Evaluation and Application of the NCAR CONUS Air Quality Research Forecasting System

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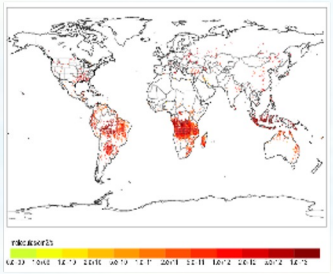
Rajesh Kumar, Shawn Honomichl, Carl Drews

NCAR

MAC-MAQ 2023

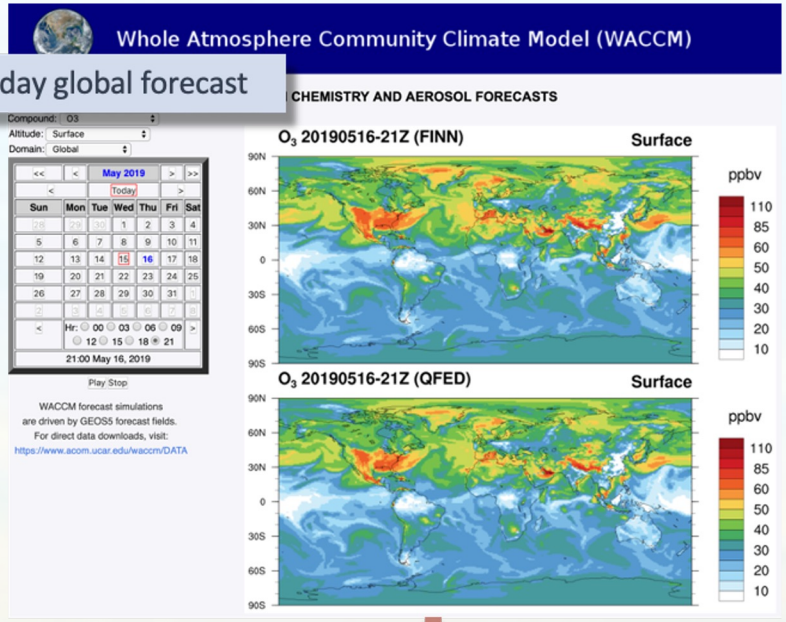
This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

NCAR's **Experimental** Air Quality Prediction System

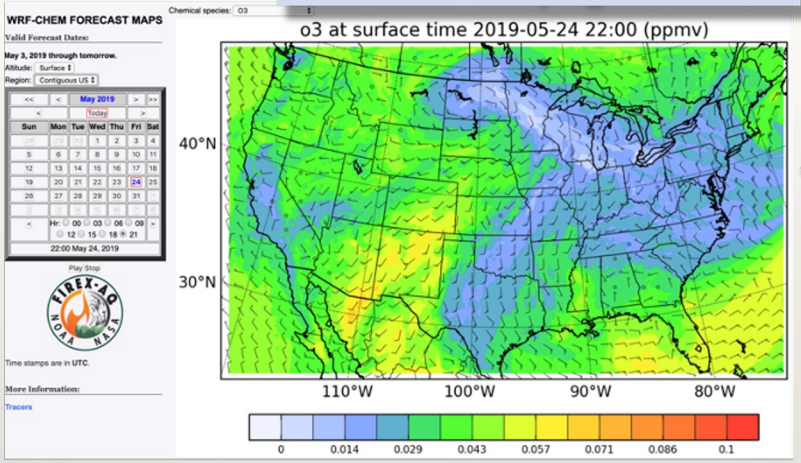


Near-real-time FINN fire emissions

WACCM – 10 day global forecast



WRF-Chem – 2 day regional forecast

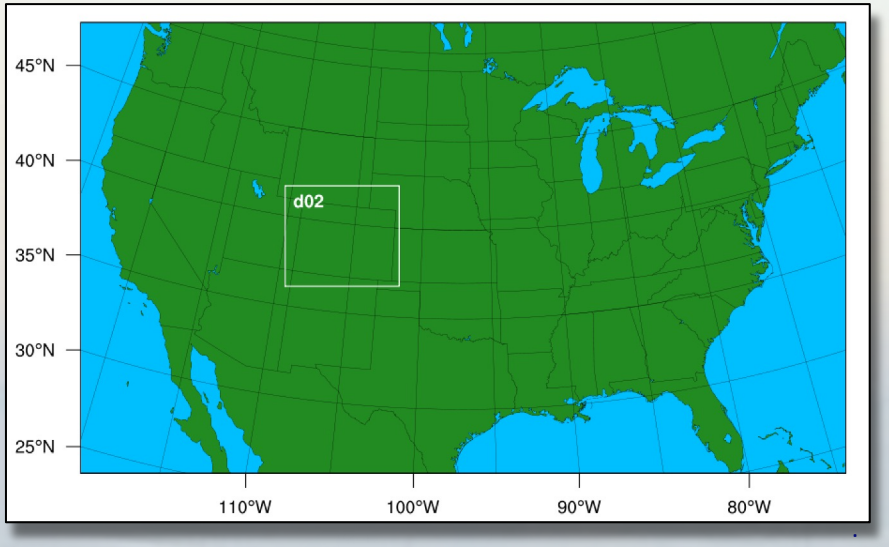


- Early identification of model errors and biases
- Field campaign planning and support
- Boundary conditions for real-time applications
- Information for policy makers - complement NOAA's operational forecast
- Forecasting for NASA TOLNET network

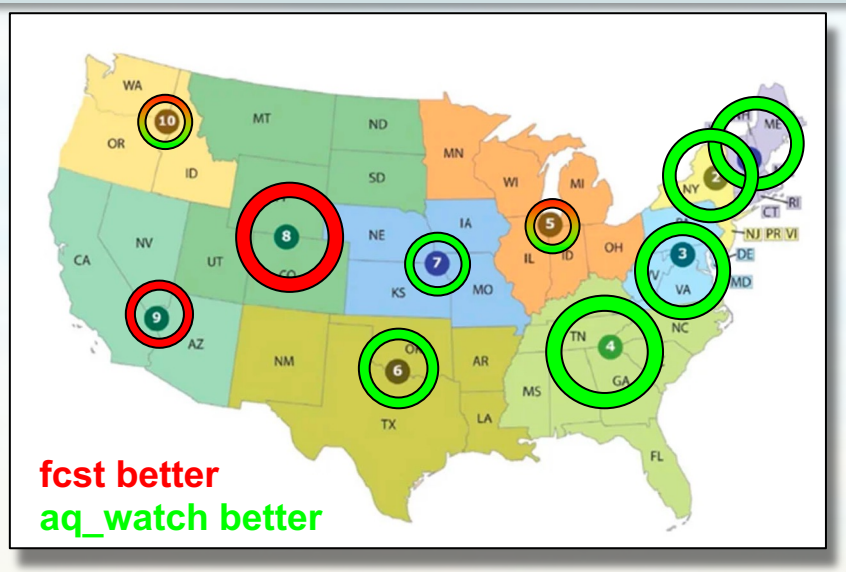
https://www.acom.ucar.edu/firex-aq/forecast.shtml

WRF-Chem Forecast Configurations

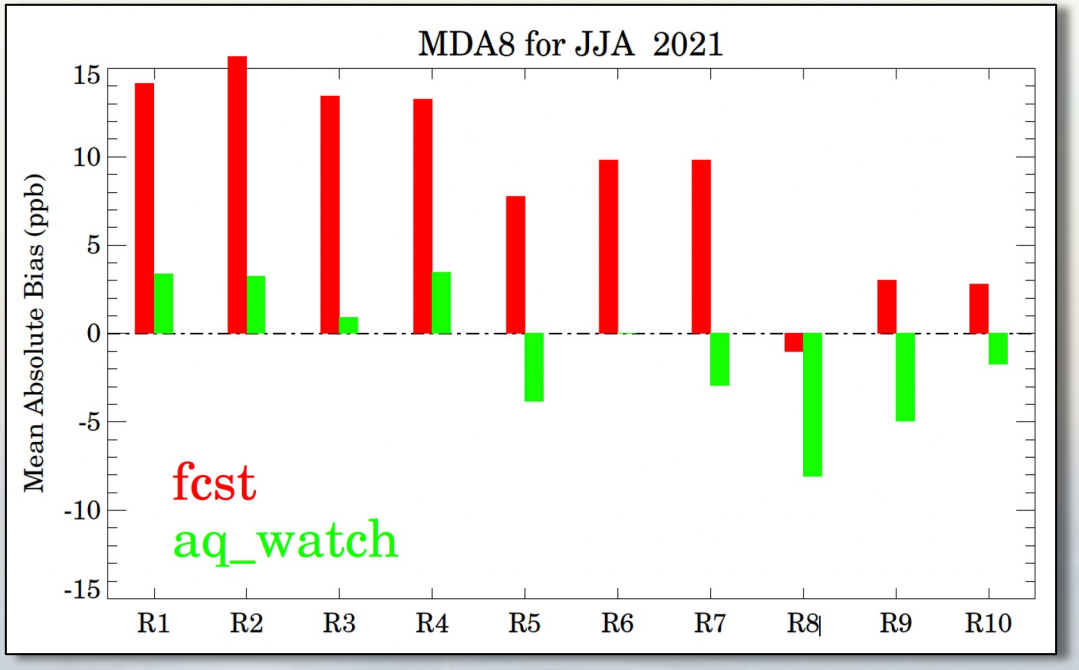
	Standard Setup “fcst”	Parallel Setup “aq_watch”
Chemical Scheme	MOZCART (MOZART V4+ GOCART)	T1-MOZCART (T1 MOZART+ GOCART)
Domain	1 domain (12x12 km^2 over CONUS)	2 domain (CONUS & 4x4 km^2 Colorado)
Model Version	WRF-Chem V3.9.1 (terrain-following coordinate)	WRF-Chem V4.1 (hybrid sigma-pressure coordinate)
Anthro. Emissions	NEI 2014 (hourly, monthly average)	NEI 2017 (Trend adjusted, hourly, day specific)
Fire Emissions	FINNv1	FINNv1, aerosols doubled
Biogenic Emissions	MEGAN online	MEGAN online with 50% reduction of isoprene
Start Date	Summer 2019	Summer 2020



Evaluation: AIRNOW Surface Ozone per EPA Region



- What changes between fcst and aq_watch drive the regional differences in performance?
- Can we identify a configuration that improves performance across CONUS?



Sensitivity Studies

Anthropogenic Emissions | Biogenic Emissions & Chemical Scheme | Urban Parameterizations

	Emissions		Chemistry	EBIO_Iso	Urban Scheme
Control	NEI2017 trend adj.	day specific	T1-MOZCART	50%	None
NEI2014	NEI2014	avg. day	T1-MOZCART	50%	None
NEI2017trend	NEI2017 trend adj.	avg. day	T1-MOZCART	50%	None
CO2014	NEI2017 trend adj. NEI2014 over CO	avg. day	T1-MOZCART	50%	None
MOZCART	NEI2017 trend adj.	day specific	MOZCART	100%	None
MOZCART_Ebio	NEI2017 trend adj.	day specific	MOZCART	50%	None
Urban1	NEI2017 trend adj.	day specific	T1-MOZCART	50%	Single-Layer
Urban 2	NEI2017 trend adj.	day specific	T1-MOZCART	50%	Multi-Layer

Simulation Period: 20-25 July 2021, 2 domains CONUS (12km) and Colorado (4km)

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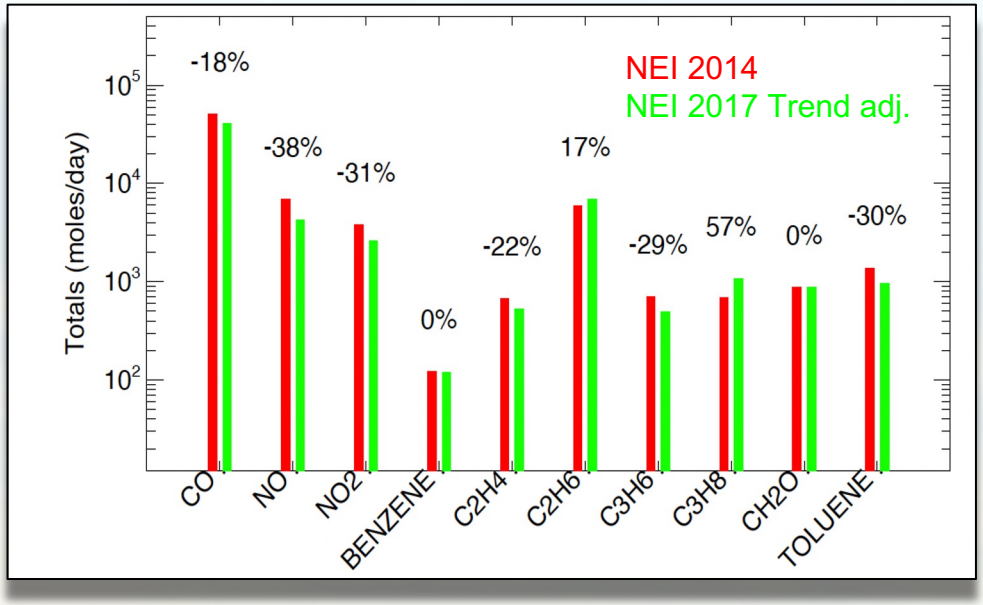
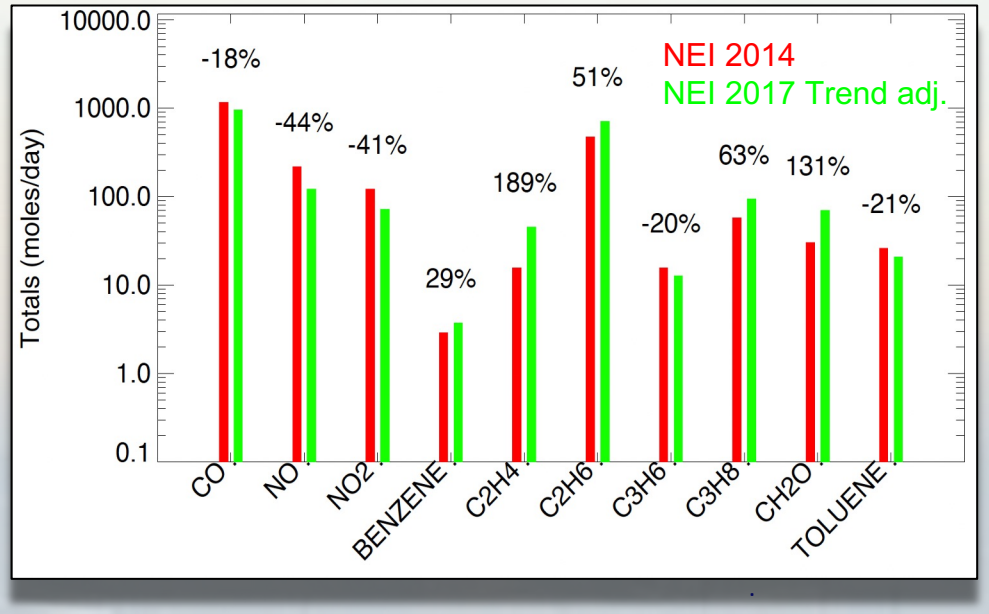
Sensitivity Studies

CONUS



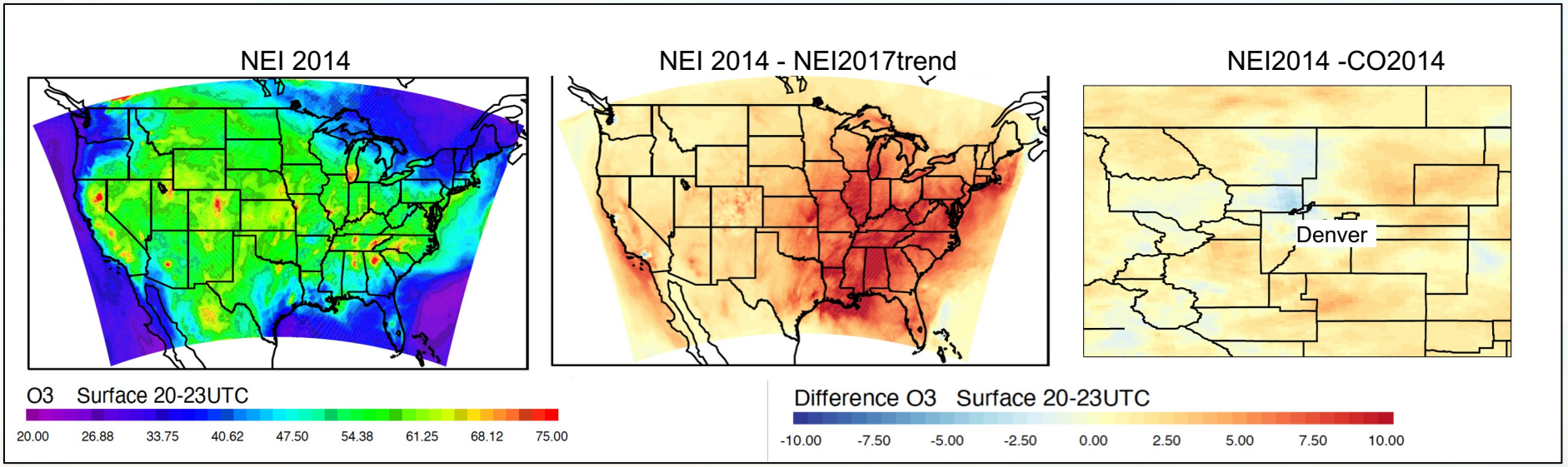
Colorado

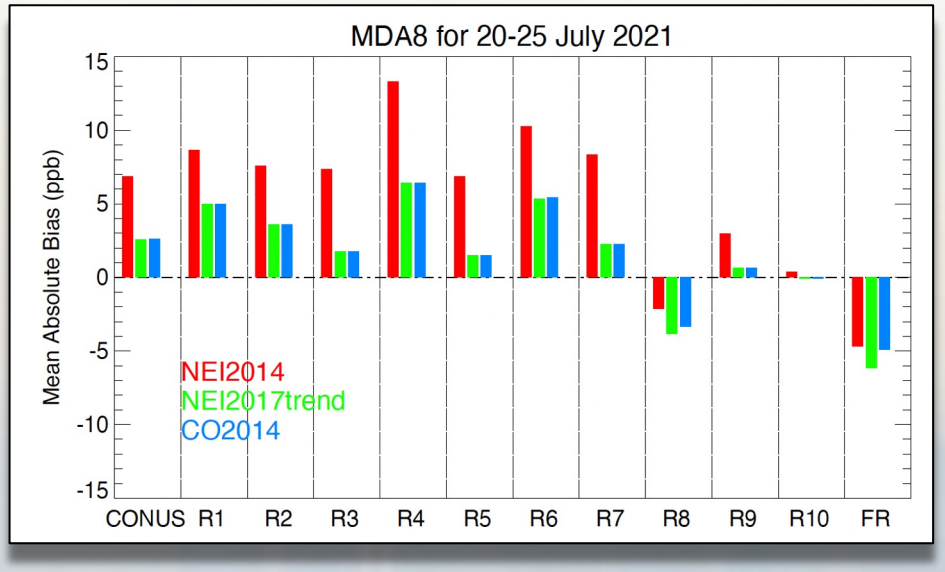


Percentage difference is (2014-2017)/2017

Anthropogenic Emissions

Sensitivity Studies





- NEI 2017 simulates lower ozone across most of CONUS
- The ozone bias decreases for all regions with NEI 2017, except for Region 8 including the Colorado Front Range (FR). This is the only region where NEI 2014 has a low bias compared to surface sites.
- Changing emissions outside of Colorado only introduces spatially variable changes in surface ozone within Colorado but the overall model bias is dominated by the local emissions used.

