Evaluation of the Offline-coupled GFSv15-FV3-CMAQv5.0.2 in Support of the Next-generation National Air Quality Forecast Capability over the Contiguous United States

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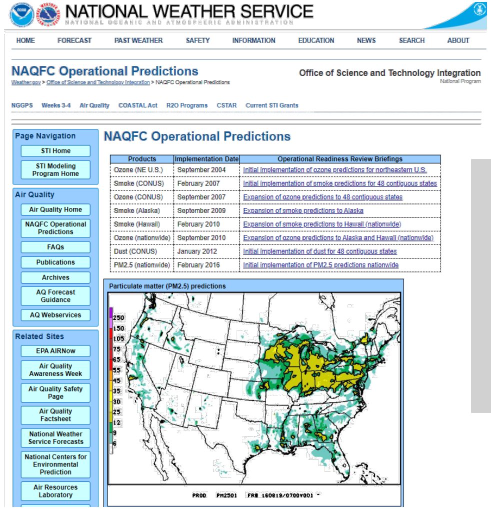
Outline

- Background and Objectives
- Model Configurations
- Evaluation of Meteorological and Chemical Forecasts
- Categorical Evaluation
- Conclusions

Background and Objectives

National Air Quality Forecasting Capability (NAQFC) by NOAA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NAQFC Operational Predictions

Office of Science and Technology Integration

NGGPS Weeks 3-4 Air Quality COASTAL Act R2O Programs CSTAR Current STI Grants

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Air Quality: Air Quality Home; NAQFC Operational Predictions; FAQs; Publications; Archives; AQ Forecast Guidance; AQ Webservices

Related Sites: EPA AIRNow; Air Quality Awareness Week; Air Quality Safety Page; Air Quality Factsheet; National Weather Service Forecasts; National Centers for Environmental Prediction; Air Resources Laboratory

NAQFC Operational Predictions

Products	Implementation Date	Operational Readiness Review Briefings
Ozone (NE U.S.)	September 2004	Initial implementation of ozone predictions for northeastern U.S.
Smoke (CONUS)	February 2007	Initial implementation of smoke predictions for 48 contiguous states
Ozone (CONUS)	September 2007	Expansion of ozone predictions to 48 contiguous states
Smoke (Alaska)	September 2009	Expansion of smoke predictions to Alaska
Smoke (Hawaii)	February 2010	Expansion of smoke predictions to Hawaii (nationwide)
Ozone (nationwide)	September 2010	Expansion of ozone predictions to Alaska and Hawaii (nationwide)
Dust (CONUS)	January 2012	Initial implementation of dust for 48 contiguous states
PM2.5 (nationwide)	February 2016	Initial implementation of PM2.5 predictions nationwide

Particulate matter (PM2.5) predictions

Operational NAQFC: NAM-CMAQv5.0.2

Transition to a FV3-based NAQFC

This experimental system: GFSv15-CMAQv5.0.2

Global Forecasting System (**GFS**) v15 is operational with **FV3**

In support of the development of GFSv16-CMAQv5.3

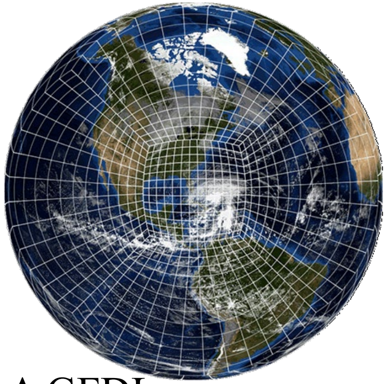
North American Mesoscale Forecast System (NAM) has stopped major updates since March 2017.

NOAA EMC has transitioned towards development of an ensemble system with the Finite-Volume Cubed-Sphere (FV3) dynamical core

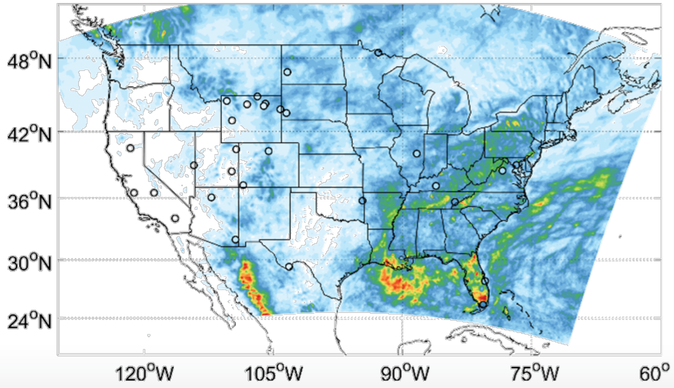
Objectives:

- **Evaluate the forecast skills of the experimental prototype of the GFSv15-CMAQv5.0.2 system**
- **Identify the major model biases and investigate underlying causes for the biases**

