Using VIIRS and GOES-16 aerosol data for aerosol detection, monitoring, and trajectories in New York State

Sarah Lu (clu4@Albany.edu)

University at Albany, State University of New York

With acknowledgments to colleagues and collaborators

U Albany	Sheng-Po Chen, Wei-Ting Wei, Jia Hong, Bhupal Shrestha, William May, Mark Beauharnois, Qilong Min, and Everette Joseph
NESDIS/STAR	Shobha Kondragunta and Hai Zhang
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NYS DEC	Michael Ku, Kevin Civerolo, Winston Hao
NOAA/ARL	Pius Lee and Daniel Tong
NOAA/EMC	Jeff McQueen, Jun Wang, Partha Bhattacharjee, Jianping Huang and Ho-Chun Huang,

Outline of the presentation

- Introduction
- IDEA-NYS using VIIRS aerosol products
- PM monitoring using GOES-16 aerosol products
- Looking forward …

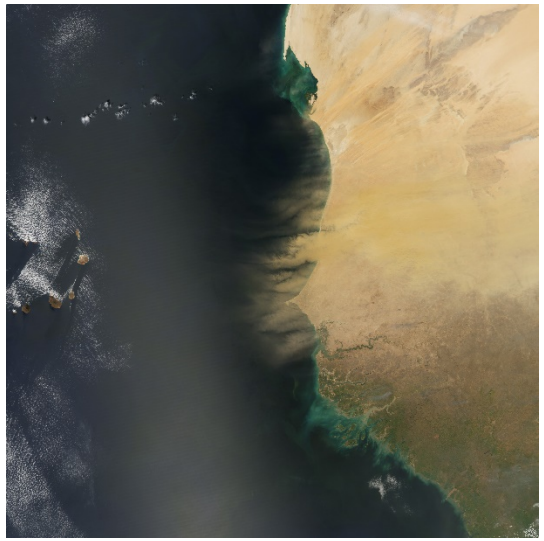
Acknowledgements:
The development of IDEA-NYS is supported by New York State Energy Research and Development Authority (NYSERDA) contract #100417

Lessons learn from my global aerosol modeling work at EMC: The utilization of satellite data to improve aerosol forecasting

Satellite observations have been used to improve aerosol products

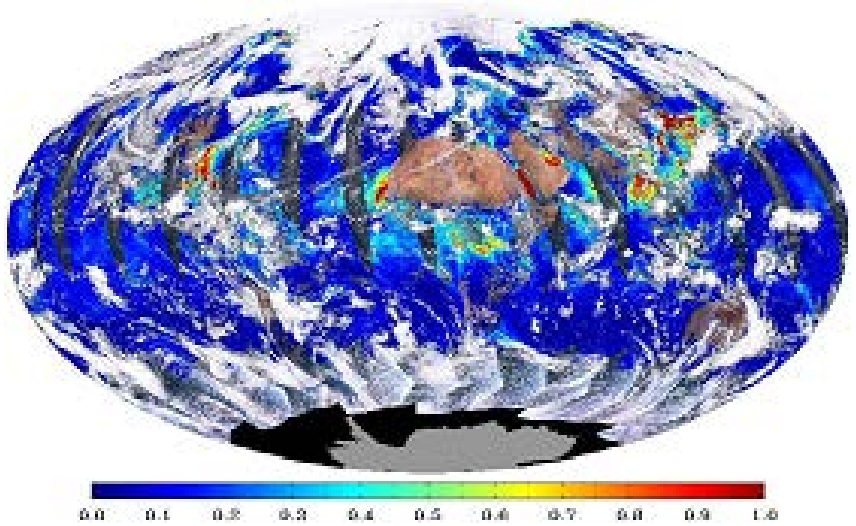
- Routine monitoring of model performance
- Near-real-time biomass burning emissions from satellite observations
- Data assimilation of satellite aerosol observations

Dust off Africa, observed by the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Aqua satellite