Bias = (Model-Obs). Derived from CONUS domain

Sensitivity Studies

Anthropogenic Emissions | **Biogenic Emissions & Chemical Scheme** | Urban Parameterizations

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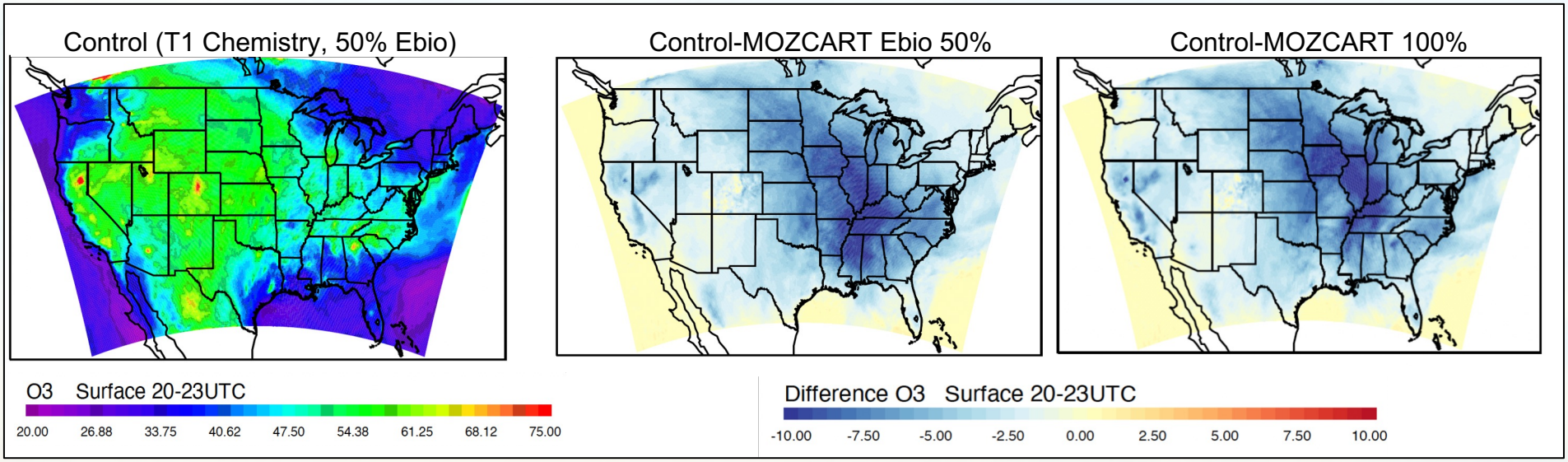
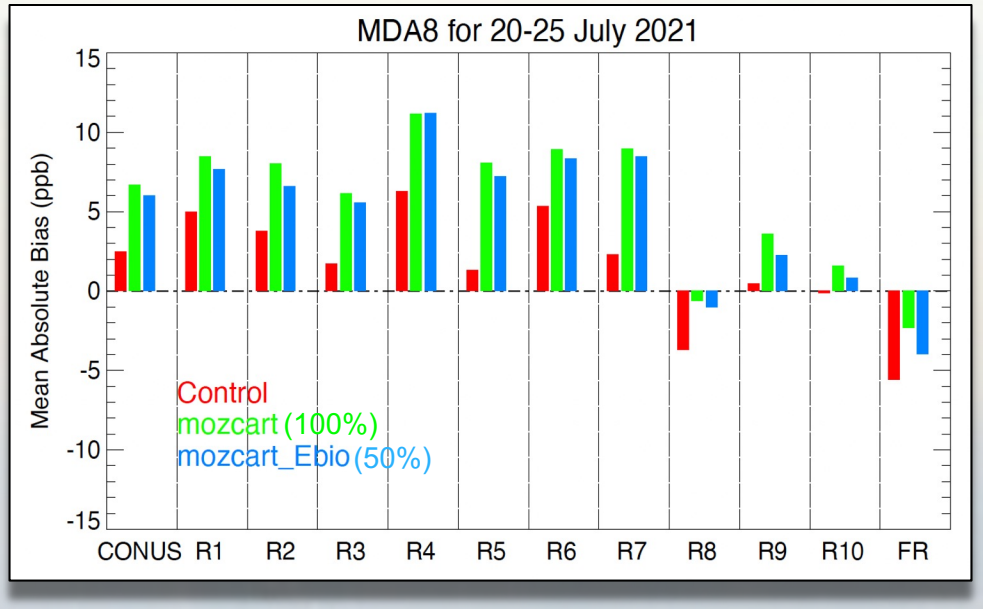
Sensitivity Studies





- MOZCART produces significantly more ozone compared to the more recent T1 chemistry
- T1 performs better over all regions - except Region 8.
- Biogenic isoprene changes have a smaller impact, but can change the surface ozone bias by a few ppb.

Bias = (Model-Obs)

Sensitivity Studies

Anthropogenic Emissions | Biogenic Emissions & Chemical Scheme | **Urban Parameterizations**

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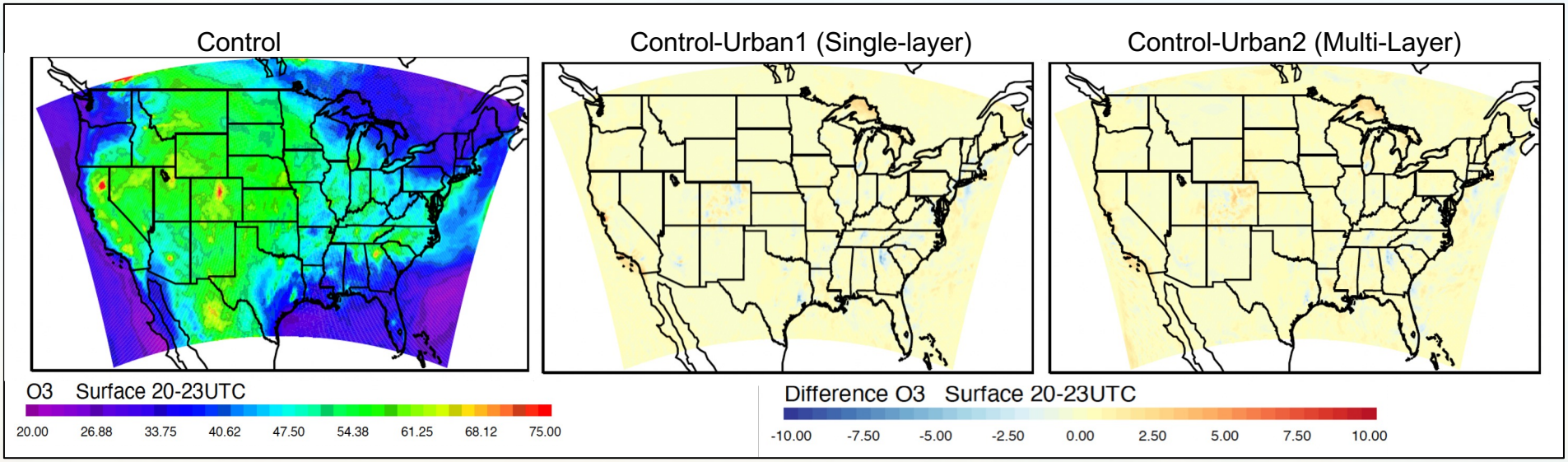
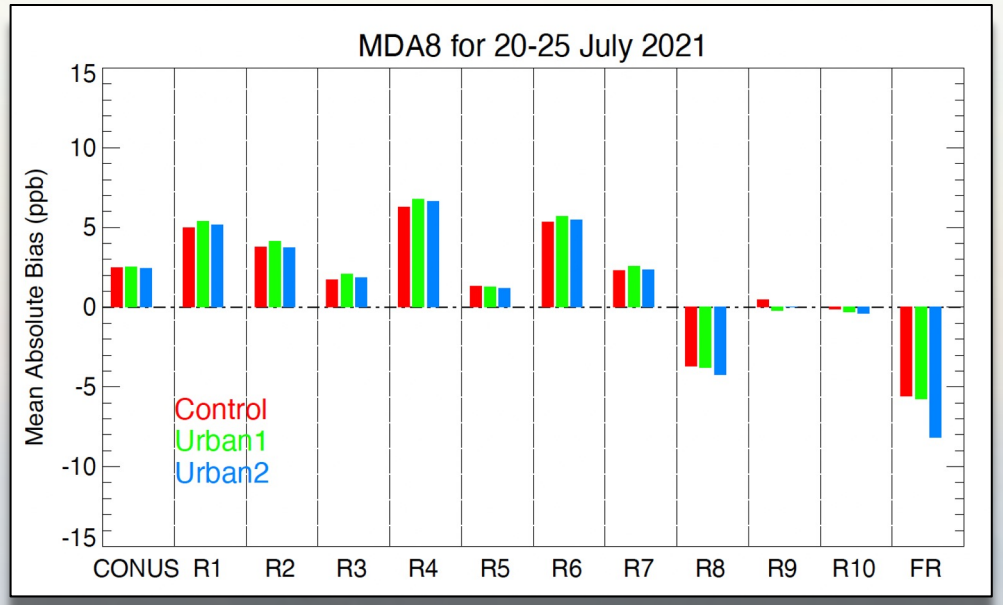
Sensitivity Studies





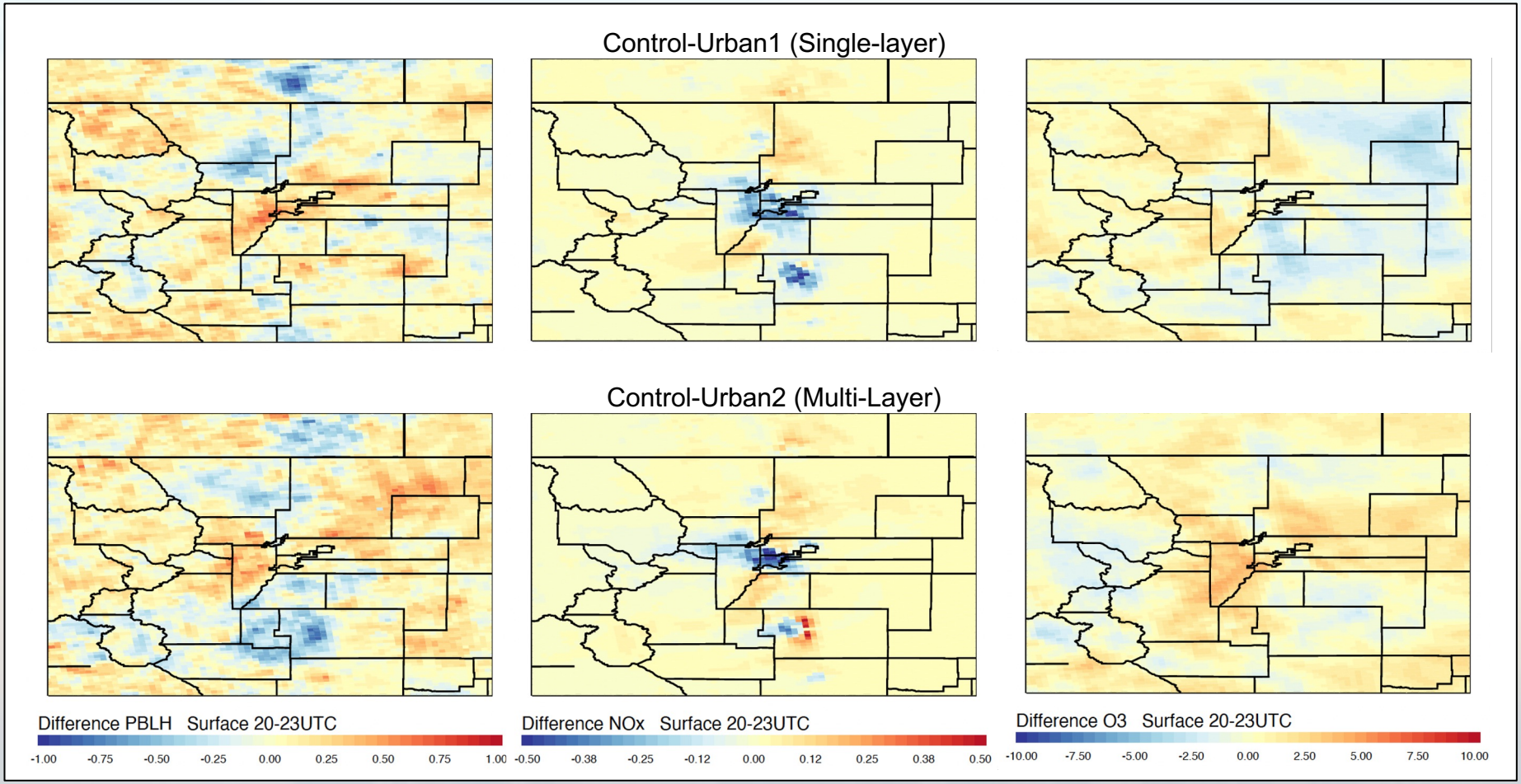
- The use of an urban canopy model in WRF-Chem does not change chemistry directly but indirectly through feedbacks on surface energy fluxes, temperature, PBL etc.
- Overall the changes in the EPA region biases are small, but locally the impacts can be more pronounced.

Bias = (Model-Obs)

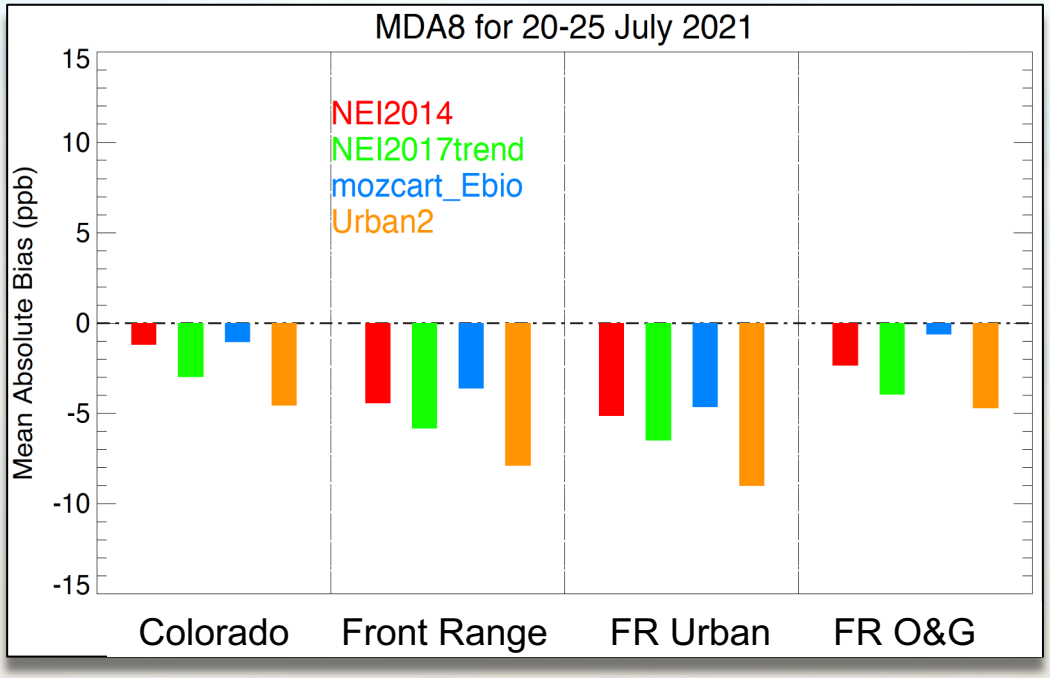
Urban Parameterizations

Sensitivity Studies

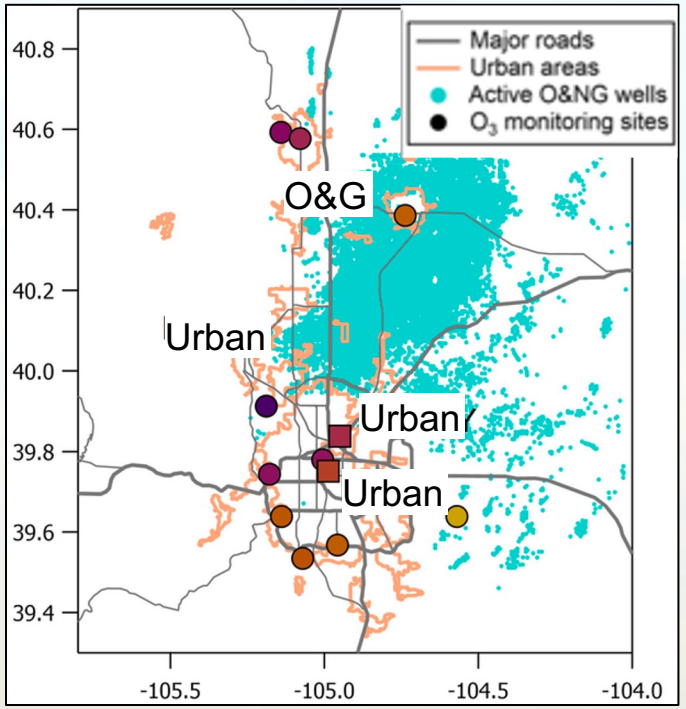
Boundary Layer | Surface NOx | Surface Ozone



Sensitivity Studies - Summary



Colorado Front Range

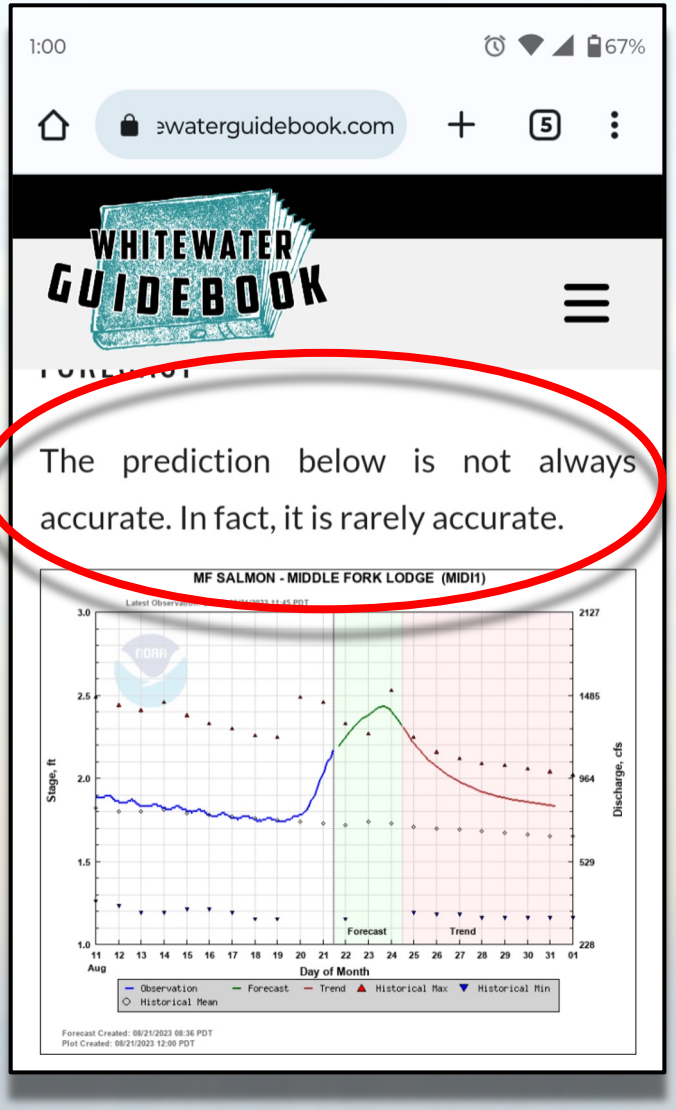


Pollack et al., 2021

Scale and site characteristics play a major role in performance assessment

Final Thoughts

- The NCAR Experimental forecasting system has shown value for research and for supporting decision making
- The most recent model updates and input data sets are not necessarily the best performing
- Performance is varying in time and space and there might not be a “one size fits all” configuration for a forecast system
- Further analysis is needed but final configuration might include different settings for CONUS and Colorado.
- TEMPO data will significantly help with the evaluation.