Configurations of the GFSv15-CMAQv5.0.2 system



FV3, NOAA GFDL



Attribute	Model Configuration
Forecast period	**Jan.-Dec., 2019**
Domain	CONUS
Resolution	Horizontal: 12 km; Vertical: 35 layers
Model inputs	
Anthropogenic emissions	Area sources from NEI 2014; Point source from NEI 2005 with projected SO_2 and NO_X to 2019
Biogenic emissions	Inline calculated by BEIS v3.14
Fire emissions	Blended Global Biomass Burning Emissions Product system (GBBEPx)
Lateral boundary conditions	GEFS-Aerosols and NEMS GFS Aerosol Component (NGAC)
Chemical Options	
Gas-phase chemistry	CB05tucl
Aqueous-phase chemistry	AQCHEM
Aerosol module	AERO6 with nonvolatile POA

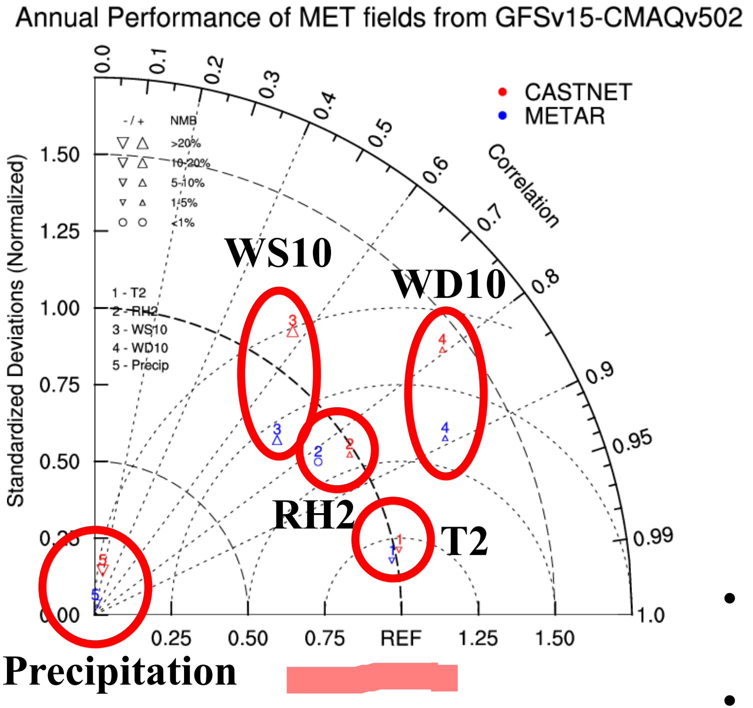
Datasets for Model Evaluation

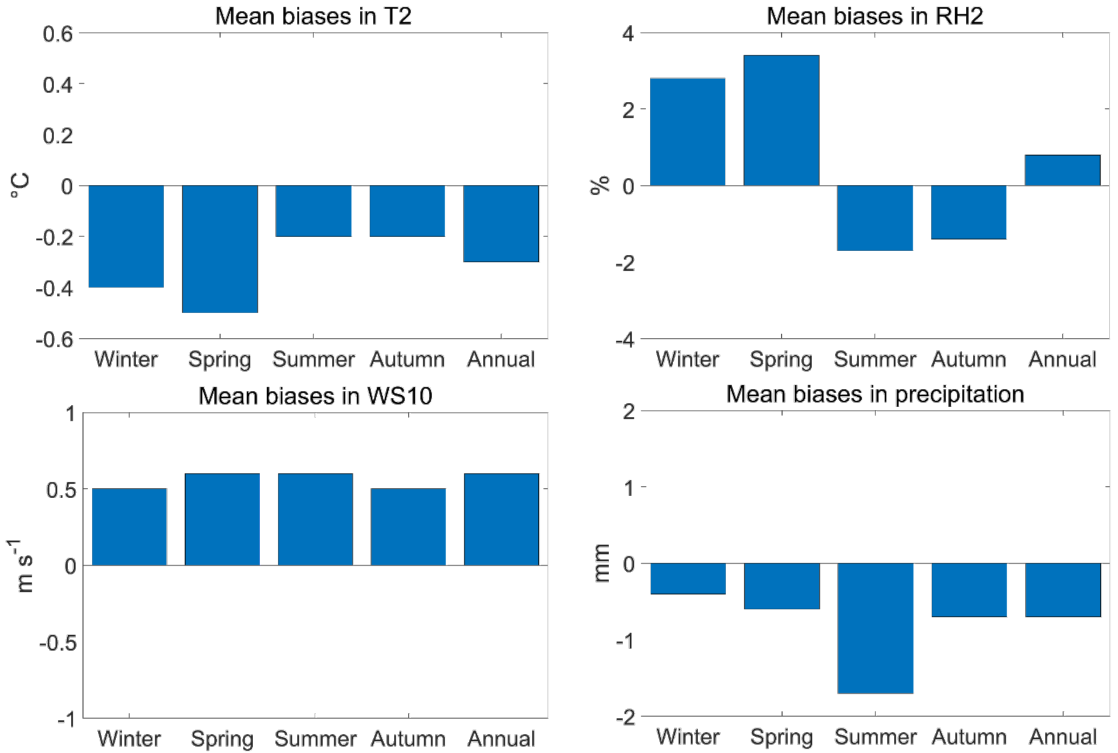
Database	Parameter	Data frequency	Number of sites / resolution
CASTNET	T2, RH2, WS10, WD10, Precipitation	Hourly	Up to 90 sites
METAR	T2, RH2, WS10, WD10, Precipitation	Hourly	Up to 1900 sites
CCPA	Precipitation	Hourly	0.125 °
GPCP	Precipitation	Monthly	2.5 °
AIRNow	O_3, $PM_{2.5}$	Hourly	Up to 1100 sites
MODIS_MOD04	Aerosol optical depth	Monthly	1 °

