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
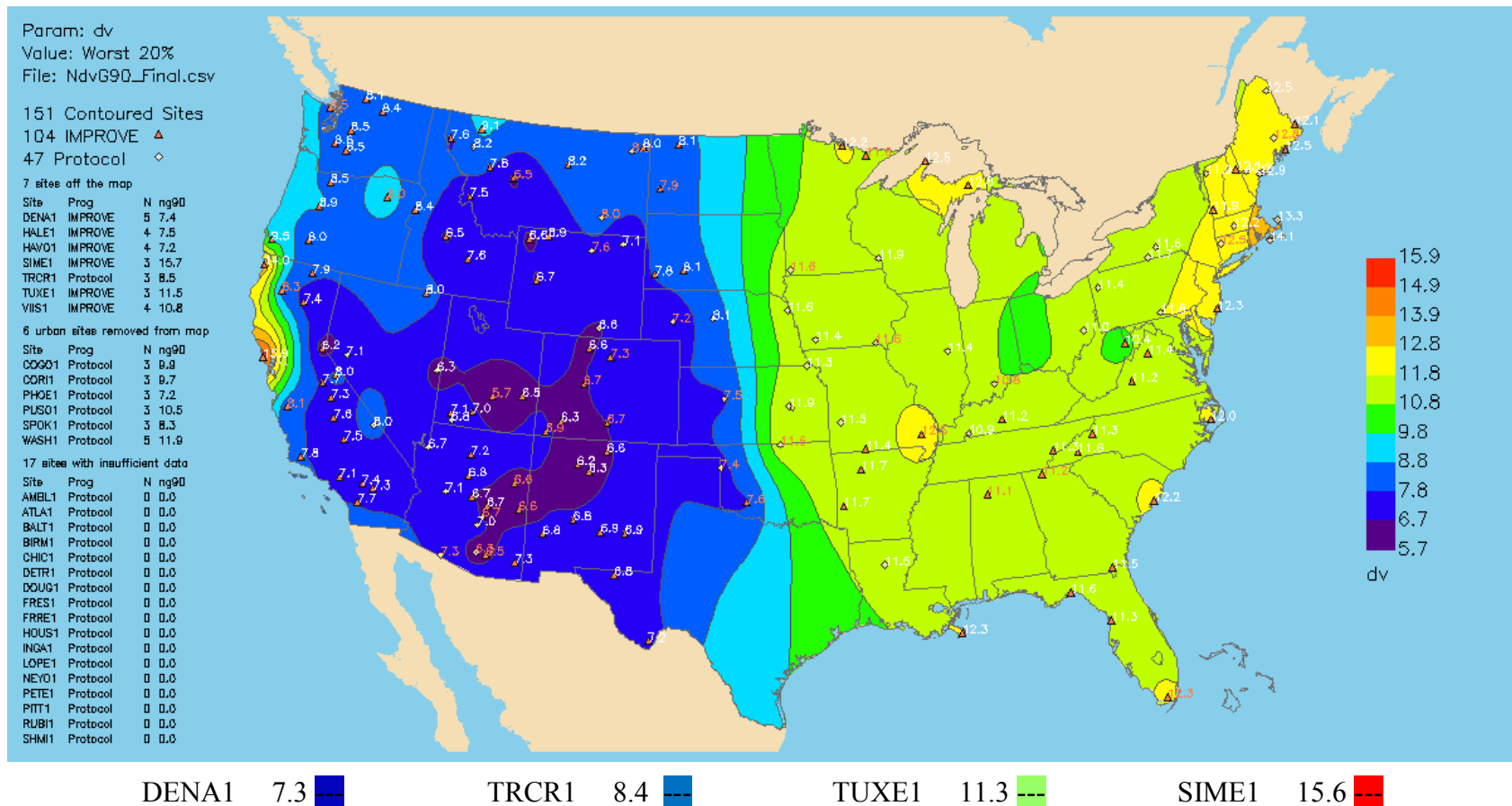 Worst Day Natural Conditions: Worst 20% estimate

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/m³
bEC	0.2	0.06	0.48	Mm⁻¹	EC	0.02	0.01	0.05	ug/m³
bNO3	0.35	0.13	0.6	Mm⁻¹	NO3	0.06	0.03	0.09	ug/m³
bOMC	2.07	0.24	7.29	Mm⁻¹	OMC	0.6	0.1	1.9	ug/m³
bSO4	0.65	0.24	1.13	Mm⁻¹	SO4	0.12	0.04	0.2	ug/m³
bSoil	0.14	0.04	0.3	Mm⁻¹	Soil	0.14	0.04	0.33	ug/m³
bSs	0.23	0.05	0.6	Mm⁻¹	Ss	0.04	0.02	0.07	ug/m³
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/m³
bEC	0.2	0.09	0.4	Mm⁻¹	EC	0.02	0.01	0.04	ug/m³
bNO3	0.54	0.17	1.11	Mm⁻¹	NO3	0.06	0.03	0.1	ug/m³
bOMC	1.89	0.23	5.95	Mm⁻¹	OMC	0.6	0.1	1.7	ug/m³
bSO4	0.89	0.28	1.79	Mm⁻¹	SO4	0.12	0.04	0.2	ug/m³
bSoil	0.15	0.05	0.3	Mm⁻¹	Soil	0.15	0.05	0.32	ug/m³
bSs	0.29	0.06	0.54	Mm⁻¹	Ss	0.05	0.02	0.05	ug/m³
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/m³
bEC	0.2	0.15	0.24	Mm⁻¹	EC	0.02	0.01	0.02	ug/m³
bNO3	1.2	0.6	1.67	Mm⁻¹	NO3	0.1	0.05	0.14	ug/m³
bOMC	1.46	0.72	2.65	Mm⁻¹	OMC	0.46	0.27	0.64	ug/m³
bSO4	1.28	0.76	1.76	Mm⁻¹	SO4	0.12	0.07	0.16	ug/m³
bSoil	0.13	0.04	0.21	Mm⁻¹	Soil	0.13	0.04	0.31	ug/m³
bSs	10.23	2.04	27.5	Mm⁻¹	Ss	1.26	0.3	3.06	ug/m³
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/m³
bEC	0.2	0.07	0.34	Mm⁻¹	EC	0.02	0.01	0.03	ug/m³
bNO3	0.87	0.36	1.58	Mm⁻¹	NO3	0.09	0.05	0.16	ug/m³
bOMC	1.98	0.26	5.49	Mm⁻¹	OMC	0.6	0.08	1.47	ug/m³
bSO4	0.96	0.3	1.79	Mm⁻¹	SO4	0.12	0.04	0.2	ug/m³
bSoil	0.1	0.03	0.14	Mm⁻¹	Soil	0.1	0.04	0.16	ug/m³
bSs	2.67	0.38	8.89	Mm⁻¹	Ss	0.38	0.06	1.13	ug/m³

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.*

Param: dv
Value: Worst 20%
File: NdvG90_Final.csv

151 Contoured Sites
104 IMPROVE △
47 Protocol ◇

7 sites off the map

Site	Prog	N	ng90
DENA1	IMPROVE	5	7.4
HALE1	IMPROVE	4	7.5
HAVO1	IMPROVE	4	7.2
SIME1	IMPROVE	3	15.7
TRCR1	Protocol	3	8.5
TUXE1	IMPROVE	3	11.5
VIIS1	IMPROVE	4	10.8

6 urban sites removed from map

Site	Prog	N	ng90
COGO1	Protocol	3	9.9
CORI1	Protocol	3	9.7
PHOE1	Protocol	3	7.2
PUSO1	Protocol	3	10.5
SPOK1	Protocol	3	8.3
WASH1	Protocol	5	11.9

17 sites with insufficient data

Site	Prog	N	ng90
AMBL1	Protocol	0	0.0
ATLA1	Protocol	0	0.0
BALT1	Protocol	0	0.0
BIRM1	Protocol	0	0.0
CHIC1	Protocol	0	0.0
DETR1	Protocol	0	0.0
DOUG1	Protocol	0	0.0
FRES1	Protocol	0	0.0
FRRE1	Protocol	0	0.0
HOUS1	Protocol	0	0.0
INGA1	Protocol	0	0.0
LOPE1	Protocol	0	0.0
NEYO1	Protocol	0	0.0
PETE1	Protocol	0	0.0
PITT1	Protocol	0	0.0
RUBI1	Protocol	0	0.0
SHMI1	Protocol	0	0.0

Legend (dv):
15.9
14.9
13.9
12.8
11.8
10.8
9.8
8.8
7.8
6.7
5.7

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

III.K.4-5

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.

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[*] 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. *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 ---
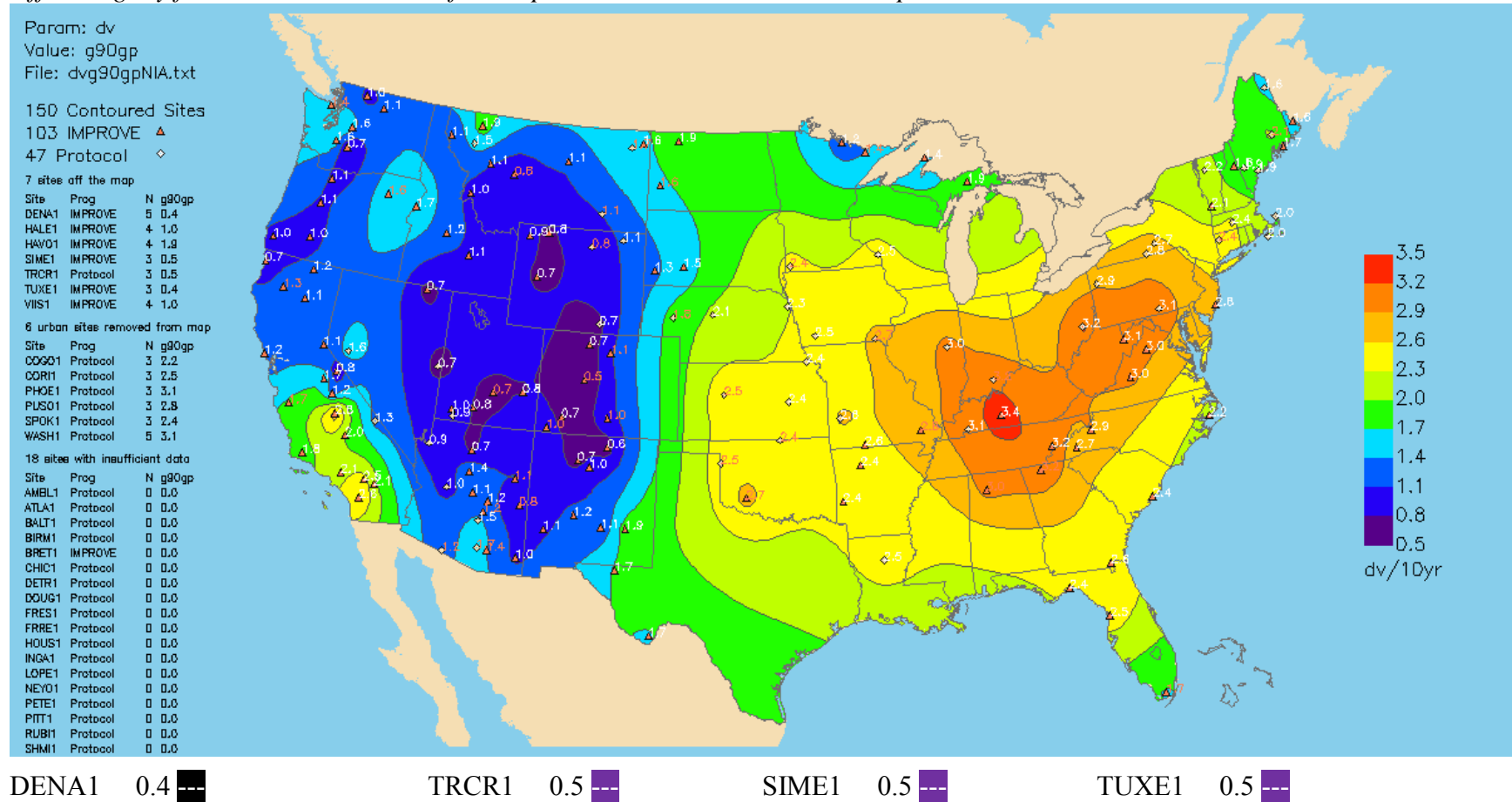
Simeonof Class I Area Baselines, Natural Conditions, Glideslope, and Interim Visibility Targets:

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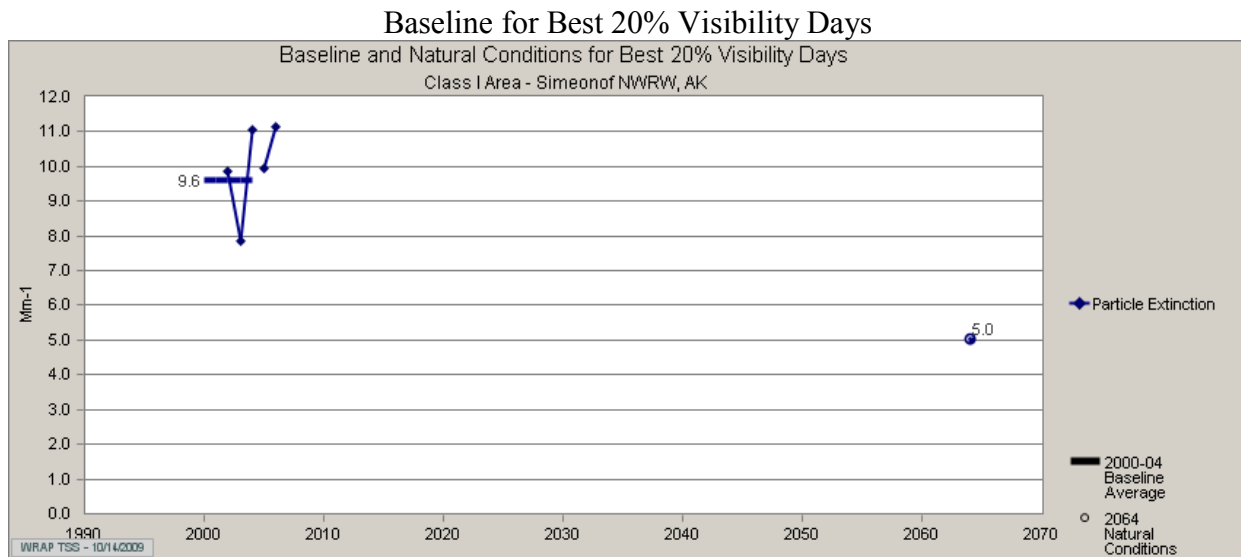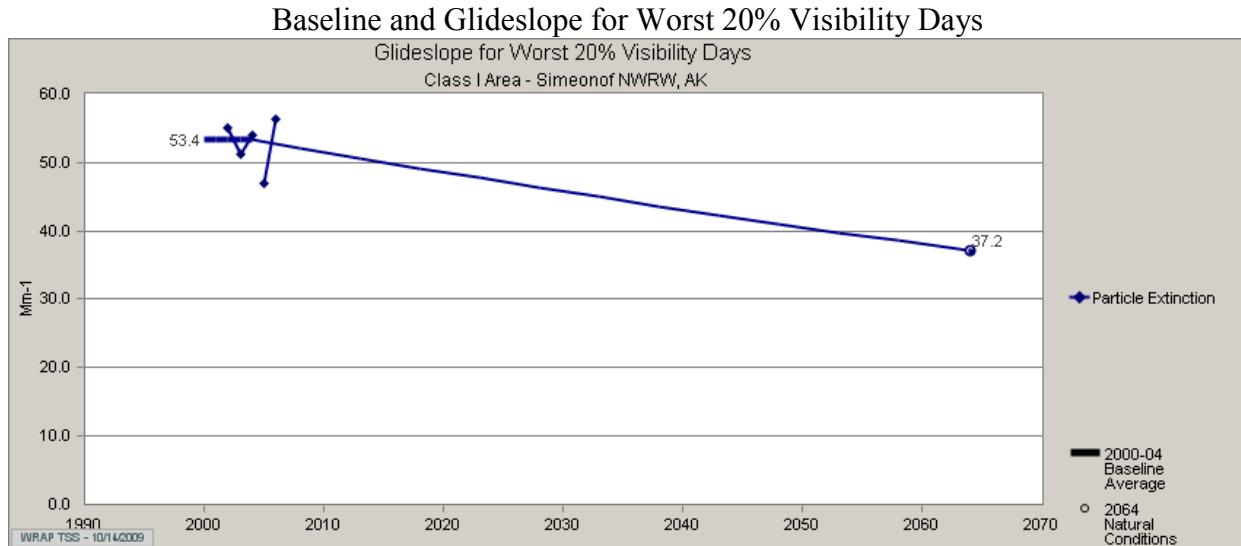
*Denali Class I Area Baselines, Natural Conditions, Glideslope, and Interim Visibility Targets:*

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
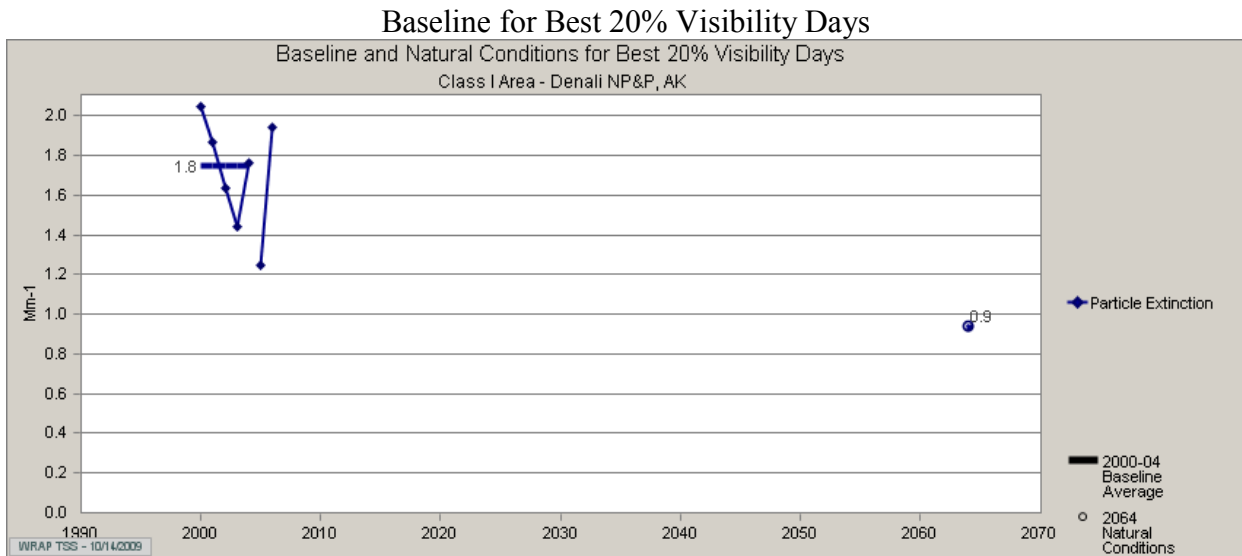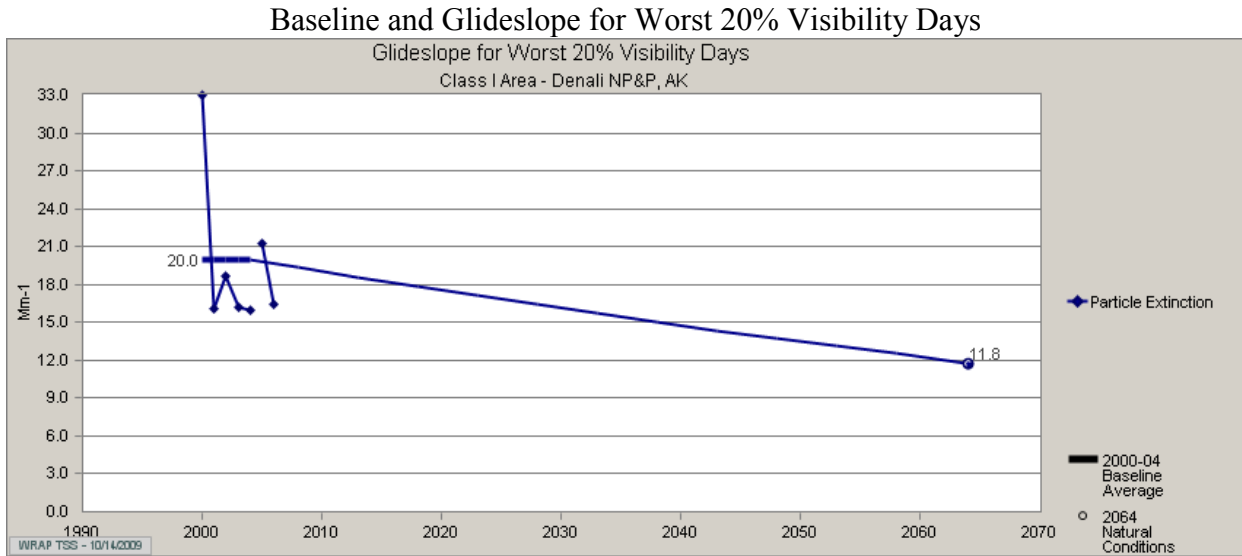
The TRCR1 (Denali) baselines and natural conditions for best and worst days are presented in Table III.K.4-6.   With baseline and target goals calculated, the glideslope was defined, and five-year target visibilities calculated (Table III.K.4-6). Figure III.K.4-5 presents the baseline, glideslope, and 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
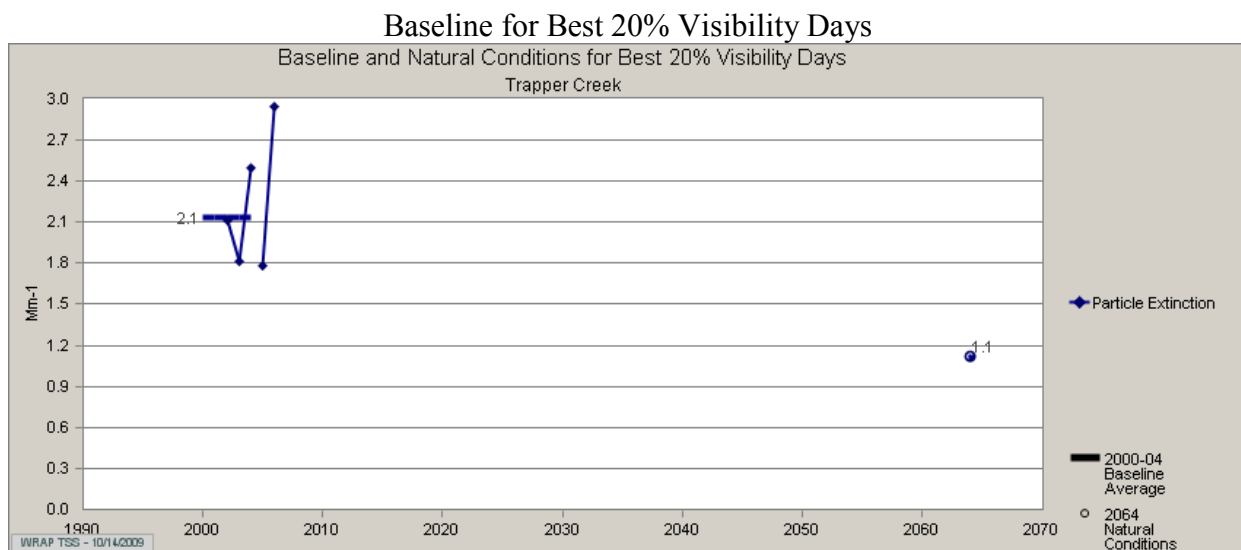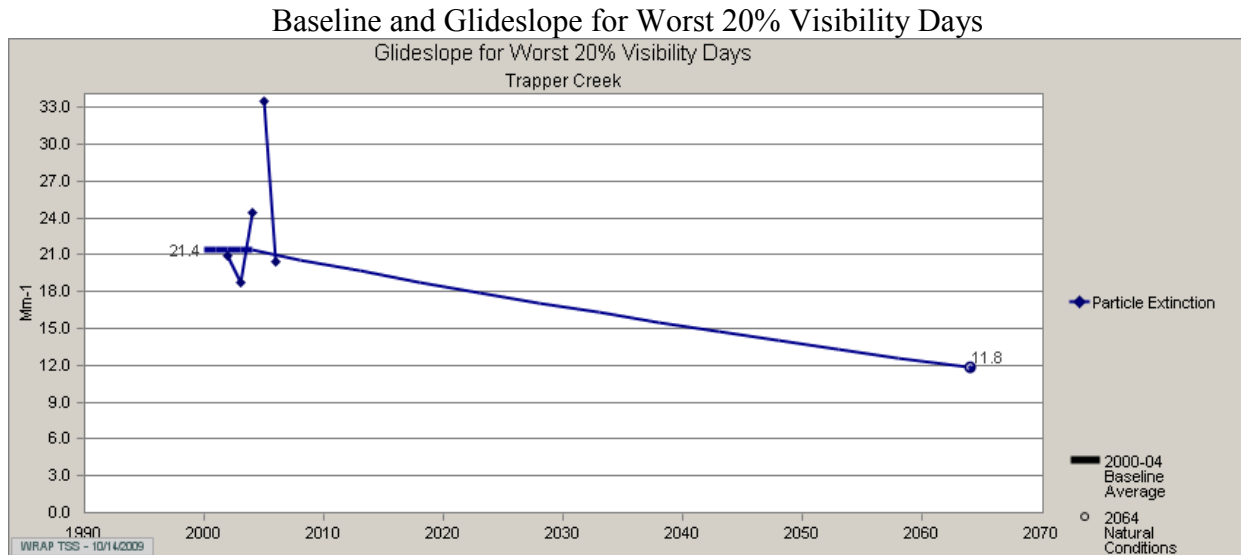
Tuxedni Class I Area Baselines, Natural Conditions, Glideslope, and Interim Visibility Targets:

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
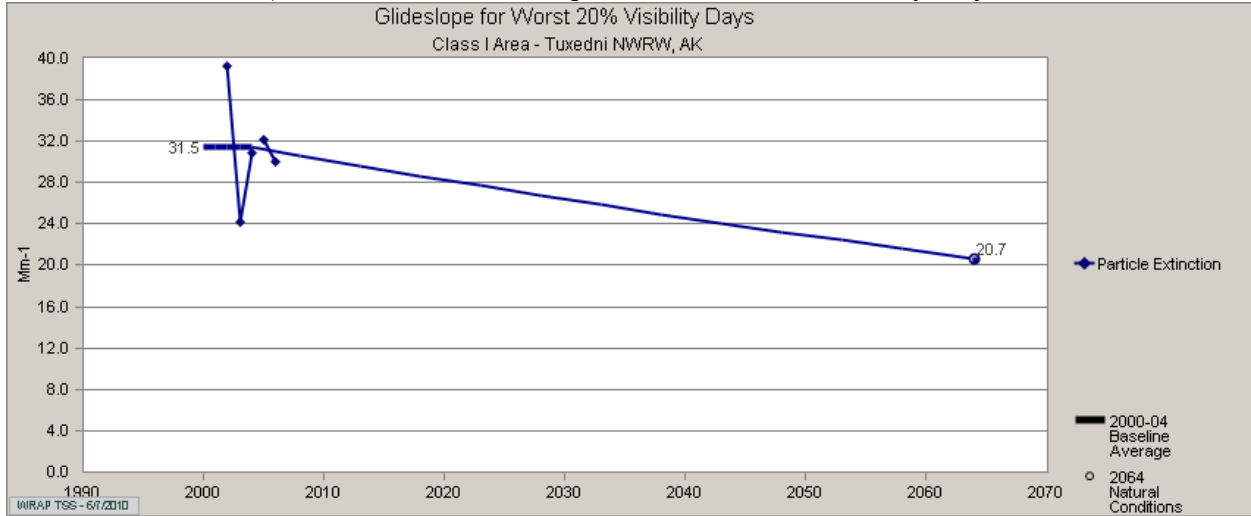
b) Baseline for Best 20% Visibility Days
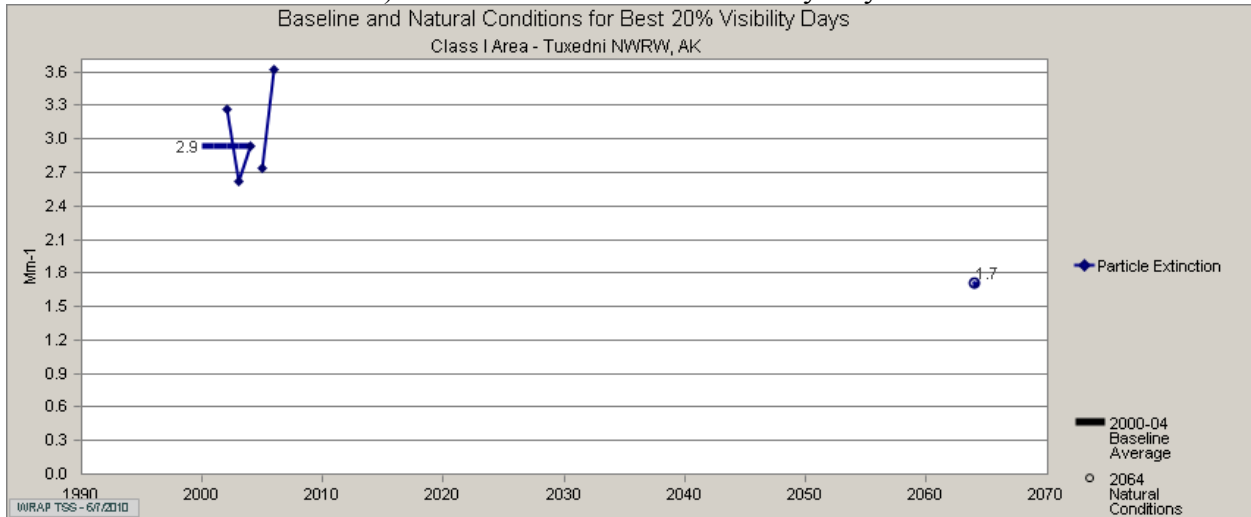
7. Choice of IMPROVE II Algorithm

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
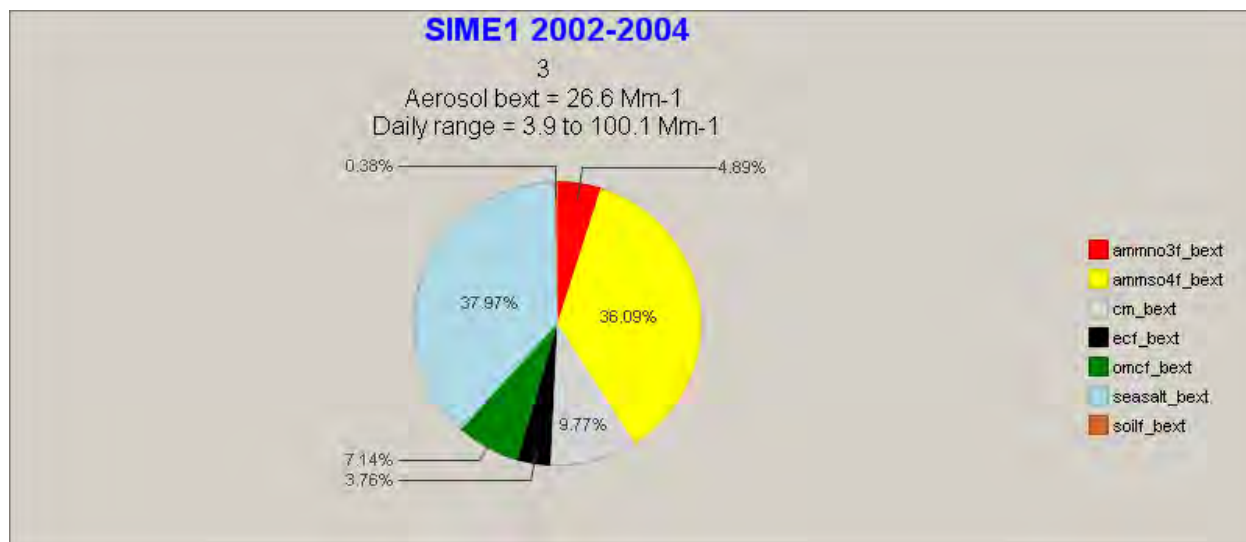
Note: Constituent aerosols are ammonium nitrate (red), ammonium sulfate (yellow), coarse mass (gray), elemental carbon (black), organic matter carbon (green), sea salt (blue), soil (orange). The chart summarizes three years of data. Total aerosol extinction (aerosol_bext) is 26.6 Mm^{-1}. Average daily 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 (SO₄) 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 (NO₃) 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
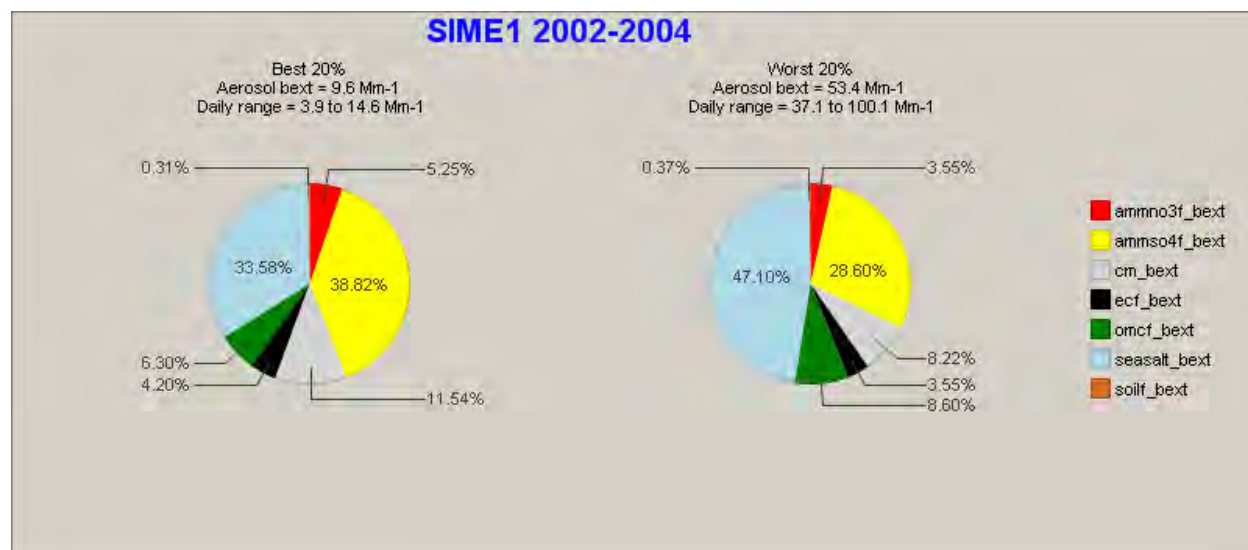
With Rayleigh scattering of 12 Mm^{-1} included, total light extinction on the best and worst days varied from 21.6 Mm^{-1}, with visual range of 181 km and 7.6 deciview, to an extinction of 65.4, with a range of 60 km and 18.6 deciview (Table III.K.4-10). The high relative contributions of Rayleigh 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%)
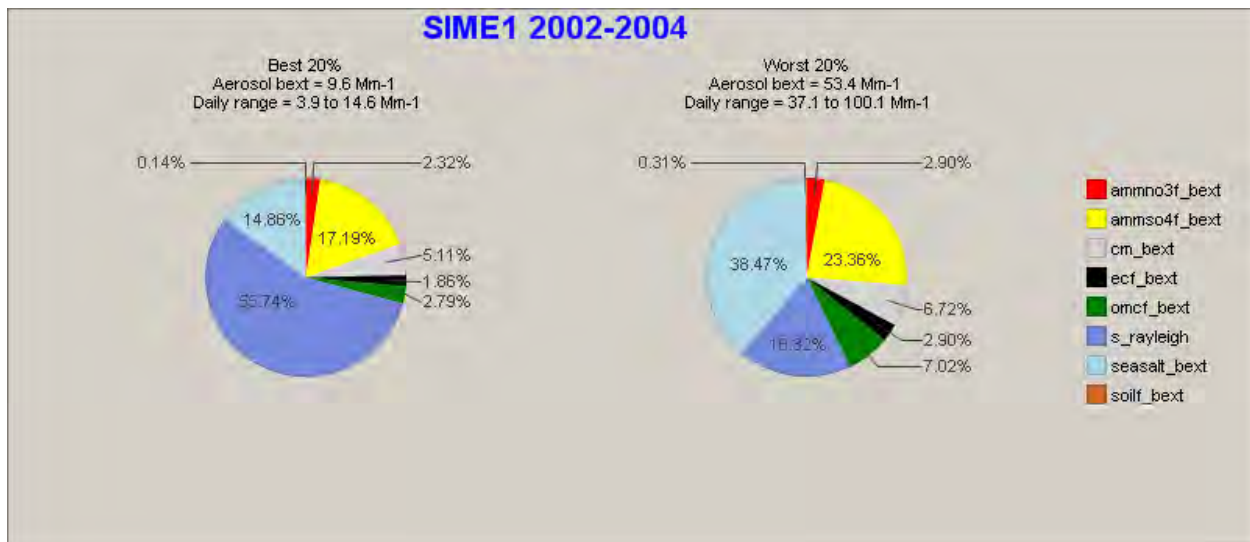
b. Seasonality, 2002-2004

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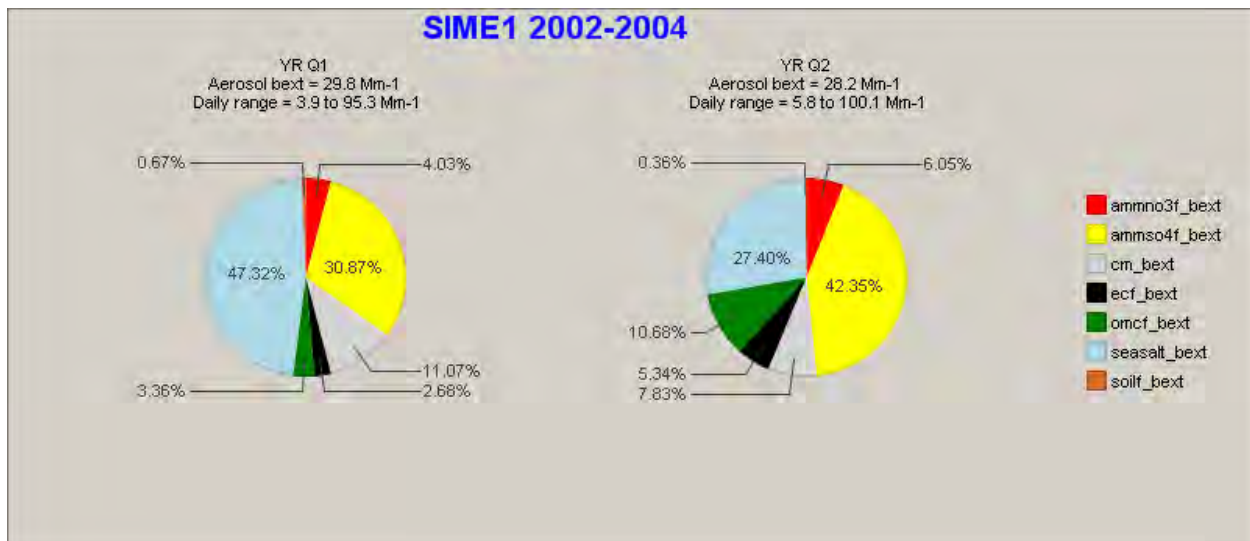
b) Calendar Quarter 3 (July-September) & Quarter 4 (October-December)
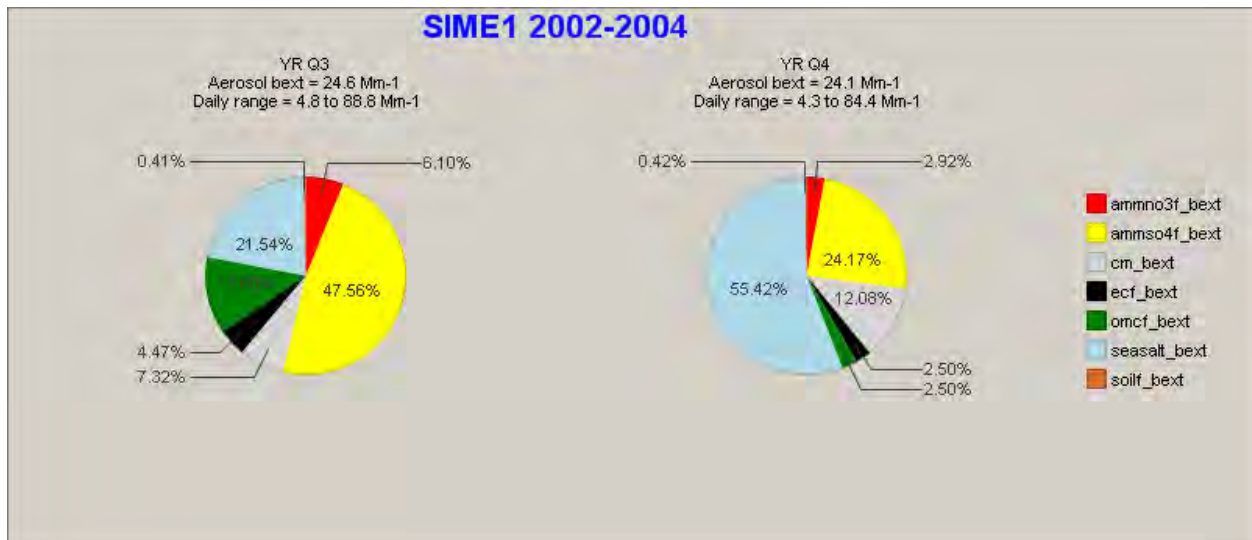
Note: Quarters 1, 2, 3, &4 are denoted on charts as YR Q1 (or 2,3,4). Total extinction for each quarter is indicated as Aerosol bext. Although aerosol proportions vary with calendar quarter, total extinction and average daily ranges vary less.