Funding: NSF, NASA ROSES and EU Horizon 2020

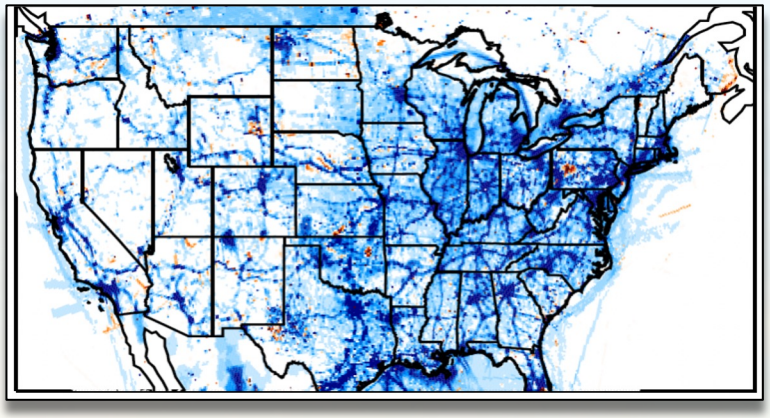
EXTRAS

Anthropogenic Emissions

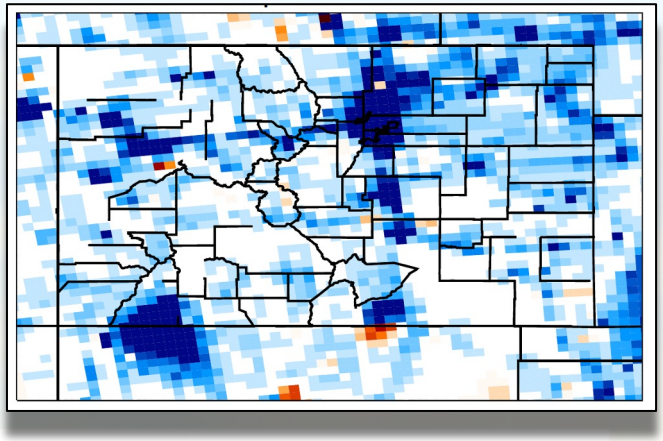
Sensitivity Studies

NEI2017trend - NEI2014

CONUS

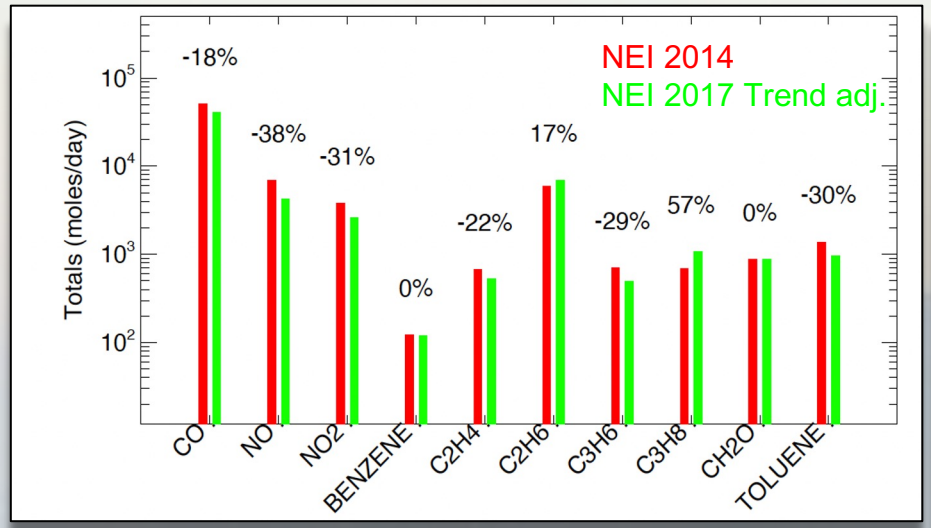


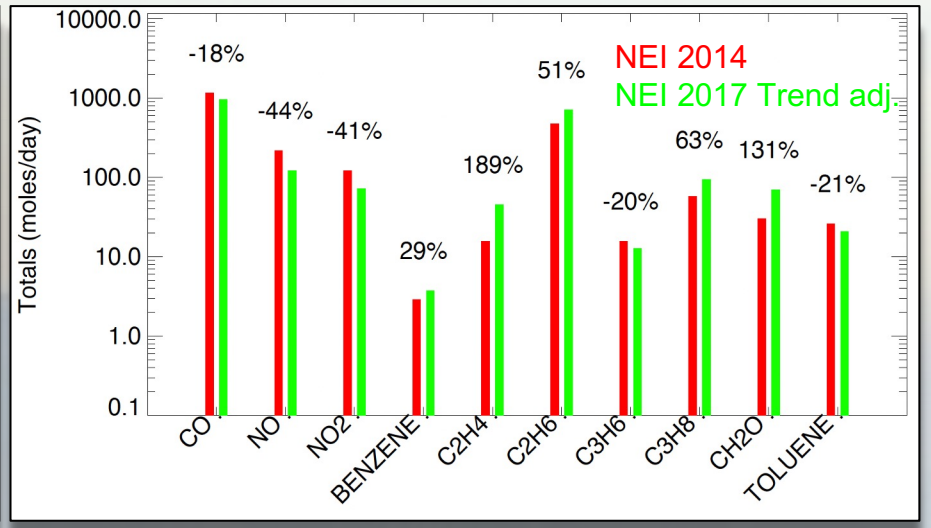
Colorado



NO Emissions Difference (mole/day/km^2)

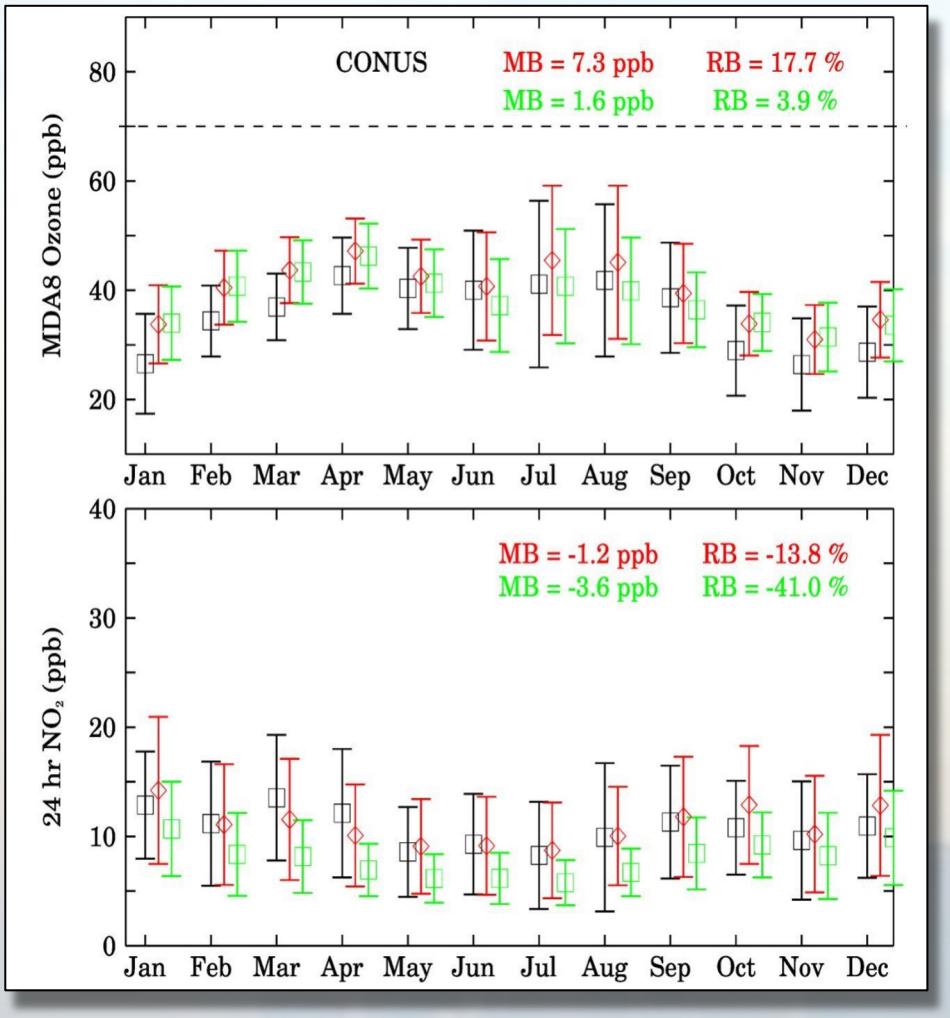
-6.250E+01 -4.167E+01 -2.083E+01 0.000E+00 2.083E+01 4.167E+01 6.250E+01

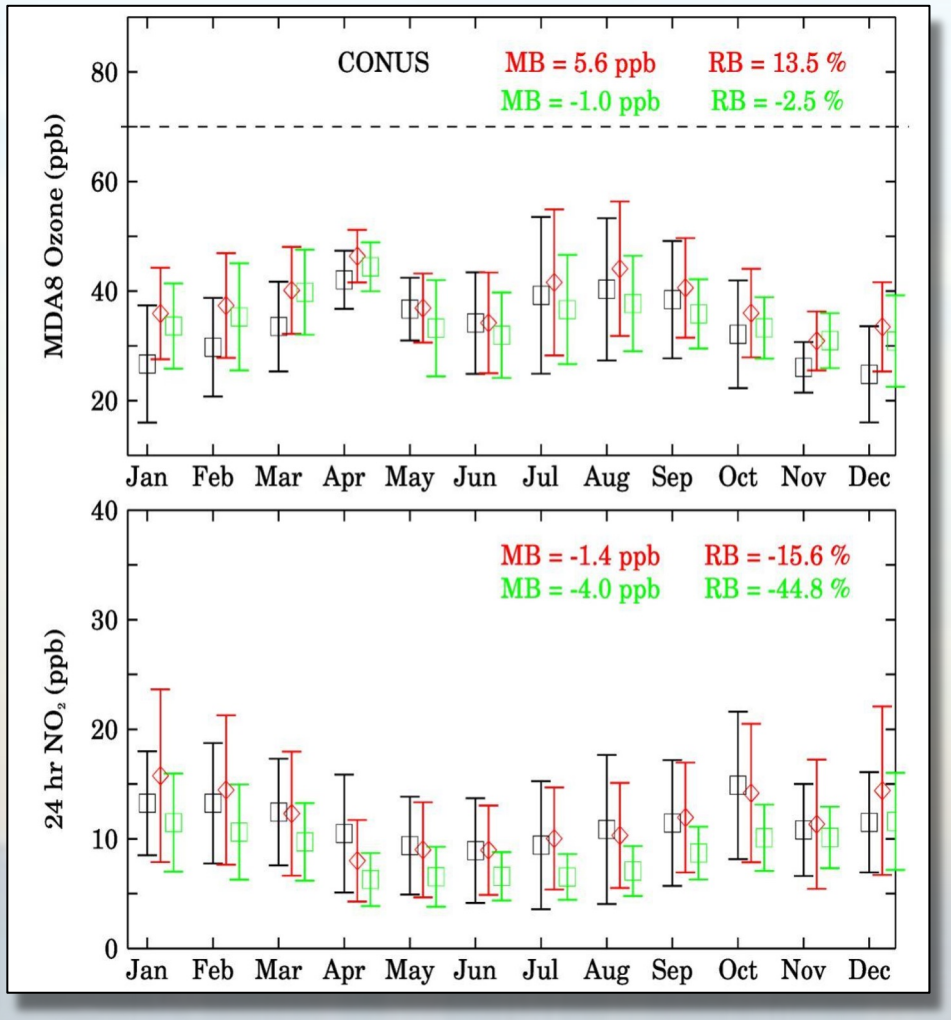




Percentage difference is (2014-2017)/2017

Evaluation: AIRNOW Surface Ozone and NO_2

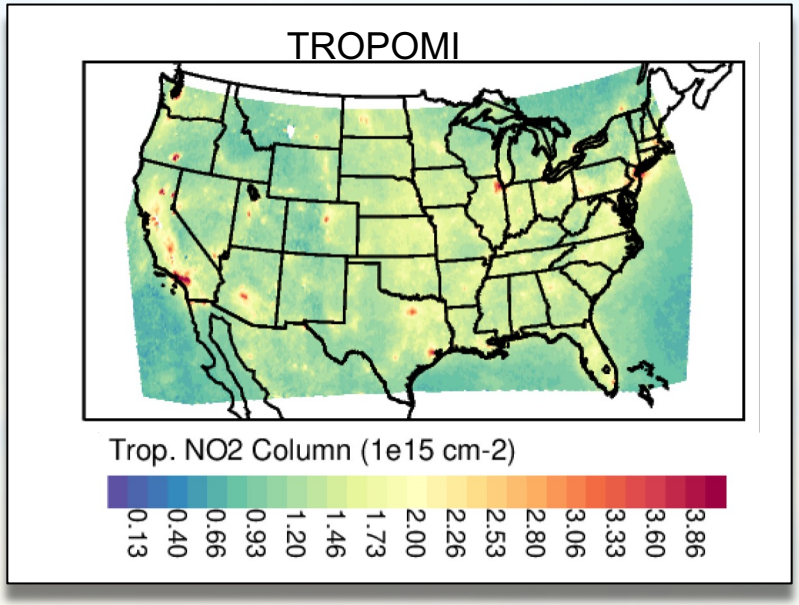


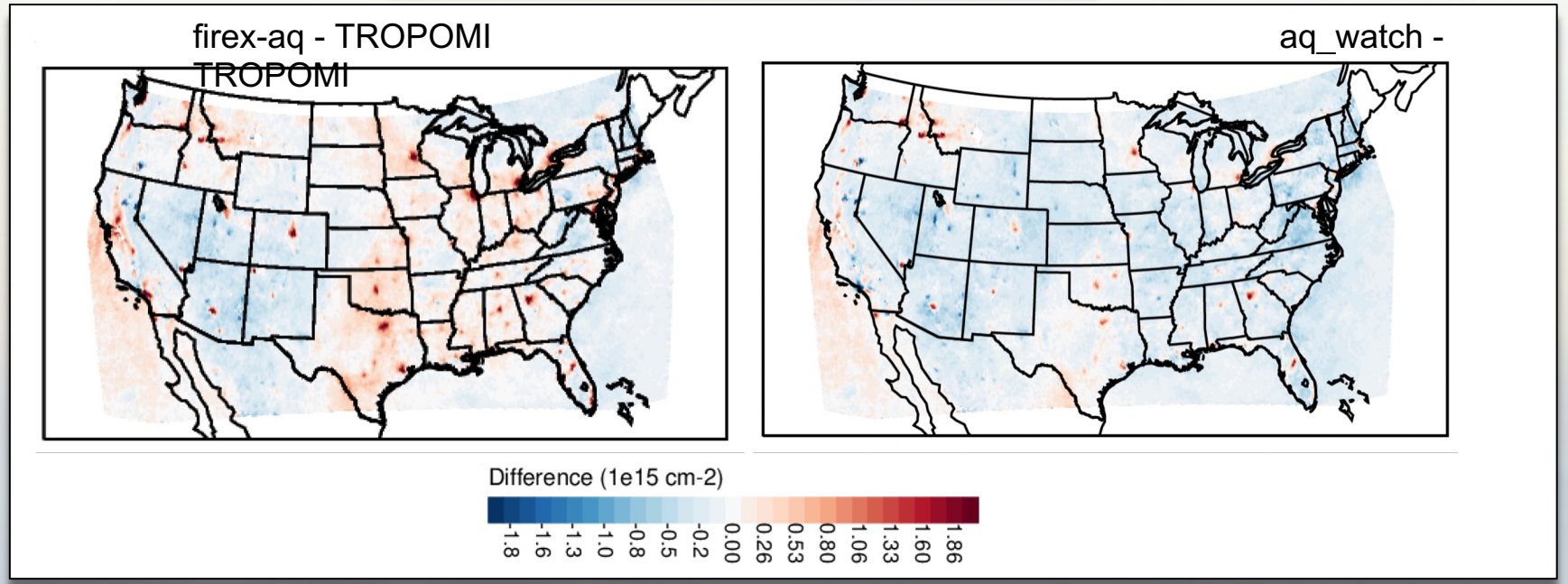


2021 **2022**

Evaluation: TROPOMI NO_2

July 2021





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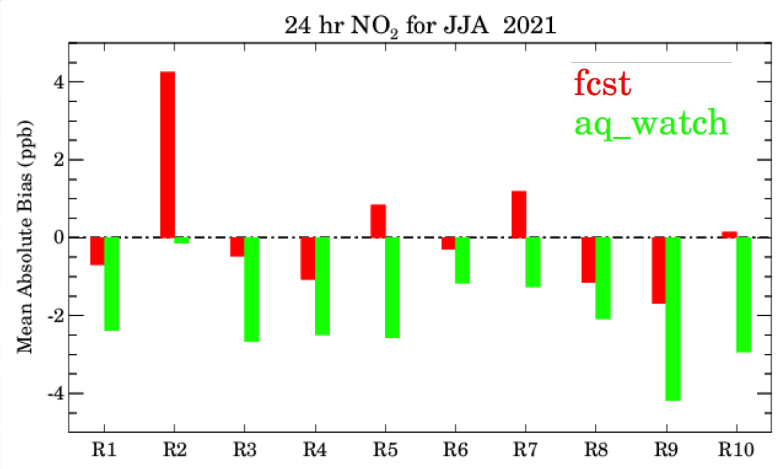

