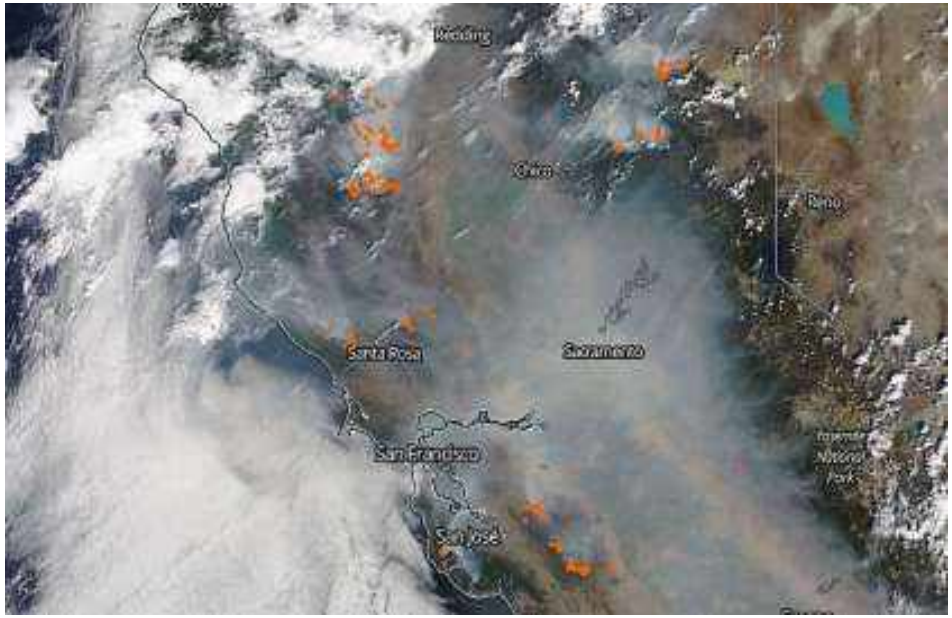
NCAR UCAR | RAL Research Applications Laboratory

Improving U.S. fine particulate matter ($PM_{2.5}$) air quality forecasts during wildfires based on chemical data assimilation

The 2013 Rim fire in and near Yosemite National Park. Credit: USFS/Mike McMillan



NASA's Terra satellite on Monday, Aug. 22, 2020. Credit: NASA

Cenlin He, Rajesh Kumar, Piyush Bhardwaj
National Center for Atmospheric Research (NCAR)

This work is supported by NOAA-OAR-OWAQ grant.