III.K.4-27

Figure III.K.4-11
2002-2005 Proportional Representation of Aerosol Species at Simeonof
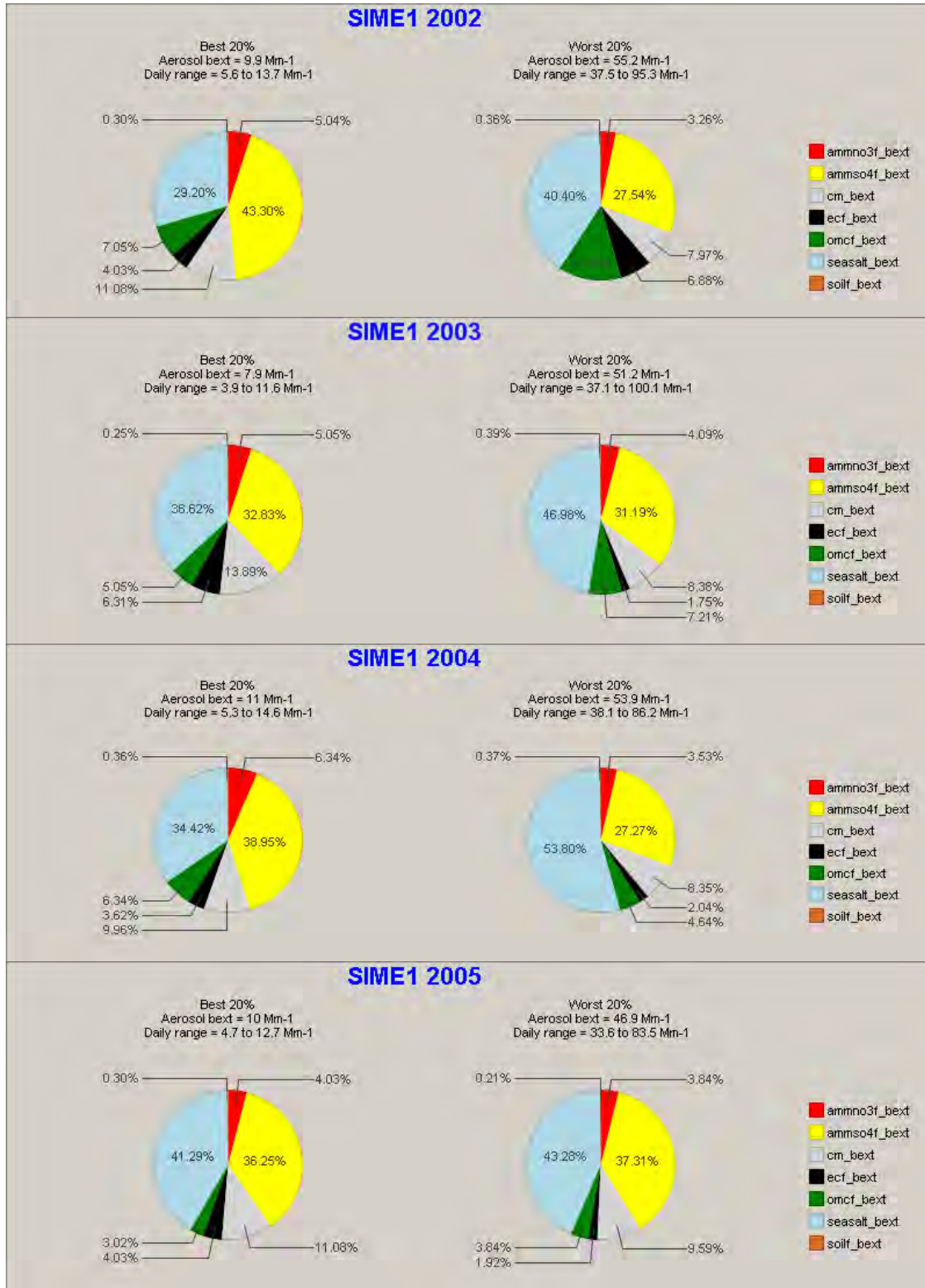
Figure III.K.4-12
2002-2005 Proportional Representation of Aerosol Species Excluding Sea Salt, at Simeonof
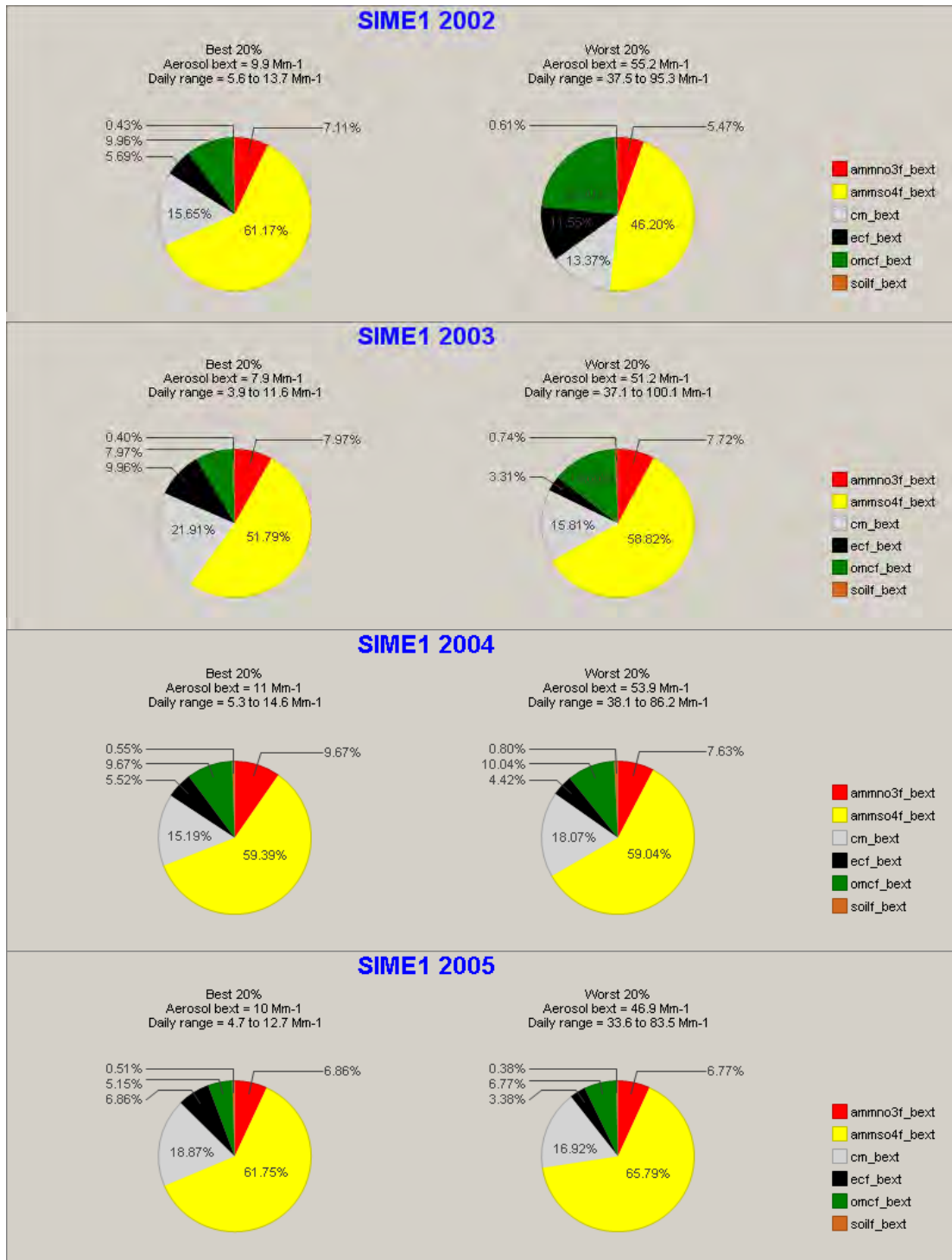
d. Daily and Seasonal Variation in Light Extinction Due to IMPROVE Aerosol Species

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
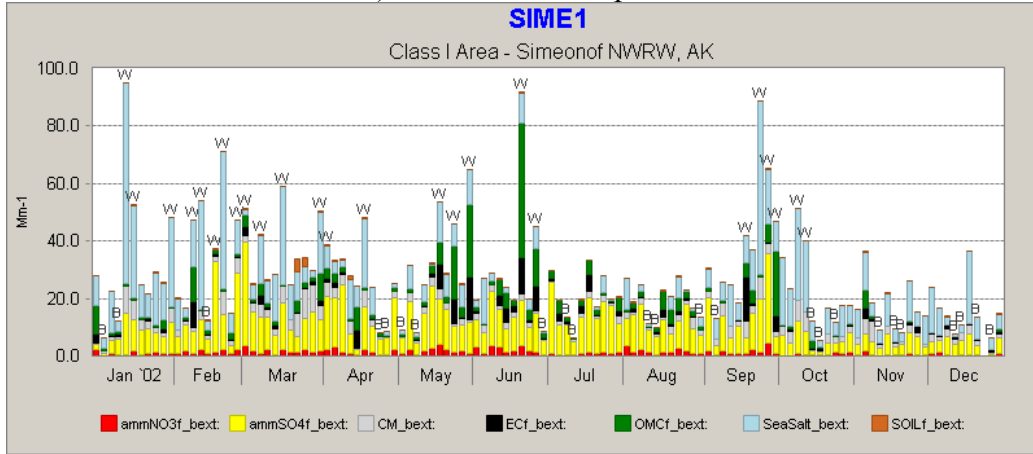
b) Excluding Sea Salt
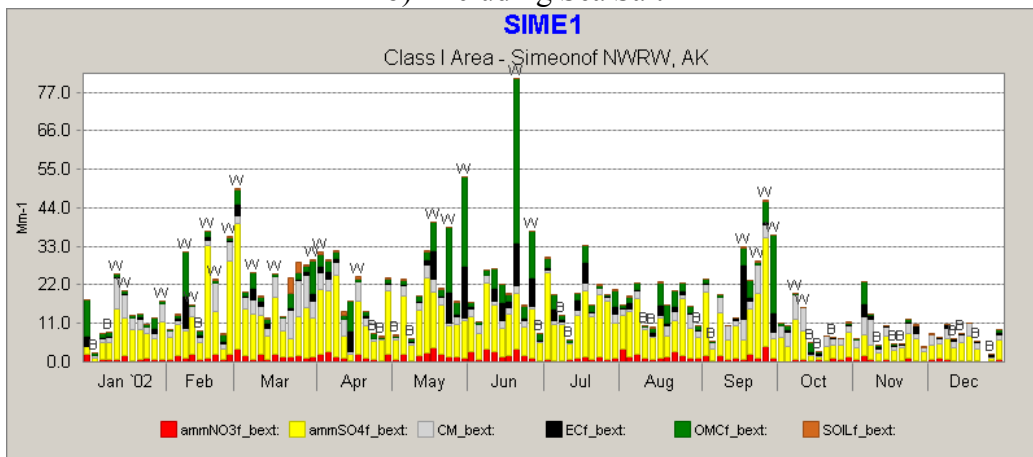
c) Excluding Sea Salt, Organic Matter Carbon, and Coarse Matter
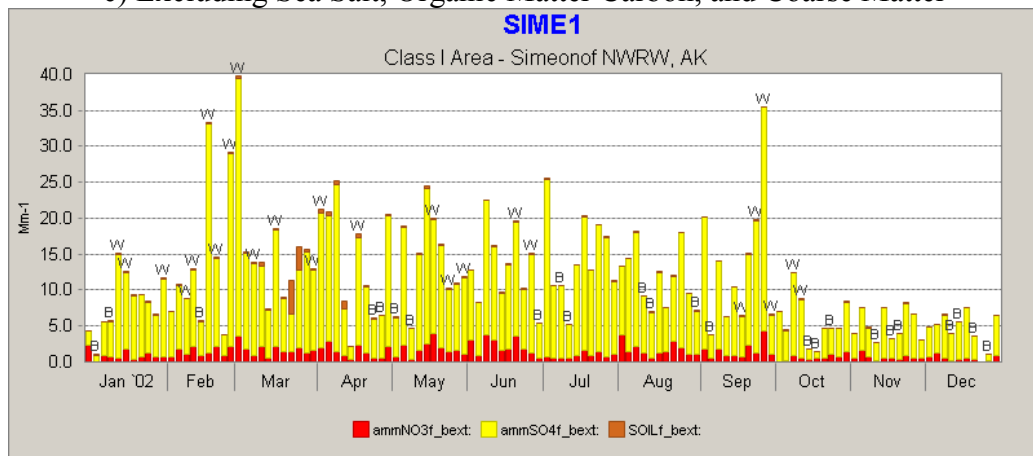
Note: Stepwise removal of species not under human control in Alaska.

Figure III.K.4-14
2002 IMPROVE Species Contributions to Visibility Impairment by Sampling Day, at Simeonof
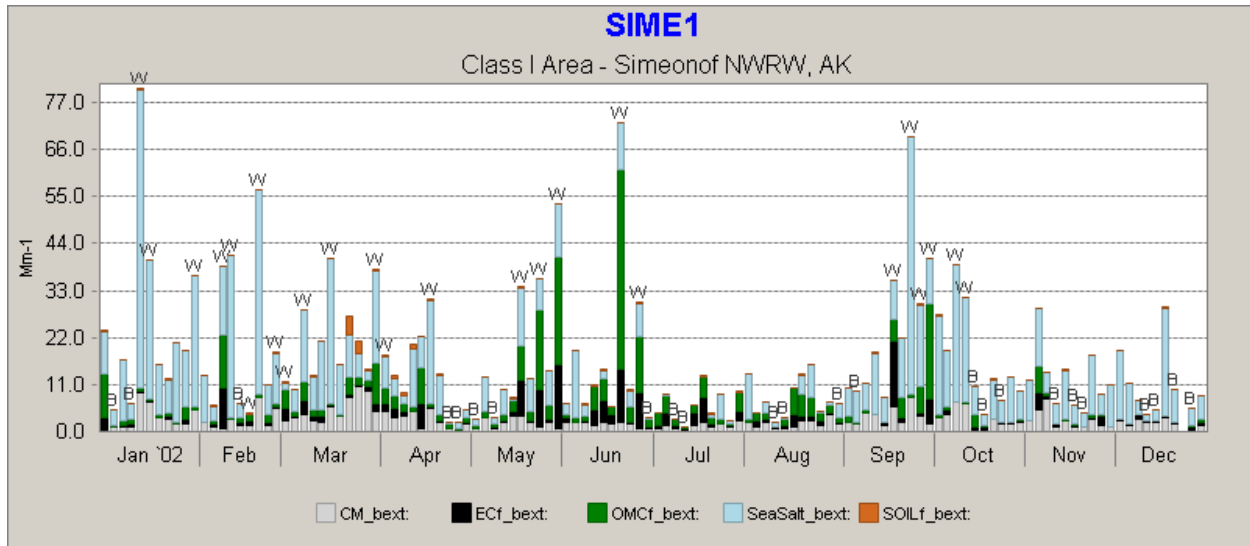
Note: Only aerosol species largely out of human control are included: Coarse mass, Elemental carbon, organic matter carbon, and sea salt.

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
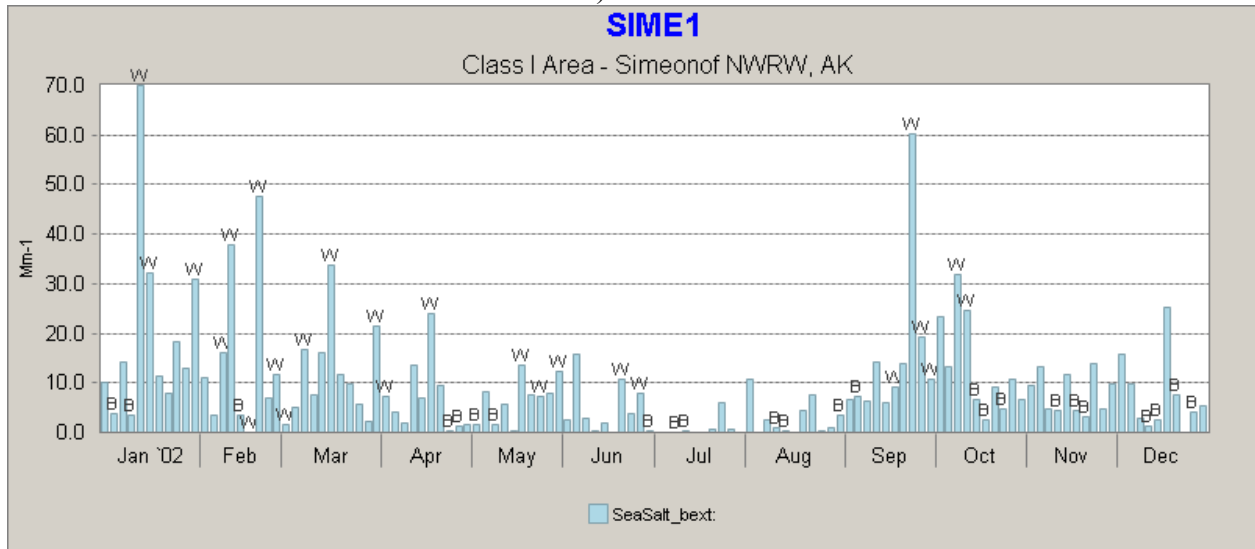
b) 2002-2005
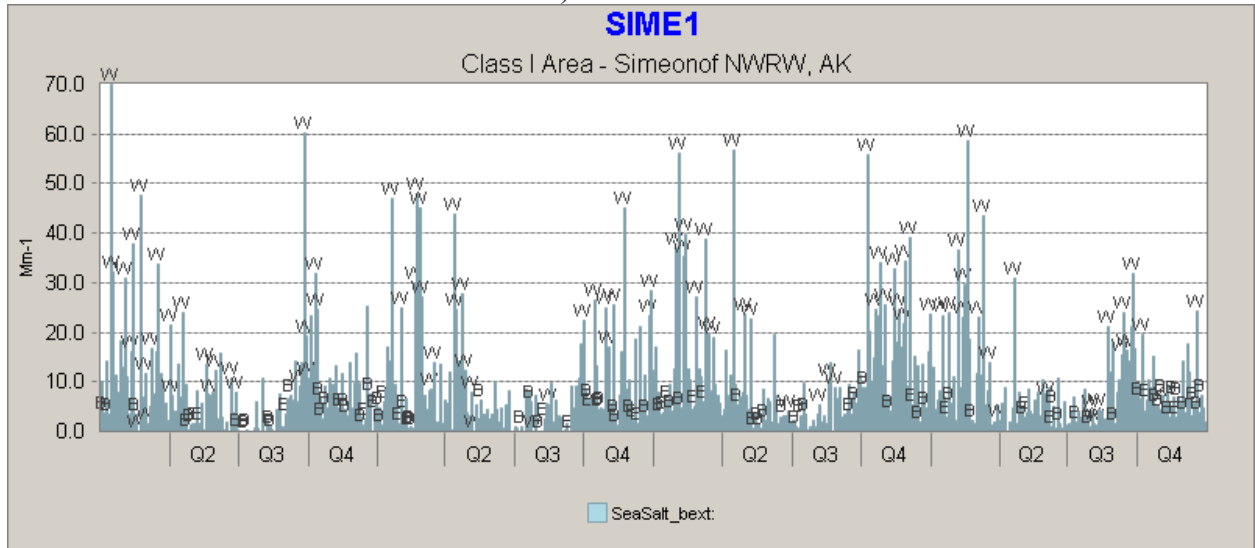
Sulfate: Sulfate is clearly correlated with impaired visibility at Simeonof (r=.65; Figure III.K.4-16). However, there is considerable variability, and sulfate is not the only factor affecting the worst days. Sulfate episodes may be tied to oceanic emissions; if so, correlations with sea surface temperatures 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
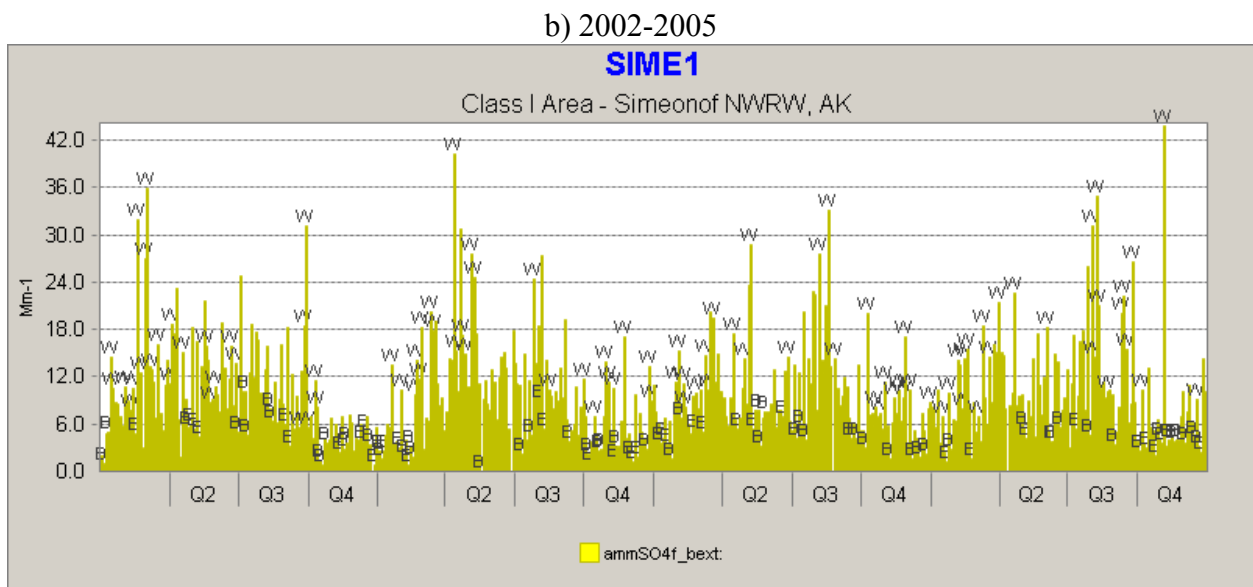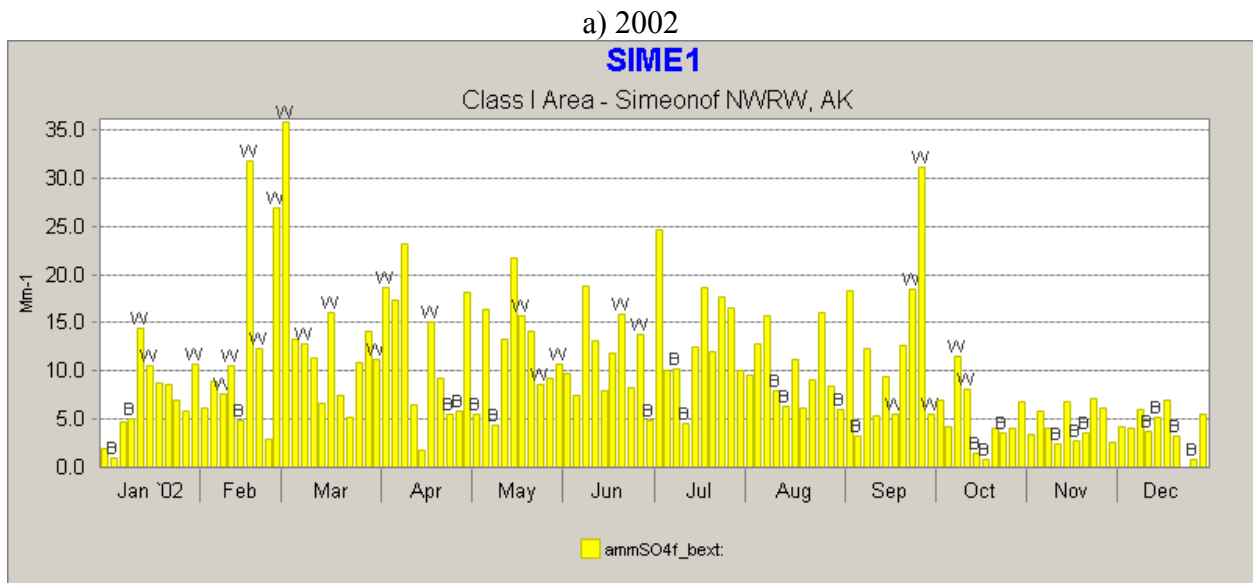
b) 2002-2005

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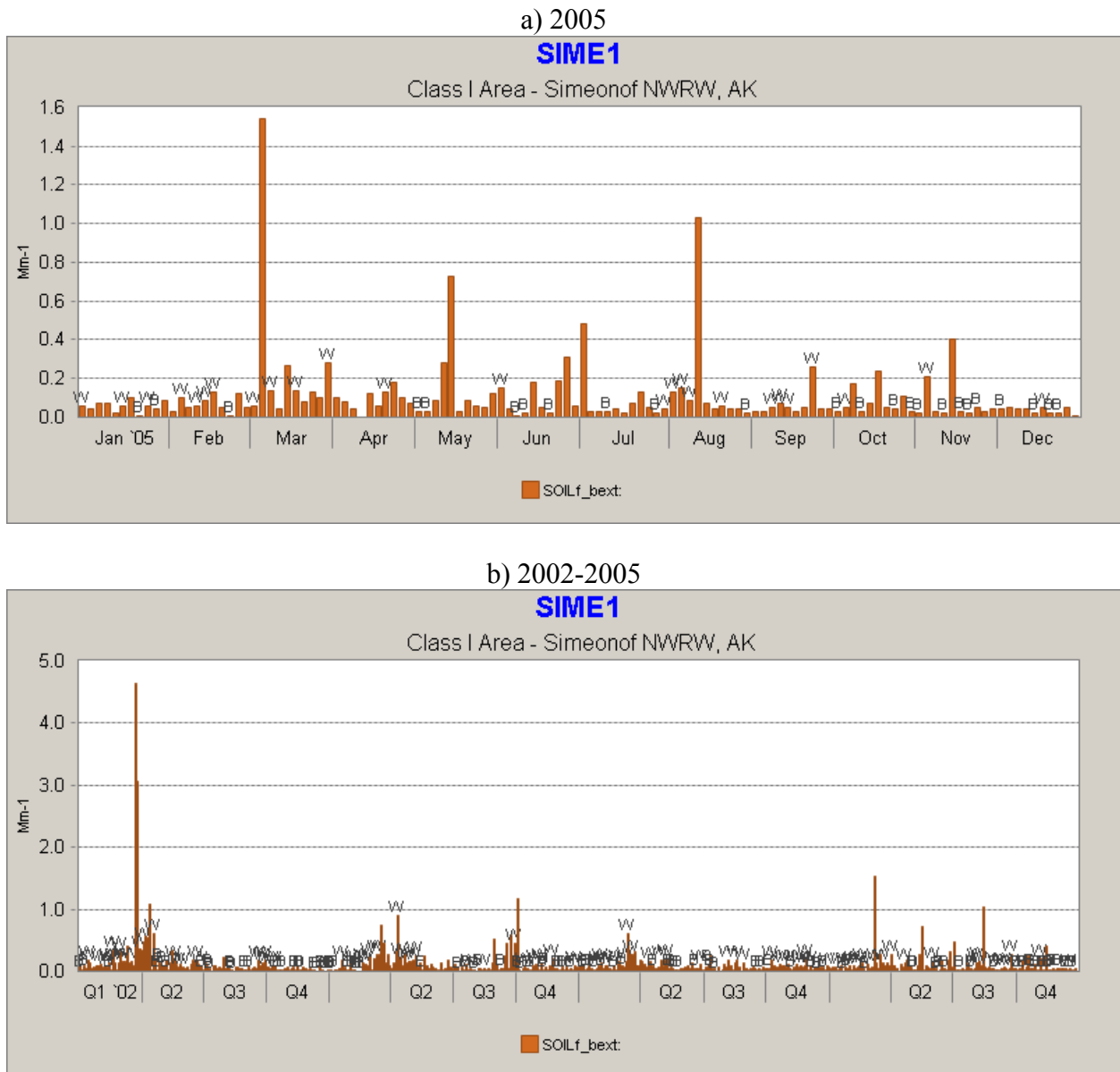
Nitrate: At Simeonof, most worst days have higher nitrate extinction (r=.55). However, extinctions due to nitrate rarely exceed 5 Mm^{-1}, while on most worst days extinction exceeds 40 Mm^{-1}. Quarter 4 may be lower statistically but not in all years (Figure III.K.4-18). Nitrates in Alaska are typically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

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

a) 2002

b) 2002-2005
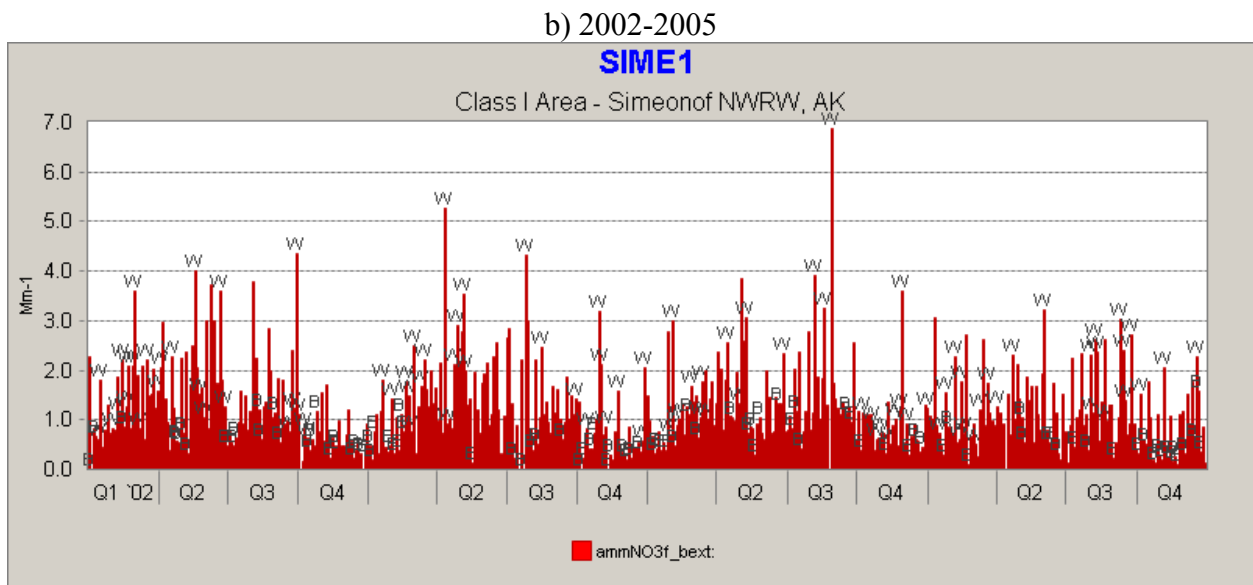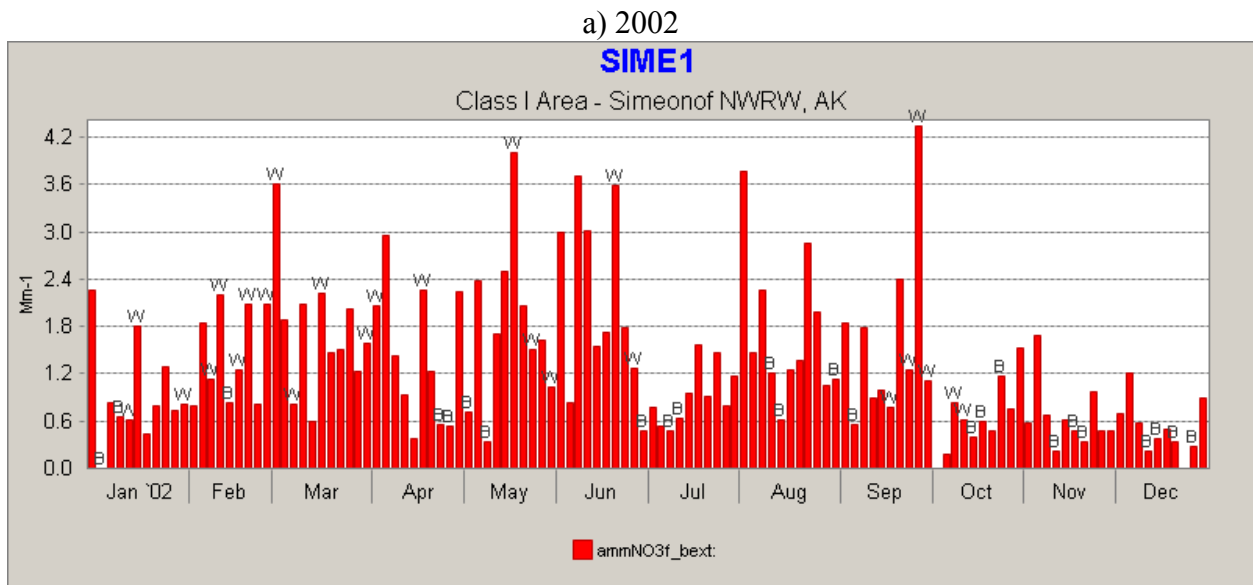
Coarse Mass: At Simeonof, most worst days have higher coarse mass (r=.60). Seasonal patterns vary, but Quarters 2&3 are typically lower (Figure III.K.4-19). Coarse mass histograms do not clearly separate best and worst days.

