Requirement (%)	Energy and Non-Air Pollution Impacts (per ton of emission reduced)				
			Electricity Requirement (kW-hr)	Steam Requirement (tons steam)	Solid Waste Produced (tons waste)	Wastewater Produced (1000 gal)	Additional CO_2 Emitted (tons)
Air-Fuel ratio controllers	NOx	a					
Ignition retarding technologies	NOx	a					
LEC retrofit	NOx	a					
SCR	NOx	0.5			0.008		0.43
NSCR	NOx	0.5			0.008		0.24
Replacement with electric motors	NOx	(100)	66,000				b
NSCR	VOC						
Replacement with electric motors	VOC						
Replacement with electric motors	SO_2						
Replacement with electric motors	PM_{10}						
Replacement with electric motors	$PM_{2.5}$						
Replacement with electric motors	EC						
Replacement with electric motors	OC						

Notes: blank indicates no impact is expected.
[a] The measure is expected to improve fuel efficiency
[b] CO_2 from the generation of electricity would be offset by avoided emissions due to replacing diesel engine

Table III.K.9-28
Estimated Energy and Non-Air Environmental Impacts of Potential Control Measures For Reciprocating Engines with Diesel and Other Liquid Fuels

Control Technology	Pollutant	Additional Fuel Requirement (%)	Energy and Non-Air Pollution Impacts (per ton of emission reduced)				
			Electricity Requirement (kW-hr)	Steam Requirement (tons steam)	Solid Waste Produced (tons waste)	Wastewater Produced (1000 gal)	Additional CO_2 emitted (tons)
Ignition timing retard	NOx	a					
EGR	NOx	2.7					2.0
SCR	NOx	0.5			0.008		0.38
Replacement of Tier 2 engines with Tier 4	NOx	c					c
Replacement of Tier 2 engines with Tier 4	PM_{10}						
Diesel Oxidation Catalyst	PM_{10}	0.5			b		316
Replacement of Tier 2 engines with Tier 4	$PM_{2.5}$						
Diesel Oxidation Catalyst	$PM_{2.5}$						
Replacement of Tier 2 engines with Tier 4	EC						
Diesel Oxidation Catalyst	EC						
Replacement of Tier 2 engines with Tier 4	OC						
Diesel Oxidation Catalyst	OC						
Replacement of Tier 2 engines with Tier 4	VOC						
Diesel Oxidation Catalyst	VOC						2.5

Notes: blank indicates no impact is expected.
[a] The measure is expected to improve fuel efficiency
[b] CO_2 from the generation of electricity would be offset by avoided emissions due to replacing diesel engine
[c] EPA has estimated that control measures used to meet Tier 4 standards will be integrated into the engine design so that sacrifices in fuel economy will be negligible

Factor 4 – Remaining Useful Life of Any Potentially Affected Sources

Engines in industrial service are often refurbished to extend their lifetimes. Therefore, the remaining lifetime of most reciprocating engines and turbines is expected to be longer than the projected lifetime of pollution control technologies analyzed for this category. In the case of add-on technologies, such as SCR, the projected lifetime is 15 years.

If the remaining life of a reciprocating engine or turbine is less than the projected lifetime of a pollution control device, then the capital cost of the control device would have to be amortized over a shorter period of time, corresponding to the remaining lifetime of the emission source. This would cause an increase in the amortized capital cost of the pollution control option, and a corresponding increase in the total annual cost of control. This increased cost can be quantified as follows:

$$A_1 = A_0 + C \times \frac{1-(1+r)^{-m}}{1-(1+r)^{-n}}$$

Where:

A_1 = the annual cost of control for the shorter equipment lifetime ($)
A_0 = the original annual cost estimate ($)
C = the capital cost of installing the control equipment ($)
r = the interest rate (0.07)
m = the expected remaining life of the emission source (years)
n = the projected lifetime of the pollution control equipment

d. Conclusions from the Four-Factor Analysis

Based on the four-factor analyses above, ADEC concluded that it is not reasonable to require additional controls for these source categories at this time. The Alaskan Class I areas do not need large visibility improvements to reach natural conditions in 2064 and natural impacts are already significant in the current analysis. As a result, the uncertainty in visibility improvements that could be achieved through control, coupled with the costs and other factors, makes control at this time unreasonable.

This initial analysis provided a useful starting point for gathering information on possible controls and costs, which can provide a basis for analysis in future SIP revisions. ADEC will reassess the need for control of these sources and further evaluate control options during this first milestone period (through 2018) to determine whether additional emission reductions in these source categories would improve Class I area visibility in the next planning period.

D. Review of Additional Emission Reductions

While the conclusions of the four-factor analysis will not affect the WEP forecast of changes in pollutants impacting the Class I areas between the baseline and 2018, additional information

needs to be considered when assessing those forecasts. A summary of the aggregate pollutant-specific reductions across all source categories, including anthropogenic and nonanthropogenic sources, is presented below in Table III.K.9-29. To provide a perspective on the split between anthropogenic and nonanthropogenic sources, the forecasted change is presented for the anthropogenic share of total emissions from all sources.

Table III.K.9-29
Change in Anthropogenic Share of WEP Forecast of Individual Pollutants for Each Class I Area Between Baseline and 2018 for 20% Worst Days
(% Share of All Anthropogenic and Nonanthropogenic Sources)

Class I Site	Year	$PM_{2.5}$	VOC	NOx	SOx	NH_3
Denali	Base	7.1	35.3	34.5	46.9	2.2
	2018	7.3	34.4	34.0	47.7	3.3
	Change	0.2	-0.9	-0.5	0.8	1.1
Simeonof	Base	5.2	27.6	42.3	20.7	4.4
	2018	5.5	30.4	39.5	18.5	2.4
	Change	0.3	2.8	-2.8	-2.2	2.0
Trapper Creek	Base	15.5	42.7	62.9	42.2	20.5
	2018	21.5	44.9	57.8	43.1	12.8
	Change	6.0	2.2	-5.1	0.9	7.7
Tuxedni	Base	22.8	61.1	85.1	57.8	44.6
	2018	24.9	62.1	68.0	44.8	79.8
	Change	2.1	1.0	-17.1	-13.0	35.2

Note: Sulfate and nitrate are highlighted because these are typically associated with anthropogenic sources and tend to be more effective at degrading visibility.

As noted in the four-factor analysis, while the focus was on fine particulate matter ($PM_{2.5}$), sulfate and nitrate pollutants, sulfate and nitrate are typically associated with anthropogenic sources and tend to be more effective at degrading visibility than fine particulate matter. For, this reason, the change in NOx and SOx values between the baseline and 2018 is highlighted. Presented below is a review of the forecasted changes in each Class I area along with a discussion of source-specific BART impacts that are not accounted for in the WEP analysis.

Denali – The WEP analysis shows the anthropogenic contribution of each of the pollutants impacting Denali varies considerably: $PM_{2.5}$ and NH_3 are at the low end, with values well below 10%; while VOC, NOx and SOx values range from roughly one third to one half of the total. It also shows that modest changes are projected for all of the pollutants impacting this site. For the key pollutants, NOx emissions are forecast to decline slightly while SOx emissions are forecast to increase slightly. The WEP analysis presented in Section III.K.7 showed the dominant boroughs impacting Denali included Yukon Koyukuk and Southeast Fairbanks (primarily natural fires impacting all of the pollutants) and Fairbanks North Star (point sources impacting SOx) and Denali (area sources impacting VOC). The BART analysis presented in Section III.K.6 showed GVEA's Healy Power Plant has a SO_2 limit in place so no increase in nearby SOx emissions can

occur. It also showed that significant visibility improvements in Denali can be expected from additional NOx controls that will be implemented at that facility. These forecasts do not account for the emissions from the HCCP at the GVEA facility in Healy (i.e., unit # 2). That facility did not operate in 2002 and is not currently operating, but is permitted to operate. If brought on line, the point source NOx emitted within the Denali Borough would increase by a factor of 4.0 and the SOx would increase by a factor of 2.8 (based on permitted not actual emissions). This would substantially increase the WEP forecast of NOx and SOx emissions impacting the Denali monitors.

