Evaluation of CMAQ and CAMx ozone and PM2.5 using the 2016v1 emissions modeling platform

Heather Simon, Shannon Koplitz, Norm Possiel, Barron Henderson, Sharon Phillips, Chris Misenis, Alison Eyth, Jeff Vukovich, Caroline Farkas

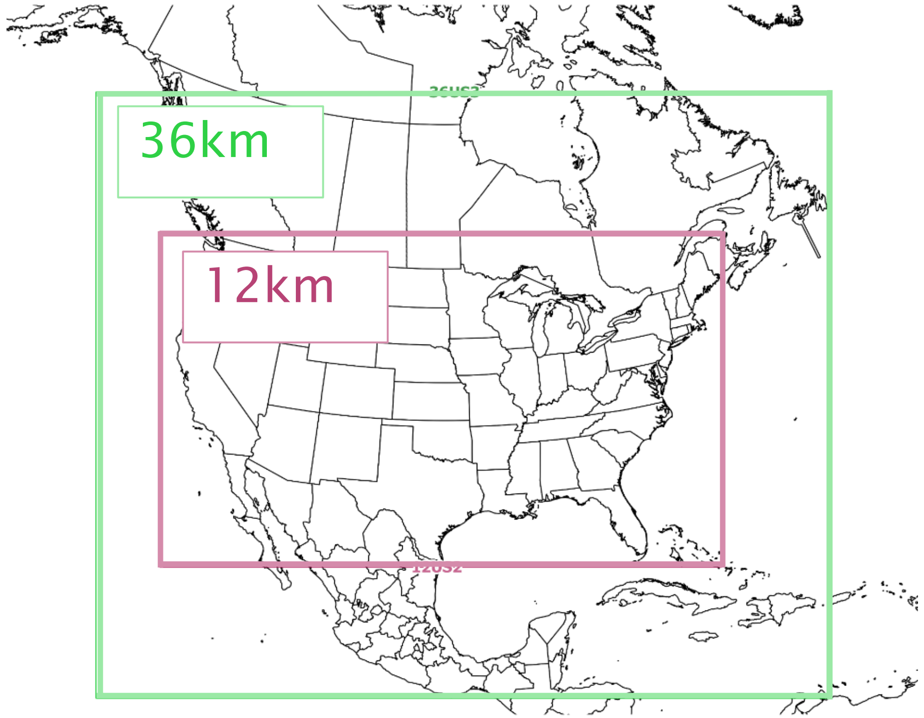
U.S. EPA OAQPS

EPA OAQPS Modeling Platforms

- OAQPS periodically develops modeling platforms which serve as the basis for regulatory modeling efforts
- Modeling platform elements
  - Emissions modeling platform: base year and future year projections
  - Meteorology inputs based on meteorological modeling
  - Initial and boundary conditions based on hemispheric or global modeling outputs
  - Regional photochemical model and configuration/science options
- Historically modeling platforms developed approximately every 3 years and are often tied to data from a new NEI
  - Modeling platform base years have included: 2002, 2005, 2007 (based on 2008 NEI), 2011, 2016 (based on 2014 NEI)

EPA OAQPS Modeling Set-up for 2016v1

- Annual model simulations with CMAQv5.3.1 and CAMxv7 beta6
  - CB6r3 chemical mechanism
  - POA treated as non-volatile (did not use VBS)
  - No bidirectional ammonia flux
- Nested 36km and 12km domains with 35 vertical layers
  - Potential 4 km modeling for domains (NE/MW/CA)
- Emissions based on 2016v1 emissions platform developed as part of collaborative effort between states and EPA
- Meteorology from WRFv3.8
- Initial and Boundary Conditions from Hemispheric CMAQv5.2.1 with 2016fe emis



Completed model sensitivity runs

- CMAQ
  - Multiple deposition schemes (M3DRY and STAGE) with and without Bidirectional NH_3 flux
  - Various meteorological options and PBL schemes in WRF
    - KZMIN = FALSE
    - WRFv4.1.1 P-X
    - WRFv4.1.1 Noah-YSU
  - GEOS-Chem boundary conditions
  - Updated VOC speciation
  - Lightning NO
- CAMx
  - Vertical diffusivity, “Kv”, sensitivities
  - Ammonia deposition sensitivities (rscale and bidi)
  - GEOS-Chem boundary conditions

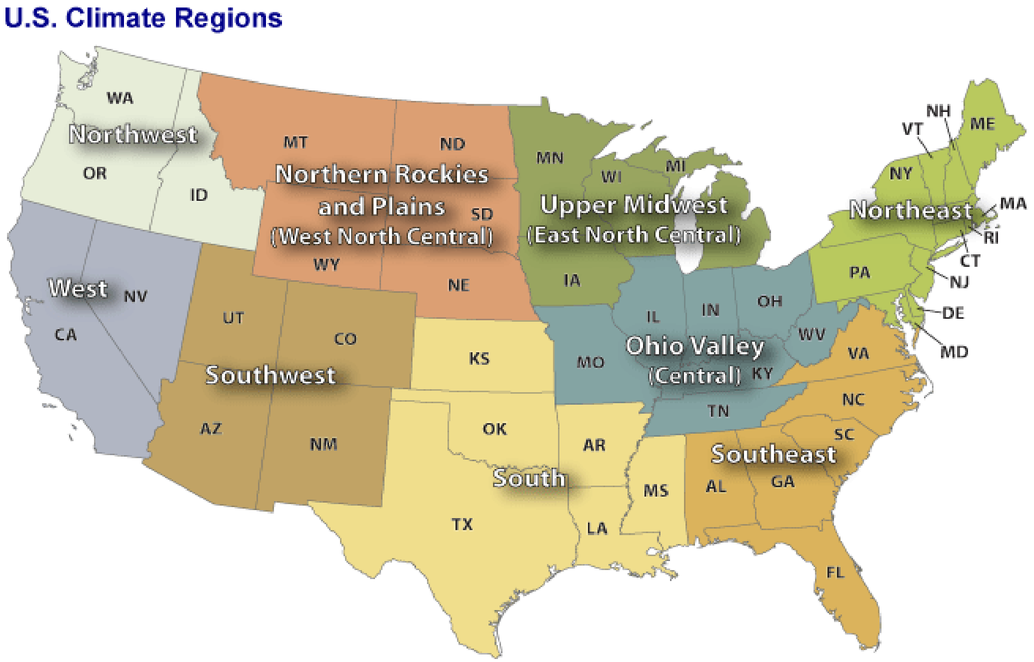
Model Performance Framework

- Performance broken out into different spatial and temporal scales
  - Spatial: NOAA climate region
  - Temporal:
    - Winter (DJF), Spring (MAM), Summer (JJA), Fall (SON)
    - Ozone season (May-September)

- Pollutants
  - Ozone, with focus on days > 60 ppb
  - PM2.5 components
    - focus sulfate and nitrate today
    - Still working to evaluate OC

- Highlights given from base CMAQ and CAMx Simulations and from key sensitivity simulations

- Results are still preliminary – this is a work in progress



Ozone

Findings – Ozone

- CMAQ and CAMx tend to under-predict MDA8 ozone > 60 ppb during the spring and summer.
  - Greater tendency for under-prediction in the West compared to the East
  - CMAQ tends to have a greater regional extent of under-prediction in the East compared to CAMx

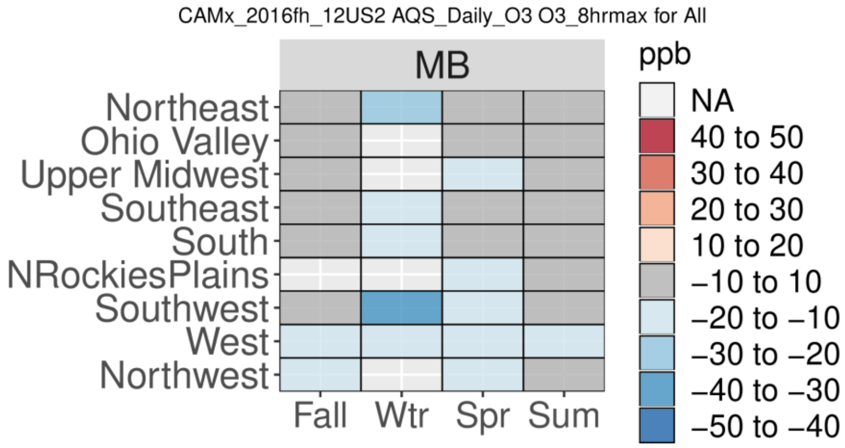
- Both models under-predict the seasonal increase in ozone from winter through spring but over-predict in July-August-September in the Northeast, Ohio Valley, and Midwest.

- Sensitivity simulations
  - GEOS-Chem and Noah-YSU sensitivities generally increase ozone making underpredictions better and overpredictions worse
  - Other sensitivities had lesser impact on ozone bias

Region/Season Mean Bias
MDA8 > 60 ppb

CAMx

CMAQ



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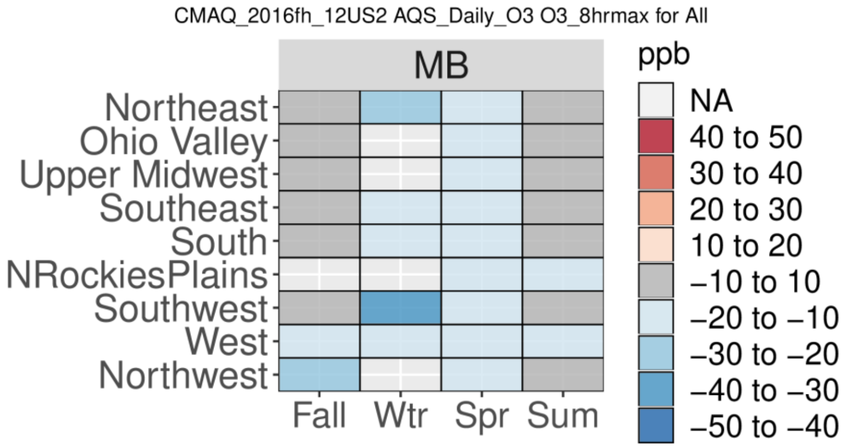