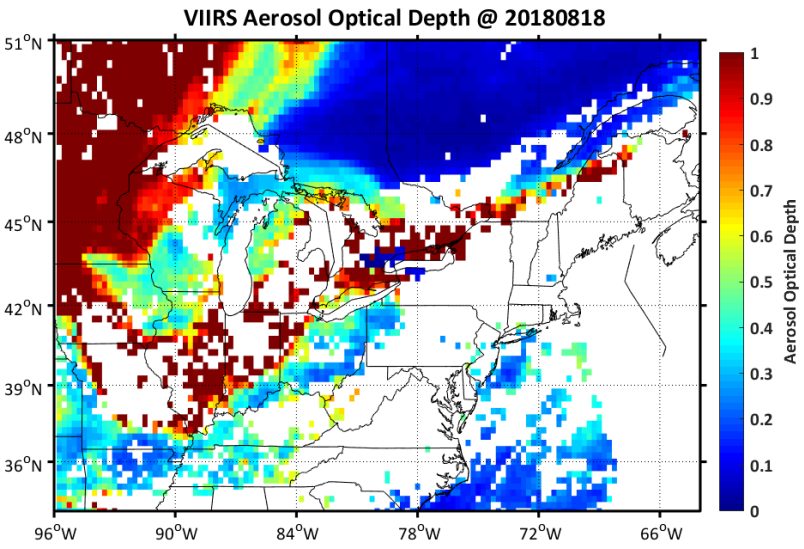
https://earthobservatory.nasa.gov

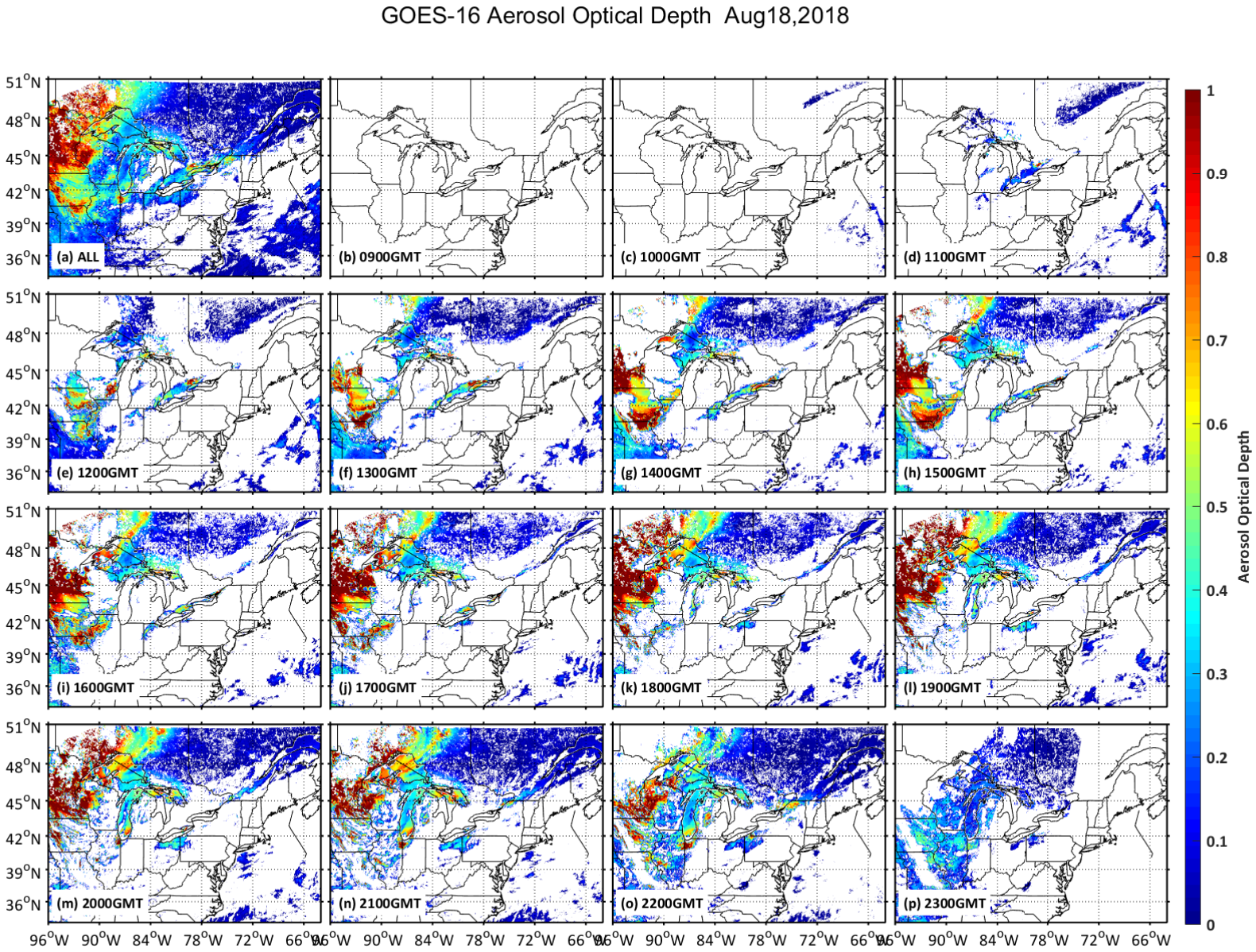
Aerosol optical depth (AOD) from Visible Infrared Imaging Radiometer Suite (VIIRS) sensor onboard the Suomi National Polar Orbiting (SNPP) satellite