Simeonof – The WEP analysis shows the anthropogenic contribution of each of the pollutants varies considerably: $PM_{2.5}$ and NH_3 are also at the low end, with values well below 10%; while VOC, NOx, and SOx values range from roughly 20% to 40%. It also shows that with the exception of $PM_{2.5}$, more significant, but still limited, changes are forecast for the pollutants impacting this site. For the key pollutants, both NOx and SOx emissions are projected to decline from 2% to almost 3%. VOC and NH_3 levels are projected to have similar increases; however, as noted earlier, their impact on visibility is much less significant. The WEP analysis presented in Section III.K.7 showed natural fires in Yukon Koyukuk are the dominant source of each of the pollutants impacting Simeonof, with share values ranging from 54% to 91%. The BART analysis did not find any benefits of additional controls significantly impacting Simeonof.

Trapper Creek – The WEP analysis shows the anthropogenic share of pollutants impacting Trapper Creek were substantially higher than seen at either Denali or Simeonof. $PM_{2.5}$ and NH_3 are shown to have the lowest impact, but their values range from roughly 10% to 20%, while VOC, NOx, and SOx values range from 40% to 60%. For the key pollutants, NOx is projected to decline by 5% while SOx is projected to have a marginal increase of 0.9%. $PM_{2.5}$, VOC, and NH_3 are all projected to increase. The WEP analysis presented in Section III.K.7 found that natural fires in Yukon Koyukuk and Southeast Fairbanks were the dominant source of all pollutants impacting this site. Anthropogenic sources, located in the Mat Su Valley and the Kenai, were also shown to impact Trapper Creek. The BART analysis presented in Section III.K.6 found the Conoco Philips Kenai LNG Plant reduced the NOx impact below the 0.5 deciview threshold at Denali (and Tuxedni). Since the WEP analysis showed that point sources in the Kenai were a significant source of NOx emissions, the Conoco NOx reductions will be in addition to 5% reductions forecast by WEP analysis.

Tuxedni – The WEP analysis shows the anthropogenic share of pollutants impacting Tuxedni were the largest of the Class I sites. $PM_{2.5}$ levels were on the order of 20% and values for the remaining pollutants ranged from roughly 40% to 80%. Despite the magnitude of the anthropogenic contribution, both NOx and SOx values are projected to have significant reductions—17% and 13%, respectively. Counterbalancing those reductions, however, is a projected 35% increase in NH_3 emissions. A review of the WEP analysis presented in Section III.K.7 shows that essentially all of the increase is coming from the Kenai. Fortunately, the BART analysis shows the Agrium, Chem-Urea Plant in the Kenai has stopped operating and has a zero emission limit for its BART eligible units. Since this unit is responsible for 98% of NH_3 emissions in the Kenai, the 35% increase forecast for NH_3 is no longer valid. Moreover, no

significant increase in NH_3 is likely to occur since any startup of that facility will trigger PSD permitting requirements.

E. Determination of Reasonable Progress Goals

The steps followed in preparing the reasonable progress demonstration were summarized earlier. While the URP for 2064 was calculated in Section III.K.4, no specific target was established for 2018. Table III.K.9-30 summarizes the calculations used to set the 2018 target. As can be seen,.

Table III.K.9-30
Calculation of Uniform Rate of Progress Target Reduction for 2018, 20% Worst Days (deciview)

Class I Site	Baseline	Natural Condition	Total Reduction	Reduction for 2018	% Reduction for 2018	2018 Target
Denali	9.9	7.3	2.6	0.6	6.0	9.3
Simeonof	18.6	15.6	3.0	0.7	3.7	17.9
Trapper Creek	11.6	8.4	3.2	0.7	6.5	10.9
Tuxedni	14.1	11.3	2.8	0.7	4.6	13.4

all of the reductions between the baseline and 2018 are less than 1 deciview, with percentage reductions ranging from roughly 4 to 6 percent of the baseline values

Since it was not possible to configure a photochemical model to represent conditions within Alaska, the State is unable to calculate deciview levels in 2018 resulting from forecasted inventory changes. Nevertheless, it is useful to contrast the percentage change in WEP values for each pollutant forecast between the baseline and 2018 versus the percentage reduction in the URP for the same period. The comparison between these values provides insight into
(a) whether the pollutants impacting each Class I area are increasing or decreasing, and
(b) whether the changes are roughly in proportion to the glide path established by the URP.
Table III.K.9-31 presents a comparison between pollutant and URP reductions for each Class I area forecast for 2018 for the 20% worst days.

Table III.K.9-31
Comparison Between % Change in WEP Forecast of Individual Pollutants and Glide Path Reduction Targets Between Baseline and 2018 for 20% Worst Days As Indicator of "Reasonable Progress" (all sources)

Class I Site	20% Worst Days, Baseline to 2018 Change in Emission Potential From All Boroughs Impacting Each Site					Glide Path Target (% deciview)
	$PM_{2.5}$	VOC	NOx	SOx	NH_3	
Denali	0.2	-0.9	-0.5	0.8	1.1	-6.0
Simeonof	0.3	2.8	-2.8	-2.2	2.0	-3.7
Trapper Creek	6.0	2.2	-5.1	0.9	7.7	-6.5
Tuxedni	2.1	1.0	-17.1	-13.0	35.2	-4.6

Note: Sulfate and nitrate are highlighted because these are typically associated with anthropogenic sources and tend to be more effective at degrading visibility.

As noted earlier, the pollutant reductions presented in Table III.K.9-31, which were computed in Section III.K.7 and displayed in Table III.K.9-29, do not account for BART-related improvements or changes resulting from facilities recently curtailing production. Ignoring those improvements for the moment, the comparison between pollutant and glide path reductions is instructive. The forecast for Denali is little change up or down for all pollutants and suggests a flat line forecast relative to the 6.0% reduction target established by the URP. The forecast for Simeonof is a modest downward slope with reductions in the key anthropogenic NOx and SOx values that are less than the 3.7% URP target. The forecast for Trapper Creek is more complex, with NOx values declining while the other pollutants register limited increases relative to a 6.5% reduction target. The Tuxedni forecast shows substantial reductions in NOx and SOx and modest increases in other pollutants. Thus, while no deciview estimate in 2018 is available for Tuxedni, the large reductions in NOx and SOx WEP values indicate that visibility levels there should improve at a rate exceeding the glide path target.

Another issue to consider when assessing forecasted pollutant reductions relative to the URP targets is the uncertainty associated with those targets. As shown in Section III.K.4, there is considerable variance in the available visibility measurements for each Class I area. That variance has been used to establish confidence bounds on the URP glide path. It is useful to contrast the URP deciview reductions expected for each site with an estimate of the deciview reductions produced by the forecasted WEP changes (approximated by averaging projected NOx and SOx changes) to determine if WEP-based changes fall within the range of uncertainty associated with each glide path.