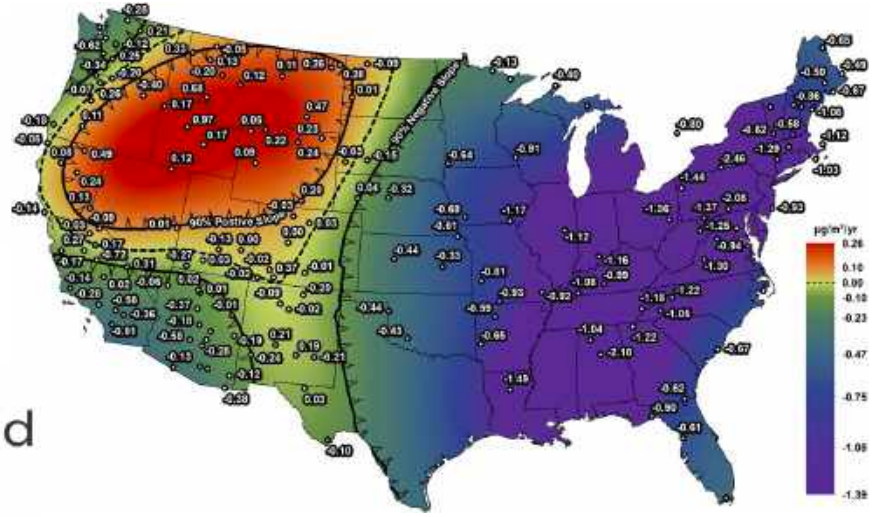
NOAA NCAR

Wildfires deteriorate U.S. $PM_{2.5}$ air quality

PNAS

US particulate matter air quality improves except in wildfire-prone areas

Crystal D. McClure and Daniel A. Jaffe



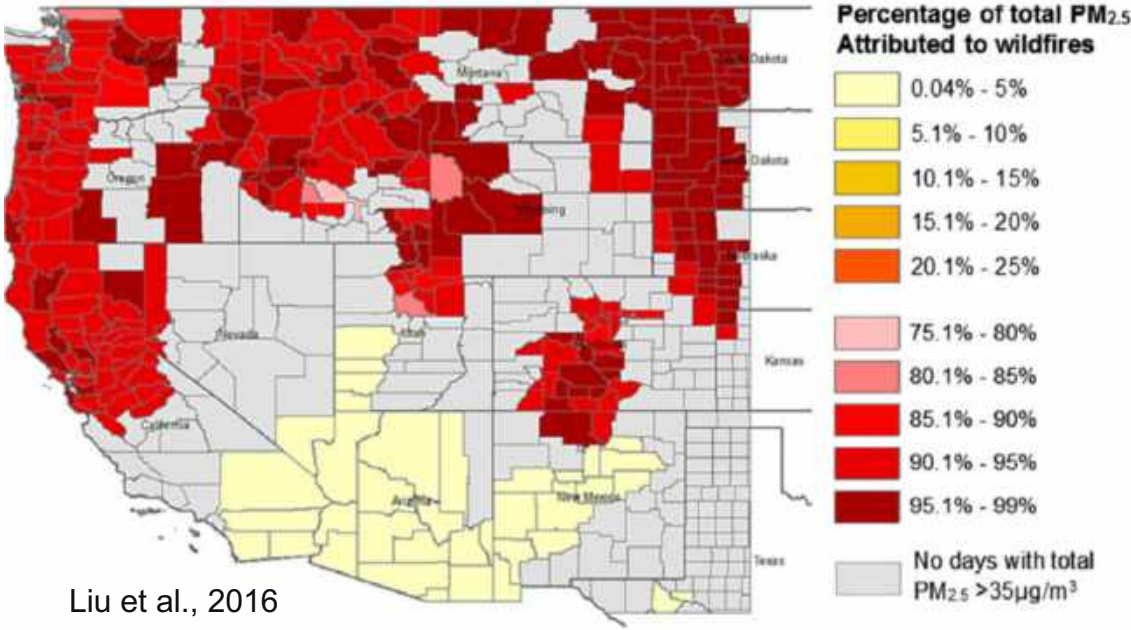
npr

ENVIRONMENT

1 In 7 Americans Have Experienced Dangerous Air Quality Due To Wildfires This Year

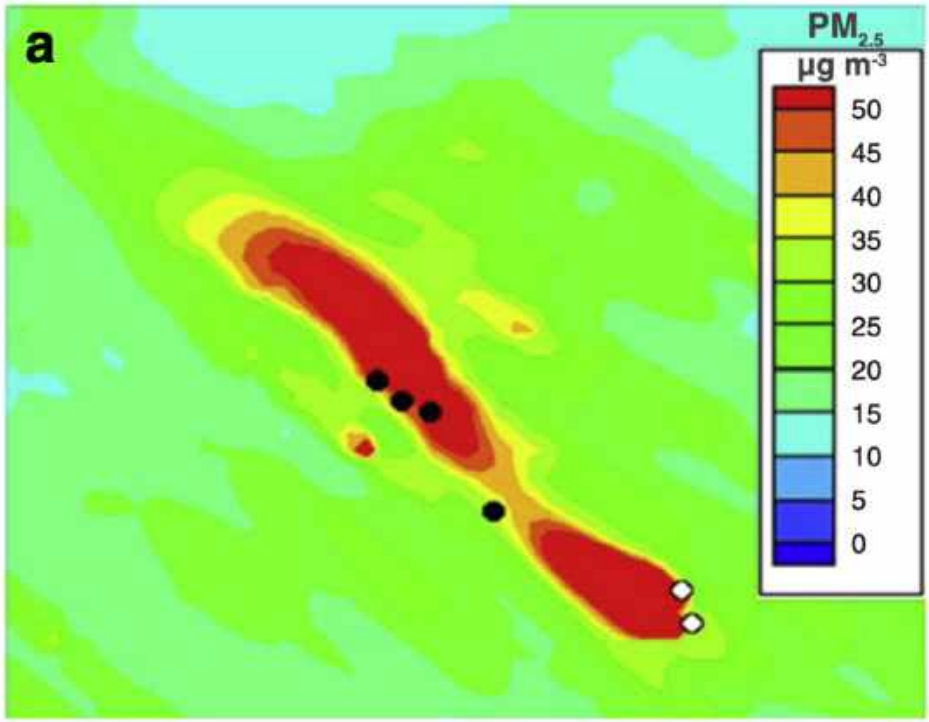
September 23, 2020 · 12:19 PM ET

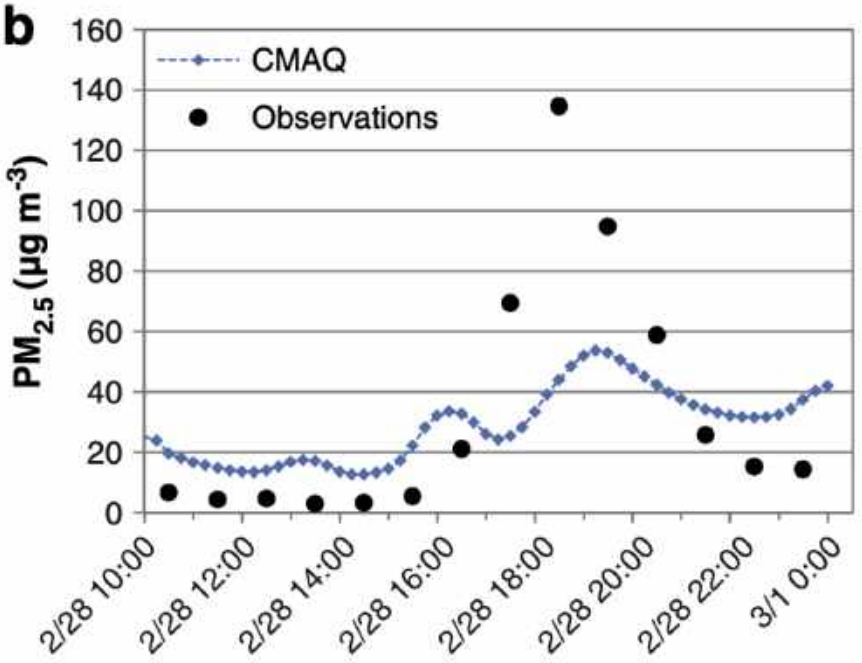
Wildfires contribute >90% to $PM_{2.5}$ on days with $PM_{2.5}$ levels exceeding the National Ambient Air Quality Standards (NAAQS) threshold.



Liu et al., 2016

Models have difficulties in capturing the high $PM_{2.5}$ levels during wildfire periods



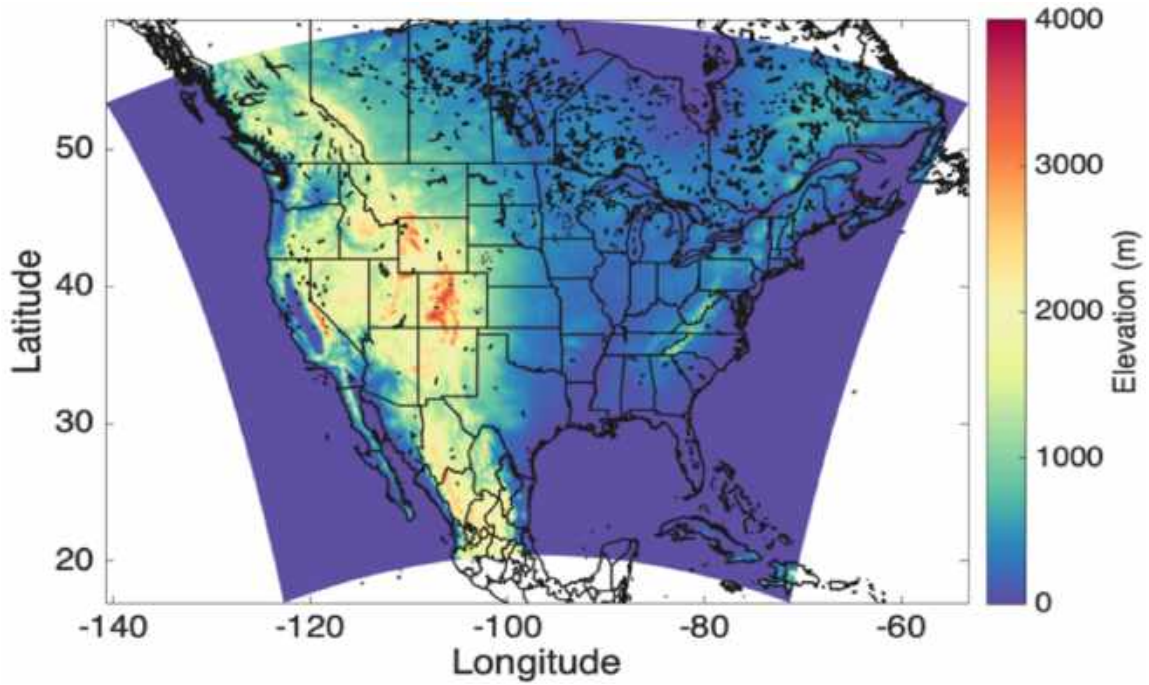


Garcia-Menendez et al., 2014

Can we improve the accuracy of $PM_{2.5}$ forecasts during wildfires via assimilation of satellite AOD retrievals?