T2: temperature at 2-m; RH2: relative humidity at 2-m; WS10: wind speed at 10-m; WD10: wind direction at 10-m; GPCP: Global Precipitation Climatology Project; CCPA: Climatology Calibrated Precipitation Analysis; MODIS: Moderate Resolution Imaging Spectroradiometer.

Evaluation of Meteorological Forecasts

Taylor diagram for annual performance

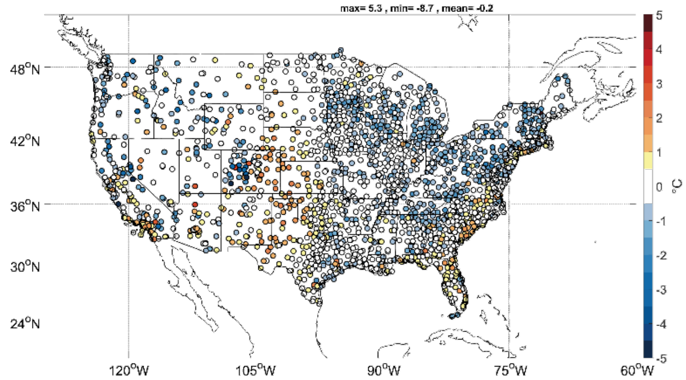




- **GFSv15 has a cold bias in lower atmosphere, comparing to the historical GFS**
- **Slight overprediction in WS10**
- **Moderate discrepancy in hourly precipitation**
- **Short rains during summer are less captured**

Evaluation of Meteorological Forecasts

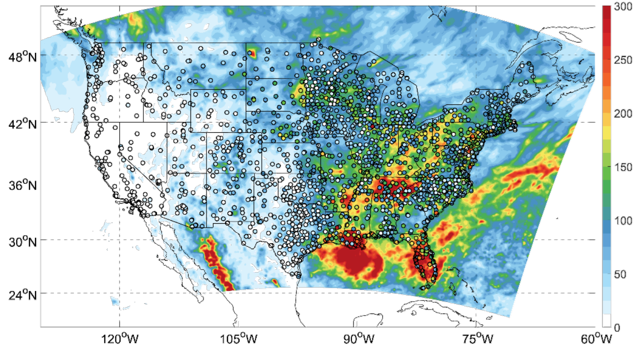
MBs of Annual T2



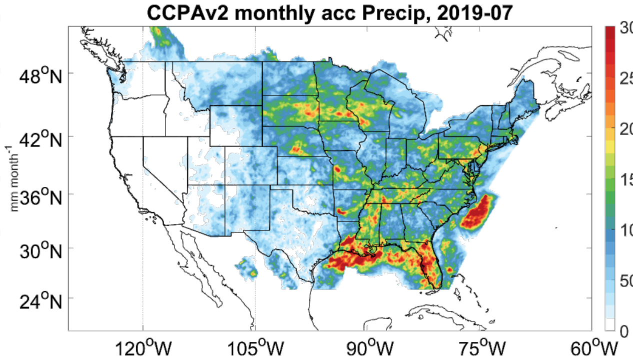
Moderate cold biases in the Midwest and Northeast