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

a) 2002

b) 2002-2005
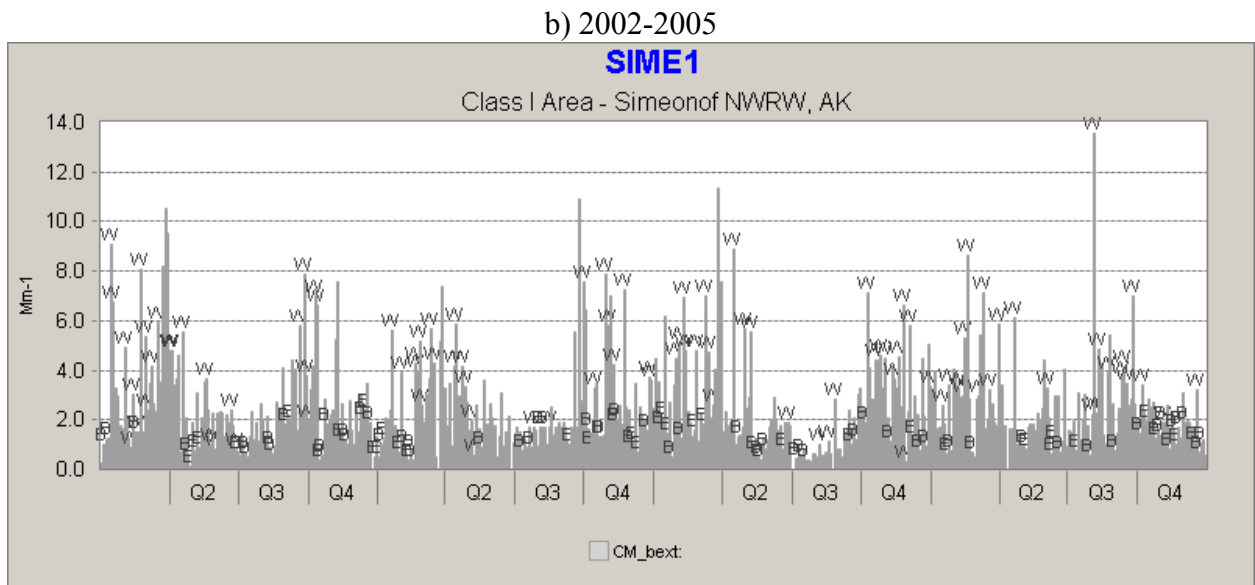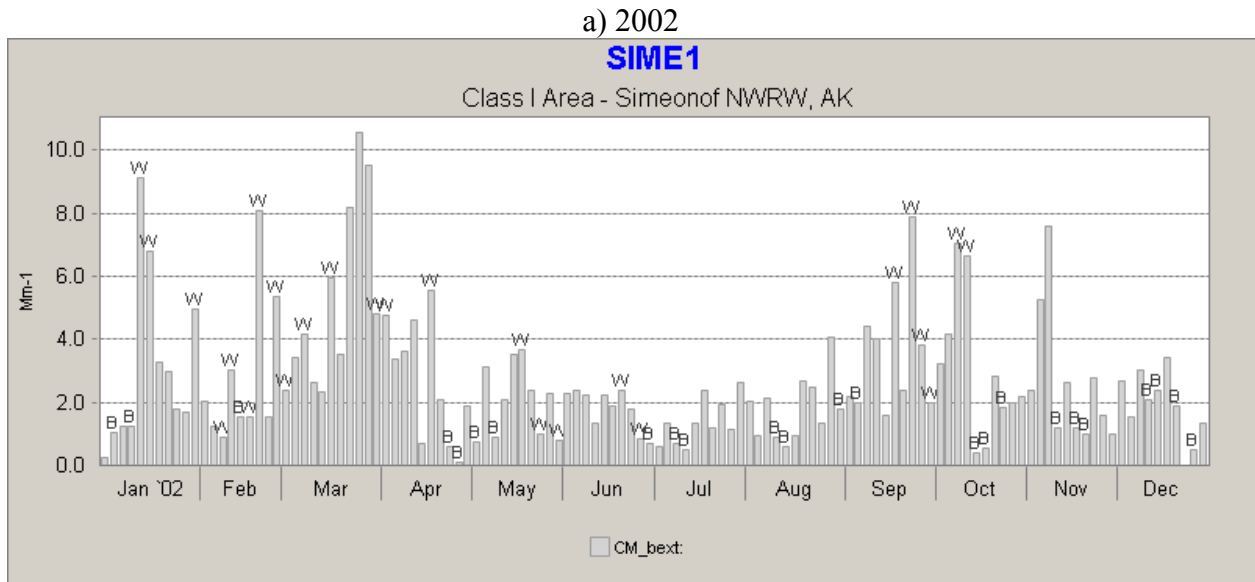
Elemental Carbon: Elemental carbon is highly episodic and highly variable from year to year. It is not correlated with overall extinction (r=.22) (Figure III.K.4-20). Elemental carbon tends to be higher during growing seasons, but does not occur only then. Many worst days lack elemental carbon. Both 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
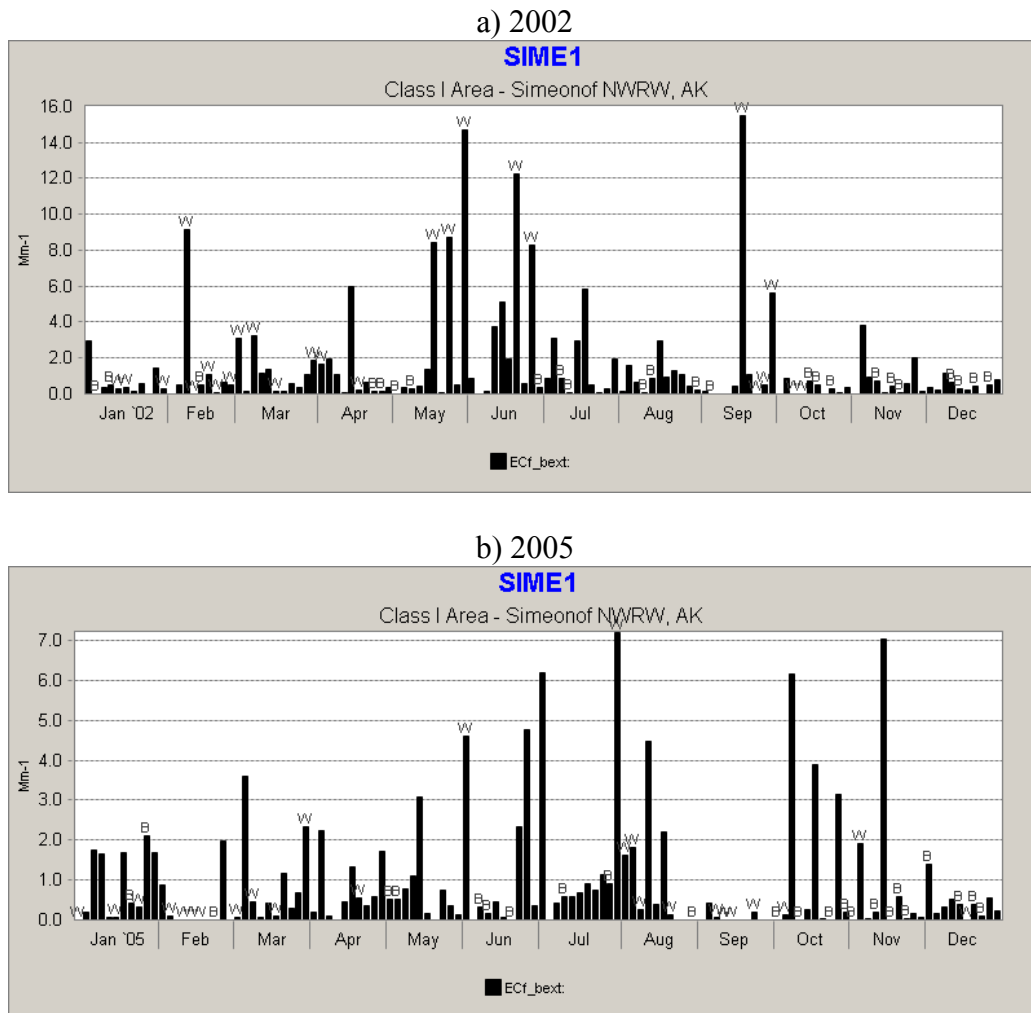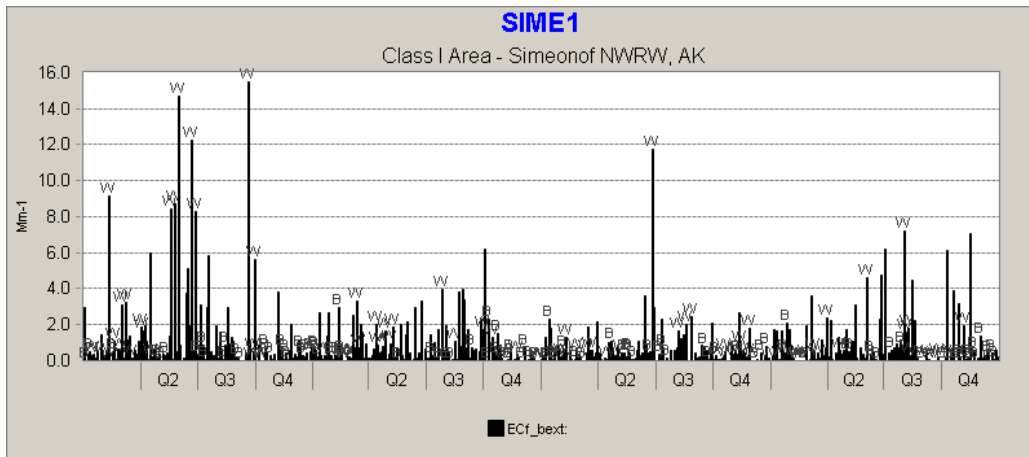
Organic Matter: Organic matter carbon is highly episodic, highly variable from year to year, and not strongly correlated with overall extinction (r=.36). It tends to be higher during growing seasons and lower in Quarters 4 and 1 (Figure III.K.4-21). Organic matter carbon sometimes drastically affects 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
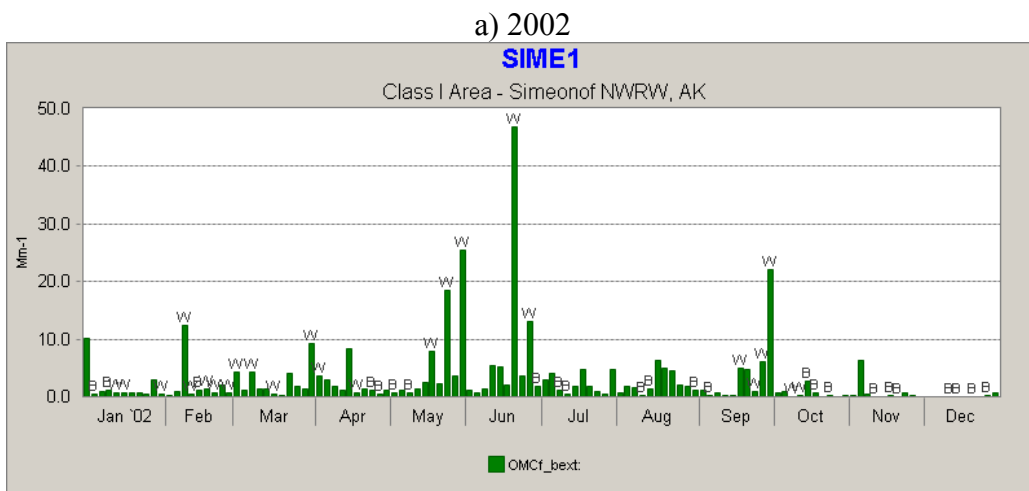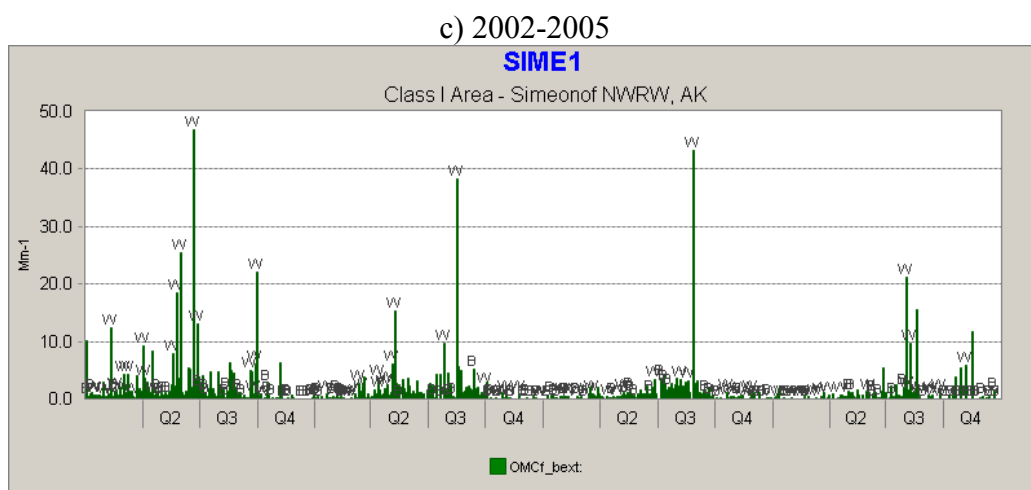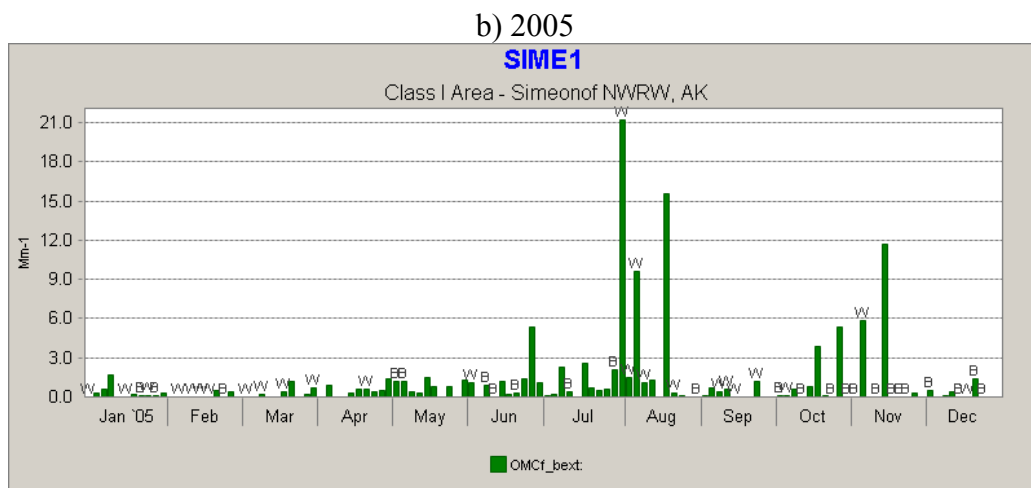
4. Correlations Among Aerosol Species at Simeonof

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:		Correlations on Worst Days:	
0.66	**NO3 SO4**	**0.58**	**NO3 SO4**
-0.03	CM EC	-0.43	CM EC
0.60	**EC OMC**	**0.58**	**EC OMC**
-0.08	CM OMC	**-0.50**	**CM OMC**
0.27	SO4 CM	-0.12	SO4 CM
0.24	NO3 CM	-0.23	NO3 CM
0.61	**SS CM**	**0.66**	**SS CM**
0.18	SS NO3	0.21	SS NO3
0.26	SS SO4	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
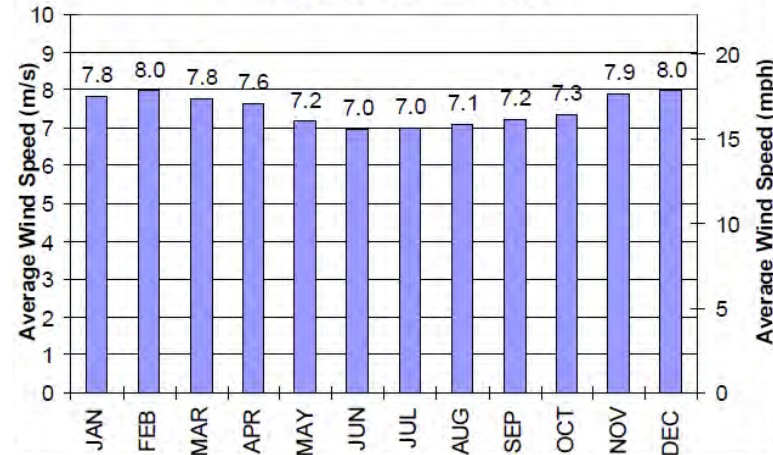
Note: Monthly average wind speeds. Summer months have lower average wind speeds.

b) Wind Speed Distribution Rose (m/s)
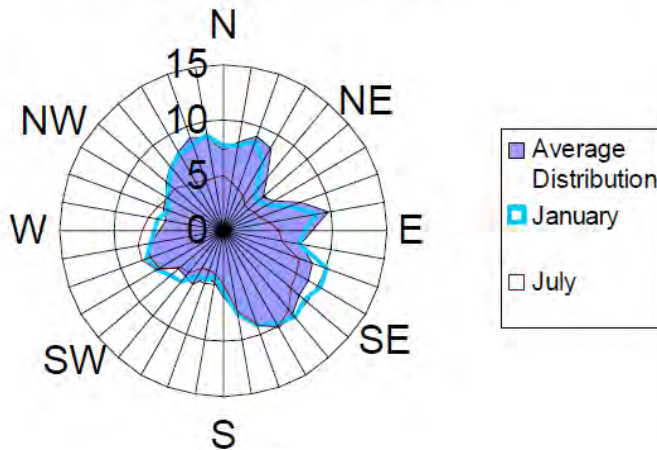
Note: Annual patterns of wind direction and speed. Northerly and easterly winds are typically milder in summer months.

c) Wind Frequency Distribution Rose (% of Time)
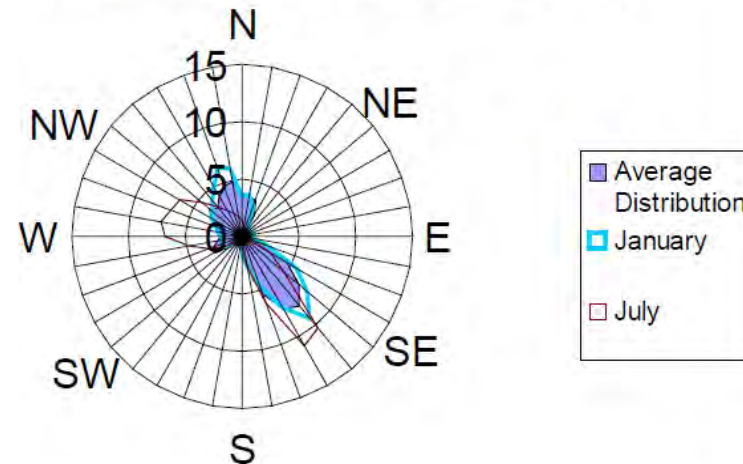
Note: Annual frequencies of wind direction. Northwesterly winds are more frequent in summer

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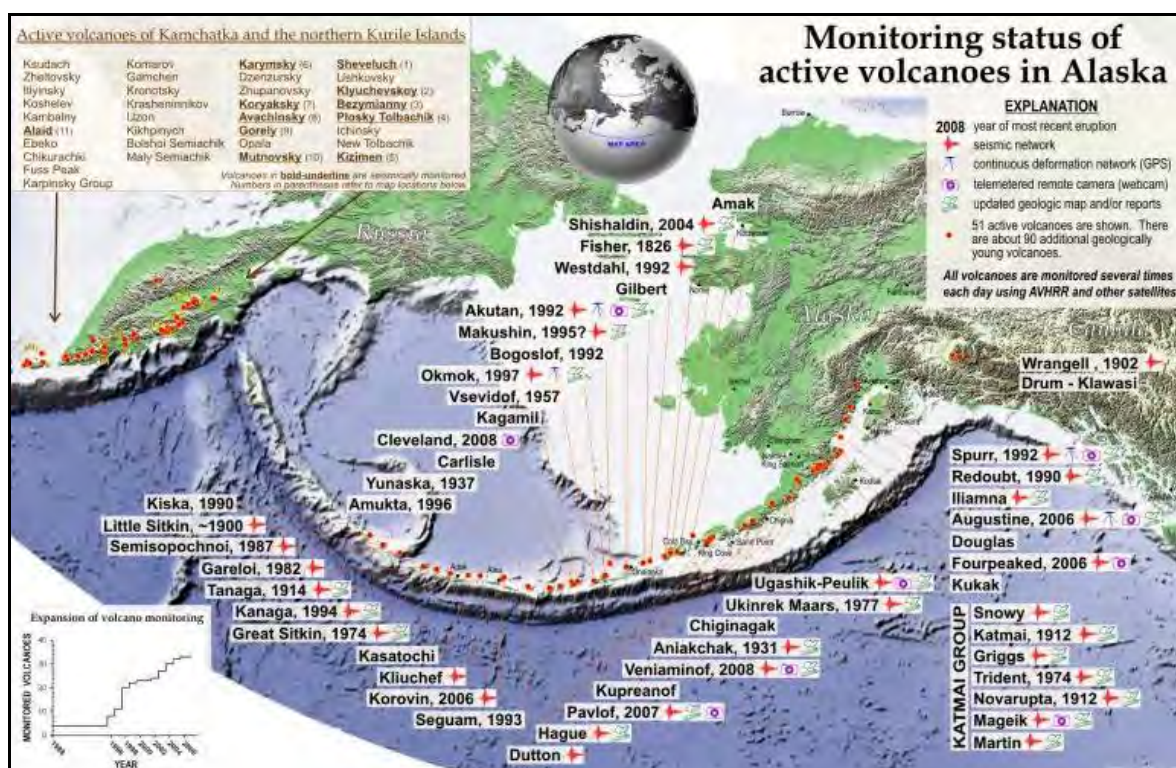
To determine whether elevated sulfate levels at Simeonof are related to volcanic activity, the following were examined:

- 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
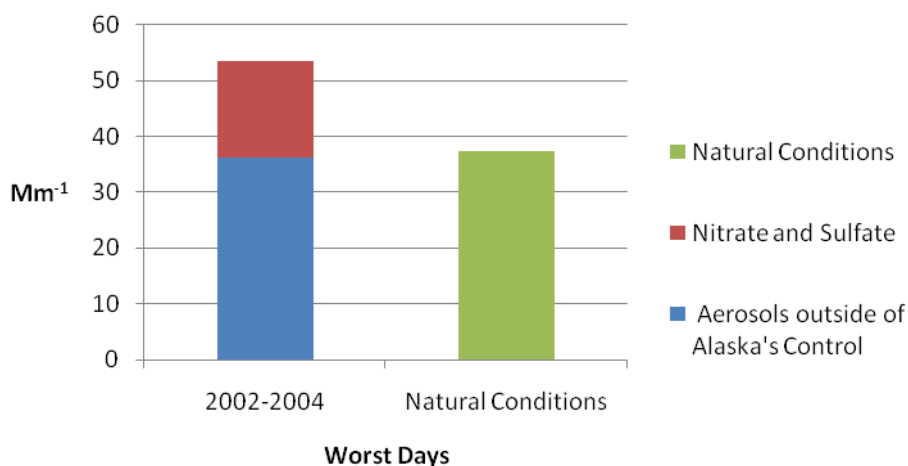
C. Denali National Park

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
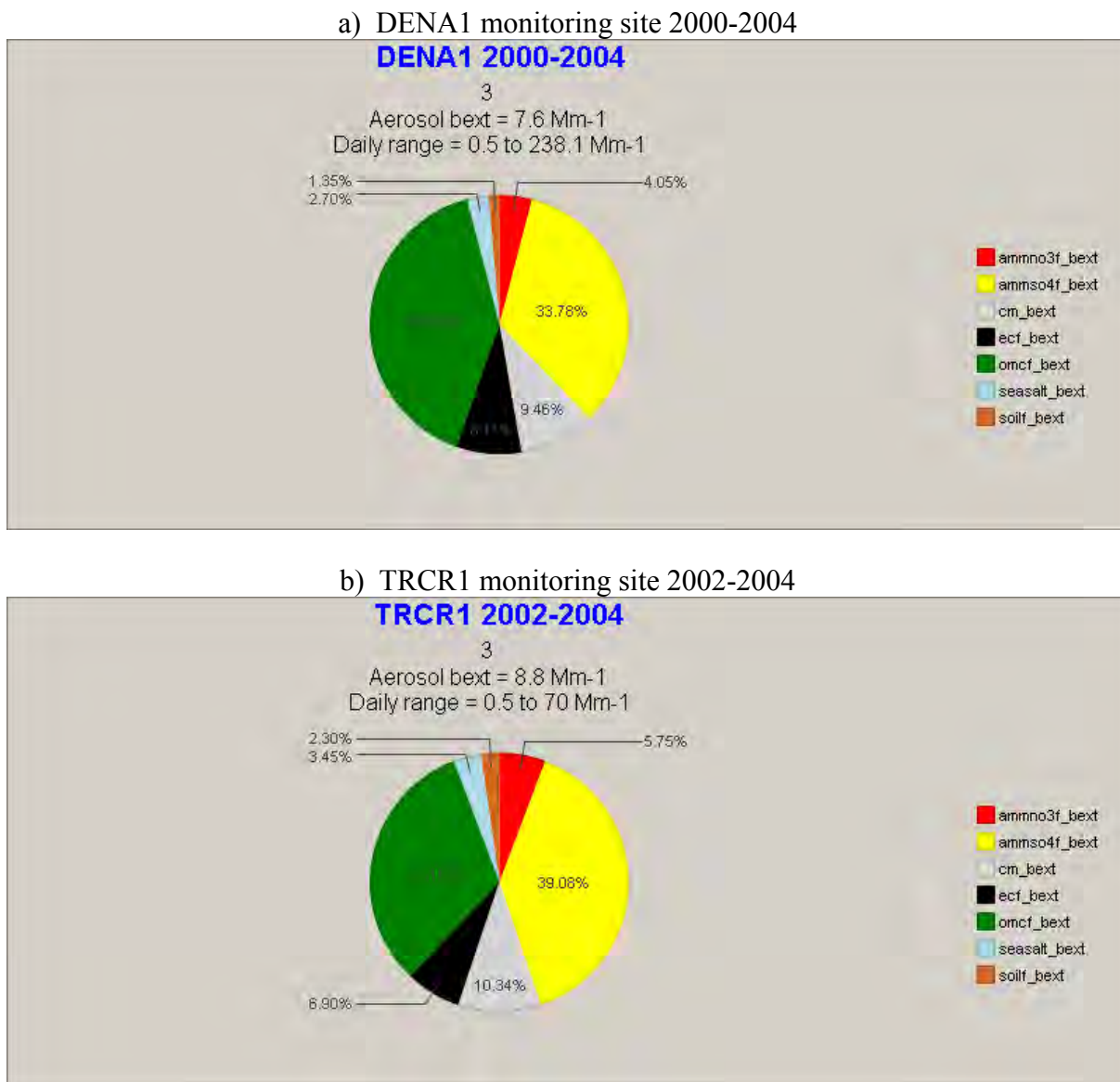
a) DENA1 monitoring site 2000-2004

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.

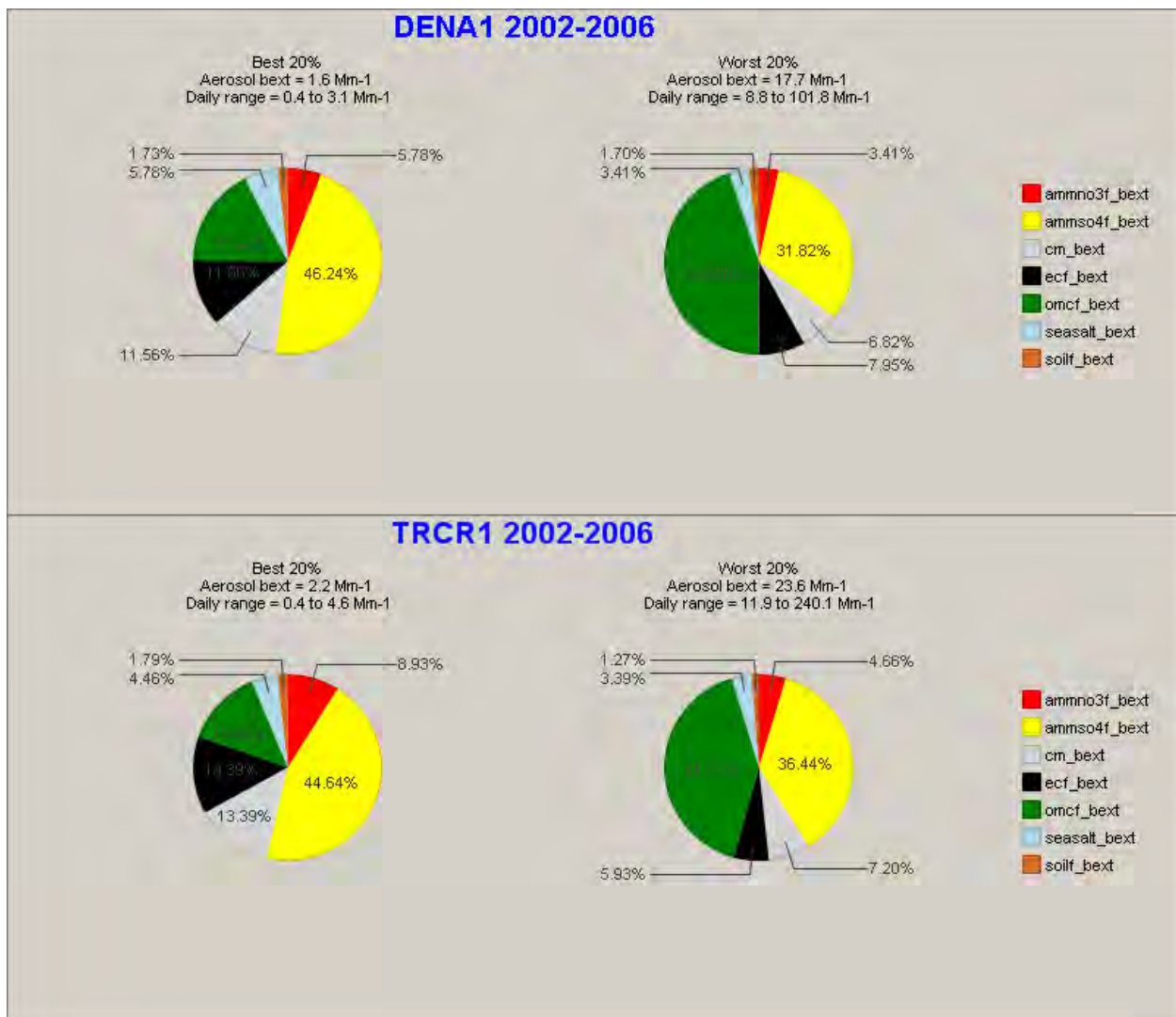**Figure III.K.4-26**
Proportional Representation of IMPROVE Aerosols on Best and Worst Days at Denali, Baseline Years
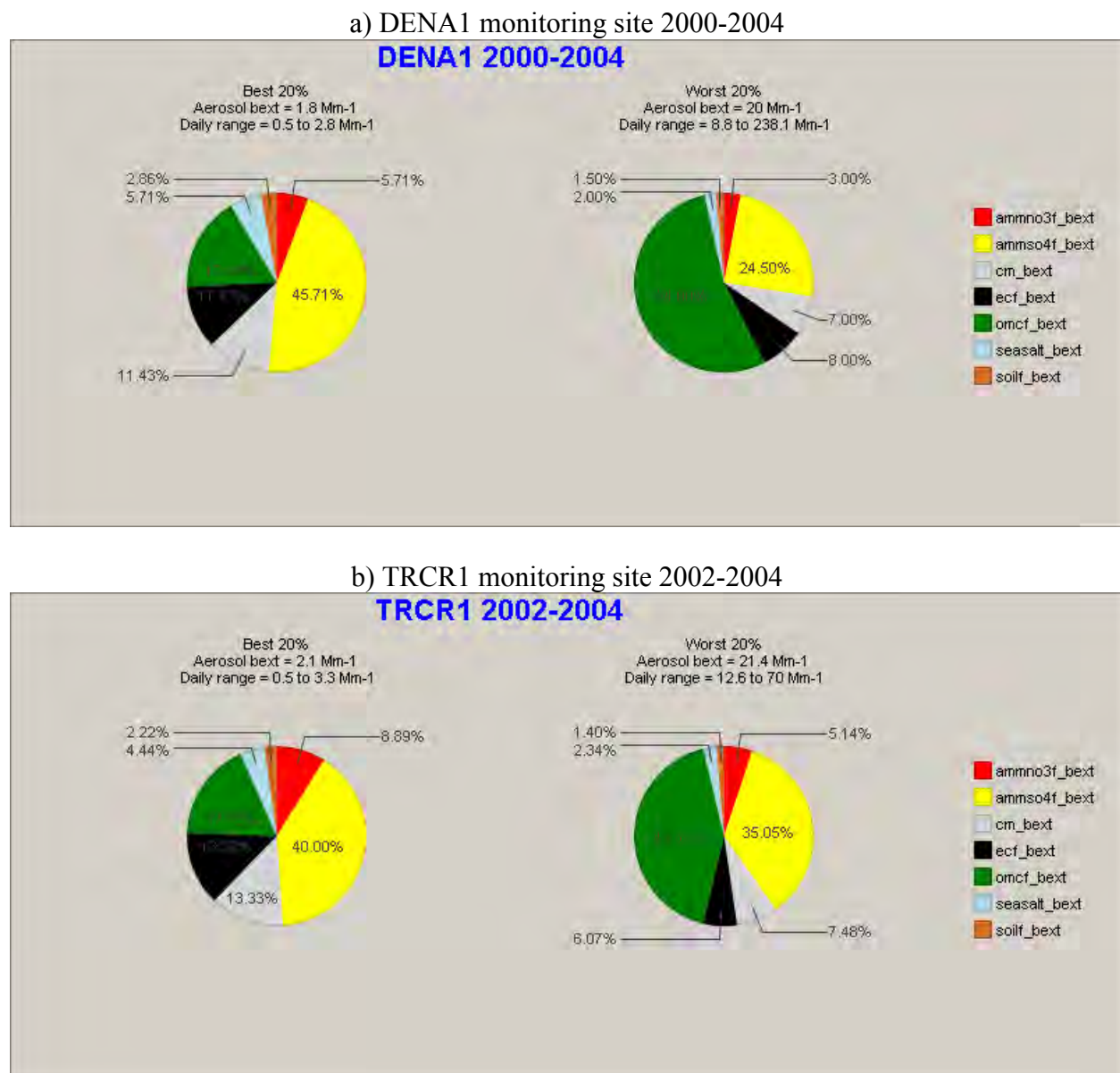
a) DENA1 monitoring site 2000-2004

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%
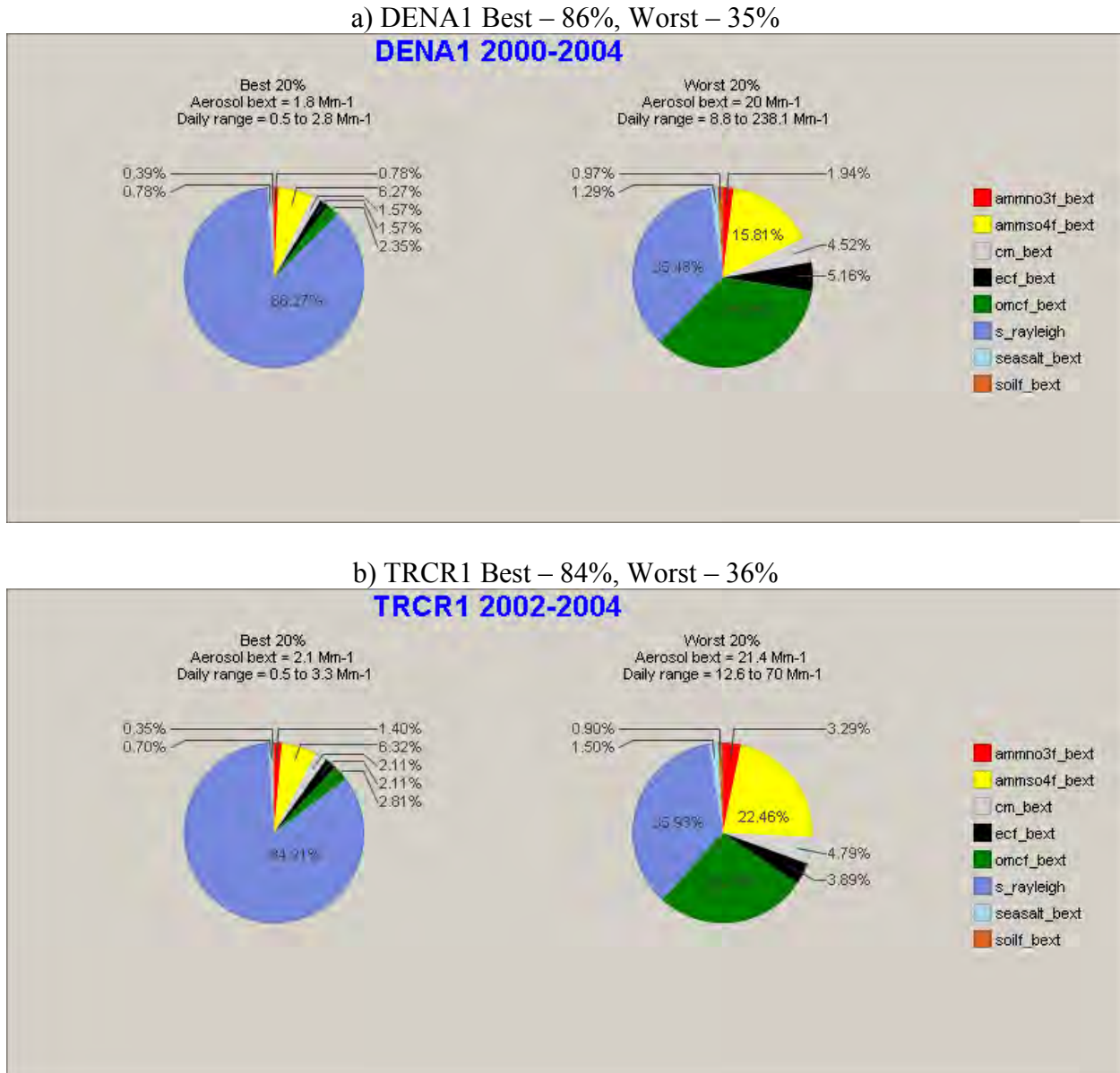
Note: Rayleigh scattering is 12 Mm-1.