Model and Assimilation System Setup

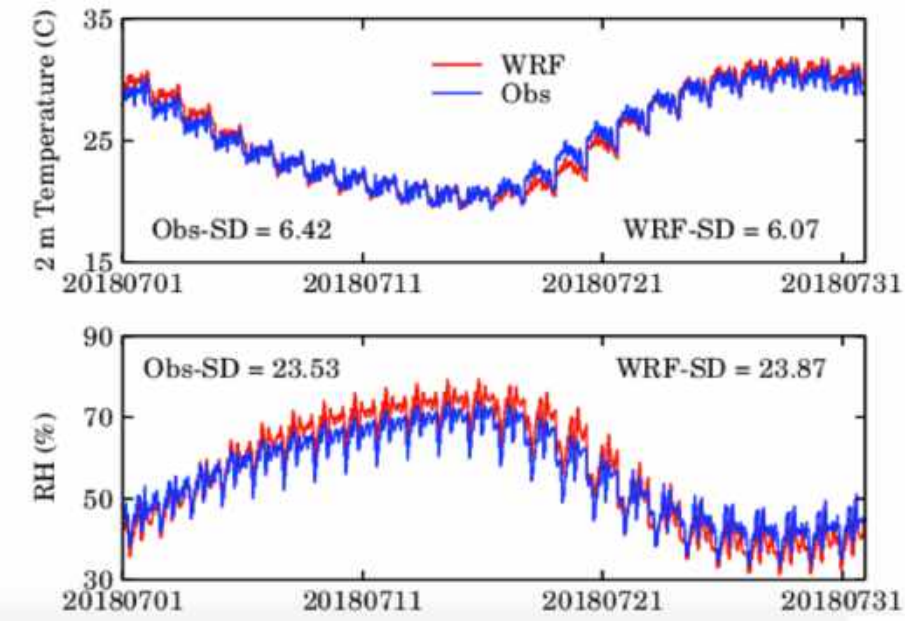
- Model: **WRF-CMAQ,** WRF v4.1.2, CMAQ v5.3.1, **follow the EPA setup** (Appel et al., 2017)
- Assimilation: Couple **GSI** with WRF-CMAQ, **assimilate MODIS & GOES AOD**
- Resolution: 12 km x 12 km, 35 vertical layers (up to 50 hPa)
- Met initial & boundary conditions: 6-hourly 0.7-deg ERA-Interim
- Chemical initial & boundary conditions: NCAR WACCM global simulation
- Nudging: 6 hourly nudging for atmospheric variables (above PBL) and 3 hourly nudging for surface/soil variables
- **Case study:** 2018 summer fire season， **1-day & 2-day Forecasts**

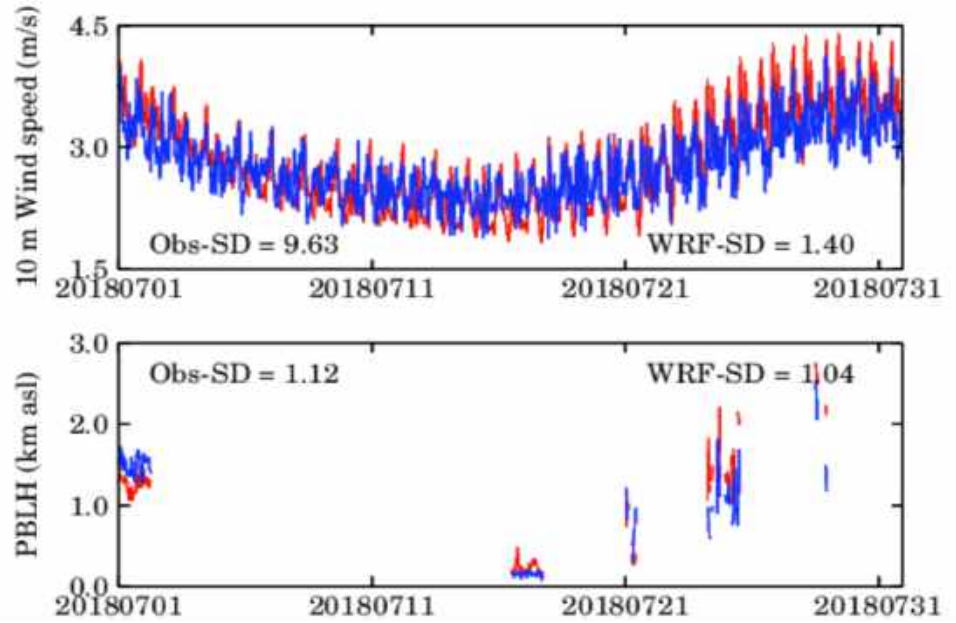


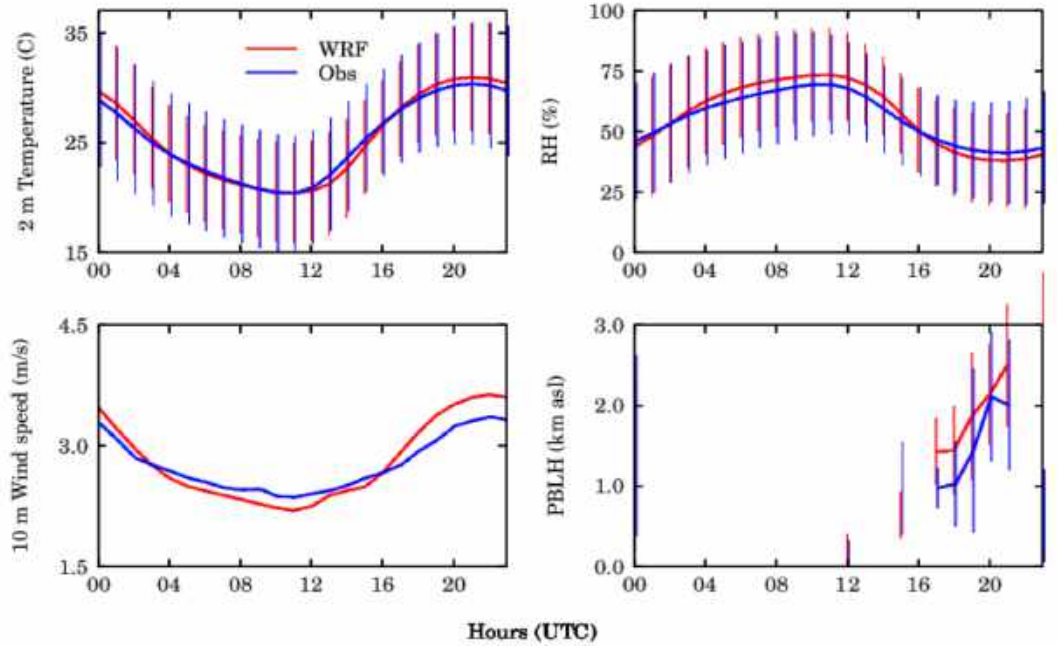
WRF-CMAQ Model Schemes

Physics	Setup-1 (standard simulation used for assimilation)	Setup-2 (sensitivity simulation used to generate background error)
Long-wave radiation	RRTMG	RRTM Longwave
Short-wave radiation	RRTMG	Goddard Shortwave
Microphysics	Morrison double-moment	Thomson
Cumulus	Kain–Fritsch version 2	Grell 3-D ensemble
Land surface model	Pleim–Xiu LSM	Unified Noah LSM
Surface Layer	Pleim–Xiu surface layer	MYNN
PBL	ACM2	MYNN level 2.5
Gas-phase chemistry	CB06	CB06
Aerosol chemistry	AERO7	AERO7
Anthropogenic and fire emissions	2014 EPA NEI scaled to 2018 (FINN capability has been developed and being tested)	EPA NEI perturbed by factors* derived from uncertainty analysis of multiple emission datasets
Biogenic emission	Online CMAQ BEIS	Offline MEGAN

