Alaska Department of Environmental Conservation (DEC)
Division of Air Quality
Technical Analysis Modeling Report for phase 1
Technical Analysis Protocol for phase 2 and 3

(Last Update November 1, 2021)

This Technical Analysis Protocol describes updates to the Fairbanks fine particulate matter (PM 2.5) Non-Attainment area State Implementation Plan (SIP) modelling platform for phase 1 (complete) and phase 2 and 3 development protocol.

1. Review of Moderate, Serious and 5% plan modeling

Moderate and Serious Area SIP modeling summary

The Fairbanks SIP modeling was completed using the photochemical air quality model version CMAQ 4.7.1, emissions processing version SMOKE 2.7, and meteorological processed WRF (Weather Research and Forecast model) data using version MCIP 3. The rationale behind using this model and all of the details for use in the Fairbanks PM 2.5 non-attainment area can be found in the Moderate and Serious Area State Implementation Plans (SIPs).[1,3]

The meteorology was selected as two-two week episodes in 2008 that represent Fairbanks winter time conditions that cause exceedances (Jan 23- Feb 10 and Nov 2 to 22nd). The details of the meteorology selection can be found in the moderate area SIP.[1,2]

Moderate Area Review

The 35 days selected to model include FRM data at the Fairbanks State Office Building (SOB) monitoring site, 12 days were used for model performance evaluation from 2008. In 2008, there was no FRM monitored data in North Pole, which is now the violating monitor. The base year for Moderate Area SIP was 2009 with a 5 year Design Value of 44.7 µg/m^3 at the State Office Building monitor and a future design value (FDV) of 39.6 µg/m^3 in 2015 and 33.5 µg/m^3 in 2019.[1]

Serious Area Review

The Serious SIP used the same 2008 meteorology and a 2013 base year with a 5 year modeling design value from 2011-2015. The modeling design values were used for North Pole (Hurst Rd monitor), State Office Building monitor, NCORE monitor and North Pole Elementary (NPE) monitor. The modeling design value is calculated using monitored data averaged from 3 design values (3 3-year averages of the 98th percentile) from the monitor (Hurst Rd is 2 3-yr averages due to availability). These modeling design

---

[1] Fairbanks PM2.5 Moderate SIP (alaska.gov)

[2] Research Regarding FNSB Particulate Matter (alaska.gov) ***Fairbanks, North Star Borough AK PM$_{2.5}$ Nonattainment Area WRF-ARW, Gaudet et al., Pennsylvania State University, January 2012.***

values are in Table 1.1. [3] The future design values were based on CMAQ model output and using the Sandwich method to have speciation monitor data equal FRM data and add together non-linear species of PM 2.5 from future years of air quality model runs. Details of the SANDWICH method recommended by EPA and all of the modeling calculations are contained in the Moderate and Serious area SIPS. [1,3]

Table 1.1 Five Year Design Value (ug/m3) for 2011-2015 [a]

	3-yr DV						Modeled DV (5-yr except Hurst)
Site	2013	2014	2015	2016	2017	2018	2011-2015 rolling average
SOB	41	40	35	37	38	37	38.9
NCORE	40	39	35	34	35	32	38.0
Hurst Road	N/A	139	124	106	85	66	131.6
NPE	45	N/A	N/A	N/A	N/A	N/A	45.3

a The modeling design value is monitored data averaged from 3 3-yr design values from the monitor or a 2 3-yr design value based on available data for Hurst.

The Future Design Value for the year 2019 was calculated from a 2013 base year and the summary for all four monitored sites is in Table 1.2.

Table 1.2 2013 Base Year and Future Design Values for the 2019 control run and 2029 expeditious attainment year

	NPFS Future Design Value (μg/m^3)	**NPE** Future Design Value (μg/m^3)	**NCORE** Future Design Value (μg/m^3)	**SOB** Future Design Value (μg/m^3)
2013 Base Year	131.63	45.3	37.96	38.93
2019 Control	104.16	36.42	28.87	29.57
2029 Expeditious Attainment	33.87	17.16	18.86	19.41

[3] Fairbanks PM2.5 Serious SIP (alaska.gov)

The year 2019 was not able to show attainment with the change in violating monitor to the Hurst Road monitor in North Pole, which is still in the Fairbanks non-attainment area. Additional attainment modeling was performed for the years 2024 and 2029.

5% Plan – 2020 amendment

The 2020 amendment to the Serious SIP modeling included a new 4 year design value from the years 2016 to 2019, a base year of 2019. The changes in design value that decreased to 64.7 ug/m3 as well as the end of 2019 has prompted a new baseline run of 2019 and a new attainment year modeling that is more expeditious than 2029 and was submitted to EPA Region 10 (R10) in December of 2020.

Table 1.3 Design Value Summary 2013-2019 of monitored data

	1 yr 98% tile FRM concentrations							3-yr Design Value							Modeled DV (5 yr except Hurst)[a]	Modeled 4 yr DV [a]
Site	2013	2014	2015	2016	2017	2018	2019	2013	2014	2015	2016	2017	2018	2019	2011-2015 rolling average	2016-2019
SOB	36.3	34.5	35.3	39.7	38.0	27	27.7	41	40	35	37	38	35	31	38.9	32.9
NCORE	36.2	31.6	36.7	30.3	34.4	25.3	27.7	40	39	35	33	34	30	29	38.0	29.6
Hurst Road	121.6	138.3	111.6	66.8	75.5	52.8	65	NA	139	124	106	85	65	64	131.6	64.7
A st							34.1							N/A		

a The modeling design value is monitored data averaged from 3 3-yr design values from the monitor or 2 3-yr design values due to availability.

The modeling platform used in the Moderate area and Serious Area SIPs were the same with one modeling performance analysis at the State Office Building monitor. There was not monitoring in North Pole until 2009.

Model Performance Summary

The only model performance results were from the initial set up of the CMAQ modeling and used the speciation data from the State Office Building. This monitor was on a 1 in 3-day schedule and 10 days were used to verify the model performance in year 2008. The overall PM 2.5 performed well, but the elemental carbon and organic carbon (OC) were overestimated (EC) and sulfate (SO4) and ammonium (NH4) performed poorly.[1]

Table 1.4 Modeled versed Observed speciation from the Moderate Area SIP

Species	Observed ($\mu g/m^3$)	Modeled ($\mu g/m^3$)
$PM_{2.5}$	36.1	35.7
OC	17.0	24.5
EC	2.3	4.3
SO_4	6.2	2.1
NO_3	1.6	1.3
NH_4	3.1	1.2
OTH	6.3	2.3
SOA	N/A	0.01

2. Summary of need for an updated modeling platform

There are several reasons why an updated modeling platform may be beneficial. The current modeling platform is outdated and new versions are available of the meteorological model (WRF), the air quality model (CMAQ) and the pre-processor models (SMOKE, MOVES, MCIP). The last meteorological episodes modeled are based on 2008 winter conditions and may no longer be representative of Fairbanks winter conditions. There were only two two-week episodes for meteorology with only 12 days of speciation data for model performance. There was no model performance completed in North Pole; the violating monitor for Fairbanks non-attainment area is at Hurst Road in North Pole. The North Pole area remains the focus for control analysis, model attainment, and poor sulfate performance. The past controls have centered on woodstoves and mainly organic carbon reduction. As the PM 2.5 attainment is closer and sulfate controls need to be further assessed, the model does not perform well for sulfate and it is difficult to quantitatively assess the benefit of sulfate controls.

Table 2.1 Comparison of the technical components of the current CMAQ 4.7.1 versus the new CMAQ system 5.3.2

CMAQ 4.7.1	CMAQ 5.3.2
Aero 5 aerosol chemistry	Aero7 aerosol chemistry
MCIP 3 (from WRF 3.1)	MCIP 5 (from WRF 3.1)
SMOKE 2.7	SMOKE 4.7
Model Performance in Fairbanks	Model performance in Fairbanks and North Pole
Speciation collected at State Office Building	Speciation collected at Hurst Rd and NCORE
2008 WRF 3.1 meteorology – 22 days	2019/2020 WRF 4.2 meteorology – 74 days

Updating the modeling platform required not only North Pole FRM and speciation data that was not available before, but new meteorology and WRF model runs, CMAQ model version update, and preprocessor model version update (SMOKE, SMOKE-MOVES and MCIP). In the next few paragraphs and Table 2.2 below, each model update and the timeline is summarized:

Table 2.2. Phases 1 ,2, and 3 of the technical updates to the modeling platform and estimated timeline

Phase 1 Development of the CMAQ 5.3.1 system using existing emissions and meteorology

Section	Component	Estimated Timeline	Notes
2.1	MCIP5 (using original 2008 WRF meteorology)	completed 7/20/20	EPA ORD as part of the FY20 RARE grant
2.2a	CMAQ 5.3.1 compile	completed 8/20/20	Compiled on the DEC Linux server using MPI and the benchmark simulation
2.2b	CMAQ 5.3.2 compile and comparison (5.3.2 released in October of 2020 and	completed	DEC/Contractor

	contained significant updates to woodstoves)		
2.3	Upgrade to SMOKE 4.7 using Serious SIP 2019 EI	completed January 2021	Contractor
2.4	CMAQ 5.3.2- 2019 EI and 2008 WRF (MCIP5)	completed 7/2021	DEC – Initial comparison modeling run on the original 2008 met and emissions
	EPA review of phase one report, concurrent with DEC review	**8/2021**	**EPA/DEC**

Phase 2 Development of the CMAQ 5.3.2 system with new emissions and meteorology

Section	Component	Estimated Timeline	Notes
2.5	WRF Meteorology simulations for new episode winter 2019/2020	Currently in process/ November 2021	Contractor
2.6	MCIP5- 2019-2020	October 2021	Contractor
2.7	North Pole Speciation Data analysis of entire winter and SMAT	October 2021	DEC
2.8	Inventory Step A Emission Inventory Revisions (2019): -Day/Hour-specific point sources - Episodic temperature dependence for other sectors	September 2021	Contractor
2.9	Inventory Step B Emission Inventory Revisions (All Applicable Years): - Updated space heating survey - Integration of MOVES3	2023	Contractor / DEC
2.10	SMOKE 4.7 2019/2020 New episode	November 2021	Contractor
2.11	CMAQ 5.3.2 model performance	February 2022	DEC/Contractor
2.12	EPA review of CMAQ 5.3.2 model performance	1-2 months	EPA
2.13	CMAQ 5.3.2 model run with new 2019 emissions and meteorology *timing subject to new activity data if collected for 2019	Effort to begin after approved model performance model runs and inventory step revisions 1-2 months of effort	DEC / Contractor – fully updated QA/QC and model performance version of CMAQ 5.3.2

Phase 3 Modeling for Regulatory Purposes

Section	Component	Estimated Timeline	Notes
2.14	5 year modeling design value	After EPA approves model performance 2022 -2023	DEC/EPA

2.15	Updated Emissions Inventory with new base year	After EPA approves model performance 2022 -2023	DEC/Contractor
2.16	SMAT /Sandwich	Jan/Feb 2022	DEC
2.17	CMAQ Future control runs (2-5 model runs)	After EPA approves model performance 2022 -2023	DEC
2.18	New Precursor Demonstration	After EPA approves model performance 2022 -2023	DEC

Phase 1

The initial phase of the modeling update is to run CMAQ 5.3.2 with existing 2008 WRF meteorology and 2019 Serious SIP emissions inventory. The purpose of this phase is to directly compare CMAQ model version differences with existing inputs. This will allow time for getting a new CMAQ system up and running and understanding a direct comparison of new speciation and chemistry with no other changes. The following four sections describe the steps to running CMAQ 5.3.2 versus CMAQ 4.7.1 with no other changes.

2.1 MCIP

MCIP is the meteorology preprocessor for the WRF meteorology to input into the CMAQ model. The original 2008 meteorology translation from WRF output to CMAQ input was completed using MCIP 3 for CMAQ 4.7.1. MCIP 3 is not compatible with CMAQ 5.3.2. For the first phase of the modeling update, a direct comparison from the old 2019 Serious SIP run using CMAQ 4.7.1 to the new CMAQ 5.3.2 is needed. The first step in the modeling platform development is to run the same meteorology and emissions through CMAQ 5.3.2. The original 2008 meteorology was reprocessed with MCIP 5 by EPA ORD as part of the FY20 RARE grant. The MCIP 5 data is in 12 min resolution and the emissions are in hourly.

2.2 Technical specifications for CMAQ 5.3.2

The new version of CMAQ 5.3.2 was compiled using PGI 19.10, updated netCDF-C and netCDF-fortran libraries. The operating environment is Centos7 and the multiple processing capacities use OpenMPI 3.1.3. The virtual Linux system runs with 16 processors and is run by DEC. Ramboll is the contractor for the model performance of 5.3.2 and the WRF episode. They have built a similar CMAQ 5.3.2 version compiled with PGI to run as a parallel system.

2.2 Parallel Machine Comparison

DEC and Contractor compiled parallel systems using PGI as the compiler and the CMAQ version 5.3.2, the latest release at the time the comparison was conducted. The run scripts were set equal and the second day was run until completion for a machine comparison on January 24, 2008. The plots below show the difference between the two machines by daily average for PM 2.5 and each major species (NH4, SO4, NOX, VOC, EC, OC). In addition, the individual plots for each machine are shown for entire domain comparison.

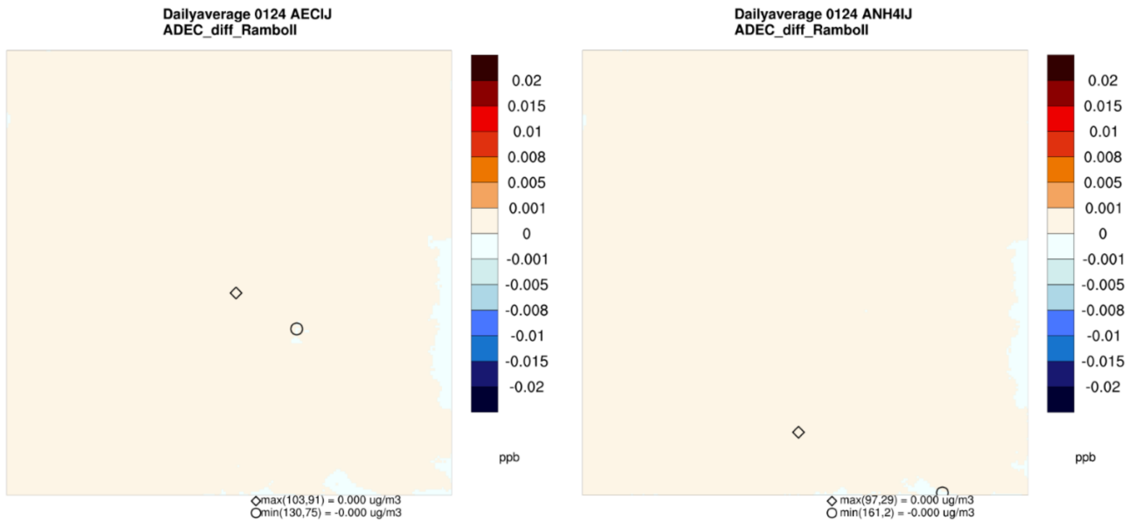


Figure 2.2-1. Elemental Carbon and Ammonium difference in ug/m3 between the DEC and Ramboll CMAQ version 5.3.2 modeling systems

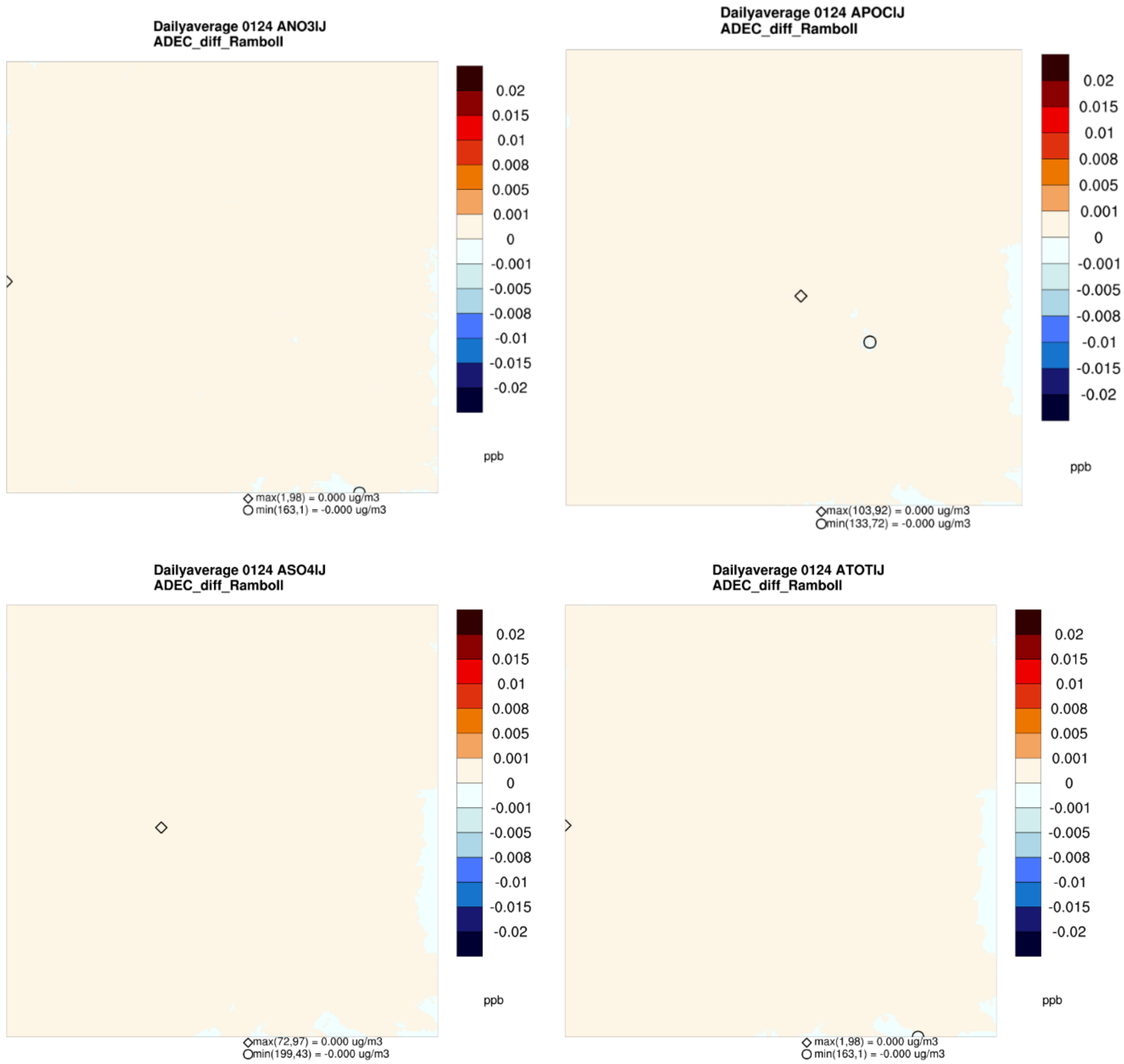


Figure 2.2-2. Nitrate (top left), Organic Carbon (top right), Sulfate (bottom left), total PM 2.5 (bottom right) difference in ug/m3 between the DEC and Ramboll CMAQ version 5.3.2 modeling systems

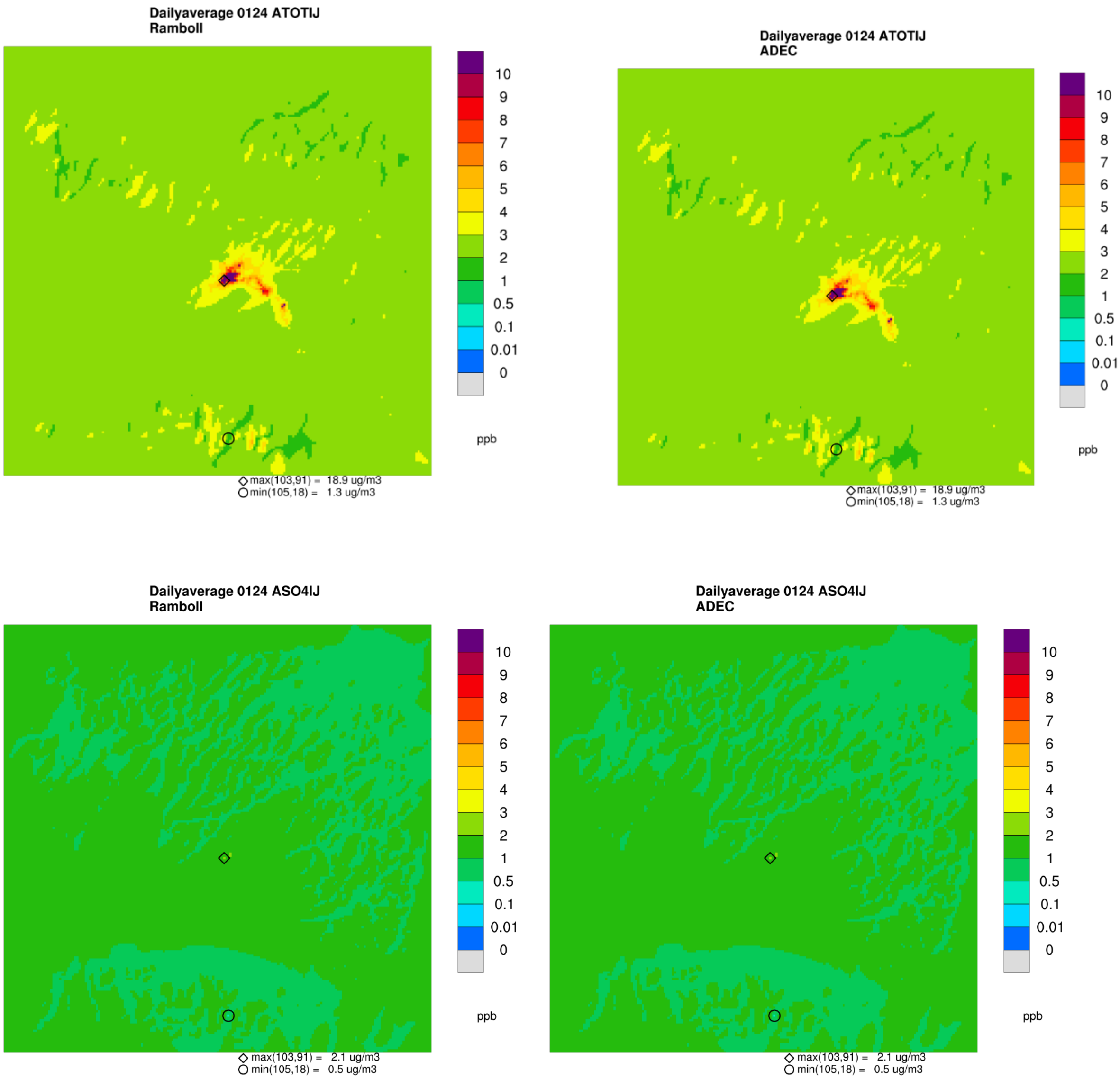


Figure 2.2-3. Total PM 2.5 and sulfate for Ramboll (left) and DEC (right) in ug/m3 for the DEC and Ramboll CMAQ version 5.3.2 modeling systems

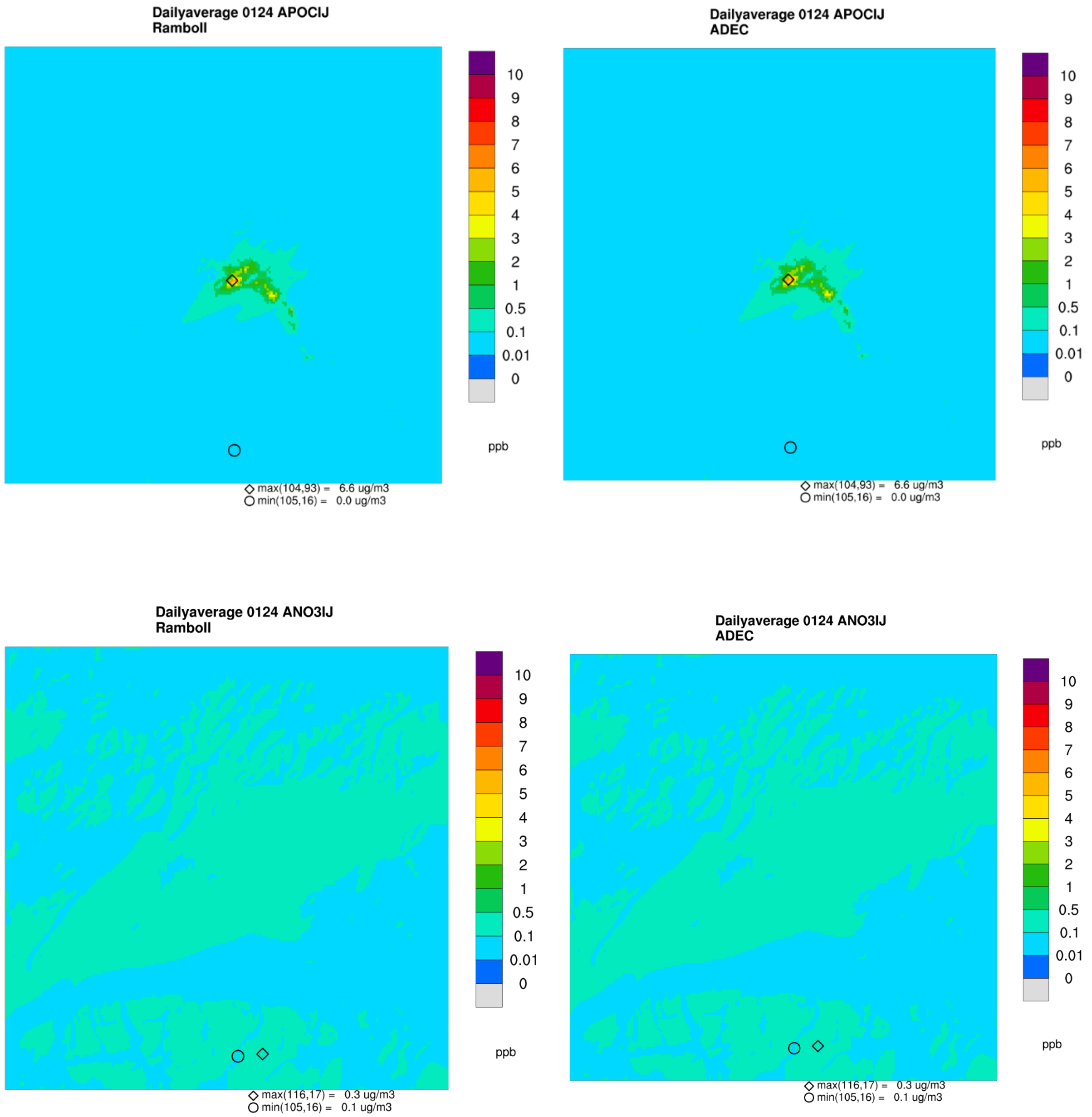


Figure 2.2-4. Primary Organic Carbon and nitrate for Ramboll (left) and DEC (right) in ug/m3 for the DEC and Ramboll CMAQ version 5.3.2 modeling systems