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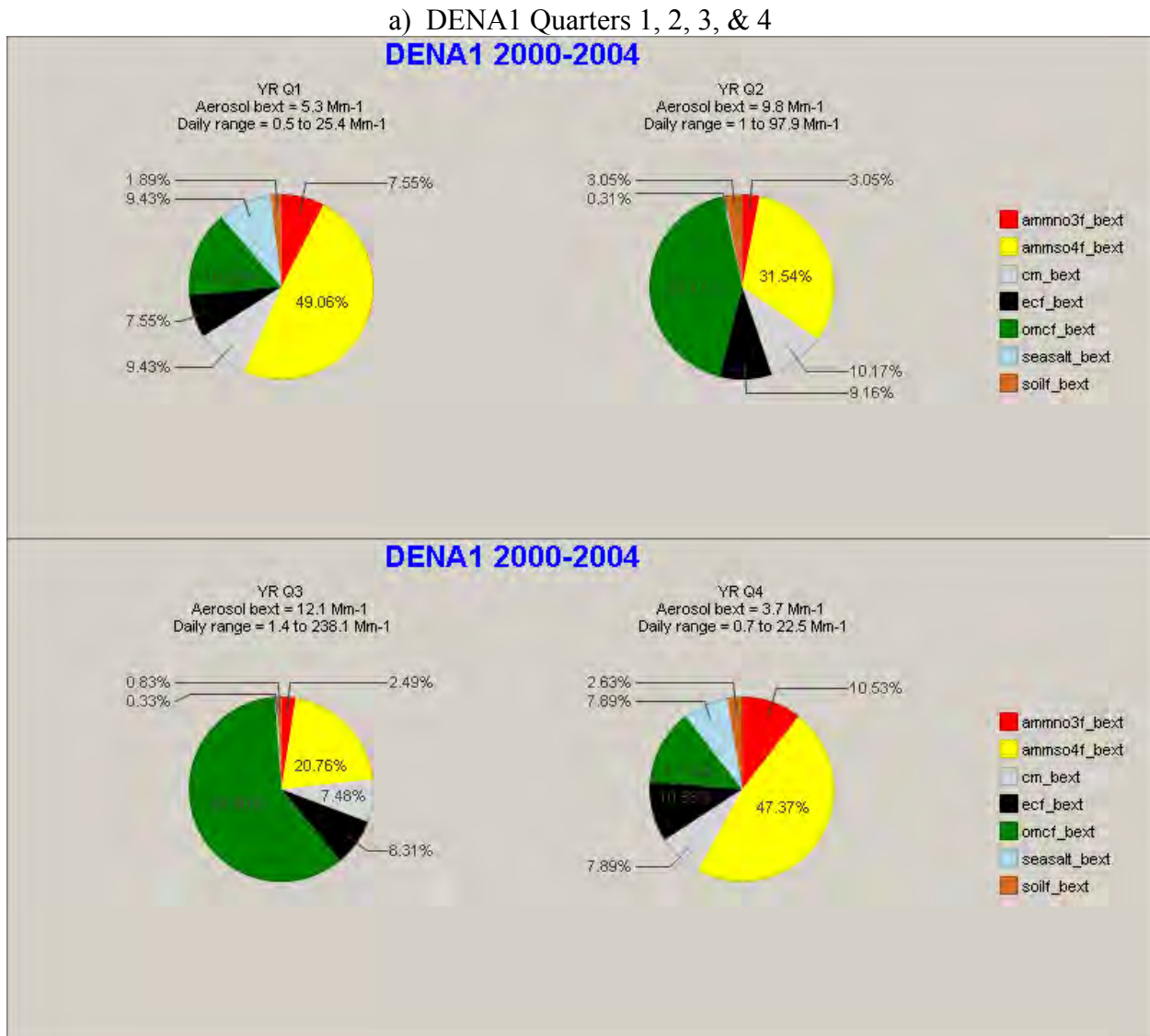
Figure III.K.4-28 (continued)
Proportional Representation of IMPROVE Aerosols for Days of Each Calendar Quarter at Denali, Baseline Years

b) TRCR1 Quarters 1, 2, 3 & 4
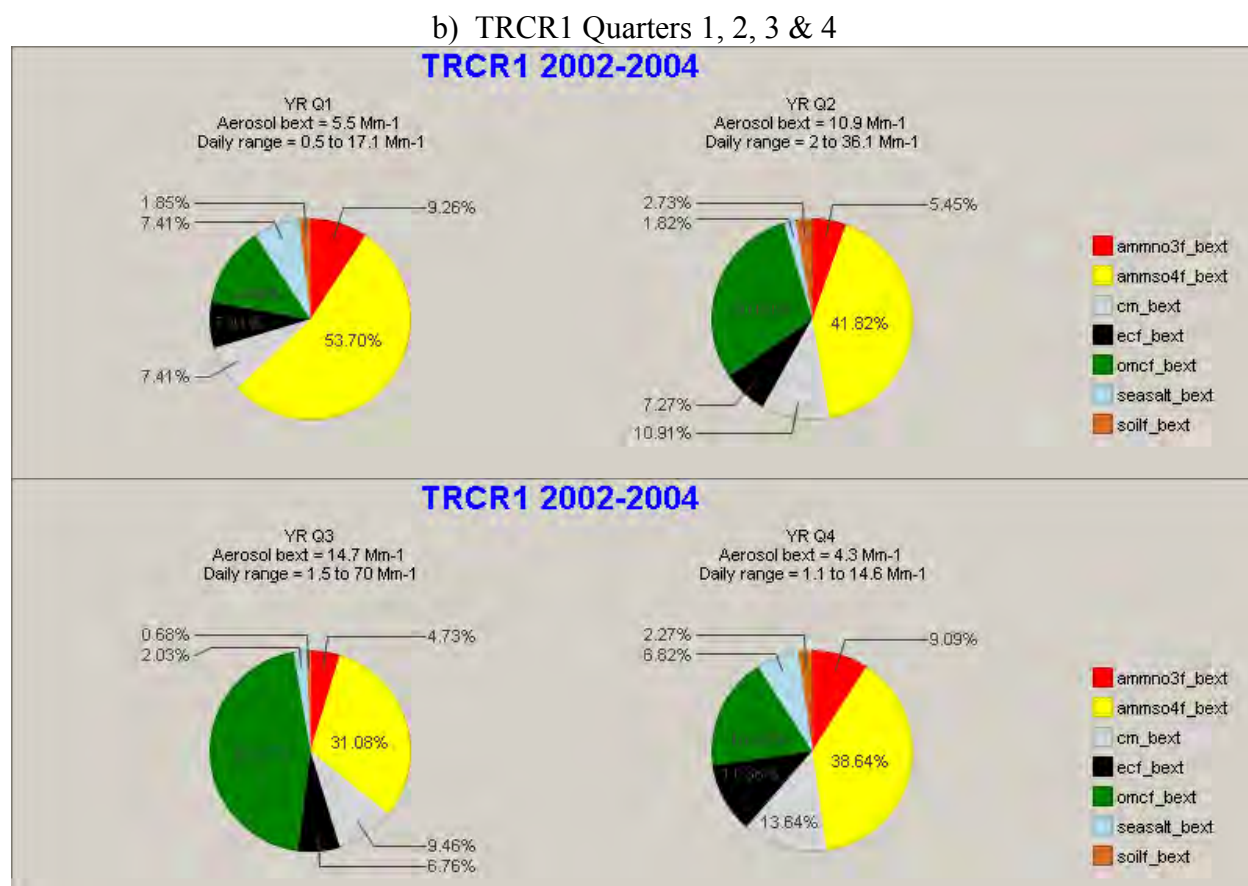
Note: Quarters 1, 2, 3, & 4 denoted on chart as YR Q1, YR Q2, YR Q3, or YR Q4.

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
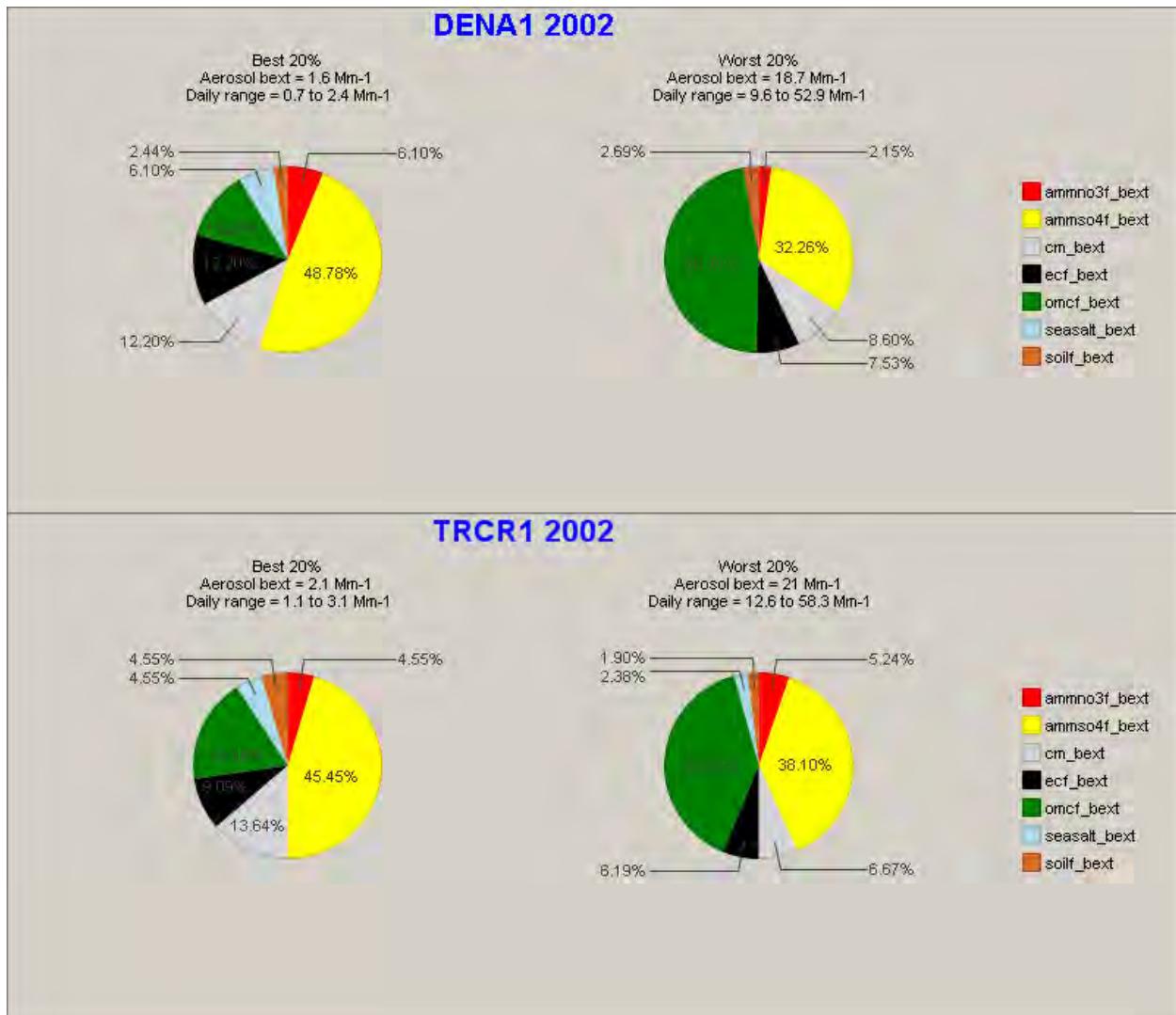
Figure III.K.4-31
2005 Proportional Representation of IMPROVE Aerosols at Denali on Best and Worst Days
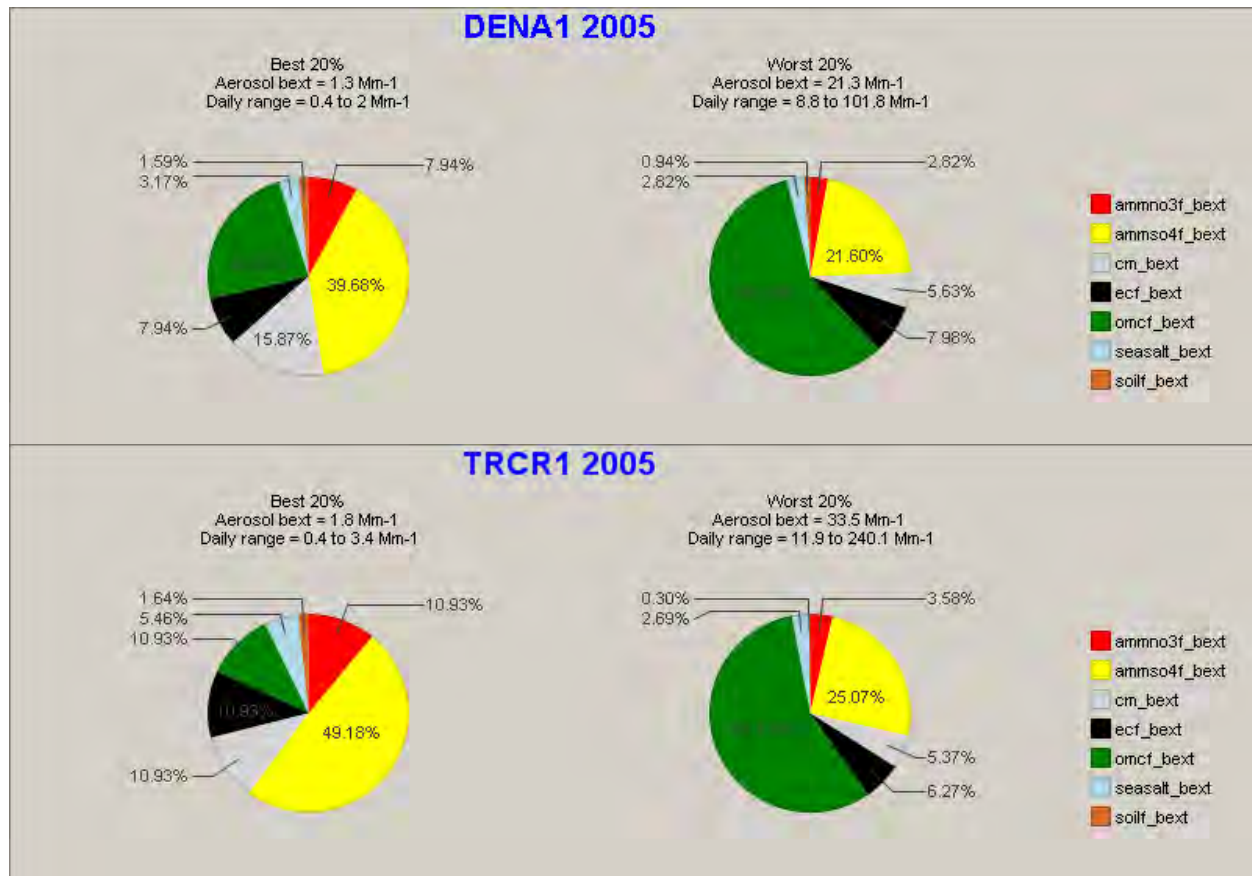
d. Daily, Seasonal, and Annual Variation in Light Extinction Due to IMPROVE Aerosol Species

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
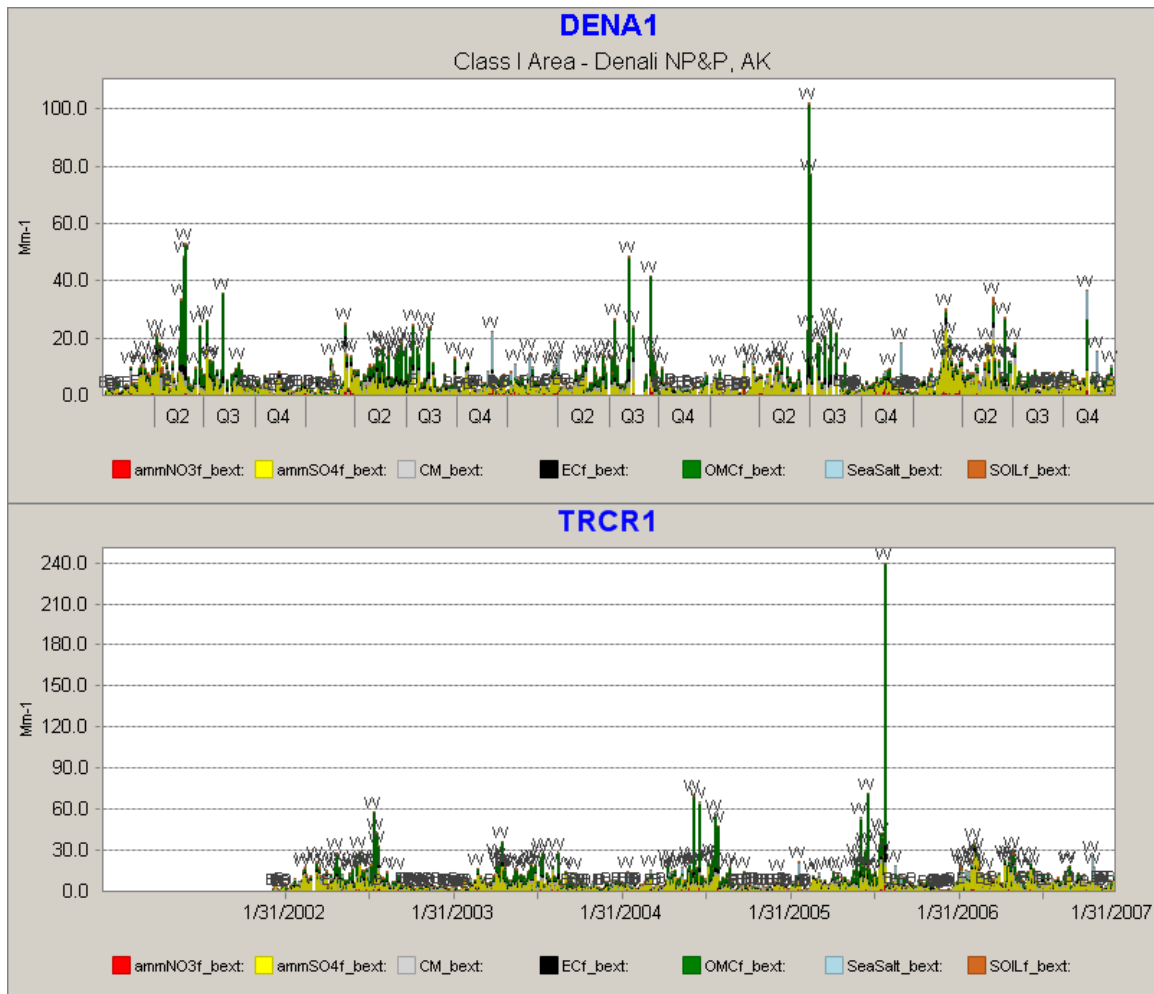
Organic matter carbon contributes heavily to worst days each year (Figure III.K.4-33). The timing and behavior of Alaska wildfires producing organic matter carbon varies year to year. Fires also contribute to worst days in spring and winter. Alaska receives organic matter carbon and elemental carbon 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

Class I Area - Denali NP&P, AK
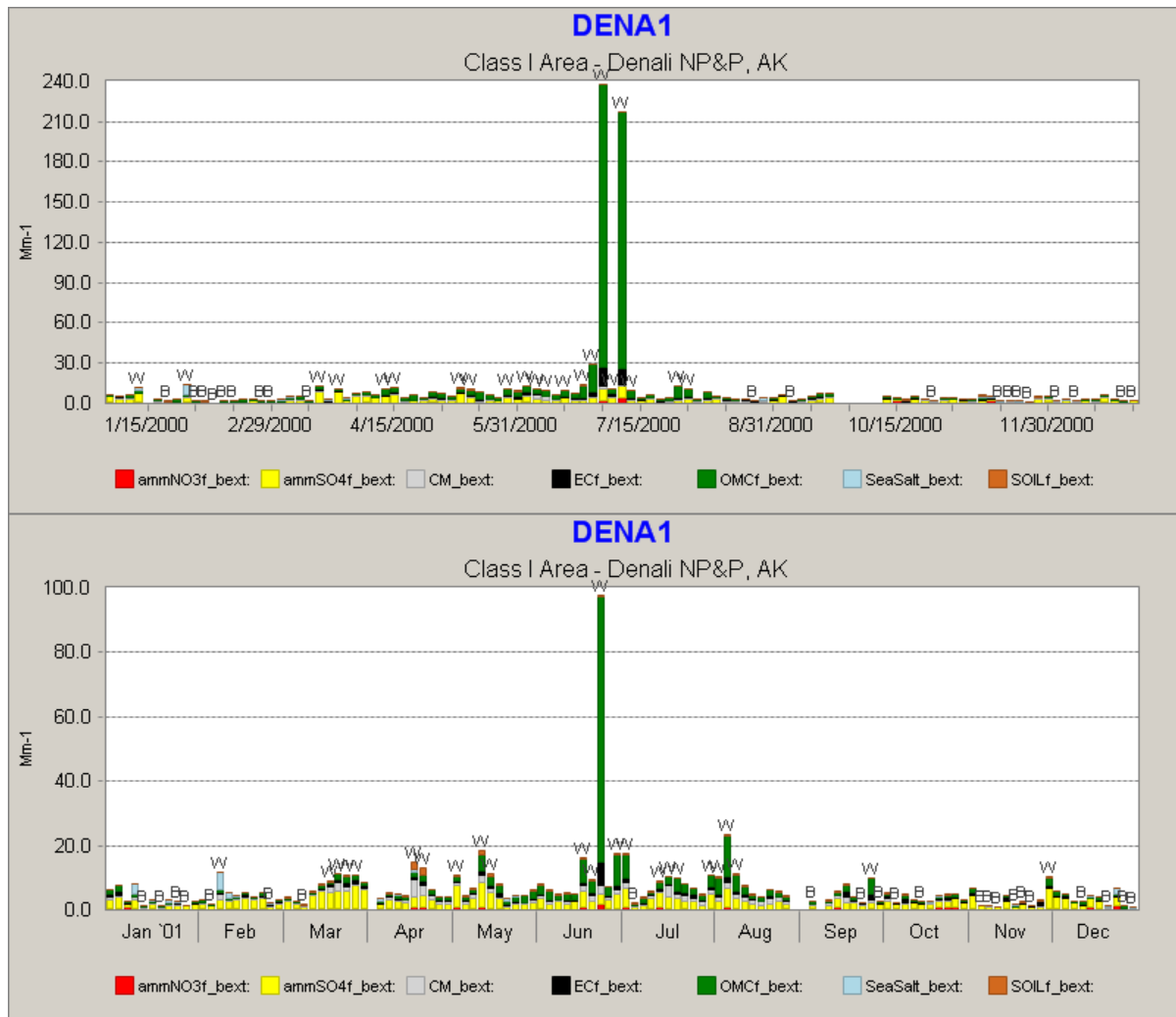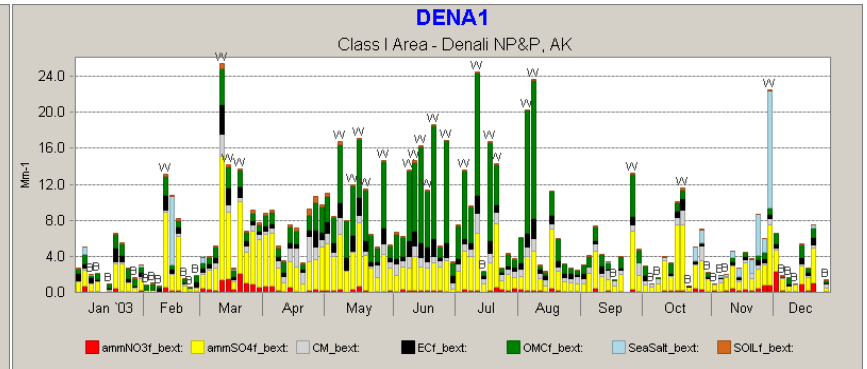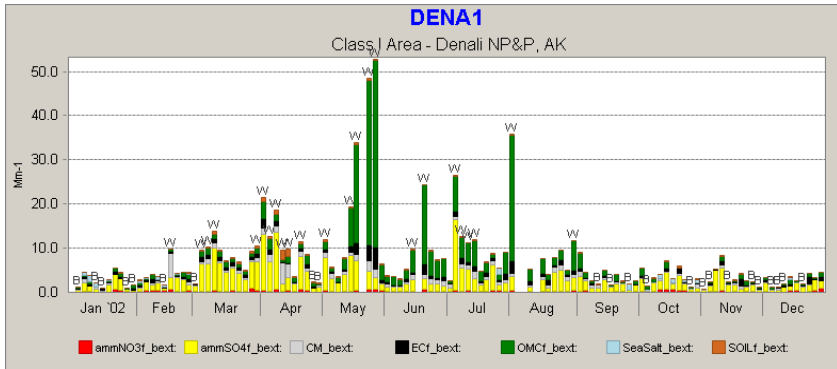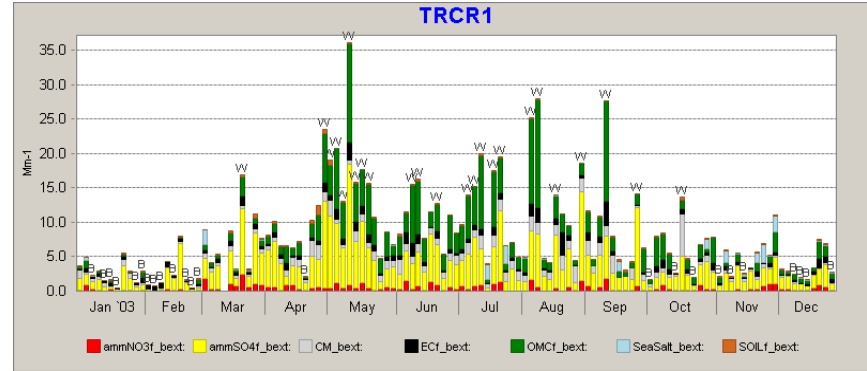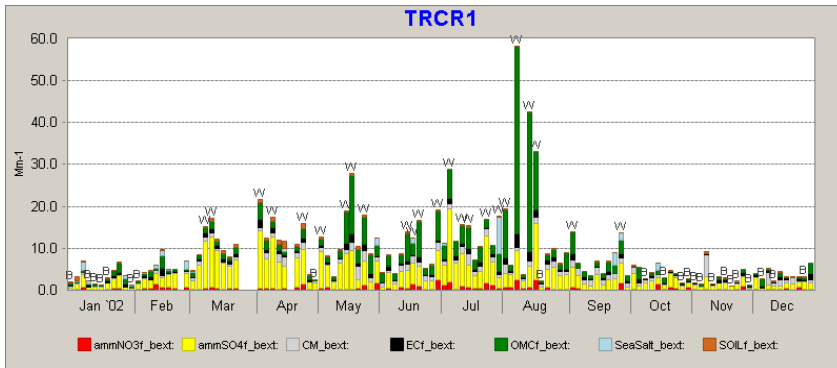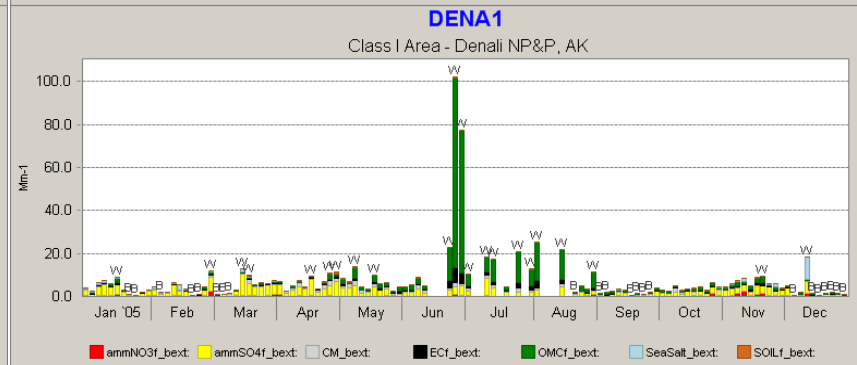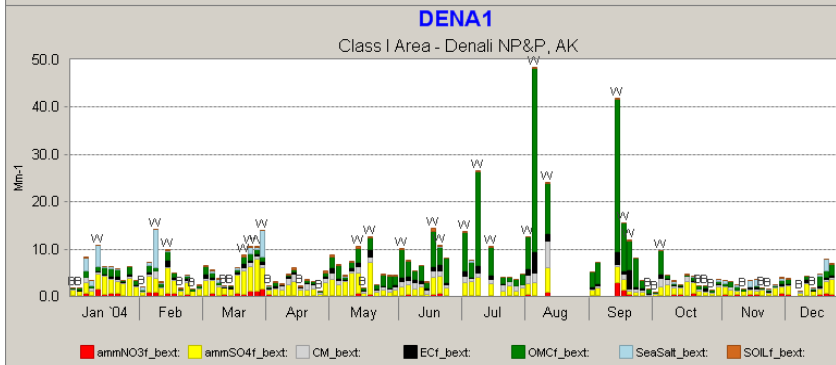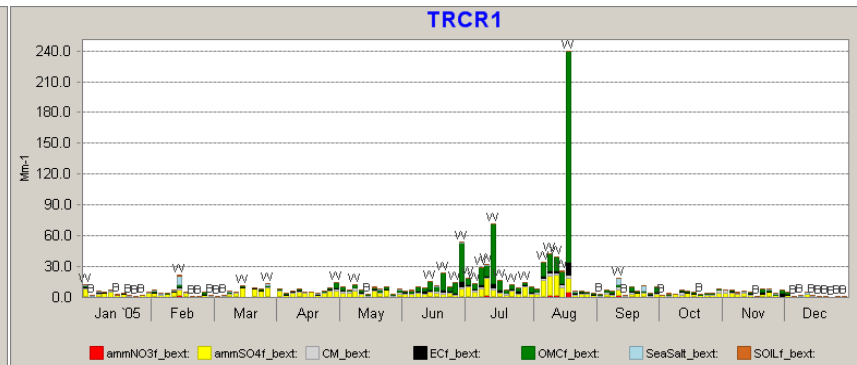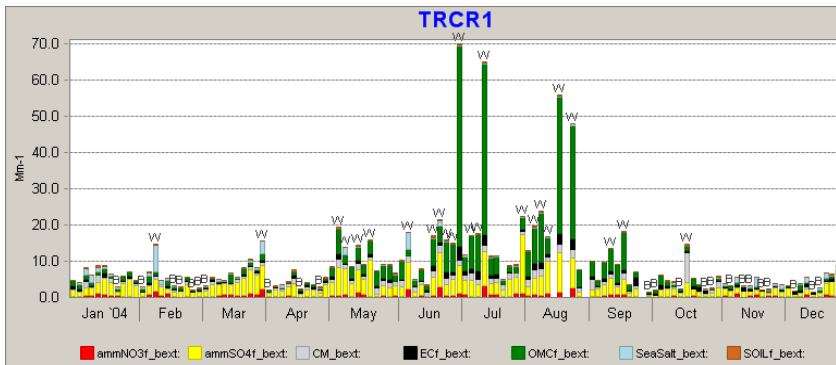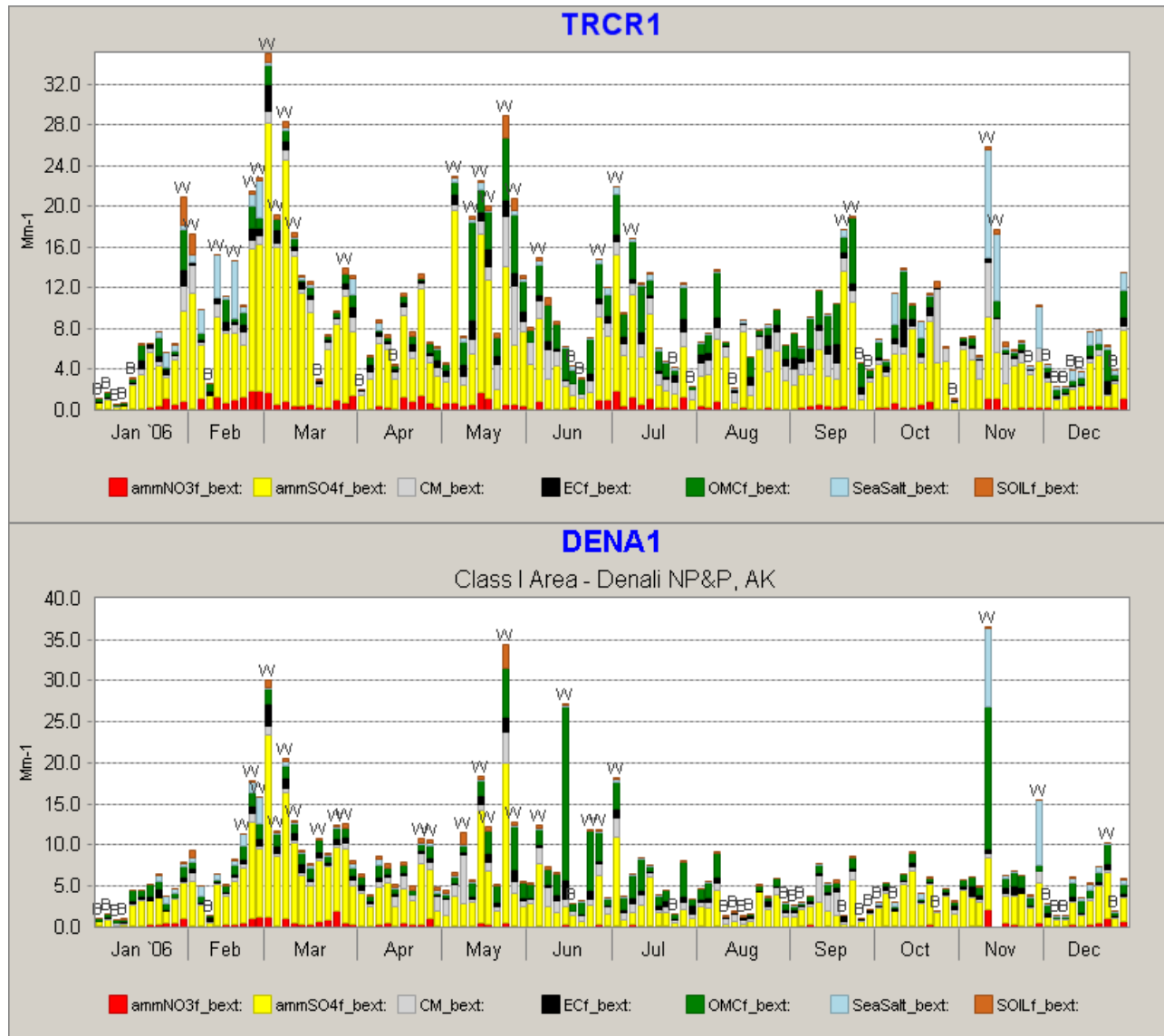
4. Correlations Among IMPROVE Aerosols Monitored at DENA1 and TRCR1