WRF Meteorological Evaluation

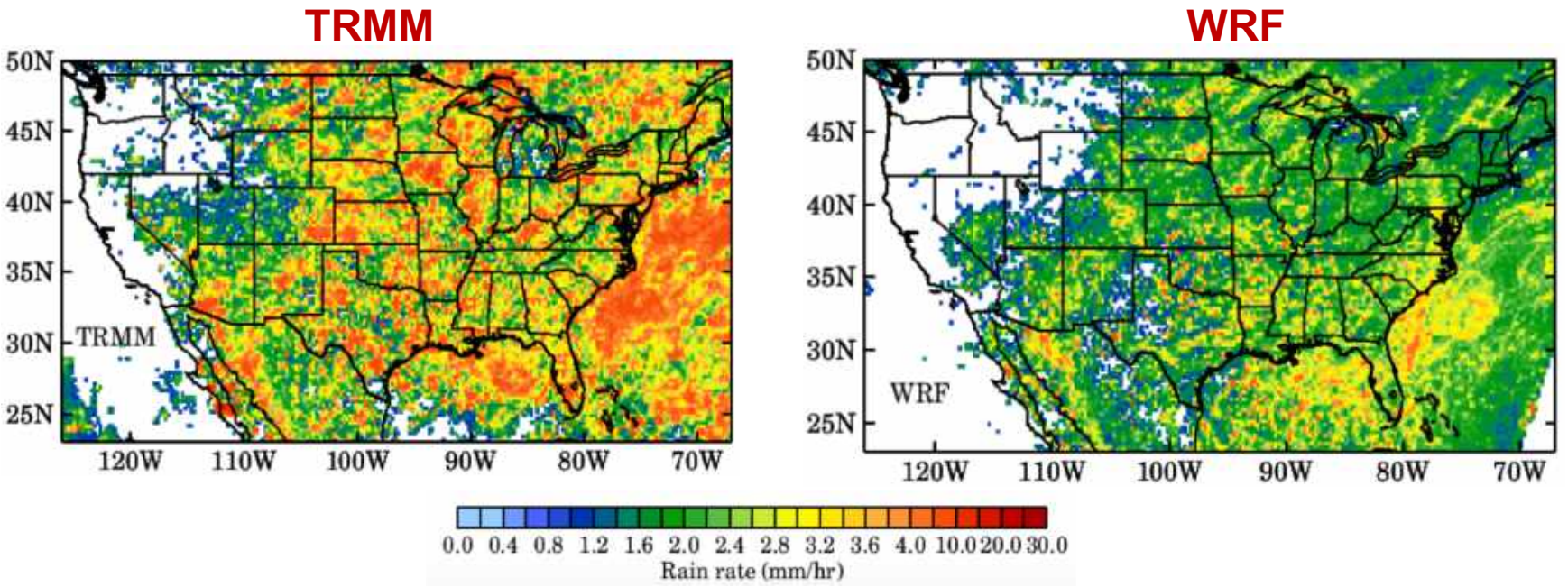






WRF Meteorological Evaluation

Precipitation



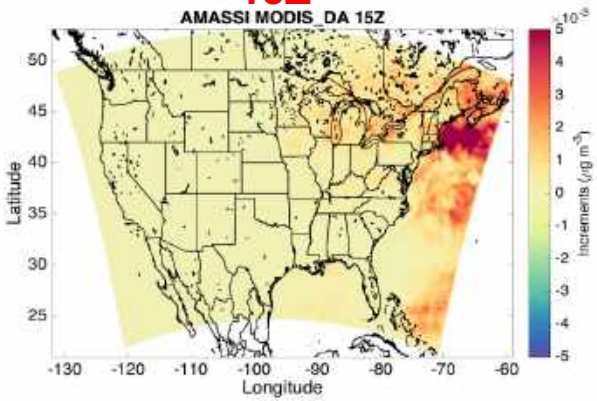
Evaluation Statistics

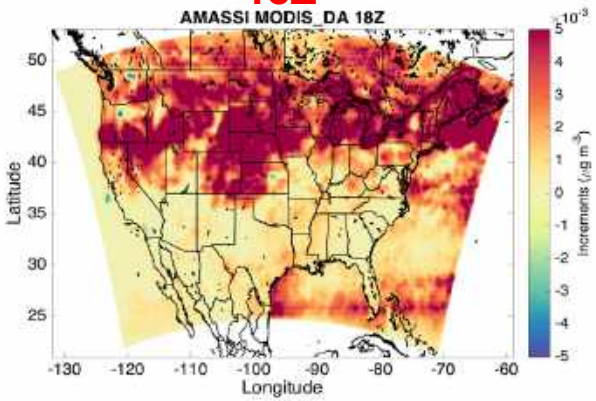
	Correlation	Mean bias	RMSE
PBLH	0.77	153.34 m	752.08 m
Surface Pressure	0.98	4.01 hPa	13.73 hPa
2 m Temperature	0.90	-0.15 K	2.80 K
Relative Humidity	0.83	-1.18%	13.88%
10 m Wind Speed	0.07	-0.04 m/s	9.64 m/s

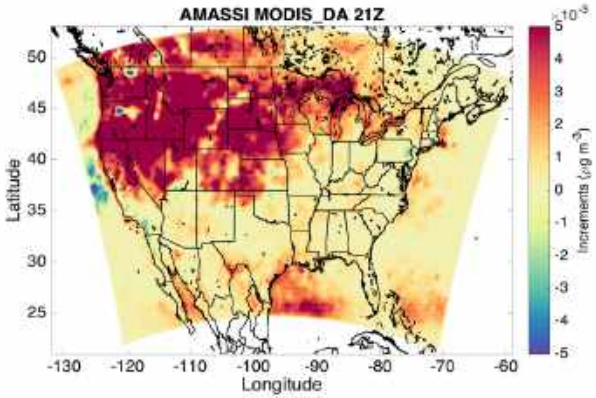
Analysis Increment for MODIS AOD Assimilation
(July 2018, UTC 15Z, 18Z, 21Z)