Monthly accumulated precipitation

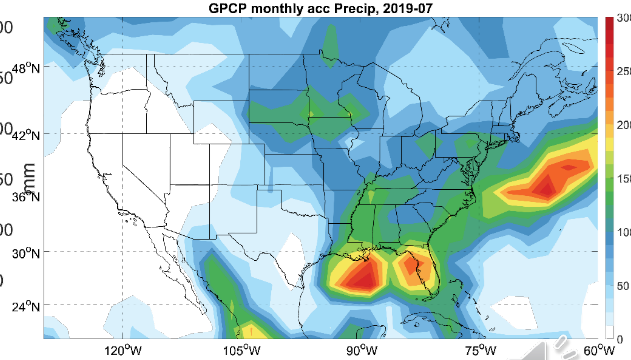
Prediction



Obs-CCPA

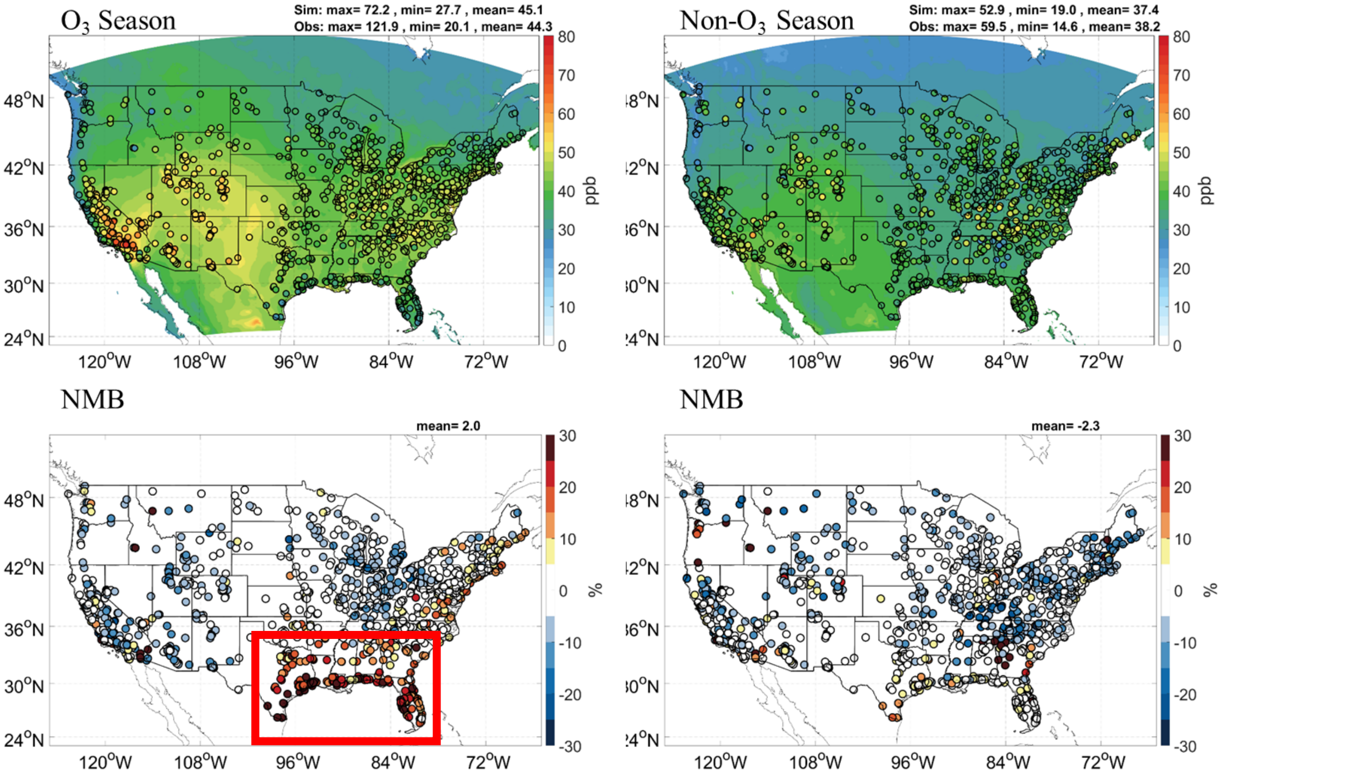


Obs-GPCP



Better consistency in spatial distribution than in hourly statistics

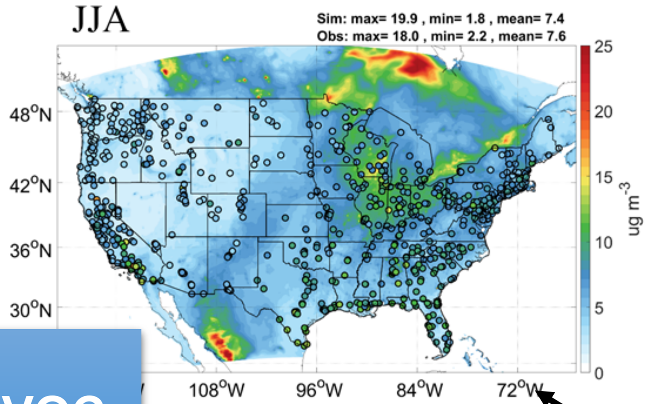
Performance of Seasonal MDA8 O_3



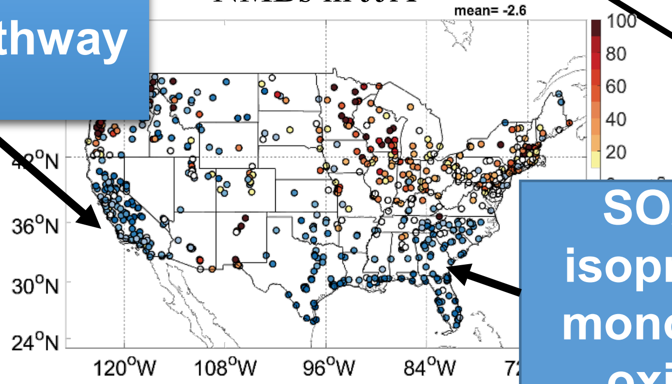
O_3 season (May-Sept):
Large overprediction near the Gulf coast.
Detailed halogen chemistry could increase O_3 deposition near the coast