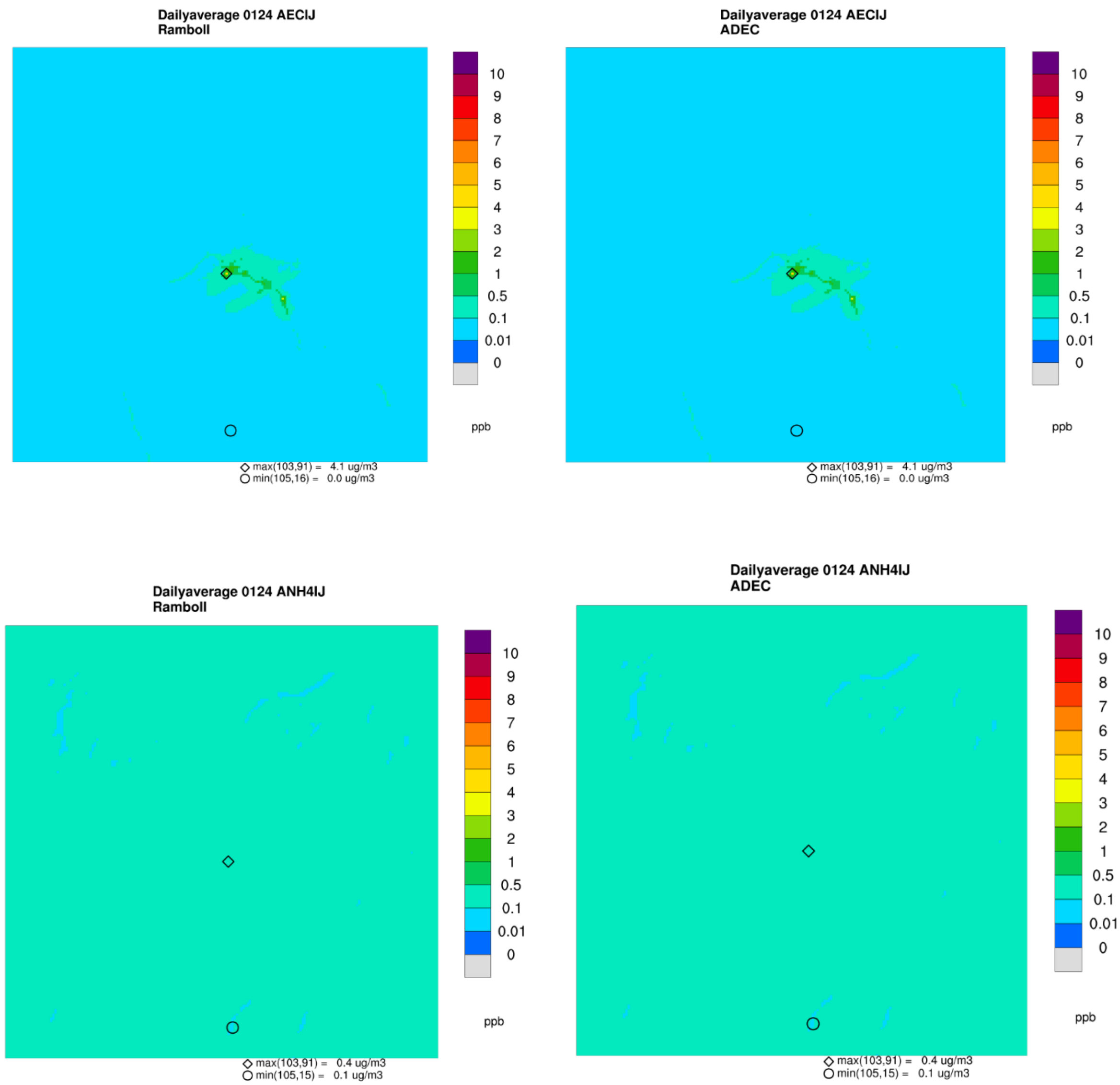


Figure 2.2-4. Elemental Carbon and Ammonium for Ramboll (left) and DEC (right) in ug/m3 for the DEC and Ramboll CMAQ version 5.3.2 modeling systems

2.3 **SMOKE** – 2019 EI processed through SMOKE

Updating the SMOKE 2.75b to SMOKE 4.7 (an updated version for CMAQ 5.3.2). The SMOKE preprocessor model has updated speciation profiles and more emission profile categories. The same 2019 Serious SIP emissions inventory needs to be run through SMOKE 4.7 to input into CMAQ 5.3.2. The DEC Linux server does not have a compiled current version of SMOKE. The tasks for DEC's contractor to run SMOKE is as follows:

- Run the 2019 emissions through SMOKE 4.7
- Set up and compile SMOKE 4.7 on the DEC Linux server for future use (Revisit after phase 2 CMAQ v5.3.2model performance)

Table 2.3.1 provides a comparison of SMOKE 2.7 and SMOKE 4.7 emissions by source sector for the same input inventory (2019 Baseline from the Fairbanks 2020 Amendments Plan) for the Grid 3 modeling domain, averaged over the 35-day historical 2008 modeling episodes.

Table 2.3.1 Comparison of SMOKE 2.7 and SMOKE 4.7 Emissions (2019 Baseline, Grid 3 Domain)

2019 Baseline Grid 3 Domain Emissions (2008 Episode Average, tons/day)					
Source Sector	**$PM_{2.5}$**	**NOx**	**SO_2**	**VOC**	**NH_3**
SMOKE 2.7 Emissions[a]					
Point	0.59	10.36	5.87	0.03	0.07
Area, Space Heating	2.21	2.61	4.16	9.55	0.14
Area, Other	0.24	0.38	0.03	2.25	0.05
On-Road Mobile	0.27	2.30	0.01	4.90	0.05
Non-Road Mobile	0.36	1.75	7.78	5.26	0.00
SMOKE 2.7 TOTALS	**3.67**	**17.40**	**17.85**	**22.00**	**0.33**
SMOKE 4.7 Emissions					
Point	0.54	9.62	5.44	0.03	0.07
Area, Space Heating	2.08	2.46	3.92	9.00	0.14
Area, Other	0.23	0.36	0.03	2.13	0.04
On-Road Mobile	0.26	2.14	0.01	4.63	0.05
Non-Road Mobile	0.35	1.85	7.20	5.33	0.00
SMOKE 4.7 TOTALS	**3.46**	**16.43**	**16.60**	**21.12**	**0.30**
% Difference (4.7 vs. 2.7)	**-6%**	**-6%**	**-7%**	**-4%**	**-9%**

[a] From Table 7.6.7 of the Fairbanks 2020 Amendments Plan

As shown at the bottom of Table 2.3.1, relative differences in the two SMOKE-processed inventories are within 9% or less for all pollutants. The major difference between SMOKE 2.7 and SMOKE 4.7 is that the point sources for space heating and airport emission are integrated into SMOKE 4.7 without having to change the code. In order to have a point source for all the home heating sector in SMOKE version 2.7, the code was changed and the point source information was added. The layer allocation in SMOKE 2.7

was adjusted outside of the SMOKE model both horizontally and vertically. The aircraft emissions were processed by the AEDT (Version2c) aircraft model. For each of the three airfields in the modeling domain (Fairbanks International, Fort Wainwright and Eielson AFB), emissions were horizontally allocated to grid cells encompassing each airfield's runway extent (plus an additional buffer for climb out and descent) and taxiing and terminal areas. AEDT was used to vertically allocate emissions based on input layers that matched those defined for the modeling domain. In SMOKE 4.7, the aircraft emissions are treated as area sources and space heating emissions are treated as point sources. For both these sectors 2D gridded emissions are generated from SMOKE and are vertically allocated in model layers 1-4 using a Layalloc SMOKE program to generate gridded 3D emission inputs. All other point sources are processed as inline in SMOKE 4.7.

The major difference in the way emissions are handled between the two versions of SMOKE may account for the large difference in SO2 at the max cell grid seen Figure 2.4-8 in the CMAQ output in grid cell 51,49 , the Fairbanks International Airport and below in Figure 2.3-1 in the aircraft emissions sector grid cell plot. The three purple grid cells in Figure 2.3-1 correspond to the Fairbanks, FT WW and Eielson Airforce base. The gridded emissions plots for SMOKE 4.7 are below for PM 2.5, PM other, sulfate and SO2 for all sectors together in Figures 2.3-2 the gridded emission plots for 2019 for SMOKE 2.7 are in lbs/day for all sector emissions together for PM 2.5, then points, non-road, road and space heating for PM 2.5 in the 2020 amendment.[4] Both sets of plots for total PM 2.5 emissions have similar high values in the Fairbanks airport area, Peger Rd and North Pole grid cells and the same magnitude at the max cell area of 360 lbs/day (0.18 tons/day) and the 100-500 lb/day values of the grid cells in SMOKE version 4.7.1 (refer to page III.D.7.6-103 of the 2020 amendment referenced above).

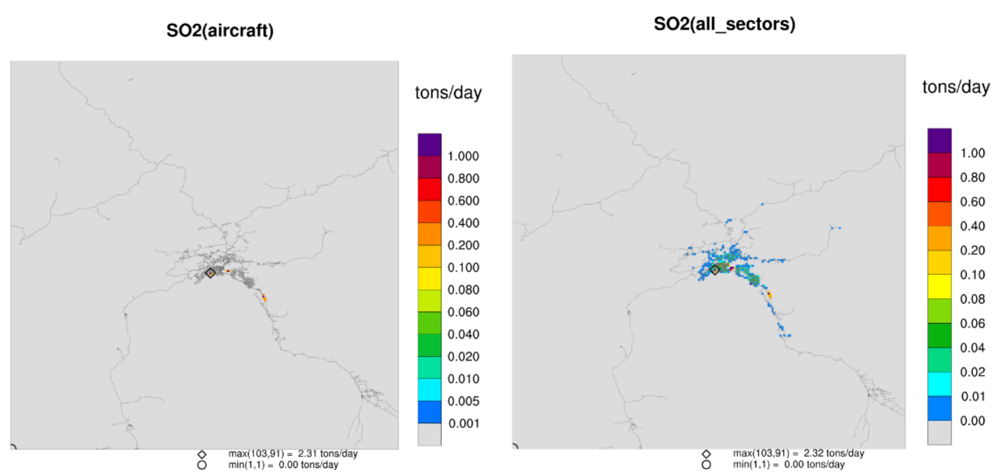


Figure 2.3-1 SO2 emissions plots for all sectors and aircraft sector in tons/day of the lowest four layers in SMOKE 4.7

[4] https://dec.alaska.gov/media/22028/iii-d-7-06-emission-inventory-11-18-20.pdf

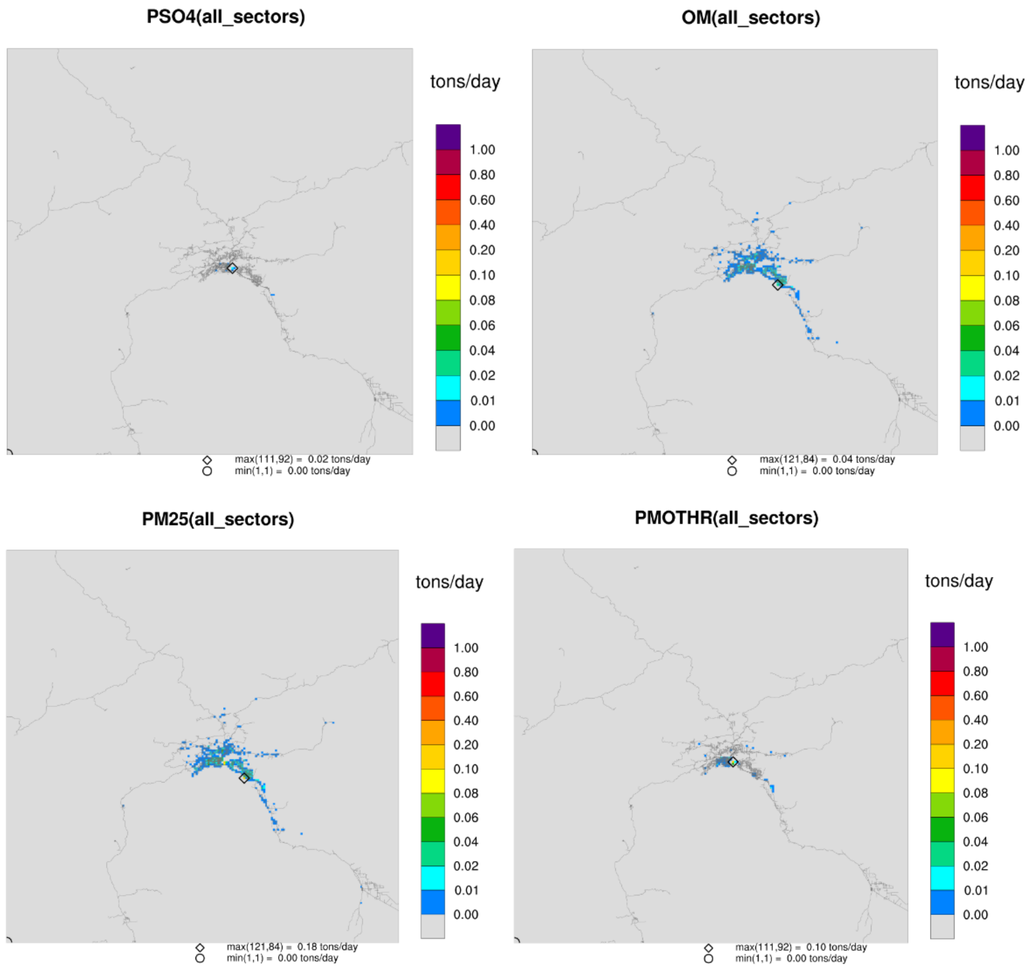


Figure 2.3-2 All sectors emissions plots for SMOKE version 4.7 with 2019 inventory for PM2.5, PMOTHR, Sulfate and SO2

2.4 **Phase 1- Model runs comparison with CMAQ 4.7.1 to CMAQ 5.3.2**

The comparison of new CMAQ model version 5.3.2 to the older version of the CMAQ model version 4.7.1 was completed using the 2019 emissions inventory for the last Fairbanks PM 2.5 SIP, the 2020 amendment.[4] The DEC Linux system was updated for CMAQ version 5.3.2 and was run on 16 processors with the current 2019 emission inventory and 2008 meteorological episodes. There is no model performance or North Pole speciation, since DEC is still using the new model version based on the 2008 meteorology and projected emissions inventory of 2019, but DEC can compare model version differences for PM 2.5, ammonium, sulfate, nitrate, organic matter (primary and secondary organic carbon) , PM other, SO2, NOx and ozone. Plotting all of the PM species and precursors will give an initial comparison of the updated model version differences.

The grid cell plots below (Figures 2.4-1-11), a raw model output of the grid cell at the Hurst road monitor and the NCORE monitor were extracted for the version 4.7.1 and version 5.3.2 ORG_EMC, BM and particle in the Table 2.4-1.

The following are the definitions for ORG_EMC, BM and Particle that are used in Table 2.4-1 and all of the species plots both episode average meteorological episodes January 23 -February 10th, 2008 and November 2-November 22, 2008. There are four model runs completed:

1) V471: The first is the original CMAQ 4.7.1 version with the identical 2019 emissions inventory processed through SMOKE 2.7 as the CMAQ 5.3.2 version processed with SMOKE 4.7.
2) ORG_EMC: The second is CMAQ version 5.3.2 utilizing the original emission control file provide with the CMAQ code download, this version ORG_EMC, is the standard CMAQ version 5.3.2. The emission control file is a new addition to CMAQ 5.3.2 where you can change or eliminate certain emission sources on the SMOKE post processed emissions.
3) BM: The third is the CMAQ version 5.3.2 emission control file and changing the semi volatile organic carbon fractions to represent a biomass dominated emissions, such as Fairbanks and wood stove emissions[5] The example emission control file in Appendix A
4) Particle: The fourth is the CMAQ version 5.3.2 emission control file and is the non-volatile version of CMAQ, changing the organic carbon to be all in the particle form. This version was to directly compare to the mechanisms available in the CMAQ version 4.7.1, but not for use in a regulatory SIP model run, since the chemistry is outdated.

The new version of CMAQ 5.3.2 has additional chemistry mechanisms in AERO7 and change in how the individual species are calculated for organic carbon. The following describes the main differences in the results comparing between versions, for a complete list of changes in the CMAQ version 5.3.2, see the EPA website. [6]

Discussion on the PM 2.5 differences from CMAQ version 4.7.1 to 5.3.2

The CMAQ version 5.3.2 compared to version 4.7.1 included a large update to the organic aerosol with the addition of semi volatile primary organic aerosol (POA).[7] The other addition is in 2012, the multiplier for OM/OC changed, but DEC did not change the raw model output or code and the formulas used are below. The 4.7.1 calculation is using a value of 1.167 and woodburning was found to be closer to 1.8 (https://pubs.acs.org/doi/abs/10.1021/es202361w) . The version 5.3.2 includes this value as OM is described in the next paragraph with gas to particle conversion.

---

[5] acp-16-4081-2016.pdf (copernicus.org)

[6] Access CMAQ Source Code | US EPA

[7] https://urldefense.com/v3/__https://acp.copernicus.org/articles/17/11107/2017/__;!!J2_8gdp6gZQ!4-sjXKetFcVpUCGihTZztkfJFhOJyGsdBT2aV22BJMy1ktpK1Xxsj7B_3UpB6y7wMpuk$).

The update to the biomass burning and combustion are semi volatile instead of all in the particle phase and a sensitivity test was completed called BM (biomass burning profile).[8] This OA (organic aerosol) update allows CMAQ to properly partition emissions between gas and the particle phase. This update recognizes that secondary organic aerosol (SOA) can dominate over POA in most seasons. In order to look at all of the OC (organic carbon) produced, the CMAQ variable AOMIJ (Aerosol Organic Matter primary and secondary, the "I" Aitken mode and "J" accumulation mode) is plotted in Figure 2.4-4. The change in actual formulas in CMAQ for organic matter are listed below. The CMAQ 5.3.2 plots in Figure 2.2-4, represent the max cell for the AOMIJ at 26.6 ug/m3 for ORG_EMC, 27.8 ug/m3 for BM and 31.2 ug/m3 for particle. This increase is attributed to the organic carbon species, updated mechanisms and partitioning of the organic aerosol. The POM (primary organic matter) in Figure 2.4-5, shows 25.8 ug/m3 compared to 26.6 ug/m3; the secondary organic matter accounts for 0.7 additional ug/m3. The OM is the largest PM 2.5 component in Fairbanks and there are regulatory controls on the OM as part of wood stove emissions. In Figure 2.4-4 for the OM there is a large increase, 10 ug/m3, and there is a shift in the max grid cell from downtown to North Pole. The emissions for North Pole are dominated by OM, which accounts for 80% of the ambient particulate organic matter in that area compared to downtown Fairbanks at 54%. There is a possibility that shift will more accurately represent the organic carbon in North Pole with further investigation into the OM in phase two of the modeling update when model performance using the speciation from the Hurst Rd site will be available.

The Organic Matter formulas for version 4.7.1 and 5.3.2 are:

AOMIJ Primary Organic Matter for version 4.7.1

- APOM IJ=1.167*AORGPAJ+1.167*AORGPAI
- AOM IJ = AORGCJ+AOLGAJ+AOLGBJ+1.167*AORGPAJ+1.167*AORGPAI

AOMIJ Organic Matter for version 5.3.2 (primary and secondary)

- AOMIJ = APOMIJ+ ASOMIJ
- AOMIJ =ALVPO1I + ASVPO1I + ASVPO2I + APOCI +APNCOMI + ALVPO1J + ASVPO1J + ASVPO2J + APOCJ + ASVPO3J + AIVPO1J + APNCOMJ + ALVOO1I + ALVOO2I + ASVOO1I + ASVOO2I + AISO1J + AISO2J + AISO3J + AMT1J + AMT2J + AMT3J + AMT4J + AMT5J + AMT6J + AMTNO3J + AMTHYDJ + AGLYJ + ASQTJ + AORGCJ + AOLGBJ + AOLGAJ + ALVOO1J + ALVOO2J + ASVOO1J + ASVOO2J +ASVOO3J + APCSOJ + AAVB1J + AAVB2J + AAVB3J + AAVB4J

After the OM, the PM other species (Figure 2.4-7) are the most significant change from CMAQ version 4.7.1 to version 5.3.2. The OM accounts for half of the increase in PM2.5 and PMother accounts for the other half. The largest components of PM 2.5 in Fairbanks are organic matter and sulfate as observed by the speciation monitoring.[9]

The sulfate increased in all three scenarios by 1 ug/m3 (Figure 2.4-6). The increase in sulfate is partly contributed to by the increase in background sulfate, this increase is from a change in the initial conditions and boundary conditions that were used in this version of 5.3.2 testing by updating the ICON

[8] https://urldefense.com/v3/__https://science.sciencemag.org/content/315/5816/1259__;!!J2_8gdp6gZQ!4-sjXKetFcVpUCGihTZztkfJFhOJyGsdBT2aV22BJMy1ktpK1Xxsj7B_3UpB6wG_BTEU$

[9] https://dec.alaska.gov/air/anpms/communities/fbks-pm2-5-serious-sip/

and BCON files of CMAQ by the USEPA.[10] The original IC/BC conditions were based on monitored values from IMPROVE monitors in Denali winter from October to February in 2008-2009 and that discussion is in the Moderate Area SIP Modeling Appendix. Those files are not supported in the new CMAQ version 5.3.2. The version 5.3.2 used profiles based on ICON/BCON files generated from four ASCII files of vertically resolved concentration profiles distributed with CMAQ to represent annual average concentrations at a grid cell over the Pacific derived from a simulation with the hemispheric CMAQv5.3beta2 for the year 2016. These conditions are representative of a remote marine environment. These are not a realistic interpretation of the conditions along the domain boundaries. The phase 2 is designed with new IC/BC, this will be completed with a nested down hemispheric CMAQ model run.[11] Without model performance there no way to attribute the additional sulfate, but in the next phase with new speciation data concurrent with meteorology and emissions during the meteorological episode DEC will evaluate the sulfate performance.

In CMAQ version 4.7.1, the NCORE and Hurst Rd monitor grid cell values for total PM 2.5 are calculated by the following formula from the standard EPA model code:

AECIJ+ANO3IJ+ASO4IJ+ANH4IJ+AOMIJ+PM25_OTH

In CMAQ version 5.3.2 the NCORE and Hurst Rd monitor grid cell values for total PM 2.5 are calculated by the following formula: ATOTIi+ATOTJ

Then ATOTIJ are broken down further for version 5.3.2:

```
ATOTI    ,ug m-3     ,ASO4I+ANO3I+ANH4I+ANAI+ACLI \
                     +AECI+AOMI+AOTHRI

ATOTJ ,ug m-3     ,ASO4J+ANO3J+ANH4J+ANAJ+ACLJ \
                     +AECJ+AOMJ+AOTHRJ+AFEJ+ASIJ \
                     +ATIJ+ACAJ+AMGJ+AMNJ+AALJ+AKJ
```

The other species category that represented the largest difference was PM other (PMOTH), in Figure 2.4-7 the PMOTH max cell in version 4.7.1 was 5.8 ug/m3. In the updated CMAQ version 5.3.2, the PMOTH is 10.8 ug/m3. The formula for the PM Other for both versions are:

PM25_OTH for version 4.7.1 : A25J+A25I+ANAJ+ANAI+ACLJ+ACL

[10] https://drive.google.com/drive/folders/1oLgDp-jVzVv4Ec3ewzCU29Jv036fGZMy

[11] https://github.com/USEPA/CMAQ/blob/main/DOCS/Users_Guide/Tutorials/CMAQ_UG_tutorial_HCMAQ_IC_BC.md

PM25_OTH for version 5.3.2: AOTHRI+AOTHRJ+ANAI+ACLI+ANAJ+ACLJ

The CMAQ model version changed the parametrization of the aerosols that has led to an increase in PMother.[12] The emissions from PMFINE were assigned to A25J (non-volatile) and in version 5.3.2, PMFINE is speciated into compounds that can partition between gas and particle phase (NH4, H2O and Cl). These three species are now emitted from anthropogenic sources. The initial and boundary conditions of the model were changed from the version 4.7.1 to 5.3.2 and that led to an increase of 0.6 ug/m3 in background concentrations. The initial and boundary conditions will likely change again as the hemispheric CMAQ model that is used to generate the IC/BC conditions will be updated.

The precursors for NOX, Ozone and SO2 are in Figures 2.4-9,10 and 11. The SO2 is higher than the max grid cells for the Version 5.3.2, this increase is not represented by the total SO2 emissions (Table 2.3-1). The difference may be meteorology or how layer one is defined in version 5.3.2 and the inline point source integrated into SMOKE 4.7. The SO2 in ppbv at the NCORE grid cell is 6ppbv for version v471 and 15.33 pbbv in version 5.3.2. The max cell differences are even higher as seen in Figure 2.4-9. These differences in SO2, are likely from the SMOKE processing changes in layer allocation as mentioned above in section 2.3. and can be seen in the gridded sector plots for the SO2 emissions in section 2.3.

[12] (https://www.airqualitymodeling.org/index.php/CMAQv5.0_PMother_speciation

Table 2.4-1. Monitor grid cell averages for both episodes for 2019 for PM 2.5 in ug/m3

Monitor Species (model variable)	4 year modeling DV(2016-2019)	FRM 98%-tile	Version 4.7.1	Version 5.3.2 ORG_EMC	Version 5.3.2 BM	Particle
NCORE PM 2.5 (ATOTIJ)	29.6	29	22.4	19.7	20.5	22.3
Sulfate (ASO4IJ)	NA	NA	2.2	2.55	2.54	2.55
Organic Matter (AOMIJ)	NA	NA	11.15	8.62	9.42	11.17
Hurst Road PM 2.5 (ATOTIJ)	64.7	64	15.9	29.8	30.9	33.6
Sulfate (ASO4IJ)	NA	NA	1.1	2.16	2.15	2.16
Organic Matter (AOMIJ)	NA	NA	11.3	21.03	22.13	24.84

The table 2.4-1. Lists the species PM 2.5, sulfate and organic matter for the grid cell at the monitor for Hurst Rd and NCORE. The sulfate increases by 1 ug/m3 at the grid cell and the organic matter has a large shift at the Hurst Rd monitor with the addition of 10 ug/m3.