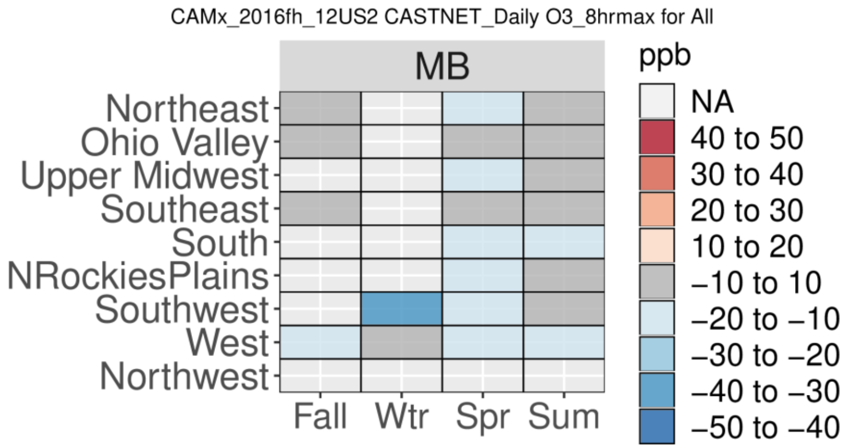

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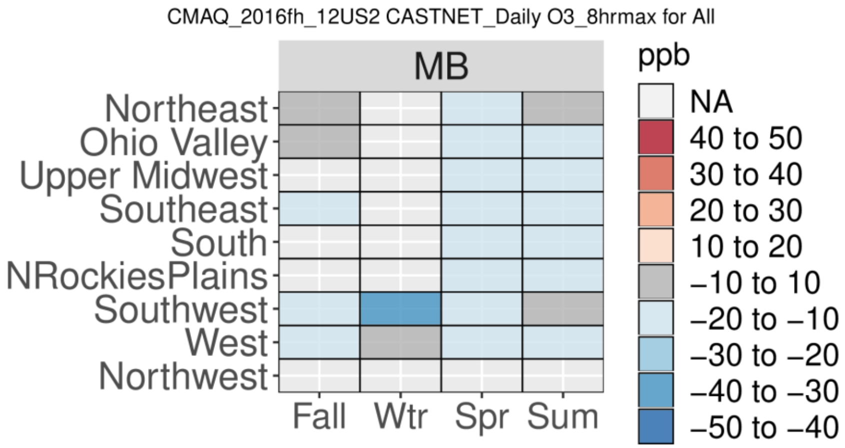
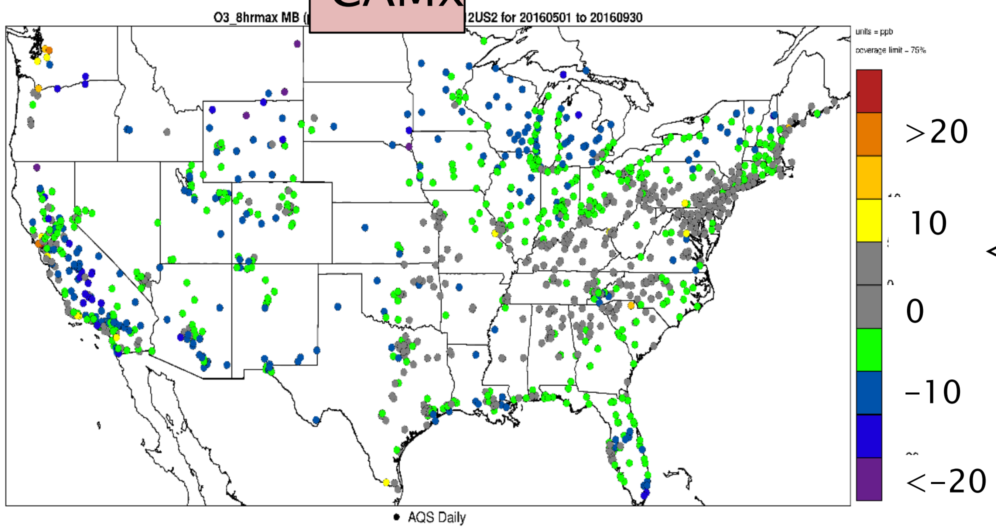
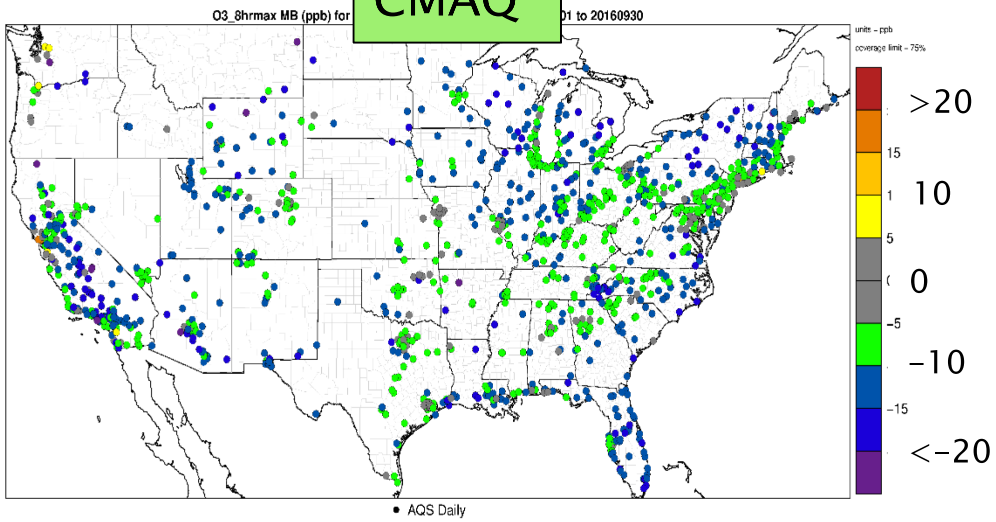