15Z 18Z 21Z

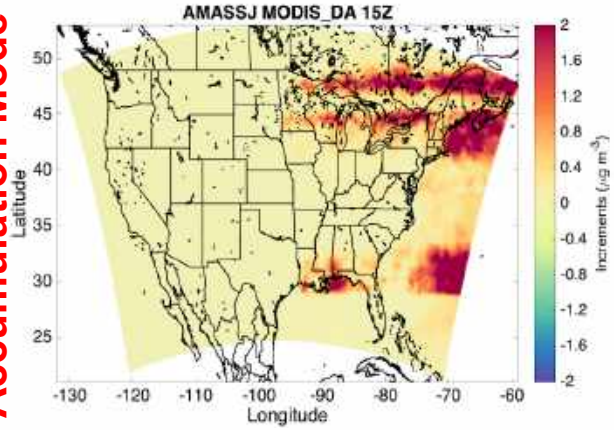
Aiken Mode

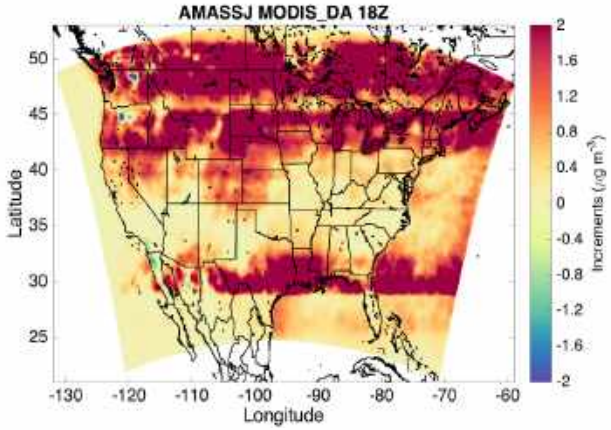


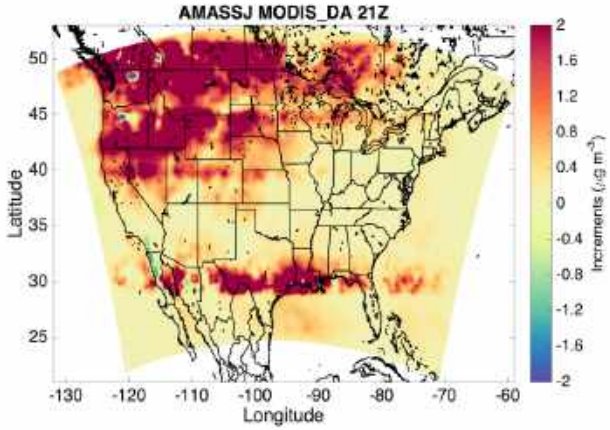




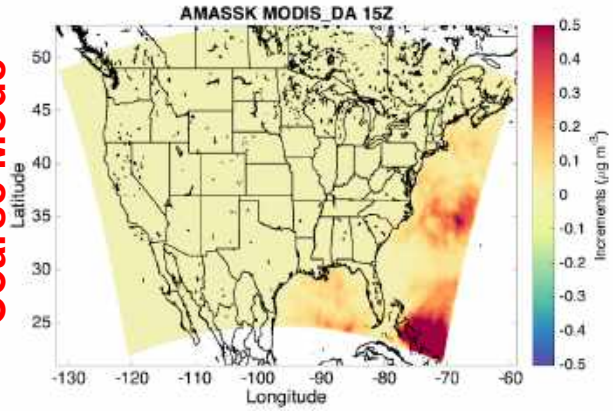
Accumulation Mode

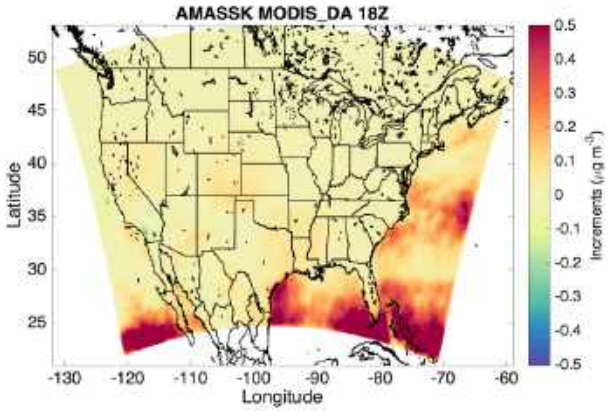


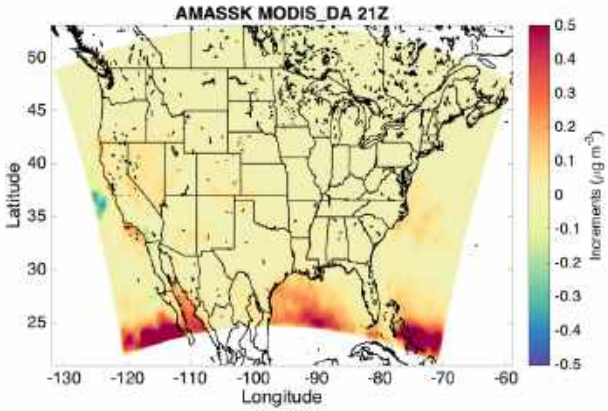




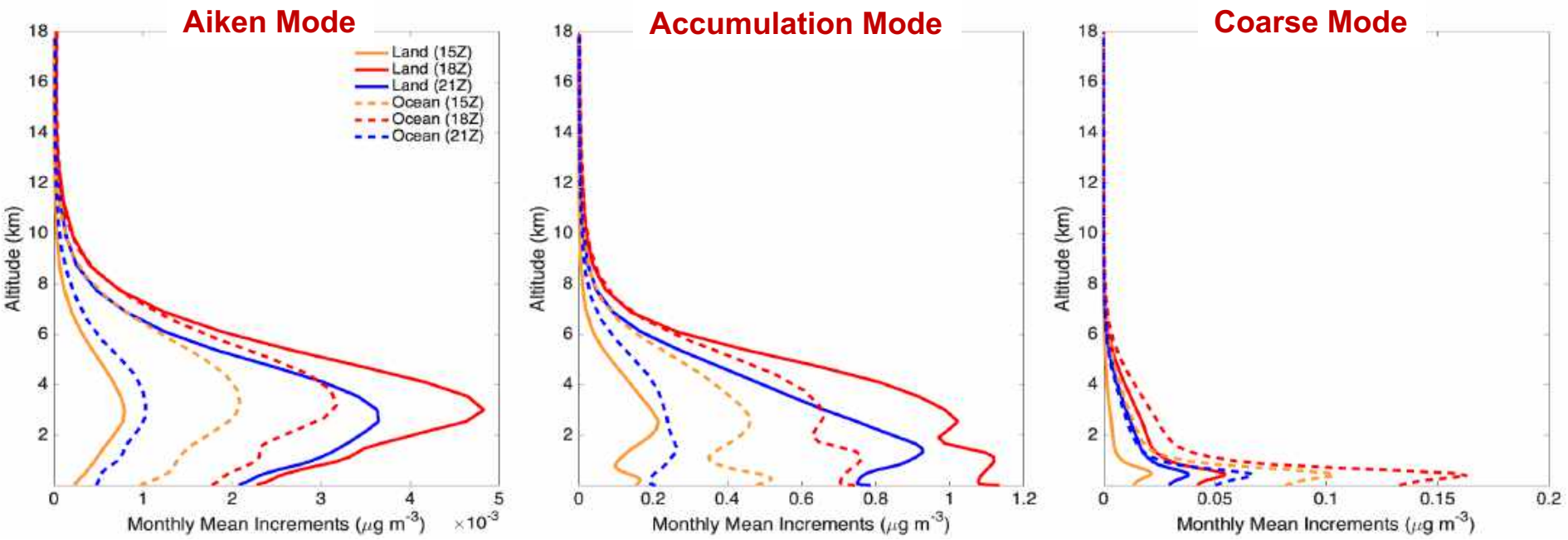