The only changes made to meteorology were from MCIP3 to MCIP 5 both using WRF 3.1, it is unclear if the meteorology played a role in the new version 5.3.2, but EPA RARE grant researchers have presented that their preliminary results of only switching from WRF 3.1 to WRF 4.1.1 showed a 20% increase in Organic Matter.[13] There may be reason to believe that the MCIP change might have added an increase in OM and SO2 at the surface. The SMOKE emissions comparison is listed in section 2.3 of this report and after comparing the SMOKE processed outputs the emissions are the same, so the SO2 increase is not from the emissions.

The modeling design value in the review section 2.1 (Table 2.1-1) was calculated in the 2020 amendment using average winter speciation from years 2016 to 2019. This is the base year of 2019 and the relative response factor used to calculate a future design value is 1 for modeling and then divided by the future years (2023, 2024, 2026). A direct comparison of the modeling design value through SMAT is not possible in phase one, without looking at future year emissions inventory for

[13] Email with Havala Pye and Kathleen Fahey from EPA ORD on the Fairbanks sulfate investigation on the RARE grant

the old 2008 meteorological episodes, as was done for the 2020 amendment. There is no other added insight into the DV calculated for the SIP until phase 2 when the increase in organic matter and sulfate can be evaluated against model performance. This evaluation will take place in phase 2 of the modeling platform update.

All of the species plots for version 5.3.2 have been compared to version 4.7.1 and differences are expected with a large update for version 5.3.2. The results of phase 1 all look reasonable and the working modeling platform with CMAQ version 5.3.2 is suitable to use with the current inventories, however, the same challenges still exist in that DEC is using the 2008 WRF without concurrent emissions and meteorology. Phase 2 of this modeling project hopes to address these challenges with model performance for all species using new monitored speciation in North Pole. A full list of all species definitions that were used in the post processing, are in Appendix A. The species definitions were downloaded from the EPA CMAQ website and no changes were made to v5.3.2 (ORG_EMC plots). The comparison of the two versions included averaging both episodes together, the same as the moderate and serious area SIPs to represent the winter high PM 2.5 exceedance days. Episode 1 and 2 have different meteorology and emissions and the individual episodes for all species and precursors are listed in Appendix A for completeness.

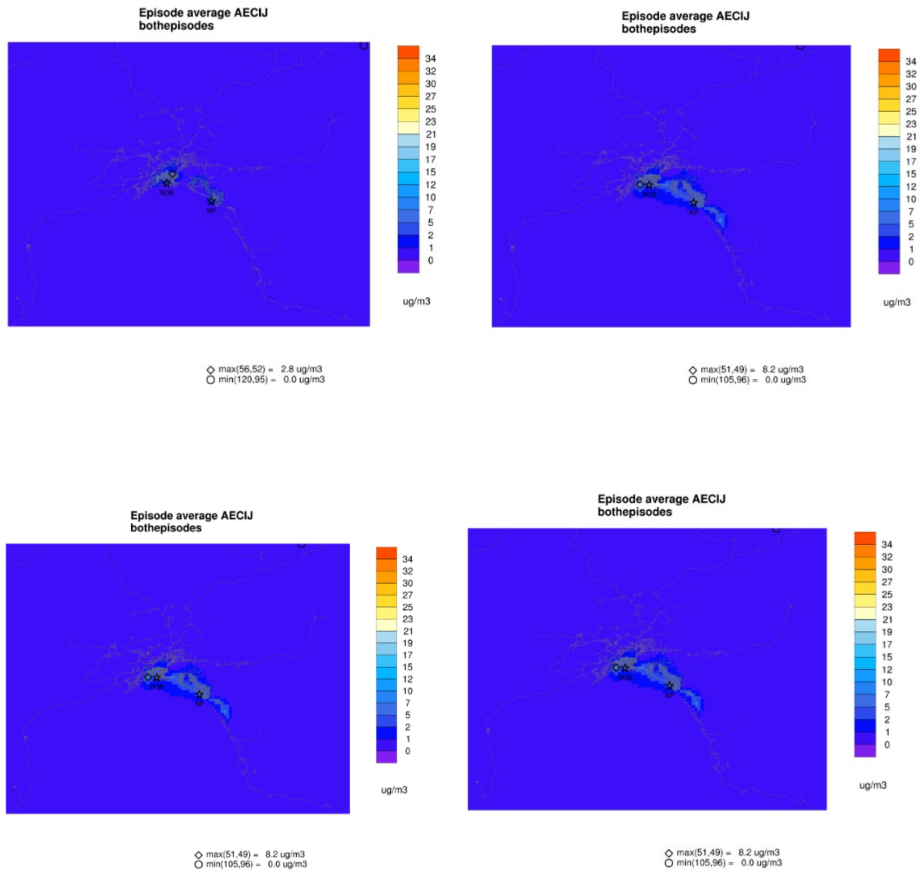


Figure 2.4-1. Elemental Carbon in ug/m3 both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

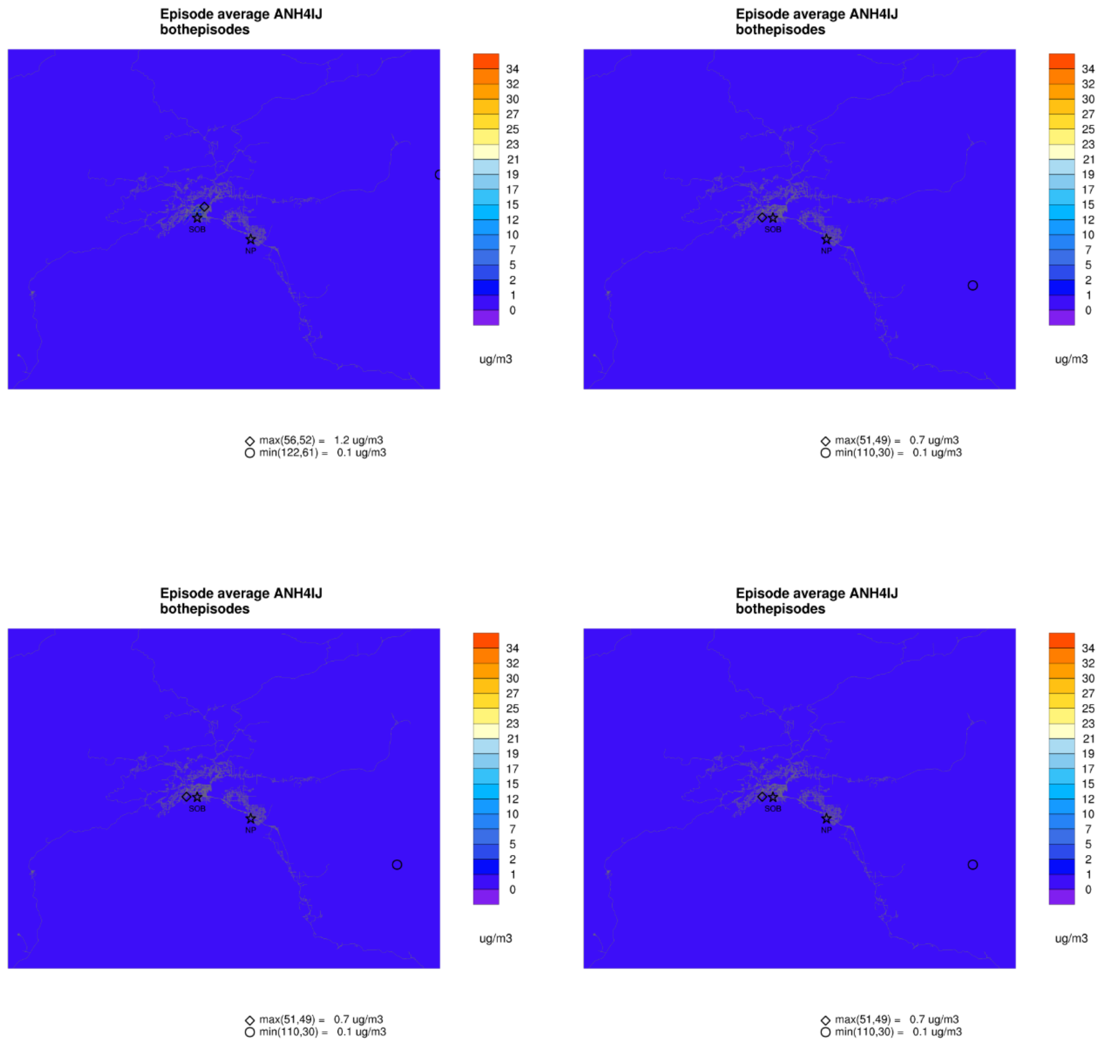


Figure 2.4-2. Ammonium (ANH4IJ) in ug/m3 both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

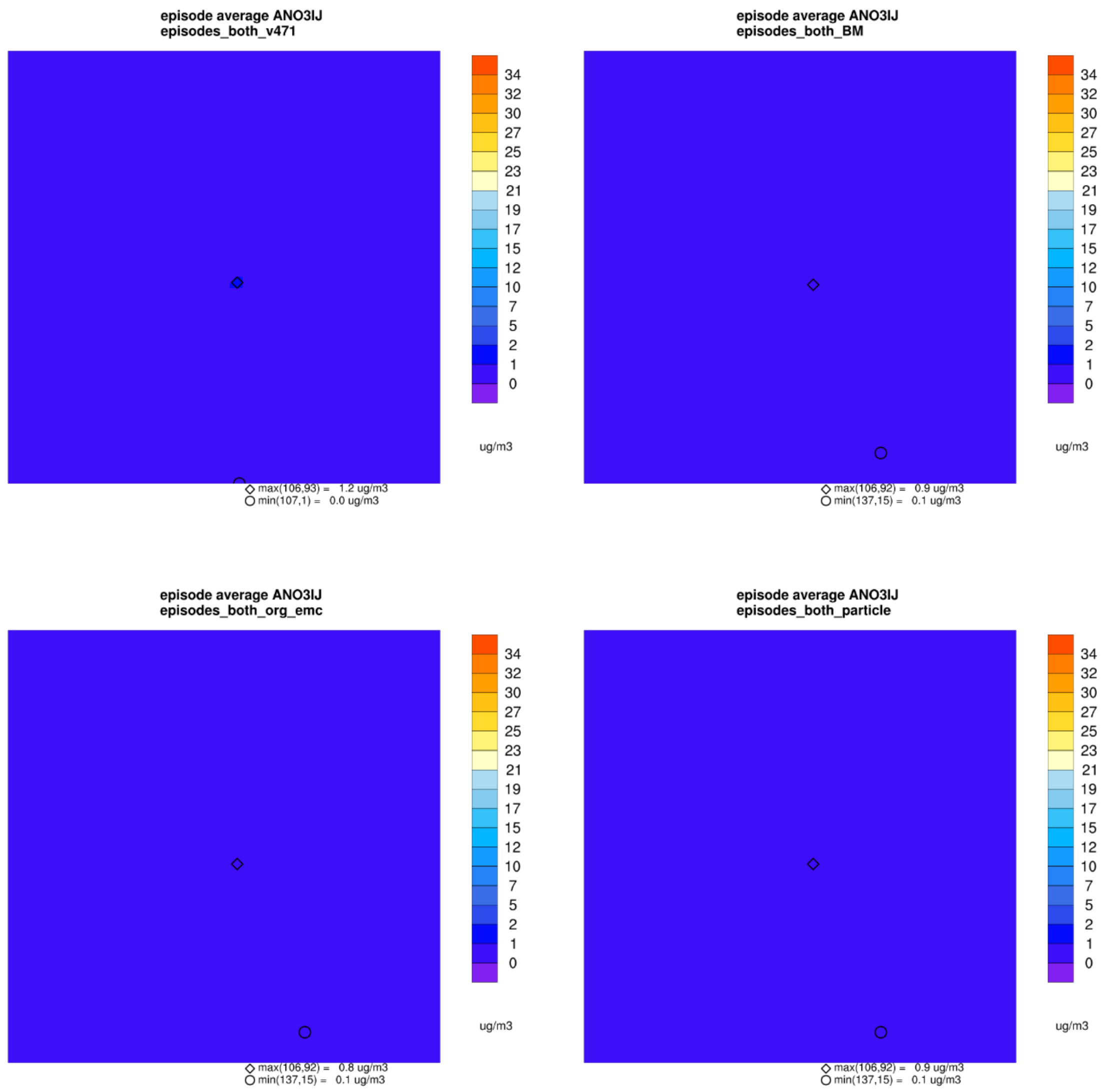


Figure 2.4-3. Nitrate (ANO3IJ) in ug/m3 both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

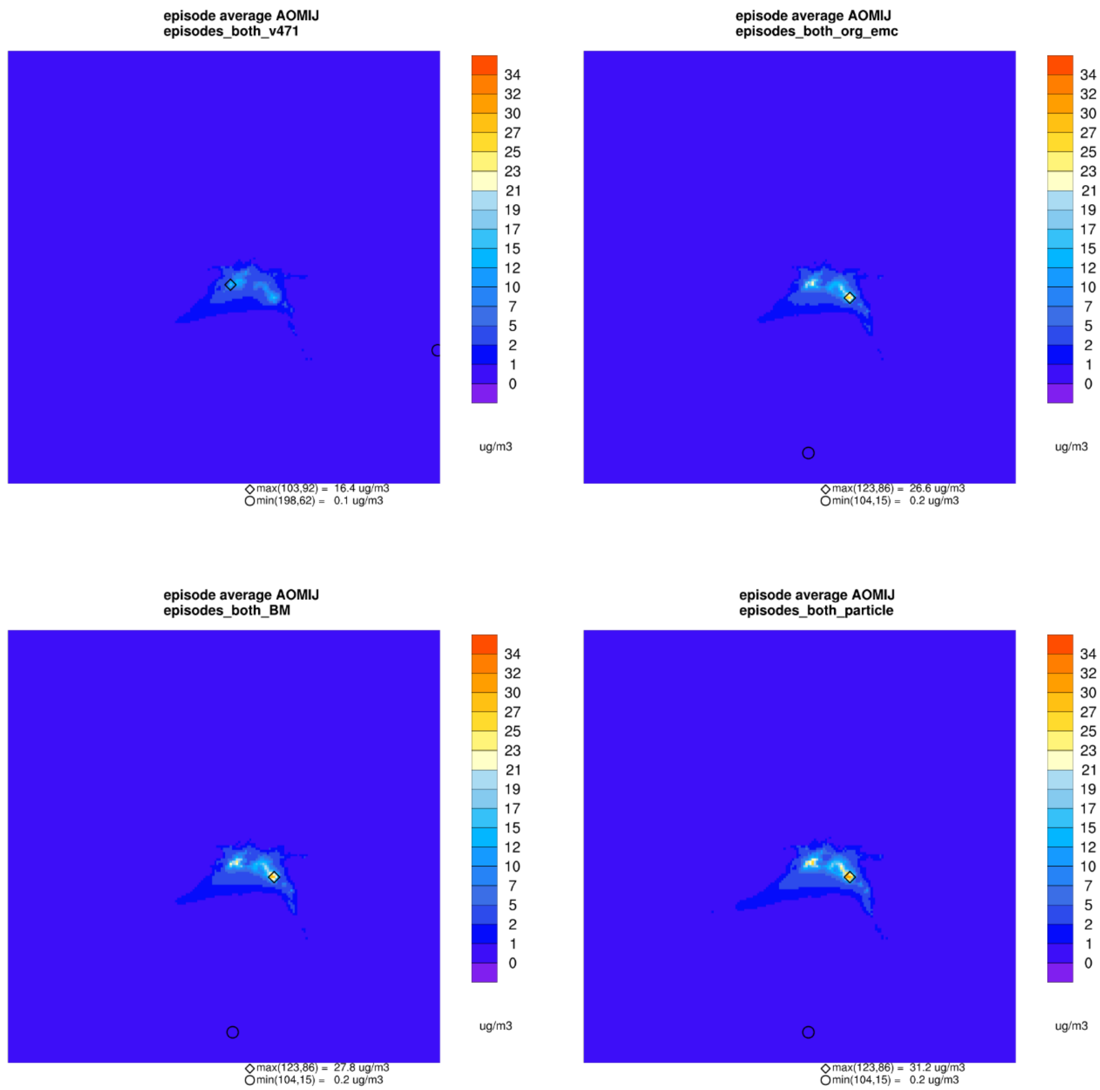


Figure 2.4-4. Organic Matter (AOMIJ) in ug/m3 both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

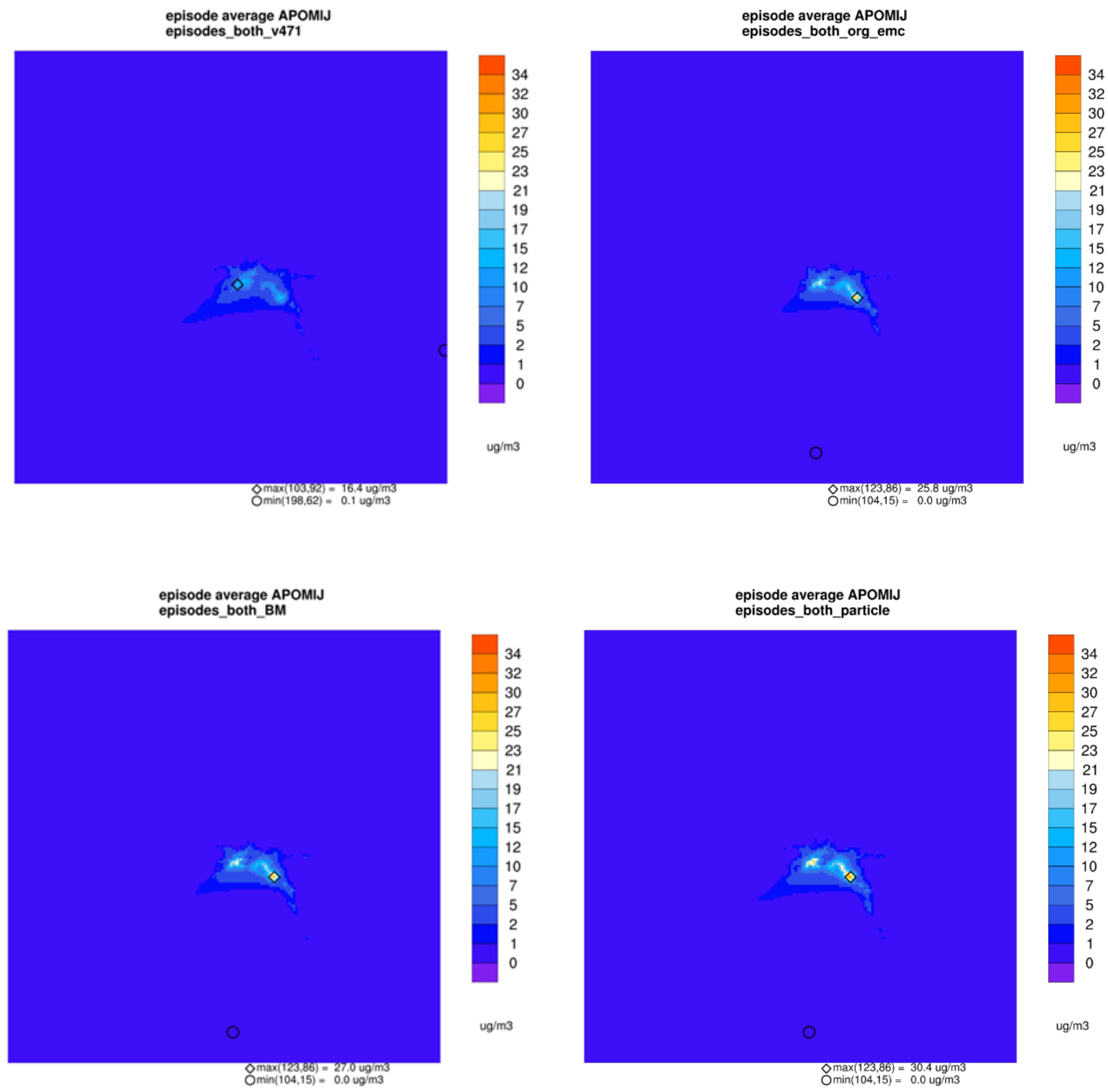


Figure 2.4-5. Particulate Organic Matter (APOMIJ) in ug/m3 both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

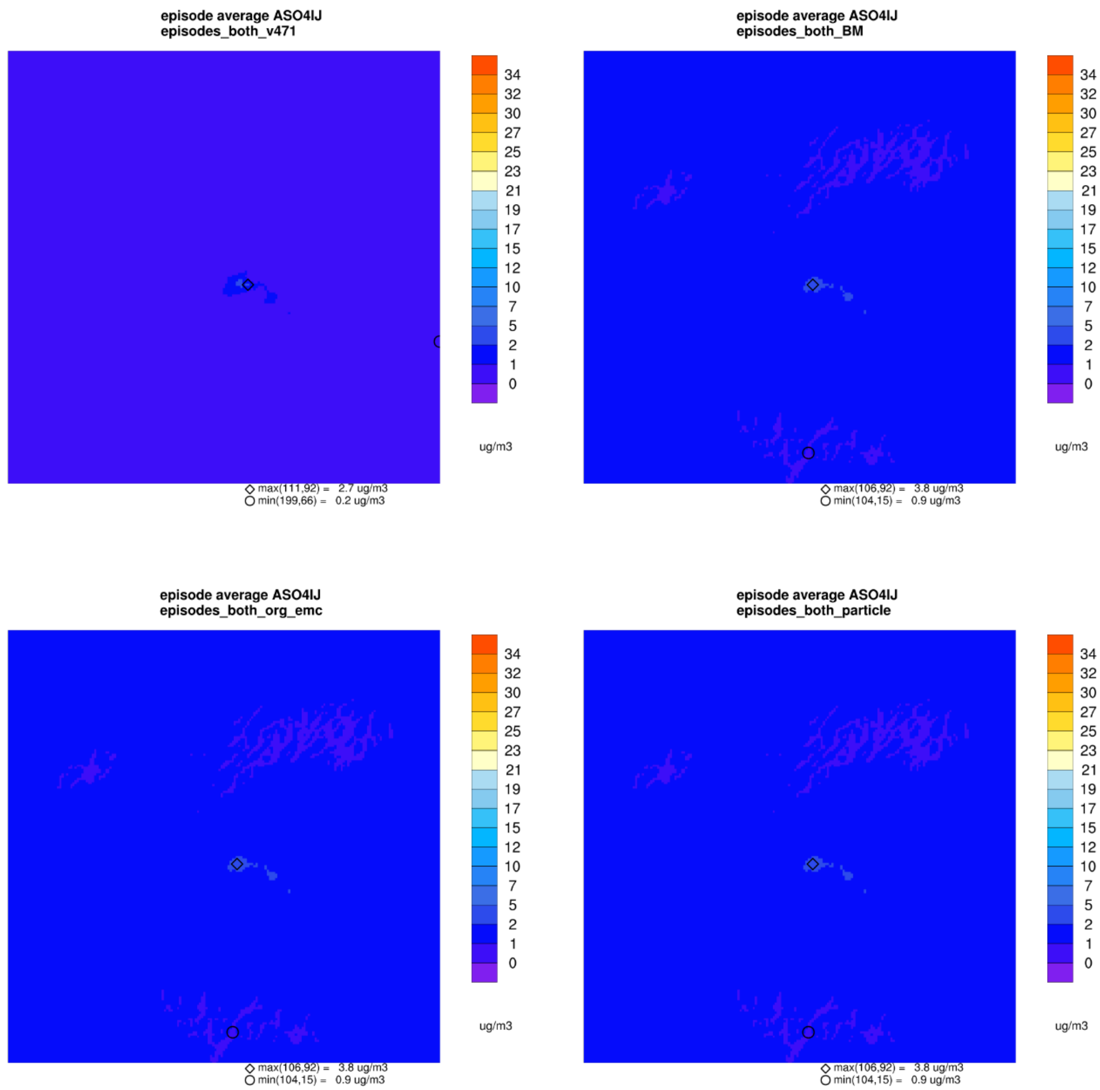


Figure 2.4-6. Sulfate (ASO4) in ug/m3 both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