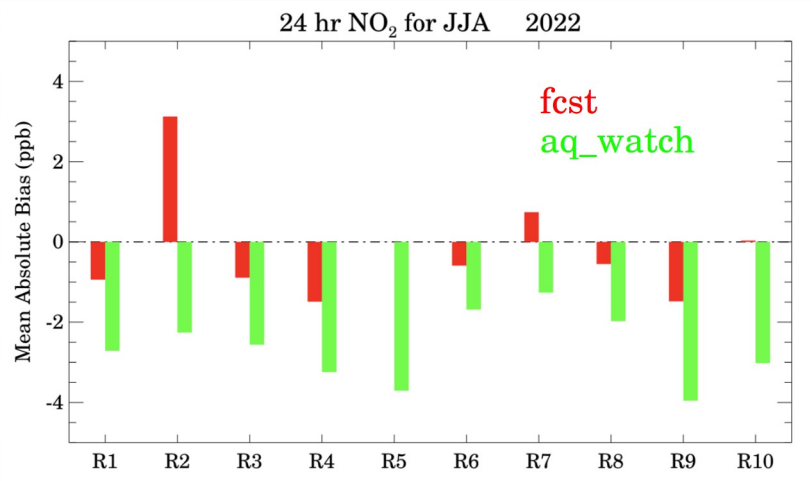

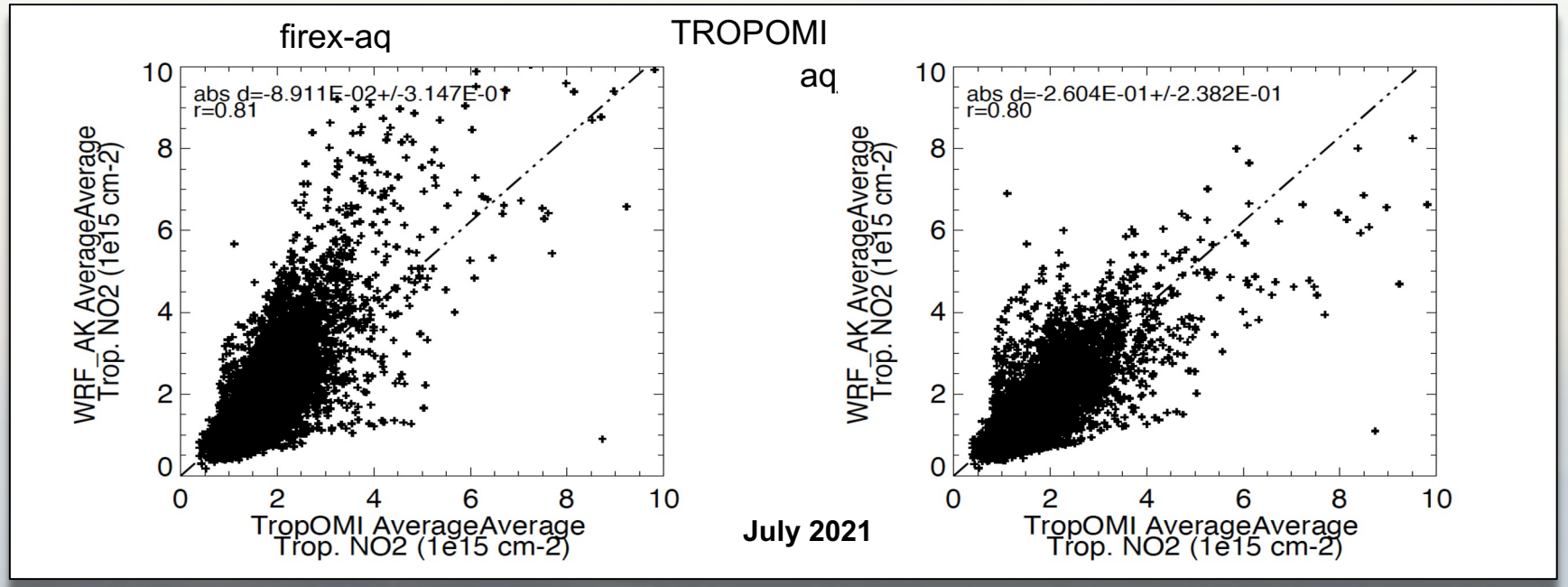

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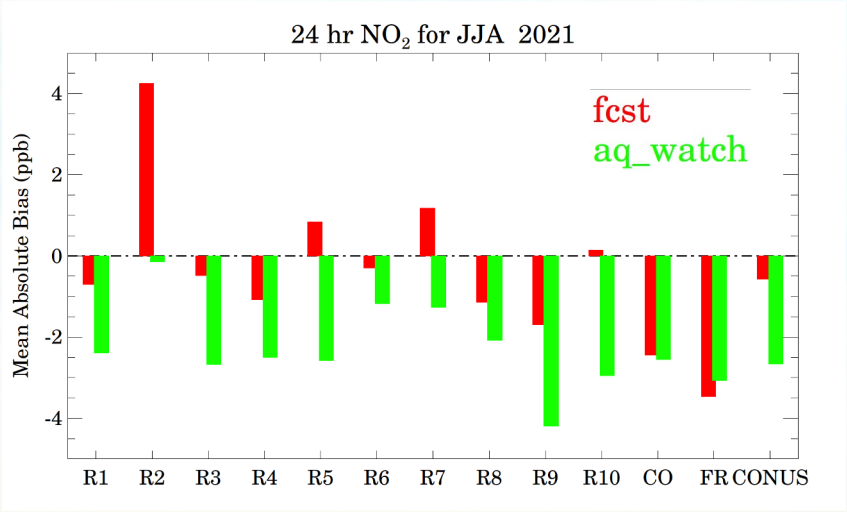
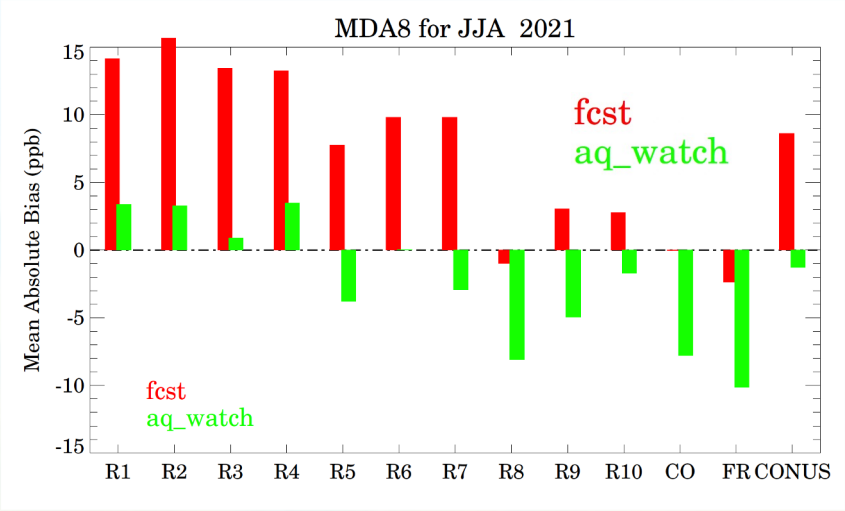
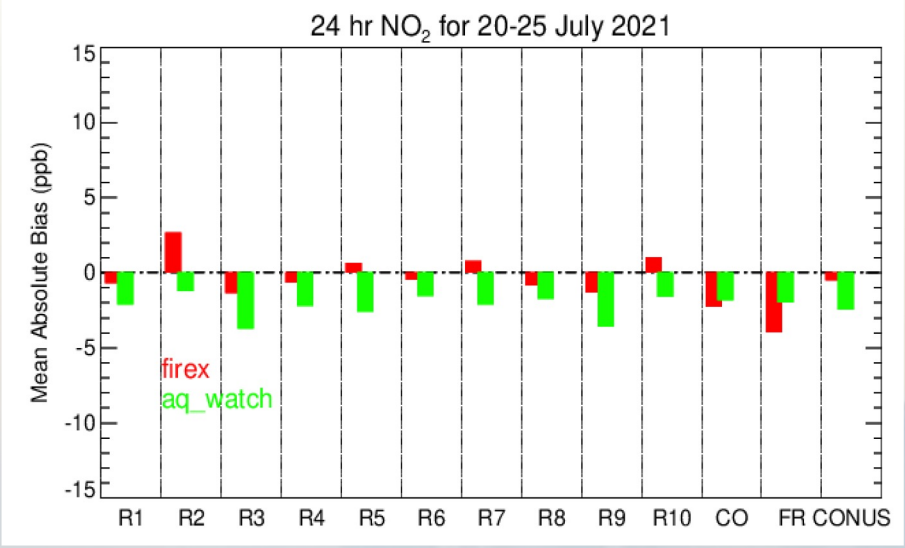
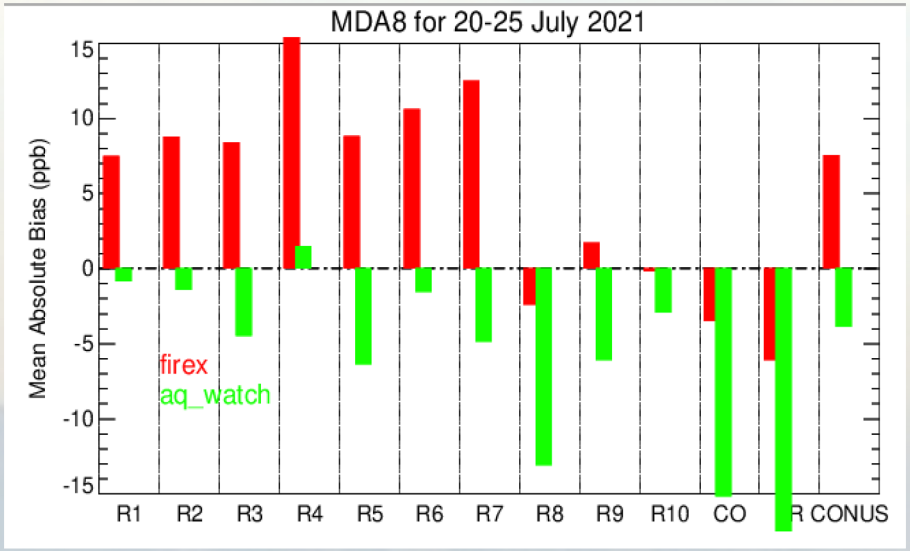
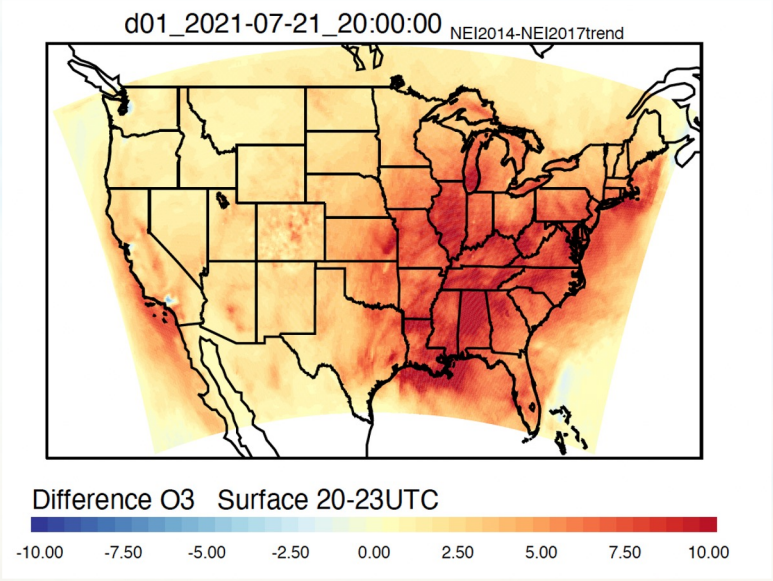


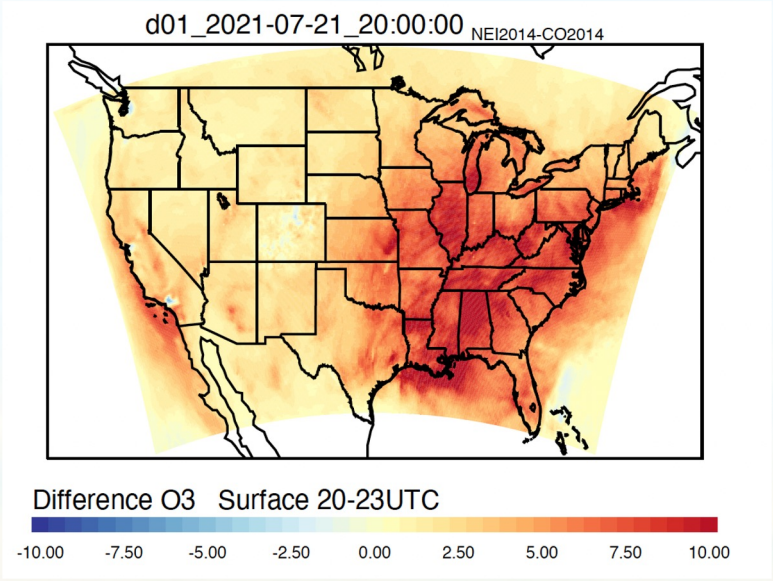




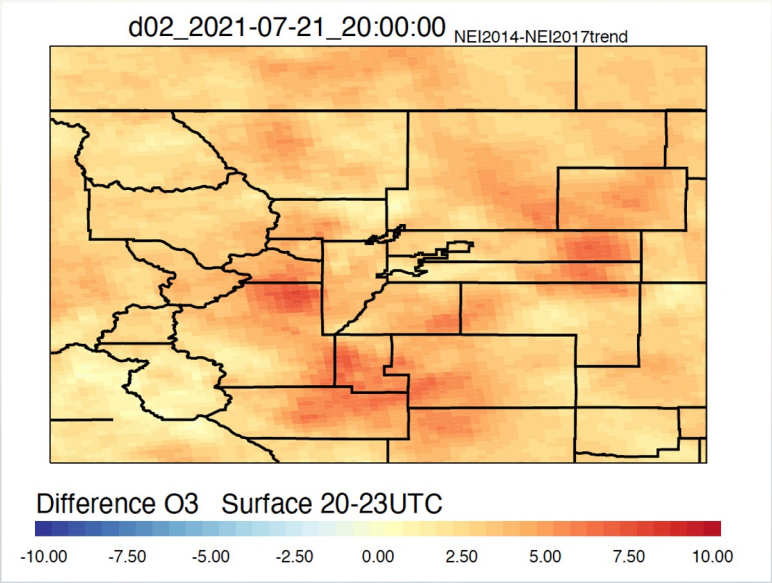


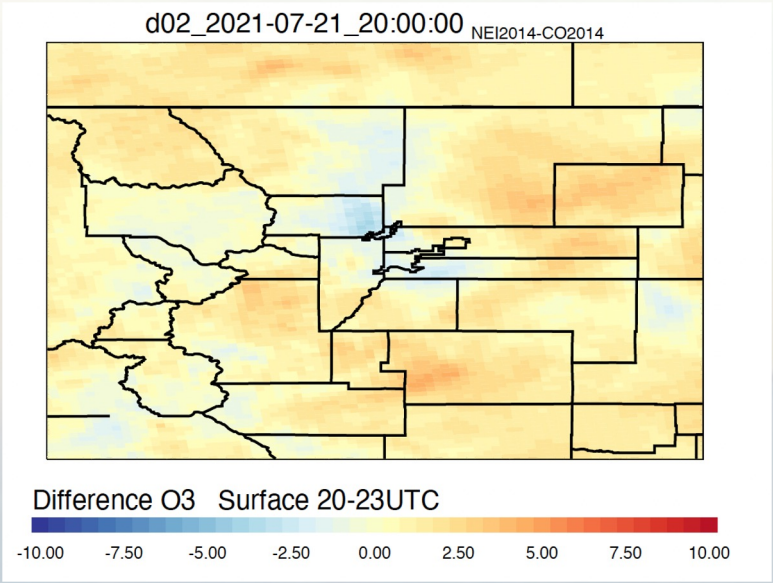
Sensitivity: Anthropogenic Emissions NEI2014-NEI2017trend





Ozone





Bias = (Model-Obs)

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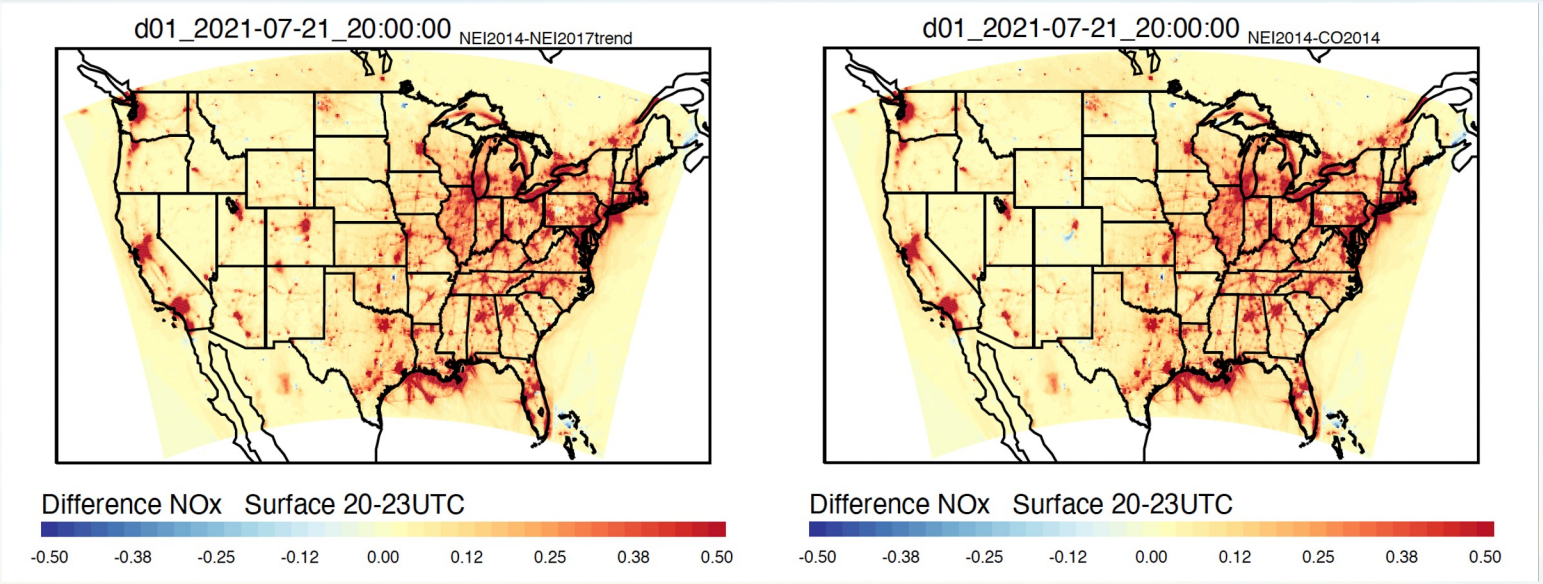
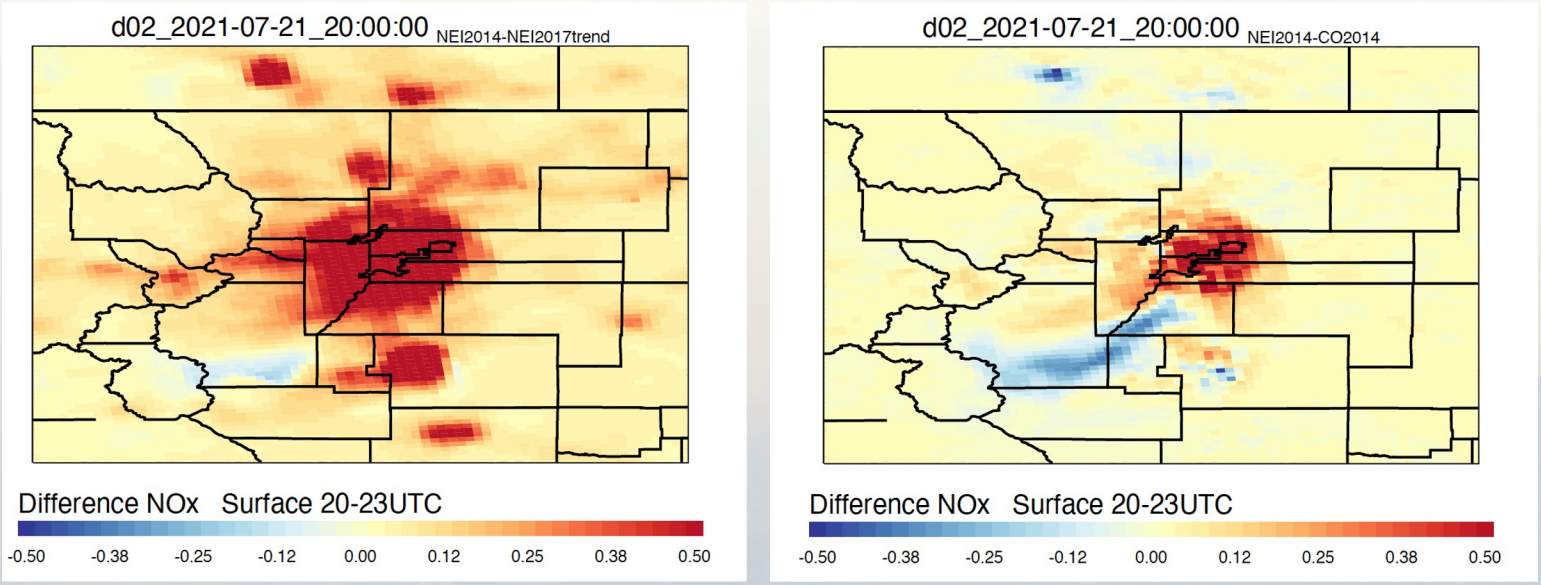