Coarse Mode



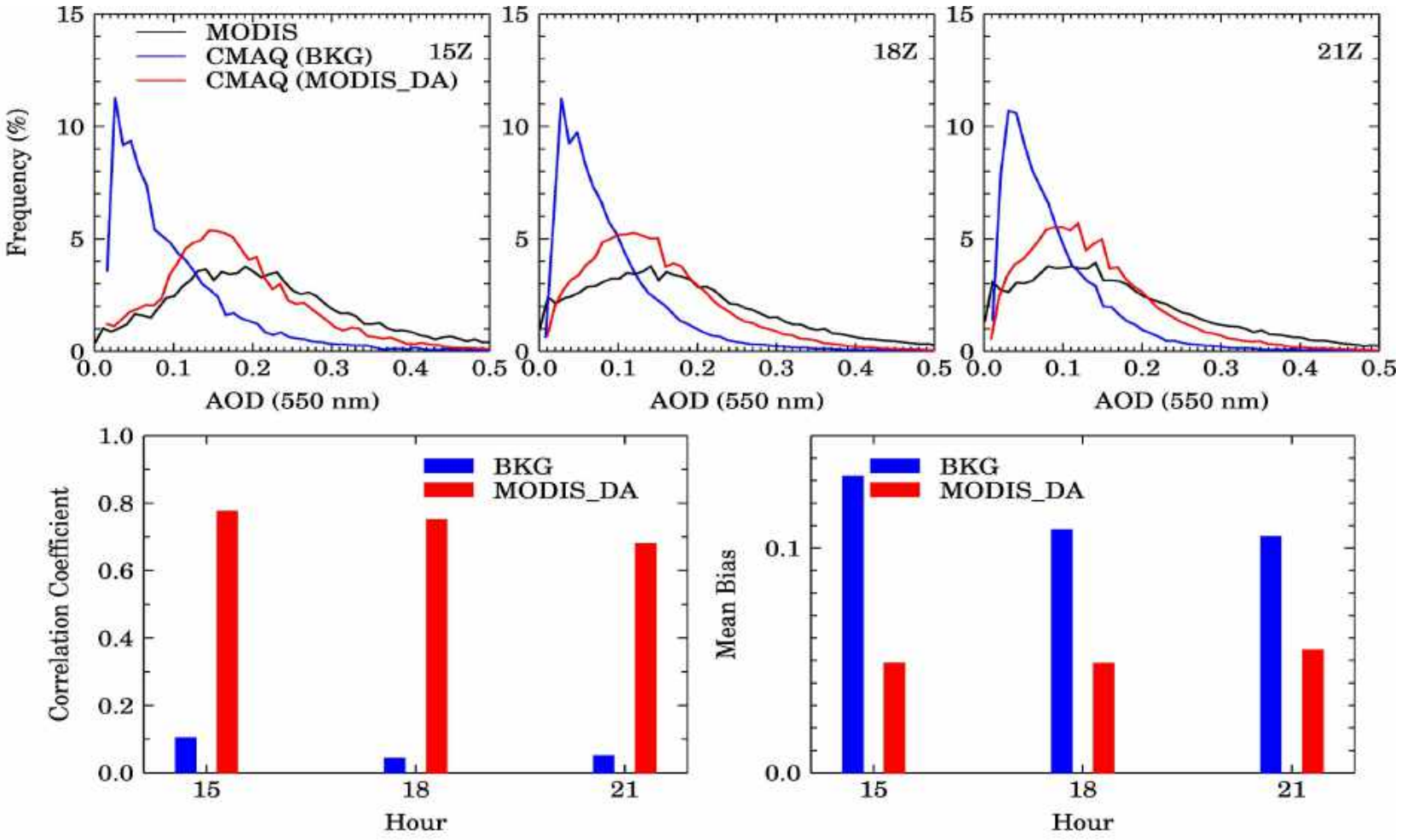




Analysis Increment for MODIS AOD Assimilation
(July 2018, UTC 15Z, 18Z, 21Z)



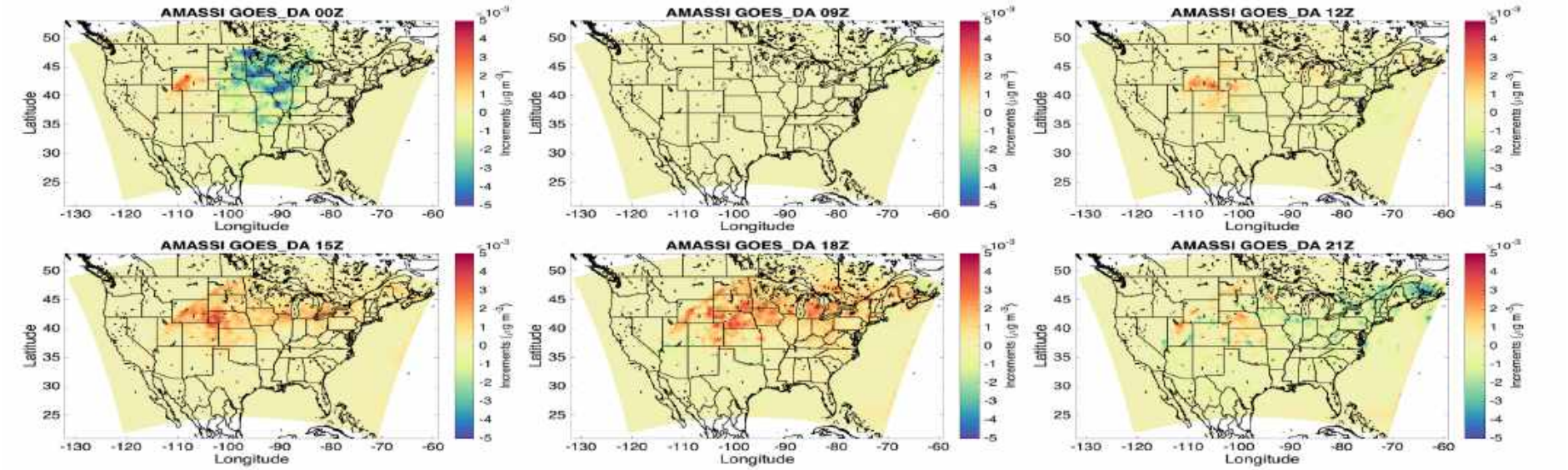
Evaluation for MODIS AOD Assimilation



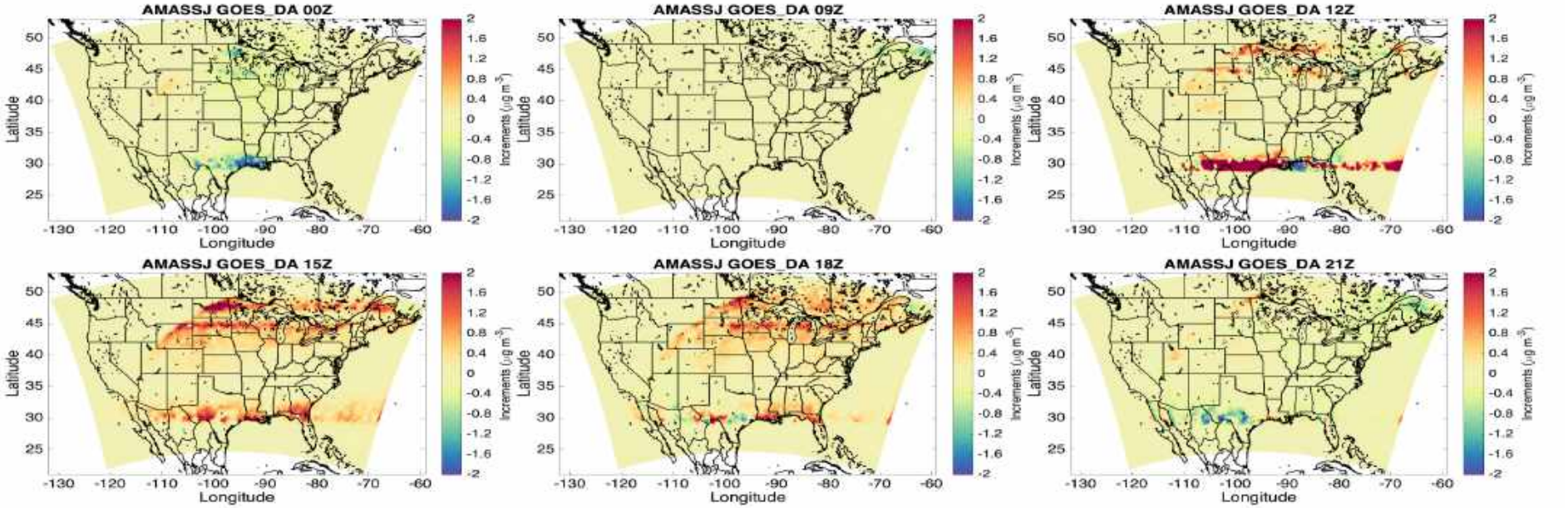
Analysis Increment for GOES AOD Assimilation