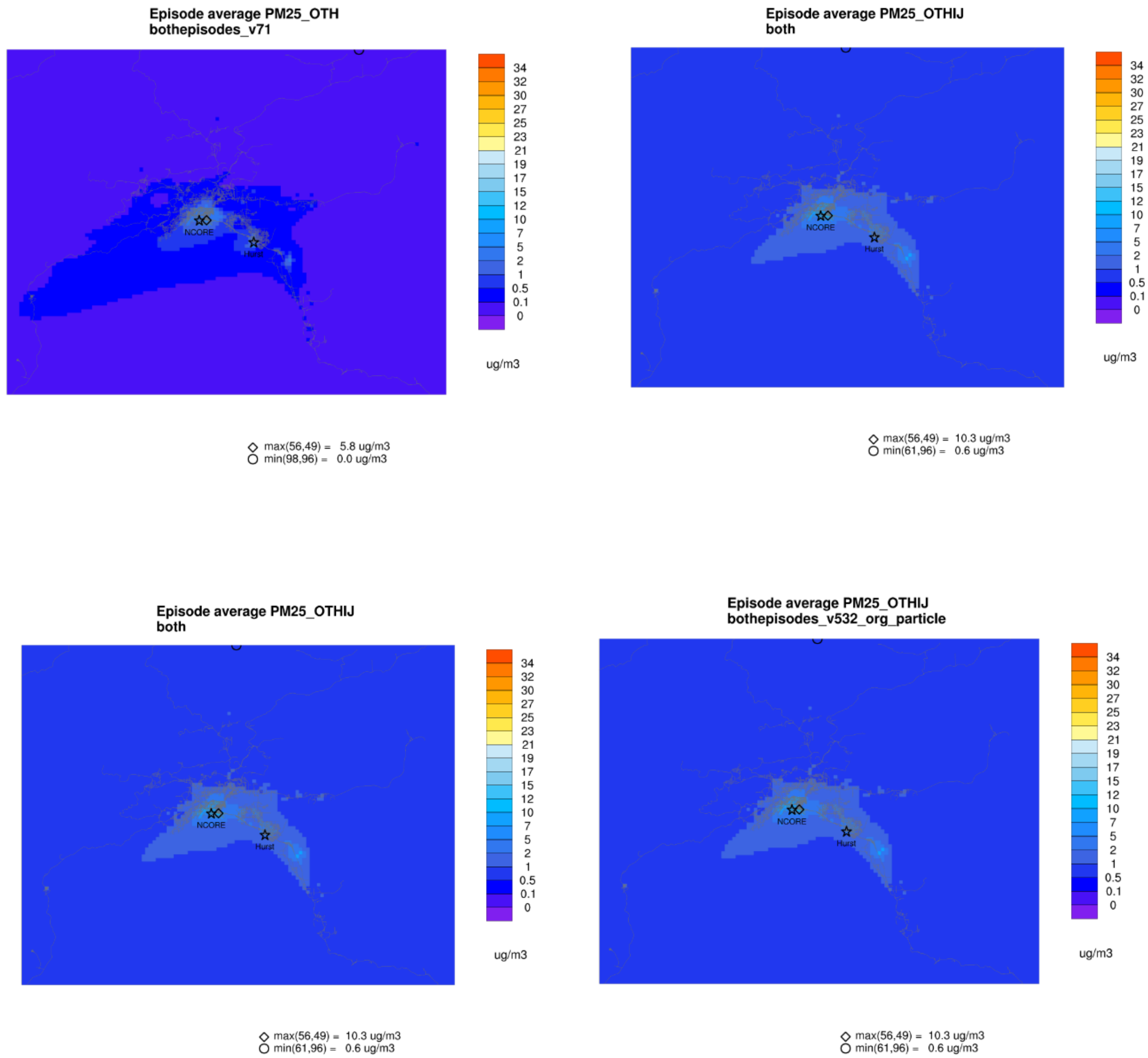


Figure 2.4-7. PM other (PMOTHIJ) in ug/m3 both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

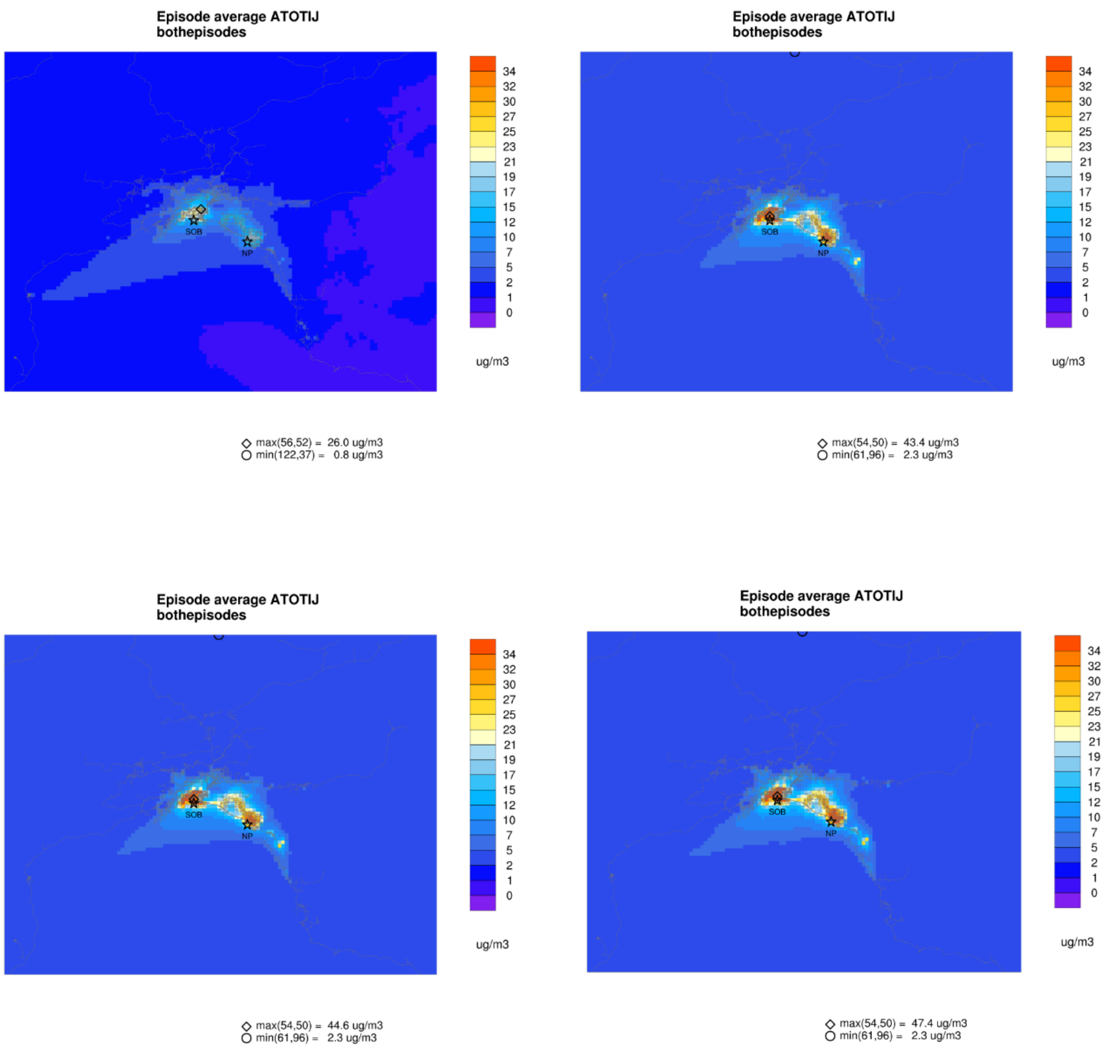


Figure 2.4-8. PM 2.5 (ATOTIJ) in ug/m3 both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

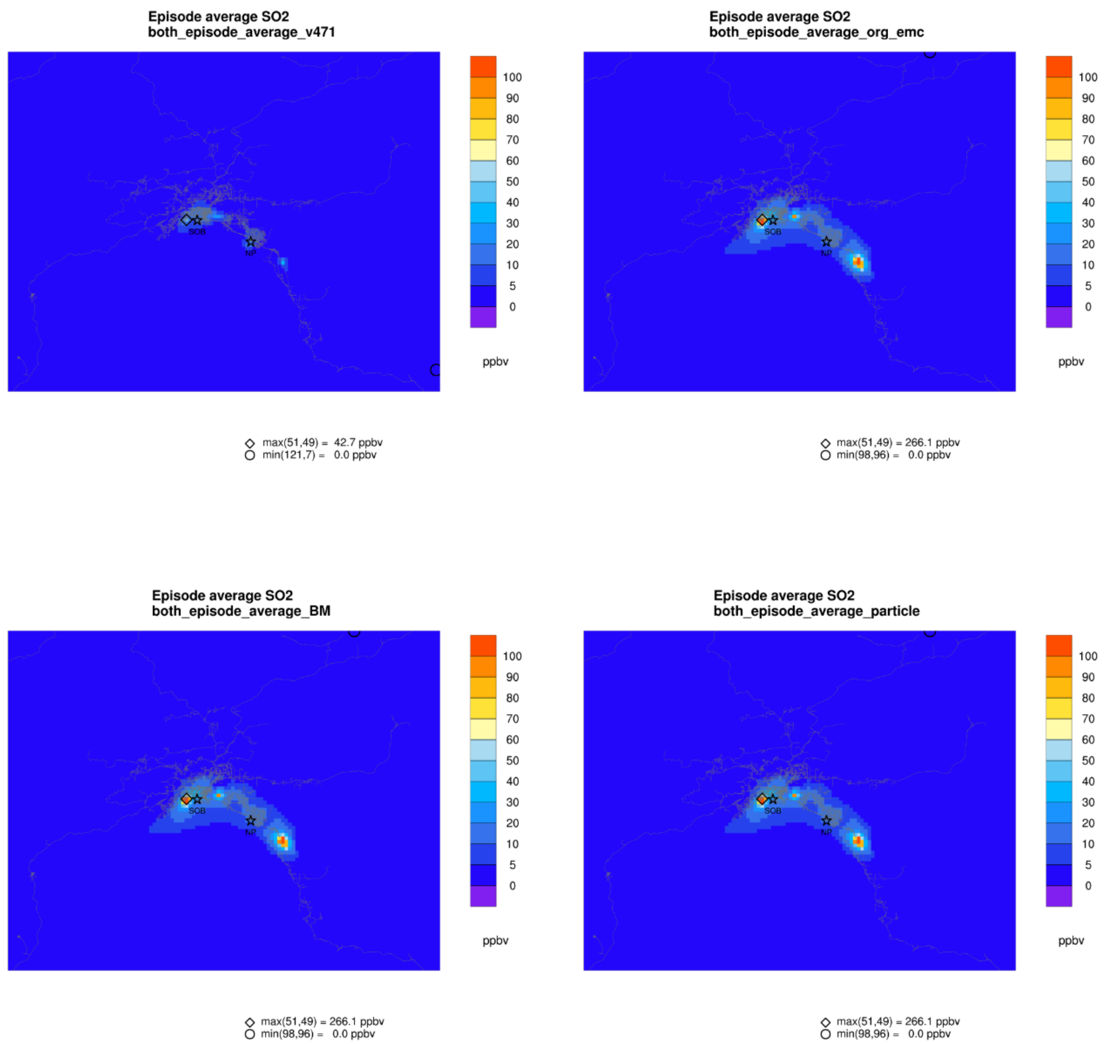


Figure 2.4-9. SO2 in ppbv both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

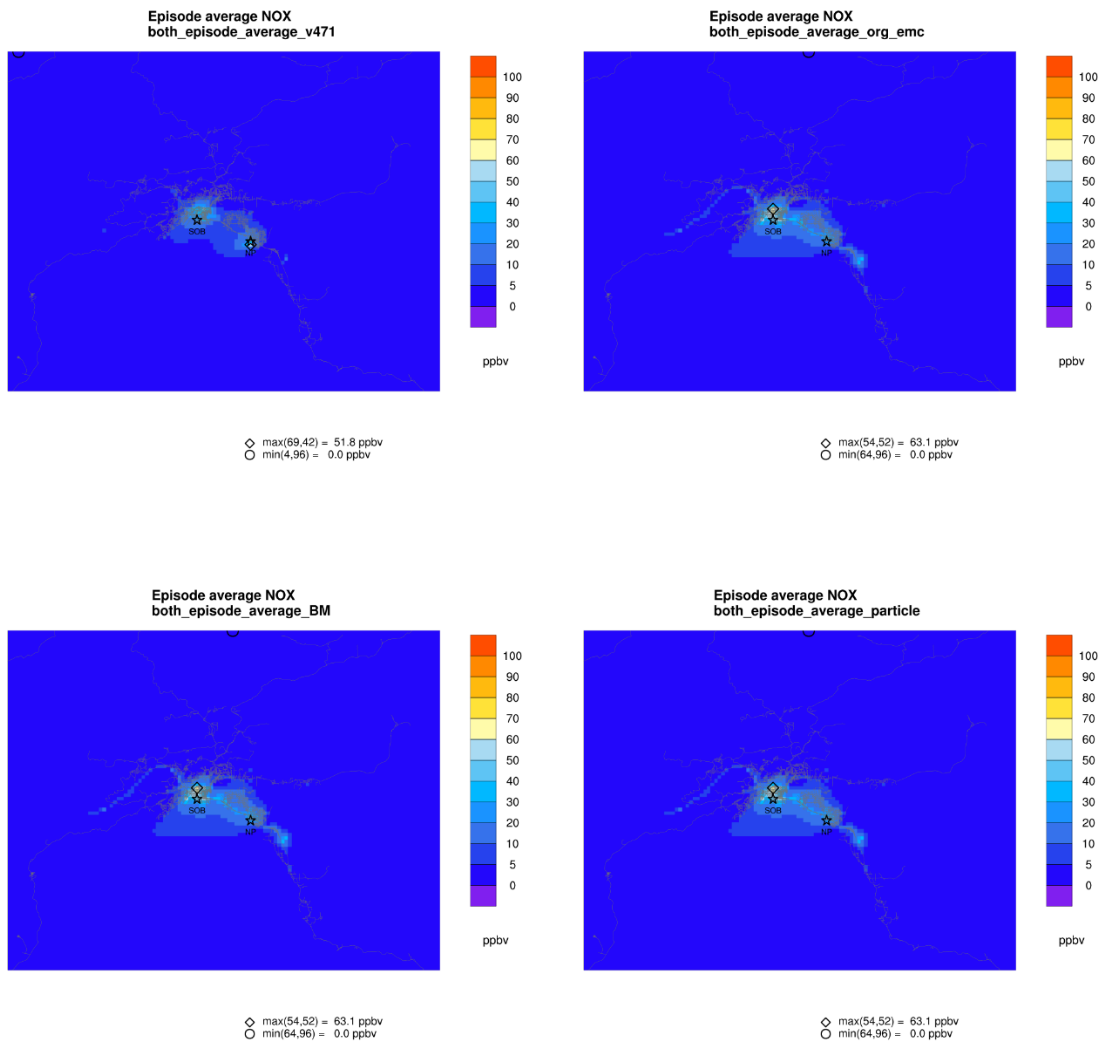


Figure 2.4-10. NOX in ppbv both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

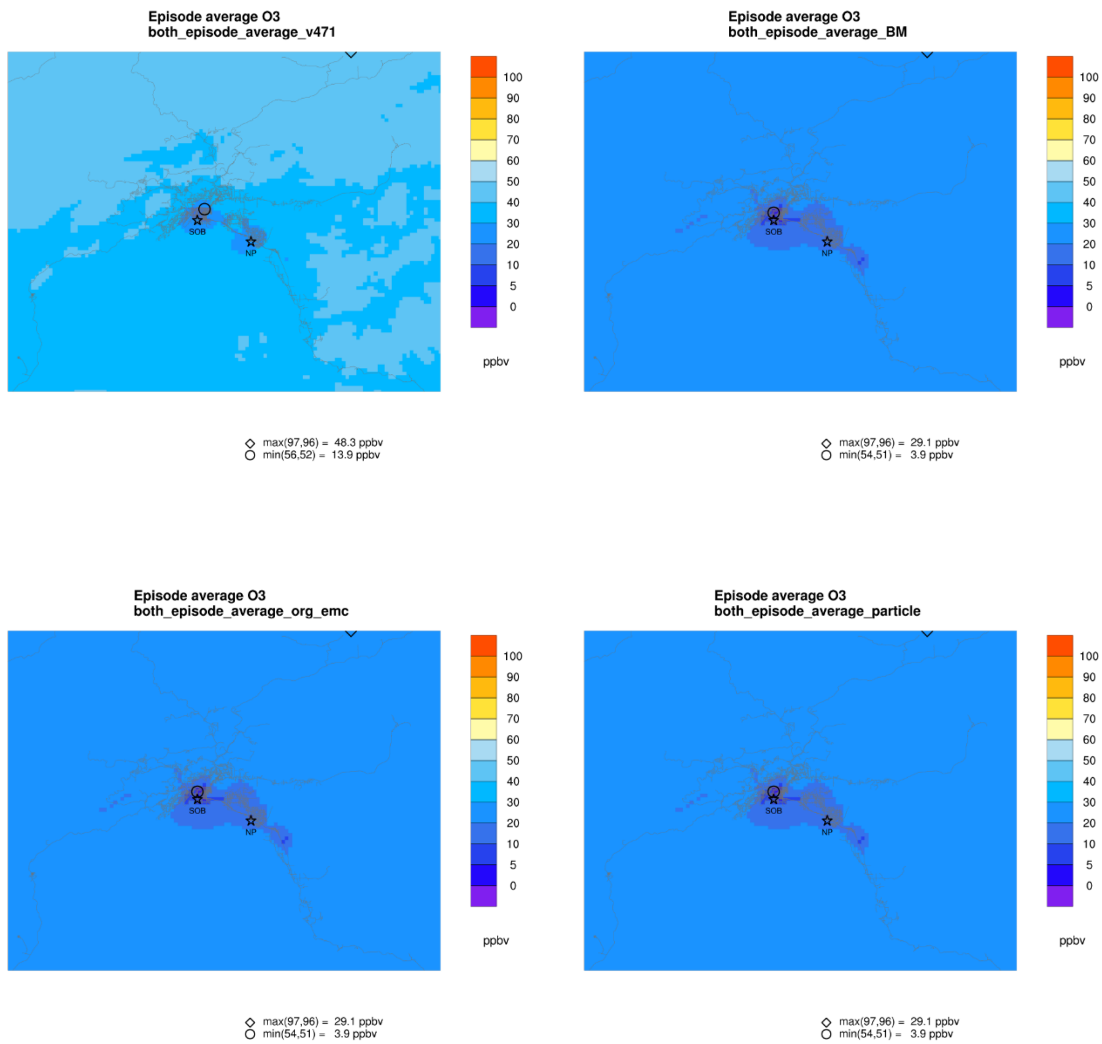


Figure 2.4-11. O3 in ppbv both episode average concentration in the domain area at 1.33 km grid cell for 2019 base year emissions inventory using CMAQ version 4.7.1 (top left), CMAQ version 5.3.2 ORG_EMC (top right), BM (bottom left) and particle (bottom right)

Phase 2

Phase 2 is new input development for the model and these contracts are in place and the work is already being completed. There is a transition period of 4 months after phase 1 and this is needed to allow the work to continue. These contracts for new WRF meteorology and modeling were established for phase 2 development work over the next two years. The transition period from phase 1 to 2 will allow continued work on these contracts. Other tasks during this transition time will be getting letters together to send to the point sources for hourly emissions for the new WRF episode. The development of a new Fairbanks wintertime meteorology episode takes time and collaboration. The model performance requires an entire winter of FRM and speciation data to be collected for North Pole. All of the tasks involved in the development of new meteorological and emissions inputs into the CMAQ model are outlined in this section.

2.5 WRF Meteorology

The winter 2019-2020 is the focus for choosing the new WRF (weather research and forecast model) episodes that represent Fairbanks's wintertime conditions that cause PM 2.5 exceedances.

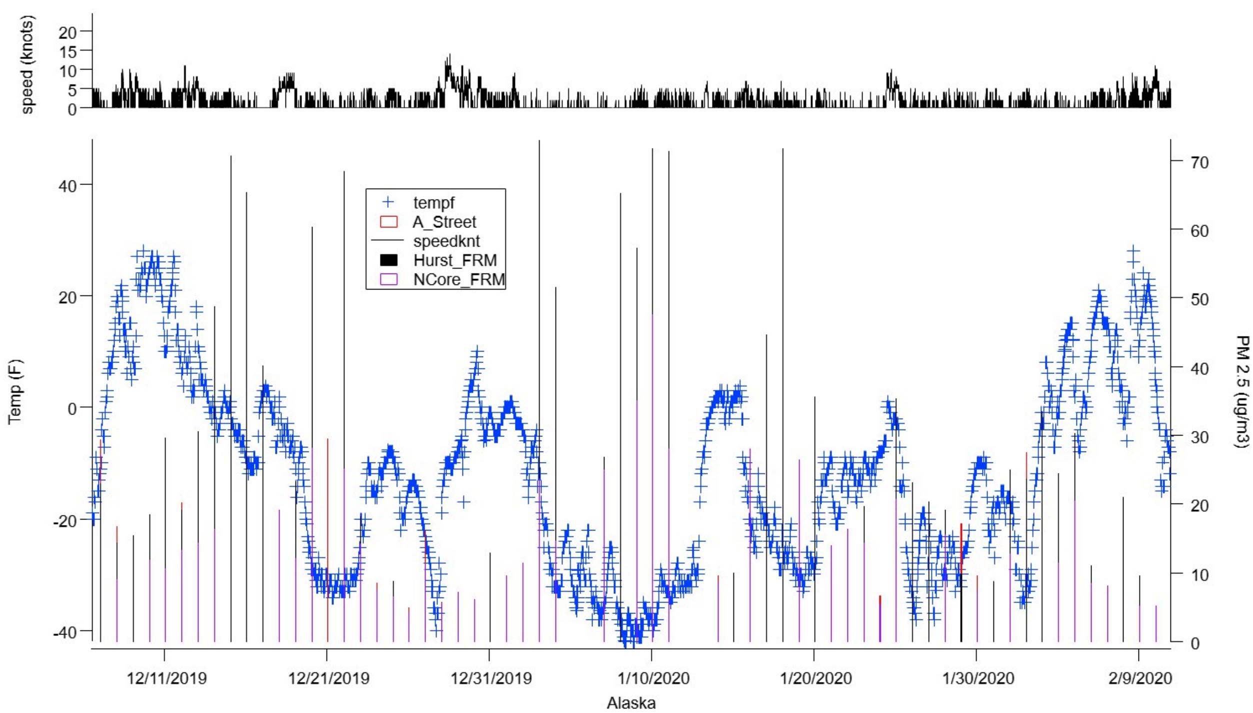


Figure 2.5-1. Proposed WRF episode for Fairbanks winter 2019-2020

The selection criteria were sent by EPA region 10 in accordance with the PM 2.5 modeling guidance. The following list summarizes the criteria that must be met based on Fairbanks winter conditions and past meteorological episode analysis.

- Days with 24-hour concentrations near the 2017-2019 design value (i.e., 69 ug/m3 at Hurst Rd).
- Sufficient days with total PM2.5 and PM2.5 speciation measurements at regulatory monitors to facilitate model performance evaluation.
- Meteorological conditions representative of inversion conditions typically associated with high pollution episodes.
- Time periods of elevated concentrations and sufficient days before and after these time periods to show the transitions from low --> high --> low pollutant concentrations

Past meteorological studies on long term weather patterns in the Crawford (2019) study, show severe inversion conditions in recent years have included temperatures decreasing to approximately -25 to -35 degrees C. Using the median temperatures (-8 to -12 degrees C) presented in the Crawford (2019) study as pollution episode guides for temperatures during non-severe pollution episodes was also suggested as a relevant criteria for the Fairbanks winter time episode.

The proposed episode selection will be from 12/7/2019 to 2/12/2020 (Figure 2.1). There are 10 days > 50 ug/m3 (all the highest PM 2.5 days at Hurst Road) and this satisfies the criteria of having design value episode days at 69 ug/m3. The wintertime episode includes all days at 40 below for the winter 2019/2020 and strong inversions. There are a few missing FRM days at 40 below, but the one long episode will ensure that there are plenty of FRM days for model performance. The quantity and quality of the sonic anemometer data at Hurst Road during this time is being evaluated by DEC. There are missing data, but with a long episode DEC will capture enough additional met data. The NCORE sonic anemometer is available at 10 and 23 meters for the Fairbanks area to help with the model performance. The Hurst Road sonic anemometers are at 3, 10 and 23 meters. The sonic anemometers track wind speed, temperature, and wind direction.

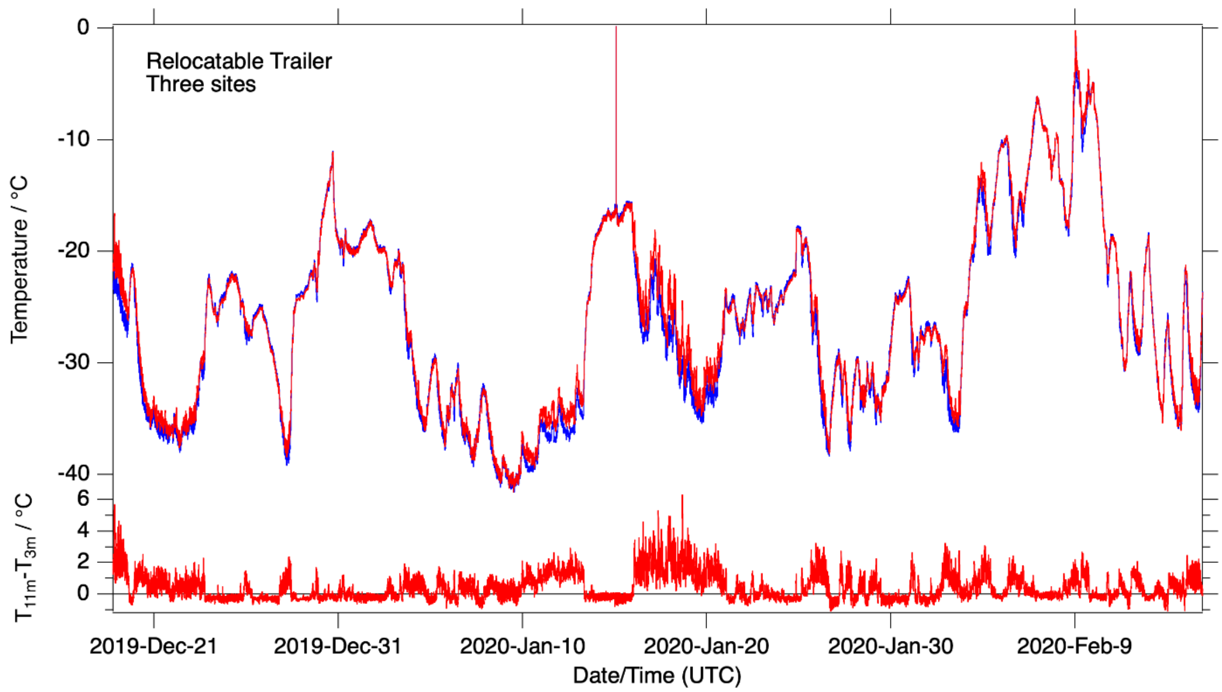


Figure 2.5.-2 Temperature gradients of three temperature sites at 11 and 3 meters in the FT WW area

The University of Alaska Fairbanks Bill Simpson research group conducted a concurrent study of temperature gradients in the Fairbanks area and the results are shown in Figure 2.5-2.In Figure 2.5-2, there are areas of large temperature gradient and a strong inversion from Jan 15-20th. A large temperature gradient where at 3 meters the temperature is 6 degrees colder than the temperature at 11 meters, there is an inversion present. These strong inversions are typical in Fairbanks winter and lead to a stable boundary layer and increasing PM 2.5. The same dates for example, Jan 15-20th coincides with Figure 2.5-1 where Hurst Rd PM 2.5 concentrations are near 70 ug/m3. There are periods of neutral stability or no temperature difference from the 12-15th of Jan. The wintertime episode contains high PM 2.5 days at different inversion strengths and includes periods of neutral stability where the PM 2.5 is low.

The WRF meteorology simulations will be performed by DEC's contractor. A modeling protocol will be presented prior to the simulations. The model performance will include comparison to local meteorological stations, sonic anemometers at NCORE and Hurst Rd as well the data presented in Figure 2.5-2 from the mobile trailers.