A series of graphs, displayed in Figures III.K.9-1 through III.K.9-4, have been prepared to display historical and projected data for each site. In the figures, blue is used to show historical and projected visibility, while red is used to show URP glide path. The blue squares give historical visibility data for the period 2000 through 2006, which is the latest year reported. The projected trend in visibility to 2018 is shown by the solid blue line (WEP trend). The WEP trend is based on projected changes in WEP (referenced to the average baseline values starting in 2004) as explained below for each site. The 2000–2004 baseline value is shown by the solid red line, and the uniform rate of progress (URP) is given by the dotted red line that connects to the baseline. The dotted red lines above and below the URP line give +/- 95 percent confidence bounds[*] on the visibility (in a future year) that could be consistent with the URP due to the uncertainty in contributions from natural causes.

[*] The only site with complete data between 2000 and 2004 is Denali. Measurements for the remaining sites did not start until 2002. Because of the limited number of baseline measurements for these sites, all of the confidence intervals were based on available measurements through 2006 (i.e., seven values for Denali and five values for the other sites).

Figure III.K.9-1
Review of URP Glide path and WEP Trend, Baseline to 2018 for 20% Worst Days, Denali

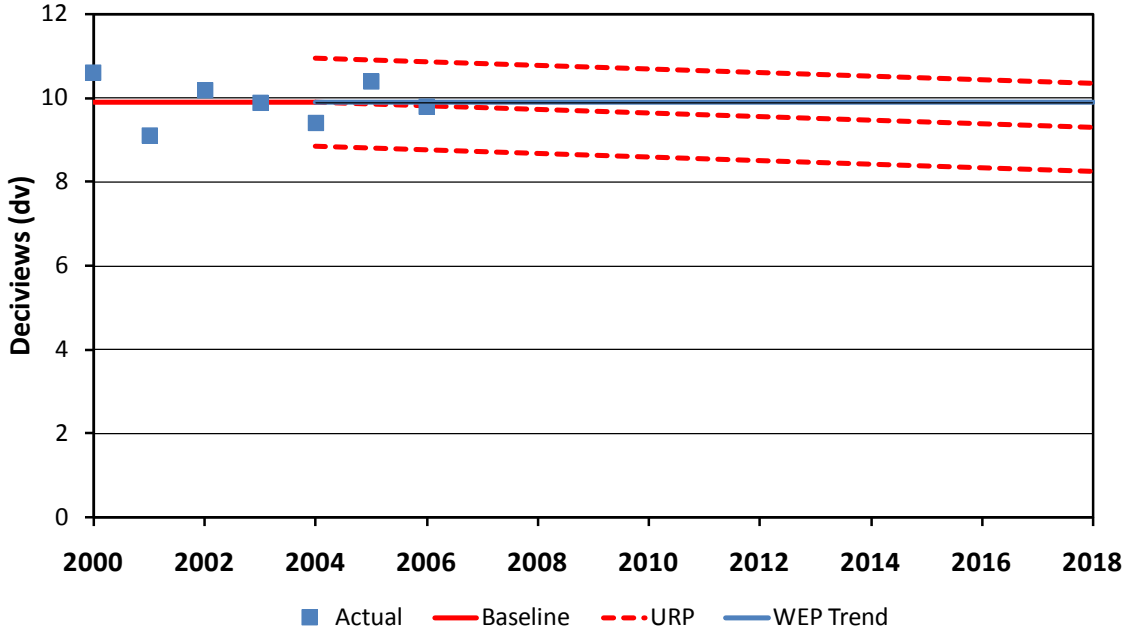


Figure III.K.9-2
Review of URP Glide path and WEP Trend, Baseline to 2018 for 20% Worst Days, Simeonof

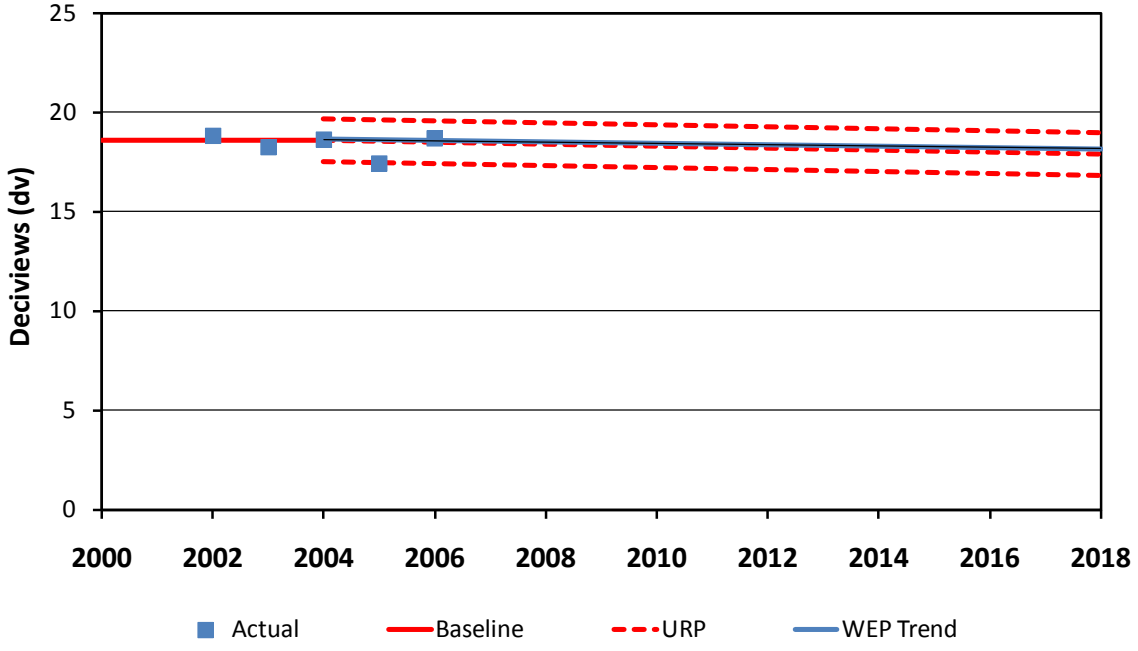


Figure III.K.9-3
Review of URP Glide path and WEP Trend, Baseline to 2018 for 20% Worst Days, Trapper Creek