https://www.star.nesdis.noaa.gov

A new era for satellite observations of aerosols has begun.





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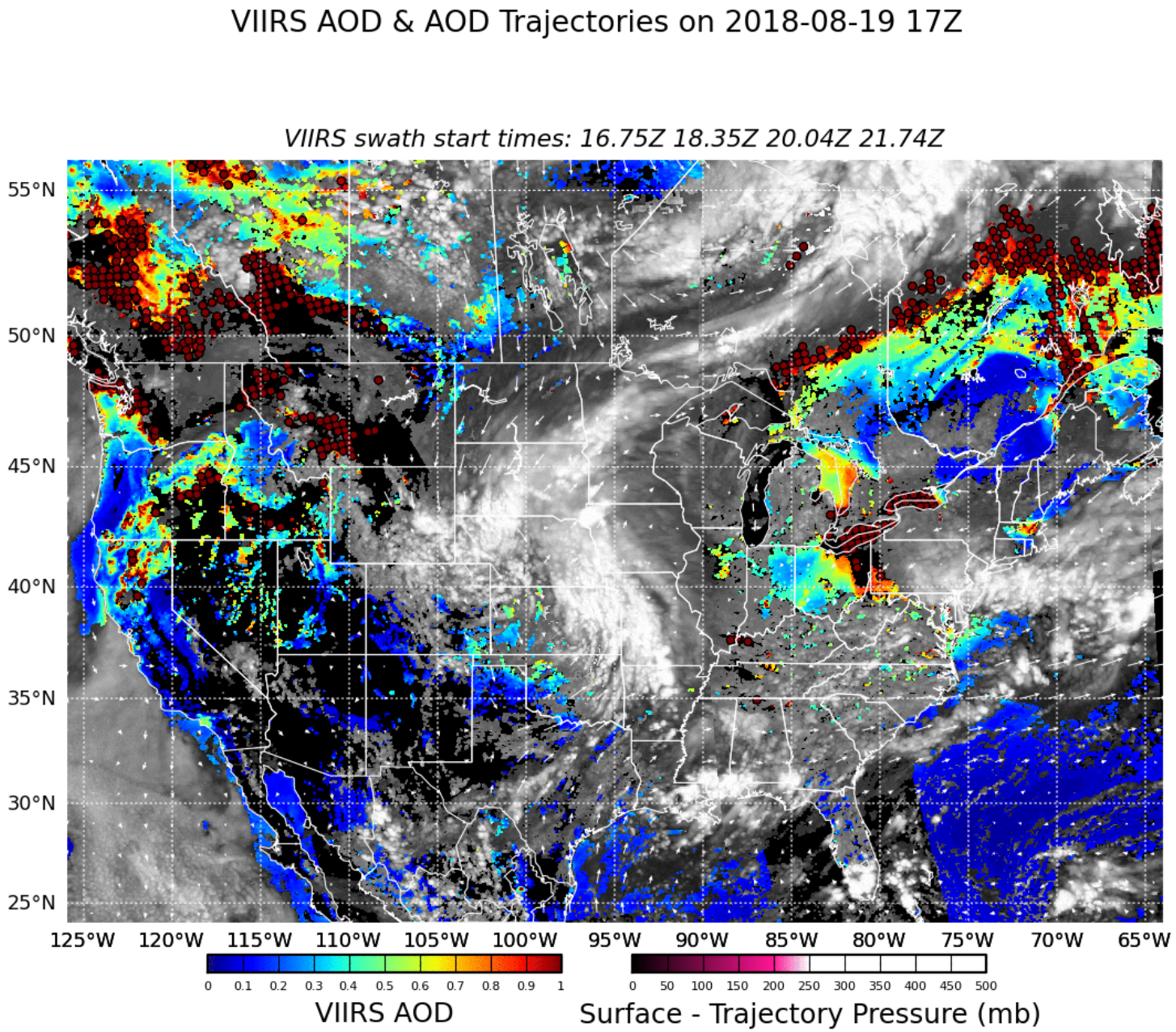
Satellite observations make critical contributions for regional applications