2.6 MCIP

MCIP 5 needs to be completed after the WRF meteorological episode is completed for Fairbanks winter 2019-2020. MCIP 5 will input into the CMAQ 5.3.2 model. This task will be completed by DEC's contractor along with the new WRF meteorology.

2.7 North Pole Speciation data analysis and SMAT

The current North Pole speciation for the Serious SIP was based on available years of data from 2012-2015 for the 2011 to 2015 modeling design value (Figure 2.7-1). The only other speciation data available in North Pole was one quarter in 2009. A SASS – speciation monitor was placed at the Hurst Road location in October of 2019 and was run through the winter 2020. The new modeling meteorology and model performance will all be concurrent for updating the modeling platform.

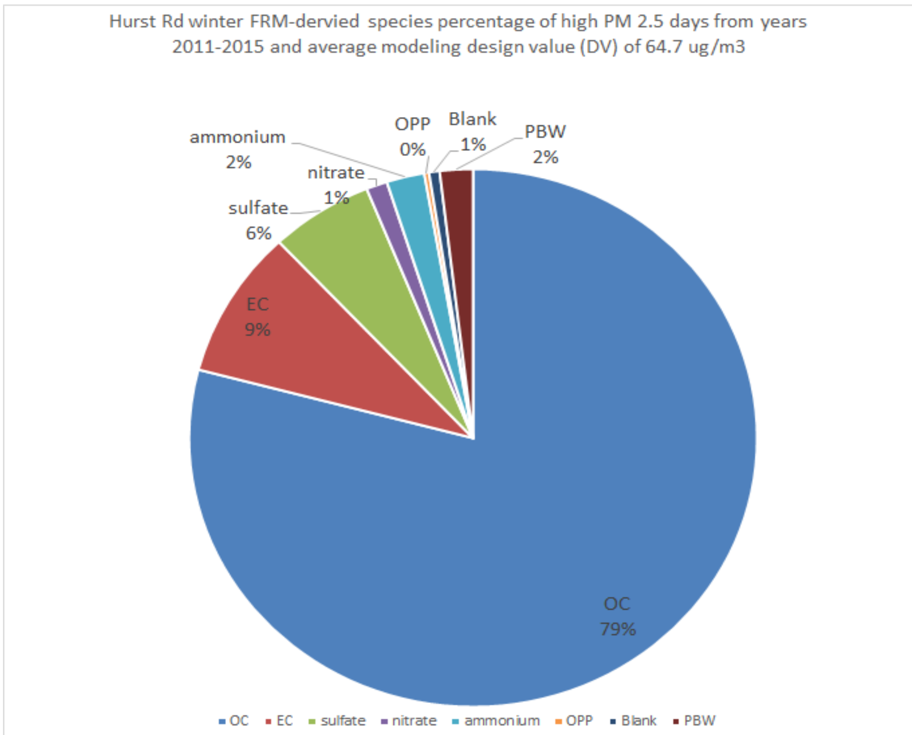


Figure 2.7-1. Serious Area SIP Hurst Rd winter FRM-derived species percentage of high PM 2.5 days from the years 2011 to 2015 and average modeling design value of 64.7 ug/m3

2.8 Inventory Step A Emission Inventory Revisions (2019)

The emissions inventories (EIs) supporting the new modeling platform will be updated in two phases dictated by likely data/model availability and lead-time requirements. As noted earlier in Table 2.2, the Step A EI will be completed in the November 2021 timeframe. Both EI phases will include emission estimates for the following pollutants: $PM_{2.5}$, PM_{10}, SO_2 (SOx), NOx, VOC, and NH_3 over the selected modeling domains.

The Step A EI will be prepared only for calendar year 2019, the Base Year for the 5% Plan based on its use in evaluating model performance for the new platform and timing. The Step A 2019 EI will utilize data sources and methods from the Initial 5% Plan with the following key revisions:

- Use of New Episode Days – New modeling episode days selected from the winter 2019/2020 monitoring period will be selected and used to update source emissions that are day-specific or temperature dependent. DEC currently envisions that the modeling episode(s) will encompass up to approximately 80 days within the winter 2019/2020 period. As described separately below, the 2019 EI revisions triggered by use of the new episodes will be handled separately by source sector.

- Incorporation of 2019/2020 Episodic Data for Point Sources – Once the 2019/2020 wintertime episode days are established, DEC will send request letters to each of the major point source facilities within the $PM_{2.5}$ nonattainment area to obtain day- and hour-specific fuel usage and emissions data by emission unit/release point corresponding to the selected 2019/2020 episode days. Eielson AFB (just outside the nonattainment area) will also be included in this episodic data solicitation since it is anticipated that Eielson's actual day-specific stationary source emissions may change associated with the F-35 squadron deployment phasing in. The data provided by the point source facilities will be reviewed/validated and re-formatted for episodic input to SMOKE using the "PTHOUR" input structure. Where only fuel usage data are provided, facility/emission unit/fuel-specific emission factors from the Initial 5% Plan will be used to calculate episodic emissions.

- Revision of Episodic Emissions for Other Source Sectors – Based on timing requirements, no new activity data will be collected for the other source sectors (Area/Nonpoint and Mobile). However, emissions for source sectors that are temperature and/or calendar day-dependent will be re-calculated based on these data from the 2019/2020 episode(s). At a minimum, this will include space heating area sources and mobile sources. The Fairbanks Home Heating Energy Model (HHEM) will be re-run to reflect temperatures and days of week from the new episode days and used to adjust space heating emissions. For mobile sources, MOVES2014b and the corresponding version of SMOKE-MOVES will be re-run to reflect the dates and ambient temperatures of the new episode(s). (Although EPA may release a new version of MOVES (MOVES202x) before early 2021, the development of the corresponding SMOKE-MOVES tool may lag the release of MOVES202x. Therefore. it is currently envisioned that the Phase 1 2019 EI will be developed using the current MOVES2014b model and SMOKE-MOVES tool.)

2.9 Step B Emission Inventory Revisions (All Applicable Years)

Emission inventory revisions expected to require new data collection with lead time and other scheduling requirements or related to new source models (e.g., MOVES) will be completed under Step B of the EI development. Step B will also include development of EIs for both 2019 and applicable future years (to be determined) to support updated attainment analysis modeling. As noted in Table 2.2, the Step B EI work is expected to be completed in 2023.

At this time, the Step B EI revisions will include (at a minimum):

- Space Heating Survey – The Initial 5% SIP utilizes space heating device and fuel use activity data within the Fairbanks HHEM based on household survey data collected in Fairbanks from 2011-2015. This is coupled with wood-oil cross-price elasticity estimated from similar data that accounts for year-to-year shifts in wood vs. heating oil usage as oil prices change. It is envisioned that additional local space heating survey work will be conducted after the Step A EI is completed to provide more current space heating device and fuel usage patterns beyond 2021 and/or verify the elasticity-based projections of this usage from the earlier 2011-2015 survey data. The results of the new survey will be used to update the space heating activity estimates by device and fuel type (and resulting emissions) within the EI.

- MOVES3 – EPA released a new version of MOVES in January 2021 called MOVES3. The latest patch to MOVES3 (MOVES3.0.2) was released in September 2021 and notably revises nonroad vehicle particulate matter emissions. The release of MOVES3 and its updates came after most of the development of the Phase 1 modeling and may involve workflow changes related to the SMOKE/MOVES tool for use in gridding emissions within SMOKE Thus revisions to mobile source based emissions (onroad and nonroad) using the newer MOVES3 model will be deferred until Step B of the EI revisions. This will give sufficient time to test and compare MOVES outputs to those from tMOVES2014b version for wintertime emissions in Fairbanks from both on-road and non-road mobile sources to ensure emission changes are consistent with the underlying improvements to the MOVES model.

Finally, DEC will also be evaluating potential use of revised solid fuel burning device emission factors from current/on-going testing research that is expected to be published under the Step B EI timeframe. Expected issues to be address under this evaluation include completeness/representativeness of testing data and test methods, mechanisms to weight the test results to Fairbanks-specific usage patterns and mapping the tested devices/technologies to the population of installed devices and/or those incentivized through state/local control programs.

2.10 SMOKE Step A 2019 EI

Once the 2019 EI is prepared for the new winter 2019/2020 episode, it will need to be re-run through SMOKE 4.7 for CMAQ 5.3.2. This task will be completed initially by DEC's contractor on a parallel system.

2.11 CMAQ model performance for 5.3.2

DEC will have new 2019 emissions processed and new MCIP5 inputs for the CMAQ 5.3.2 and then model performance tests will be performed for PM 2.5 and all species and precursor gases. The CMAQ model sensitivity tests in phase 1 showed that the original emission control file, which bases the temperature dependent partitioning of organic aerosol volatility on a diesel engine and the biomasses based on wood burning specific profile are very similar. The difference results in 1.5 ug/m3 increase with biomass. These results were presented to the USEPA ORD RARE grant group on 9/14/21 and the question of which emissions control file profile to use was raised. Both represent volatility based on temperature and at cold temperatures this volatility is low. EPA stated that both would be representative of wood burning due to the cold temperatures. The decision was made to start with the original emission control file that will speed up the modeling and if the model performance is acceptable then the additional runs using the biomass profile will not be run. This will include OC, EC, SO4, NH4, NO3, Other and precursor gases, SO2, NOx, NH3 and VOCs. The model performance will be performed on NCORE and Hurst RD speciation data.

2.12 Modeling performance discussion and approval

The model performance and resulting metrics, including soccer plots, will be discussed and presented to EPA with collaboration between DEC, FNSB, EPA and stakeholders on the final modeling platform. The specific operational model performance evaluation (MPE) is outlined in section 3.1 of the Ozone and PM 2.5 modeling guidance.[14] The final report will be written up and sent to EPA for review and approval of the new modeling platform.

2.13 CMAQ 5.3.2

Once the model performance and any other sensitivity run have been performed and the model performance is acceptable, then the model run with new emissions and meteorology can be run for an updated modeling platform 2019 baseline model run.

Phase 3 PM2.5 Model for regulatory purposes

Phase 3 of the modeling platform update is using the new model (completed from Phase 2) for regulatory work including SIP updates and precursor demonstrations. There are mandatory steps that must be completed before a model may be used for regulatory purposes. These mandatory steps have been documented previously in the Moderate and Serious SIPs. Briefly, these steps include development of a new 5-yr modeling design value with concurrence from EPA; selection of a new base year and the development of a new emissions inventory. These items require updating due to the time that has passed since the last regulatory modelling was conducted.

When conducting regulatory modeling there are several steps in additional to those identified above. For example, the raw model outputs from the updated CMAQ model are run through SMAT (speciated model attainment testing) to identify a baseline design value and a future design value. Future modeling runs and different scenarios are identified and run through the model based on things like current regulations and control programs in place and input from stakeholder groups, community members, FNSB, DEC and EPA. Then future year model runs are conducted to assess controls and precursors. It can take multiple model runs to assess various control measures, typically 2-5 runs. Phase 3 of the modeling update has not started yet, except to identify elements that need to be updated and that have significant lead time (e.g. Home heating survey). Model runs to support pollutant-specific precursor demonstrations may only be conducted at the end of Phase 3 when all the mandatory steps are completed.

[14] o3-pm-rh-modeling_guidance-2018.pdf (epa.gov)

Appendix A.

1- Emission Control File –BM (Biomass burning profile)

```
! --> Nonvolatile POA
 'EVERYWHERE', 'ALL'         ,'POC'    ,'APOC'       ,'FINE',0.   ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'APNCOM'     ,'FINE',0.   ,'MASS','a',
! --> Semivolatile POA
! Modified by mtrail (3/19/2021) to resemble biomass burning (https://acp.copernicus.org/articles/16/4081/2016/acp-16-4081-2016.pdf)
 'EVERYWHERE', 'ALL'         ,'POC'    ,'VLVP01'     ,'GAS' ,0.   ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'VLVP01'     ,'GAS' ,0.   ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'VSVP01'     ,'GAS' ,0.0  ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'VSVP01'     ,'GAS' ,0.0  ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'VSVP02'     ,'GAS' ,0.0  ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'VSVP02'     ,'GAS' ,0.0  ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'VSVP03'     ,'GAS' ,0.2  ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'VSVP03'     ,'GAS' ,0.2  ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'VIVP01'     ,'GAS' ,0.4  ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'VIVP01'     ,'GAS' ,0.4  ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'ALVP01'     ,'FINE',0.20 ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'ALVP01'     ,'FINE',0.20 ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'ASVP01'     ,'FINE',0.10 ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'ASVP01'     ,'FINE',0.10 ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'ASVP02'     ,'FINE',0.10 ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'ASVP02'     ,'FINE',0.10 ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'ASVP03'     ,'FINE',0.   ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'ASVP03'     ,'FINE',0.   ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'POC'    ,'AIVP01'     ,'FINE',0.   ,'MASS','a',
 'EVERYWHERE', 'ALL'         ,'PNCOM'  ,'AIVP01'     ,'FINE',0.   ,'MASS','a',
```

2- SPECIES Definition File for CMAQ version 5.3.2

!#start YYYYJJJ 010000
!#end YYYYJJJ 000000
!#layer 1

/
! This Species Definition File is for Use with the COMBINE tool built for
! post-processing CMAQ output. It is compatible with CMAQv5.2.
! Date: May 12 2017

! Output variables that begin with 'PM' represent those in which a size cut was
! applied based on modeled aerosol mode parameters. For example, PM25_NA is all
! sodium that falls below 2.5 um diameter. These 'PM' variables are used for
! comparisons at IMPROVE and CSN sites.

! Output variables that begin with 'PMAMS' represent the mass that would have
! been detected by an Aerosol Mass Spectrometer.

! Output variables beginning with 'A' (aside from AIR_DENS) represent a
! combination of aerosol species in which no size cut was applied. For example,
! ASO4IJ is the sum of i-mode and j-mode sulfate. These 'A' variables are used
! for comparisons at CASTNet sites.

! Output variables beginning with 'PMC' refer to the coarse fraction of total PM,
! computed by summing all modes and subtracting the PM2.5 fraction. These 'PMC'

```
! variables are used for comparisons at SEARCH sites.

! This Species Definition File is just for use with the uncoupled, offline CMAQ,
! model. If you are processing WRF-CMAQ results, a different Species Definition
! file is required.

/ File [1]: CMAQ conc/aconc file


/new species    ,units     ,expression

!-------------------------------------------!
!--------------- Particles -----------------!
!-------------------------------------------!
!! Crustal Elements
AFEJ          ,ug m-3     ,AFEJ[1]
AALJ          ,ug m-3     ,AALJ[1]
ASIJ          ,ug m-3     ,ASIJ[1]
ATIJ          ,ug m-3     ,ATIJ[1]
ACAJ          ,ug m-3     ,ACAJ[1]
AMGJ          ,ug m-3     ,AMGJ[1]
AKJ           ,ug m-3     ,AKJ[1]
AMNJ          ,ug m-3     ,AMNJ[1]
ASOILJ        ,ug m-3     ,2.20*AALJ[1]+2.49*ASIJ[1]+1.63*ACAJ[1]+2.42*AFEJ[1]+1.94*ATIJ[1]

!! Non-Crustal Inorganic Particle Species
AHPLUSIJ      ,umol m-3   ,(AH3OPI[1]+AH3OPJ[1])*1.0/19.0
ANAK          ,ug m-3     ,0.8373*ASEACAT[1]+0.0626*ASOIL[1]+0.0023*ACORS[1]
AMGK          ,ug m-3     ,0.0997*ASEACAT[1]+0.0170*ASOIL[1]+0.0032*ACORS[1]
AKK           ,ug m-3     ,0.0310*ASEACAT[1]+0.0242*ASOIL[1]+0.0176*ACORS[1]
ACAK          ,ug m-3     ,0.0320*ASEACAT[1]+0.0838*ASOIL[1]+0.0562*ACORS[1]
ACLIJ         ,ug m-3     ,ACLI[1]+ACLJ[1]
AECIJ         ,ug m-3     ,AECI[1]+AECJ[1]
ANAIJ         ,ug m-3     ,ANAJ[1]+ANAI[1]
ANO3IJ        ,ug m-3     ,ANO3I[1]+ANO3J[1]
ANO3K         ,ug m-3     ,ANO3K[1]
ANH4IJ        ,ug m-3     ,ANH4I[1]+ANH4J[1]
ANH4K         ,ug m-3     ,ANH4K[1]
ASO4IJ        ,ug m-3     ,ASO4I[1]+ASO4J[1]
ASO4K         ,ug m-3     ,ASO4K[1]

!! Organic Particle Species
APOCI         ,ugC m-3    ,ALVPO1I[1]/1.39 + ASVPO1I[1]/1.32 + ASVPO2I[1]/1.26 \
```

```
                  +APOCI[1]
APOCJ       ,ugC m-3    ,ALVPO1J[1]/1.39 + ASVPO1J[1]/1.32 + ASVPO2J[1]/1.26 \
                  +ASVPO3J[1]/1.21 + AIVPO1J[1]/1.17  + APOCJ[1]
APOCIJ      ,ugC m-3    ,APOCI[0] + APOCJ[0]

APOMI        ,ug m-3     ,ALVPO1I[1] + ASVPO1I[1] + ASVPO2I[1] + APOCI[1]     \
                  +APNCOMI[1]
APOMJ        ,ug m-3     ,ALVPO1J[1] + ASVPO1J[1] + ASVPO2J[1] + APOCJ[1]     \
                  +ASVPO3J[1] + AIVPO1J[1]  + APNCOMJ[1]
APOMIJ       ,ug m-3     ,APOMI[0] + APOMJ[0]

ASOCI       ,ugC m-3    ,ALVOO1I[1]/2.27 + ALVOO2I[1]/2.06  \
                  +ASVOO1I[1]/1.88 + ASVOO2I[1]/1.73
ASOCJ       ,ugC m-3    ,AISO1J[1]/2.20  + AISO2J[1]/2.23  + AISO3J[1]/2.80 \
                  +AMT1J[1]/1.67   + AMT2J[1]/1.67   + AMT3J[1]/1.72  \
                  +AMT4J[1]/1.53   + AMT5J[1]/1.57   + AMT6J[1]/1.40  \
                  + AMTNO3J[1]/1.90 + AMTHYDJ[1]/1.54               \
                  +AGLYJ[1]/2.13   + ASQTJ[1]/1.52                  \
                  +AORGCJ[1]/2.00  + AOLGBJ[1]/2.10  + AOLGAJ[1]/2.50 \
                  +ALVOO1J[1]/2.27 + ALVOO2J[1]/2.06 + ASVOO1J[1]/1.88\
                  +ASVOO2J[1]/1.73 + ASVOO3J[1]/1.60 + APCSOJ[1] /2.00 \
                  +AAVB1J[1]/2.70  + AAVB2J[1]/2.35  + AAVB3J[1]/2.17  \
                  +AAVB4J[1]/1.99
ASOCIJ      ,ugC m-3    ,ASOCI[0] + ASOCJ[0]

ASOMI        ,ug m-3     ,ALVOO1I[1] + ALVOO2I[1] + ASVOO1I[1] + ASVOO2I[1]
ASOMJ        ,ug m-3     ,+AISO1J[1]+ AISO2J[1]  + AISO3J[1]             \
                  +AMT1J[1]   + AMT2J[1]   + AMT3J[1]   + AMT4J[1]  \
                  +AMT5J[1]   + AMT6J[1]   + AMTNO3J[1]\
                  +AMTHYDJ[1] + AGLYJ[1]   + ASQTJ[1]              \
                  +AORGCJ[1]  + AOLGBJ[1]  + AOLGAJ[1]             \
                  +ALVOO1J[1] + ALVOO2J[1] + ASVOO1J[1] + ASVOO2J[1]\
                  +ASVOO3J[1] + APCSOJ[1]  + AAVB1J[1] + AAVB2J[1]\
                  +AAVB3J[1] + AAVB4J[1]
ASOMIJ       ,ug m-3     ,ASOMI[0] + ASOMJ[0]

AOCI        ,ugC m-3    ,APOCI[0]  + ASOCI[0]
AOCJ        ,ugC m-3    ,APOCJ[0]  + ASOCJ[0]
AOCIJ       ,ugC m-3    ,APOCIJ[0] + ASOCIJ[0]

AOMI         ,ug m-3     ,APOMI[0]  + ASOMI[0]
AOMJ         ,ug m-3     ,APOMJ[0]  + ASOMJ[0]
AOMIJ        ,ug m-3     ,APOMIJ[0] + ASOMIJ[0]
```

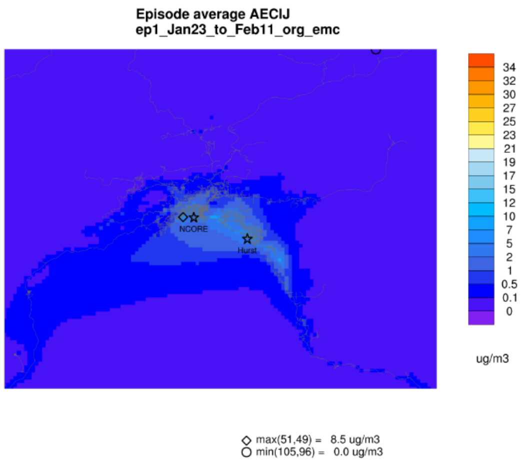
```
!!! Anthropogenic-VOC Derived Organic Aerosol
AORGAJ        ,ug m-3     ,AAVB1J[1]+AAVB2J[1]+AAVB3J[1]+AAVB4J[1]+AOLGAJ[1] \

!!! Biogenic-VOC Derived Organic Aerosol
AORGBJ        ,ug m-3     ,AISO1J[1] + AISO2J[1] + AISO3J[1]          \
                 +AMT1J[1]  + AMT2J[1]  + AMT3J[1] + AMT4J[1]  \
                 +AMT5J[1]  + AMT6J[1]                    \
                 +AMTNO3J[1]+ AMTHYDJ[1] + AGLYJ[1]           \
                 +ASQTJ[1]  + AOLGBJ[1]

!!! Cloud-Processed  SOA
AORGCJ        ,ug m-3     ,AORGCJ[1]

!!! OM/OC ratios
AOMOCRAT_TOT    ,ug ug-1    ,AOMIJ[0]/AOCIJ[0]

!! Total PM Aggregates
ATOTI         ,ug m-3     ,ASO4I[1]+ANO3I[1]+ANH4I[1]+ANAI[1]+ACLI[1] \
                 +AECI[1]+AOMI[0]+AOTHRI[1]
ATOTJ         ,ug m-3     ,ASO4J[1]+ANO3J[1]+ANH4J[1]+ANAJ[1]+ACLJ[1] \
                 +AECJ[1]+AOMJ[0]+AOTHRJ[1]+AFEJ[1]+ASIJ[1]  \
                 +ATIJ[1]+ACAJ[1]+AMGJ[1]+AMNJ[1]+AALJ[1]+AKJ[1]
ATOTK         ,ug m-3     ,ASOIL[1]+ACORS[1]+ASEACAT[1]+ACLK[1]+ASO4K[1] \
                 +ANO3K[1]+ANH4K[1]
ATOTIJ        ,ug m-3     ,ATOTI[0]+ATOTJ[0]
ATOTIJK       ,ug m-3     ,ATOTIJ[0]+ATOTK[0]

PM25_OTHIJ     ,ug m-3    ,AOTHRI[1]+AOTHRJ[1]+ANAI[1]+ACLI[1]+ANAJ[1]+ACLJ[1]

!!! gas species
CO          ,ppbV     ,1000.0*CO[1]
O3          ,ppbV     ,1000.0*O3[1]
SO2         ,ppbV     ,1000.0*SO2[1]
NOX         ,ppbV     ,1000.0*(NO[1] + NO2[1])
```

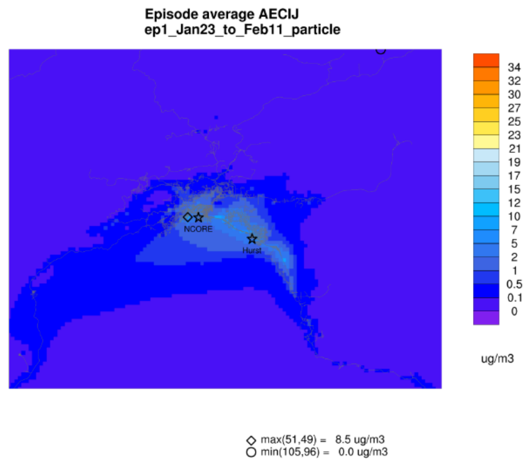
3- Species Def file for CMAQ 4.7.1

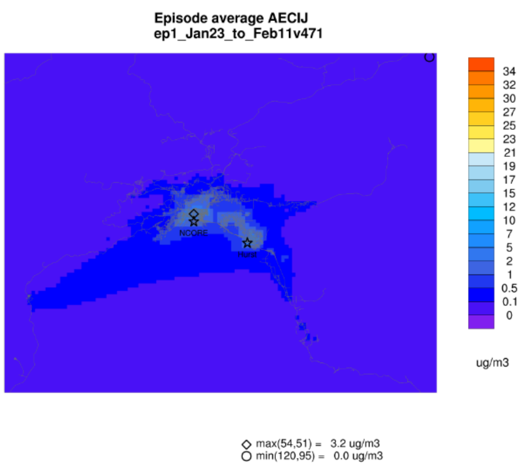
```
/new species    ,units     ,expression
AECIJ         ,ug m-3     ,AECI[1]+AECJ[1]
ANAIJ         ,ug m-3     ,ANAJ[1]+ANAI[1]
ANO3IJ        ,ug m-3     ,ANO3I[1]+ANO3J[1]
ANH4IJ        ,ug m-3     ,ANH4I[1]+ANH4J[1]
```