NOx



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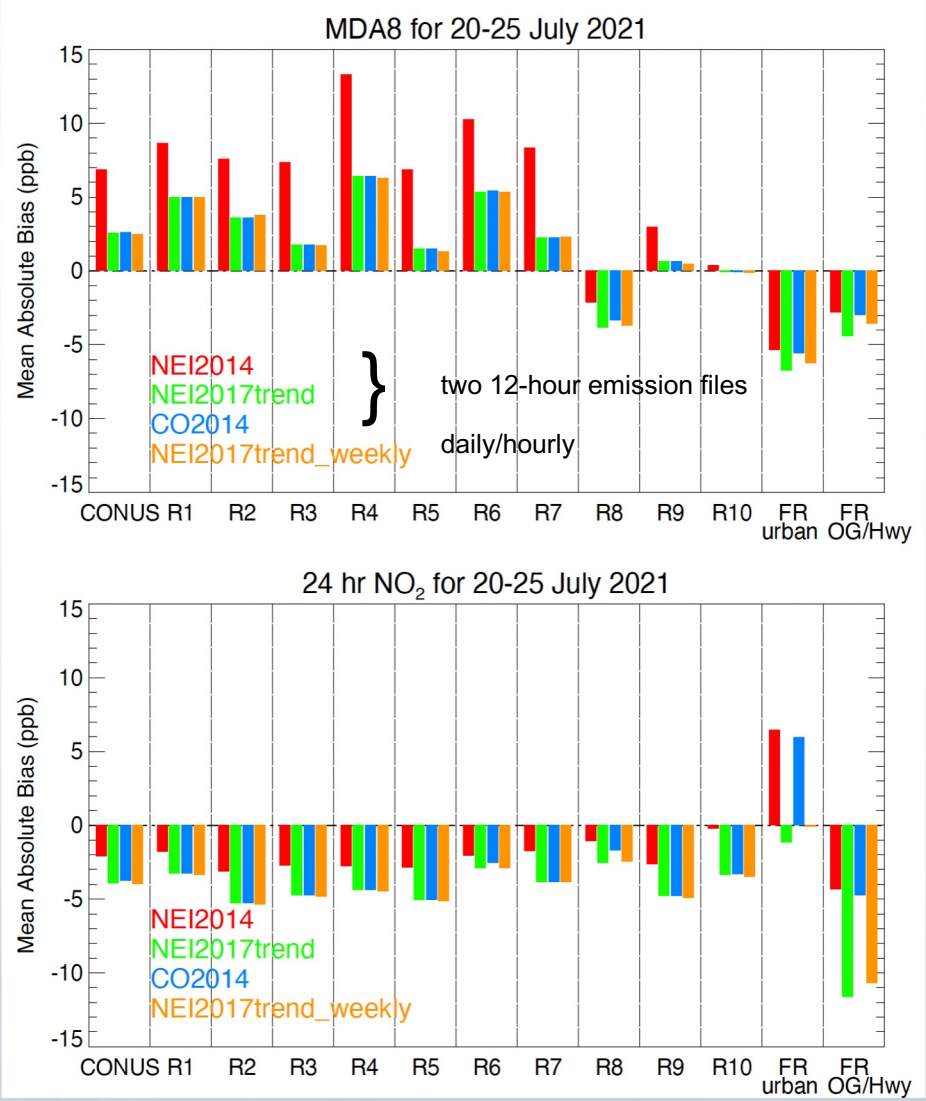
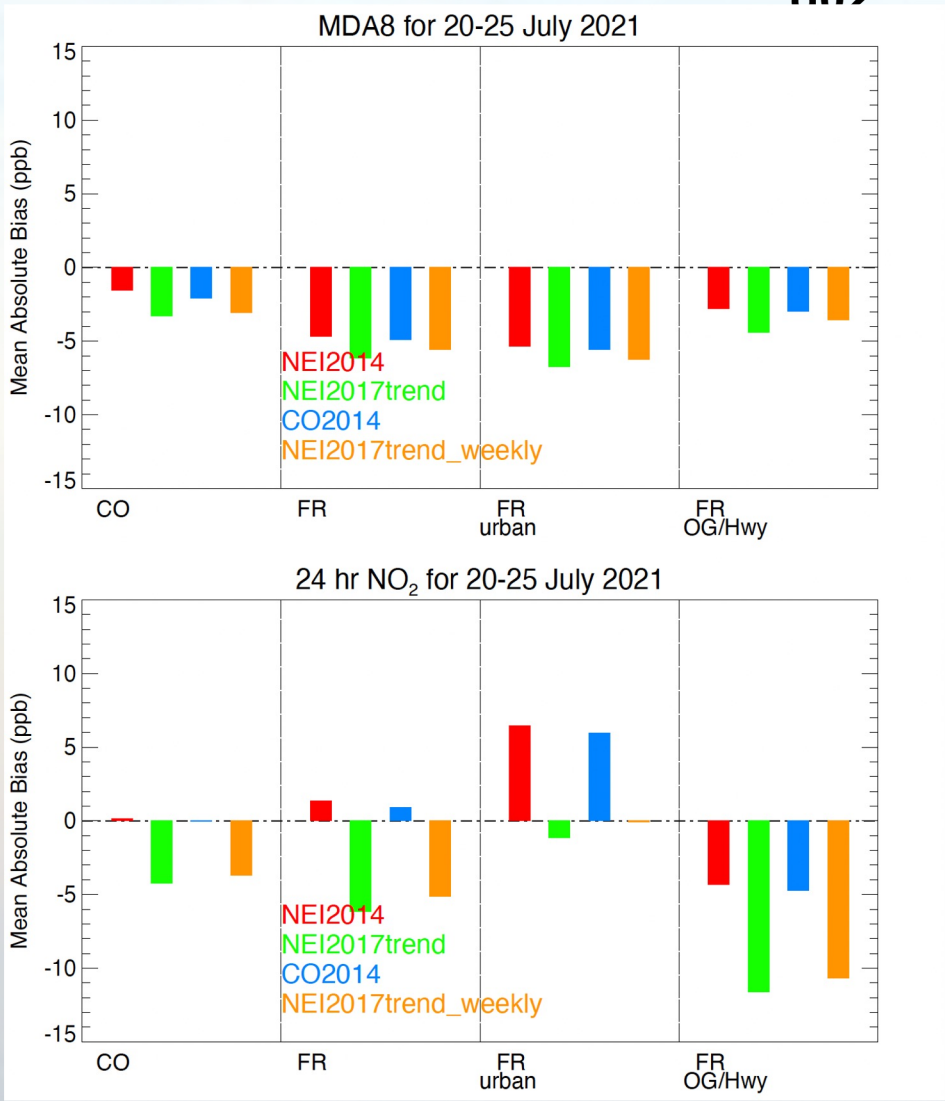
Sensitivity: Anthropogenic Emissions

d01

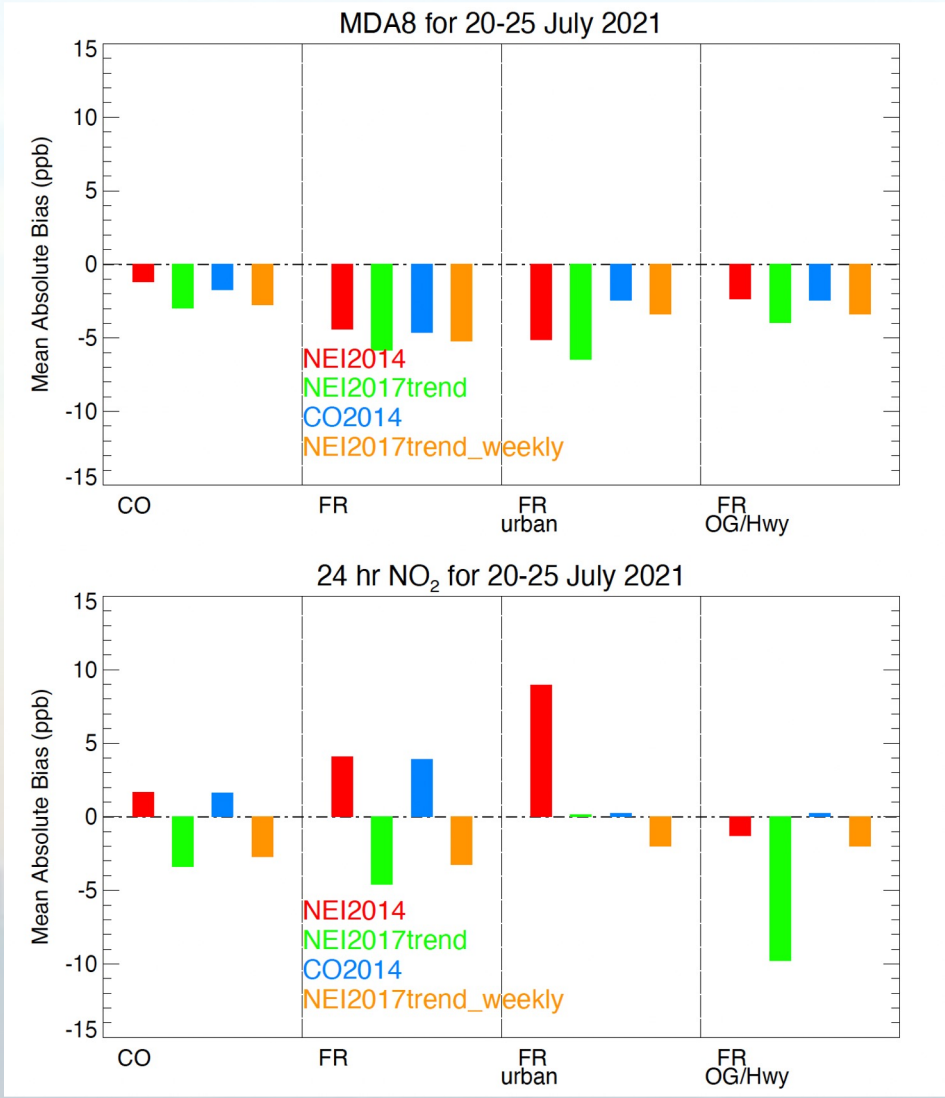


Sensitivity: Anthropogenic Emissions

d01

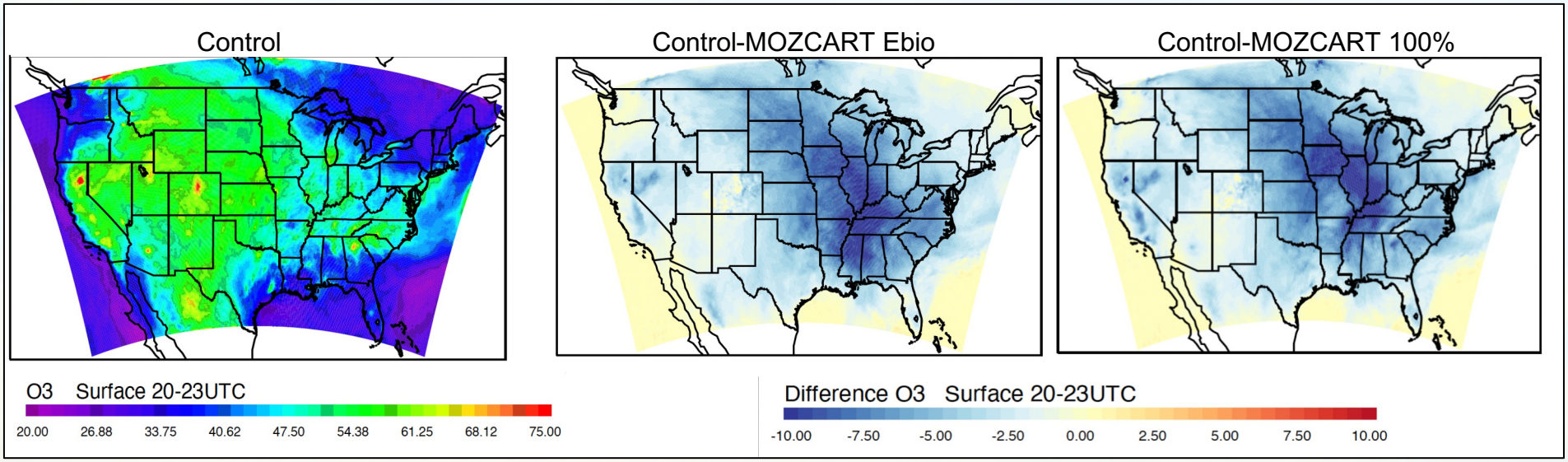


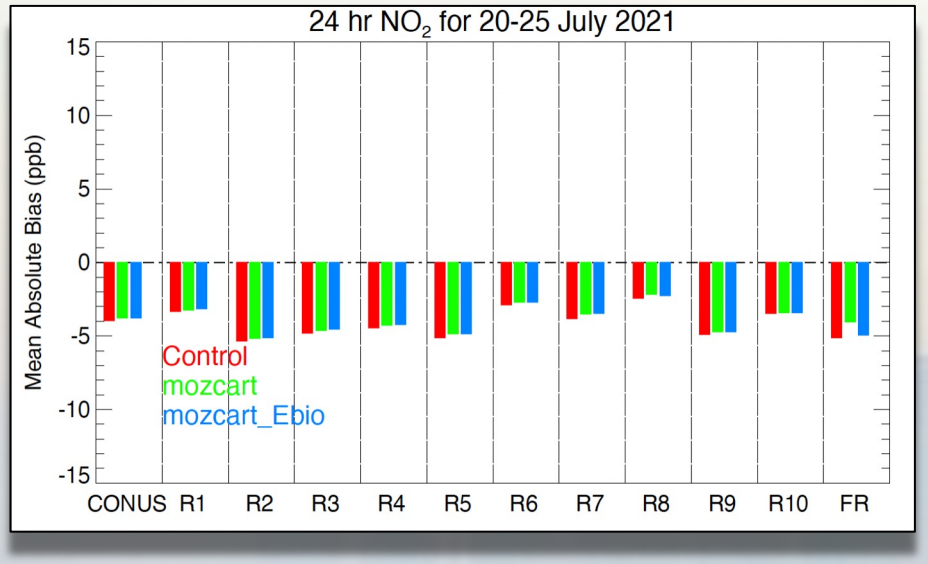
d02

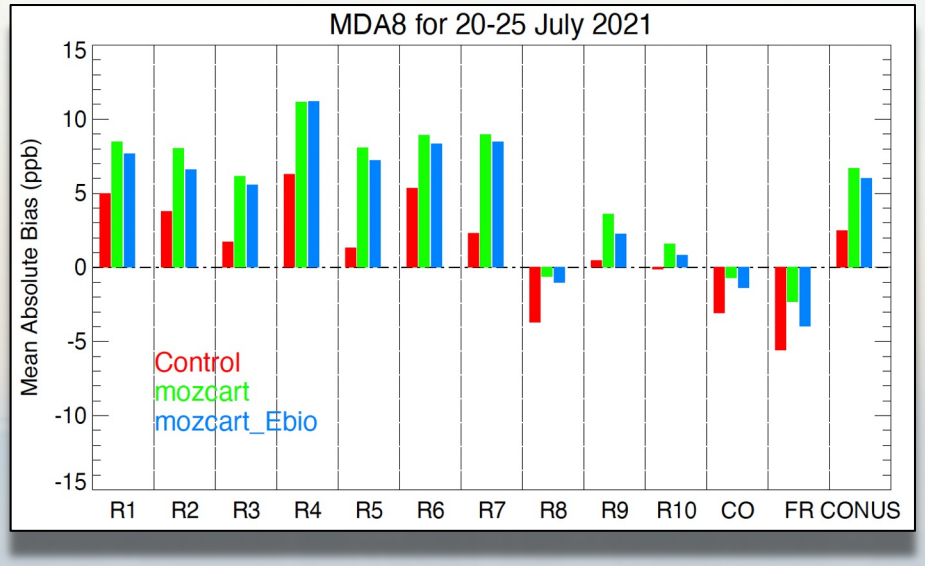


Biogenic Emissions & Chemical Scheme

Sensitivity Studies



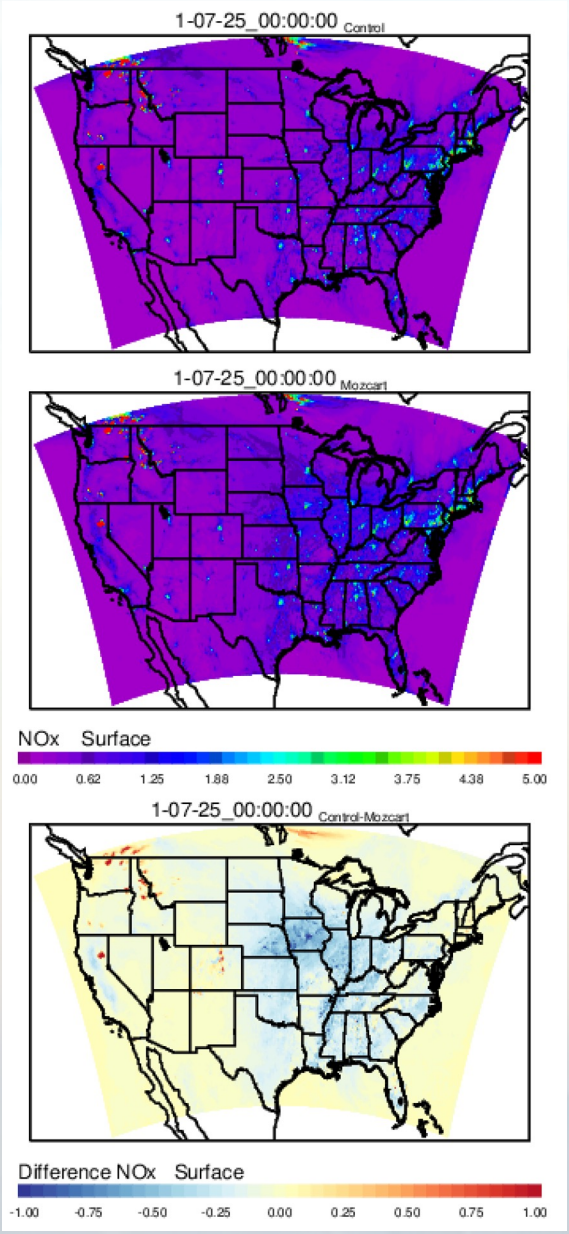


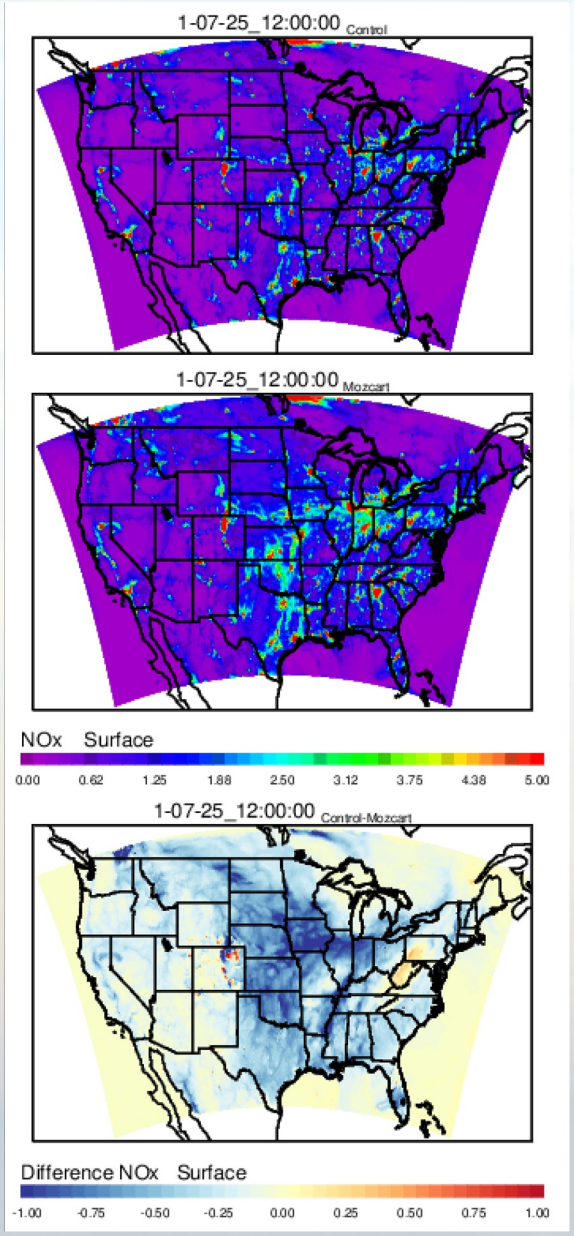


Bias = (Model-Obs)