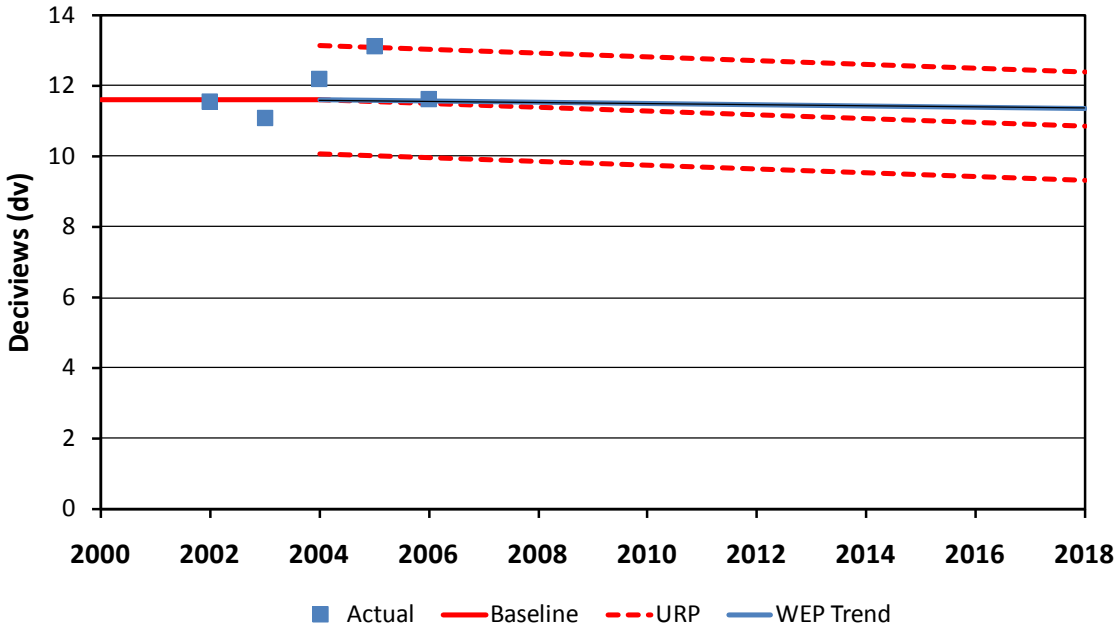
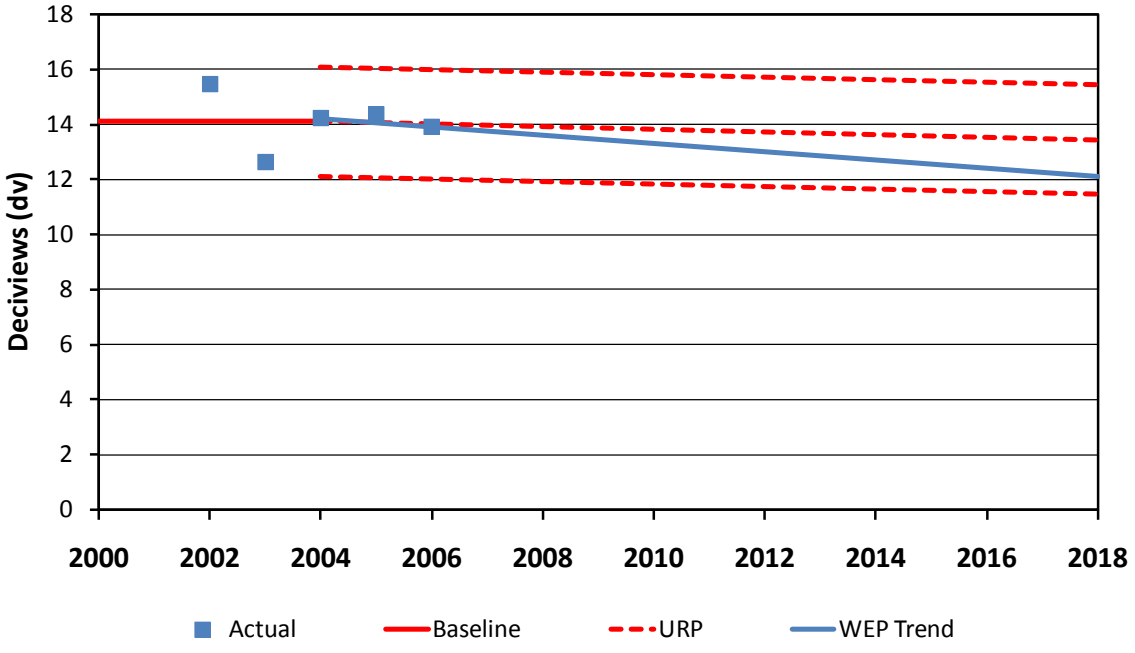


Figure III.K.9-4
Review of URP Glide path and WEP Trend, Baseline to 2018 for 20% Worst Days, Tuxedni



Forest fires and other natural events are larger causes of reduced visibility in Alaska than anthropogenic sources, and these events lead to substantial year-to-year variation in visibility as indicated by the fluctuation in the historical data. Even if a control program puts a site exactly on the URP line, on average, the actual visibilities measured historically and in the future can vary substantially from the URP trend on a year-to-year basis, making both program planning and the demonstration of progress more difficult. The extent of the deviations that can occur is indicated by the 95% confidence bounds, which were developed from the historical data. On a statistical basis, 19 of 20 years are expected to fall within these bounds. Given the extent of the year-to-year variability, the post-2000 historical data series are too limited (five or seven years) to permit estimating historical trends with any confidence. Instead, the standard deviation of the visibility values around the historical average was used to estimate the expected year-to-year fluctuation. The results presented for each site are discussed below.

Denali – Figure III.K.9-1 shows the URP glide path is quite modest relative to the baseline values (i.e., a 0.6 deciview reduction over a 14-year period). It also shows there is considerable variance in the 2000-2006 deciview measurements, which produce a standard deviation of 0.5 deciview. It is clear the WEP trend falls well within the resulting 95% confidence bounds surrounding the URP glide path. This indicates that there is no difference between the flat (i.e., no change) WEP forecast of pollutants impacting the site and the URP reduction target computed for 2018. . The WEP forecast does not account for emissions from GVEA's HCCP (i.e., Healy unit # 2). As previously noted, that facility did not operate in 2002, is not currently operating, but is permitted to operate. If it is brought on line, the permitted NOx and SOx emission levels would cause the WEP trend line to fall well above the 95% confidence bounds surrounding the URP glide path.

ADEC is well aware that changes in the operating status of major point sources have the potential to significantly impact visibility levels in one or more of the Class I areas. At this point the information available for assessing the potential effects of the HCCP facility on Denali visibility is mixed. While the WEP analysis shows the potential for negative impacts, the PSD modeling analysis for that facility demonstrated little potential for visibility impacts from plumes and haze derived that facility's operations. Another consideration is that HCCP is a clean coal demonstration project that integrates a slagging, multi-staged coal combustor system with an innovative sorbent injection / spray dryer absorber / baghouse exhaust gas scrubbing system. Since many of the coal fired boiler control options considered in the four-factor analysis have already been implemented at this facility, the modeling results provide conflicting views of the potential impacts and the facility has an active permit, as a result ADEC is not mandating additional controls prior to startup through this SIP.

Simeonof – Figure III.K.9-2 shows a similarly modest URP glide path (i.e., a 0.7 deciview reduction over a 14-year period). Since the average baseline value is almost twice that of Denali, the variance in the 2002–2006 measurements appears less pronounced. The standard deviation, however, is a slightly larger 0.6 deciview. There is little difference between the WEP trend and the URP glide path displayed. Clearly, the WEP trend falls within the 95% confidence bounds surrounding the URP glide path. Again, this indicates there is no difference between the WEP forecast of pollutants impacting the site and URP reduction target computed for 2018.

Trapper Creek – Figure III.K.9-3 also shows a modest URP glide path (i.e., a 0.7 deciview reduction over a 14-year period). Considerable variance in the 2002-2006 deciview measurements is evident, which produce a standard deviation of 0.8 deciview. The resulting 95% confidence bounds surrounding the URP glide path are wide enough to encompass the WEP trend, indicating there is no difference between the WEP forecast of pollutants impacting the site and the URP reduction targets computed for 2018.

Tuxedni – Consistent with the other sites, Figure III.K.9-4 shows a modest URP glide path (i.e., a 0.7 deciview reduction over a 14-year period). Considerable scatter, particularly for the 2002 and 2003, is evident in the 2002-2006 deciview measurements. This produces a standard deviation of 1.0 deciview, the largest observed across the Class I sites. The resulting 95% confidence bounds surrounding the URP glide path are wide enough to encompass the relatively large decline in the WEP trend, again indicating there is no difference between the WEP forecast of pollutants impacting the site and the URP reduction targets computed for 2018.