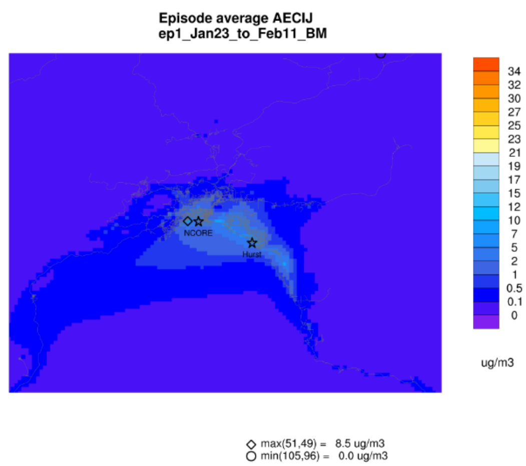
```
ASO4IJ        ,ug m-3     ,ASO4I[1]+ASO4J[1]
APOMIJ        ,ug m-3     ,1.167*AORGPAJ[1]+1.167*AORGPAI[1]
AOMIJ         ,ug m-3
,AORGCJ[1]+AOLGAJ[1]+AOLGBJ[1]+1.167*AORGPAJ[1]+1.167*AORGPAI[1]
CO            ,ppbV      ,1000.0*CO[1]
O3            ,ppbV      ,1000.0*O3[1]
SO2           ,ppbV      ,1000.0*SO2[1]
NOX           ,ppbV      ,1000.0*(NO[1] + NO2[1])
PM25_OTH      ,ug/m3   ,A25J[1]+A25I[1]+ANAJ[1]+ANAI[1]+ACLJ[1]+ACLI[1]
ATOTIJ        ,ug/m3   ,AECIJ[0]+ANO3IJ[0]+ASO4IJ[0]+ANH4IJ[0]+AOMIJ[0]+PM25_OTH[0]
```

4- Figures for the CMAQ version comparison with 2019 EI and 2008 WRF for episode 1 and episode 2: PM 2.5, OM (organic matter, primary and secondary), POM (primary organic matter), POC (primary organic carbon), PMOTH, AN4, NO3, SO4, NOx, SO2 and O3 are following for CMAQ v471, v532_org_emc, v532_BM and v532_particle

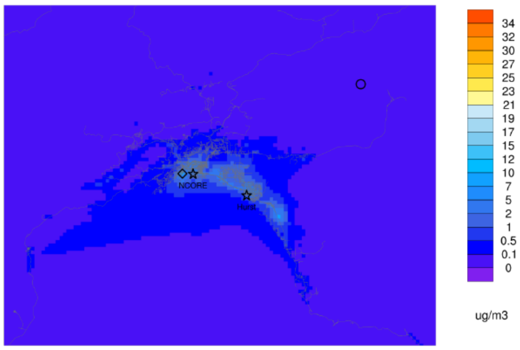

Episode average AECIJ
ep1_Jan23_to_Feb11_org_emc
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
NCORE
Hurst
max(51,49) = 8.5 ug/m3
min(105,96) = 0.0 ug/m3


Episode average AECIJ
ep1_Jan23_to_Feb11_particle
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
NCORE
Hurst
max(51,49) = 8.5 ug/m3
min(105,96) = 0.0 ug/m3


Episode average AECIJ
ep1_Jan23_to_Feb11v471
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
NCORE
Hurst
max(54,51) = 3.2 ug/m3
min(120,95) = 0.0 ug/m3

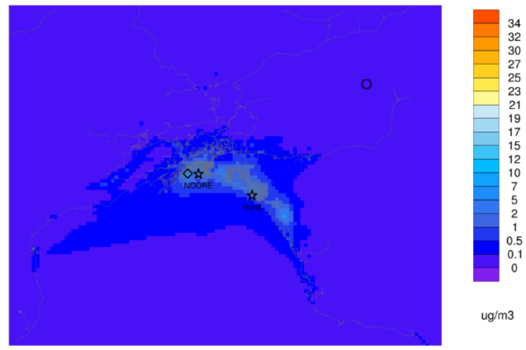

Episode average AECIJ
ep1_Jan23_to_Feb11_BM
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
NCORE
Hurst
max(51,49) = 8.5 ug/m3
min(105,96) = 0.0 ug/m3

Episode average AECIJ
ep2_Nov2_to_Nov22_org_emc



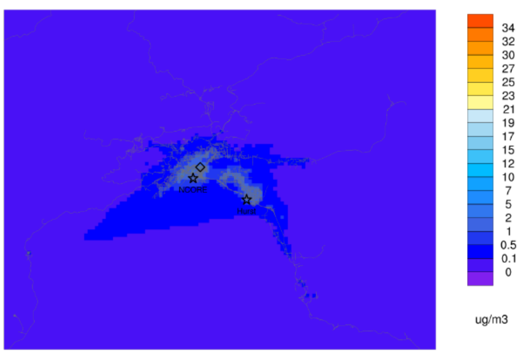
◇ max(51,49) = 7.8 ug/m3
○ min(101,74) = 0.0 ug/m3

Episode average AECIJ
ep2_Nov2_to_Nov22_particle



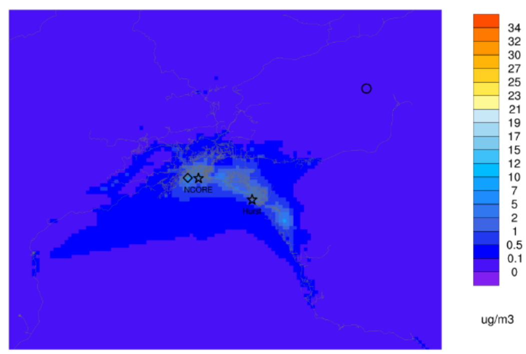
◇ max(51,49) = 7.8 ug/m3
○ min(101,74) = 0.0 ug/m3

Episode average AECIJ
ep2_Nov2_to_Nov22v471

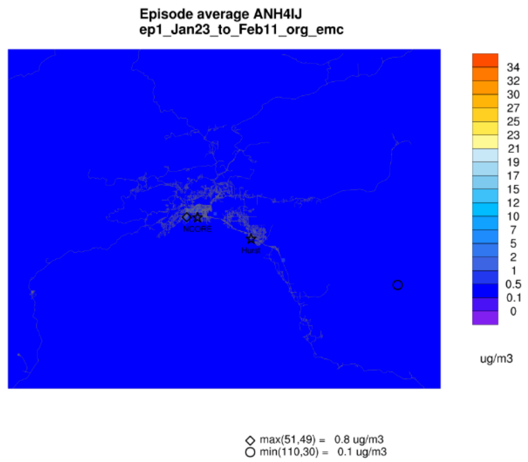


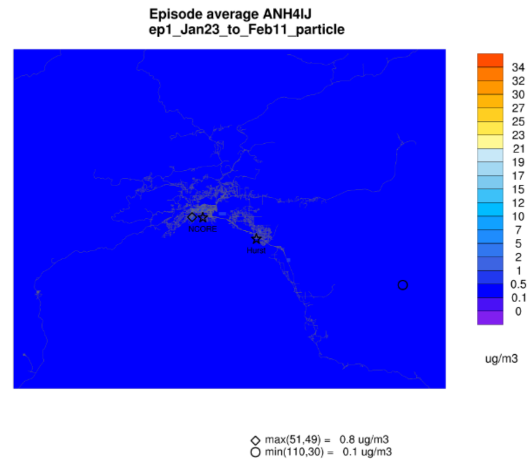
◇ max(56,52) = 2.4 ug/m3
○ min(122,14) = 0.0 ug/m3

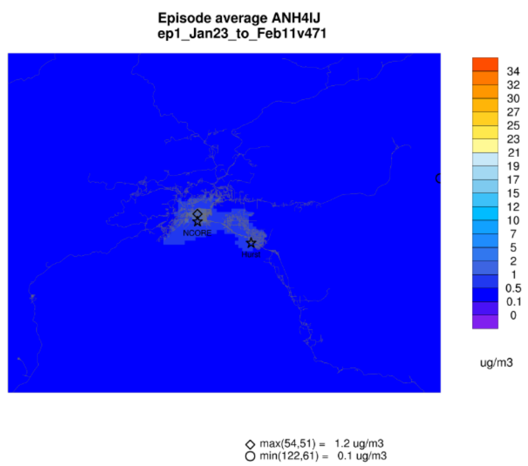
Episode average AECIJ
ep2_Nov2_to_Nov22_BM

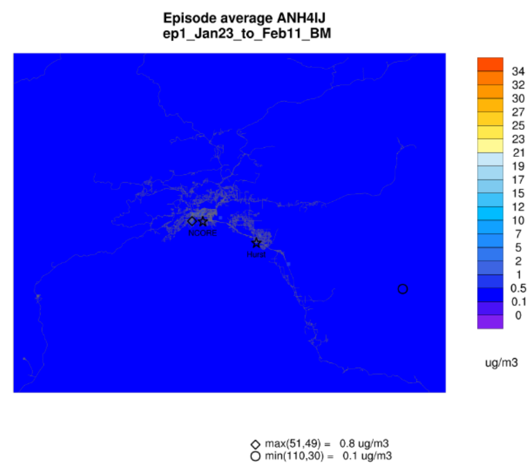


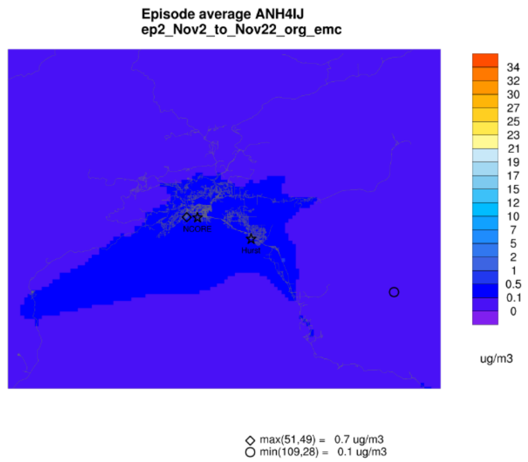
◇ max(51,49) = 7.8 ug/m3
○ min(101,74) = 0.0 ug/m3

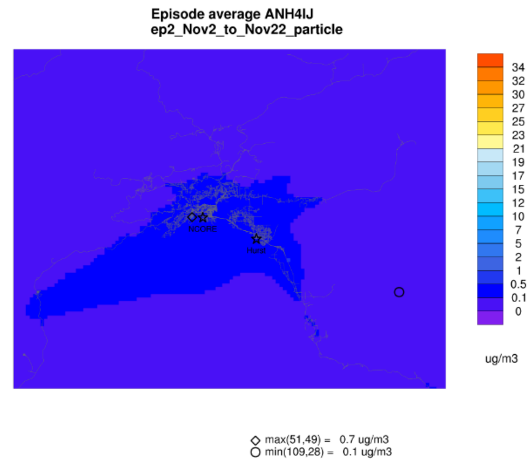

Episode average ANH4IJ
ep1_Jan23_to_Feb11_org_emc
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
max(51,49) = 0.8 ug/m3
min(110,30) = 0.1 ug/m3

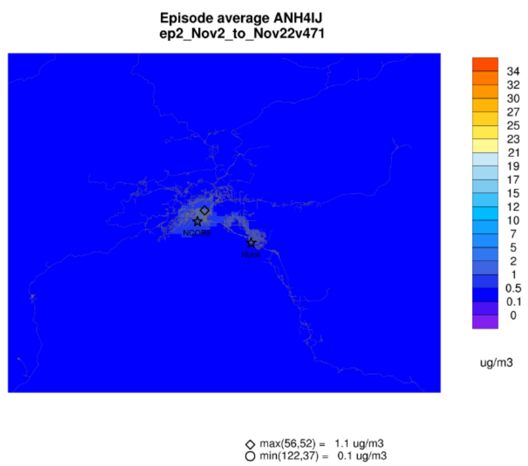

Episode average ANH4IJ
ep1_Jan23_to_Feb11_particle
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
max(51,49) = 0.8 ug/m3
min(110,30) = 0.1 ug/m3

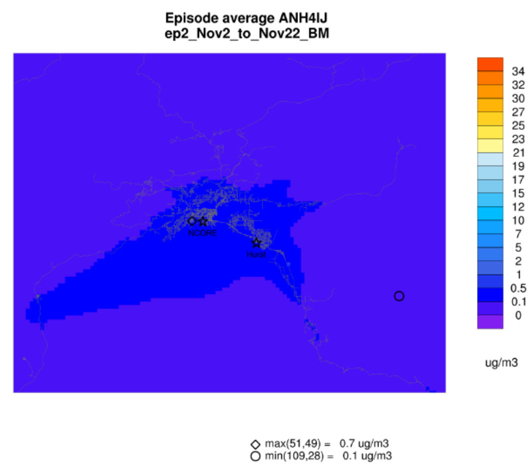

Episode average ANH4IJ
ep1_Jan23_to_Feb11v471
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
max(54,51) = 1.2 ug/m3
min(122,61) = 0.1 ug/m3

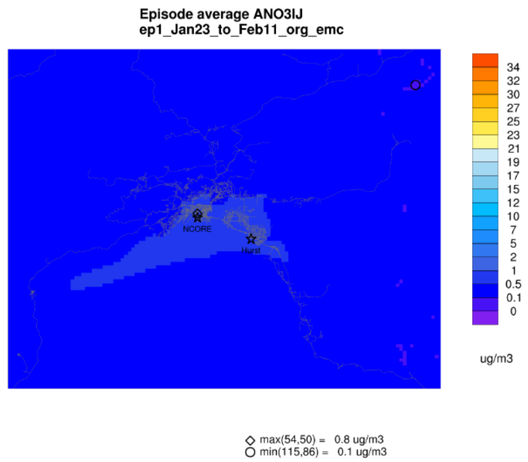

Episode average ANH4IJ
ep1_Jan23_to_Feb11_BM
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
max(51,49) = 0.8 ug/m3
min(110,30) = 0.1 ug/m3

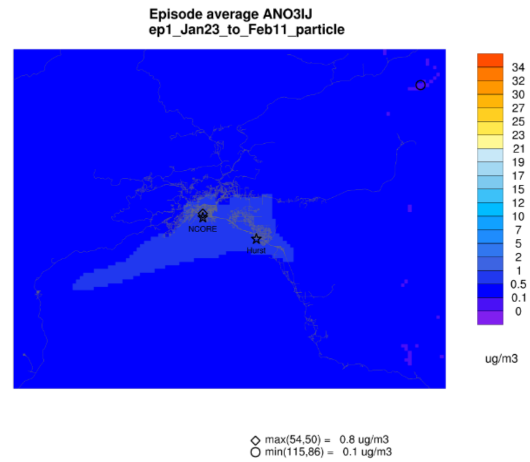

Episode average ANH4IJ
ep2_Nov2_to_Nov22_org_emc
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(51,49) = 0.7 ug/m3
min(109,28) = 0.1 ug/m3

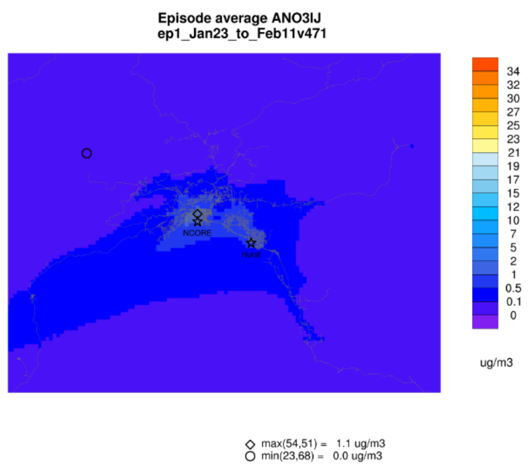

Episode average ANH4IJ
ep2_Nov2_to_Nov22_particle
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(51,49) = 0.7 ug/m3
min(109,28) = 0.1 ug/m3

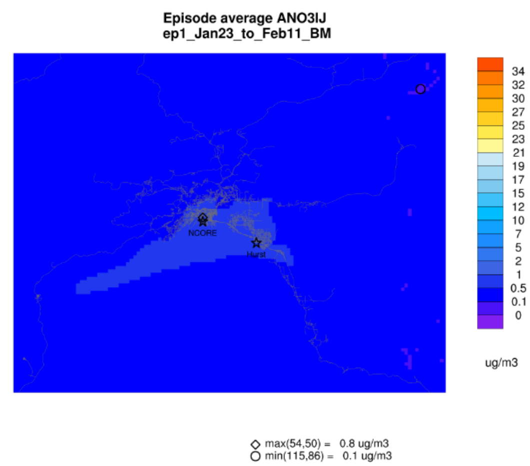

Episode average ANH4IJ
ep2_Nov2_to_Nov22v471
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(56,52) = 1.1 ug/m3
min(122,37) = 0.1 ug/m3

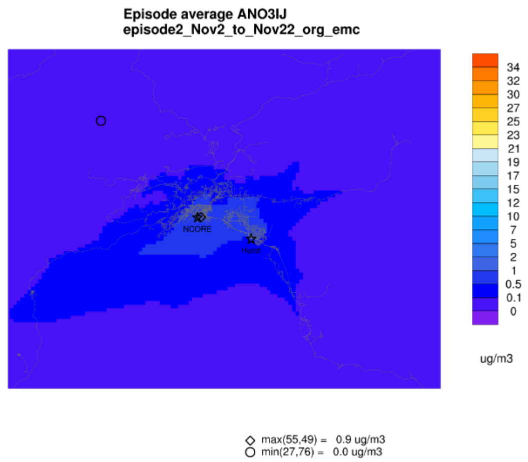

Episode average ANH4IJ
ep2_Nov2_to_Nov22_BM
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(51,49) = 0.7 ug/m3
min(109,28) = 0.1 ug/m3

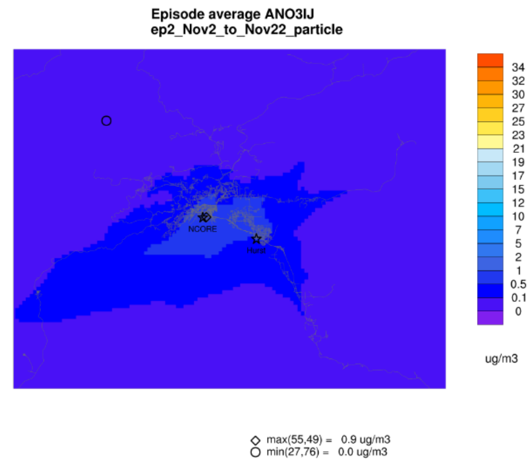

Episode average ANO3IJ
ep1_Jan23_to_Feb11_org_emc
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 0.8 ug/m3
min(115,86) = 0.1 ug/m3

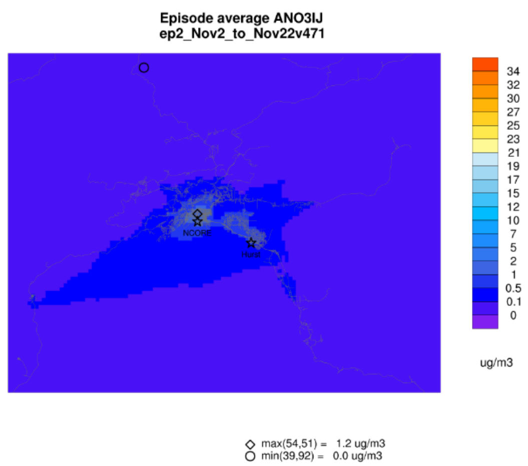

Episode average ANO3IJ
ep1_Jan23_to_Feb11_particle
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 0.8 ug/m3
min(115,86) = 0.1 ug/m3

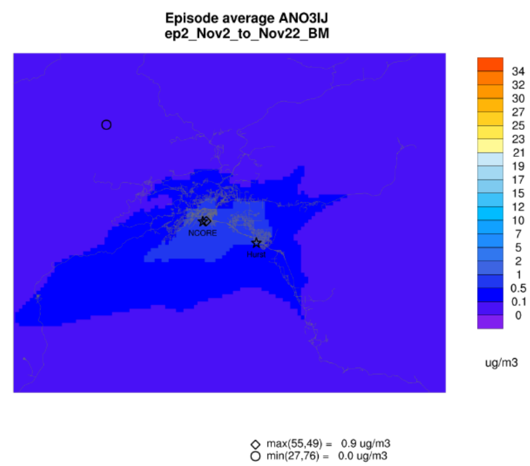

Episode average ANO3IJ
ep1_Jan23_to_Feb11v471
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,51) = 1.1 ug/m3
min(23,68) = 0.0 ug/m3

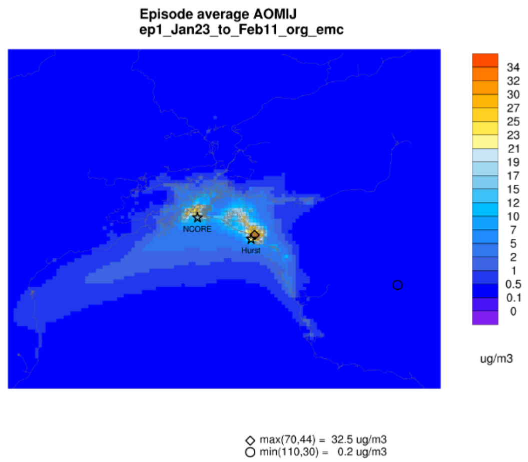

Episode average ANO3IJ
ep1_Jan23_to_Feb11_BM
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 0.8 ug/m3
min(115,86) = 0.1 ug/m3

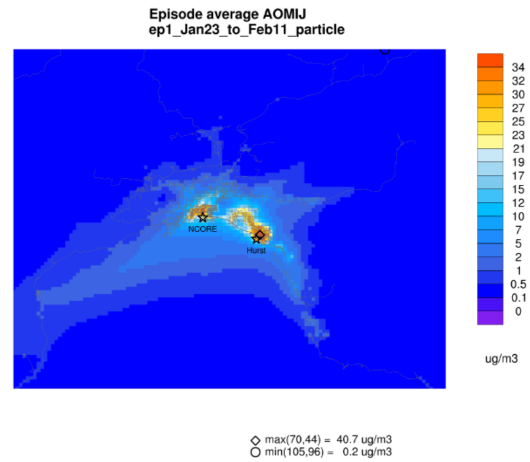

Episode average ANO3IJ
episode2_Nov2_to_Nov22_org_emc
NCORE
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(55,49) = 0.9 ug/m3
min(27,76) = 0.0 ug/m3

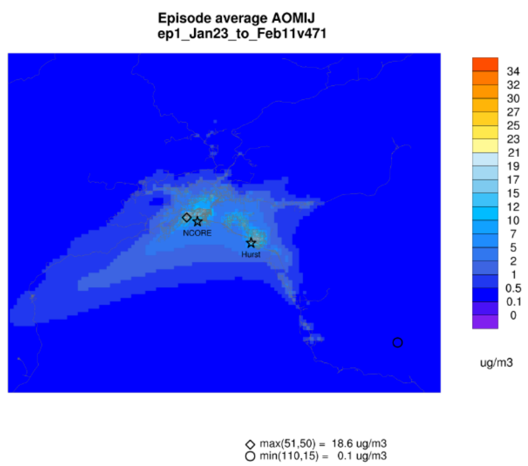

Episode average ANO3IJ
ep2_Nov2_to_Nov22_particle
NCORE
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(55,49) = 0.9 ug/m3
min(27,76) = 0.0 ug/m3

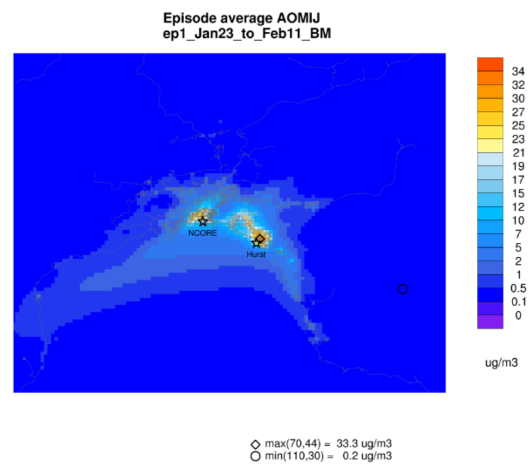

Episode average ANO3IJ
ep2_Nov2_to_Nov22v471
NCORE
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,51) = 1.2 ug/m3
min(39,92) = 0.0 ug/m3

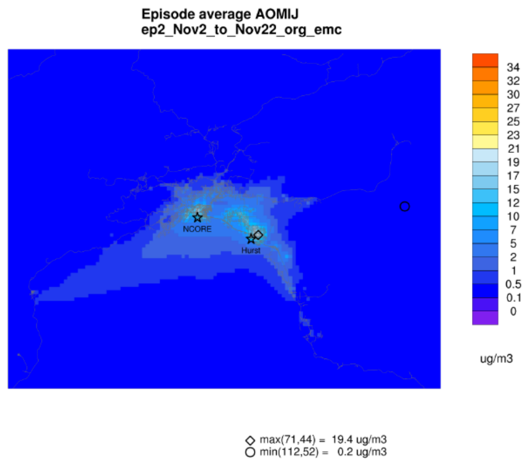

Episode average ANO3IJ
ep2_Nov2_to_Nov22_BM
NCORE
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(55,49) = 0.9 ug/m3
min(27,76) = 0.0 ug/m3

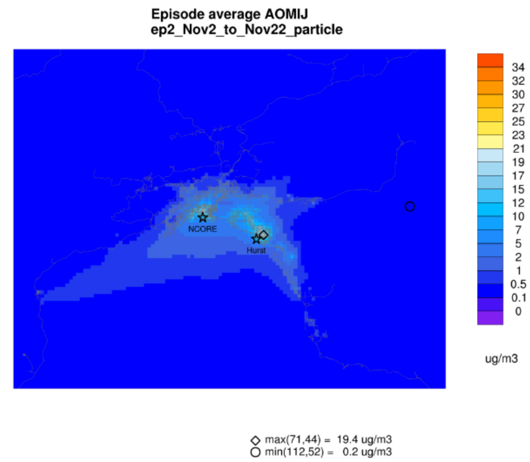

Episode average AOMIJ
ep1_Jan23_to_Feb11_org_emc
NCORE
Hurst
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
◇ max(70,44) = 32.5 ug/m3
○ min(110,30) = 0.2 ug/m3

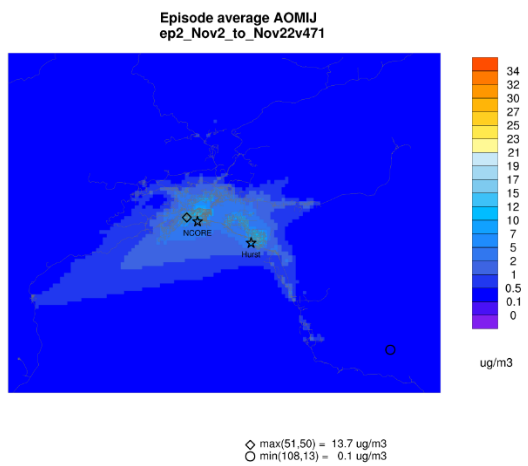

Episode average AOMIJ
ep1_Jan23_to_Feb11_particle
NCORE
Hurst
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
◇ max(70,44) = 40.7 ug/m3
○ min(105,96) = 0.2 ug/m3