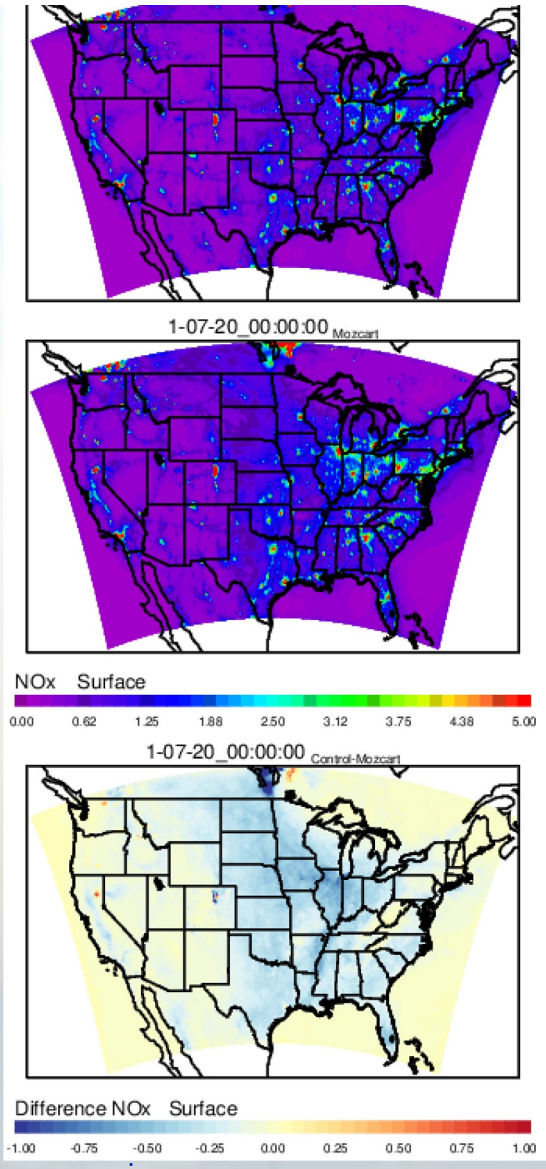
Biogenic Emissions & Chemical Scheme

Sensitivity Studies



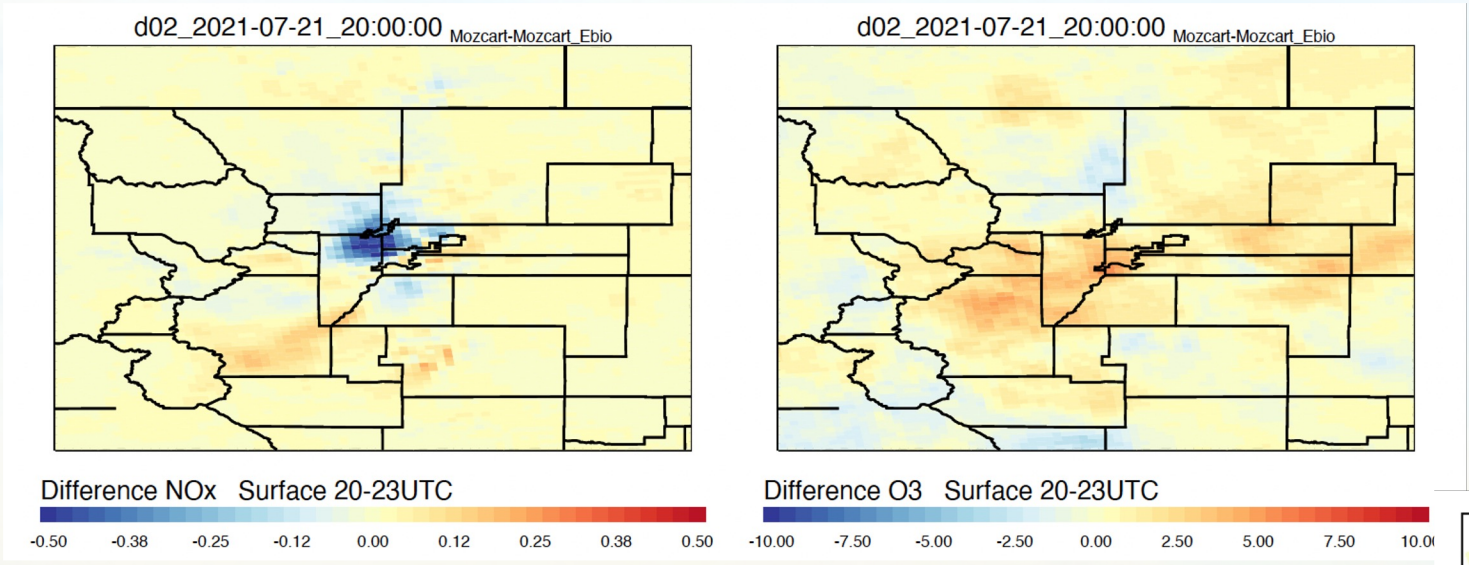


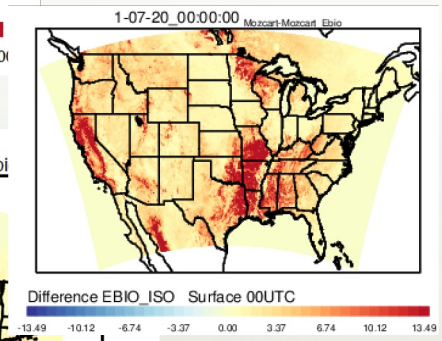
Avg over all 12&00UTC wrfout_d01 files

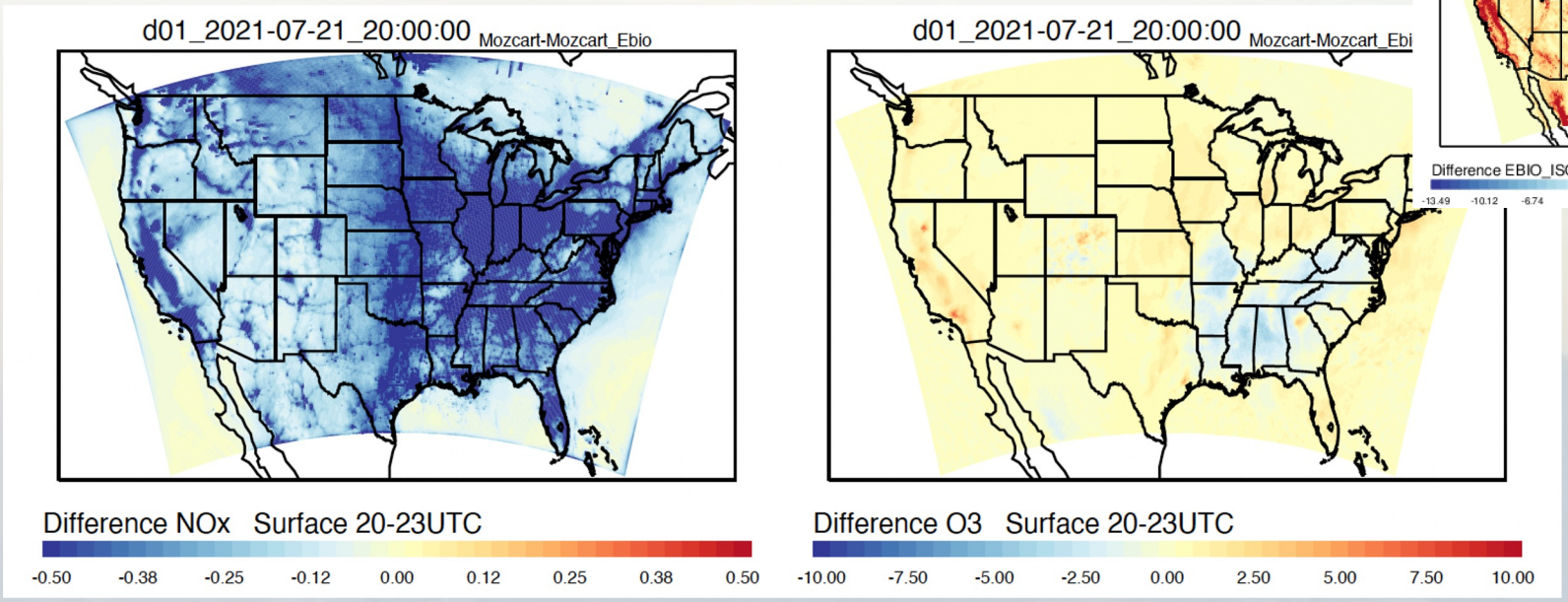


Biogenic Emissions & Chemical Scheme

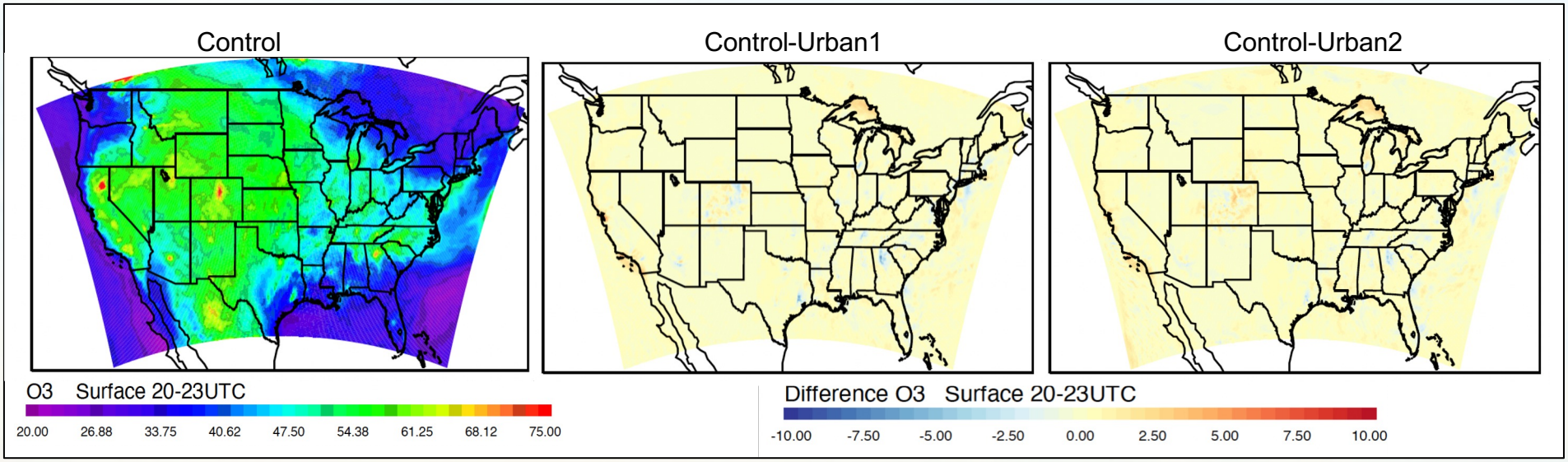
Sensitivity Studies

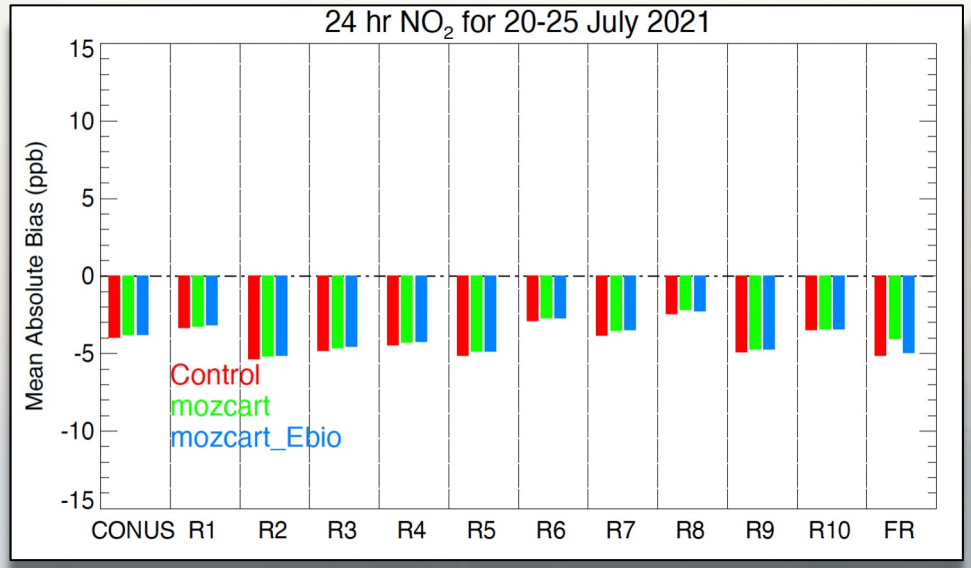


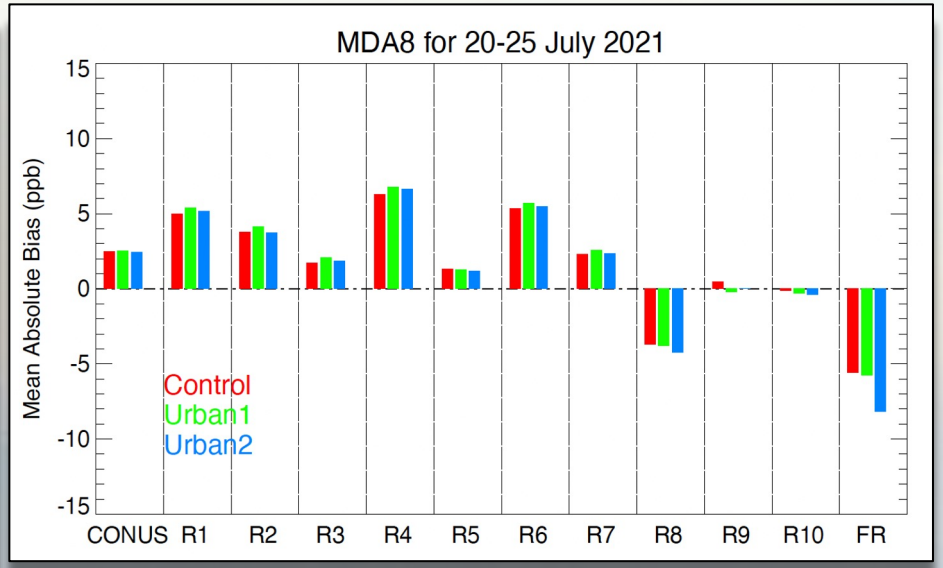




Sensitivity Studies

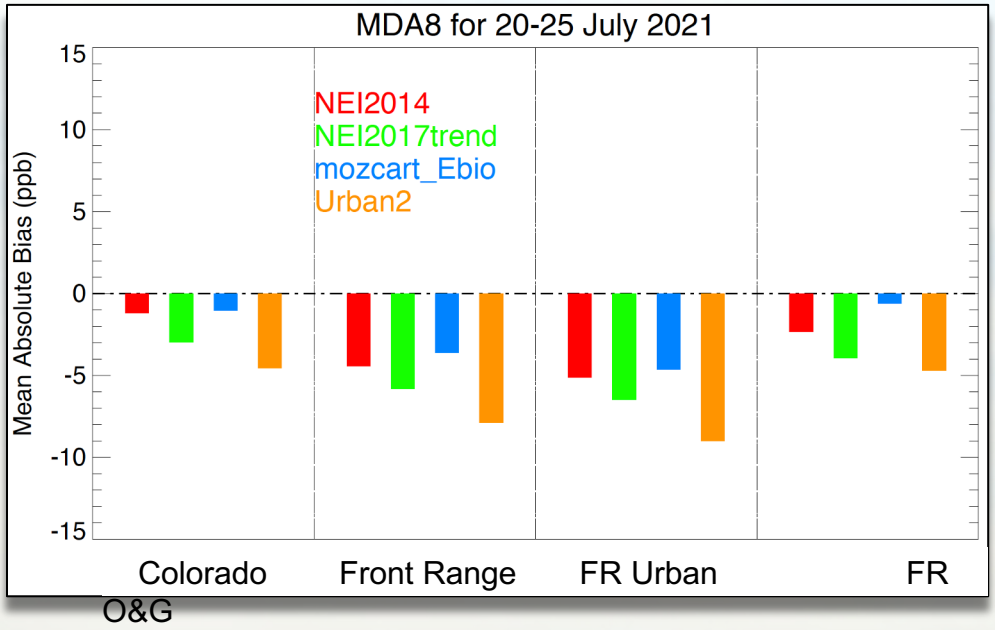


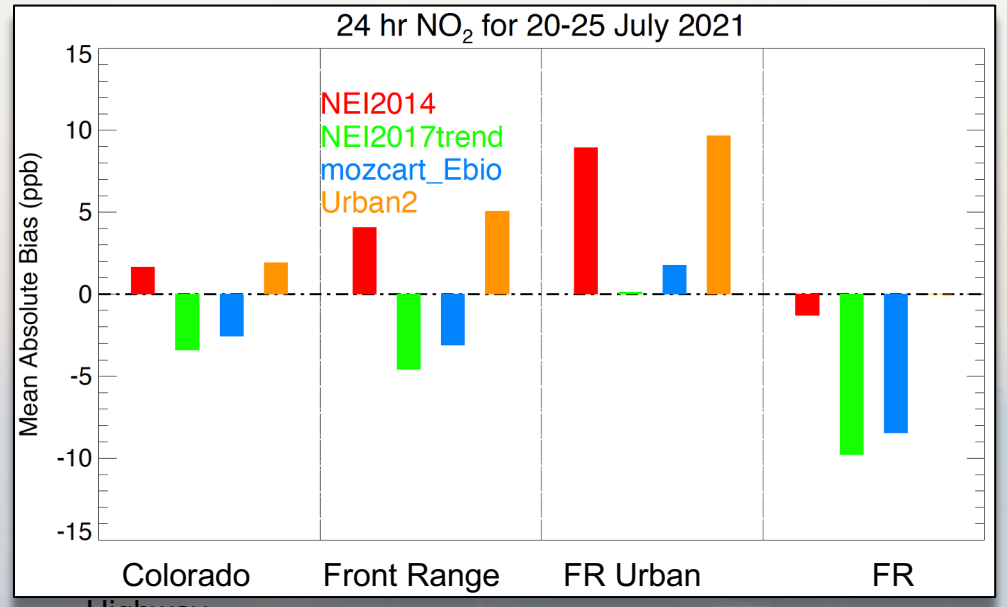




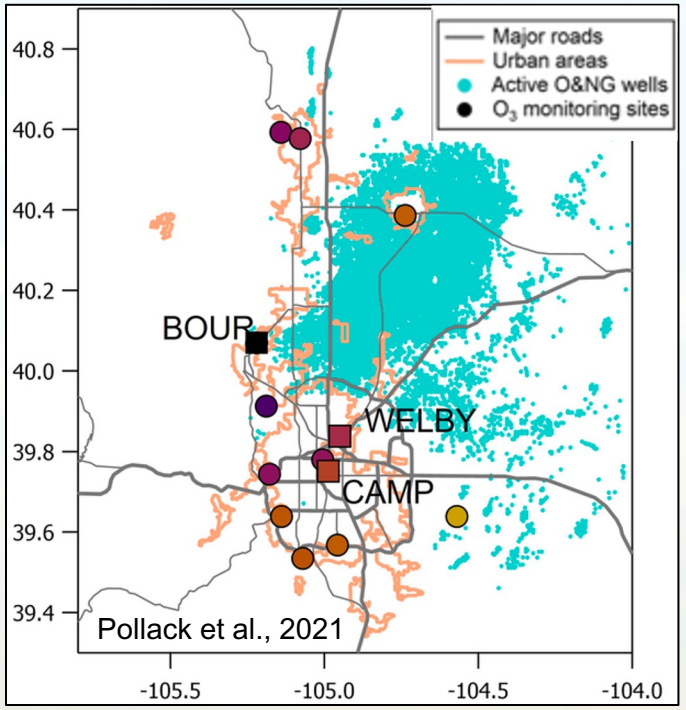
Bias = (Model-Obs)