Based on the information presented in Figures III.K.9-1 through III.K.9-4, Alaska has determined that the RPG for each site on the 20% worst days should be the same as the 2018 URP target. The 2018 RPG values for the 20% worst days are as follows:

- Denali – 9.3 deciview
- Simeonof – 17.9 deciview
- Trapper Creek – 10.9 deciview
- Tuxedni – 13.4 deciview

Since none of the WEP trends on the 20% worst days indicate an increase in deciview levels and Alaska lacks the capability to model deciview levels for either best or worst days, the State has determined that RPGs for the 20% best days should be the same as the baseline deciview condition for each site, presented in Section III.K.4. As a result, the 2018 RPGs for the 20% best days are as follows:

- Denali – 2.4 deciview
- Simeonof – 7.6 deciview
- Trapper Creek – 3.5 deciview
- Tuxedni – 4.0 deciview

This decision is supported by (1) limited growth forecast for the State, (2) the results of the WEP analysis, (3) the additional BART reductions not reflected in the WEP analysis, and (4) reductions in $PM_{2.5}$ and related precursor emissions that will be produced by controls implemented under the $PM_{2.5}$ SIP that is being developed for Fairbanks.

To summarize, RPGs for 2018 were set by first comparing the percentage change in anthropogenic contributions between 2002 and 2018 from the WEP analyses to the target uniform rate of progress for 2018, and then in addition evaluating the uncertainty of the URP targets relative to the forecasted WEP reductions.

F. Affirmative Demonstration of RPGs for 20% Worst Days

As discussed earlier, EPA guidance indicates states may select an RPG that provides for lesser, equivalent, or greater visibility improvement than described by the URP glide path. The RPGs selected for 2018 on the 20% worst days show an improvement in visibility that is consistent with the URP targets in 2018. Outlined below are the factors that were considered when selecting the RPGs.

1. WEP Forecast – Since the WRAP was unable to perform photochemical modeling for Alaska, the WEP analysis provides the most insightful forecast of pollutant, source, and location impacting each Class I area. ADEC put considerable resources into the development of the statewide emissions inventory, the first prepared for the state. That inventory accounts for differences in emissions between each source category and community across the state in 2002 and 2018. When combined with the back trajectories of air parcels impacting each site on the 20% worst days, the WEP values provide substantial insight into which pollutant, source and borough have the greatest impacts at each site. They also provide a basis for assessing the benefits of additional controls that may be applied to sources impacting each site.

2. Four-Factor Analysis – The analysis was conducted as specified under Section 308 (d)(1)(i)(A). While that review determined that it was not reasonable to control additional source categories at this time, ADEC commits to reassess the need for control of these sources and further evaluate control options during this first milestone period (through 2018) to determine whether additional emission reductions in these source categories would improve Class I area visibility in the next planning period.

3. BART Analysis – Several key sources will be implementing additional controls that reduce pollutants impacting Denali, Trapper Creek, and Tuxedni. GVEA's Healy Power Plant has limits in place for SO_2, NOx, and PM_{10}. More importantly, additional NOx controls will be added to reduce the estimated visibility impacts at Denali below the 0.5 deciview significance threshold. This reduction is not reflected in the WEP analysis and indicates that deciview values at Denali will decline and not stay constant as indicated in the uncertainty analysis. The Conoco Philips Kenai LNG plant will also add new controls to reduce NOx levels below the 0.5 deciview significance threshold impacting Trapper Creek. These reductions are also not reflected in the WEP analysis and indicate that the deciview values at Trapper Creek are likely to decline more rapidly than indicated in the uncertainty analysis. Finally, the Agrium, Chem-Urea Plant in the Kenai has stopped operating and dramatically reduced NH_3 emissions impacting Tuxedni (by 98%). Significant reductions in NOx and $PM_{2.5}$ have also occurred (18% and 93%, respectively). These reductions in emissions from the Kenai ensure that the deciview values at Tuxedni should decline even more rapidly than indicated in the uncertainty analysis.

4. Additional Reductions – On December 13, 2009, Fairbanks was formally designated as a $PM_{2.5}$ nonattainment area. It has less than three years to prepare a SIP demonstrating

attainment with the ambient standard by the end of 2014. The control measures implemented to prepare an attainment demonstration will provide benefits to Denali as the WEP analysis demonstrated that sources in Fairbanks were significant contributors to NOx and SOx levels impacting Denali. These reductions are not reflected in the uncertainty analysis and further indicate that deciview values at Denali will decline and not stay constant as indicated in the uncertainty analysis. The WEP analysis also identified several older point sources located in areas impacting Class I areas that are not BART eligible. As these sources replace aging operating units, compliance with BART, PSD, and other EPA requirements ensures additional emission reductions will accrue and further enhance visibility at the impacted sites. ADEC plans to monitor modifications at these facilities and track the benefits for impacted Class I areas.

5. Evidence of Natural Source Significance – The speciation analysis presented in Section III.K.4 and the WEP analysis clearly demonstrate that natural fires are the dominant source of pollutants impacting the non-Simeonof Class I areas within Alaska on the 20% worst days. Since natural fires are larger causes of reduced visibility in Alaska than anthropogenic sources, these events lead to substantial year-to-year variation in visibility as indicated by the fluctuation in the historical data. Thus, even if a control program puts a site exactly on the URP line, on average, the actual visibilities measured historically and in the future can vary substantially from the URP trend on a year-to-year basis, making both program planning and the demonstration of progress difficult. For this reason, ADEC will track progress relative to the glide path and determine whether additional emission reductions are needed to ensure that (1) visibility is not degrading in any of the Class I areas and (2) reductions towards RPGs are achieved.

6. New Maritime Emission Regulations – The recent decision of the International Maritime Organization (IMO) to designate waters off of North American coasts as an emission control area (ECA) ensures large reductions in particulate and sulfur emissions from vessels operating in areas that impact ports and coastal areas. These reductions were not included in the WEP analysis and are expected to further improve visibility at Tuxedni, as it is located within the ECA; and to a lessor extent Simeonof, which is outside of the ECA, but, as shown in Section III.K.4 is significantly impacted by sea salt. Given its location, it is likely that reductions in maritime sulfur and particulate levels will enhance Simeonof visibility.

III.K.10 COMMITMENT TO FUTURE 308 PLAN REVISIONS

Section 51.308(f) of the Regional Haze Rule requires that regional haze plans be revised and submitted to EPA by July 31, 2018, and every ten years thereafter. In accordance with those requirements, ADEC commits to revising and submitting this Plan by July 31, 2018, and every ten years thereafter as required.

40 CFR 51.308(g) requires states to submit a progress report to EPA every five years evaluating progress towards the reasonable progress goal(s). The first progress report is due five years from the submittal of the initial implementation plan and must be in the form of an implementation plan revision that complies with 40 CFR Sections 51.102 and 51.103. At a minimum, the progress reports must contain the elements in 40 CFR 51.308(g)(1) through (7) for each Class I area as summarized below.

1. Implementation status of the current SIP measures;
2. Summary of emissions reductions;
3. Assessment of worst and best days;
4. Analysis of emission reductions by pollutant;
5. Significant changes in anthropogenic emissions;
6. Assessment of the current SIP sufficiency to meet reasonable progress goals; and
7. Assessment of visibility monitoring strategy.

In accordance with the requirements listed in Section 51.308(g) of the federal regional haze rule, ADEC commits to submitting a report on reasonable progress to EPA every five years following the initial submittal of the SIP, with the first report to be submitted by July 31, 2013. The reasonable progress report will evaluate the progress made towards the reasonable progress goal for each mandatory Class I area located within Alaska and in each mandatory Class I area located outside Alaska, which may be affected by emissions from Alaska. It will also assess whether emissions from any new major point source have the potential to impact Class I visibility. If this occurs, ADEC will reassess the need for control of these sources and further evaluate controls options during this five-year period to determine whether additional emission reductions in these sources would improve Class I area visibility in the next planning period. ADEC will also evaluate the monitoring strategy adequacy in assessing reasonable progress goals. This assessment will be submitted as part of the SIP submissions.