MDA8 O3 Mean Bias:
May – September days ≥ 60 ppb

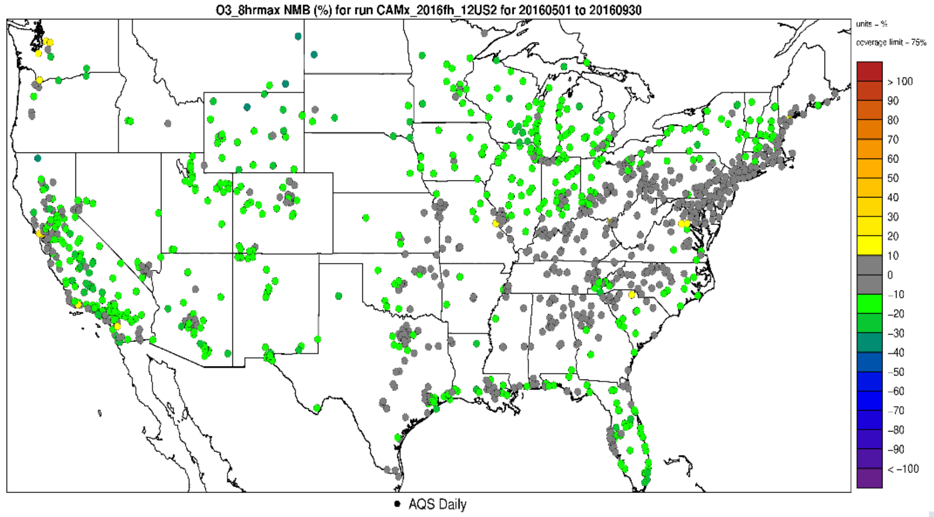
CAMx



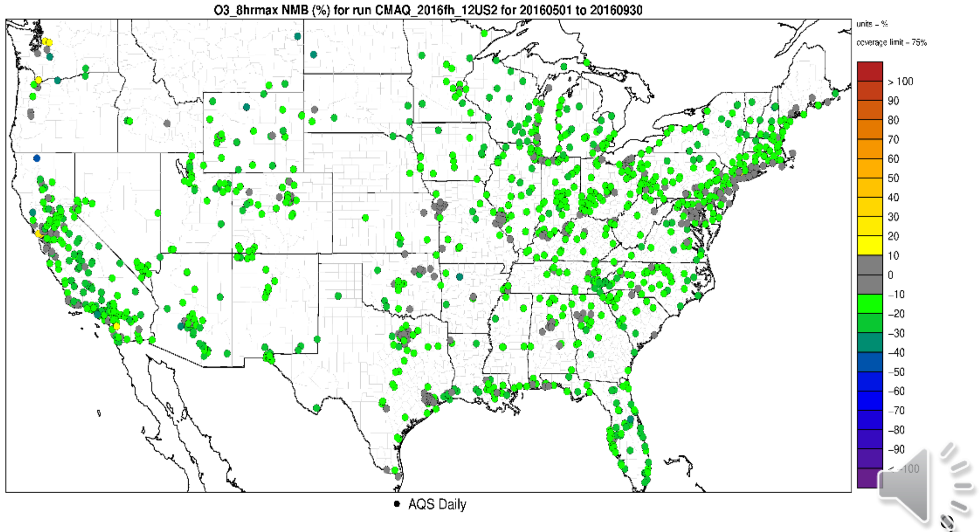
CMAQ



<= Mean =>
Bias



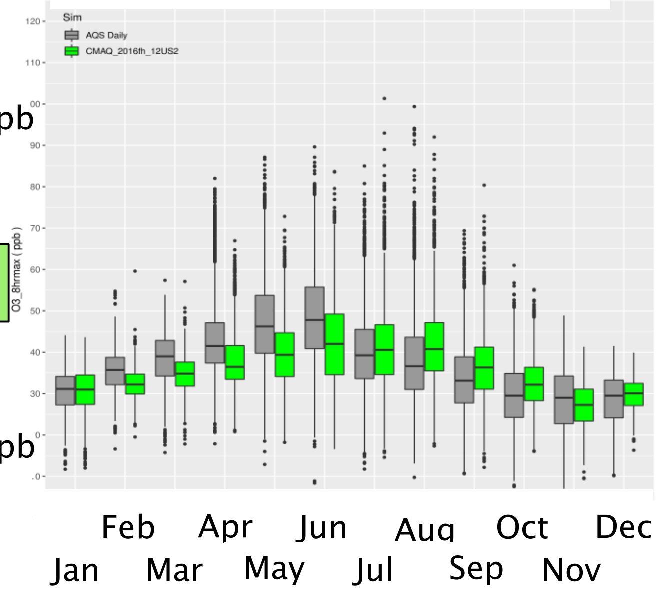
<= Normalized =>
Mean
Bias

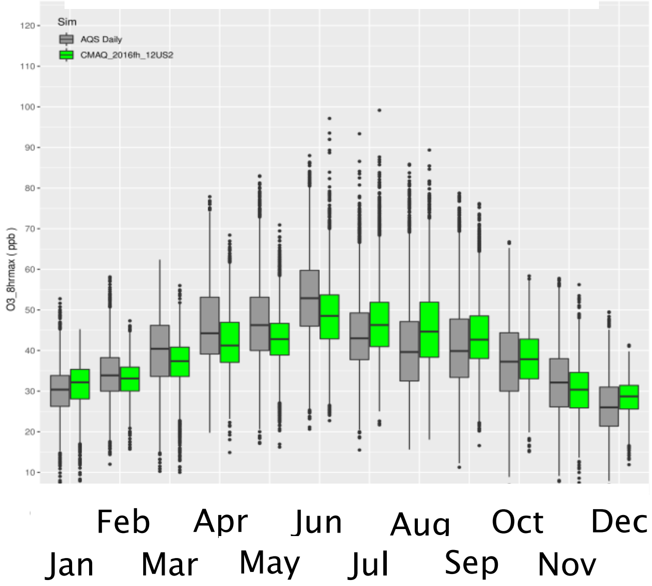


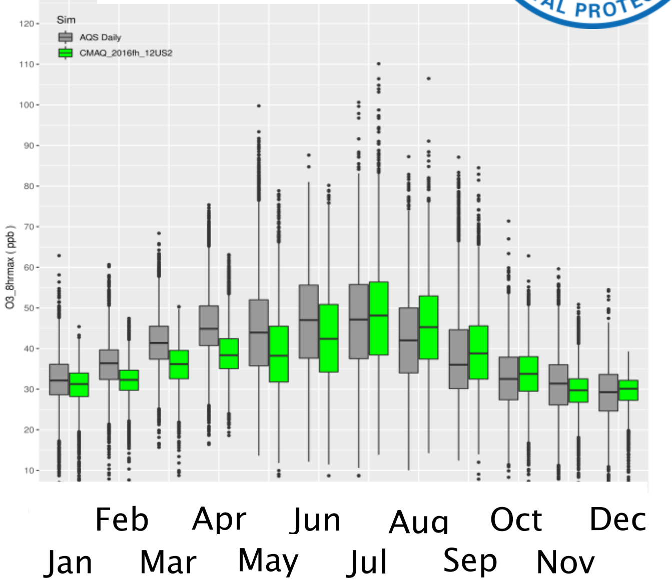
MDA8 O3 Monthly Box Plots by Region

Upper Midwest | Ohio Valley | Northeast