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 ALL DAYS	MASS 2002-2006	TRCR1 ALL DAYS	MASS 2002-2006	DENA1 WORST DAYS	MASS 2002-2006	TRCR1 WORST DAYS	MASS 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
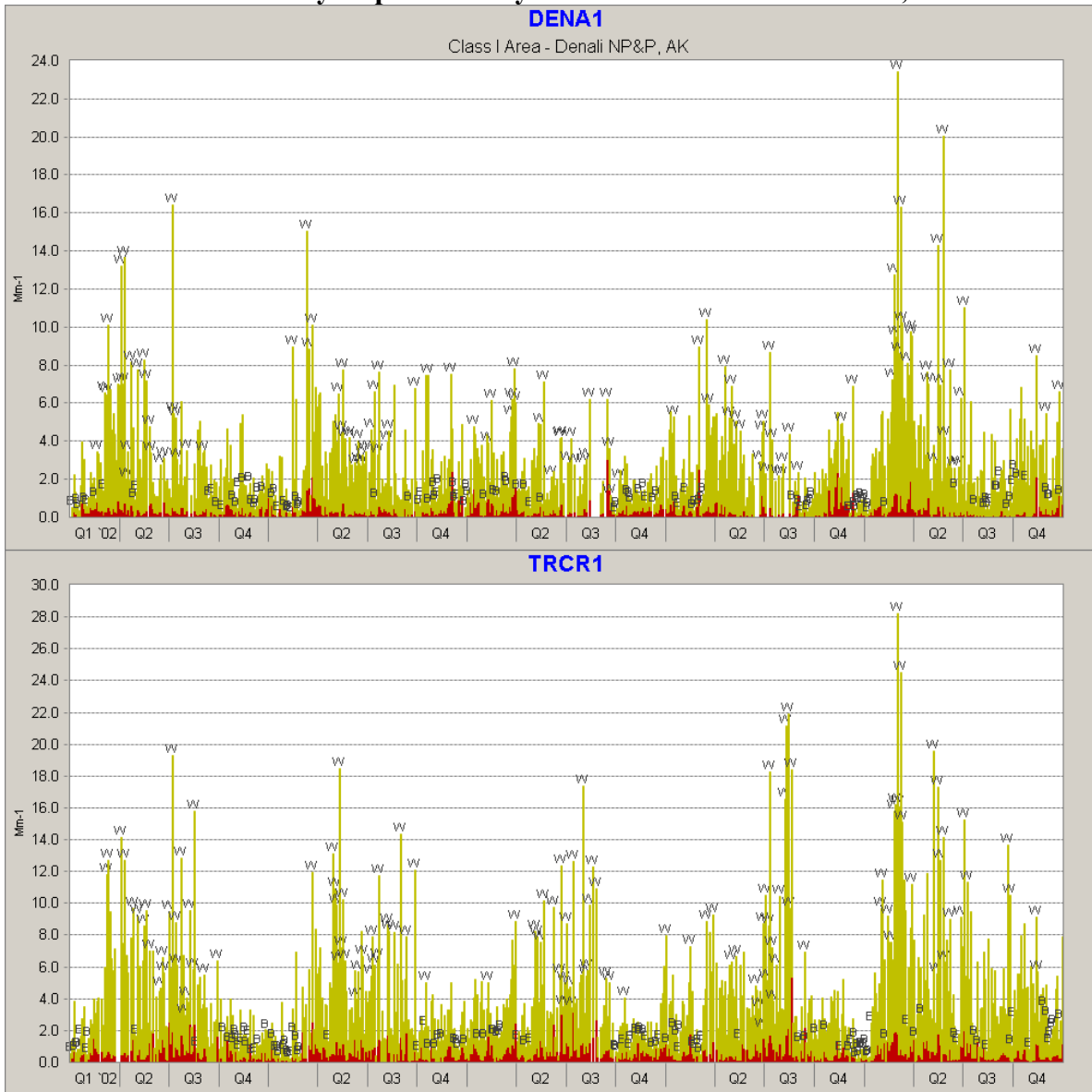
Figure III.K.4-35
2002 Visibility Impairment by Nitrate and Sulfate at Denali
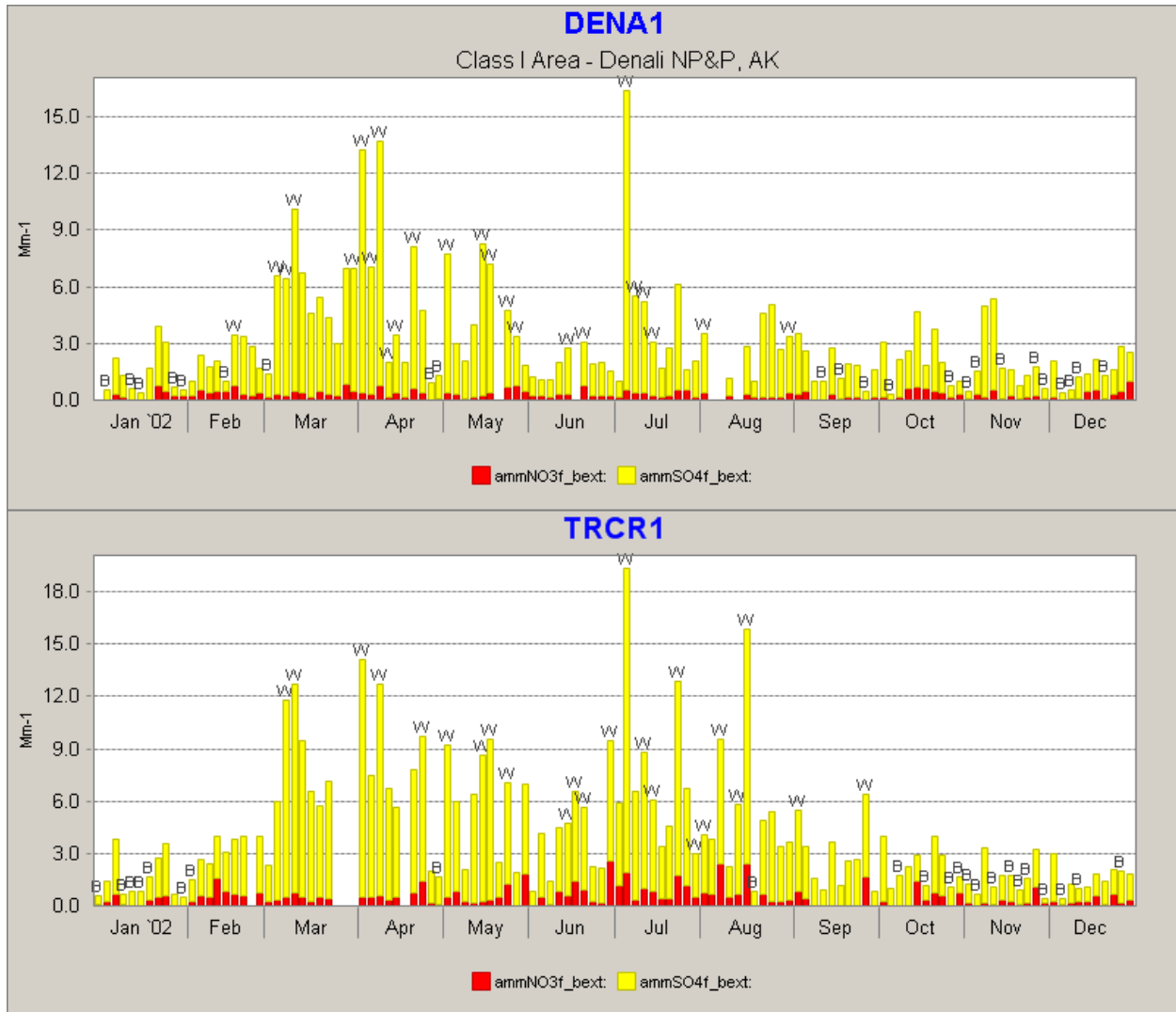

5. Wildfire Impacts Within Denali National Park

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})
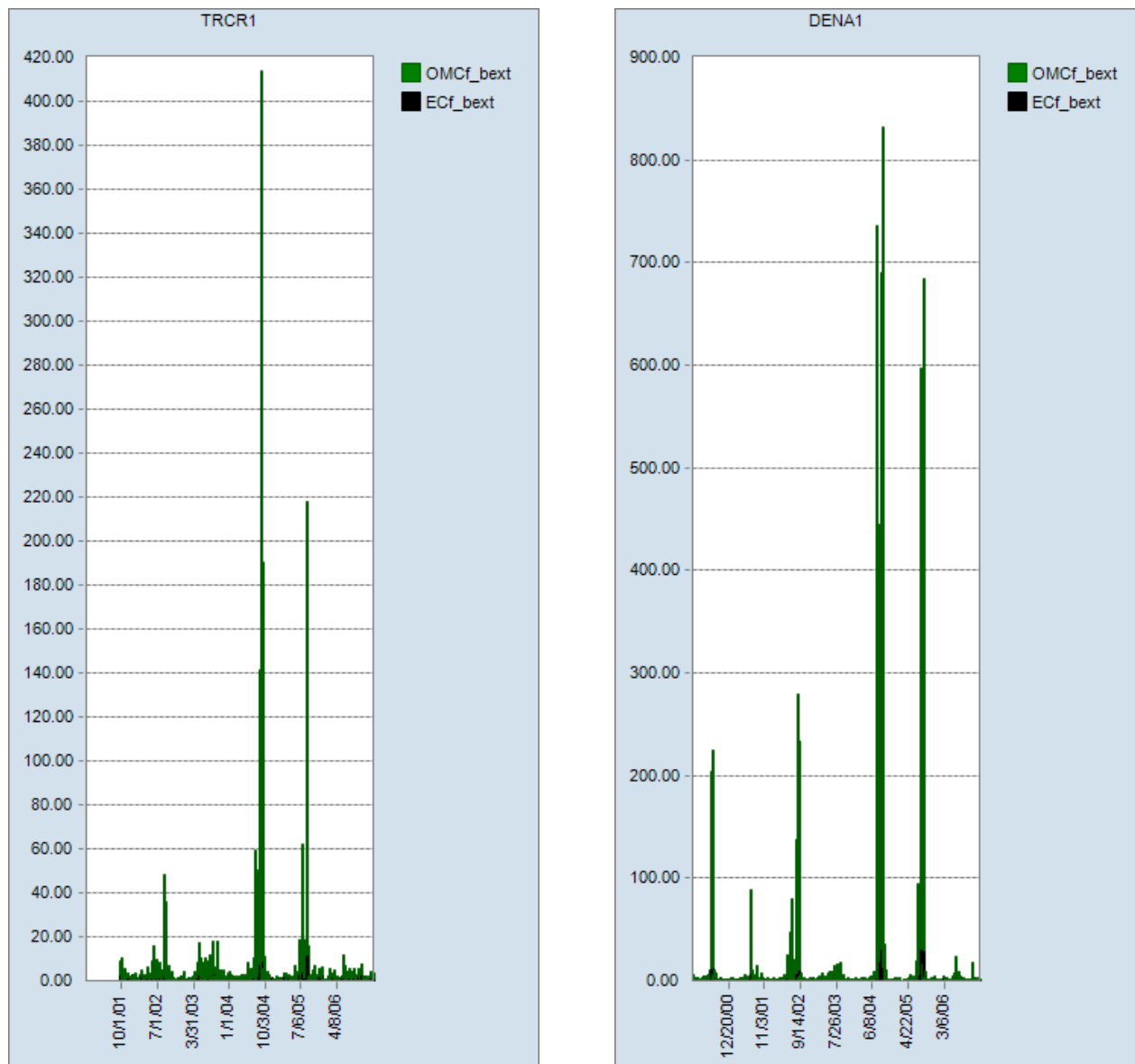
Close to a fire, organic matter carbon is the dominant aerosol. Specifically, worst days have higher average proportions of organic matter, and lower proportions of elemental carbon (Figure III.K.4-38). The proportional disparity between best and worst days is no greater in the years most affected by 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
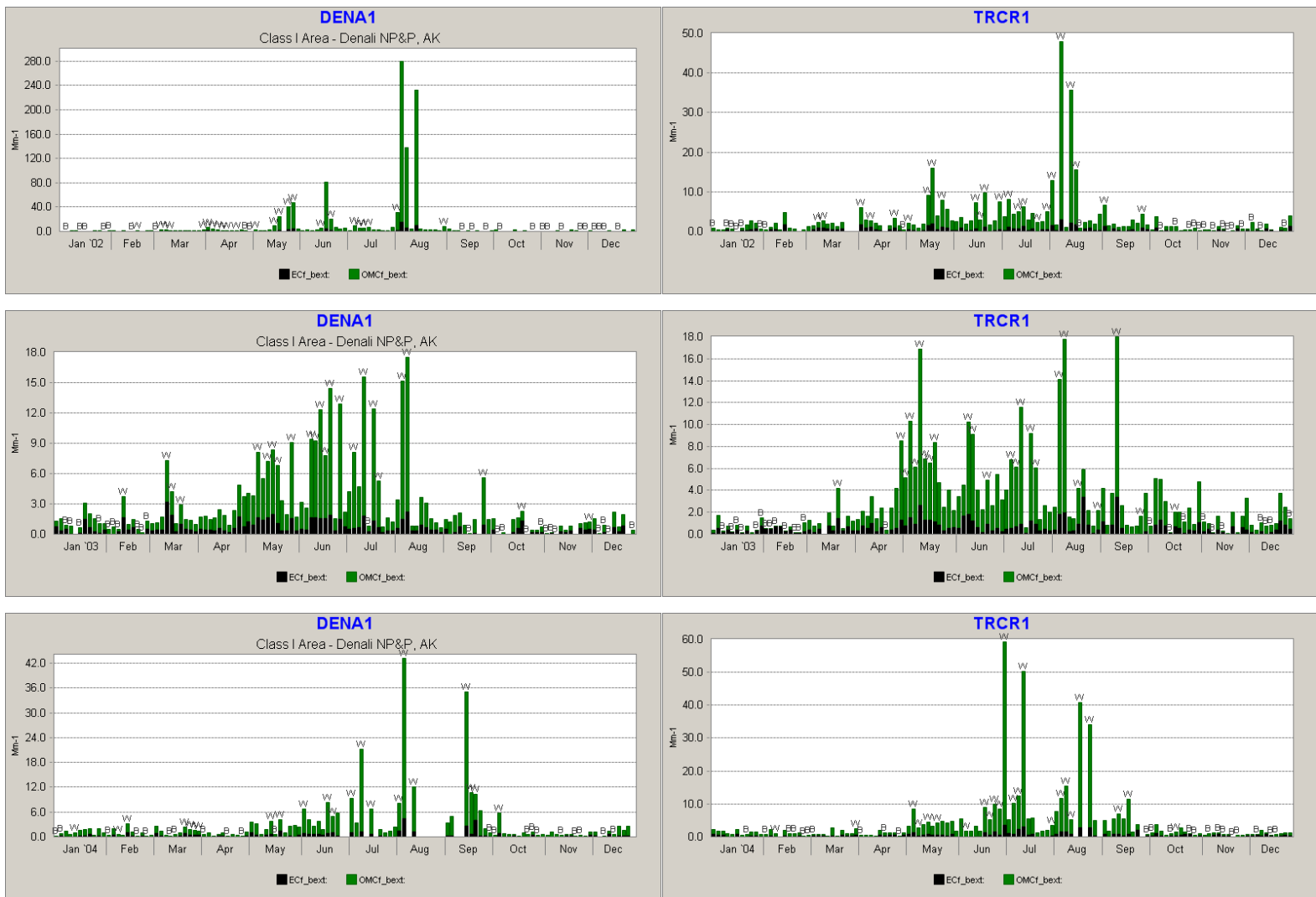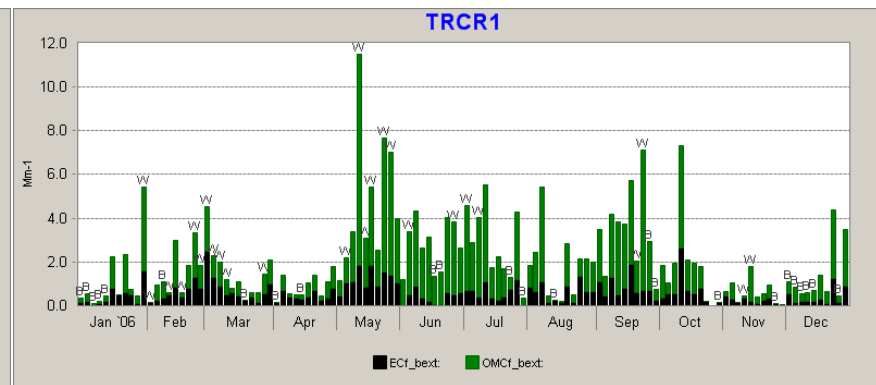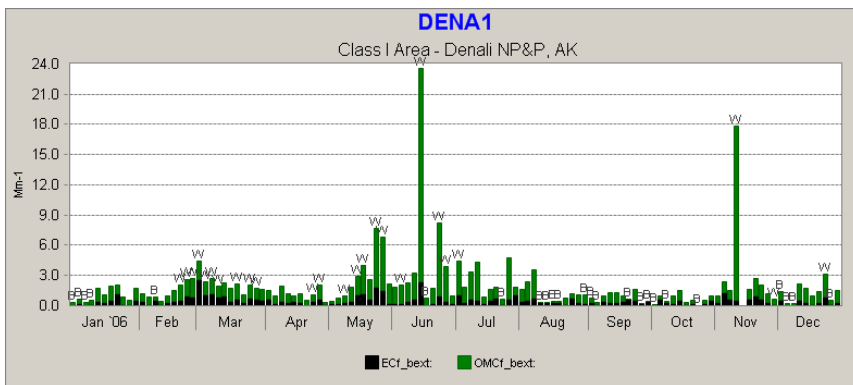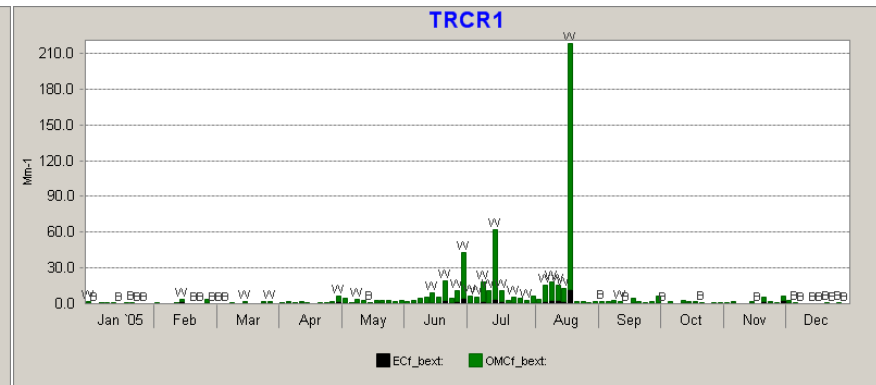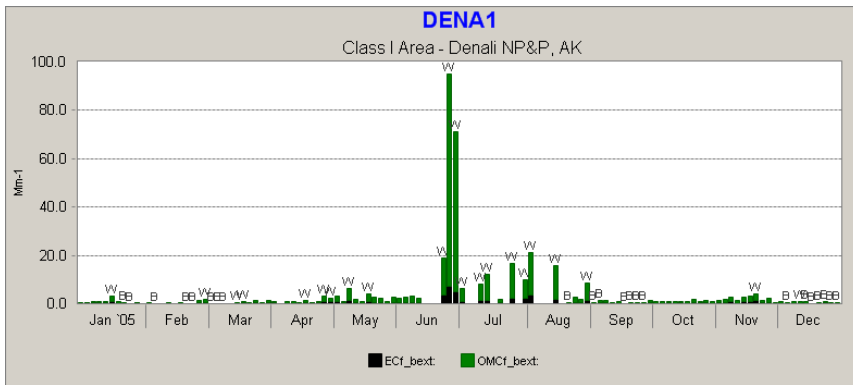
Figure III.K.4-38
Best and Worst Days, Relative Contributions of Organic Matter Carbon and Elemental Carbon at Denali for 2000-2006, 2002-2006, 2002, 2006

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.
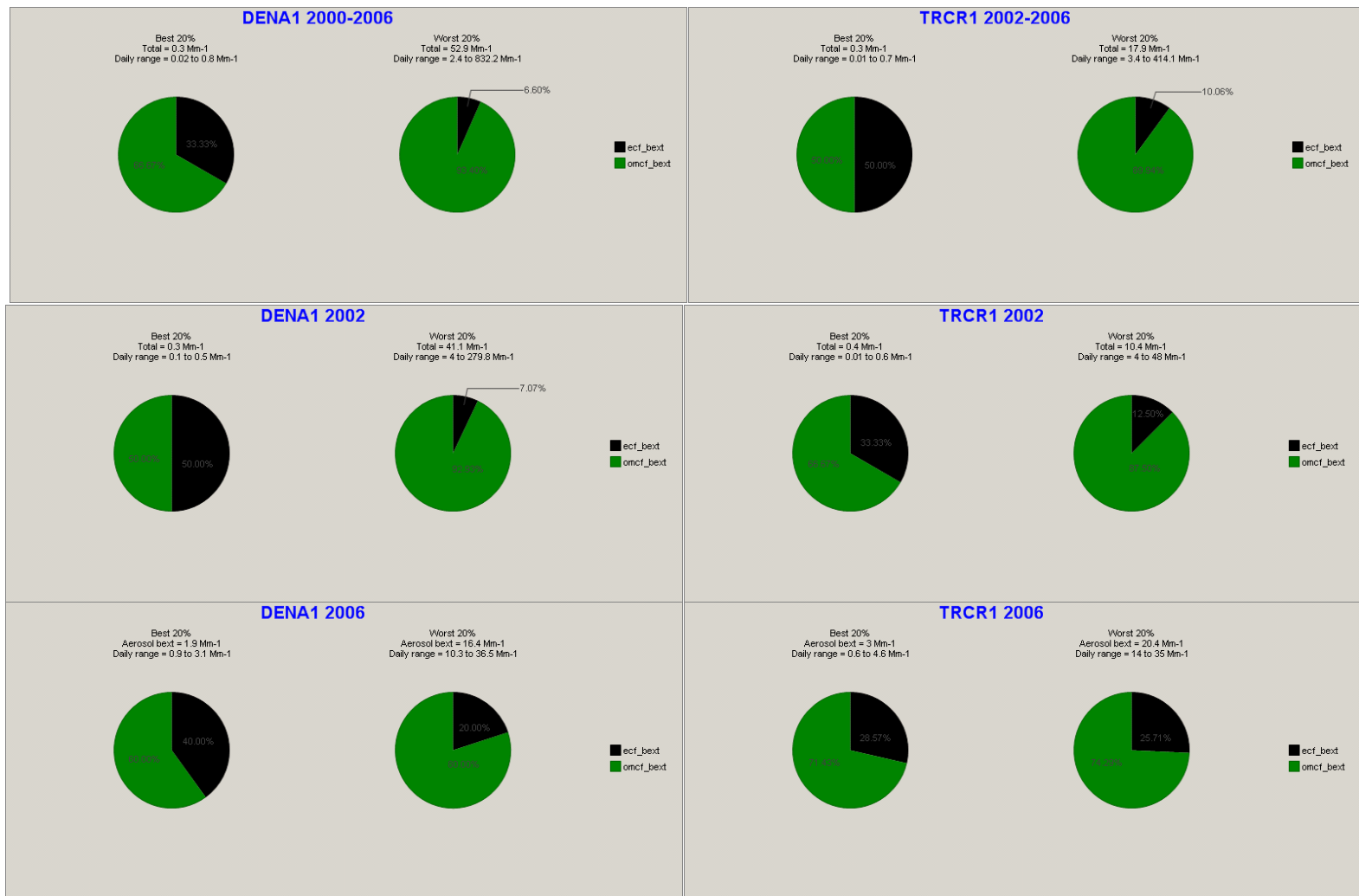
Figure III.K.4-40
Compilation Map of Wildfires Surrounding Denali for 1990-2009
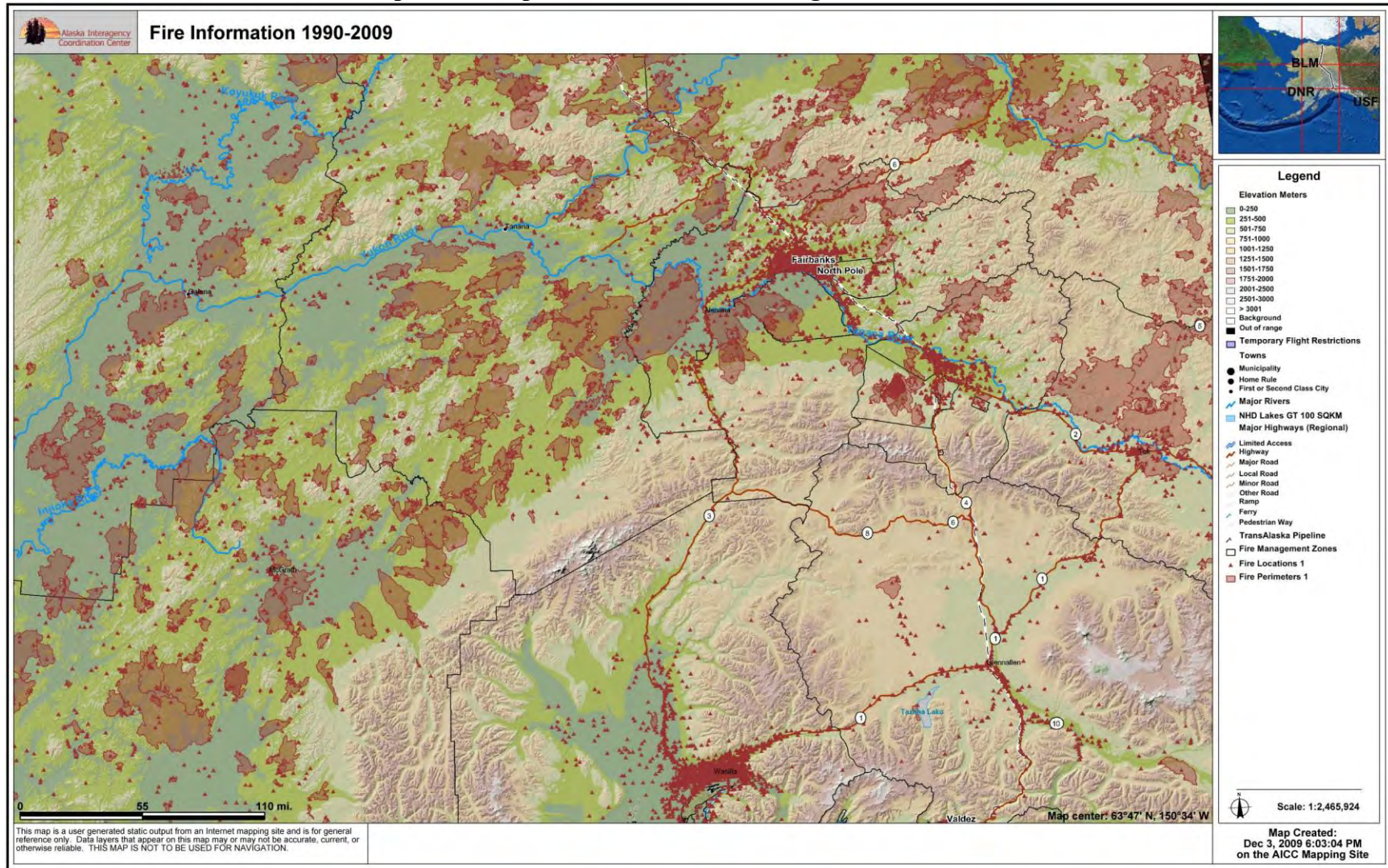
Figure III.K.4-41
Compilation Map of Wildfires Surrounding Denali for 2000-2006
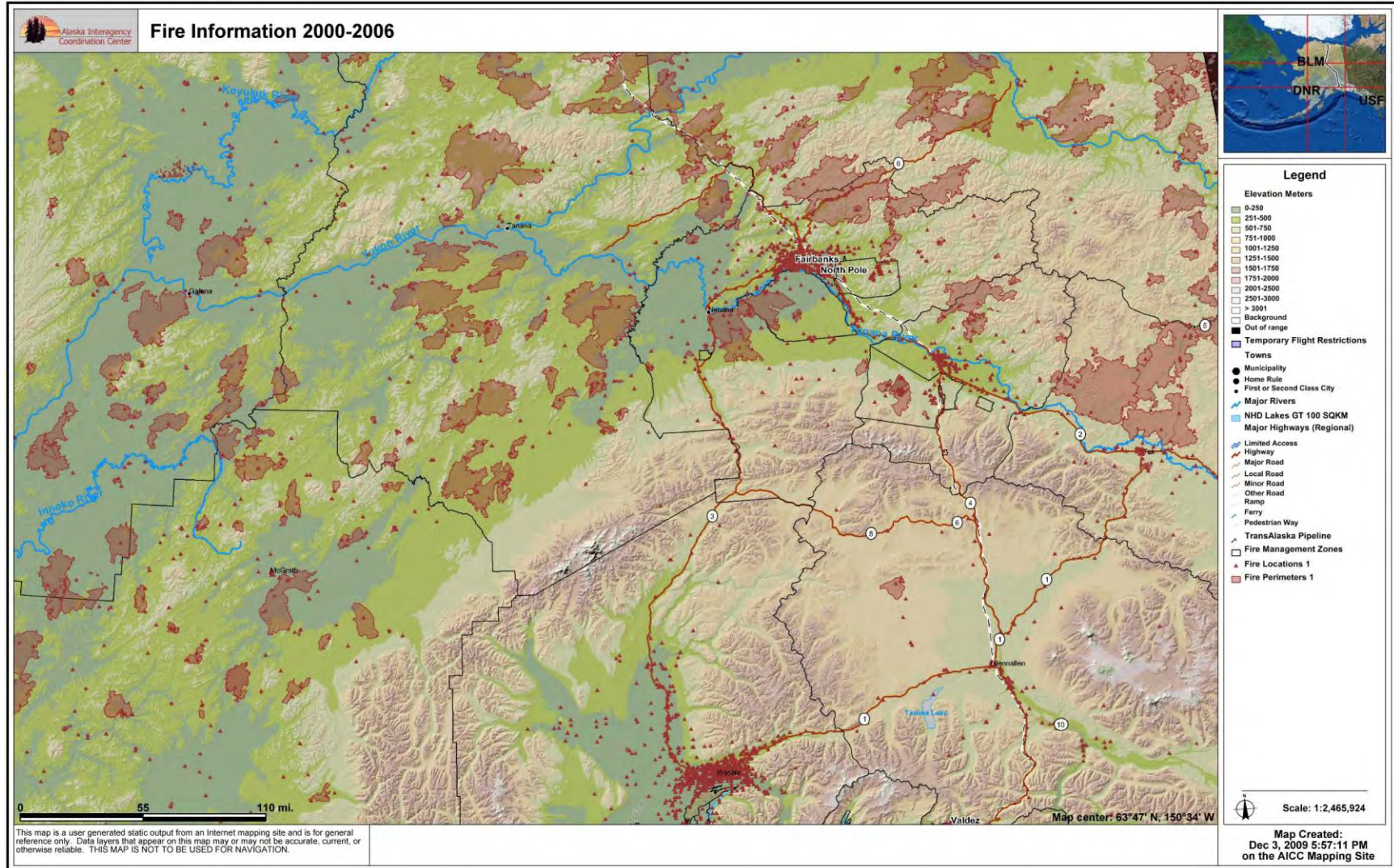
b. Wildfire Variability

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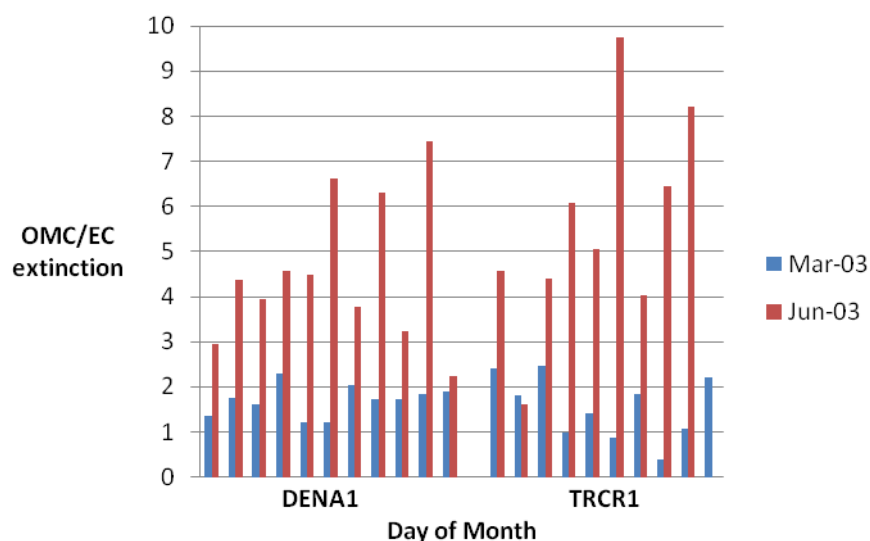
Note: March aerosols are assumed to originate outside the state,
as Alaska landscapes are snow covered in March.

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 μ g/m^3	DENA1 Worst Days μ g/m^3	TRCR1 Worst Days μ g/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

Date	RHR Group	DENA1 Speciation Data								RHR Group	TRCR1 Speciation Data							
		Total	NO$_3$	SO$_4$	CM	EC	OMC	Sea Salt	SOIL		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

Date	RHR Group	DENA1 Speciation Data								RHR Group	TRCR1 Speciation Data							
		Total	NO$_3$	SO$_4$	CM	EC	OMC	Sea Salt	SOIL		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
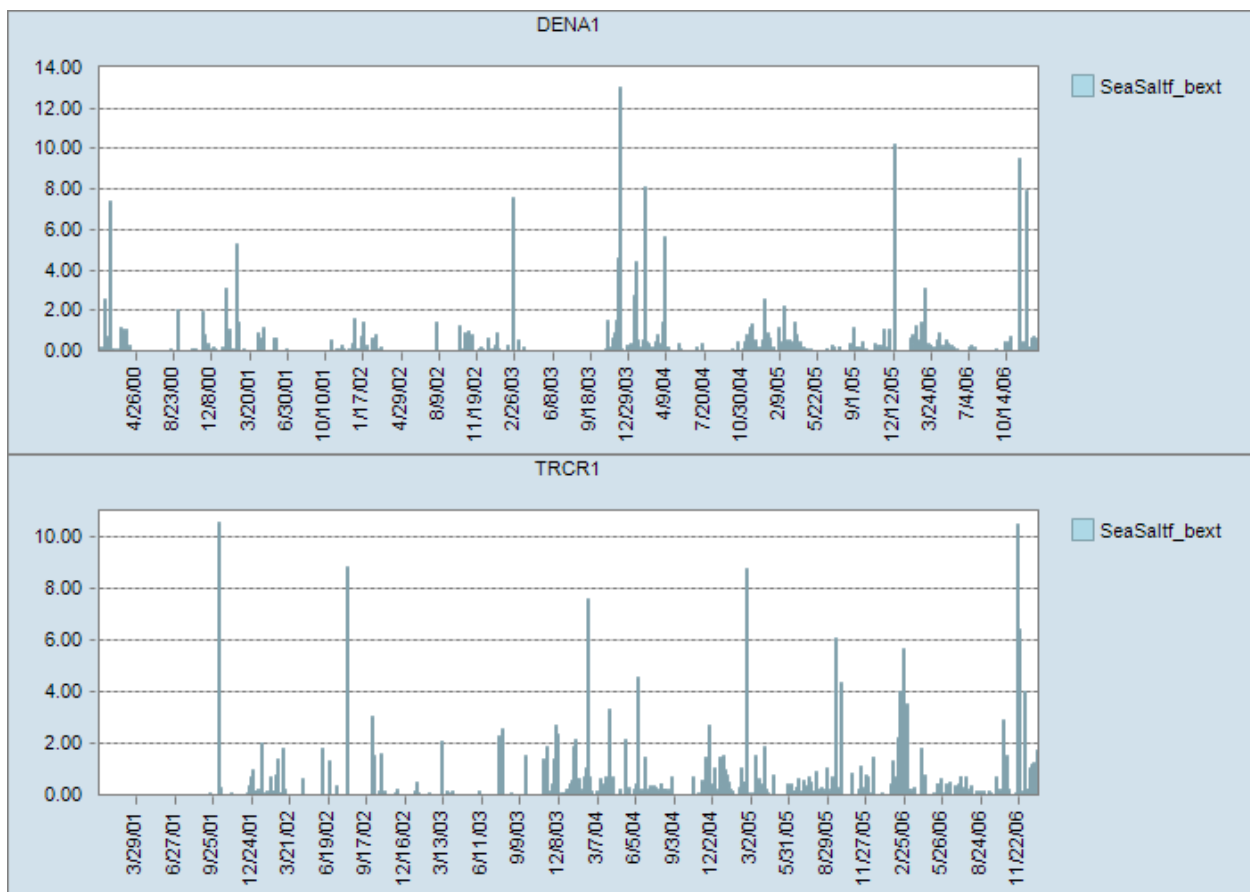
Figure III.K.4-44
2004 Contribution of Sea Salt to Light Extinction on Best and Worst Days at Denali
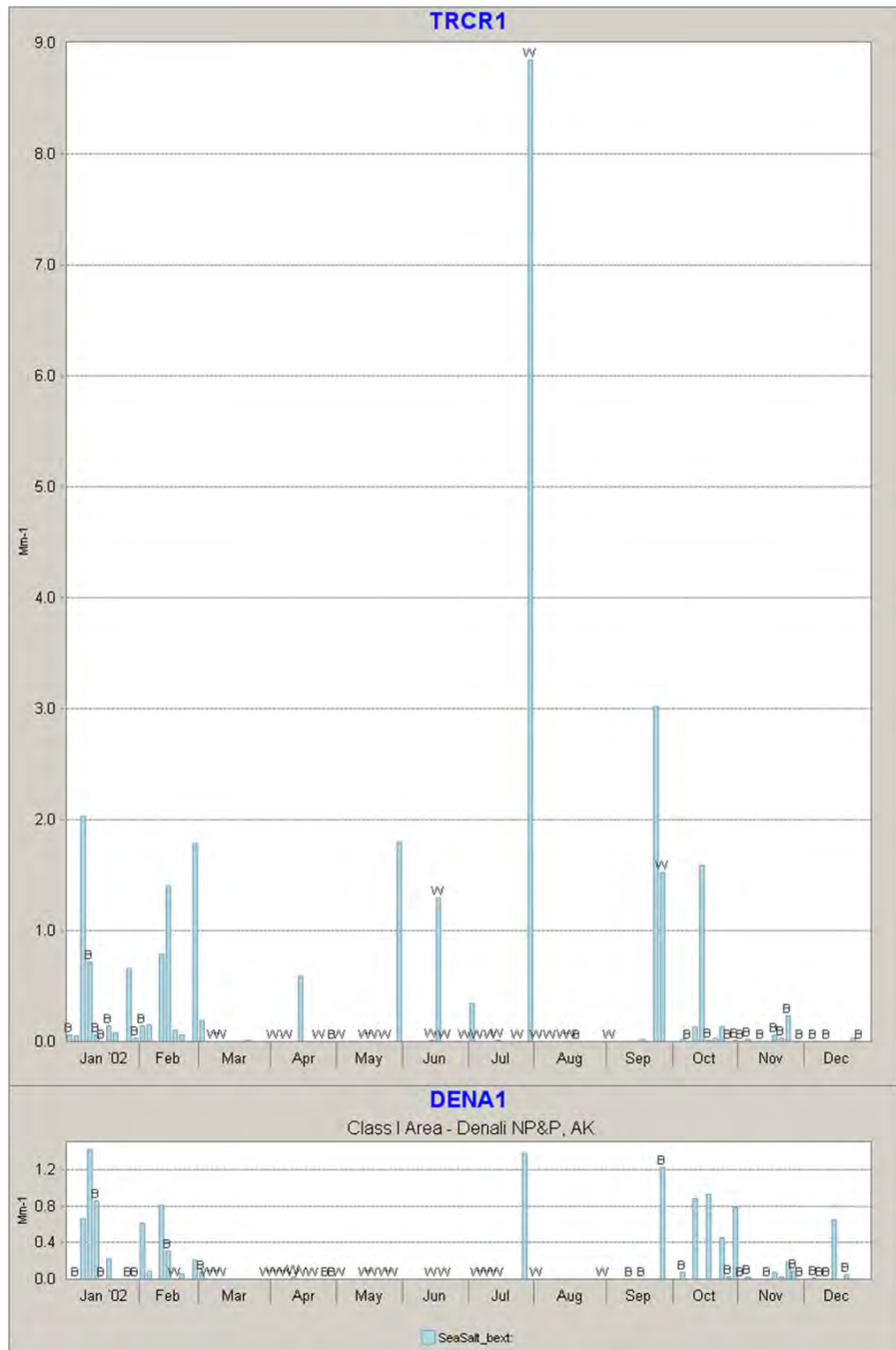
Note: Best days (B) and worst days (W) are identified on the histograms. When extinction is low, B, W, and E (for missing data) labels overlap at the base of the histogram.