Sensitivity Studies - Summary



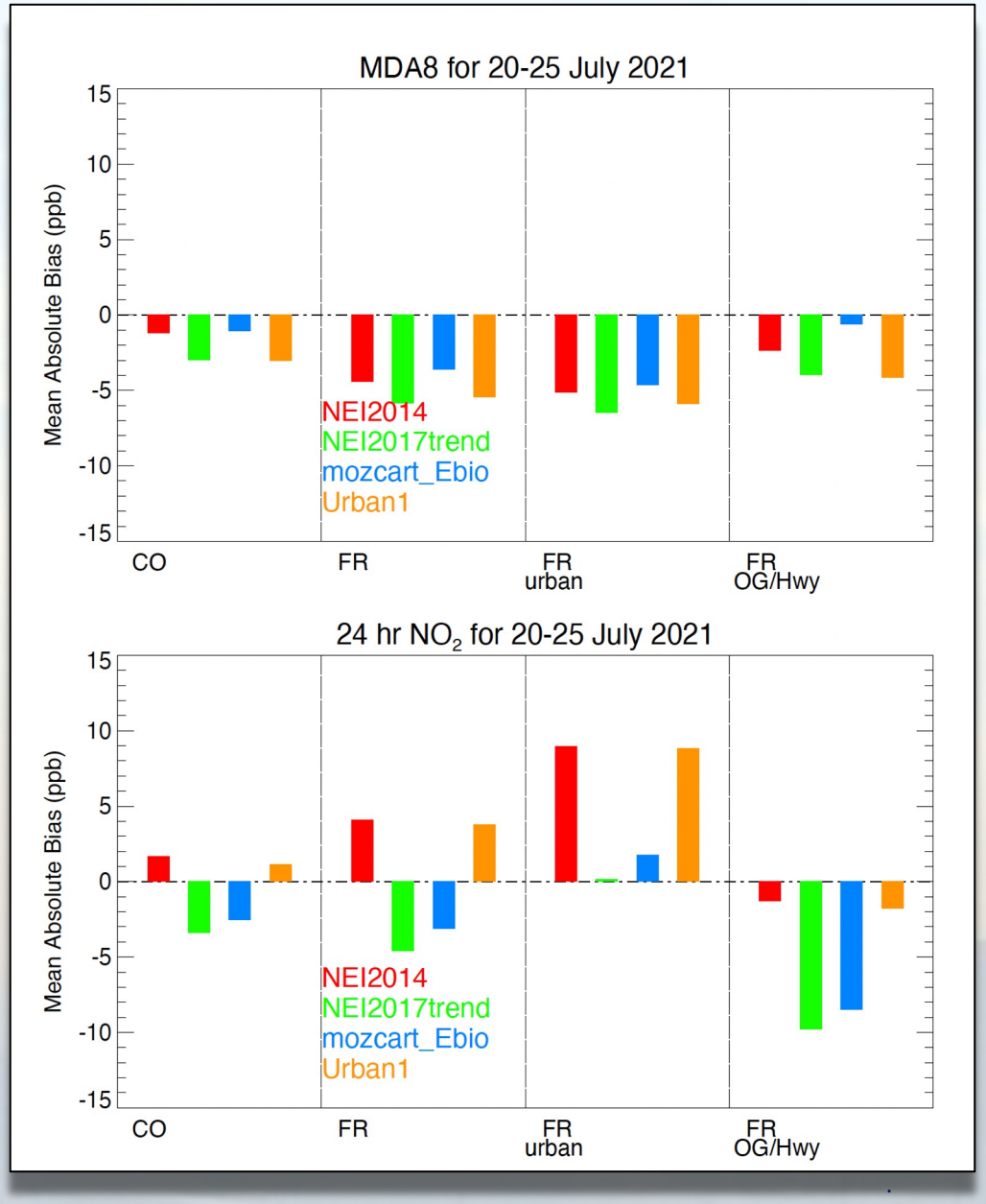


Colorado Front Range

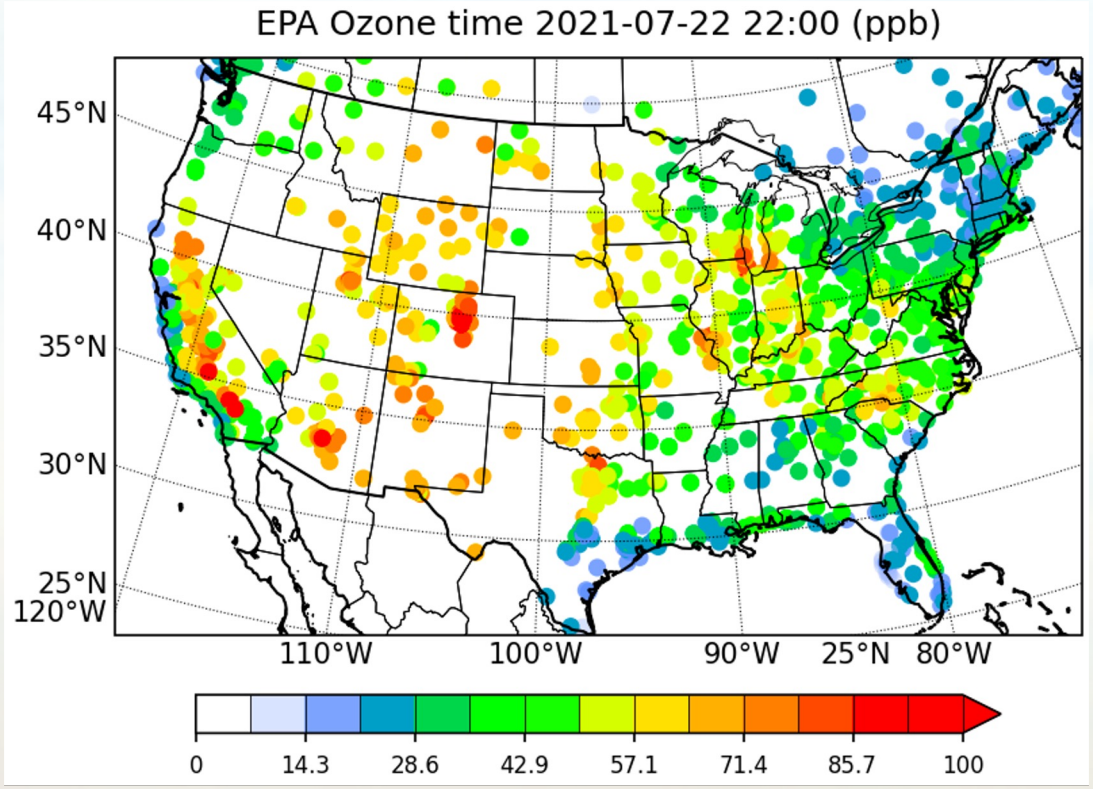


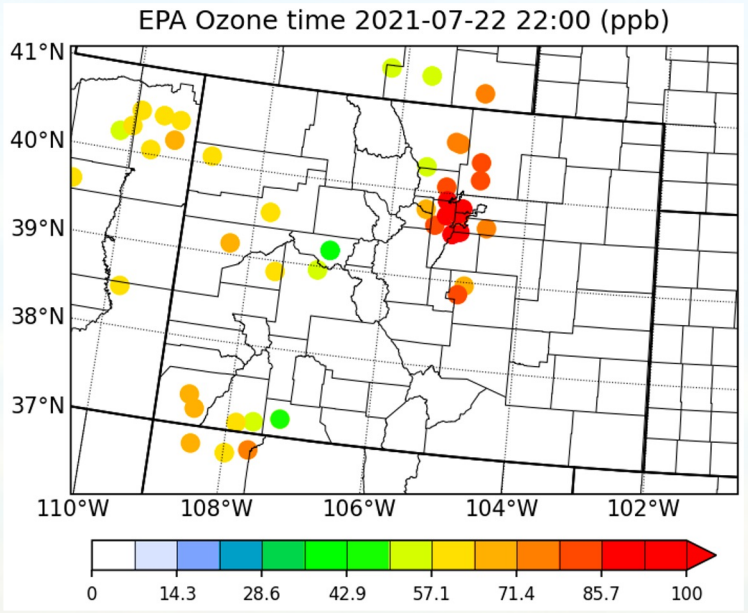
Region of interest and site characteristics play a major role in performance assessment.

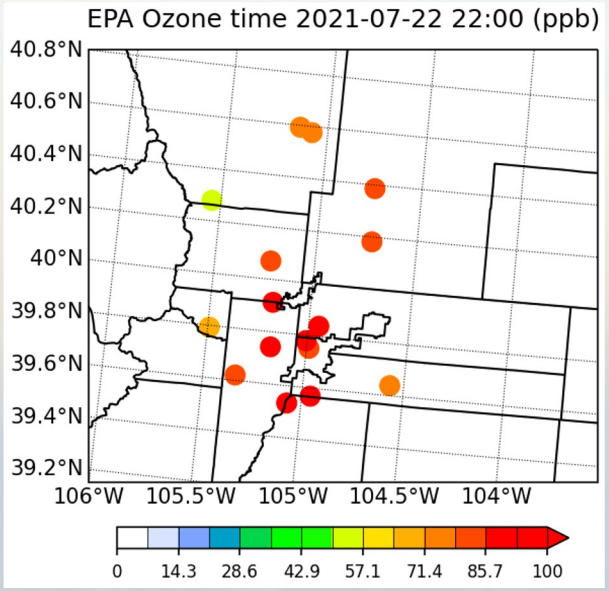
Performance for separate FR regions d02



Surface Ozone Monitors

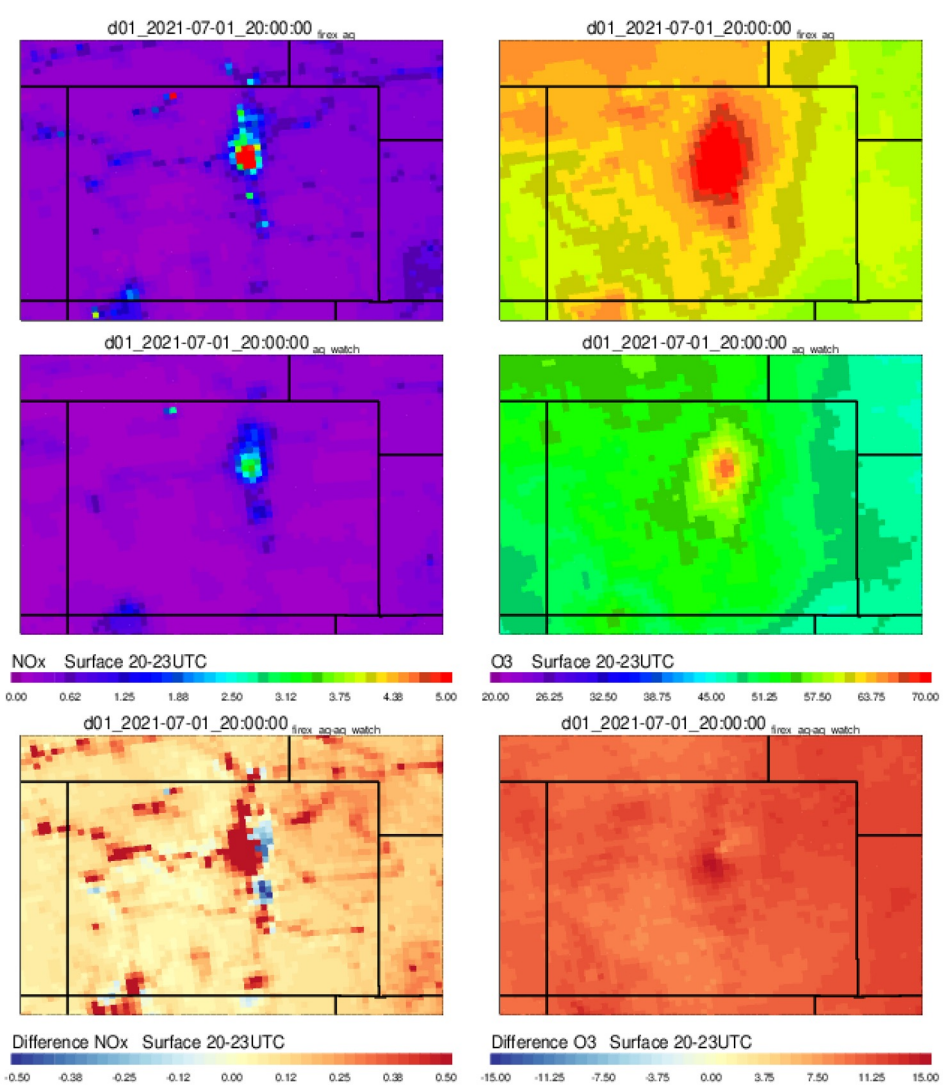


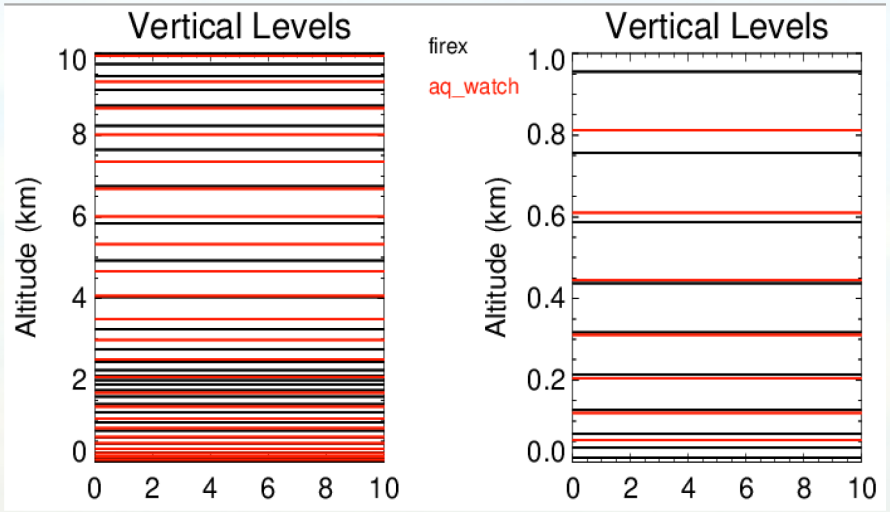




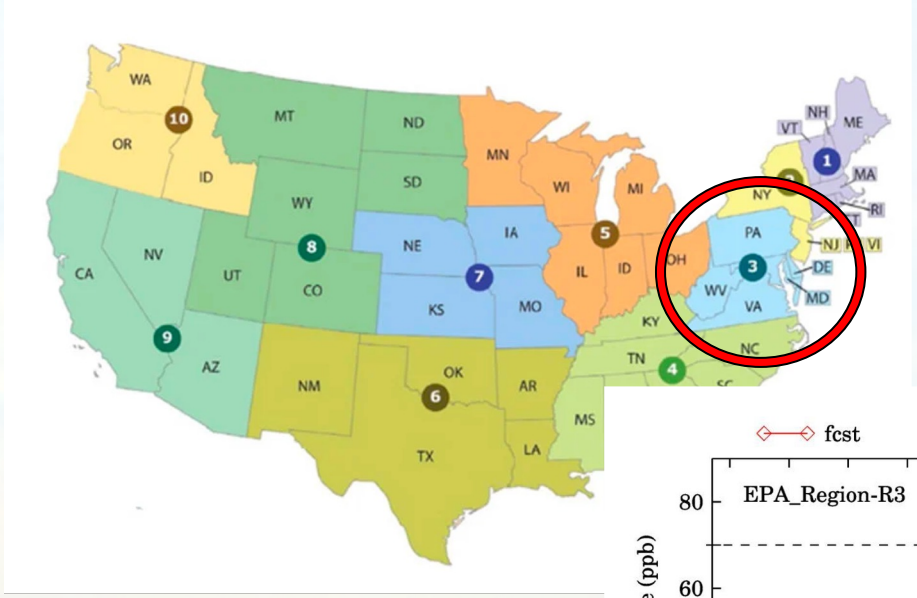
Why the different performance in Regions 8 & 9?

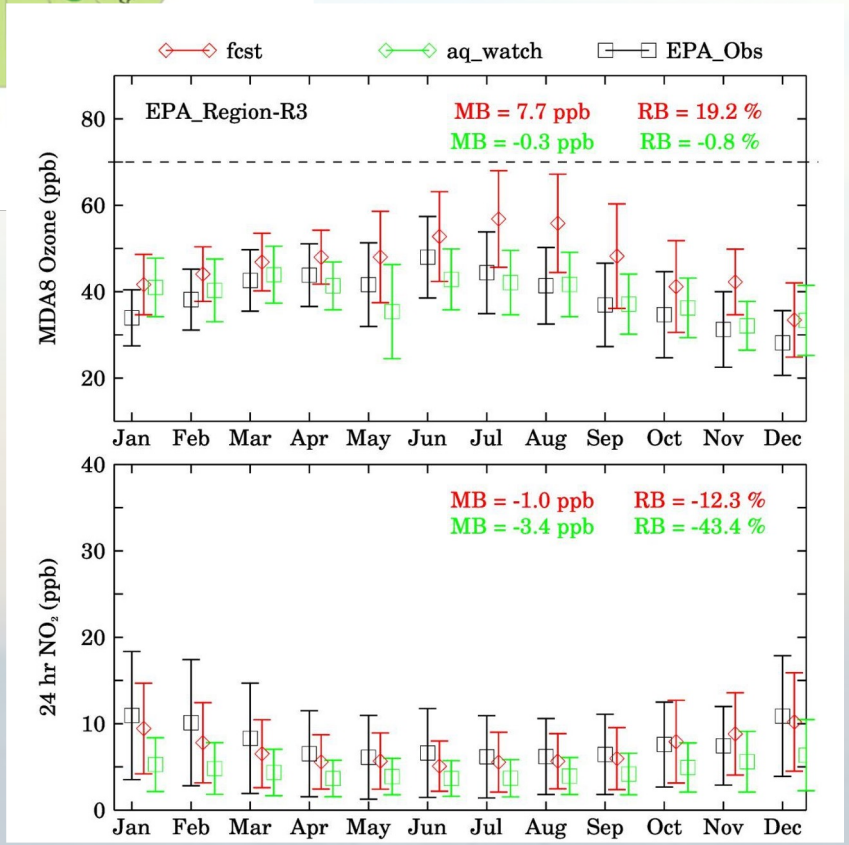
map of surface ozone afternoon from aq_watch and firex and their difference for test week July 2021