Non-O_3 season (Jan-Apr and Oct-Dec):
Overall underprediction.
Wintertime O_3 deposition to snow

Performance of Seasonal $PM_{2.5}$

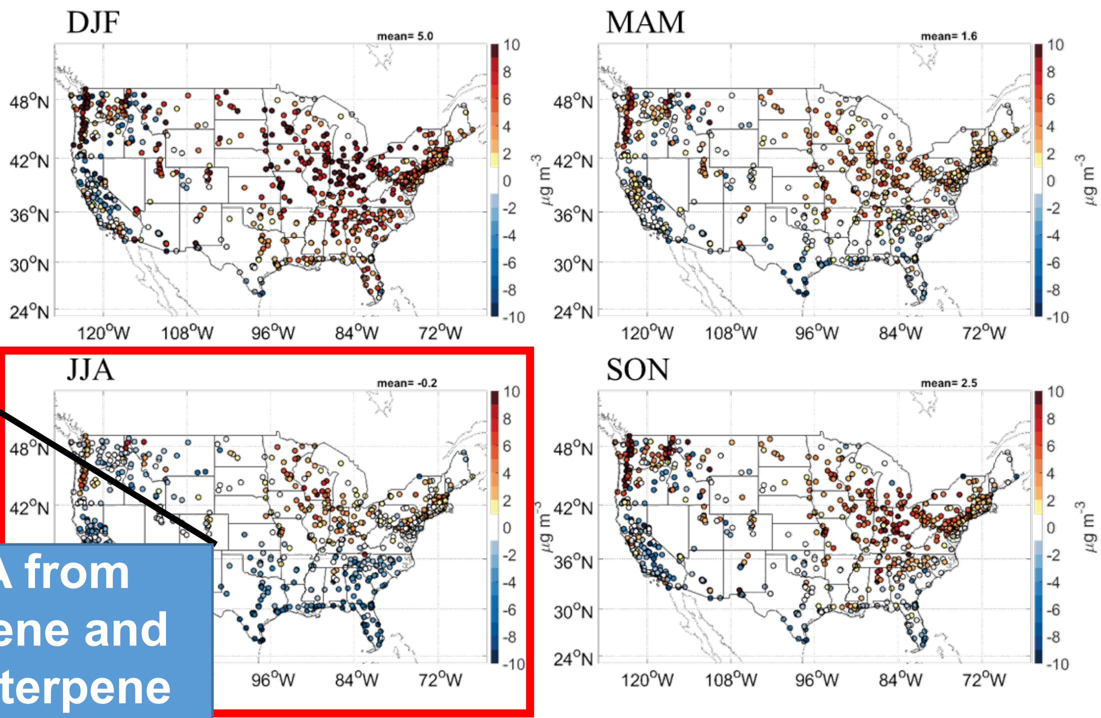


NMBs in JJA



S/IVOC pathway

MBs of seasonal 24-hr avg $PM_{2.5}$

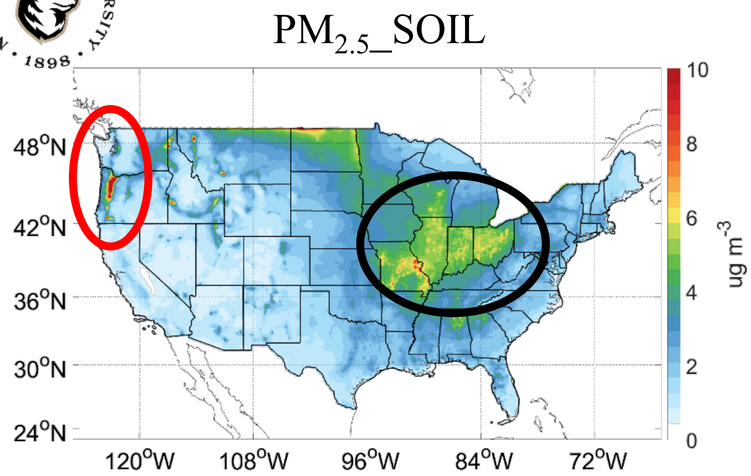


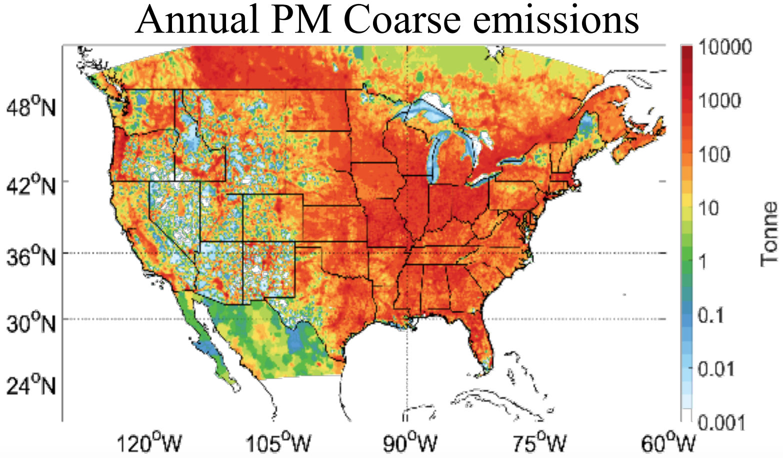
SOA from isoprene and monoterpene oxidation

Overall overprediction in the Midwest, OR, and WA.