Revisions and progress reports depend on future visibility monitoring. Assessment of monitoring strategy and analysis of monitoring data is required for progress reports. Alaska will depend on the IMPROVE monitoring program to collect and report data for reasonable progress tracking of the three Alaska Class 1 Areas currently monitored. Because Regional Haze is a long-term tracking program with a 60-year implementation period, Alaska expects the configuration of the monitors, sampling site locations, laboratory analysis methods and data quality assurance, and network operation protocols will not change, or if changed, will remain directly comparable to those operated by the IMPROVE program during the 2000-2004 Regional Haze baseline period. Technical analyses and reasonable progress goals in this plan are based on data from these sites.

Alaska plans to use data reported by the IMPROVE program with the analysis tools found at the Visibility Information Exchange Web System (VIEWS), and those sponsored by the WRAP. Alaska will depend on the routine, timely reporting of monitoring data by the IMPROVE program to VIEWS for the tracking reasonable progress. Alaska will continue to rely on U.S. EPA to operate the IMPROVE monitoring network.

40 CFR 51.308(h) requires that states determine the adequacy of their existing SIP revision. In accordance with this requirement, ADEC commits to submitting a determination of adequacy of its regional haze SIP revision whenever a progress report is submitted. Depending on the findings of its five-year review, ADEC will take one or more of the following actions at that time, whichever actions are appropriate or necessary:

- If ADEC determines that the existing State Implementation Plan requires no further substantive revision in order to achieve established goals for visibility improvement and emissions reductions, ADEC will provide to the EPA Administrator a negative declaration stating that further revision of the existing plan is not needed.

- If ADEC determines that its implementation plan is or may be inadequate to ensure reasonable progress as a result of emissions from sources in one or more other states that participated in the regional planning process, ADEC will provide notification to the EPA Administrator and to those other states. ADEC will also collaborate with the other states through the regional planning process for the purpose of developing additional strategies to address any such deficiencies in Alaska's plan.

- If ADEC determines that its implementation plan is or may be inadequate to ensure reasonable progress as a result of emissions from sources in another country, ADEC will provide notification, along with available information, to the EPA Administrator.

- If ADEC determines that the implementation plan is or may be inadequate to ensure reasonable progress as a result of emissions from sources within the state, ADEC will revise its implementation plan to address the deficiencies.

III.K.11 CONSULTATION

In developing the Regional Haze SIP and in future revisions to the SIP, ADEC coordinates and consults with FLMs, tribes, and other states. In addition, ADEC provides opportunities for public participation and review of the SIP prior to its adoption and submittal to EPA. Requirements related to these consultation and outreach activities along with ADEC's efforts to meet the requirements for the initial Regional Haze SIP are discussed in greater detail in the following sub-sections.

A. FLM Consultation

40 CFR Section 51.308(i) of the Regional Haze Rule requires coordination between states and the FLMs. ADEC has provided agency contacts to the FLMs as required under 51.308(i)(1). During the development of this plan, the FLMs were consulted in accordance with the provisions of 51.308(i)(2).

Numerous opportunities were provided by the Western Regional Air Partnership for FLMs to participate fully in the development of technical documents developed by the WRAP and included in this plan. This included the ability to review and comment on these analyses, reports, and policies. A summary of WRAP-sponsored meetings and conference calls is provided in Appendix III.K.11 to this plan. In addition, ADEC has provided additional opportunities for coordination and consultation with FLMs as the plan was developed through local meetings and stakeholder workshops within Alaska. Appendix III.K.11 includes details of this state-specific process.

The State of Alaska has provided an opportunity for FLM consultation, at least 60 days prior to holding any public hearing on the SIP. This SIP was submitted to the FLMs on June 24, 2010 for review and comment. Comments were received from the FLMs on August 23, 2010. As required by 40 CFR Section 51.308(i)(3), the FLM comments and State responses are included in Appendix III.K.11 to this plan.

40 CFR Sections 51.308(f-h) establish requirements and timeframes for states to submit periodic SIP revisions and progress reports that evaluate progress toward the reasonable progress goal for each Class I area. As required by 40 CFR Section 51.308(i)(4), ADEC will continue to coordinate and consult with the FLMs during the development of these future progress reports and plan revisions, as well as during the implementation of programs having the potential to contribute to visibility impairment in mandatory Class I areas. This consultation process shall provide on-going and timely opportunities to address the status of the control programs identified in this SIP, the development of future assessments of sources and impacts, and the development of additional control programs. In particular, ADEC commits to the following consultation requirements:

- DEC will provide the FLM an opportunity to review and comment on SIP revisions, the five-year progress reports, and other developing programs that may contribute to Class I visibility impairment.

- DEC will afford the FLM with an opportunity for consultation in person and at least 60 days prior to holding any public hearing on a SIP revision. The FLM consultation must include the opportunity to discuss their assessment of visibility impairment in each federal Class I area; and to provide recommendations on the reasonable progress goals and on the development and implementation of the visibility control strategies. ADEC will include a summary of how it addressed the FLM comments in the revised RH SIP.

B. Tribal Consultation

For its SIP planning, ADEC has kept in contact with participants in the Alaska Tribal Air Workgroup and will continue to remain in contact with those Tribes which are in close proximity to Alaska's Class I areas and which may reasonably be anticipated to cause or contribute to visibility impairment in Alaska's mandatory Class I Federal area(s). Public workshops in Anchorage on <Insert Date>, Healy on <Insert Date>, Sand Point on <Insert Date>, and Kenai on <Insert Date> will be held. Documentation of ADEC's coordination and consultation with tribes will be maintained and included in Appendix III.K.11. In addition, EPA bears a trust responsibility to the federally recognized tribal governments in Alaska. As a result, Alaskan tribes also have an opportunity for consultation with EPA on this plan through the federal approval process.

C. Inter-State Consultation/Coordination

DEC has not identified any other state that is impacting Alaskan Class I areas and ADEC has not been identified as a contributor to impacts in other state's Class I areas. However, in accordance with 40 CFR 51.308(d)(1)(iv) and 51.308(d)(3)(i), ADEC commits to continue consultation with states which may reasonably be anticipated to cause or contribute to visibility impairment in federal Class I areas located within Alaska. ADEC will also continue consultation with any state for which Alaska's emissions may reasonable be anticipated to cause or contribute to visibility impairment in that state's federal Class I areas.

With regards to the established or updated goal for reasonable progress, should disagreement arise between another state or group of states, ADEC will describe the actions taken to resolve the disagreement in future Regional Haze SIP revisions for EPA's consideration. With regards to assessing or updating long-term strategies, ADEC commits to coordinate its emission management strategies with any affected states and will continue to include in its future Regional Haze SIP revisions all measures necessary to obtain its share of emissions reductions for meeting progress goals.

D. Regional Planning Coordination

DEC commits to continued participation in the WRAP process and commits to coordinate future plan revisions with other WRAP member states in addressing regional haze. As part of this commitment, ADEC will include the following in future Regional Haze SIP revisions.

- Demonstration of on-going WRAP participation and commitment for continue participation in addressing regional haze [51.308(c)(1)(I)].

- Description of the regional planning process, including the list of member states, goals, objectives, management, decision making structure, established product deadlines, and schedule for adopting RH SIP revisions implementing WRAP's recommendations [51.308(c)(1)(iii)].