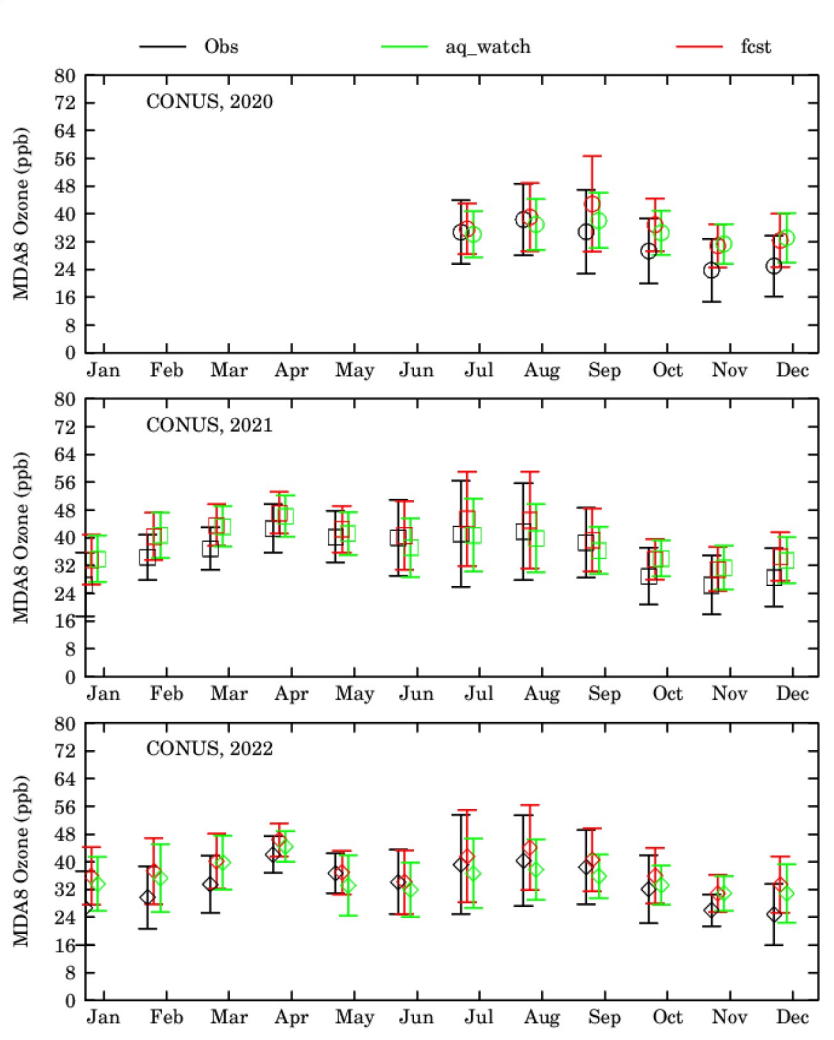


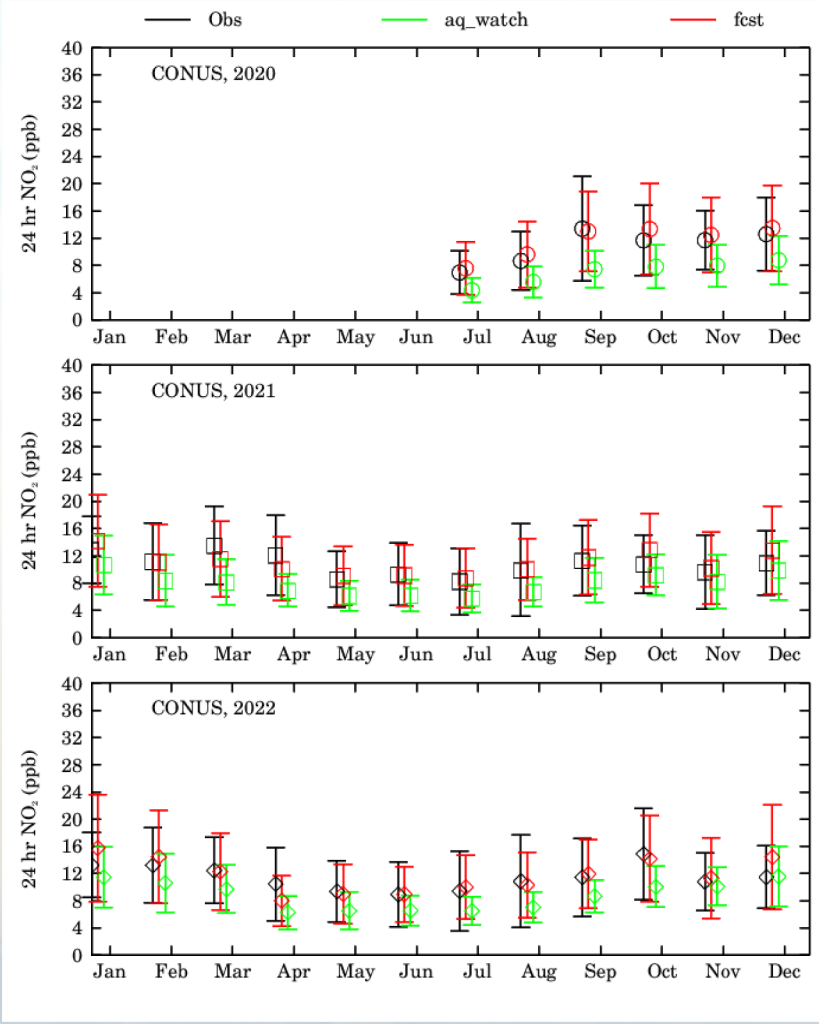
Evaluation with AIRNOW Surface Obs (2022)



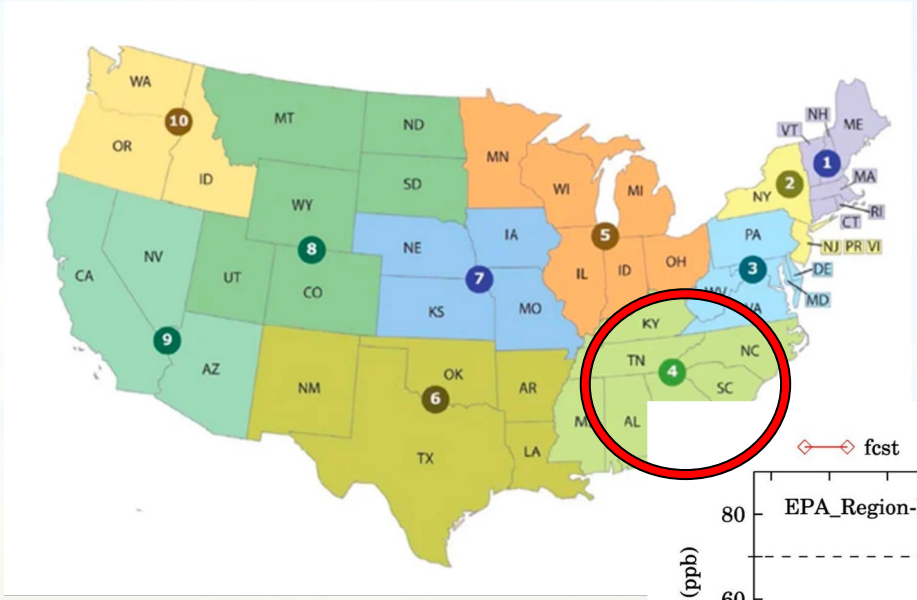


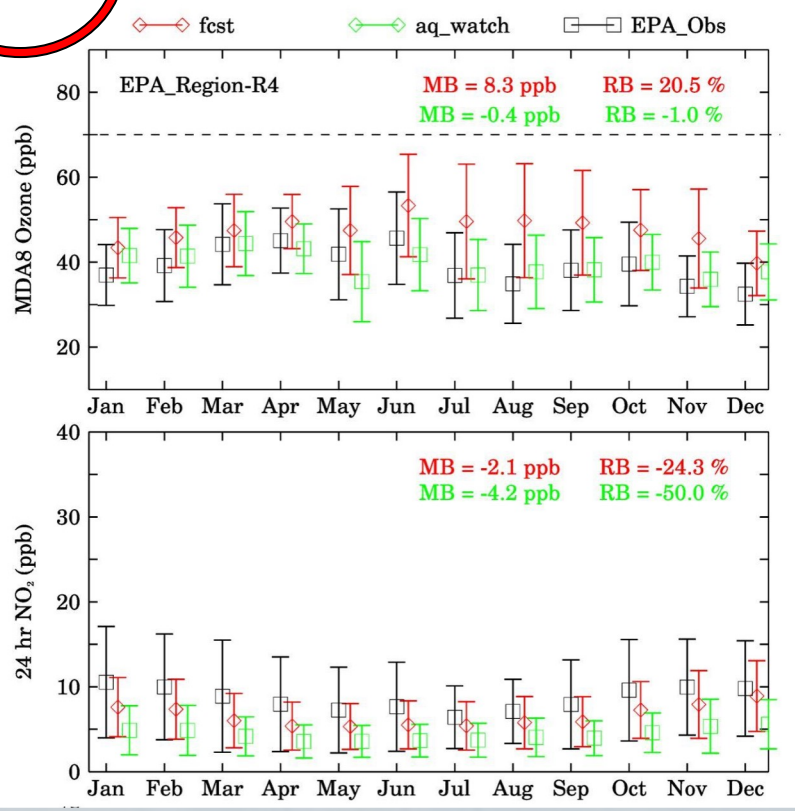
Evaluation with AIRNOW Surface Obs (2021 & 2022)



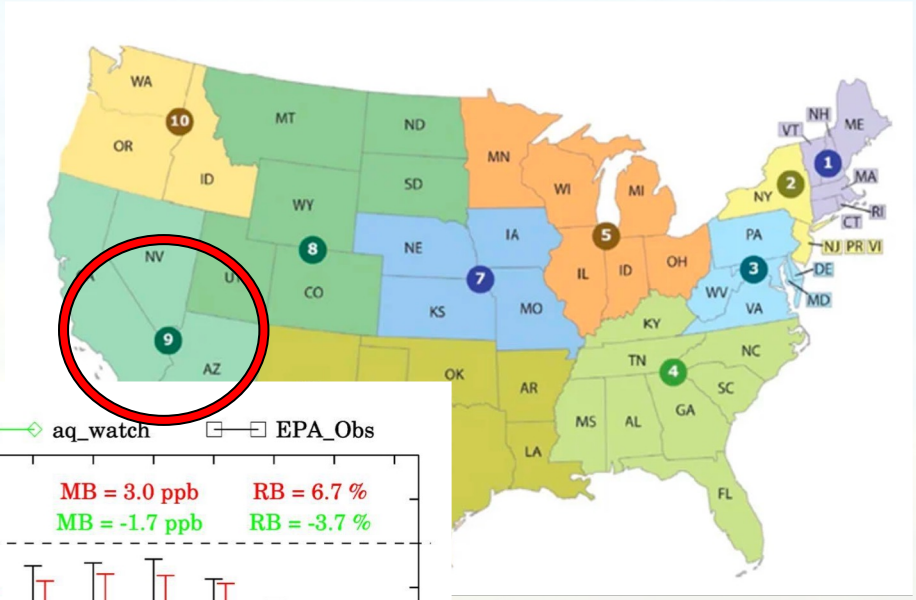


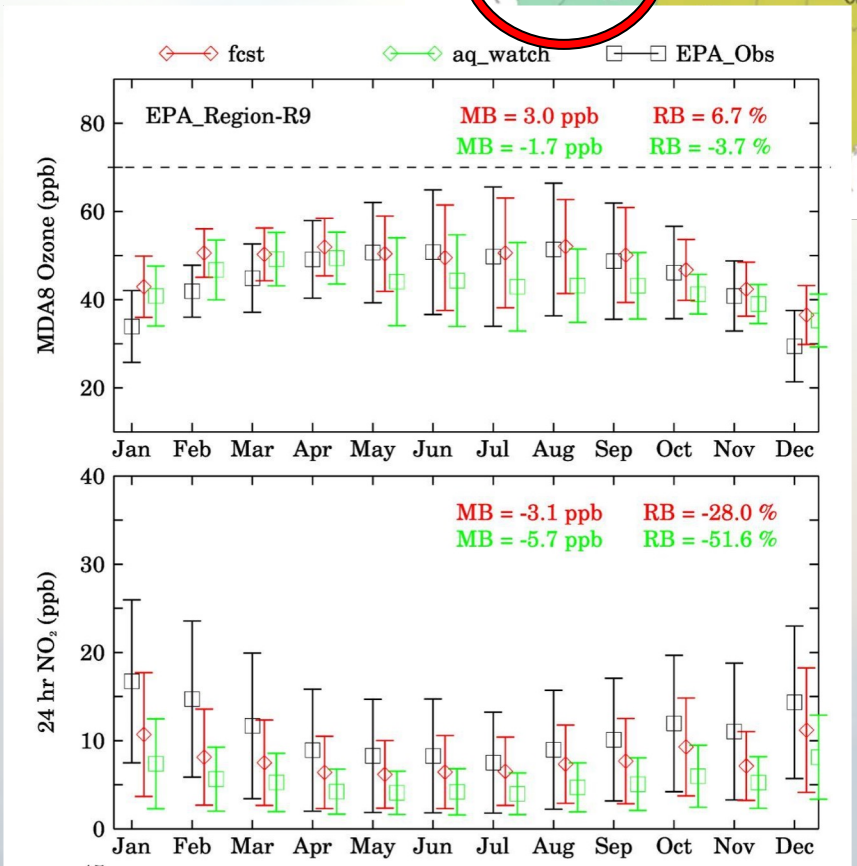
Evaluation with AIRNOW Surface Obs (2022)



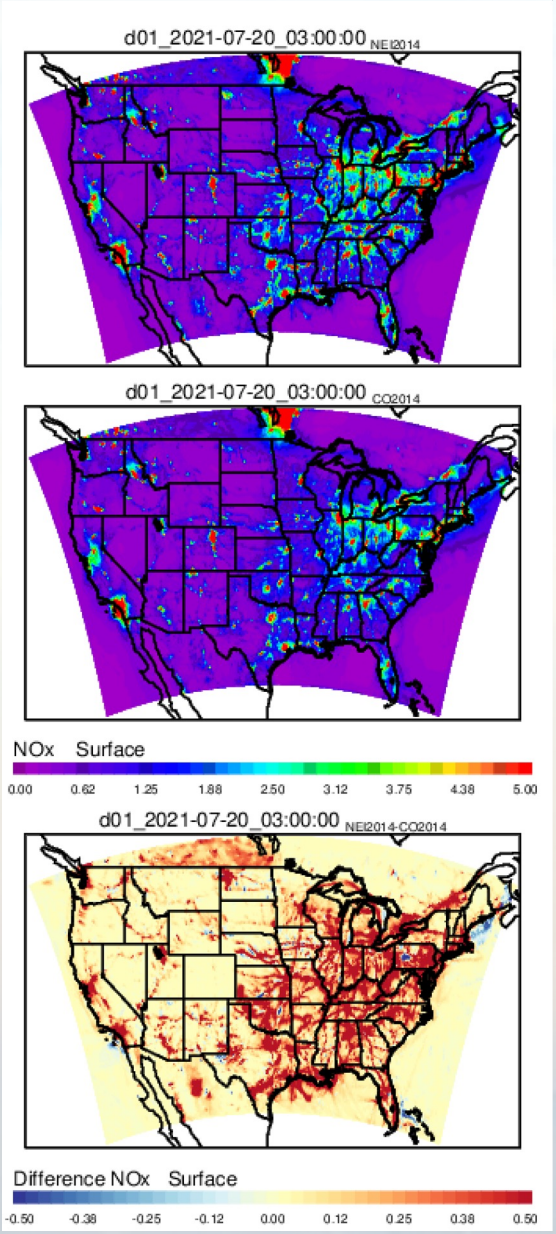


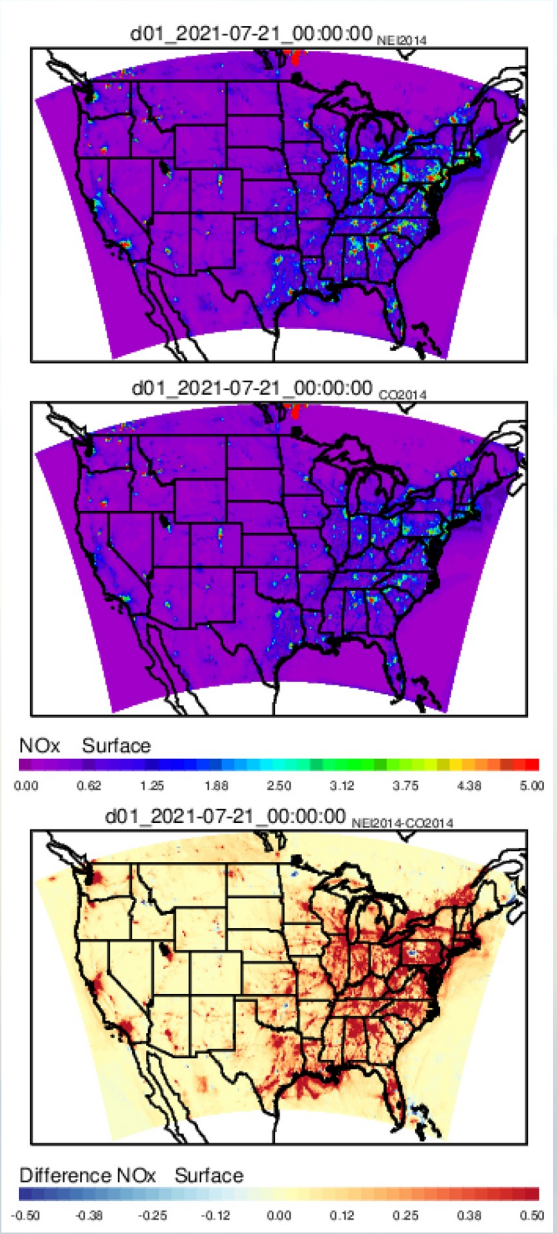
Evaluation with AIRNOW Surface Obs (2022)

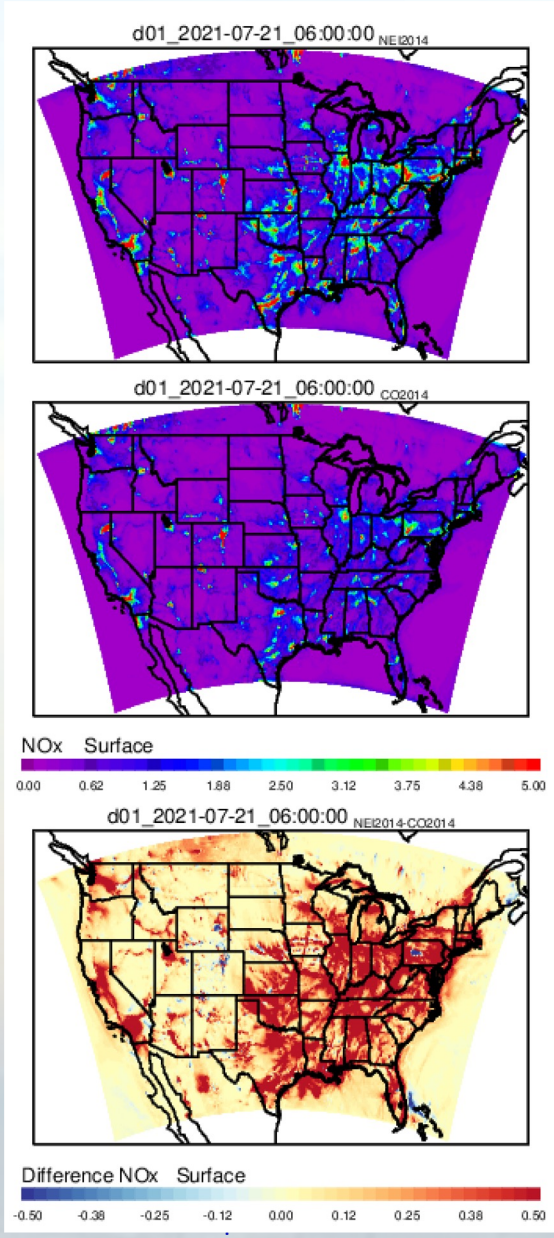




NEI 2014 versus CO2014







NEI 2017trend versus CO2014_no feedback