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
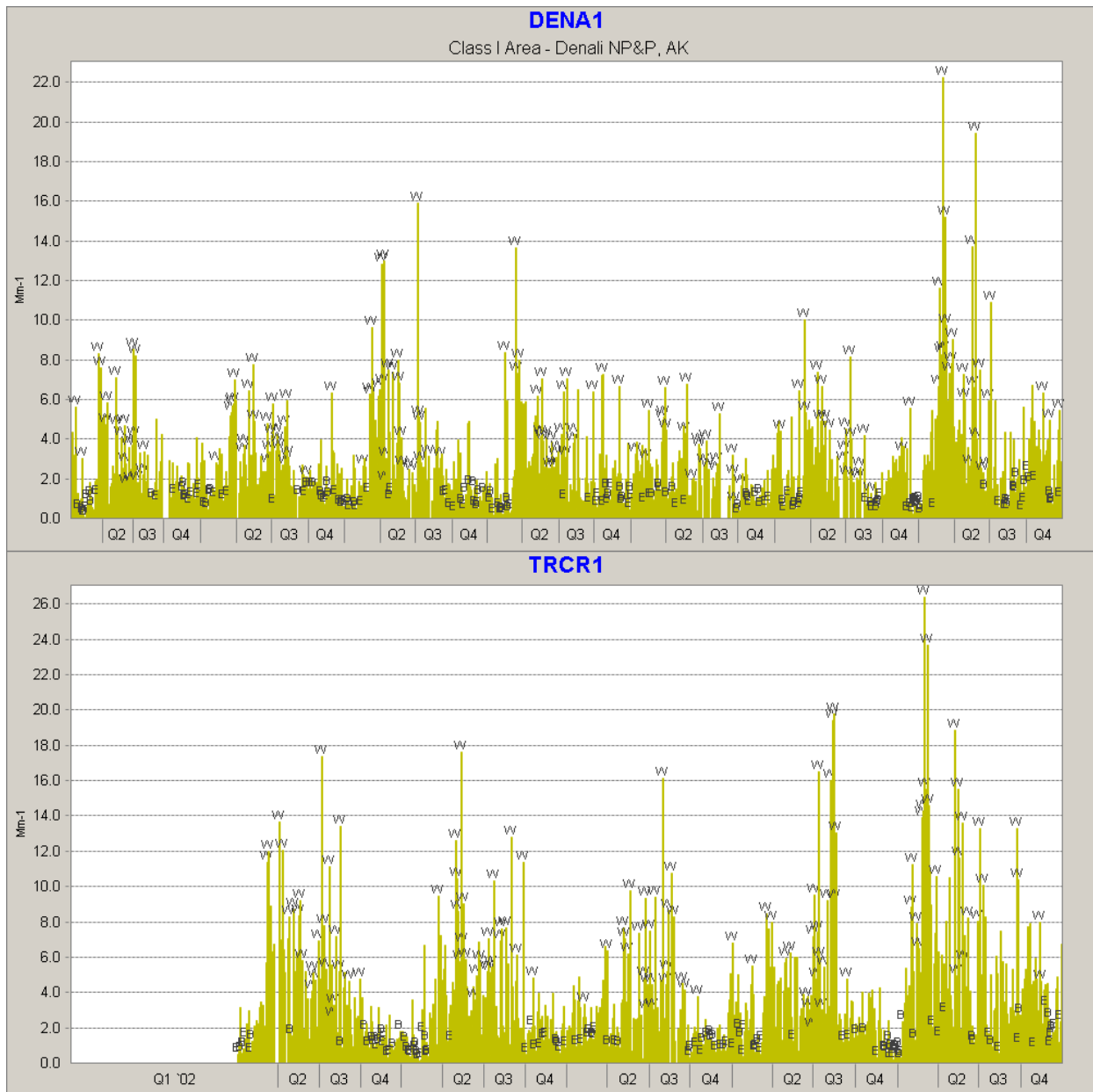
Figure III.K.4-46
2002 and 2005 Contributions of Sulfate at Denali
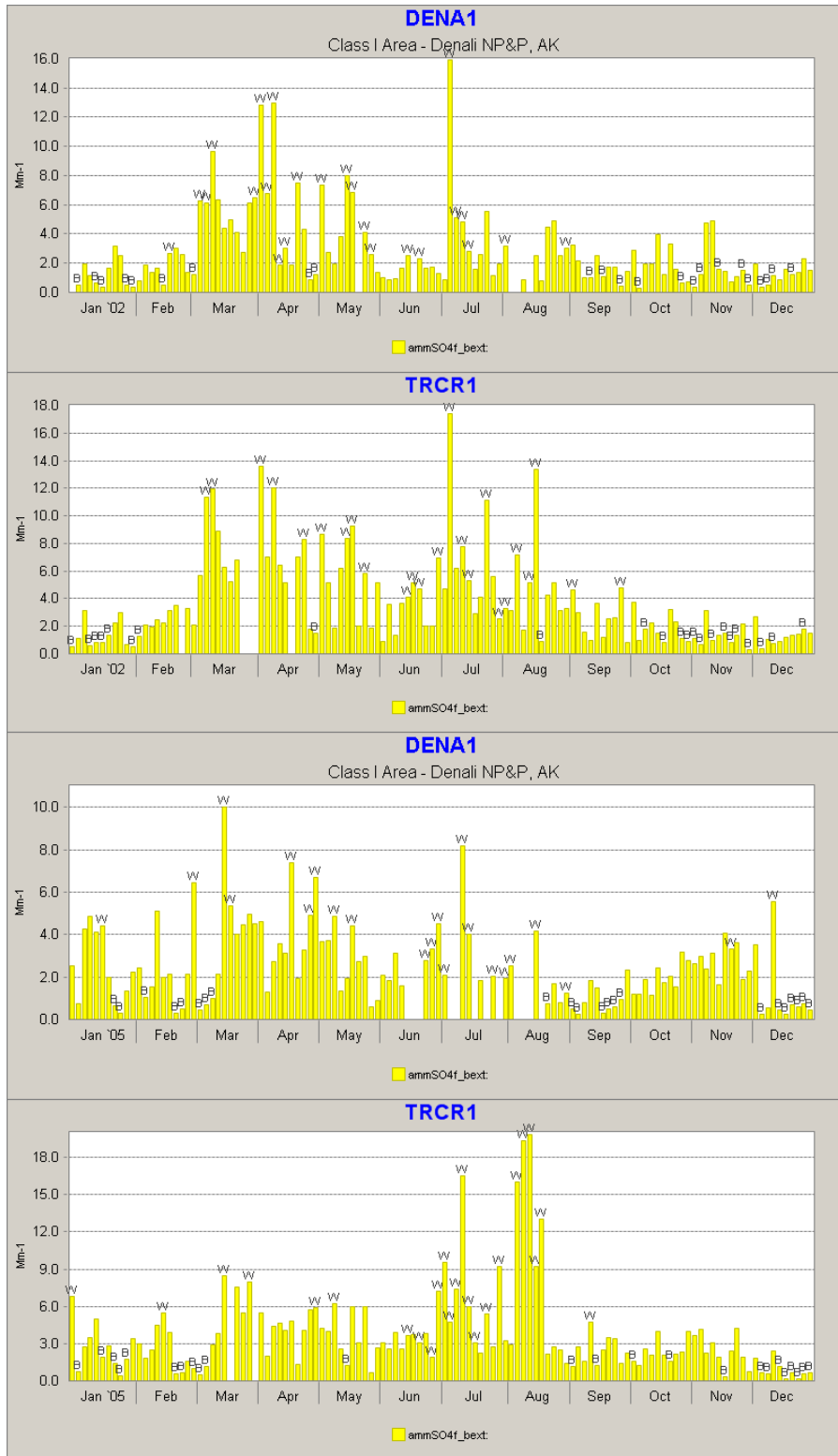
Table III.K.4-19
Annual Variability in Sulfate Aerosols at Denali, Peak Months and Light Extinction

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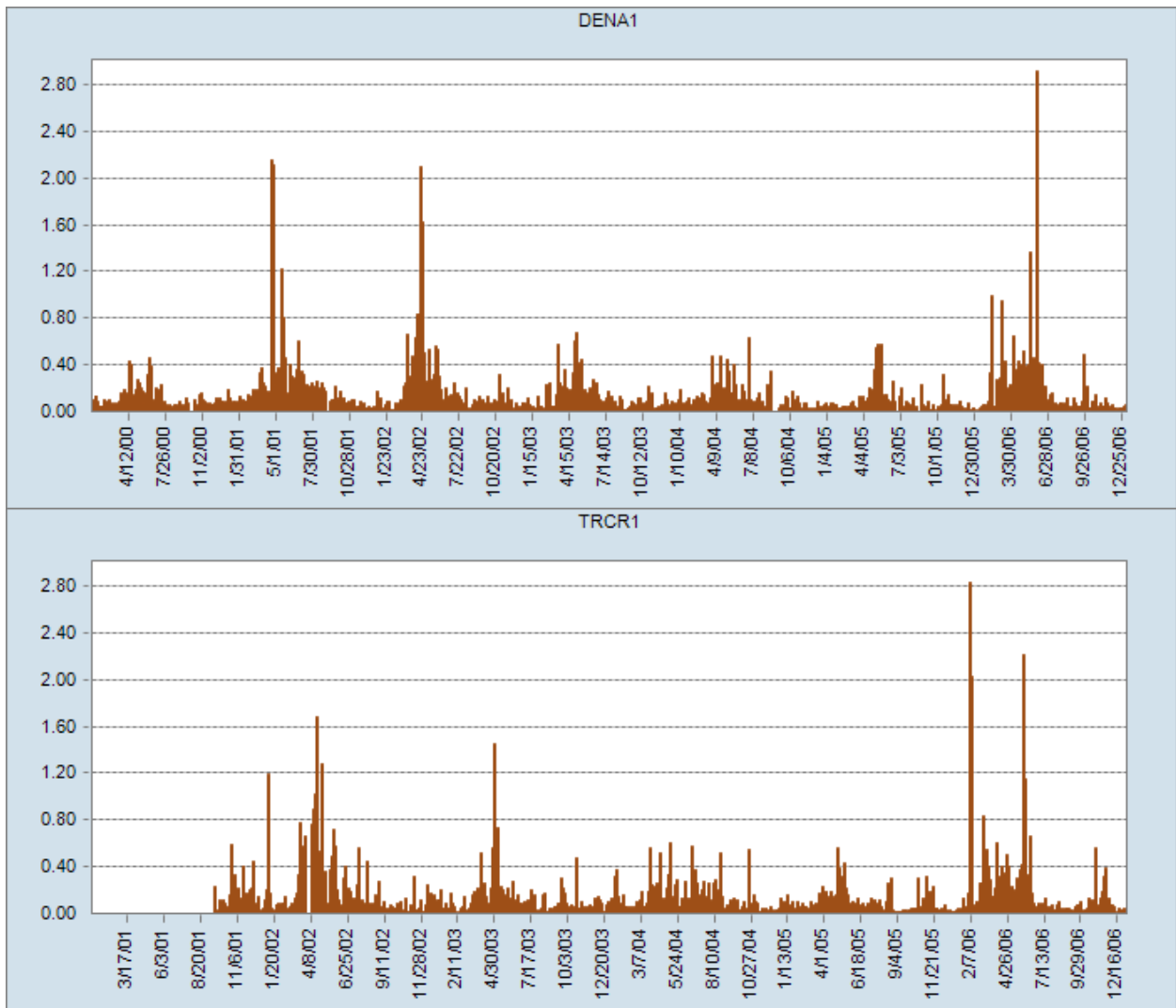
Table III.K.4-20
Annual Variability in Soil Aerosols at Denali, Peak Months and Light Extinction

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
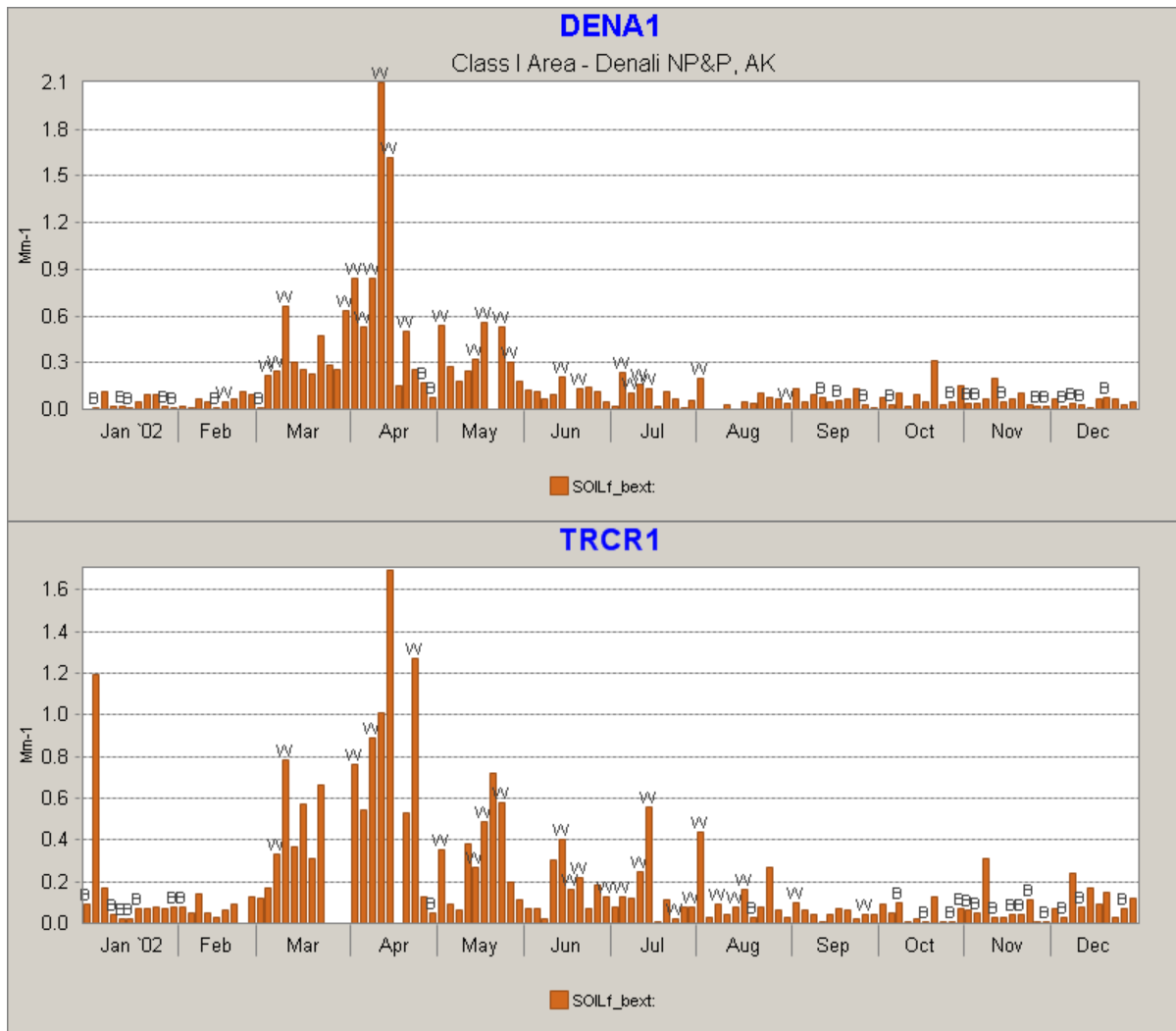
d. Nitrate

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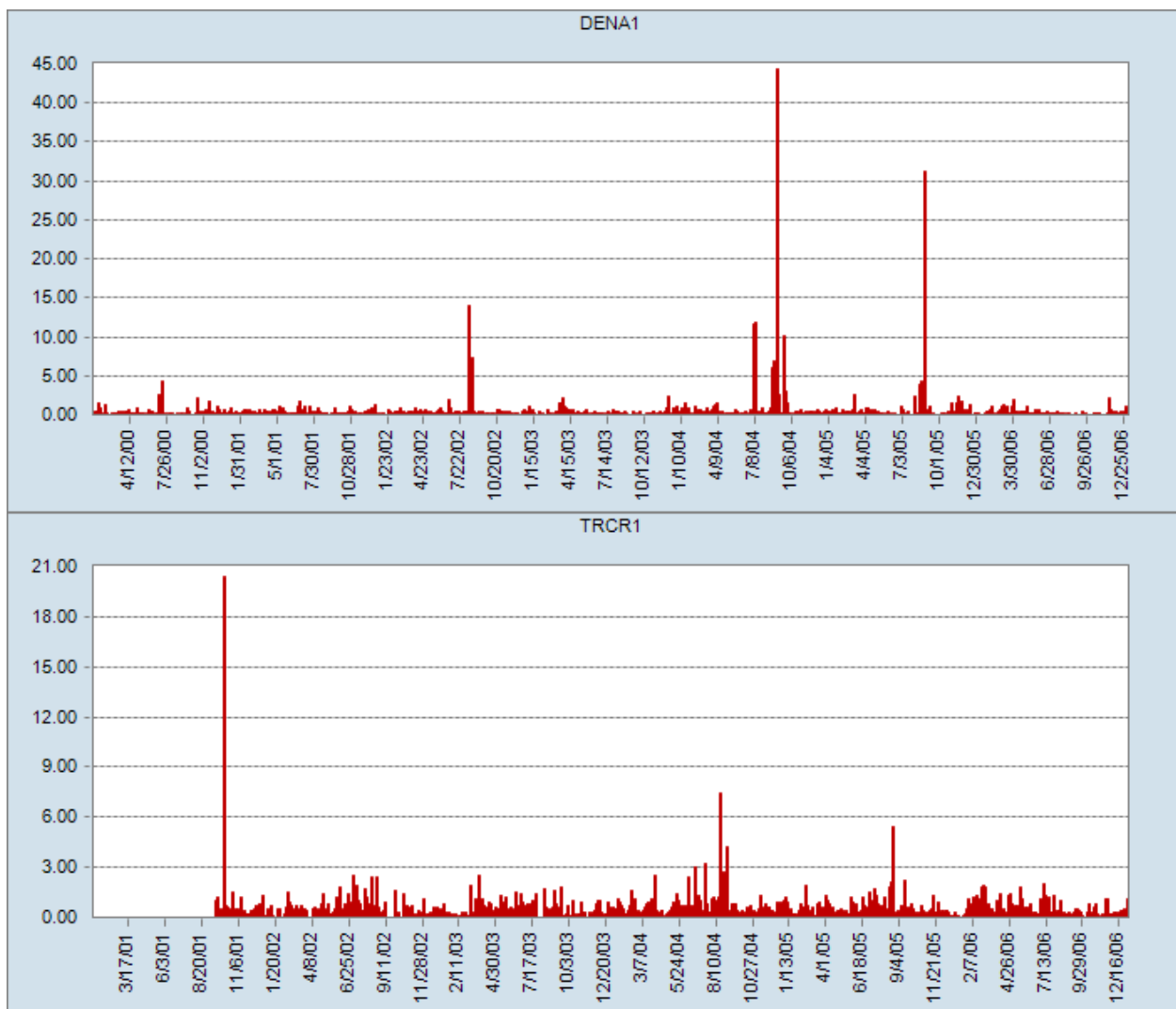
Figure III.K.4-50
2002 and 2004 Contributions of Nitrate at Denali
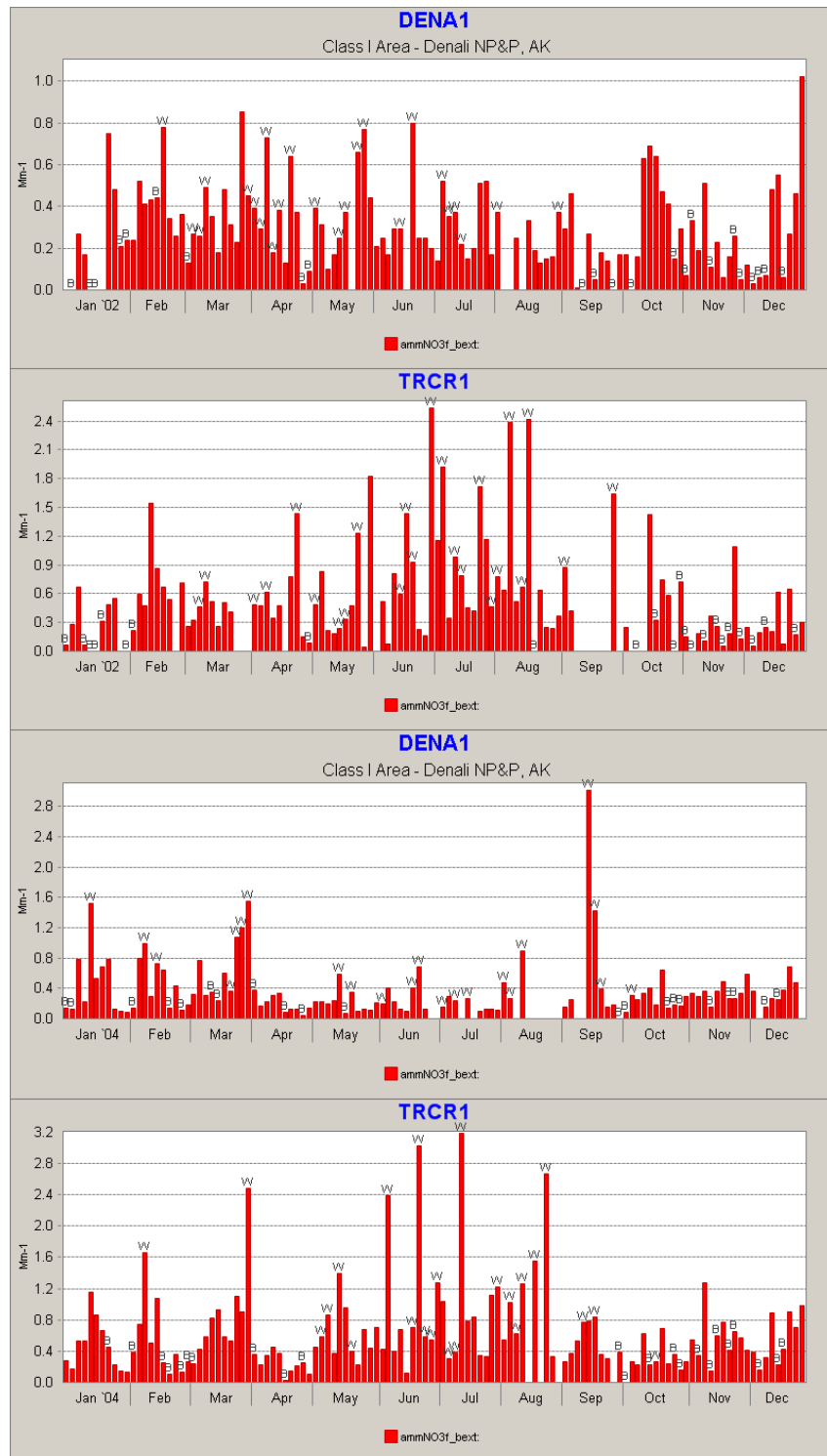
e. Coarse Mass

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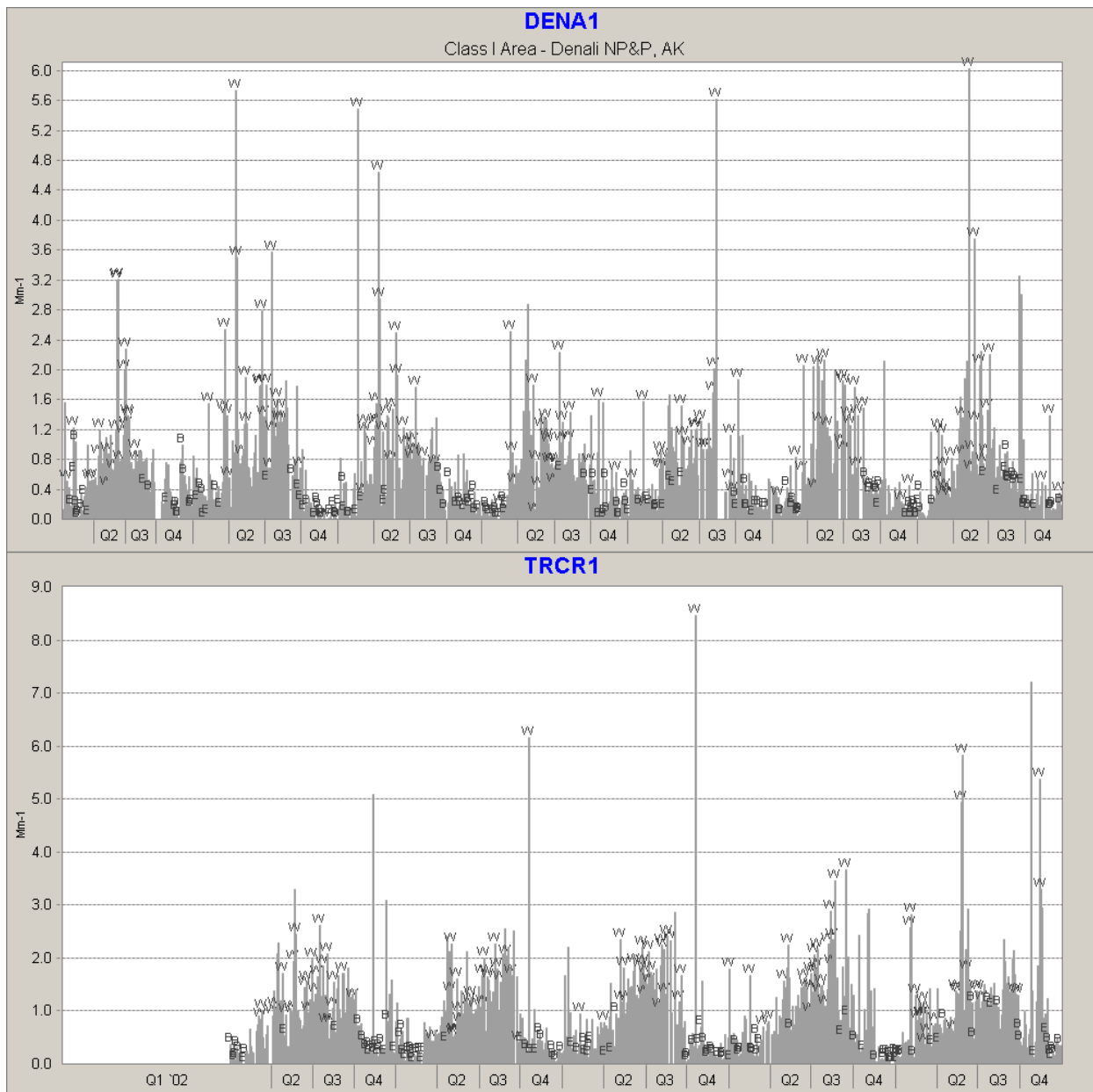
Figure III.K.4-52
2002 Contributions of Coarse Mass at Denali
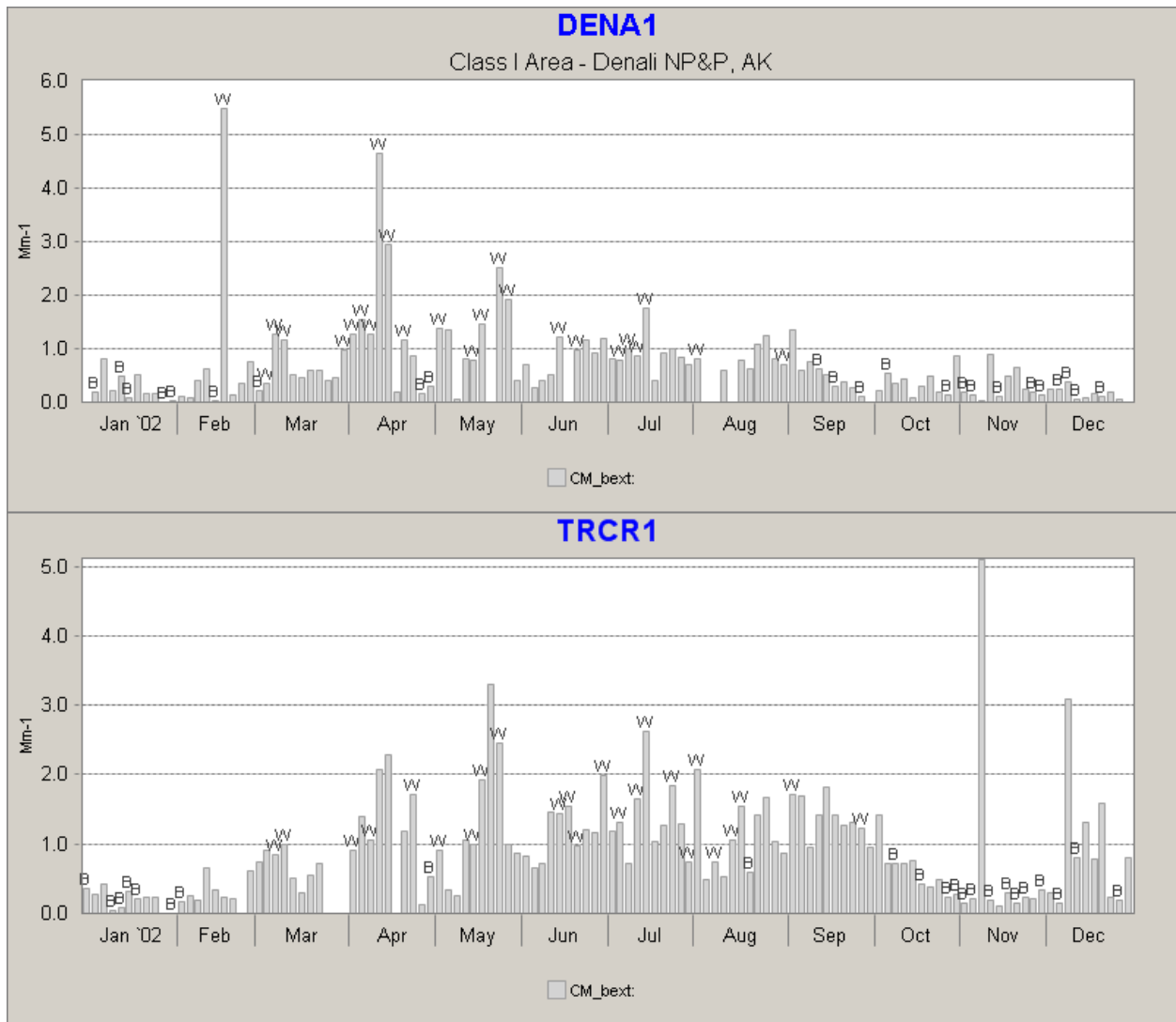
f. Elemental Carbon

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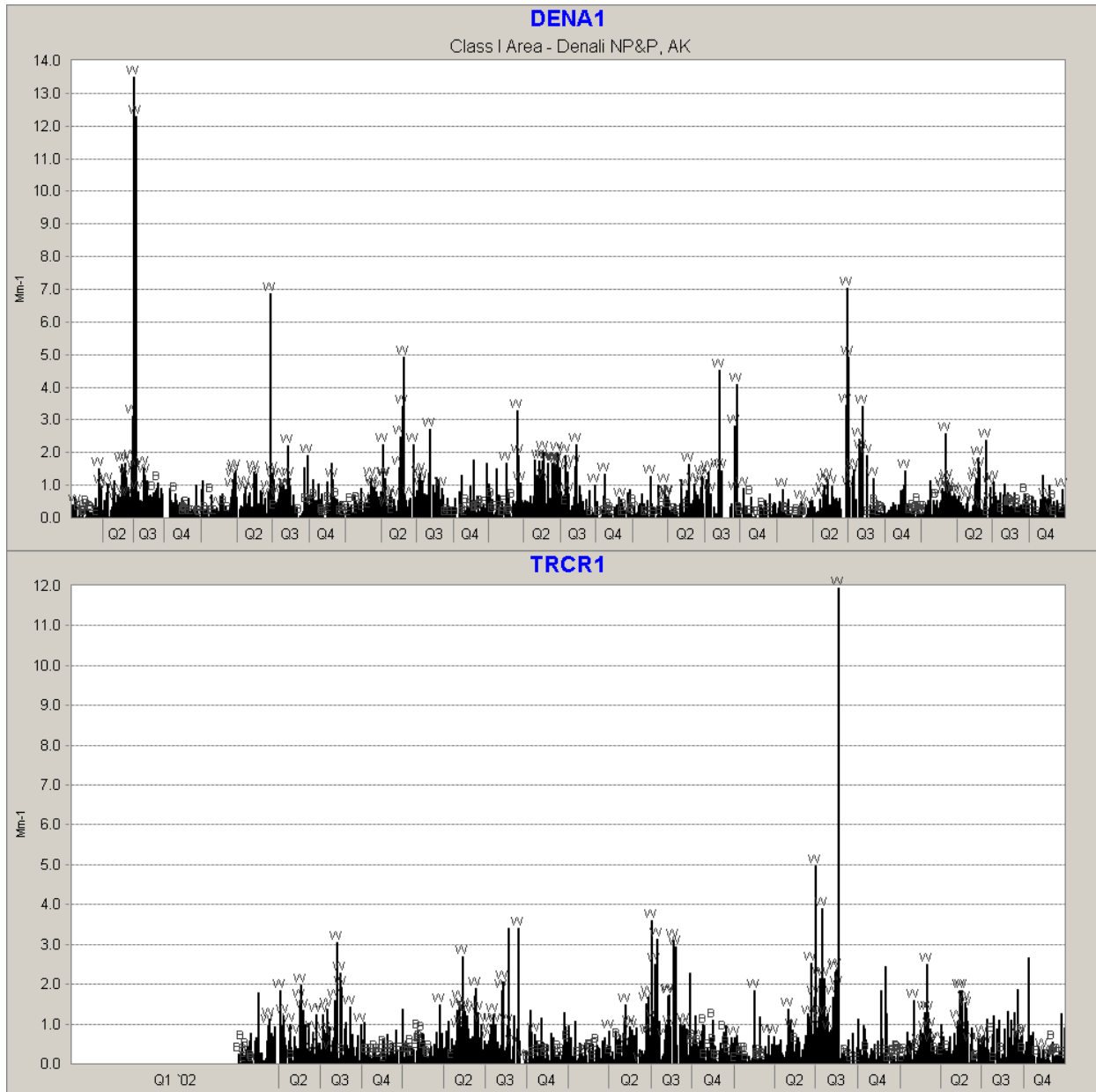
Figure III.K.4-54
2002 Contributions of Elemental Carbon at Denali
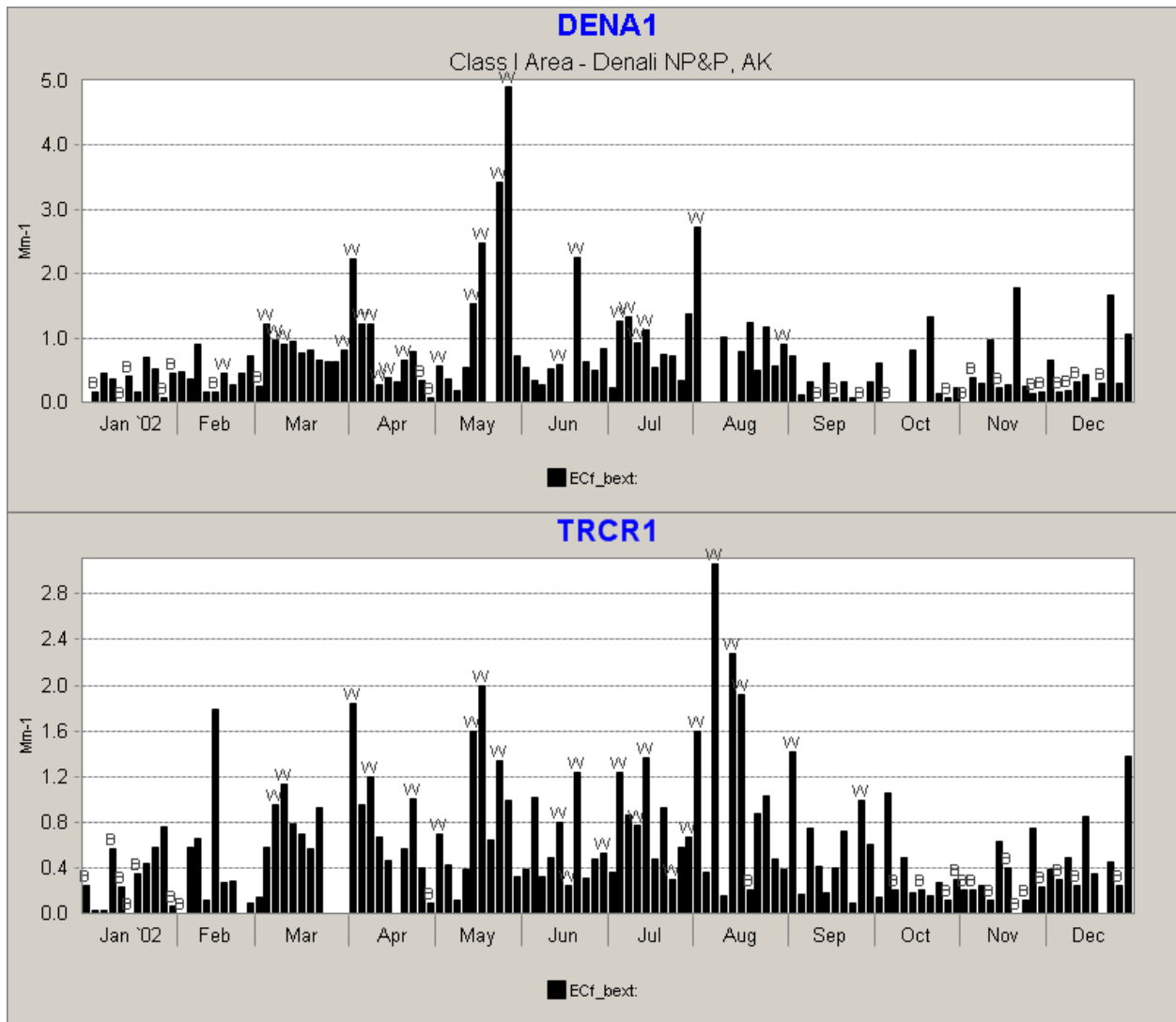
g. Organic Matter Carbon