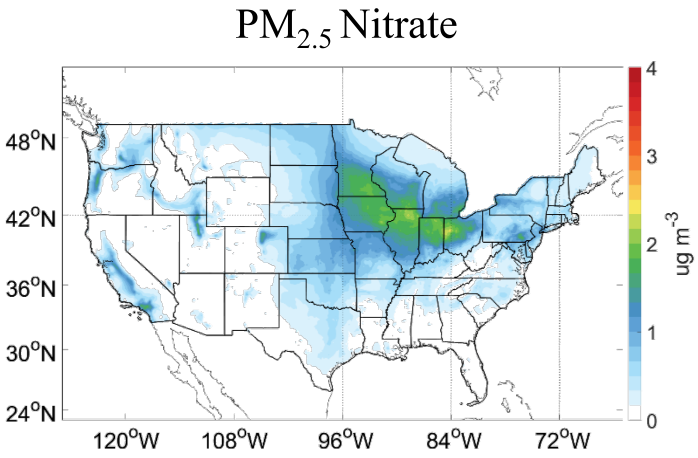
Underprediction in CA and the Southeast during summer.

$PM_{2.5}$ Compositions





$PM_{2.5}$_SOIL= ASOIL+ACORS:
soil components and unspecified coarse mode components

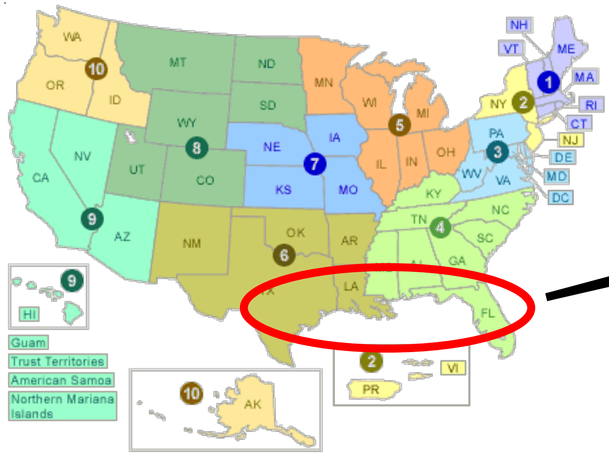


Higher predicted nitrate PM attributed to cold biases

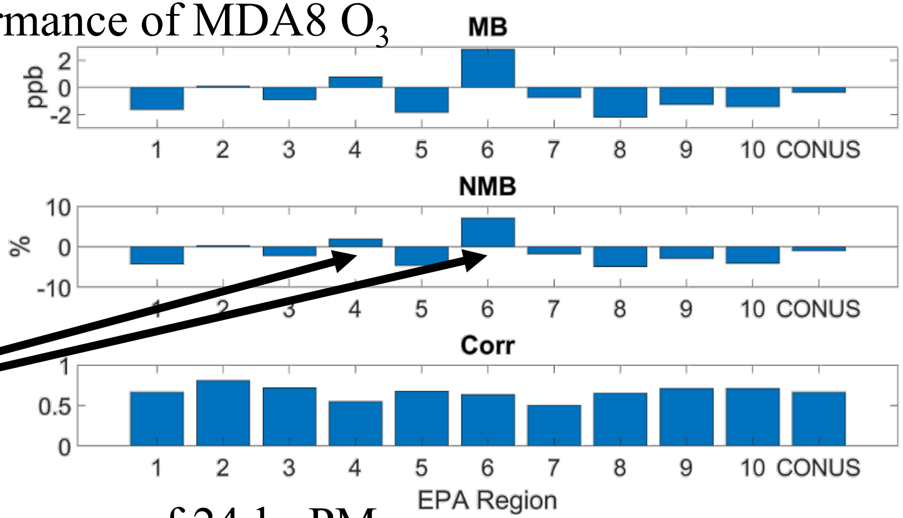
Large PMC emissions from anthropogenic fugitive dust