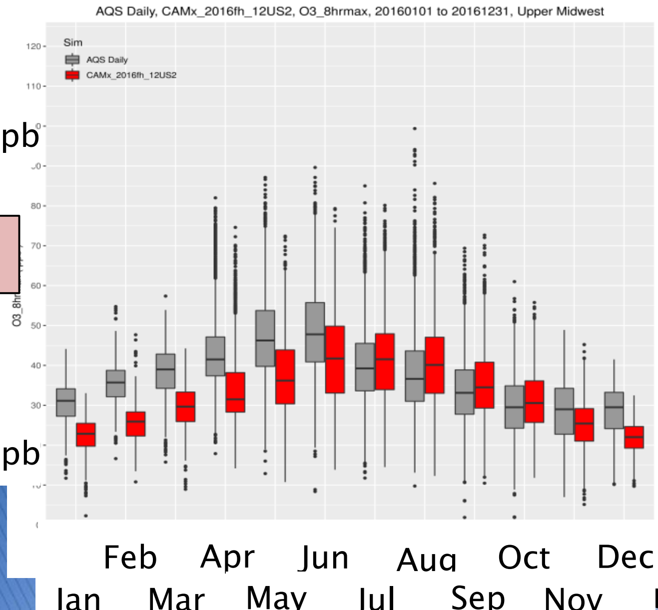
CMAQ =>

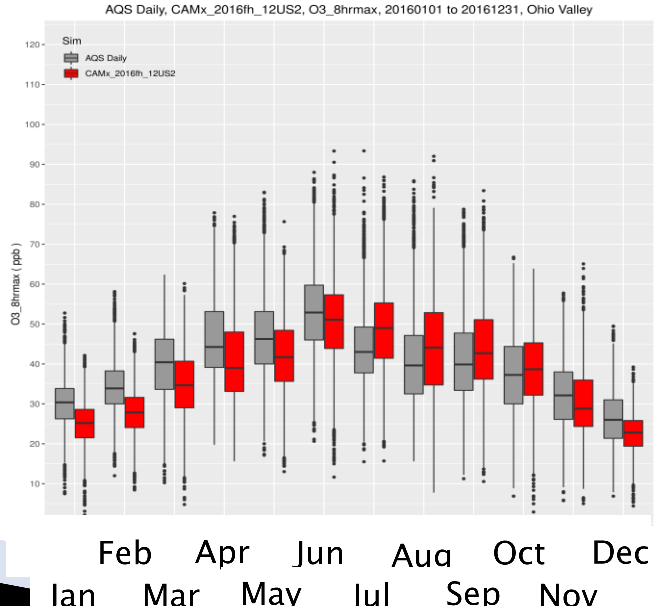


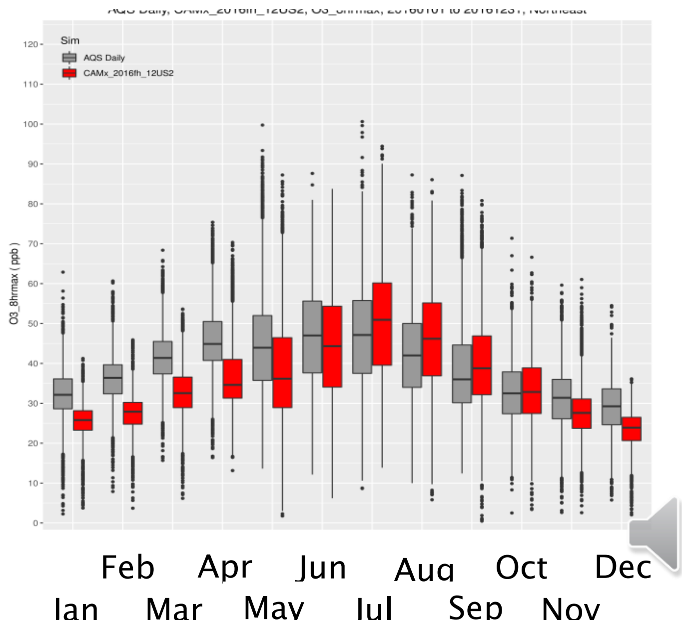




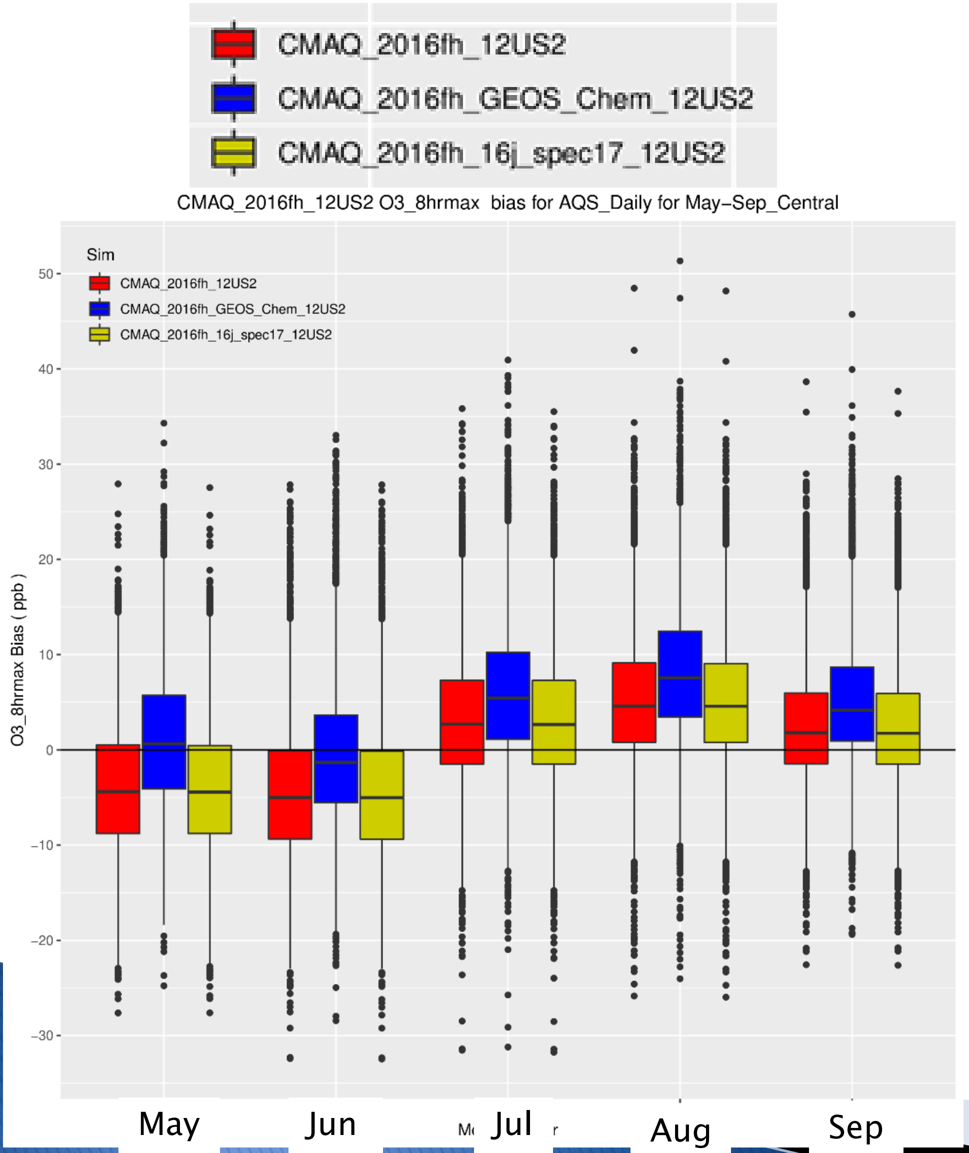
CAMx =>

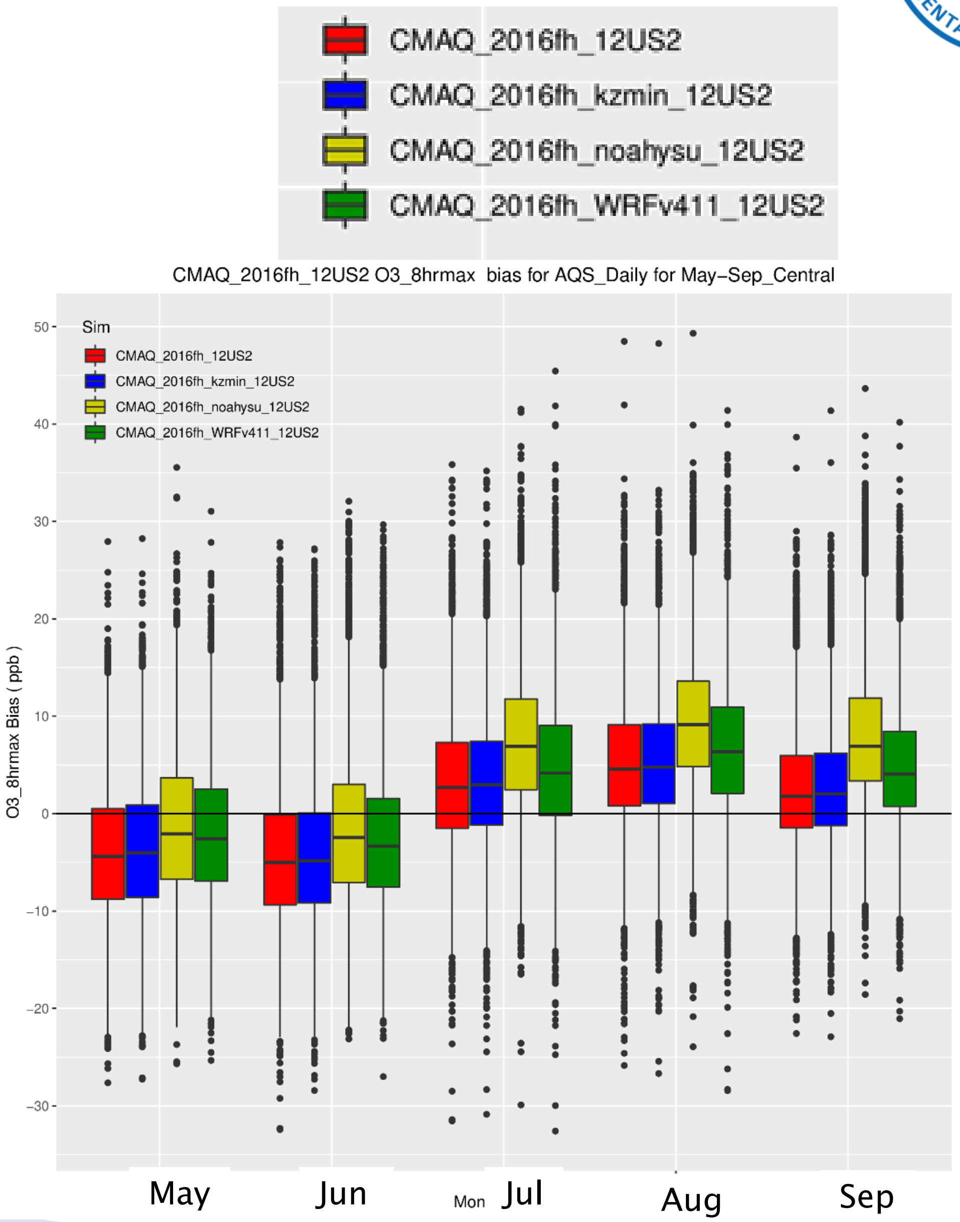




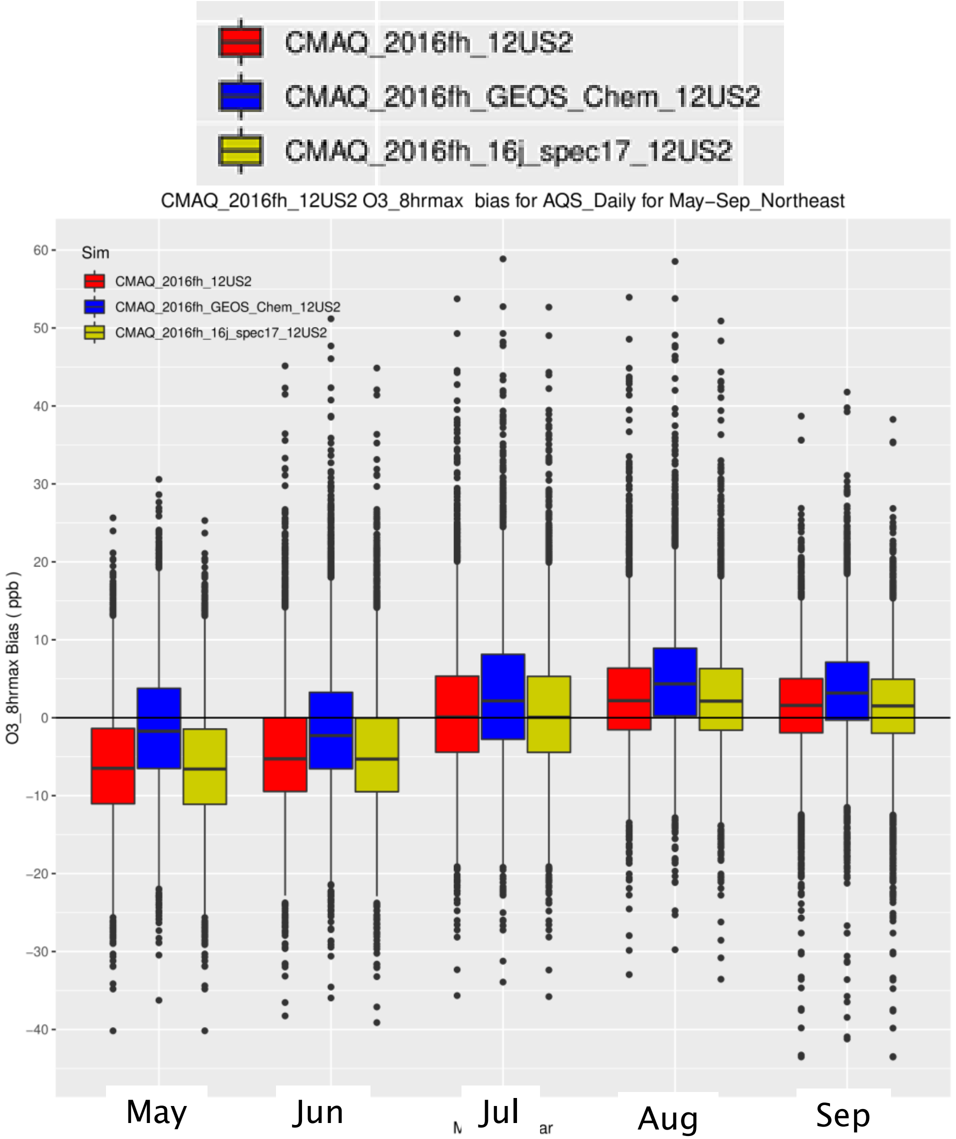


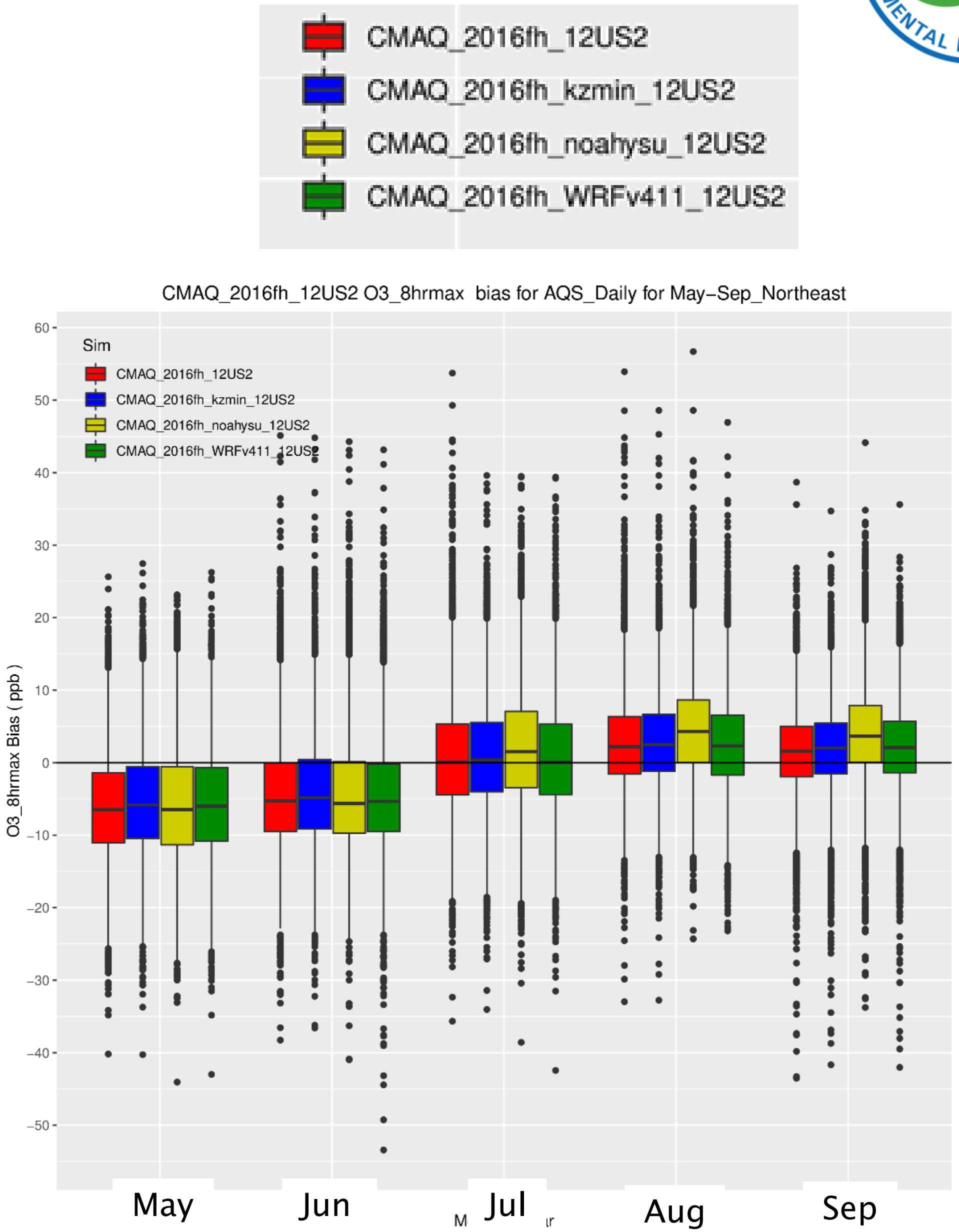
Select CMAQ ozone Sensitivities: Ohio Valley Region