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)
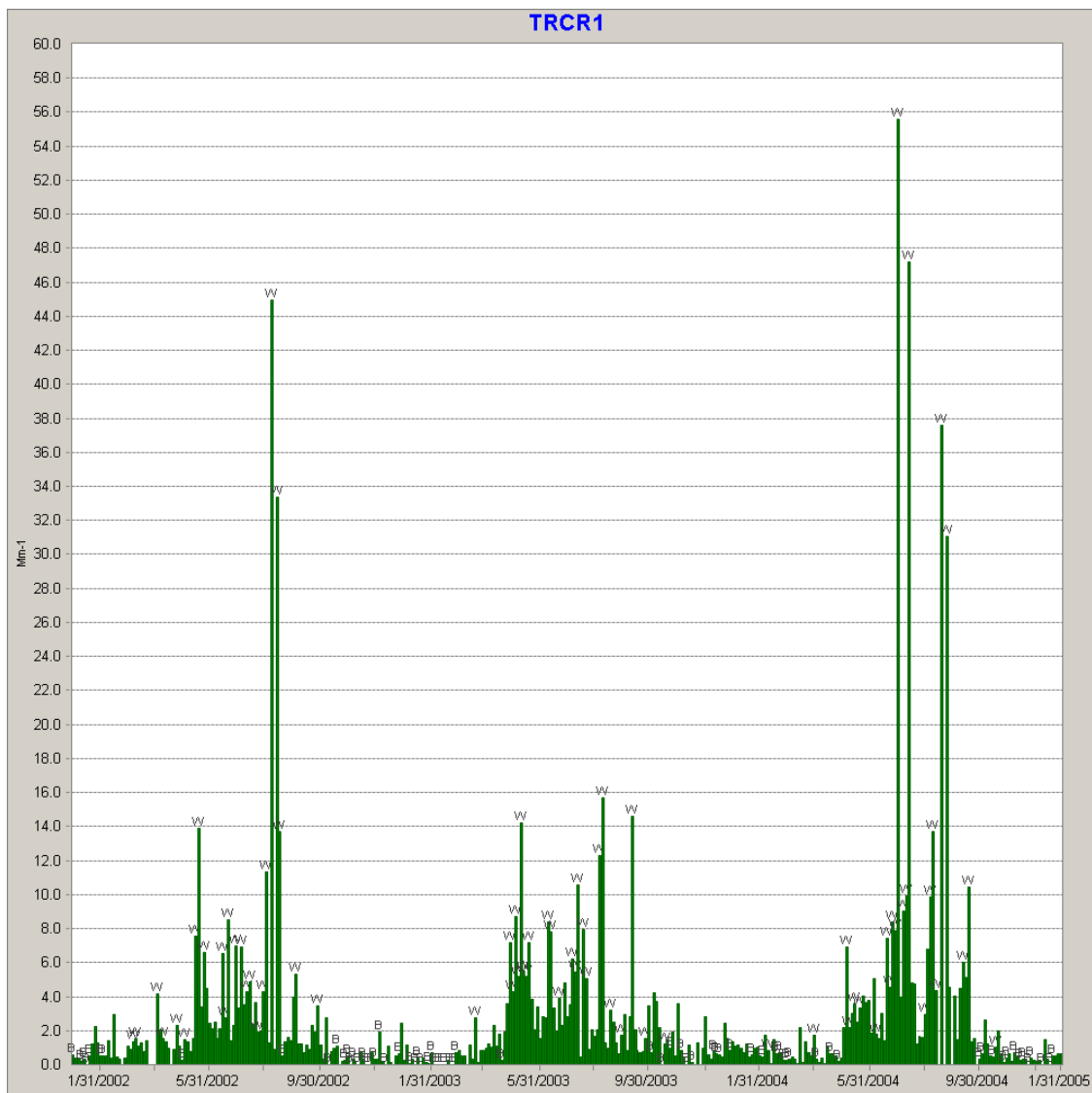
Figure III.K.4-56
2002 Contributions of Organic Matter Carbon at Denali
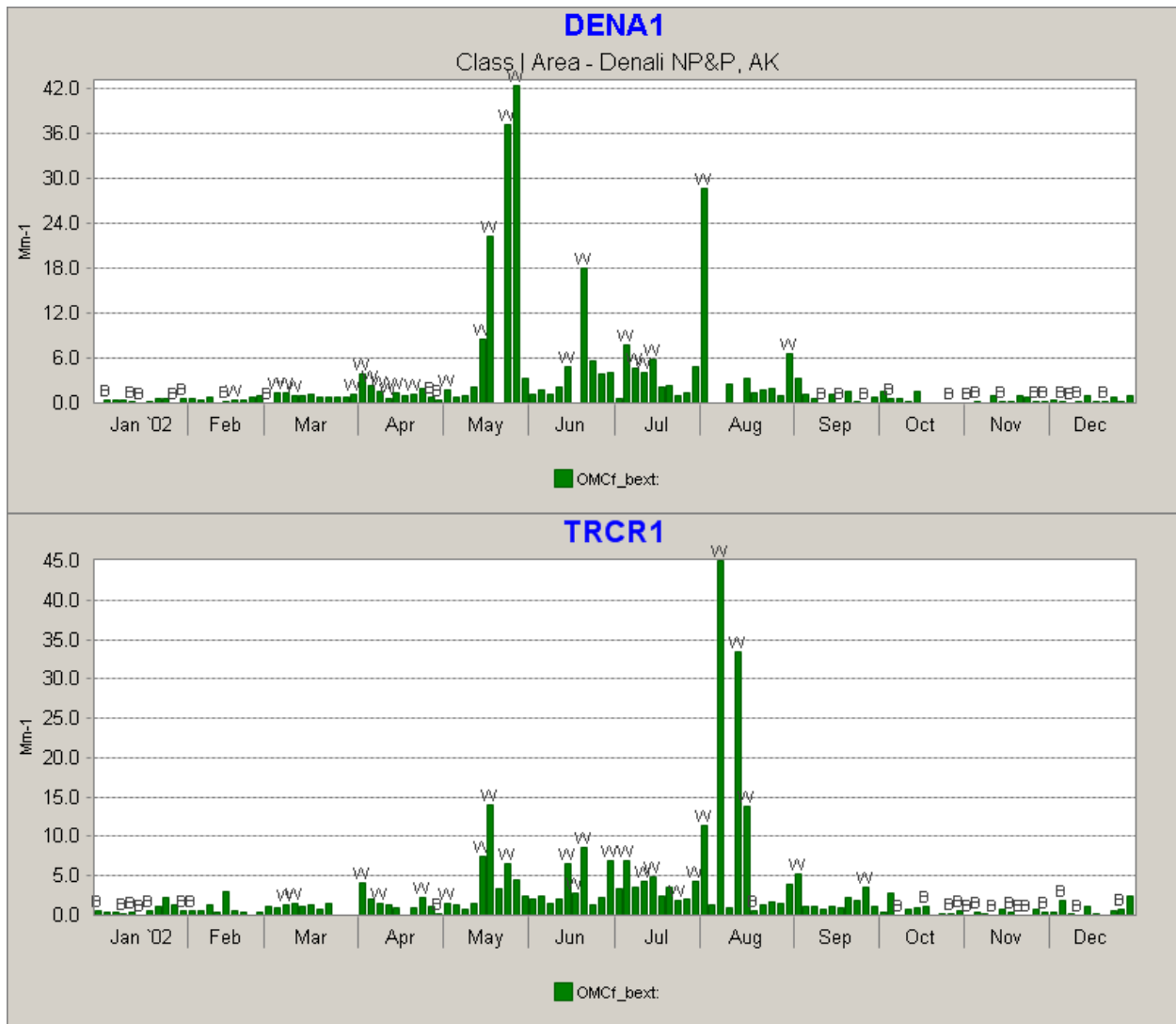
8. Evaluation of the Effects of Uncontrollable Processes on Species of Pollutants at Denali

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

TRCR1, Denali Class I Area

DENA1, Denali Class I Area
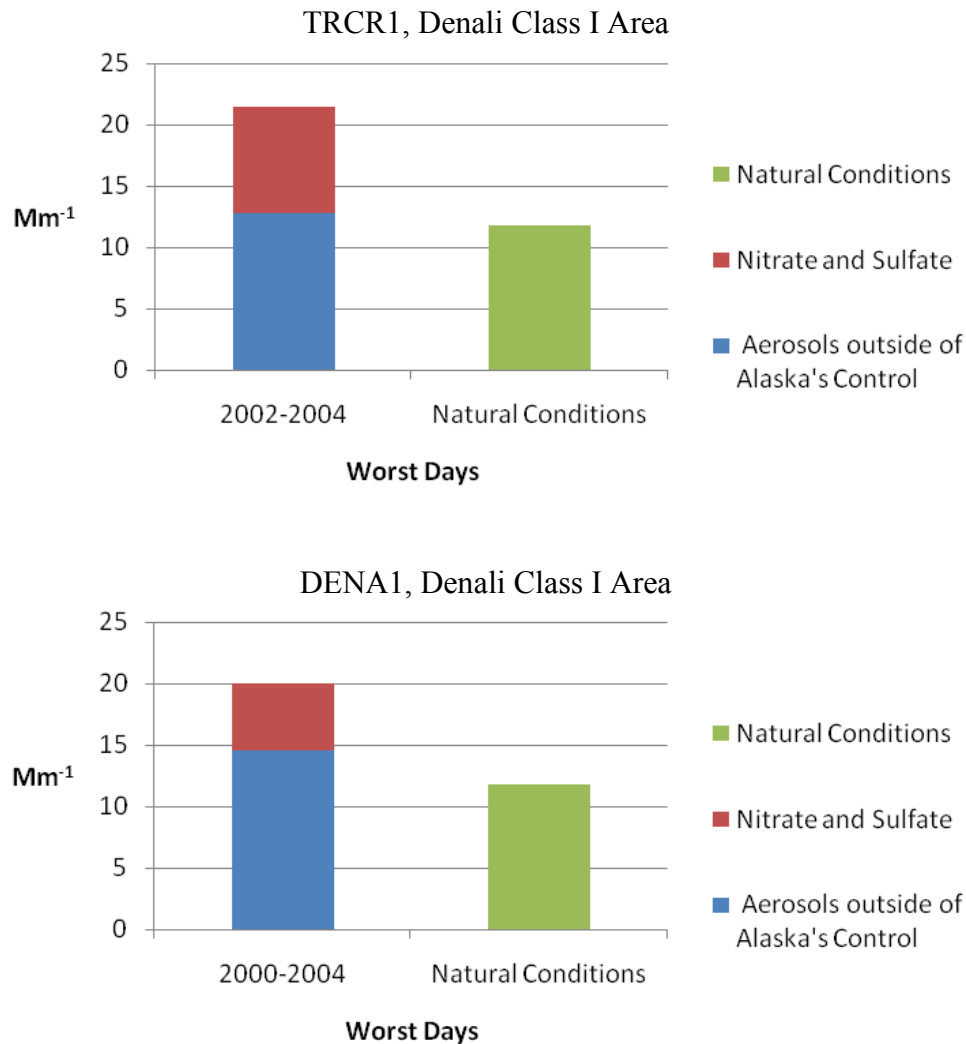
D. Tuxedni (TUXE)

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).

<div align="center">

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

</div>

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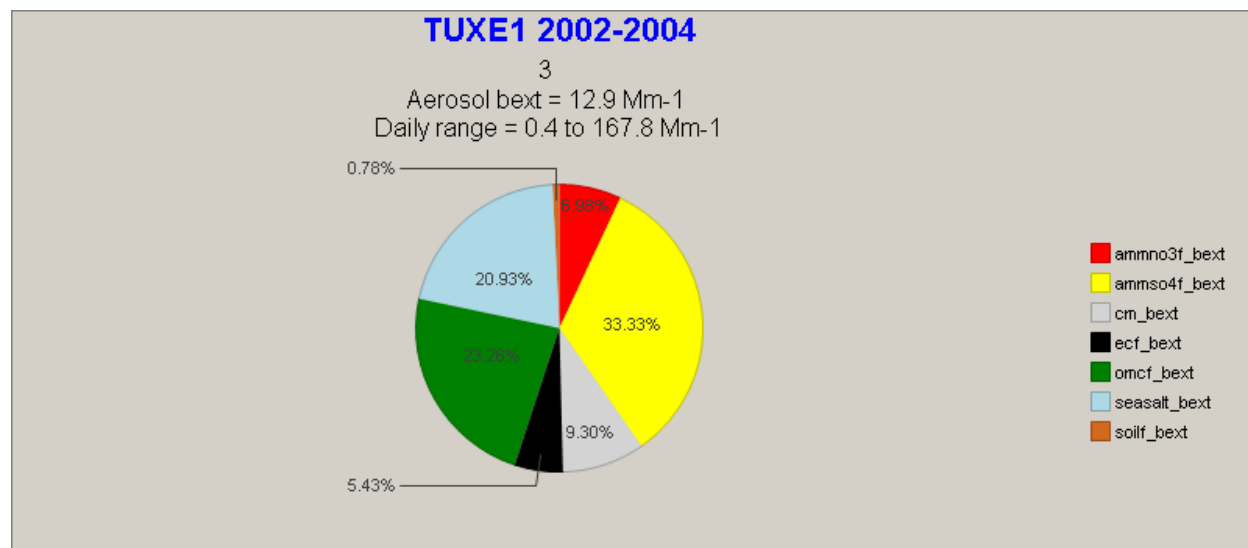
2. Origins of Aerosol Species Influencing Regional Haze at Tuxedni Class I Area

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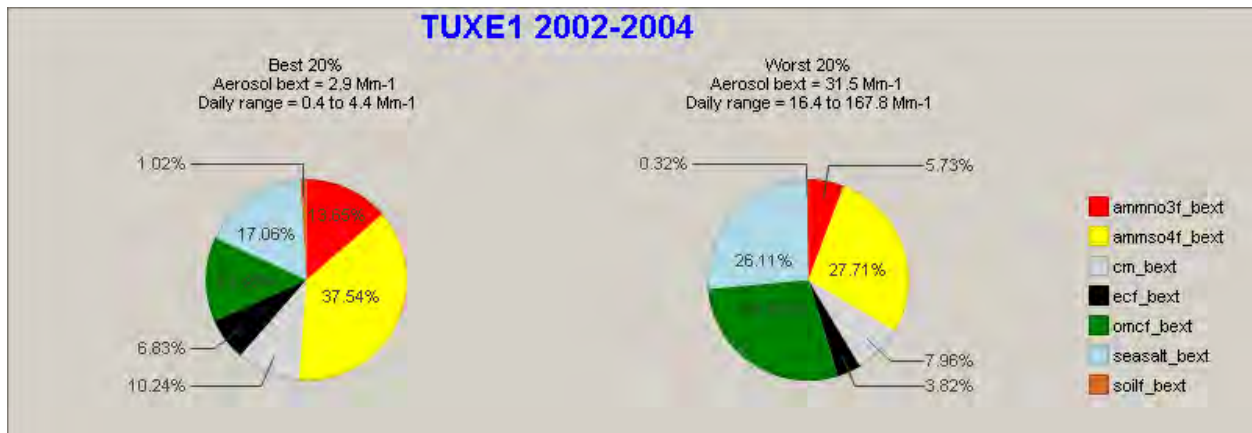
strongest determinants of worst days at the Tuxedni IMPROVE site, but they are highly variable and not amenable to control. The high relative contributions of Rayleigh scattering to best and worst days (Figure III.K.4-60) underscore the low aerosol concentrations monitored at Tuxedni.

Figure III.K.4-60
Relative Contributions of Rayleigh Scattering to Visibility Impairment at Tuxedni on Best (80%) and Worst days (28%)
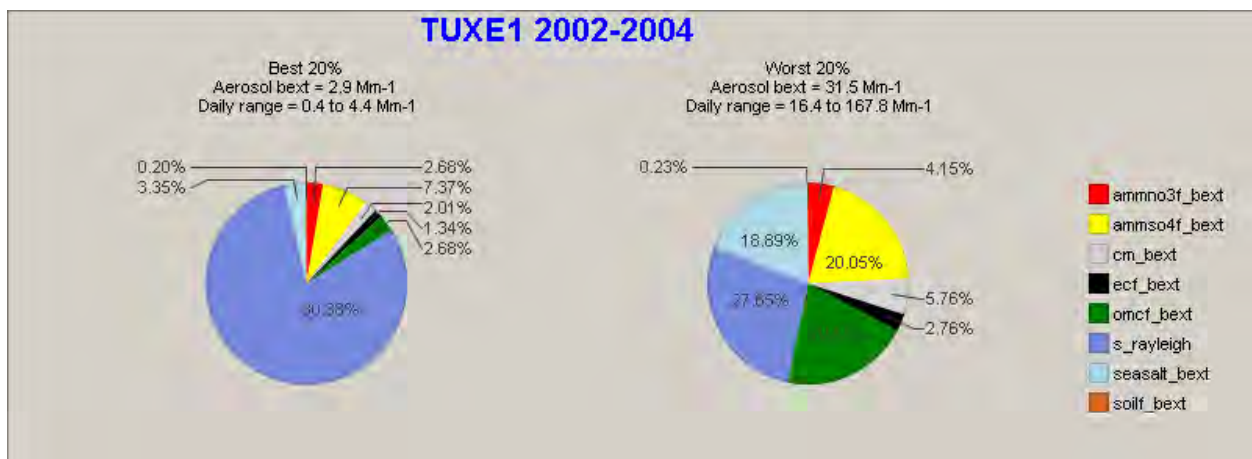
b. Seasonality, 2002-2004

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
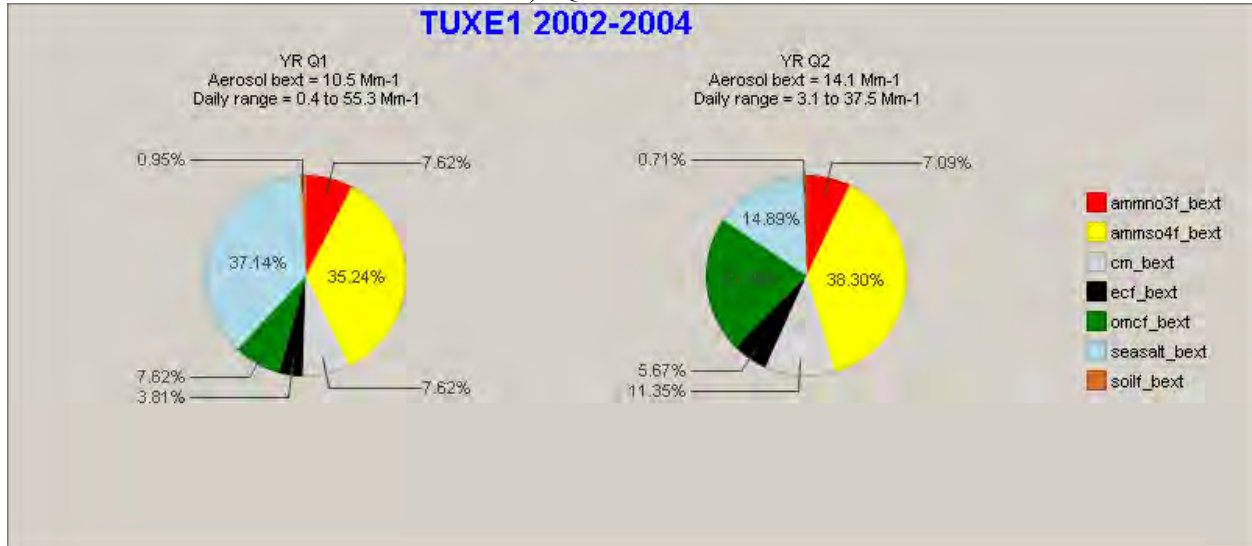
b) Quarters 3 & 4
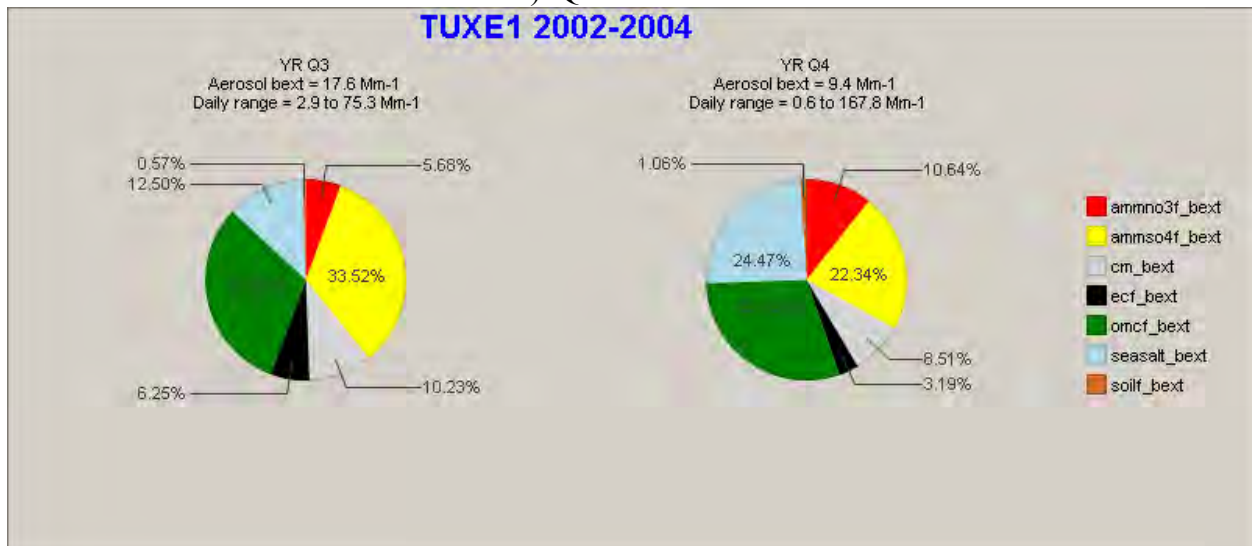
c. Proportional Representation of Pollutant Species: Best Days/Worst Days, by Year

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
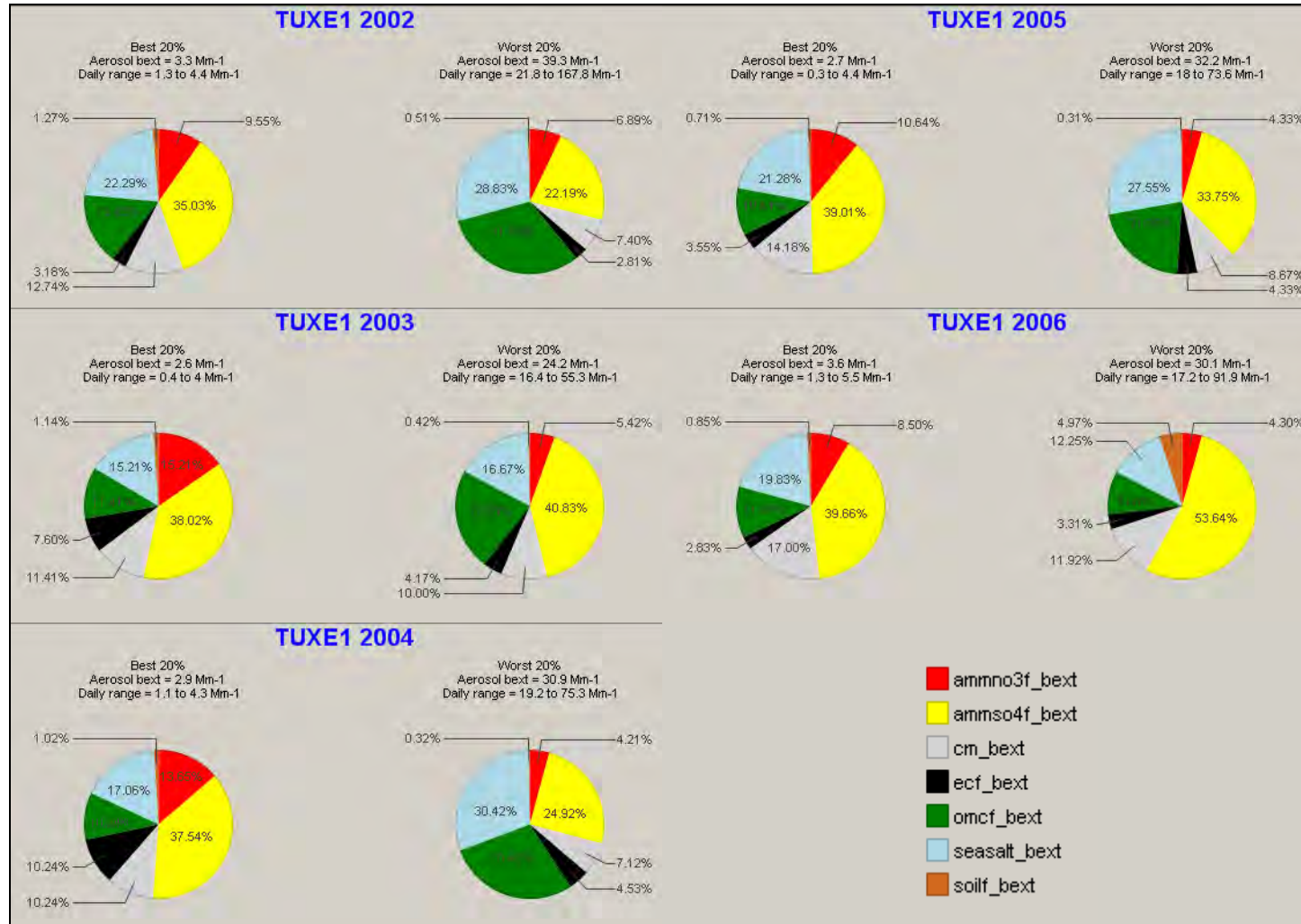
Removal of those components of haze least correlated with human activities can reveal the underlying processes (Figure III.K.4-63). Sea salt is highly dependent on local meteorology and is crucial at this coastal site, varying year to year and seasonally. Organic matter carbon and elemental carbon are 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
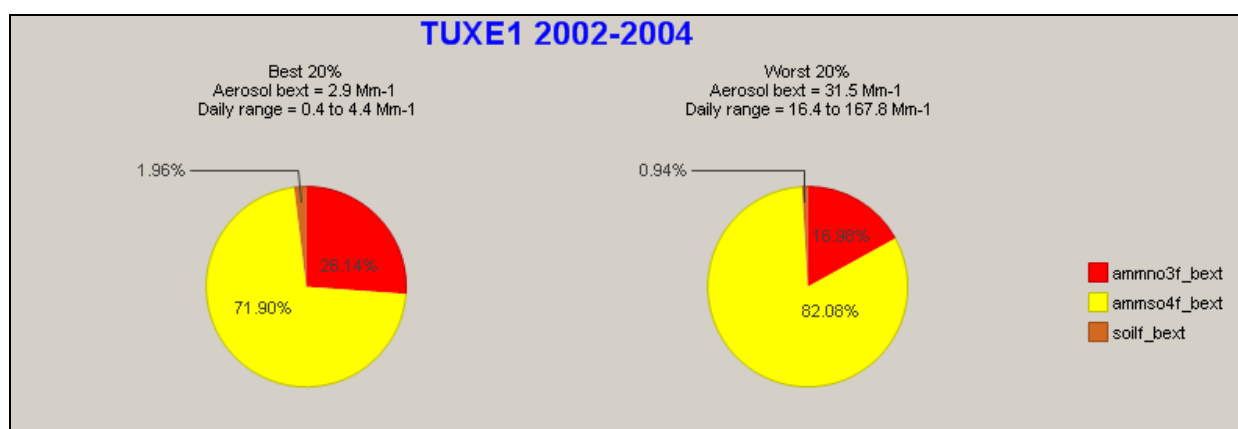
d. Daily, Seasonal, and Annual Variation in Light Extinction Due to IMPROVE Aerosol Species

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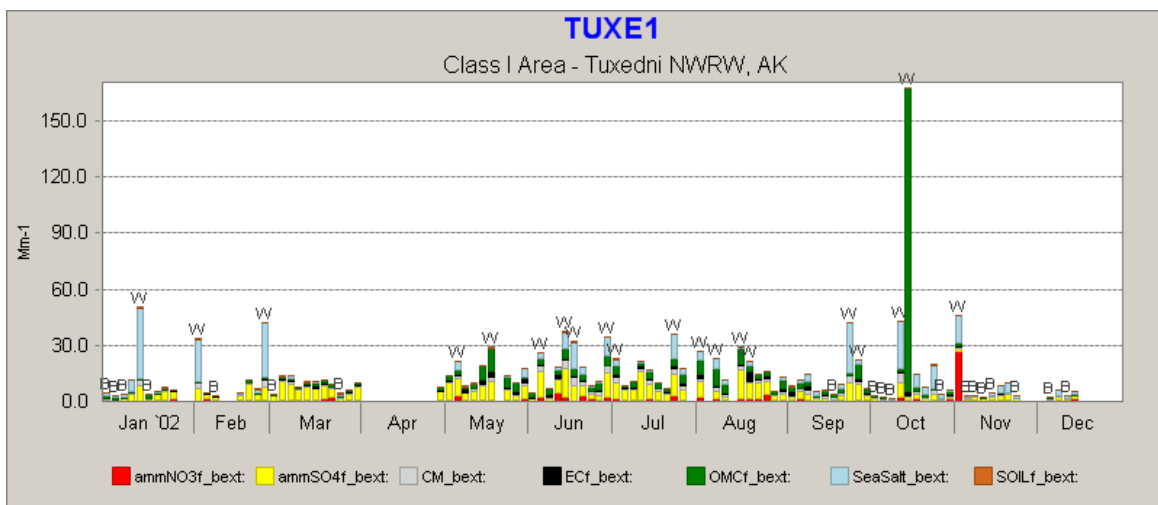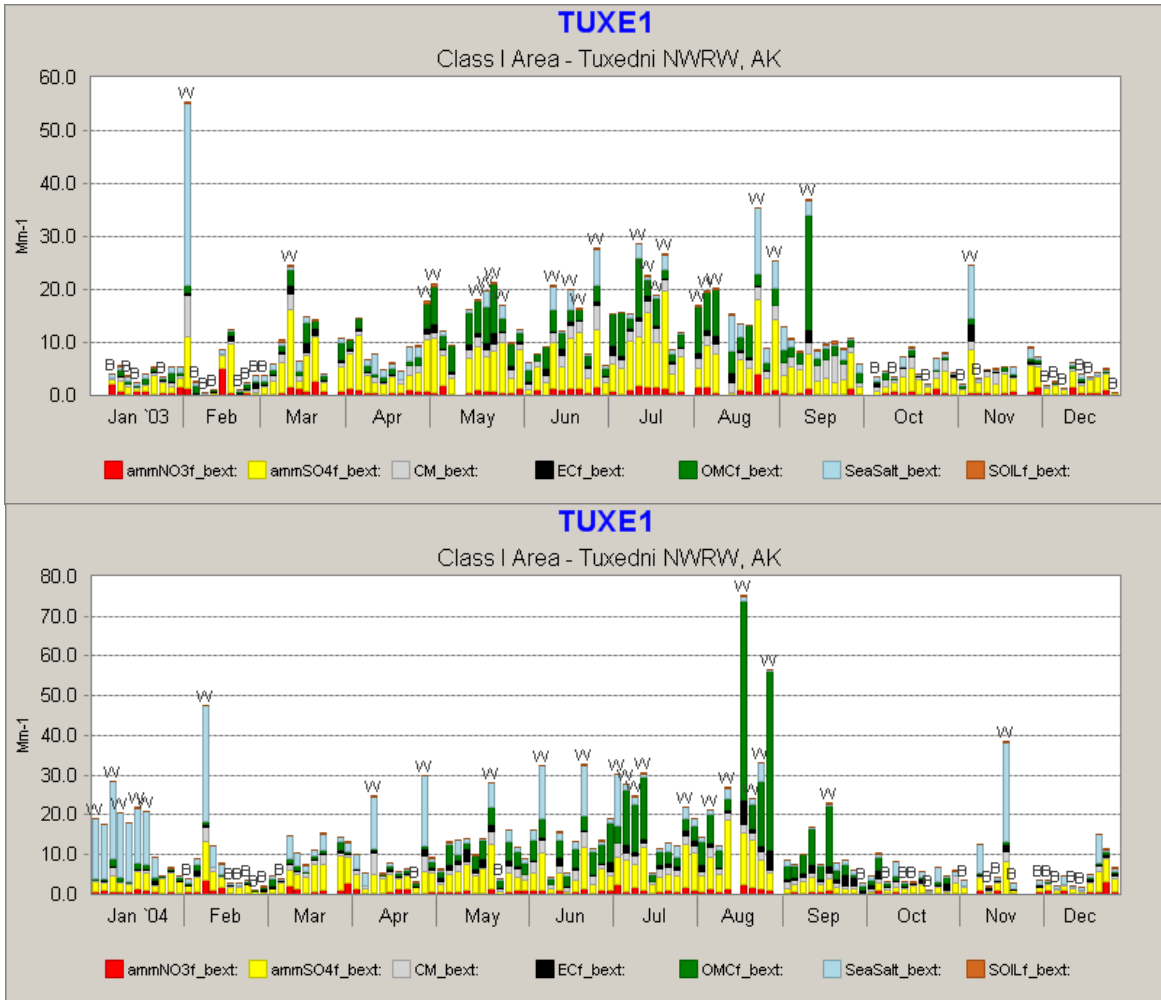
Figure III.K.4-64 (continued)
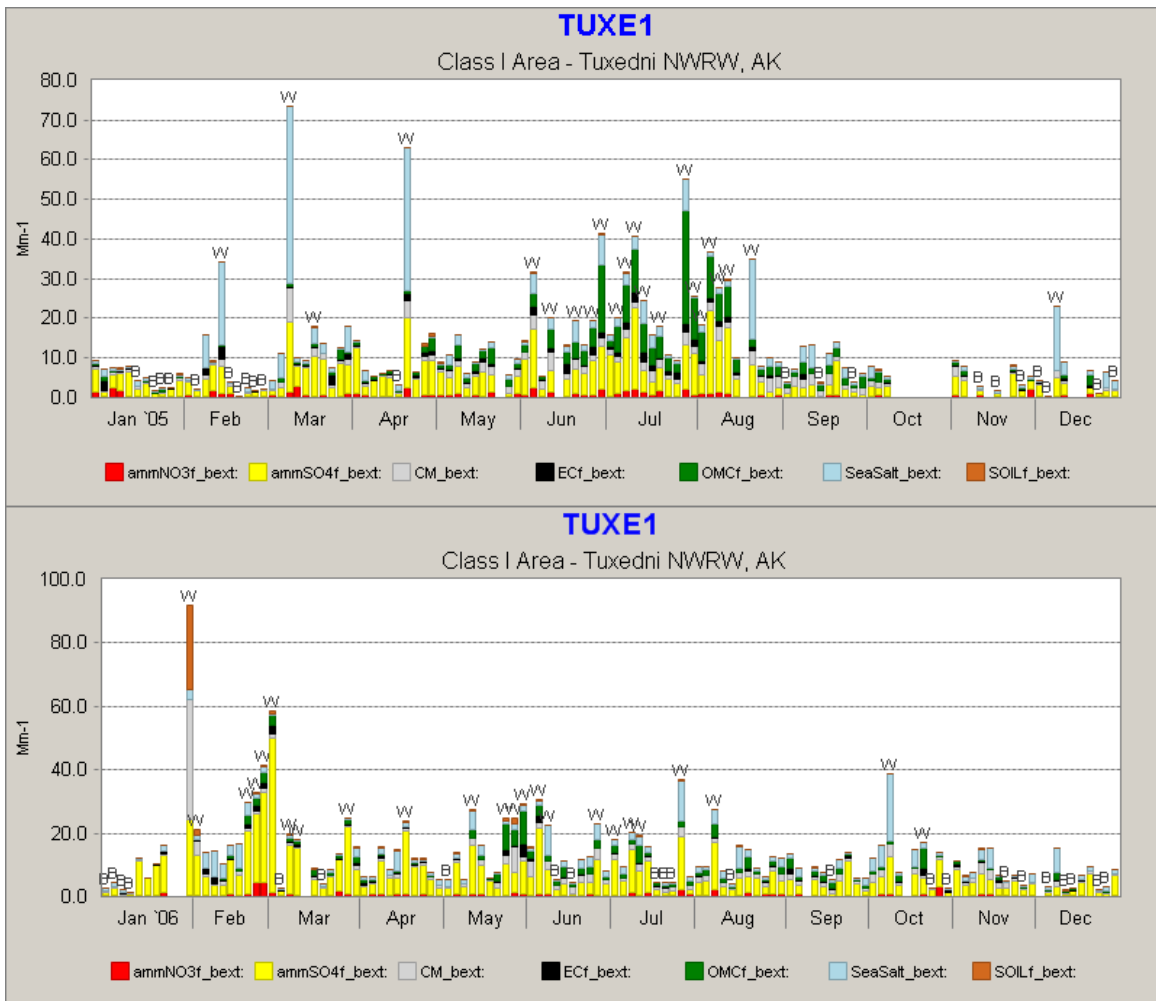**Contribution of Aerosol Species to Light Extinction at Tuxedni on Best and Worst Days,**
**2002-2006**