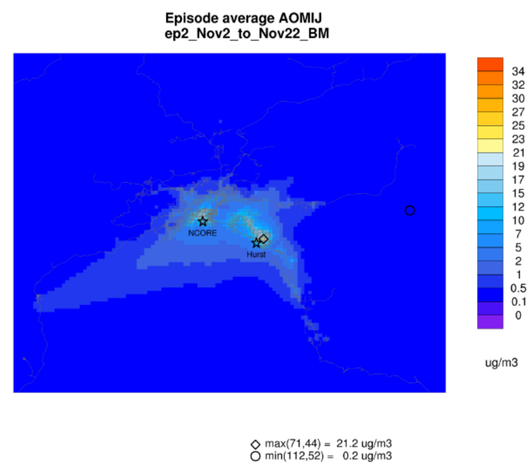

Episode average AOMIJ
ep1_Jan23_to_Feb11v471
NCORE
Hurst
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
◇ max(51,50) = 18.6 ug/m3
○ min(110,15) = 0.1 ug/m3


Episode average AOMIJ
ep1_Jan23_to_Feb11_BM
NCORE
Hurst
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
◇ max(70,44) = 33.3 ug/m3
○ min(110,30) = 0.2 ug/m3

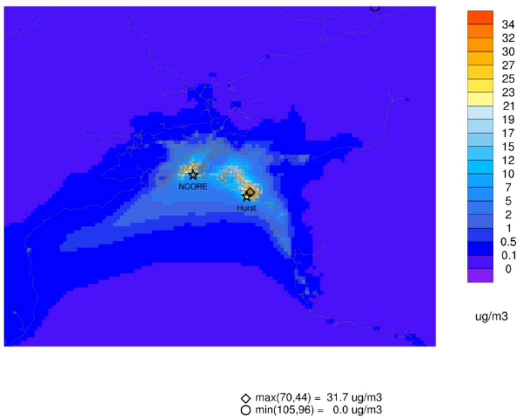

Episode average AOMIJ
ep2_Nov2_to_Nov22_org_emc
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(71,44) = 19.4 ug/m3
min(112,52) = 0.2 ug/m3


Episode average AOMIJ
ep2_Nov2_to_Nov22_particle
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(71,44) = 19.4 ug/m3
min(112,52) = 0.2 ug/m3

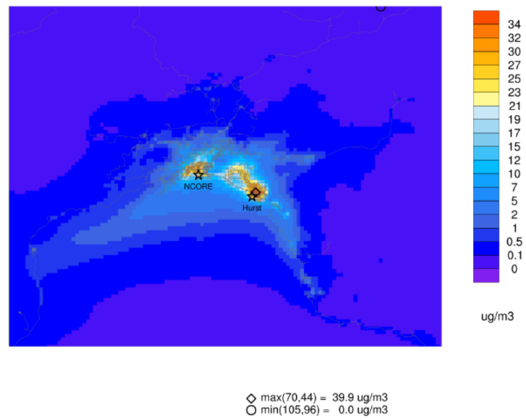

Episode average AOMIJ
ep2_Nov2_to_Nov22v471
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(51,50) = 13.7 ug/m3
min(108,13) = 0.1 ug/m3


Episode average AOMIJ
ep2_Nov2_to_Nov22_BM
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(71,44) = 21.2 ug/m3
min(112,52) = 0.2 ug/m3

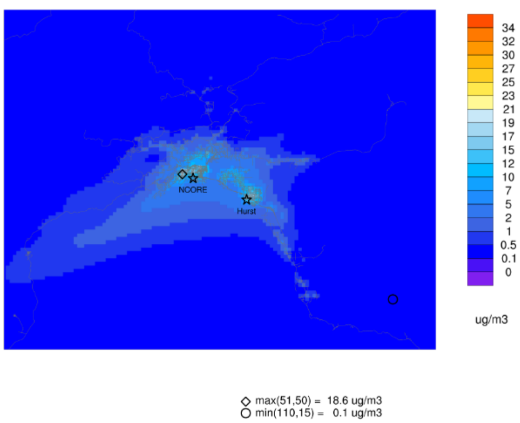
Episode average APOMIJ
ep1_Jan23_to_Feb11_org_emc



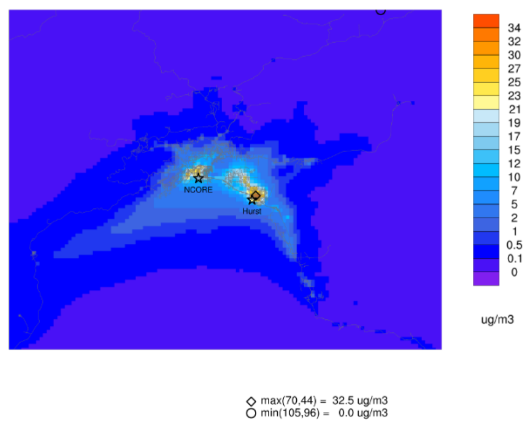
Episode average APOMIJ
ep1_Jan23_to_Feb11_particle



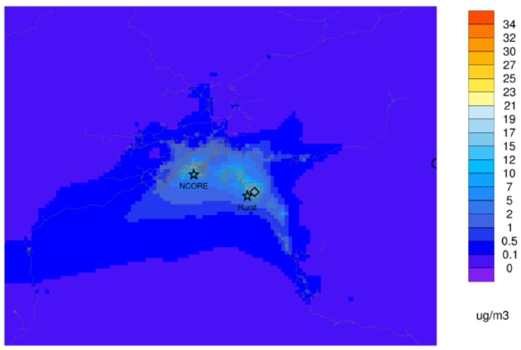
Episode average APOMIJ
ep1_Jan23_to_Feb11v471



Episode average APOMIJ
ep1_Jan23_to_Feb11_BM

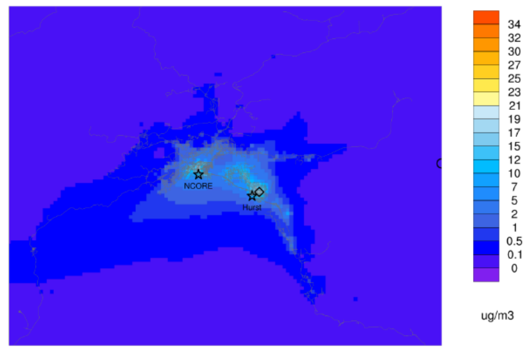


Episode average APOMIJ
ep2_Nov2_to_Nov22_org_emc



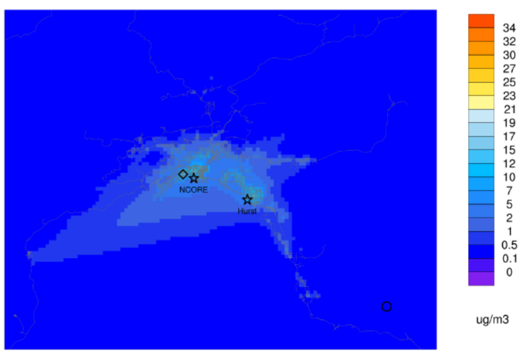
◇ max(71,44) = 18.6 ug/m3
○ min(122,52) = 0.0 ug/m3

Episode average APOMIJ
ep2_Nov2_to_Nov22_particle



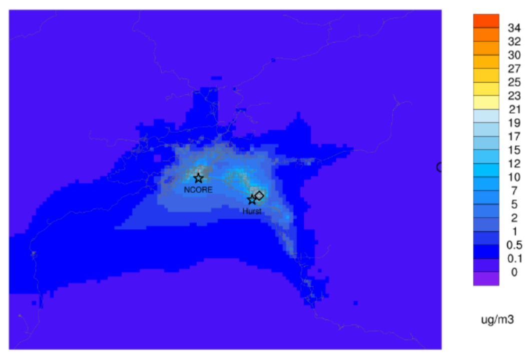
◇ max(71,44) = 18.6 ug/m3
○ min(122,52) = 0.0 ug/m3

Episode average APOMIJ
ep2_Nov2_to_Nov22v471

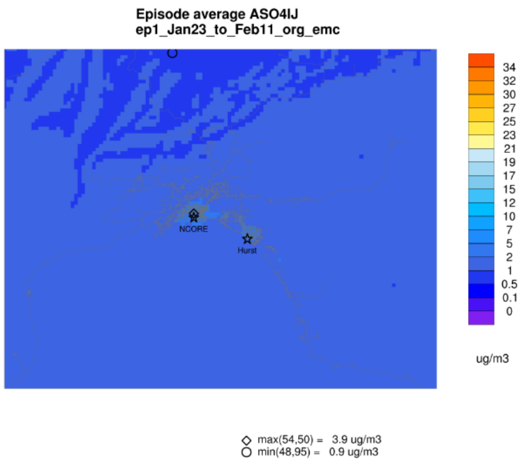


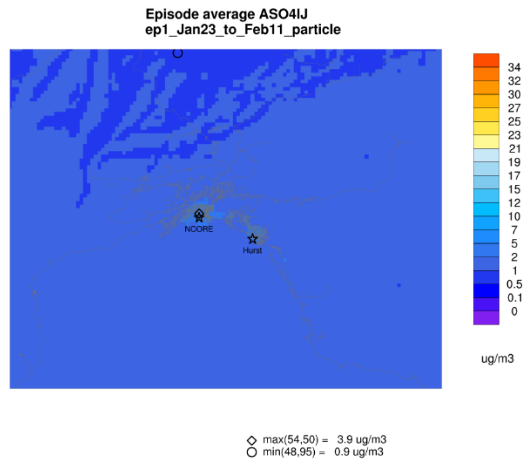
◇ max(51,50) = 13.7 ug/m3
○ min(108,13) = 0.1 ug/m3

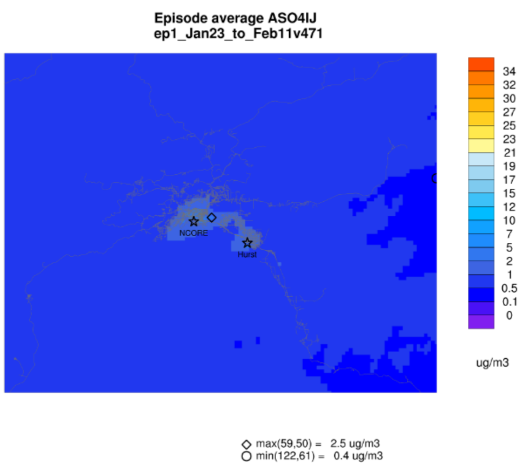
Episode average APOMIJ
ep2_Nov2_to_Nov22_BM

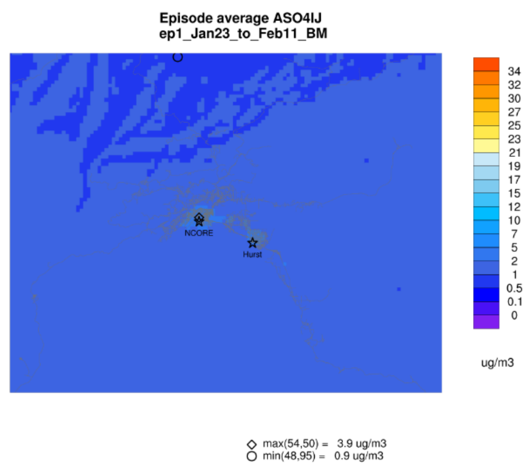


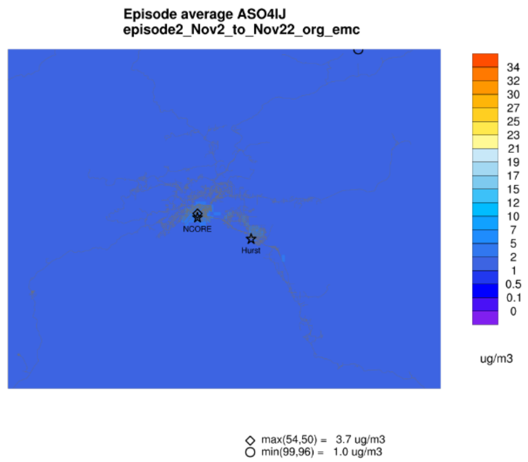
◇ max(71,44) = 20.4 ug/m3
○ min(122,52) = 0.0 ug/m3

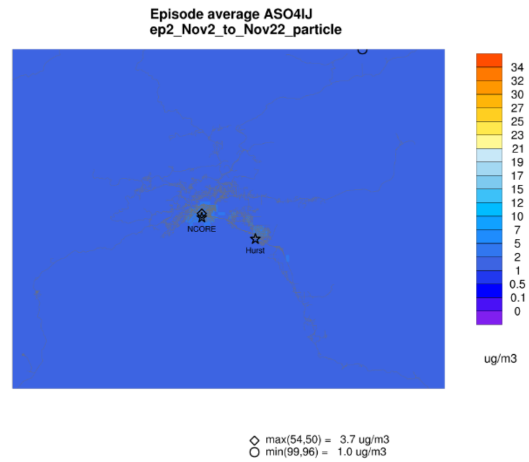

Episode average ASO4IJ
ep1_Jan23_to_Feb11_org_emc
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
NCORE
Hurst
max(54,50) = 3.9 ug/m3
min(48,95) = 0.9 ug/m3

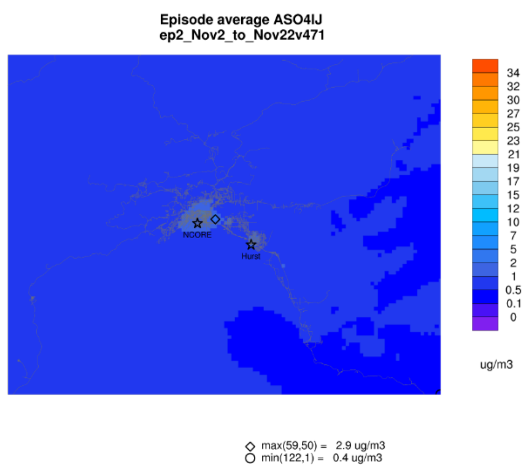

Episode average ASO4IJ
ep1_Jan23_to_Feb11_particle
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
NCORE
Hurst
max(54,50) = 3.9 ug/m3
min(48,95) = 0.9 ug/m3

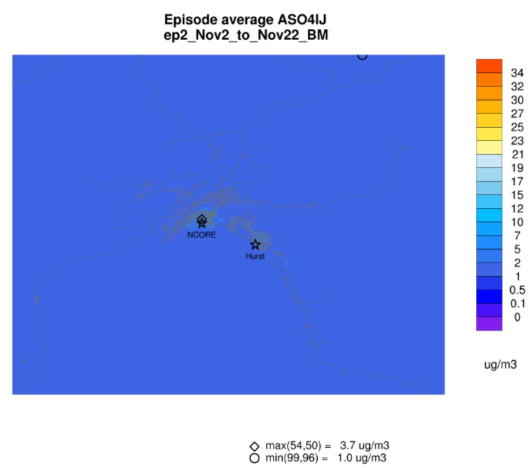

Episode average ASO4IJ
ep1_Jan23_to_Feb11v471
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
NCORE
Hurst
max(59,50) = 2.5 ug/m3
min(122,61) = 0.4 ug/m3

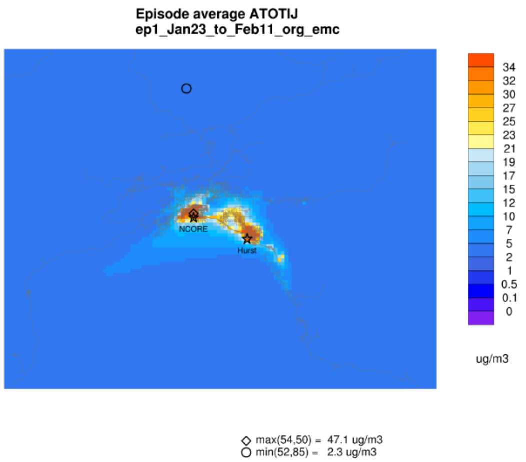

Episode average ASO4IJ
ep1_Jan23_to_Feb11_BM
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
NCORE
Hurst
max(54,50) = 3.9 ug/m3
min(48,95) = 0.9 ug/m3

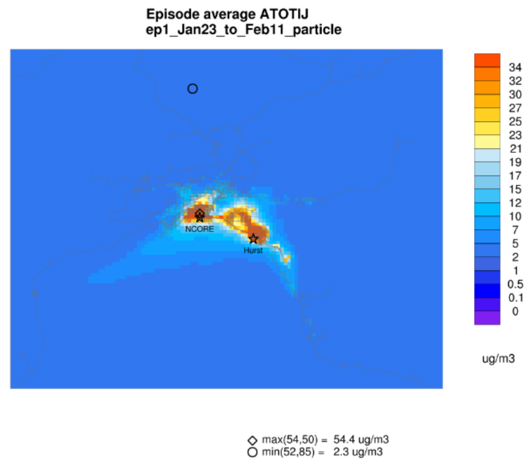

Episode average ASO4IJ
episode2_Nov2_to_Nov22_org_emc
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 3.7 ug/m3
min(99,96) = 1.0 ug/m3

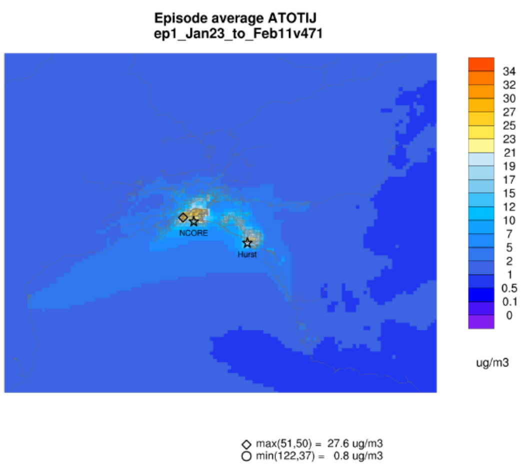

Episode average ASO4IJ
ep2_Nov2_to_Nov22_particle
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 3.7 ug/m3
min(99,96) = 1.0 ug/m3

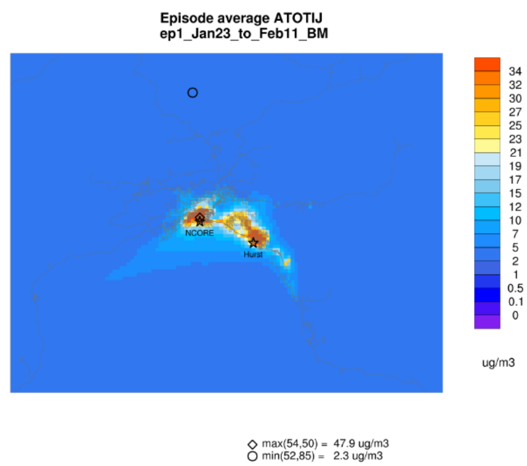

Episode average ASO4IJ
ep2_Nov2_to_Nov22v471
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(59,50) = 2.9 ug/m3
min(122,1) = 0.4 ug/m3

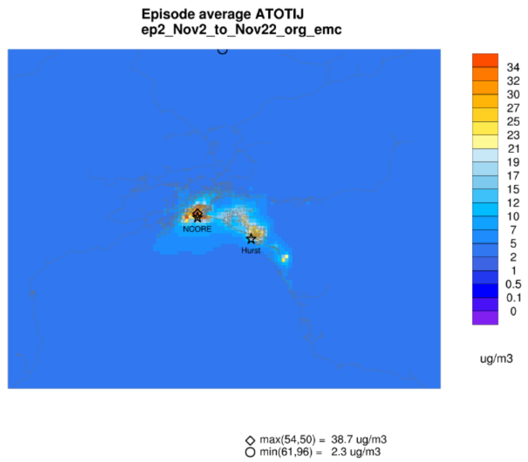

Episode average ASO4IJ
ep2_Nov2_to_Nov22_BM
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 3.7 ug/m3
min(99,96) = 1.0 ug/m3

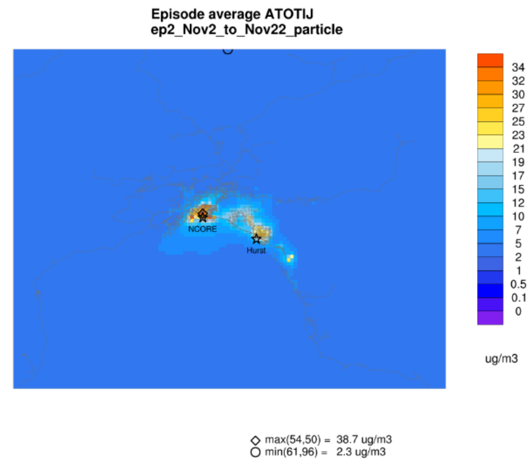

Episode average ATOTIJ
ep1_Jan23_to_Feb11_org_emc
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 47.1 ug/m3
min(52,85) = 2.3 ug/m3

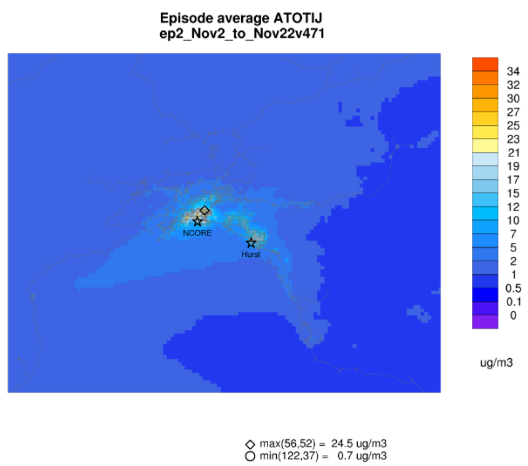

Episode average ATOTIJ
ep1_Jan23_to_Feb11_particle
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 54.4 ug/m3
min(52,85) = 2.3 ug/m3

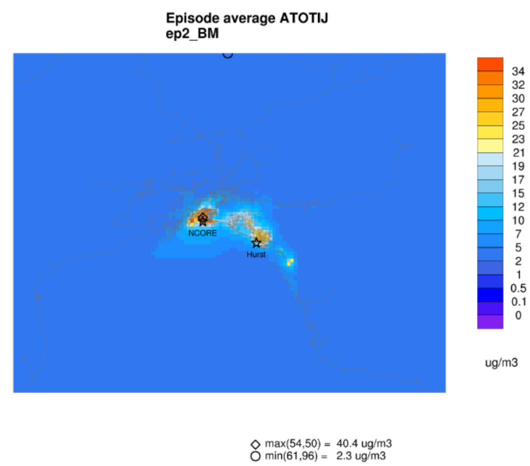

Episode average ATOTIJ
ep1_Jan23_to_Feb11v471
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(51,50) = 27.6 ug/m3
min(122,37) = 0.8 ug/m3

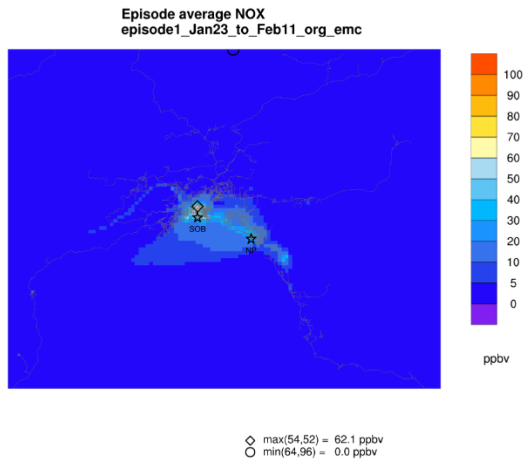

Episode average ATOTIJ
ep1_Jan23_to_Feb11_BM
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(54,50) = 47.9 ug/m3
min(52,85) = 2.3 ug/m3

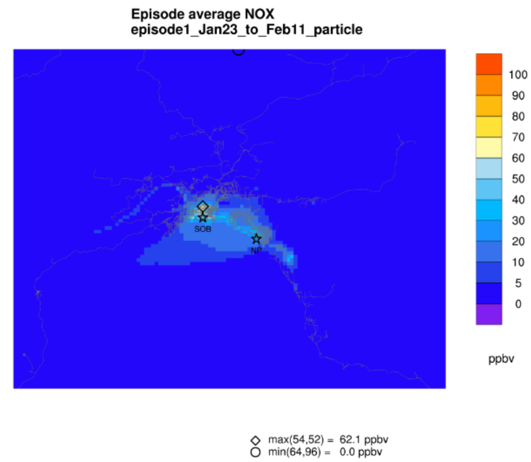

Episode average ATOTIJ
ep2_Nov2_to_Nov22_org_emc
NCORE
Hurst
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
max(54,50) = 38.7 ug/m3
min(61,96) = 2.3 ug/m3

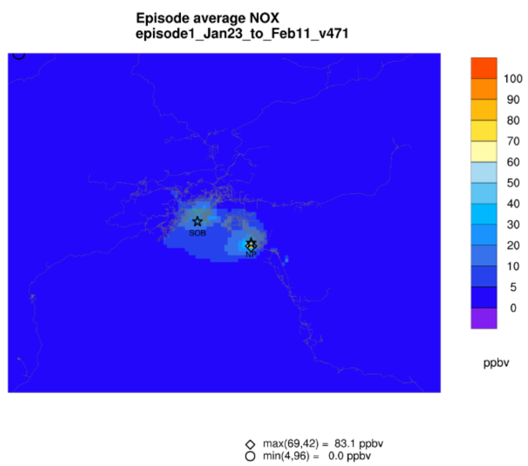

Episode average ATOTIJ
ep2_Nov2_to_Nov22_particle
NCORE
Hurst
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
max(54,50) = 38.7 ug/m3
min(61,96) = 2.3 ug/m3

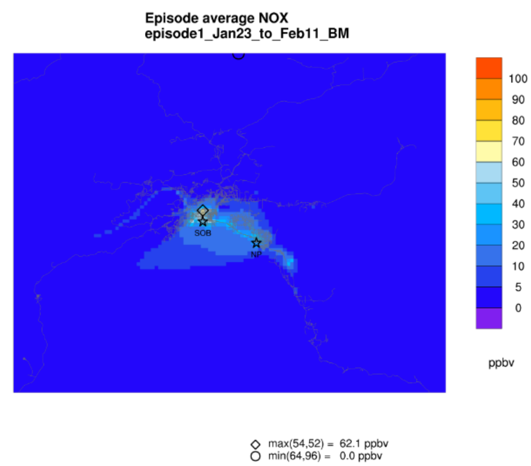

Episode average ATOTIJ
ep2_Nov2_to_Nov22v471
NCORE
Hurst
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
max(56,52) = 24.5 ug/m3
min(122,37) = 0.7 ug/m3