Select CMAQ ozone sensitivities: Northeast Region





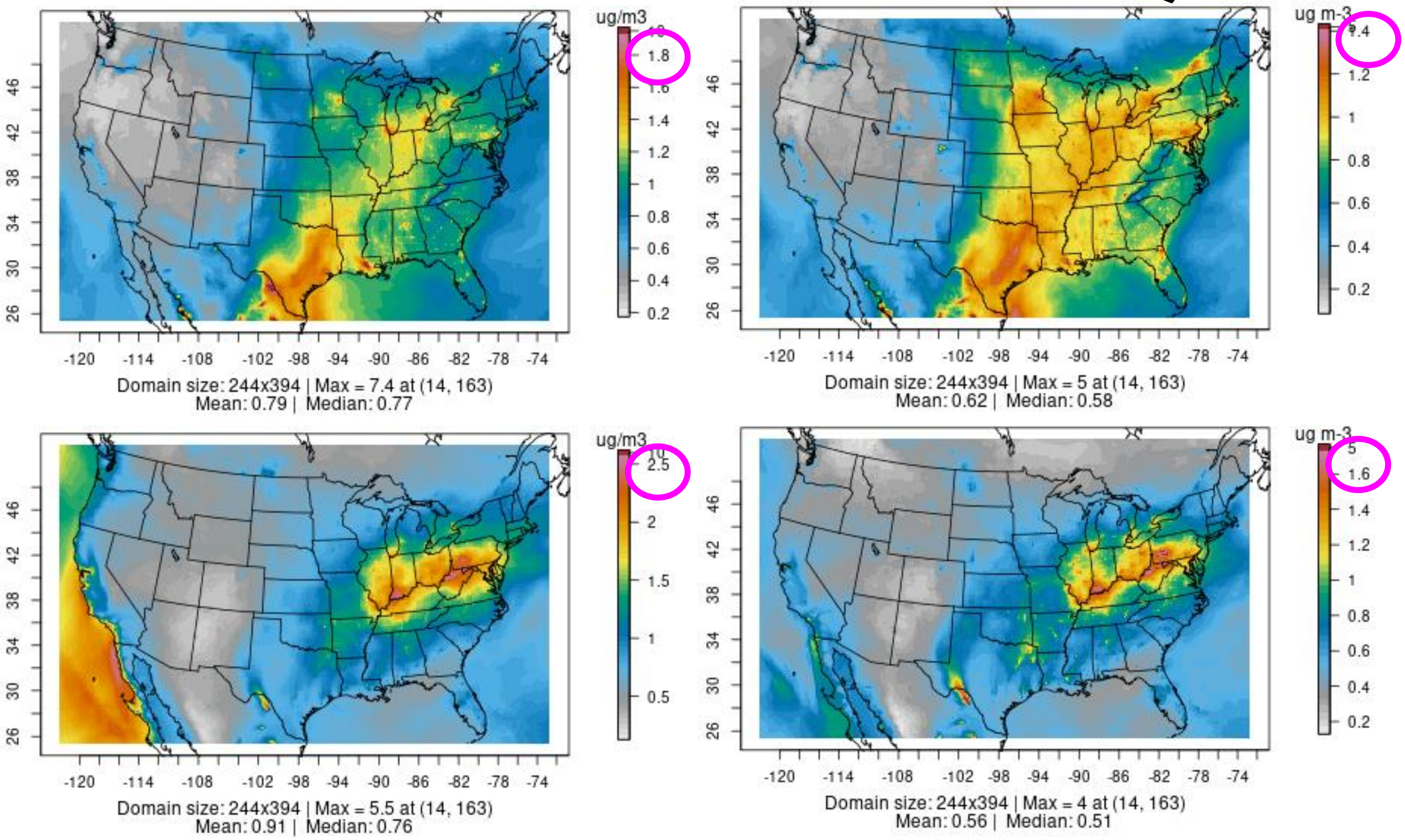
PM2.5 Sulfate

Sulfate spatial patterns in CMAQ and CAMx

Base CAMx | Base CMAQ

January

July



Focus evaluation on locations with high sulfate concs

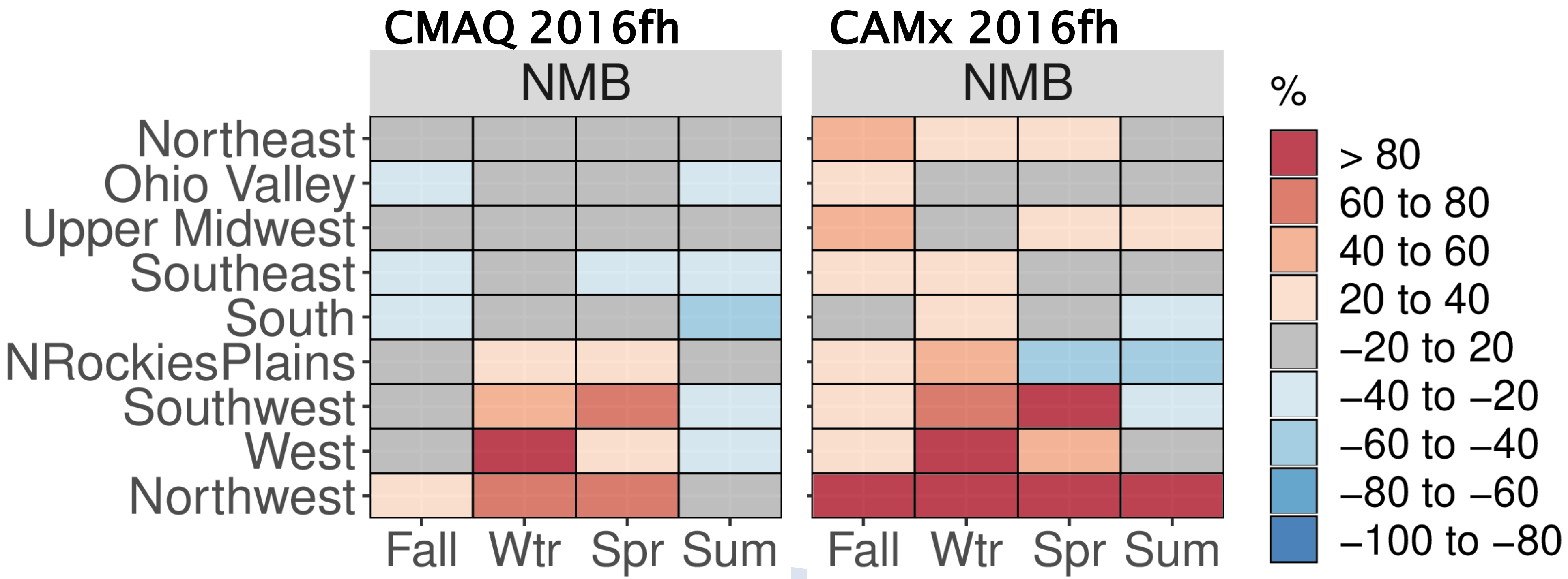
- Winter: entire Eastern US
- Summer: Ohio River Valley

Sulfate Bias (%) – Overview

Sulfate overprediction in the Western US where concentrations are very low – very small absolute bias

Winter Eastern US: CAMx bias is mostly between –20% and +40%, CMAQ underpredictions are generally less than –20%

Summer Ohio River Valley: CAMx bias is between –20% and +20%, CMAQ bias is between –40% and –20%



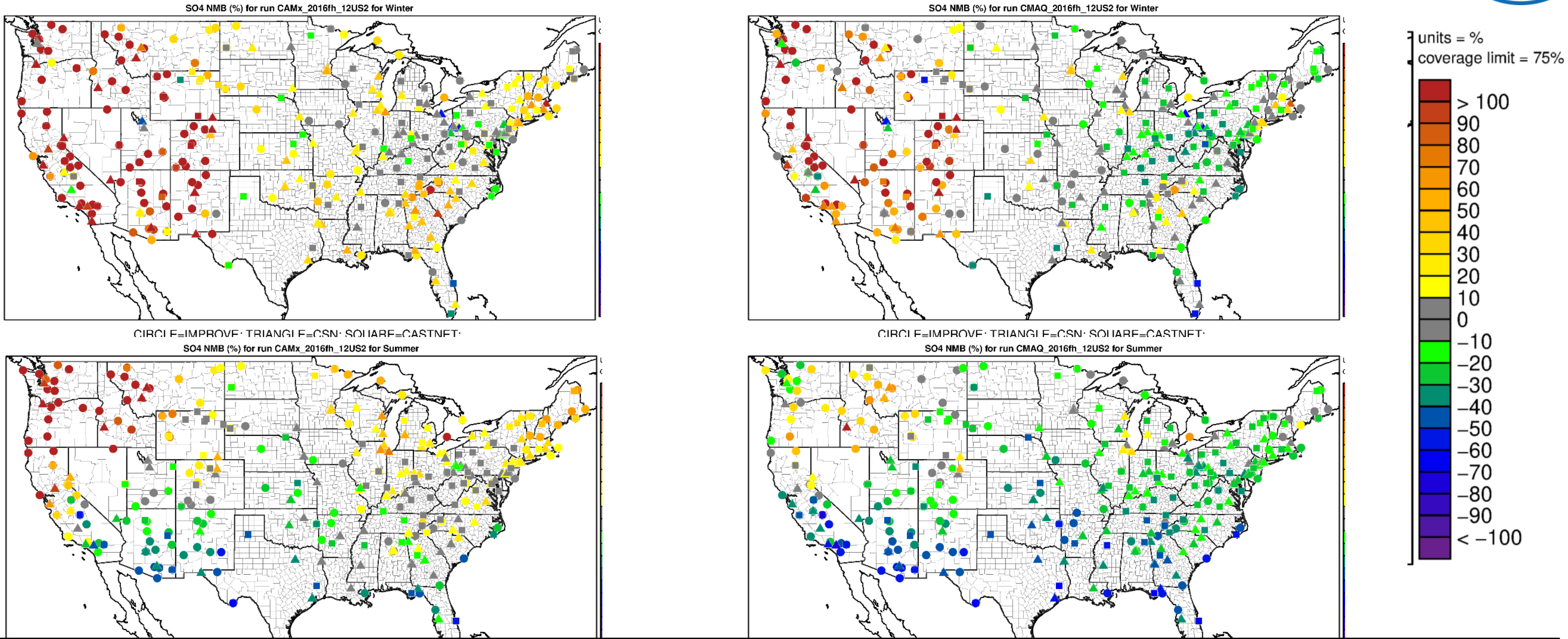
Sulfate – 2016fh National NMB (%)