(July 25-31, 2018, every 3 hourly)

Aiken Mode



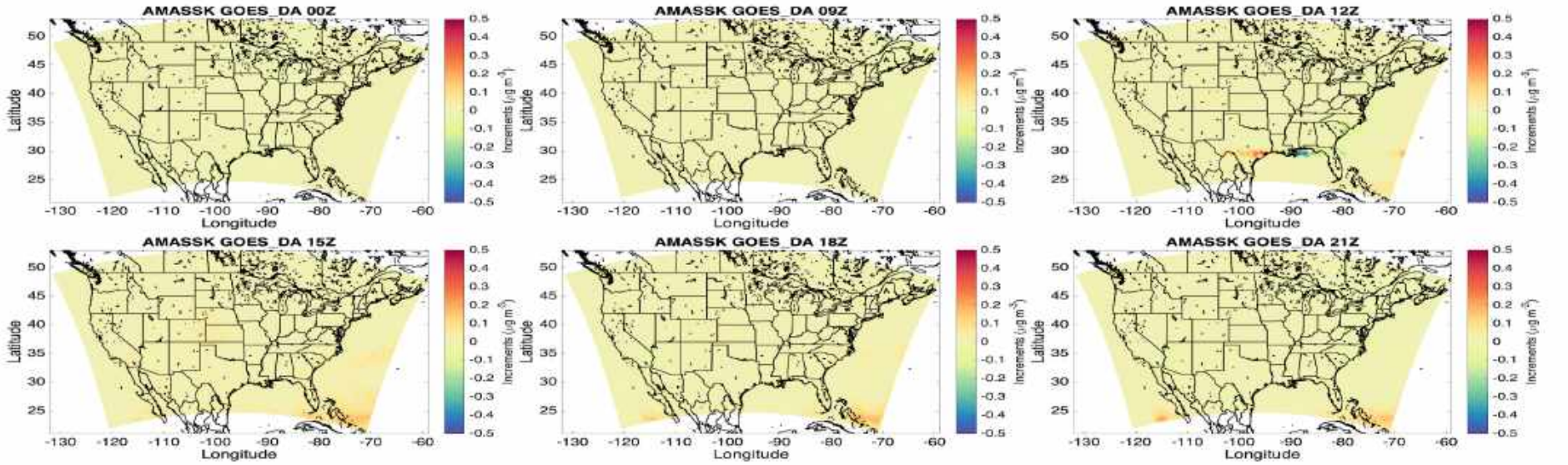
Accumulation Mode



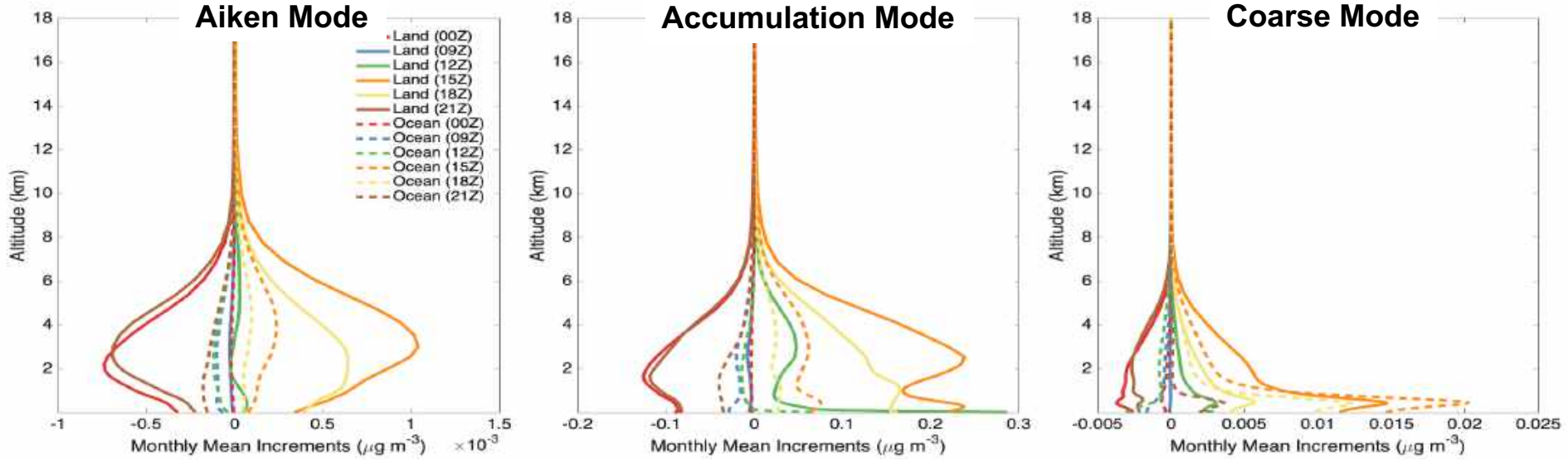
Analysis Increment for GOES AOD Assimilation

(July 25-31, 2018, every 3 hourly)