Real-time aerosol forecast and analysis system for New York State, resulting from the adoption of IDEA-I (Infusing satellite Data Environmental Applications - International) air quality forecasting system from NOAA/NESDIS/STAR (Pierce and Kondragunta)

IDEA-NYS Configuration

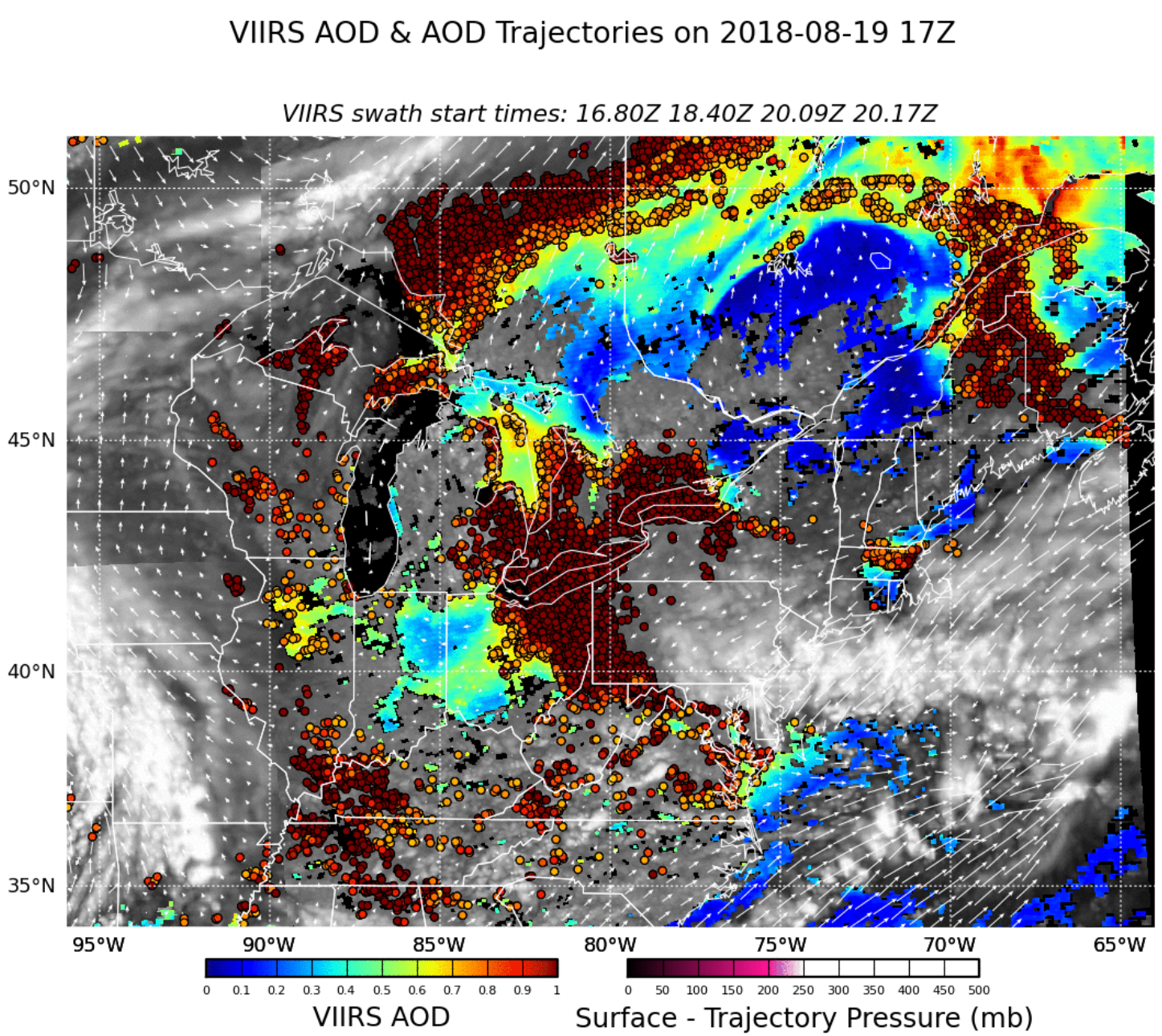
	IDEA-NYS	IDEA-NYS HR
Domain	Lon: 126W to 69W Lat: 24N to 56N	Lon: 96W to 64W Lat: 34N to 51N
Met input	GFS 0.5°, 3-hourly, out to 60hr	NAM 3 km, hourly, out to 36 hr
AOT	VIIRS EDR 6 km (5x5) ~ 30 km	VIIRS EPS 750m (8x8) ~ 6km
Clouds	VIIRS using CLAVR-x cloud retrievals	
Input	Met: 3.3G Satellite: CLAVR-x (7.9G), VIIRS (80M)	Met: 46G Satellite: CLAVR-x (7.9G), VIIRS (1.9G)
Output	42 M	632 M
Run Time	20 min	120 min (> 80min downloading data)