CAMx

CMAQ

Winter

Summer



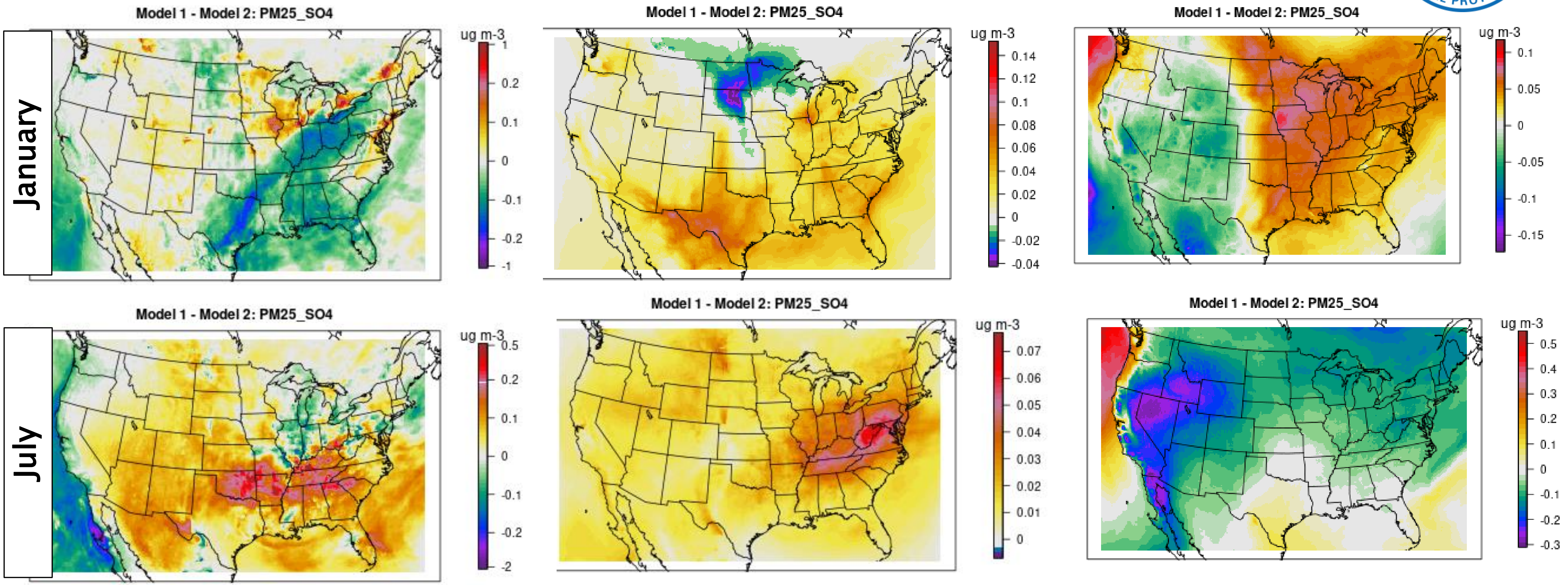
Sulfate overprediction in the Western US where concentrations are very low – very small absolute bias

Winter Eastern US: CAMx bias is mostly between -20% and +40%, CMAQ underpredictions are generally less than -20%

Summer Ohio River Valley: CAMx bias is between -20% and +20%, CMAQ bias is between -40% and -20%

Key CMAQ Sulfate Sensitivity Simulations

NoahYSU – Base | STAGE – Base | GEOSChem – Base



Base run sulfate overprediction in the Western US where concentrations are very low – very small absolute bias

Winter Eastern US: Base run CAMx bias is mostly between -20% and +40%, Base run CMAQ underpredictions are generally less than -20%

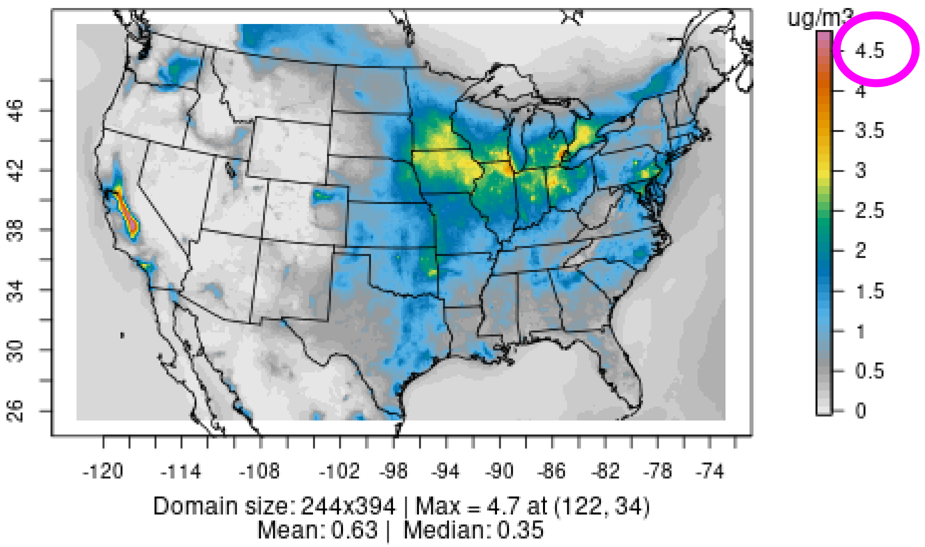
Summer Ohio River Valley: Base run CAMx bias is between -20% and +20%, Base run CMAQ bias is between -40% and -20%

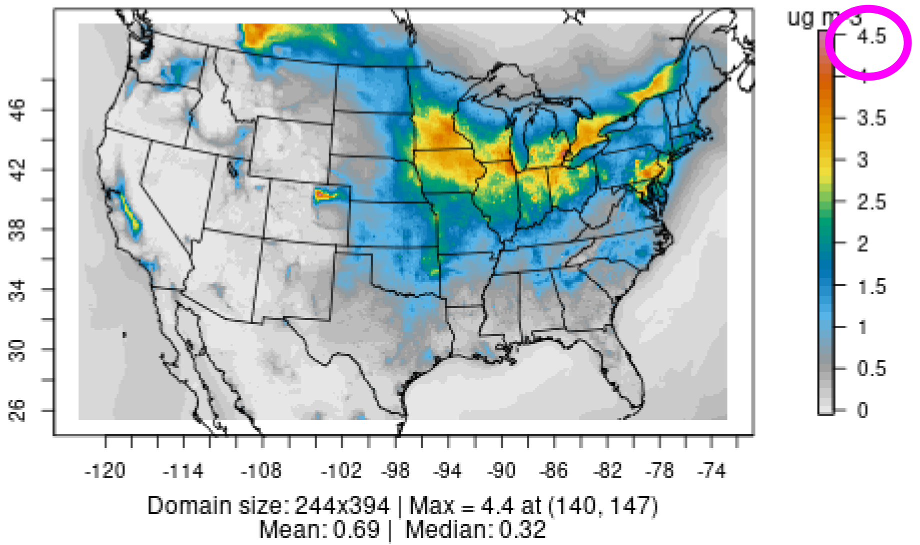
PM2.5 Nitrate

Nitrate spatial patterns in CMAQ and CAMx

Base CAMx / Base CMAQ

January





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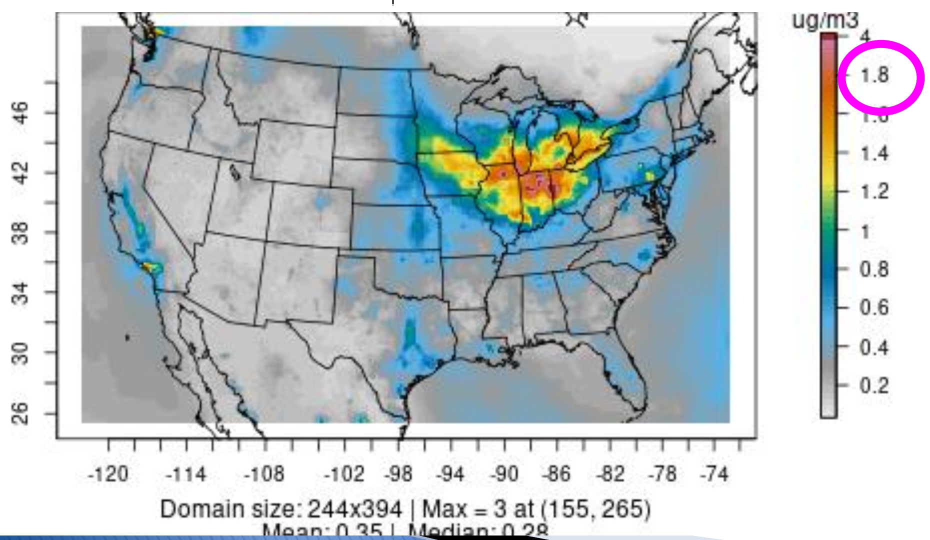
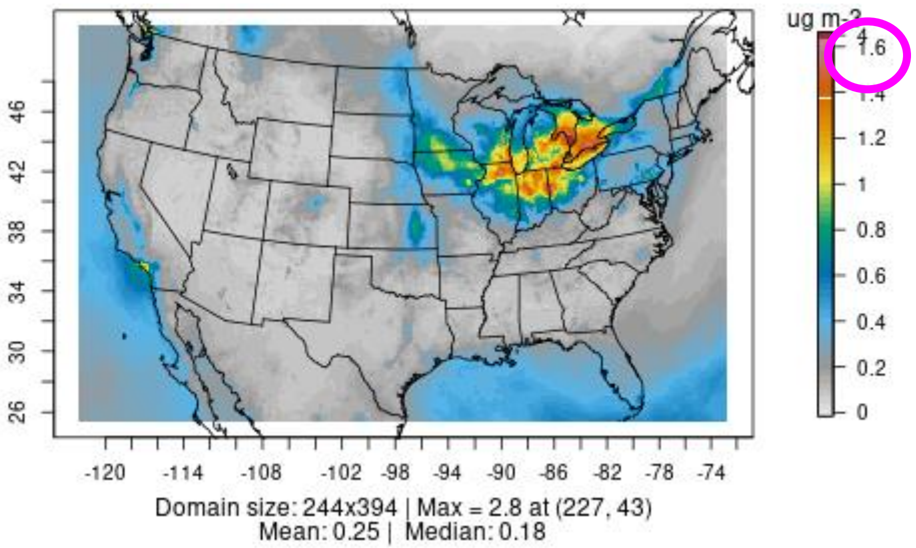




Focus evaluation on locations with high nitrate concs

- Winter: Midwest US and California
  - Note both models miss high winter nitrate in Salt Lake City
- Spring: Midwest US
- Summer (not shown): California