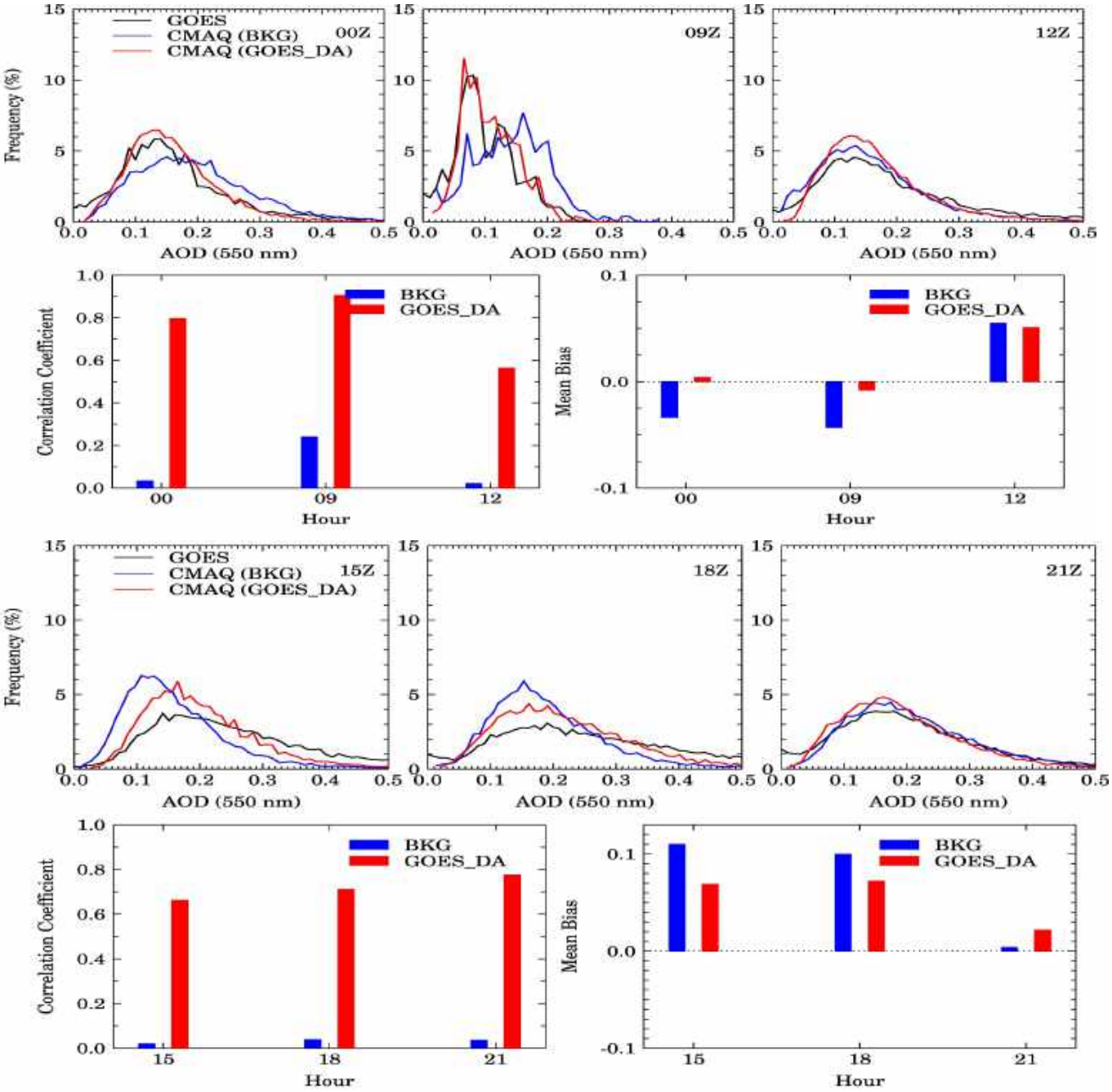
Coarse Mode



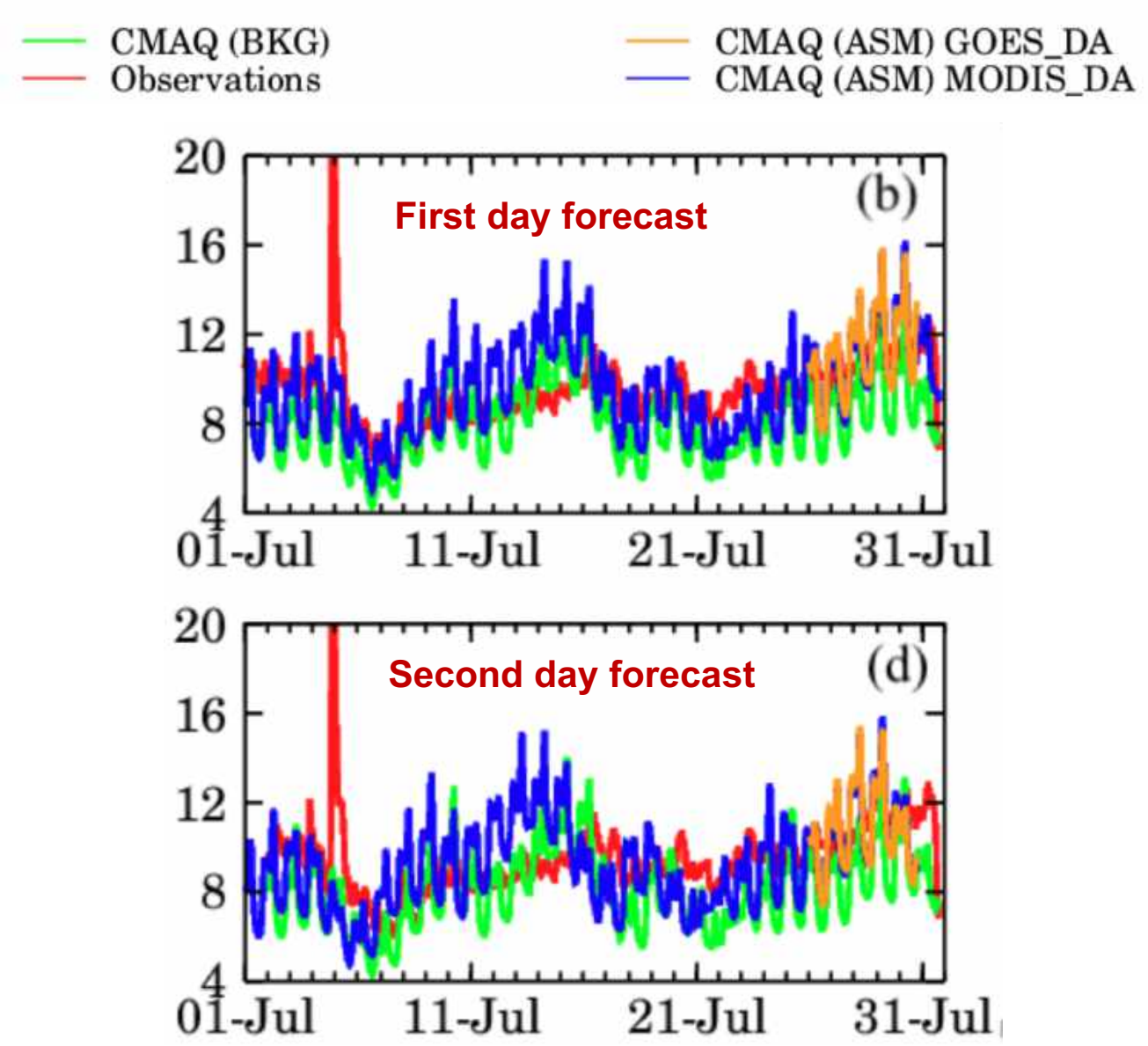
Vertical Profiles



Evaluation for GOES AOD Assimilation



Similar results for GOES and MODIS AOD DA during 25-31 July



On-going work

- Another Case study for Aug-Sept 2018 (due to GOES AOD issue) during WE-CAN wildfire field campaign period
- Re-do the aforementioned analysis and particularly focus on whether using GOES AOD has some benefits due to the high assimilation frequency compared to MODIS
- Evaluate results against WE-CAN measurements
- Conduct long-term (2010-2019) fire season (summer) assimilation and analysis

Thank you!

If you are interested in my work, please email me:
cenlinhe@ucar.edu