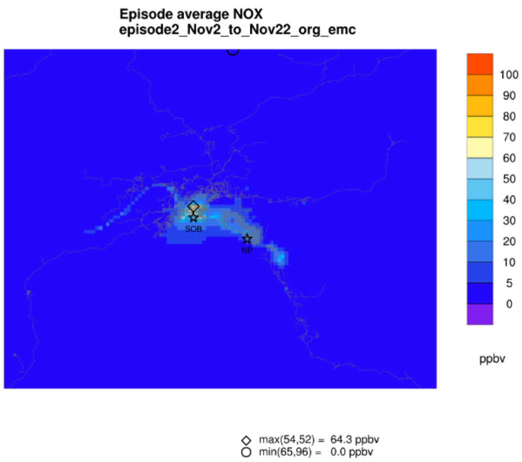

Episode average ATOTIJ
ep2_BM
NCORE
Hurst
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
max(54,50) = 40.4 ug/m3
min(61,96) = 2.3 ug/m3

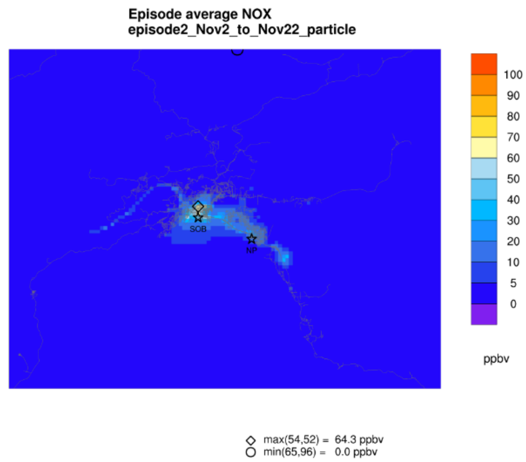

Episode average NOX
episode1_Jan23_to_Feb11_org_emc
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(54,52) = 62.1 ppbv
min(64,96) = 0.0 ppbv

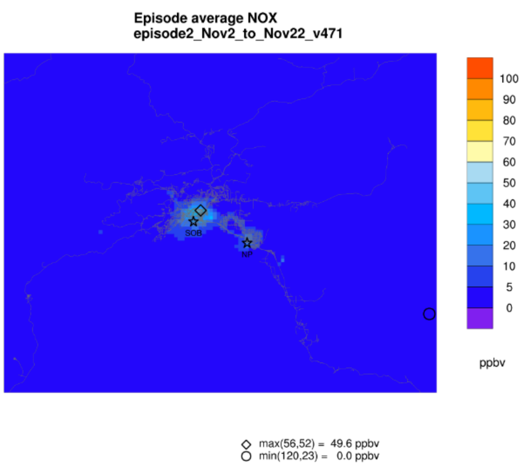

Episode average NOX
episode1_Jan23_to_Feb11_particle
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(54,52) = 62.1 ppbv
min(64,96) = 0.0 ppbv

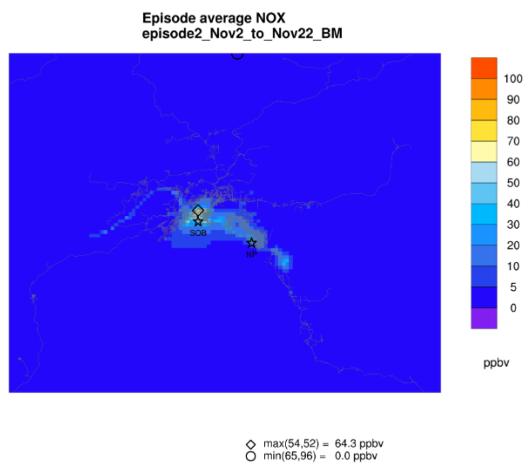

Episode average NOX
episode1_Jan23_to_Feb11_v471
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
max(69,42) = 83.1 ppbv
min(4,96) = 0.0 ppbv

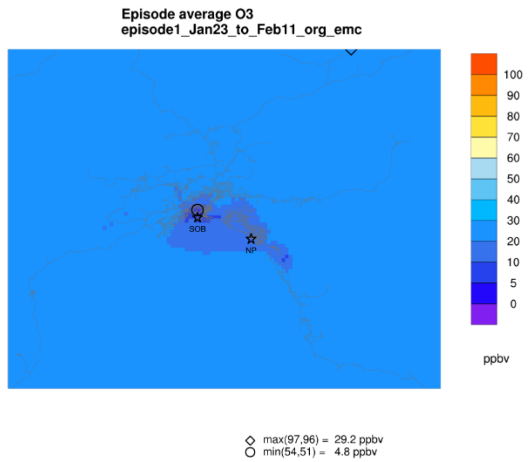

Episode average NOX
episode1_Jan23_to_Feb11_BM
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(54,52) = 62.1 ppbv
min(64,96) = 0.0 ppbv

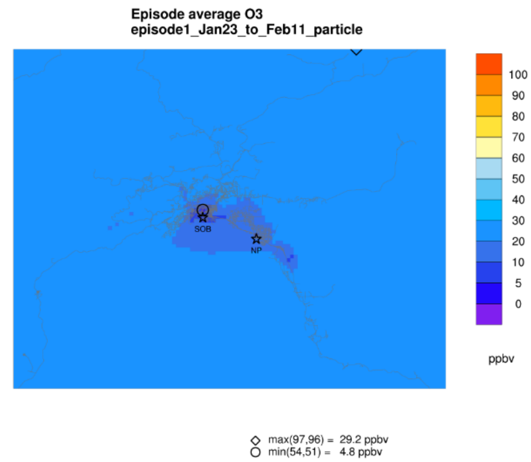

Episode average NOX
episode2_Nov2_to_Nov22_org_emc
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
max(54,52) = 64.3 ppbv
min(65,96) = 0.0 ppbv

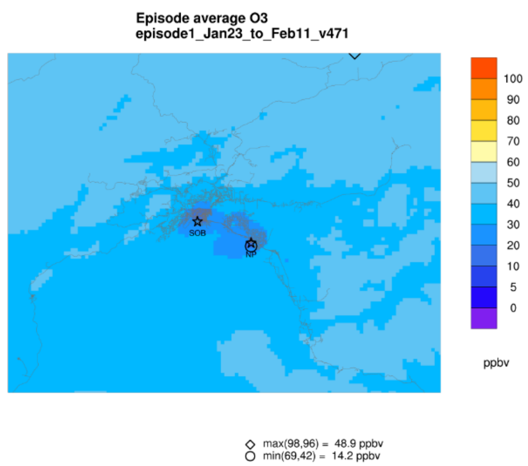

Episode average NOX
episode2_Nov2_to_Nov22_particle
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
max(54,52) = 64.3 ppbv
min(65,96) = 0.0 ppbv

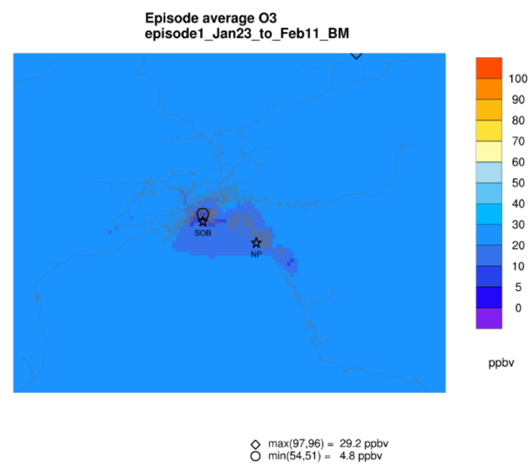

Episode average NOX
episode2_Nov2_to_Nov22_v471
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
max(56,52) = 49.6 ppbv
min(120,23) = 0.0 ppbv

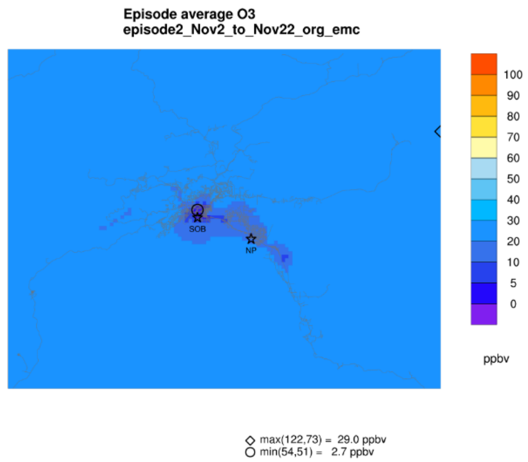

Episode average NOX
episode2_Nov2_to_Nov22_BM
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
max(54,52) = 64.3 ppbv
min(65,96) = 0.0 ppbv

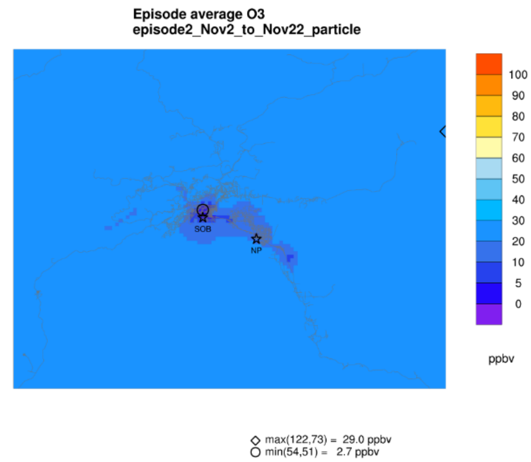

Episode average O3
episode1_Jan23_to_Feb11_org_emc
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(97,96) = 29.2 ppbv
min(54,51) = 4.8 ppbv

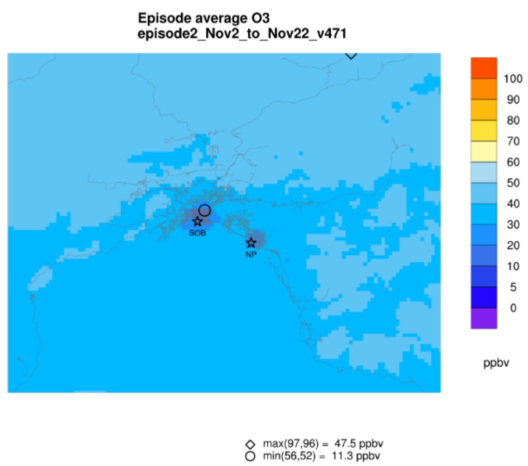

Episode average O3
episode1_Jan23_to_Feb11_particle
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(97,96) = 29.2 ppbv
min(54,51) = 4.8 ppbv

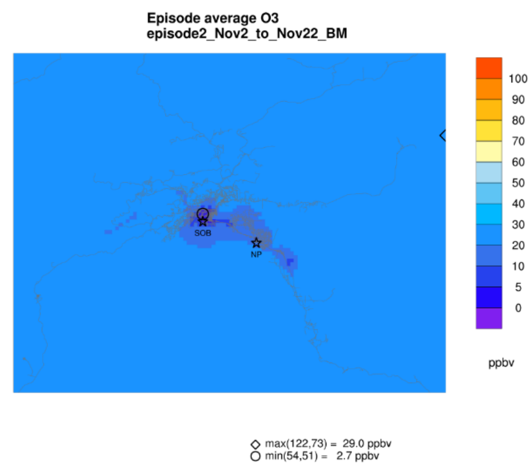

Episode average O3
episode1_Jan23_to_Feb11_v471
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(98,96) = 48.9 ppbv
min(69,42) = 14.2 ppbv

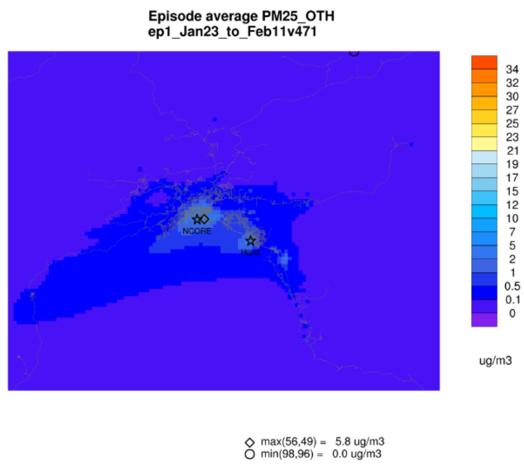

Episode average O3
episode1_Jan23_to_Feb11_BM
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(97,96) = 29.2 ppbv
min(54,51) = 4.8 ppbv

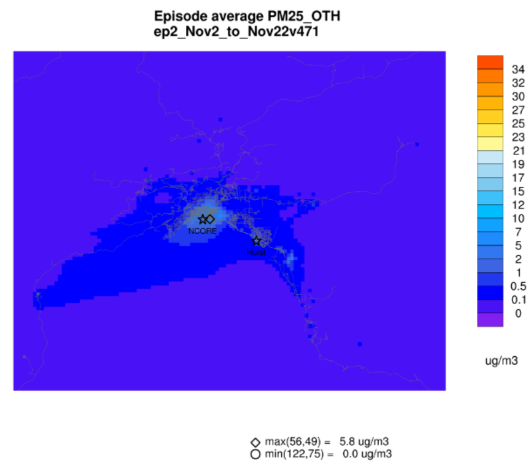

Episode average O3
episode2_Nov2_to_Nov22_org_emc
SOB
NP
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
max(122,73) = 29.0 ppbv
min(54,51) = 2.7 ppbv

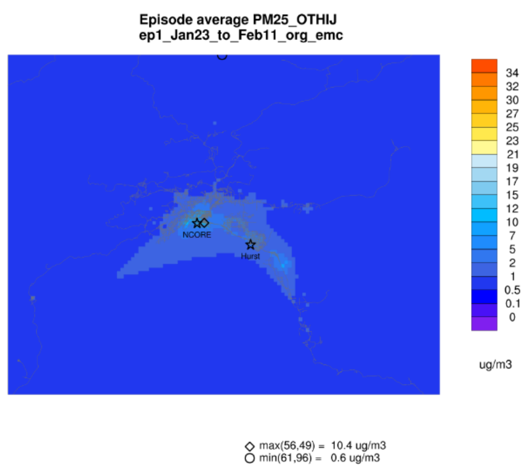

Episode average O3
episode2_Nov2_to_Nov22_particle
SOB
NP
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
max(122,73) = 29.0 ppbv
min(54,51) = 2.7 ppbv

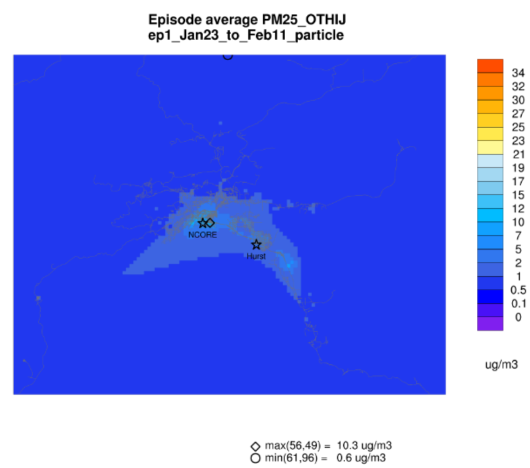

Episode average O3
episode2_Nov2_to_Nov22_v471
SOB
NP
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
max(97,96) = 47.5 ppbv
min(56,52) = 11.3 ppbv

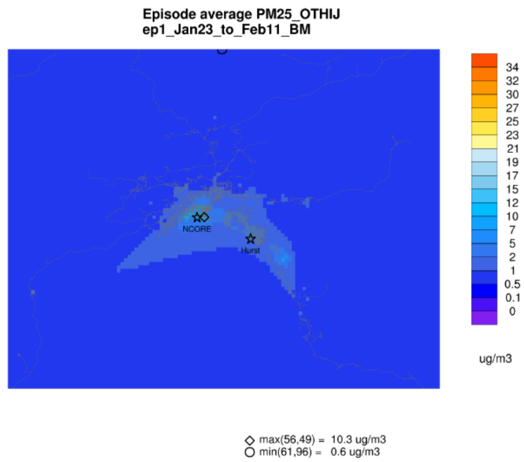

Episode average O3
episode2_Nov2_to_Nov22_BM
SOB
NP
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
max(122,73) = 29.0 ppbv
min(54,51) = 2.7 ppbv

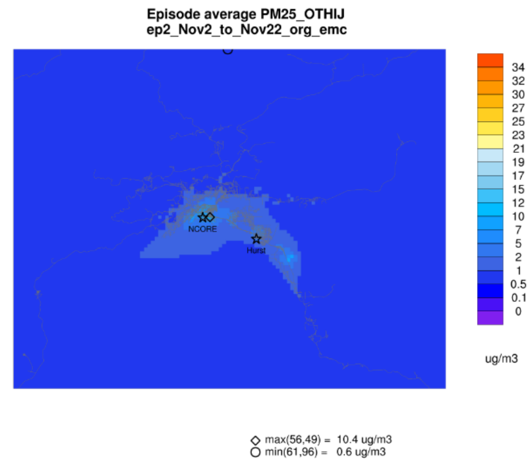

Episode average PM25_OTH
ep1_Jan23_to_Feb11v471
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
NCORE
max(56,49) = 5.8 ug/m3
min(98,96) = 0.0 ug/m3

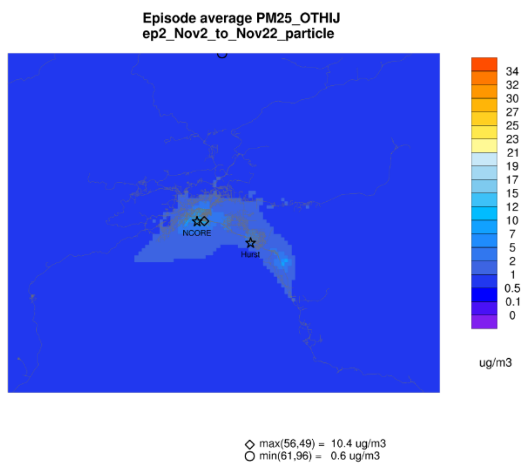

Episode average PM25_OTH
ep2_Nov2_to_Nov22v471
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
NCORE
max(56,49) = 5.8 ug/m3
min(122,75) = 0.0 ug/m3

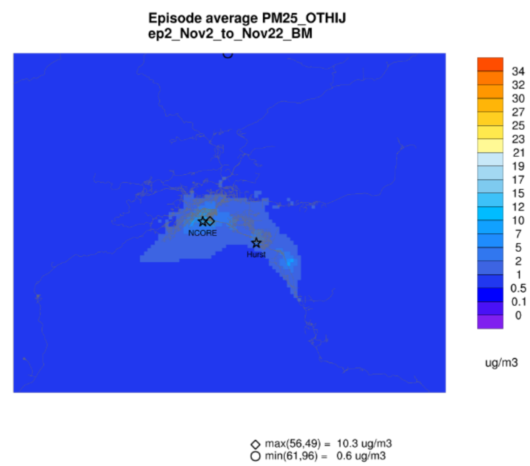

Episode average PM25_OTHIJ
ep1_Jan23_to_Feb11_org_emc
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
NCORE
Hurst
max(56,49) = 10.4 ug/m3
min(61,96) = 0.6 ug/m3

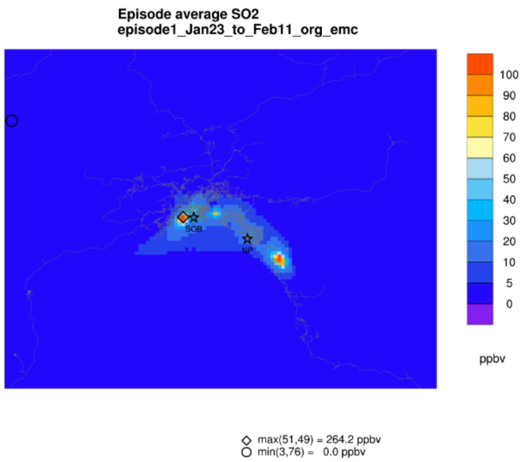

Episode average PM25_OTHIJ
ep1_Jan23_to_Feb11_particle
34 32 30 27 25 23 21 19 17 15 12 10 7 5 2 1 0.5 0.1 0
ug/m3
NCORE
Hurst
max(56,49) = 10.3 ug/m3
min(61,96) = 0.6 ug/m3

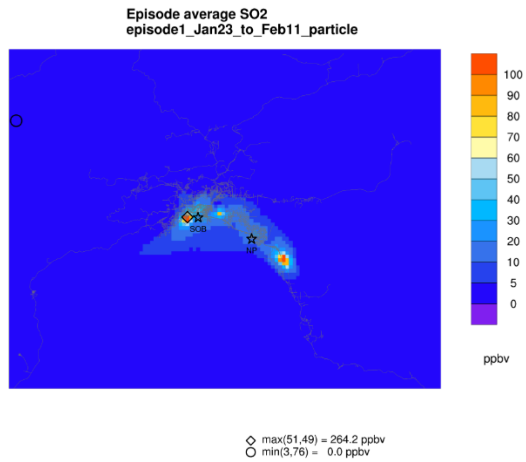

Episode average PM25_OTHIJ
ep1_Jan23_to_Feb11_BM
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(56,49) = 10.3 ug/m3
min(61,96) = 0.6 ug/m3

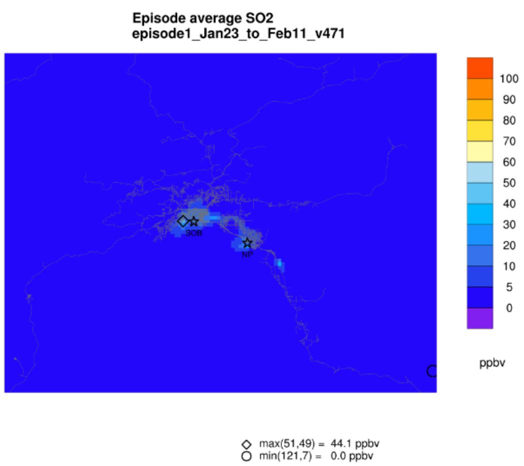

Episode average PM25_OTHIJ
ep2_Nov2_to_Nov22_org_emc
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(56,49) = 10.4 ug/m3
min(61,96) = 0.6 ug/m3

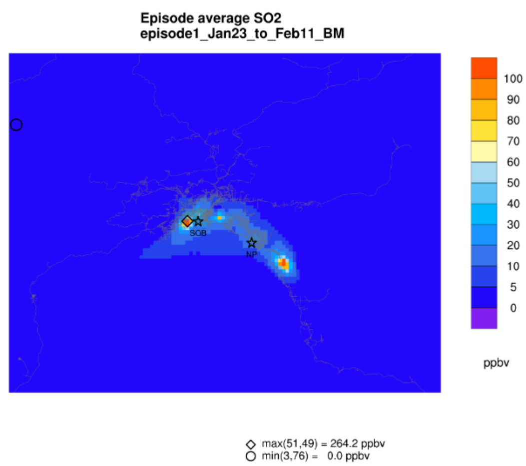

Episode average PM25_OTHIJ
ep2_Nov2_to_Nov22_particle
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(56,49) = 10.4 ug/m3
min(61,96) = 0.6 ug/m3


Episode average PM25_OTHIJ
ep2_Nov2_to_Nov22_BM
NCORE
Hurst
34
32
30
27
25
23
21
19
17
15
12
10
7
5
2
1
0.5
0.1
0
ug/m3
max(56,49) = 10.3 ug/m3
min(61,96) = 0.6 ug/m3

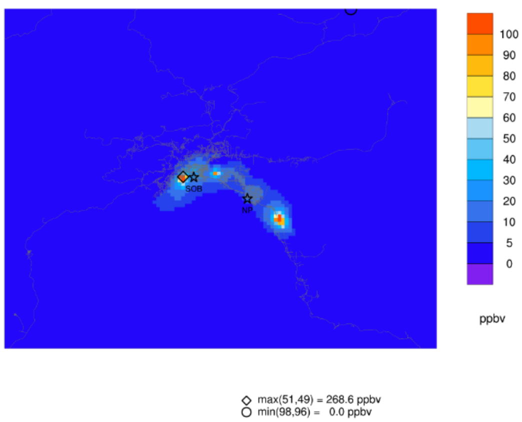

Episode average SO2
episode1_Jan23_to_Feb11_org_emc
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(51,49) = 264.2 ppbv
min(3,76) = 0.0 ppbv


Episode average SO2
episode1_Jan23_to_Feb11_particle
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(51,49) = 264.2 ppbv
min(3,76) = 0.0 ppbv

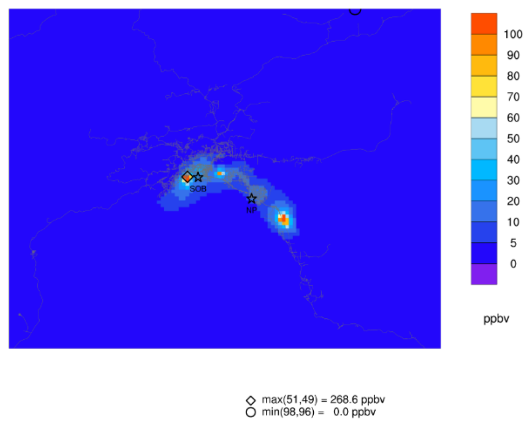

Episode average SO2
episode1_Jan23_to_Feb11_v471
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(51,49) = 44.1 ppbv
min(121,7) = 0.0 ppbv


Episode average SO2
episode1_Jan23_to_Feb11_BM
100
90
80
70
60
50
40
30
20
10
5
0
ppbv
SOB
NP
max(51,49) = 264.2 ppbv
min(3,76) = 0.0 ppbv

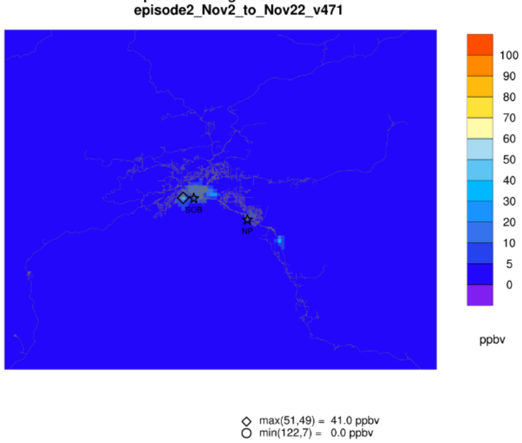
Episode average SO2
episode2_Nov2_to_Nov22_org_emc



Episode average SO2
episode2_Nov2_to_Nov22_particle



Episode average SO2
episode2_Nov2_to_Nov22_v471



Episode average SO2
episode2_Nov2_to_Nov22_BM