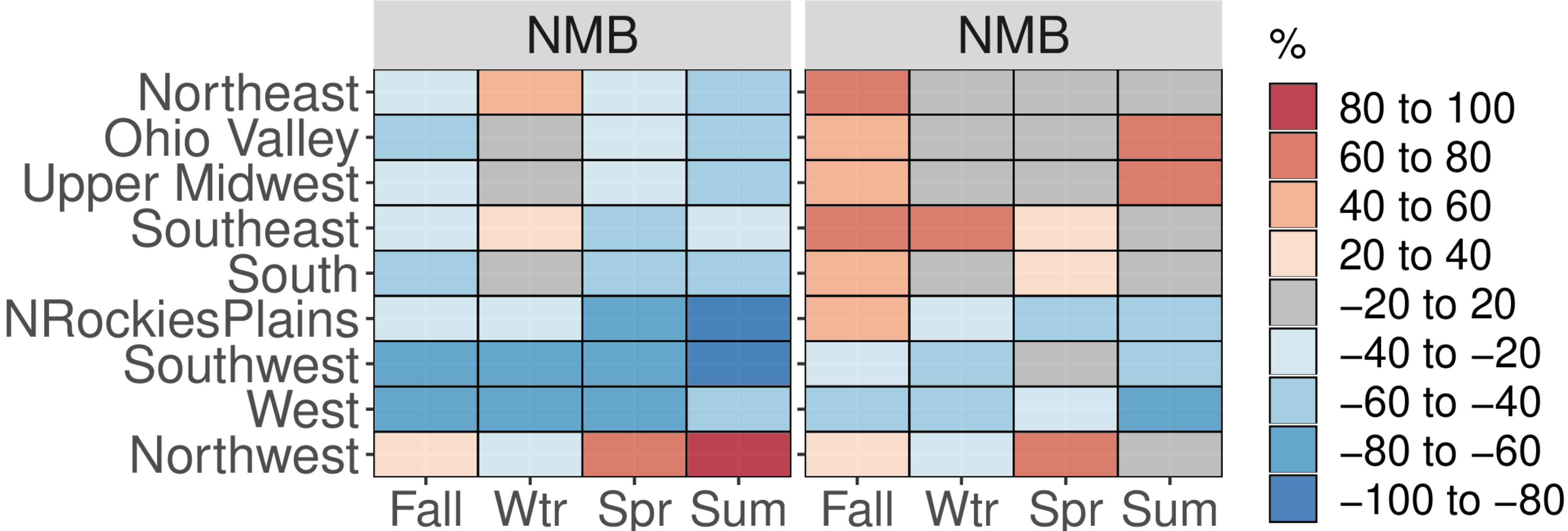
Nitrate Bias (%) – Overview

California (West region) underpredicted year-round in both models

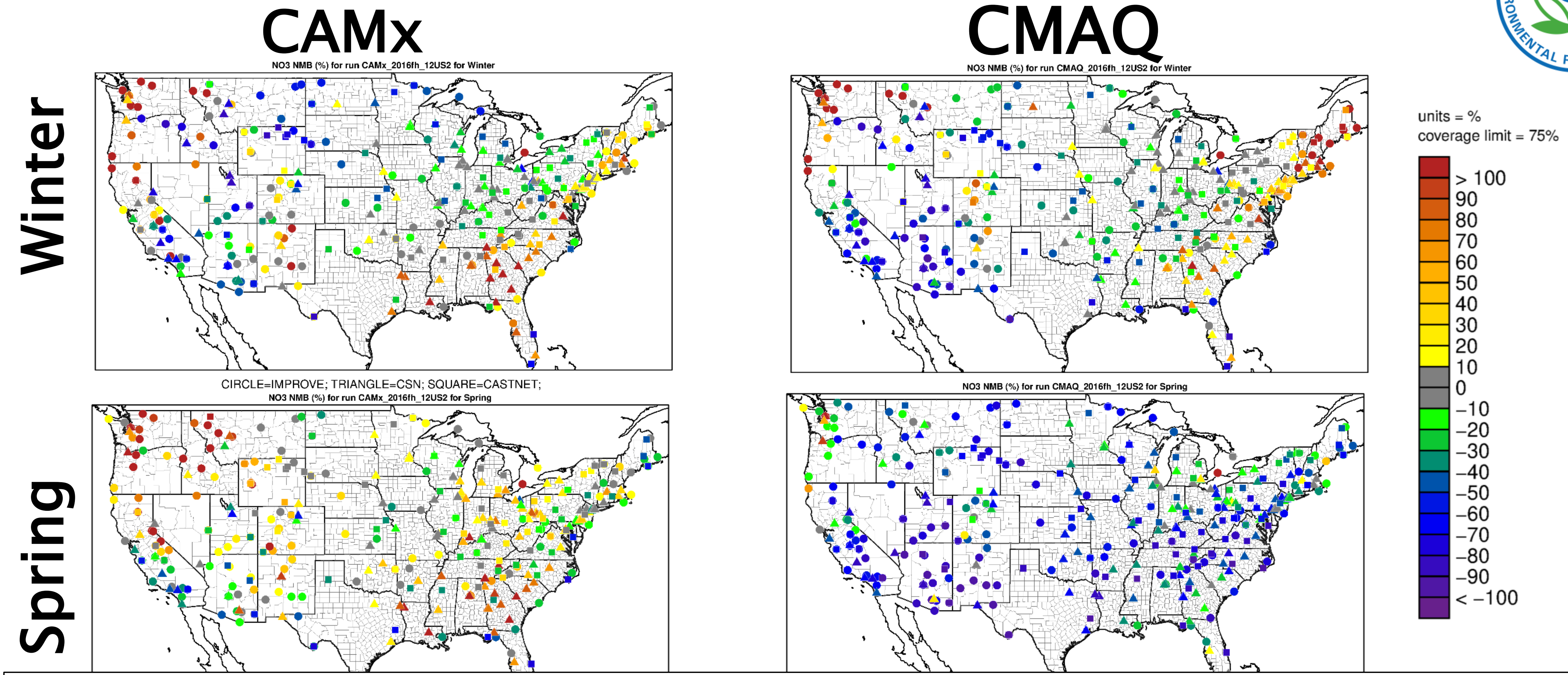
Winter Eastern US : Midwest shows underpredictions up to 20%, Northeast corridor shows overpredictions in both models , underpredictions in SW (including SLC), performance in both models look similar

Spring Midwest: CMAQ is underpredicted, CAMx bias is between -20% and + 20%

CMAQ 2016fh CAMx 2016fh



Nitrate – 2016fh National NMB (%)



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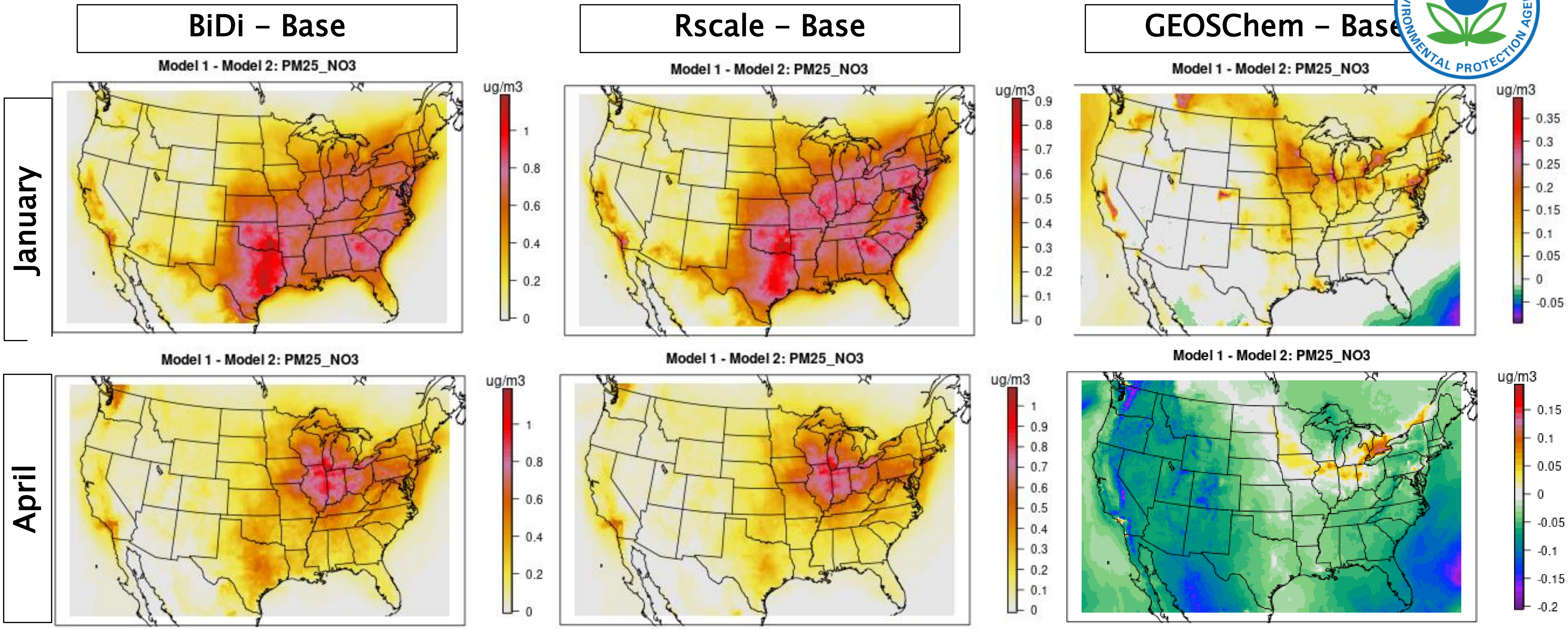
Key Nitrate Sensitivity Simulations: CAMx