Region-specific evaluation over CONUS

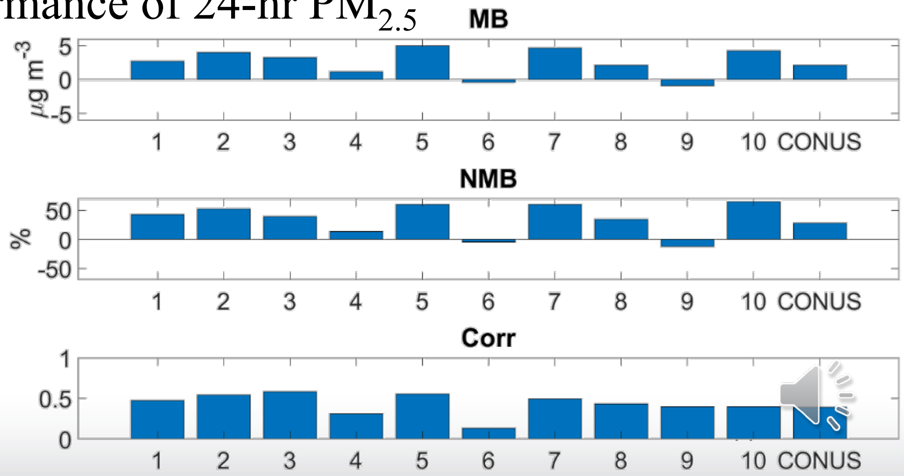
EPA 10 regions
(www.epa.gov/aboutepa)



Annual Performance of MDA8 O_3



Annual Performance of 24-hr $PM_{2.5}$



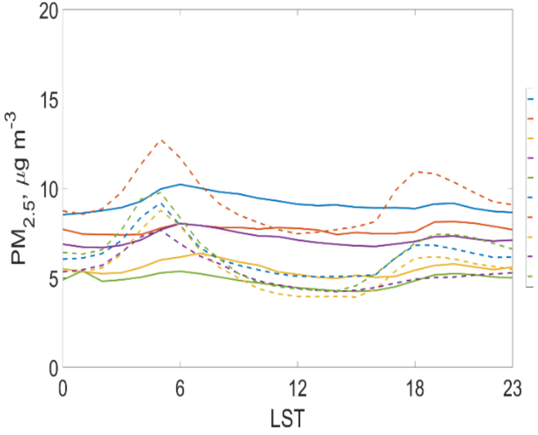
MDA8 O_3:
Regions 4 and 6: overpredictions near the Gulf coast
Regions 1 and 5: cold biases in T2 and deposition to snow
$PM_{2.5}$:
Regions 4 and 6: missing SOA sources from BVOCs
Region 9: missing SOA sources from S/IVOCs
Large amplitude of $PM_{2.5}$ variations