The dual resolution system provides detailed information on aerosol loading in the NYS region as well as information on long-range aerosol transport reaching the NY area.



Sample trajectory forecast for high VIIRS AOD, with VIIRS AOD (in color contours), VIIRS cloud optical thickness (in gray contours), 850 mb winds (white arrows), and animated 60-hour trajectory forecast (in magenta-white colors).

The dual resolution system provides detailed information on aerosol loading in the NYS region as well as information on long-range aerosol transport reaching the NY area.



Sample trajectory forecast for high VIIRS AOD, with VIIRS AOD (in color contours), VIIRS cloud optical thickness (in gray contours), 850 mb winds (white arrows), and animated 36-hour trajectory forecast (in magenta-white colors).

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Linear Mixed-Effect (LME) Model

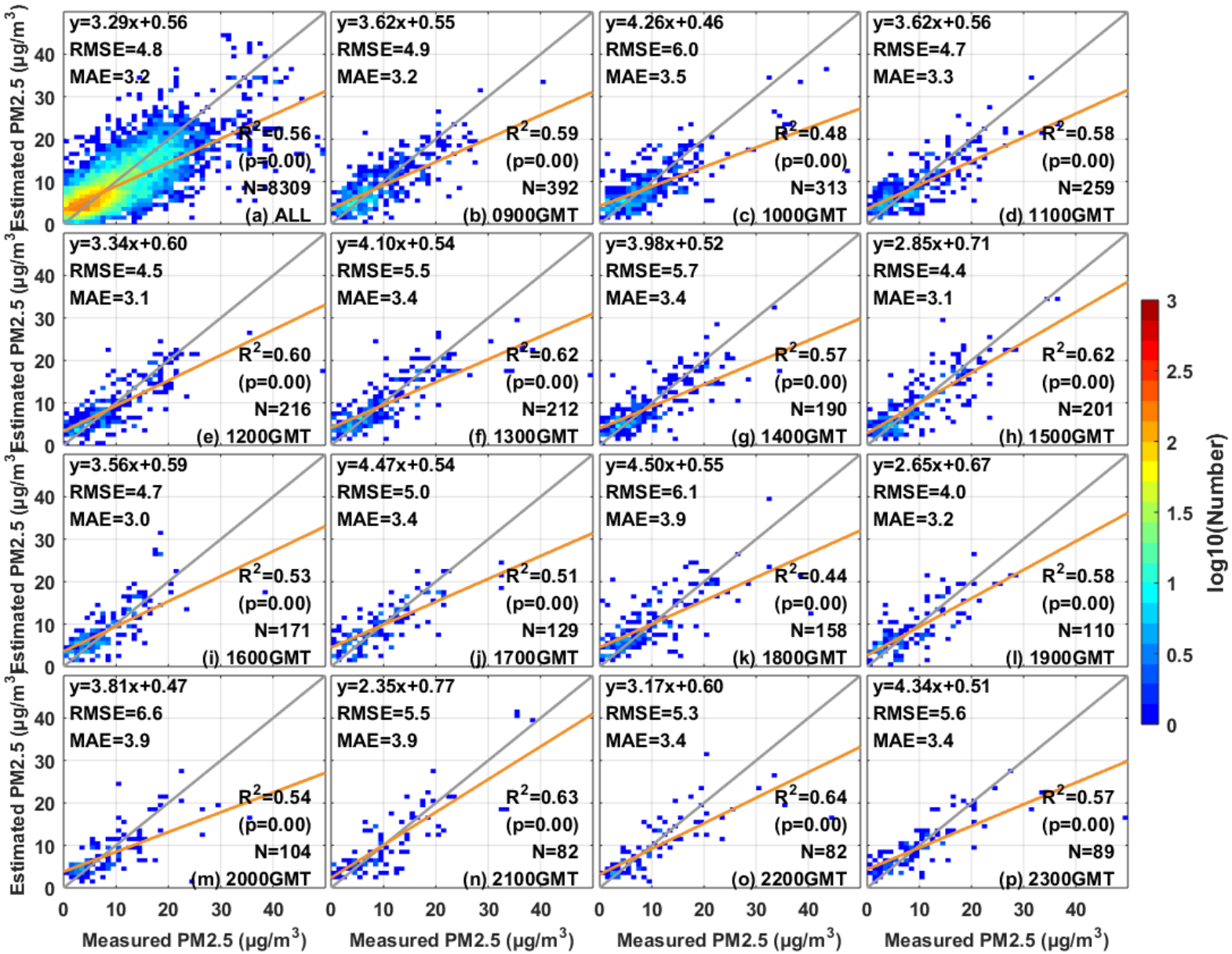
The model consists of two parts: fixed effects and random effects.

The model structure is expressed as follows:

$$\mathrm{PM2.5}_{n,m} = [\beta_0 + b_{0,n,m}^{hour}] + [\beta_1 + b_{1,n,m}^{hour}] \times AOD_{n,m} + \beta_2 \times RH_{n,m} + \beta_3 \times BLH_{n,m} + \beta_4 \times DEM_{n,m} + \beta_5 \times NDVI_{n,m} + \varepsilon_{n,m};$$

Dataset	Variable(s)	Spatial Resolution	Temporal Resolution	Source
HRRR	PBLH, RH2, T2, PRES (sfc pres), U10, V10	3 km	hourly	NOAA/ESRL
GOES-16	AOD	2 km	5 min for CONUS	NOAA/STAR
AirNow	PM2.5	Site	hourly	EPA
Land	DEM	1 km	Static	USGS
	MODIS NDVI	1 km	16-day	NASA