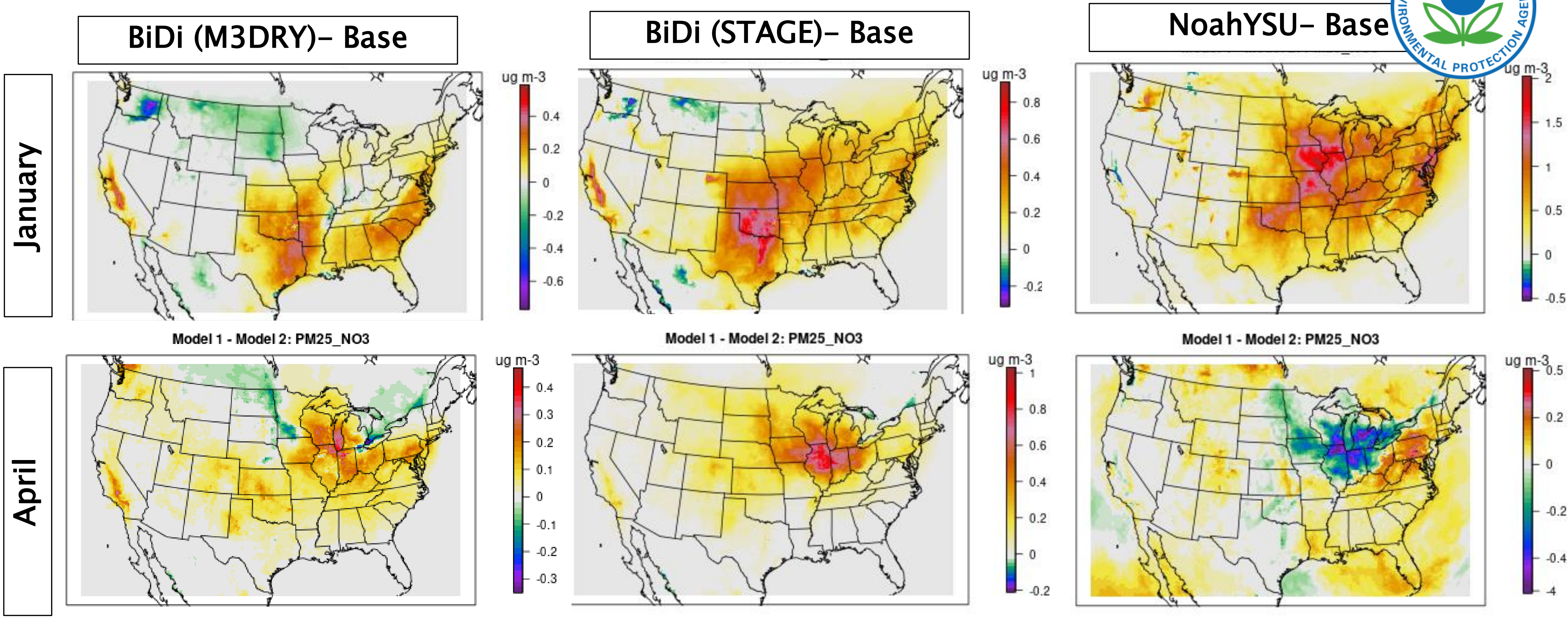


California (West region) underpredicted year-round in both base run model simulations

Winter Eastern US base model runs: Midwest shows underpredictions up to 20%, Northeast corridor shows overpredictions in both models, underpredictions in SW (including SLC), performance in both models look similar

Spring Midwest: Base run CMAQ is underpredicted, Base run CAMx bias is between -20% and + 20%

Key Nitrate Sensitivity Simulations: CMAQ



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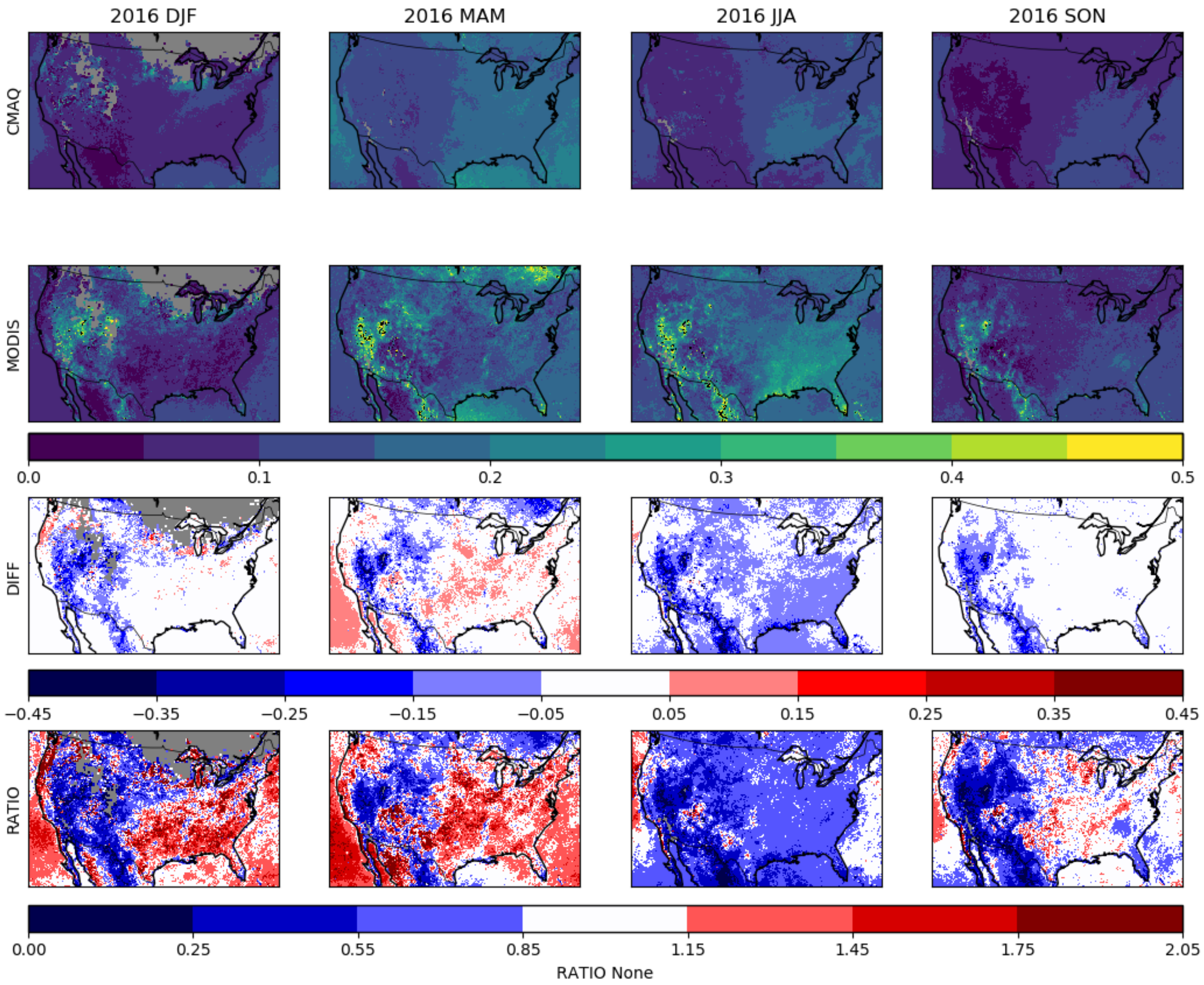
How does CMAQ compare to MODIS AOD?



Methods:

- MODIS AOD (500nm) obtained from RSIG and regridded to CMAQ 12km grid: modis.mod43k.Optical_Depth_Land_And_Ocean
- CMAQ variable AOD_W550_ANGST from PHOTDIAG1. Grid cells filtered to:
    - Select approximate overpass times
    - Select only successful retrieval time/grid cells.
- Average all data to monthly resolution

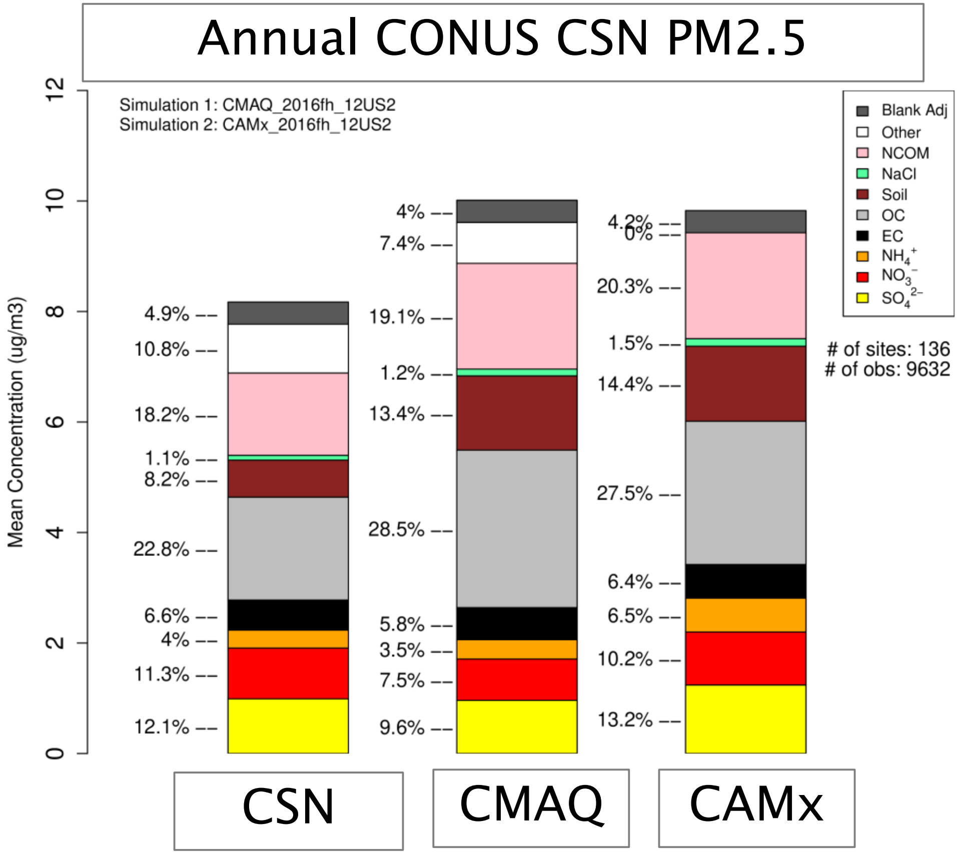
Results plotted based on Remer et al. 2005 suggested uncertainty at the

- +- 0.05
- +-15% AOD

Comparisons with satellite products is still a work in progress

Findings – Sulfate and Nitrate

- Sulfate
  - CAMx:
    - bias is mostly between -20% and +40% in winter/Eastern US
    - bias is between -20% and +20% in summer/Ohio River Valley
  - CMAQ:
    - underpredictions are generally less than -20% in winter/Eastern US
    - bias is between -40% and -20% in summer/Ohio River Valley
- Nitrate:
  - CMAQ
    - Winter Midwest shows underpredictions up to 20%, Northeast corridor shows overpredictions, underpredictions in SW
    - Spring underpredictions across entire US
    - Using STAGE and M3DRY bi-direction ammonia flux improve performance
  - CAMx
    - Winter Midwest shows underpredictions up to 20%, Northeast corridor shows overpredictions, underpredictions in SW
    - Spring CAMx bias is between -20% and + 20%
  - Both models: Underestimates in California at 12km resolution



Concluding Thoughts and Next steps

- Model performance for ozone, sulfate, and nitrate in our 2016 modeling is generally in the range of similar applications reported in the literature

- We plan finalize evaluation of gas and PM components not shown in this presentation
  - NOx, VOC, CO, SO2
  - OC, EC, crustal elements

- We will continue to analyze the results of the sensitivities

- We are considering additional sensitivities that focus on better understanding the drivers of times/locations when performance suggests the need for further investigation