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
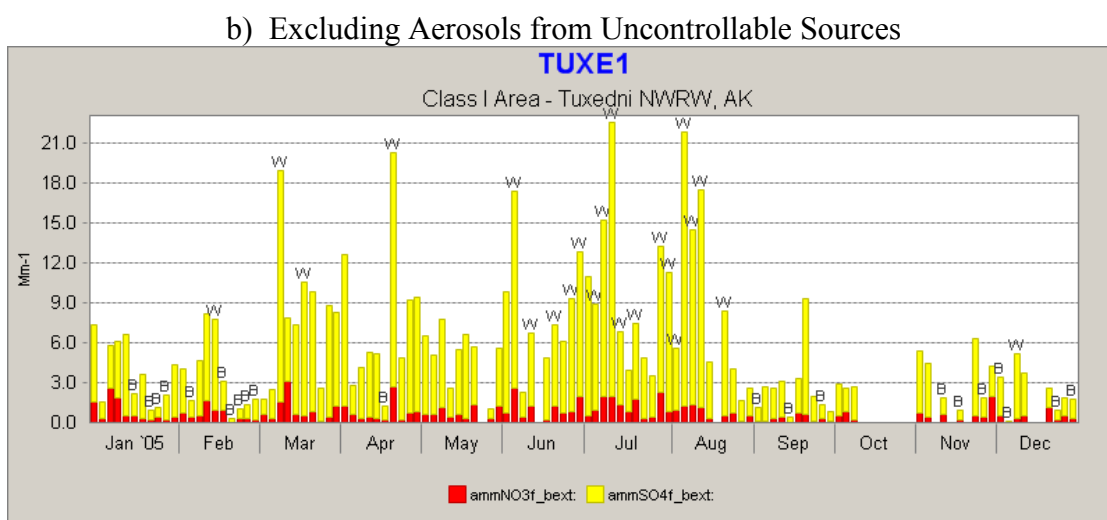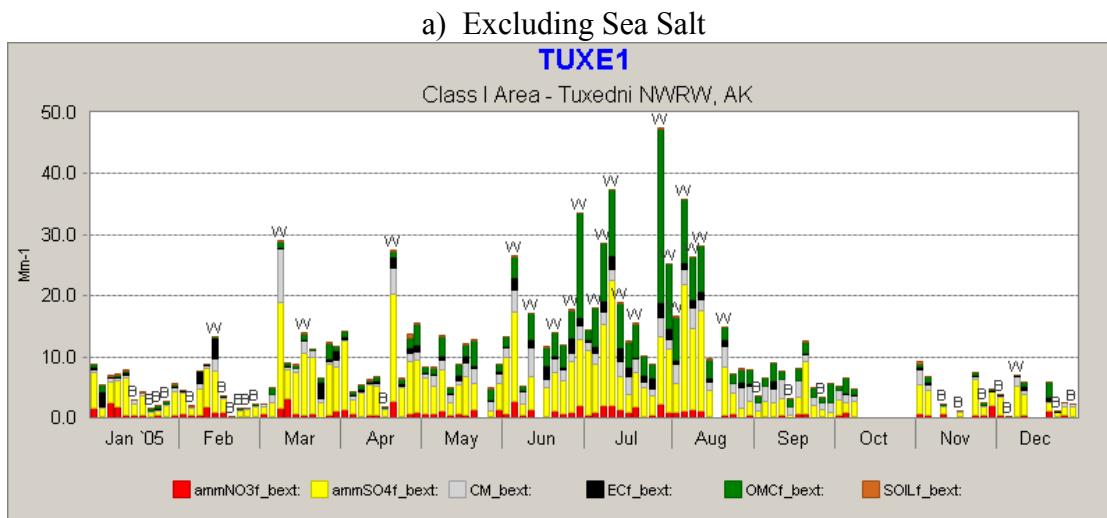
4. Correlations Among IMPROVE Aerosols Monitored at TUXE1

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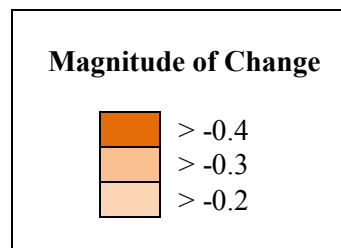
Note: Species pairs with correlations above +/- 0.45 are shown in bold. Shading represents the change in correlations between All days and worst days.
SS - Sea Salt

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
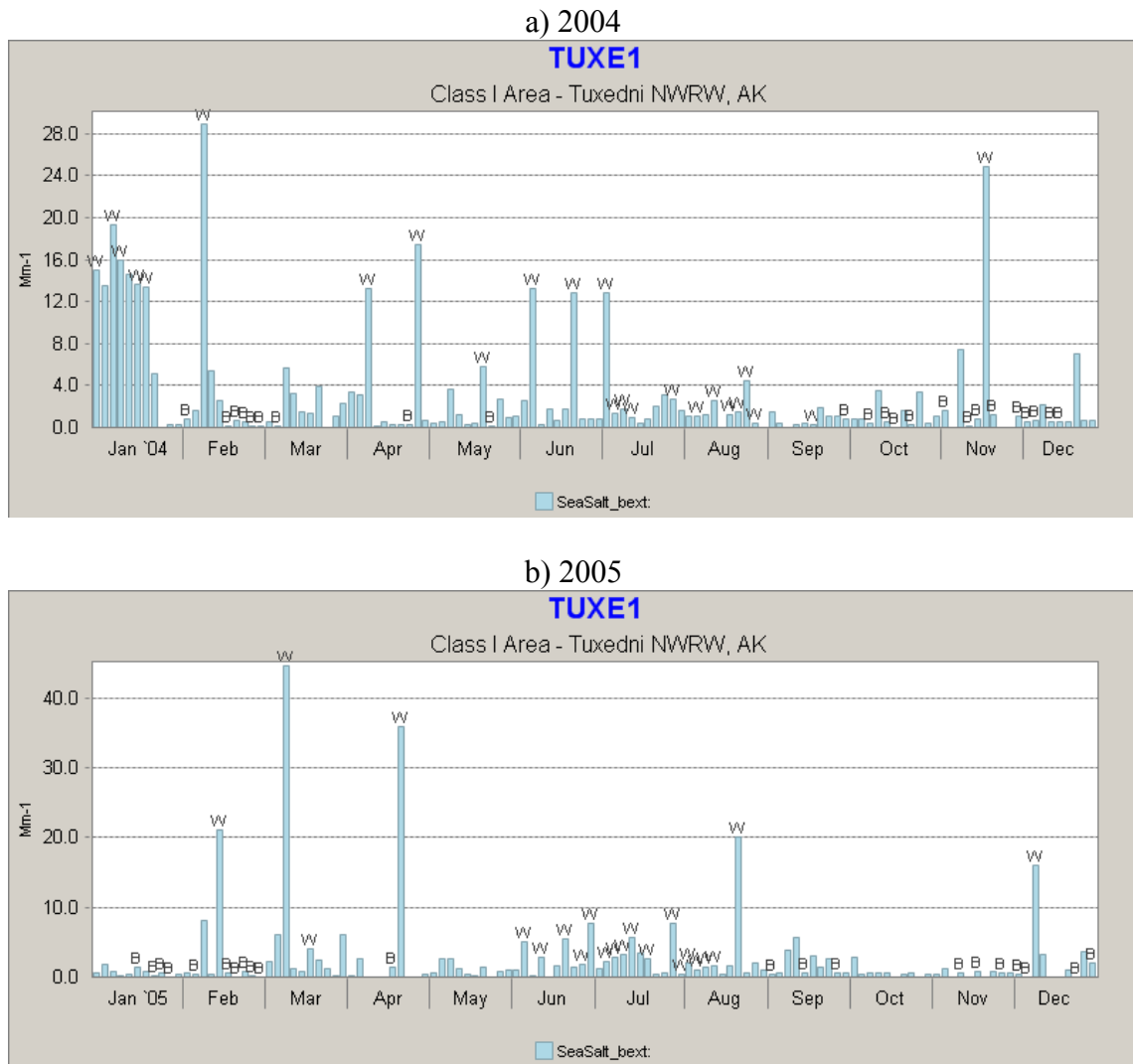
Organic Matter Carbon: Organic matter carbon at Tuxedni is quite seasonal, and may be episodic or continuous. Organic matter carbon increases during the Alaska growing (and wildfire) season, June through September in most years (Figure III.K.4-67, III.K.4-68a). Organic matter carbon is relatively high 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
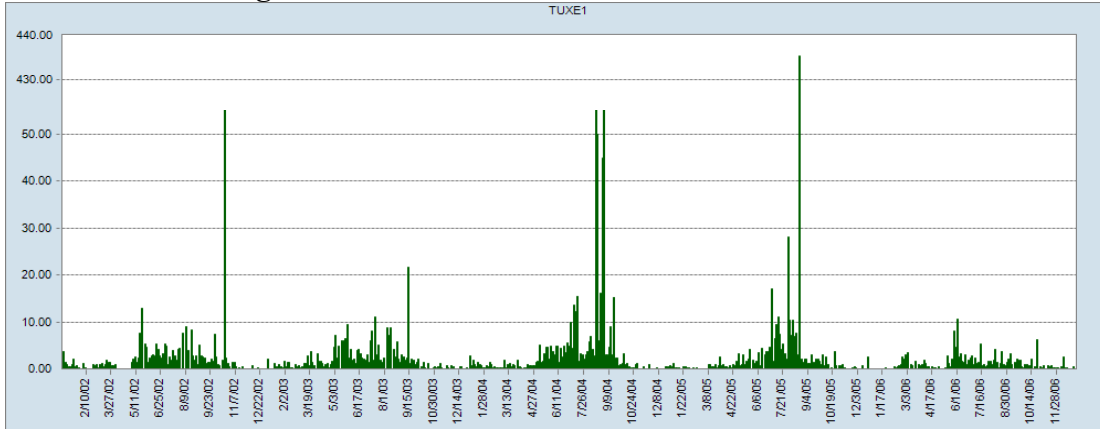
Figure III.K.4-68
Organic Matter Carbon at Tuxedni for 2005, 2006
a) 2005
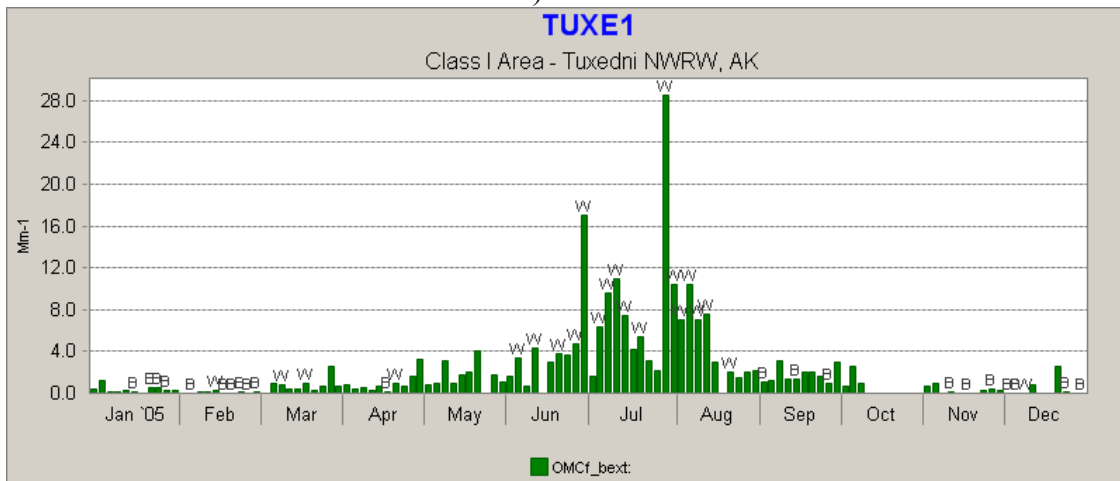
b) 2006
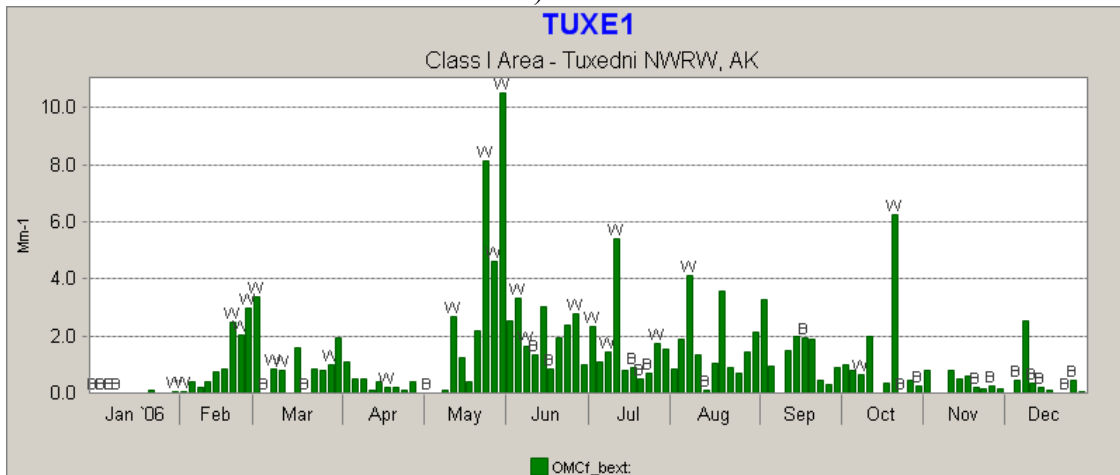
Elemental Carbon at Tuxedni may be episodic or continuous, and is typically seasonal. Figure III.K.4-69 shows the variability of elemental carbon from year to year. Figure III.K.4-70 shows a typical year.

Figure III.K.4-69
Elemental Carbon at Tuxedni for 2002-2006
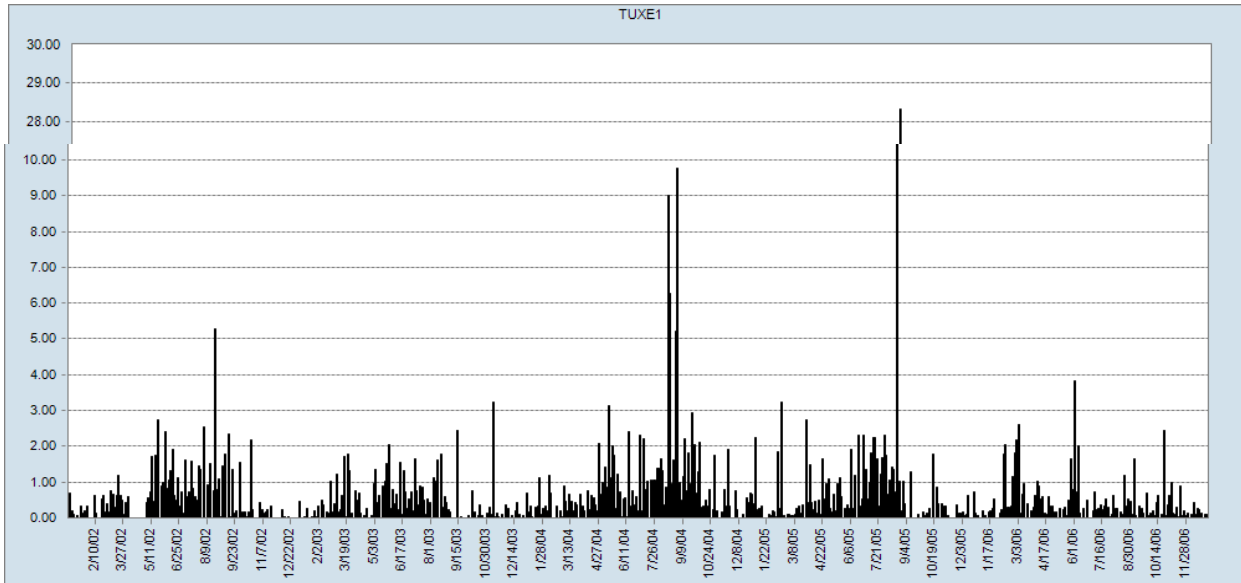
Figure III.K.4-70
Elemental Carbon at Tuxedni for 2005
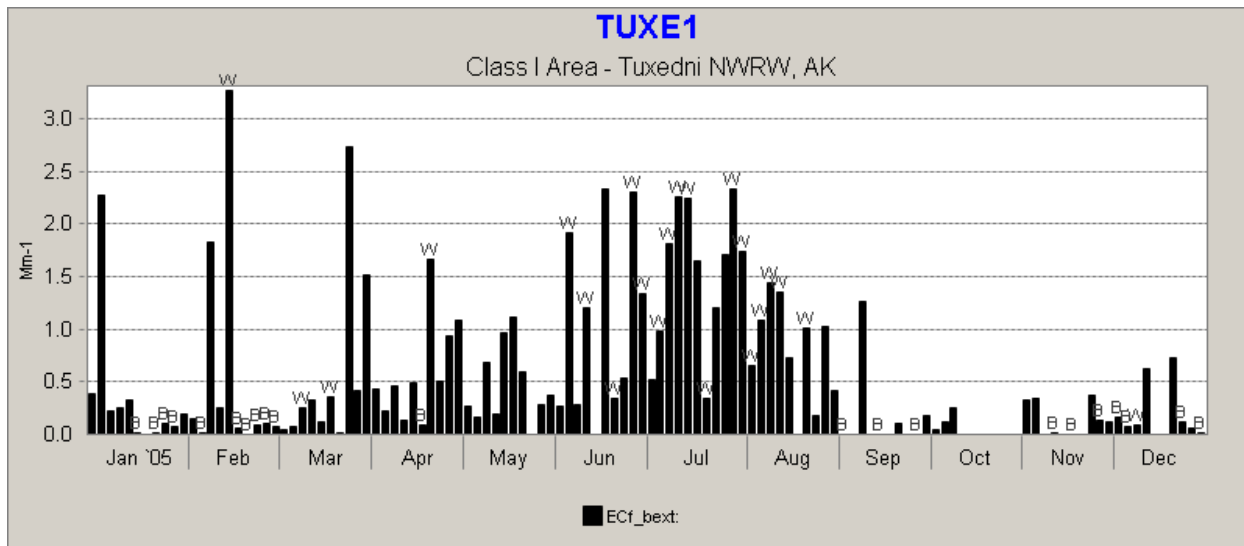
Sulfate at Tuxedni is present continuously, and is typically seasonal, increasing in May through August. Figure III.K.4-71 shows the variability of sulfate from year to year; 2006 is quite different from 2002-2005. Figure III.K.4-72 shows a typical year, with increased summer levels and suggestions of 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
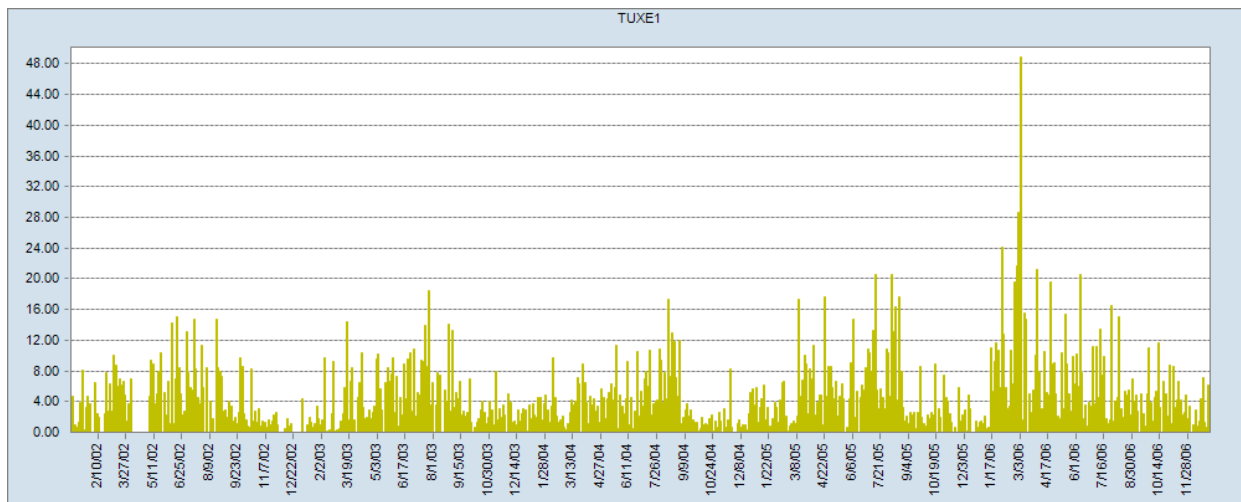
Figure III.K.4-72
Sulfate at Tuxedni for 2005

III.K.4-115
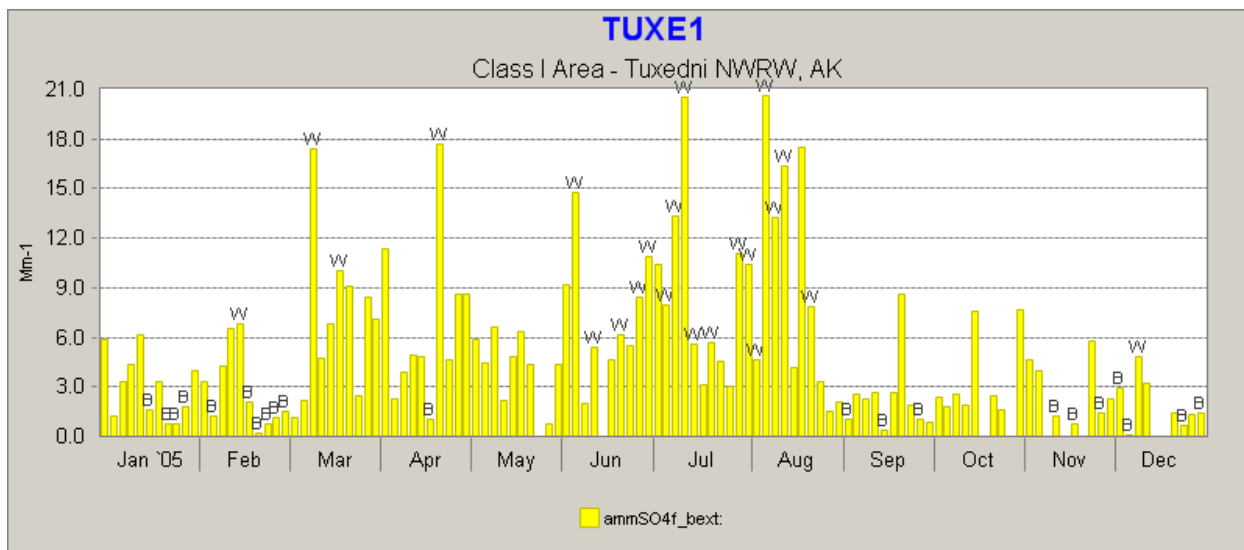
Nitrate extinction is highly variable, so does not show a clear seasonal pattern (Figure III.K.4-73). However, nitrate aerosols may be statistically higher in summer. Nitrate extinction is typically below 3 Mm^{-1}, although peaks above as high as 27 Mm^{-1} do occur (Figure III.K.4-74).
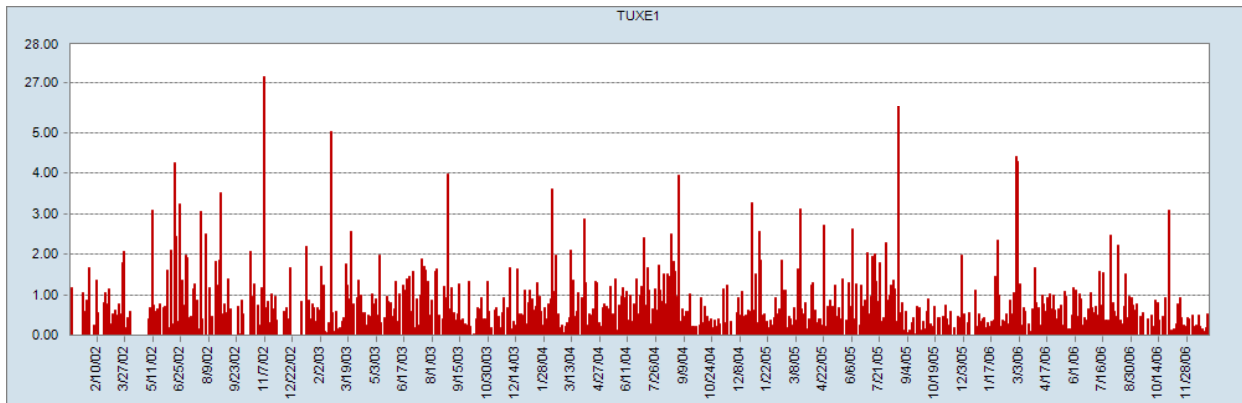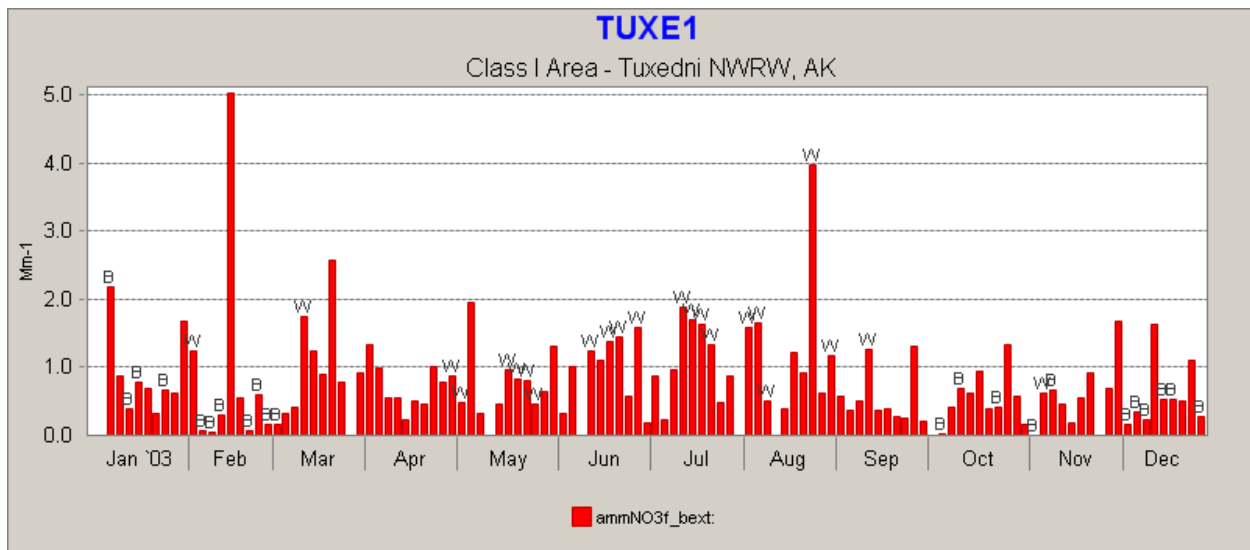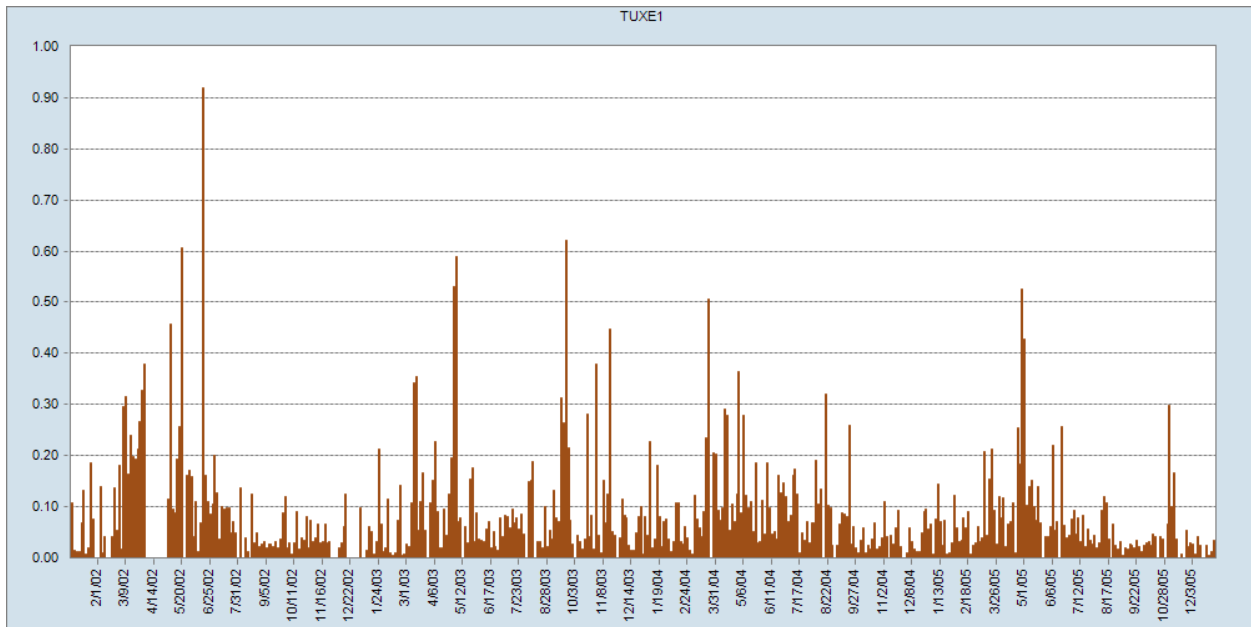
Figure III.K.4-73
Nitrate at Tuxedni for 2002-2006

**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
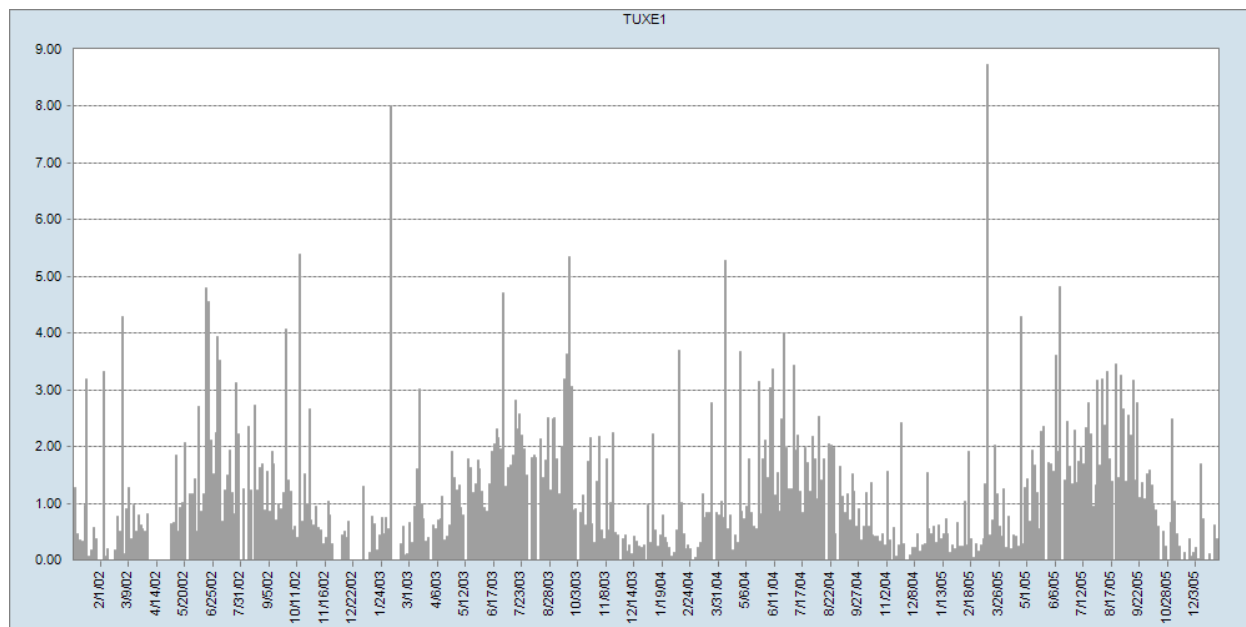
## 6. Fire Impacts at Tuxedni

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
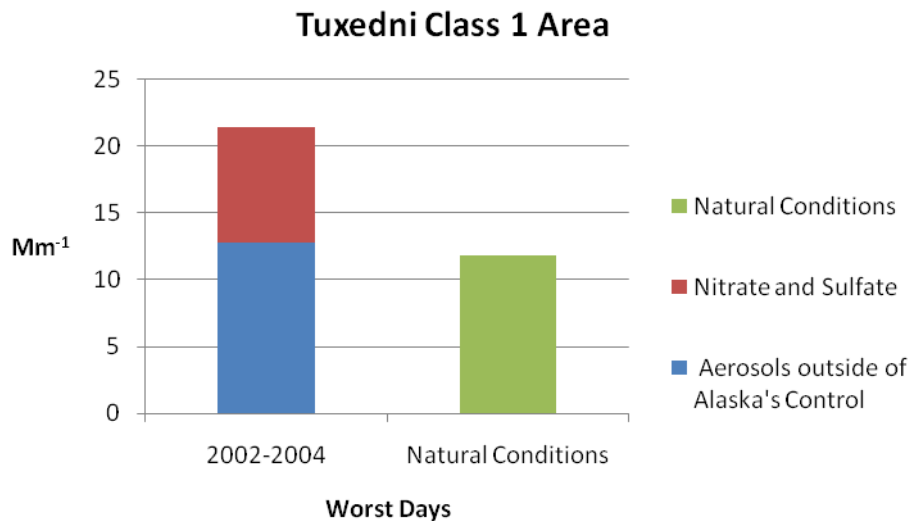
E. Bering Sea Wilderness Area

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
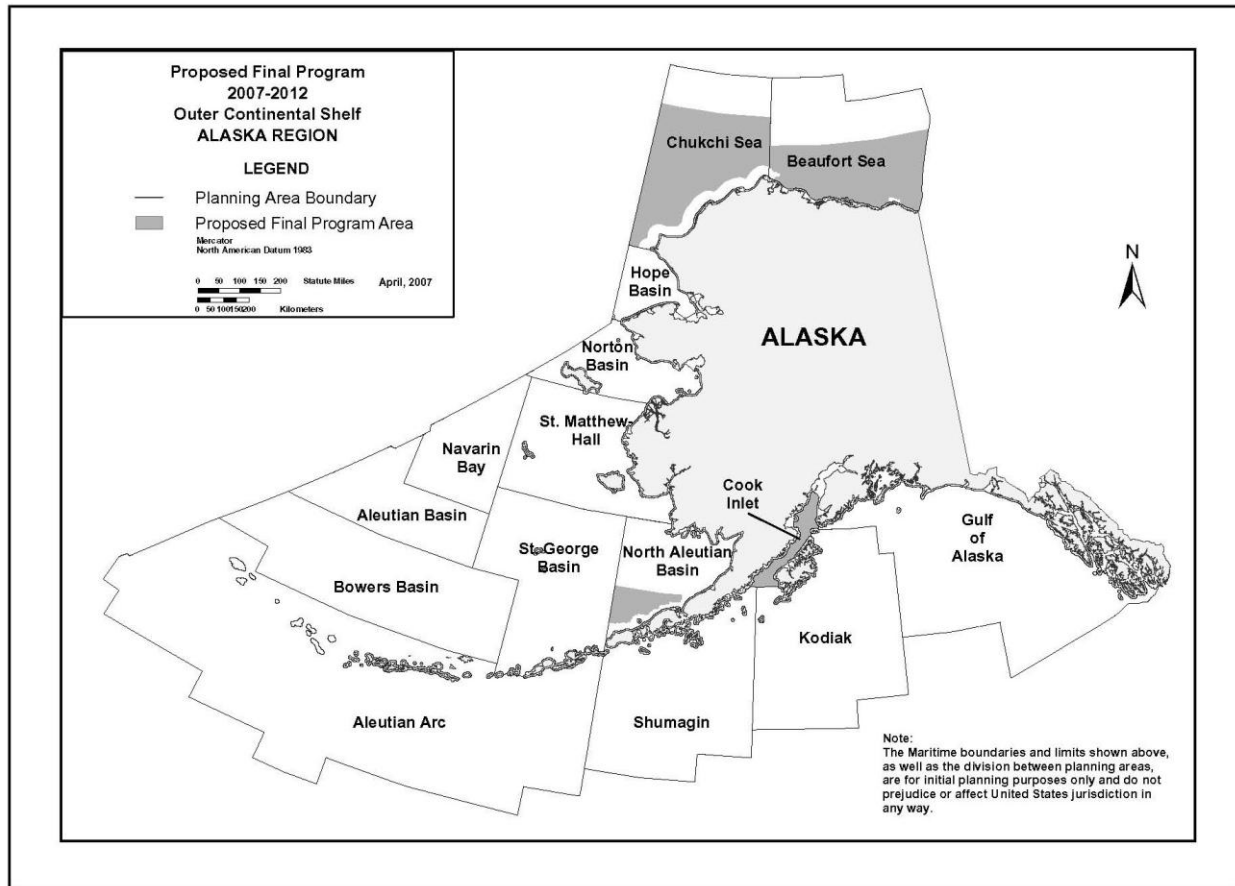
Proposed Final Program Outer Continental Shelf Oil and Gas Leasing Program 2007-2012.
U.S. Department of the Interior, Minerals Management Service April 2007

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.