- Showing of inter-state visibility impairment in federal Class I areas based on available inventory, monitoring, or modeling information [51.308(c)(1)(ii)].

- Address fully the recommendations of WRAP, including Alaska's apportionment of emission reduction obligations as agreed upon through WRAP and the resulting control measures required [51.308(c)(1)(iv) and 51.308(d)(3)(ii)].

A summary of WRAP-sponsored meetings and conference calls related to the development of this initial Regional Haze plan is provided in Appendix III.K.11.

E. Public Participation and Review Process

Section 110(a) of the CAA requires that a state provide reasonable notice and public hearings of SIP revisions prior to their adoption and submission to EPA. In addition to the open public meetings of the Western Regional Air Partnership process, the state administrative process for adoption of regulation ensures that the public has adequate opportunity to comment on this Regional Haze State Implementation Plan. Prior to regulatory adoption of this SIP, ADEC held a public comment period on the revisions from <Insert Date> through <Insert Date> including a public workshop in Anchorage on <Insert Date>, Healy on <Insert Date>, Sand Point on <Insert Date>, and Kenai on <Insert Date>. A statewide teleconference hearing on <Insert Date> provided a forum for the public to comment on the air quality plan prior to its adoption at the state level and submission to EPA. ADEC responded to public comments (Appendix III.K.11). Another opportunity for public comment occurs during the EPA approval process.

III.K.12 REFERENCES

1. This transport discussion was adapted from the original thesis "The Origin and Composition of Aerosols in the Alaska Airshed," by W. J. Wilcox, II., PhD Thesis, University of Alaska Fairbanks, Dept. of Chemistry, 2001
2 . Cahill, C.F., "Asian Dust Transport to Denali National Park and Preserve and Crater Lake Nation Park," First International Conference on Trans-Pacific Transport of Atmospheric Contaminants, Seattle, WA, 2000.
3. Cahill, C.F. and A.J. Blakesley, "Air Quality Monitoring in Denali National Park: What Does It Tell Us?" presented at the AAAS 50th Arctic Scient Conference, Denail National Park and Preserve, Alaska, September 19-22, 1999.
4. Rahn, K.A. and G.E. Shaw, "Sources and Transport of Arctic Pollution Aerosol: A Chronicle of Six Years of ONR Research," Naval Research Reviews 34: 3-26, 1982.
5. AMAP Assessment Report: Arctic Pollution Issues, Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, 1998. www.amap.no
6. Seinfeld, J.H., and S.N. Pandis, Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, John Wiley and Sons, Inc., New York, 1998.
7. Wallace, J.M. and P. Hobbs, Atmospheric Science: An Introductory Survey, Academic Press, San Diego, 1977.
8. Tarrasón, L., and T. Iversen, 1992: The influence of North American Anthropogenic Sulphur Emissions over Western Europe. Tellus 44B:114–132.
9. Aerosol Research, NOAA Climate Monitoring and Diagnostics Laboratory, 1998. http://wwwsrv.cmdl.noaa.gov/aero/science/
10. Barrie, L.A., "Arctic Air Pollution: An Overview of Current Knowledge," Atmospheric Environment 20: 643-663, 1986.
11. Shaw, G.E. and M.A.K. Khalil, "Arctic Haze," in The Handbook of Environmental Chemistry, Springer-Verlag, Berlin, pp 69-111, 1989.
12. Perry, K.D., T.A. Cahill, R.C. Schnell, and J.M. Harris, "Long-Range Transport of Anthropogenic Aerosols to the National Oceanic and Atmospheric Administration Baseline Station at Mauna Loa Observatory, Hawaii," Journal of Geophysical Research 104: 18521-18533, 1999.
13. Rahn, K.A., R. Borys, and G.E. Shaw, "The Asian Source of Arctic Haze Bands," Nature 268: 713-715, 1977.
14. Shaw, G.E., "Transport of Asian Desert Aerosol to the Hawaiian Islands" Journal of Applied Metereology 19:1254-1259, 1980.
15. Biscaye, P.E., F.E. Grousset, M. Revel, S. VanderGaast, G.A. Zielinski, A. Vaars, and G. Kukla, "Asian Provenance of Glacial Dust (Stage 2) in the Greenland Ice Sheet PRoejct 2 Ice Core, Summit, Greenland," Journal of Geophysical Research 102: 26765-26781, 1997.
16. Rex, R.W., J.K. Syers, M.L. Jackson, and R.N. Clayton, "Aeolian Origian of Quartz in Soils of Hawaiian Islands and in Pacific Pelagic Sediments," Science 163: 277-291,1969.
17. Dymond, J., P.E. Biscaye, and R.W. Rex, "Aeolian Origin of Mica in Hawaiian Soils," Geological Society of America Bulletin 85: 37-40, 1974.

18. Kennedy, M.S., O.A. Chadwick, P.M. Vitousek, L.A. Derry, and D.M. Hendricks, "Changing Sources of Base Cations During Ecosystem Development, Hawaiian Islands," Geology 26: 1015-1018, 1998.
19. Chadwick, O.A., L.A. Derry, P.M. Vitousek, B.J. Huebert, and L.O. Hedin, "Changing Sources of Nutrients During Four Million Years of Ecosystem Development," Nature 397: 491-497, 1999.
20. Prospero, J.M. and D.L. Savoie, "Effect of Continental Sources of Nitrate Concentrations Over the Pacific Ocean," Nature 339: 687-698, 1989.
21. Jaffe, D.A. A. Mahura, J. Kelley, J. Atkins, P.C. Novelli, and J. Merrill, "Impact of Asian Emissions on the Remote North Pacific Atmosphere: Interpretation of CO Data from Shemy, Guam, Midway and Mauna Loa," Journal of Geophysical Research `102: 28627-28636, 1997.
22. Talbot, R.W., J.E. Dibb, B.L. Lefer, J.D. Bradshow, S.T. Sandholm, D.R. Blake, N.J. Blake, G.W. Sachse, J.E. Collins, B.G. Heikes, J.T. Merrill, G.L. Gregory, B.E. Anderson, H.B. Singh, D.C. Thornton, A.R. Bandy, and R.F. Pueschel, et al., "Chemical Characteristics of Continental Outflow from Asia to the Troposphere over the Western Pacific Ocean during February-March 1994: Results from PEM-West B," Journal of Geophysical Research 102: 28255-28274, 1997.
23. Jaffe, D.A., T. Anderson, D. Covert, R. Kotchenruther, B. Trost, J. Danielson, W. Simpson, T. Bernsten, S. Karlsdottir, D. Blake, J. Harris, G. Carmichael, and I. Uno, "Transport of Asian Air Pollution to North America," Geophysical Research Letters 26: 711-714, 1999.
24. Th. F. Mentel, J. Wildt, A. Kiendler-Scharr, E. Kleist, R. Tillmann, M. Dal Maso, R. Fisseha, Th. Hohaus, H. Spahn, R. Uerlings, R. Wegener, P. T. Griffiths, E. Dinar, Y. Rudich, and A. Wahner. "Photochemical Production of Aerosols from Real Plant Emissions," Atmos. Chem. Phys. 9: 4387–4406. 2009, http://www.atmos-chem-phys.net/9/4387/2009/
25. T. D. Sharkey, A. E. Wiberley, and A. R. Donohue. "Isoprene Emission from Plants: Why and How Annals of Botany 101: 5–18, 2008. DOI: 10.1093/aob/mcm240, available online at http://www.aob.oxfordjournals.org
26. E. Pattey, R. L. Desjardins, H. Westberg, B. Lamb, and T. Zhu. "Measurement of Isoprene Emissions over a Black Spruce Stand Using a Tower-Based Relaxed Eddy-Accumulation System," Journal of Applied Meteorology 38: 870-877. 1999
27. S. Hayward, A. Tani, S. M. Owen and C. N. Hewitt. "Online Analysis of Volatile Organic Compound Emissions from Sitka Spruce (Picea sitchensis)," Tree Physiology 24: 721–728. 2004.
28. P. Tiiva, P. Faubert, A. Michelsen, T. Holopainen, J. K. Holopainen, R. Rinnan. "Climatic warming increases isoprene emission from a subarctic heath," New Phytologist 180: 853-863. 2008, DOI: 10.1111/j.1469-8137.2008.02587.x
29. B. H. Svensson, J. C. Lantsheer and H. Rodhe. "Sources and Sinks of Methane," Ambio 20(3/4):155-160, May 1991. Stable URL: http://www.jstor.org/stable/4313805
30. Katey, M.W., L.C. Smith, F.S. Chapin III, "Methane Bubbling from Northern Lakes: Present and Future Contributions to the Global Methane Budget," Phil. Trans. R. Soc. A (2007) 365: 1657–1676, doi:10.1098/rsta.2007.2036