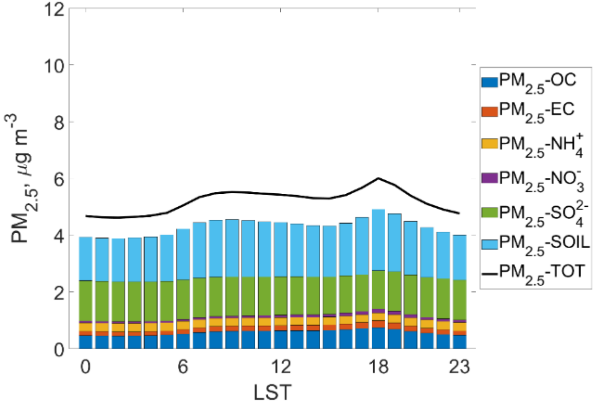
Region-specific evaluation over CONUS

Diurnal $PM_{2.5}$ for regions 6-10

Predicted $PM_{2.5}$ compositions over CONUS

May-Sept

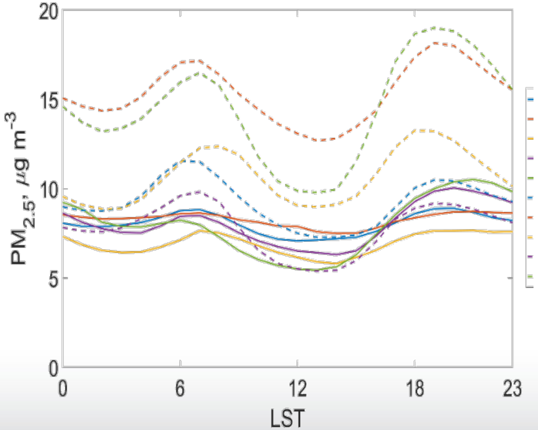


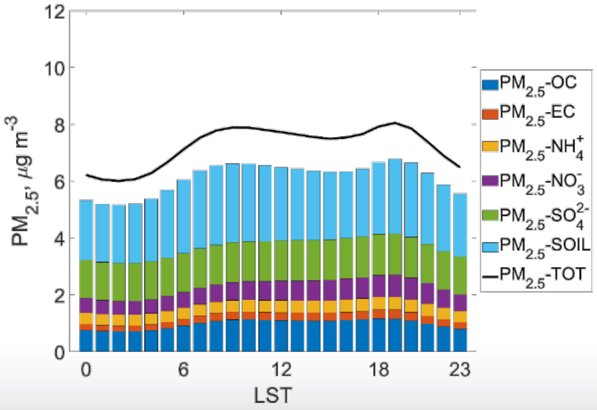


Dawn and dusk $PM_{2.5}$ prediction peaks are prominent

Large variance between warmer and cooler months

Jan-Apr & Oct-Dec





Higher predicted dust and nitrate compositions during cooler months

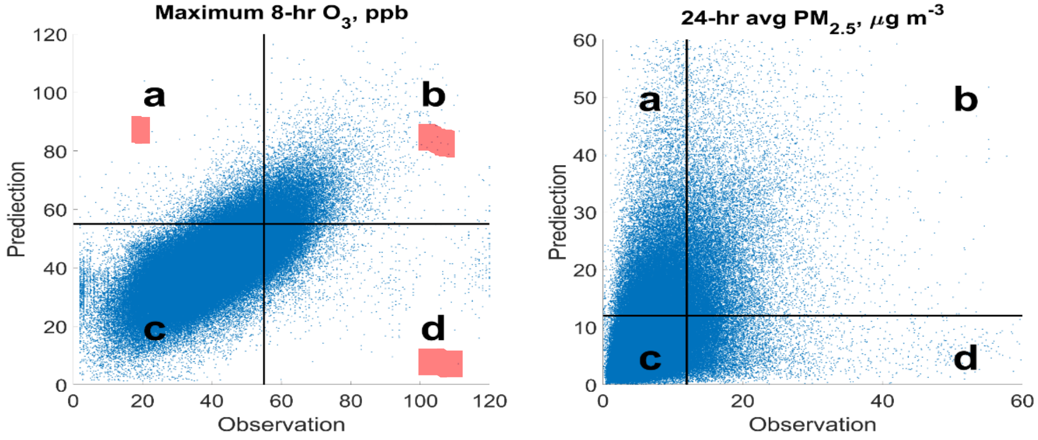
Categorical evaluation

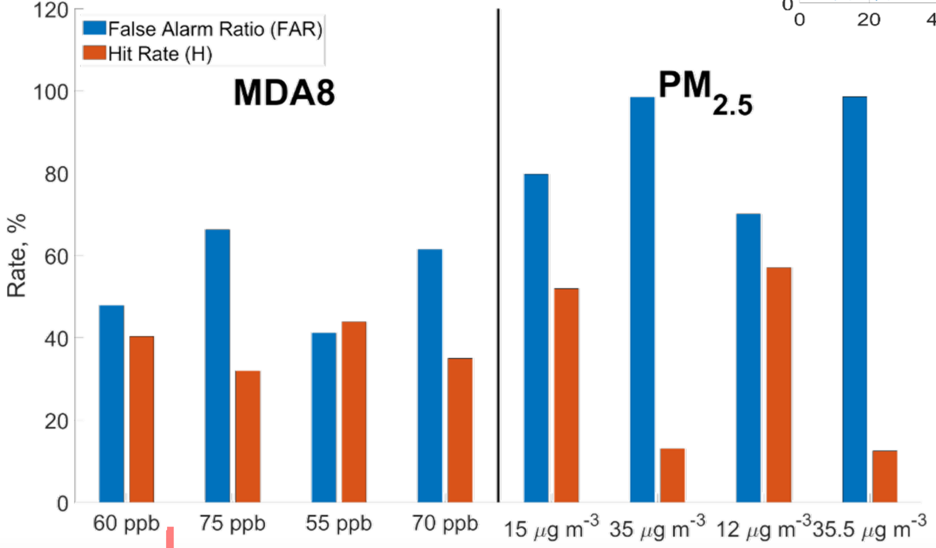
False Alarm Ratio:

$$\text{FAR}=\frac{a}{a+b}\times 100\%$$

Hit Rate:

$$H=\frac{b}{b+d}\times 100\%$$





Previous AQI standards Current

Higher categorical performance in current AQI standard comparing to the historical ones

Similar performance in O_3 comparing to previous NAQFC studies

Poorer performance in $PM_{2.5}$ mainly attributed to large overprediction during cooler months

Conclusion

- Moderate cold biases. Issue in interpolating the hourly precipitation.
- Good forecast skills in predicting O_3 but has mixed performance for $PM_{2.5}$
- Varied biases and underlying causes for regions
- Capture well the air quality classification of "Moderate" described by the AQI. Poorer categorical performance for $PM_{2.5}$ due mainly to the overprediction during the cooler months

Expected improvement:

- Updated gas-phase and aerosol chemistry (e.g. detailed halogen chemistry, and increased S/IVOC pathway and monoterpene oxidation in CMAQ v5.3)
- Updated emissions with more recent and accurate anthropogenic fugitive dust
- Reduce biases in T2 and precipitation by development of the GFSv16-CMAQv5.3 system

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- The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect the views of NOAA or the Department of Commerce. The views expressed in this presentation are solely those of the authors and do not necessarily reflect those of the U.S. EPA. EPA does not endorse any products or commercial services mentioned in this publication.
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