31. Kulmala, M.; Hämeri, K.; Mäkelä, J. M.; Aalto, P. P.; Pirjola, L.; Väkevä, M.; Koponen, I. K.; Buzorius, G.; Keronen, P.; Rannik, Ü.; Seidl, W.; Forkel, R.; Hoffmann, T.; Spanke, J.; Nilsson, E. D.; Janson, R.; Hansson, H.-C.; O'Dowd, C.; Becker, E.; Paatero, J.; Teinilä, K.; Hillamo, R.; Viisanen, Y.; Laaksonen, A.; Bigg, E.K.; Swietlicki, E.; Salm, J.; Hari, P.; Altimir, N.; Weber, R. "Biogenic aerosol formation in the boreal forest," Boreal Environment Research 2000, 5, pp.281-297.

32. M. Kulmala, K. Hämeri, P. P. Aalto, J. M. Mäkelä, L. Pirjola, E. Douglas Nilsson, G. Buzorius, Ü. Rannik, M. Dal Maso, W. Seidl, T. Hoffman, R. Janson, H.C. Hansson, Y. Viisanen, A. Laaksonen and C. D. O'Dowd. "Overview of the International Project on Biogenic Aerosol Formation in the Boreal Forest (BIOFOR)," Tellus B, 53:324-343.
33. M. Kulmala, K. Hämeri, P. P. Aalto, J. M. Mäkelä, L. Pirjola, E. Douglas Nilsson, G. Buzorius, Ü. Rannik, M. Dal Maso, W. Seidl, T. Hoffman, R. Janson, H.C. Hansson, Y. Viisanen, A. Laaksonen and C. D. O'Dowd. "Overview of the International Project on Biogenic Aerosol Formation in the Boreal Forest (BIOFOR)," Tellus B, 53:324-343.
34. P. Tunved, H.-C. Hansson, V.-M. Kerminen, J. Ström, M. Dal Maso, H. Lihavainen, Y. Viisanen, P. P. Aalto, M. Komppula, and M. Kulmala. "High Natural Aerosol Loading over Boreal Forests," Science 14: Vol. 312(5771):261-263, April 2006, DOI: 10.1126/science.1123052
35. W. Wang, M. H. Wu1, L. Li, T. Zhang, X. D. Liu, J. L. Feng, H. J. Li, Y. J. Wang, G. Y. Sheng, M. Claeys, and J. M. Fu. "Polar Organic Tracers in $PM_{2.5}$ Aerosols from Forests in Eastern China," Atmos. Chem. Phys. 8: 7507–7518, 2008.
36. J. Spanke, Ü. Rannik, R. Forkel, W. Nigge, and T. Hoffmann. "Emission fluxes and atmospheric degradation of monoterpenes above a boreal forest: field measurements and modeling," Tellus B, 53: 406-422. 2001, DOI: 10.1034/j.1600-0889.2001.530407.x
37. F. Pingquing, K. Kawamura, J. Chen, and L. Barrie. "Isoprene, Monoterpene, and Sesqueterpene Oxidation Products in the High Arctic Aerosols during late winter to early summer," Environ. Sci. Technol. 2009, 43 (11), pp 4022-4028 DOI: 10.1021/es803669a

38. Buzorius, G., Ü. Rannik, P. Aalto, M. dal Maso, E. D. Nilsson, K. E. J. Lehtinen, and M. Kulmala (2003), On particle formation prediction in continental boreal forest using micrometeorological parameters, *J. Geophys. Res.*, 108(D13), 4377, doi:10.1029/2002JD002850.

P. Tunved, H.-C. Hansson, V.-M. Kerminen, J. Ström, M. Dal Maso, H. Lihavainen, Y. Viisanen, P. P. Aalto, M. Komppula, and M. Kulmala. "High Natural Aerosol Loading over Boreal Forests," Science 14: Vol. 312(5771):261-263, April 2006, DOI: 10.1126/science.1123052.

39. O'Dowd et al. 1999
40. Doukas and McGee, 2002
41. Federal Register, Vol. 63, No. 126, July 1, 1999
42. Air Sciences, Inc., "Development of 2000-04 Baseline Period and 2018 Projection Year Emission Inventories," prepared for Western Governors Association/Western Regional Air Partnership," Project No. 178-8, May 2007.
43. http://laborstats.alaska.gov/?PAGEID=67&SUBID=163

44. L. Williams, et al., Sierra Research, Inc., "Criteria Pollutant Inventory for Anchorage, Fairbanks and Juneau in 2002, 2005 and 2018," prepared for Alaska Department of Environmental Conservation, July 13, 2007.
45. S. Delaney and R. Dulla, Sierra Research, Inc., "Alaska Rural Communities Emission Inventory," prepared for Western Governors' Association, Western Regional Air Partnership and Alaska Department of Environmental Conservation, Report No. SR2007-02-01, February 2007.
46. K. Thesing and A. Mammino, E.H. Pechan & Associates, "Commercial Marine Inventories for Selected Alaskan Ports," prepared for Alaska Department of Environmental Conservation, Report No. 05.05.004/9499.001
47. S. Delaney and R. Dulla, Sierra Research, Inc., "Alaska Aviation Emission Inventory," prepared for Western Regional Air Partnership, Report No. SR2005-06-02, June 14, 2005.
48. Western Regional Air Partnership On-Line Emissions Inventory Report (EDMS) Tool available at: http://vista.cira.colostate.edu/TSS/EDMS.aspx
49. http://www.labor.state.ak.us/research/pop/estimates/08T2.1.xls
50. http://www.labor.state.ak.us/research/pop/projections/AkSubStatePopProj.xls
51. Criteria Pollutant Inventory for Anchorage, Fairbanks and Juneau in 2002, 2005 and 2018, prepared by Sierra Research for Alaska Department of Environmental Conservation, July 13, 2007.
52. D. Randall., Technical Memorandum: Fire Emissions Inventory – Phase III Base-Control Case, Prepared for Western Regional Air Partnership Fire Emissions Joint Forum by Dave Randall, Air Sciences, Inc., April 28, 2006.
53. A. Pollisar, et al., "Source Regions for Atmospheric Aerosol Measured at Barrow," Environmental Science & Technology 2001 35 (21): 4214-4226.
54. ENVIRON, "Preliminary WRAP Alaska Visibility Modeling Draft Modeling Protocol," prepared for Western Regional Air Partnership, October 15, 2004.