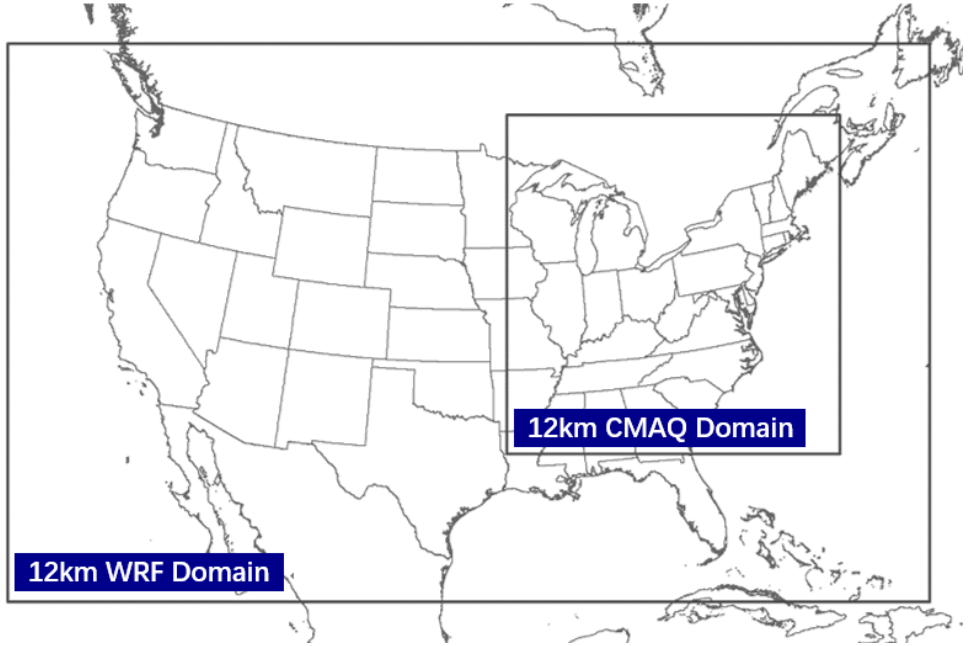
Wang, W., Mao, F., Du, L., Pan, Z., Gong, W., & Fang, S. (2017). Deriving Hourly PM2.5 Concentrations from Himawari-8 AODs over Beijing–Tianjin–Hebei in China. *Remote Sensing*, 9(8), 858.



Cross-validation

10-fold cross-validation of estimated PM2.5 concentrations based on GOES-AOD during June 1- Aug 31 contrasts with measured PM2.5

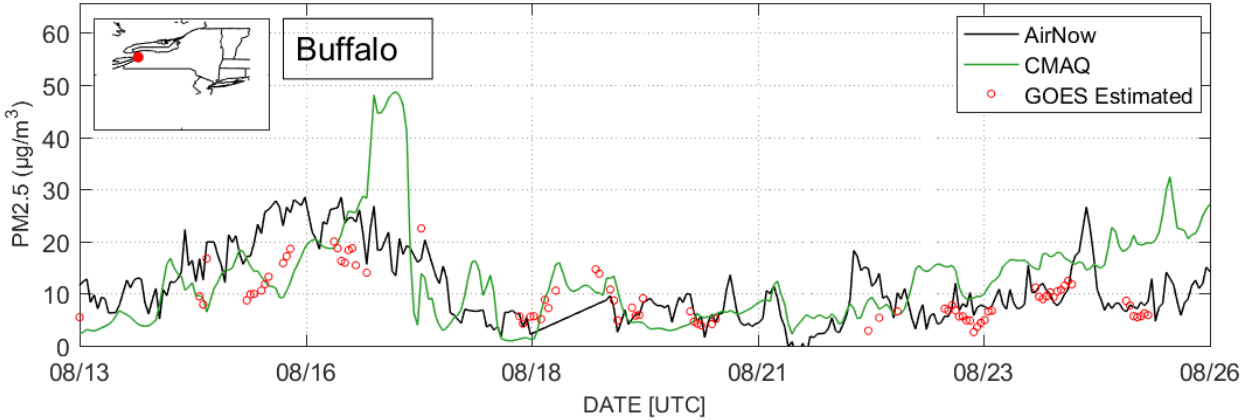
12km WRF-CMAQ Configuration

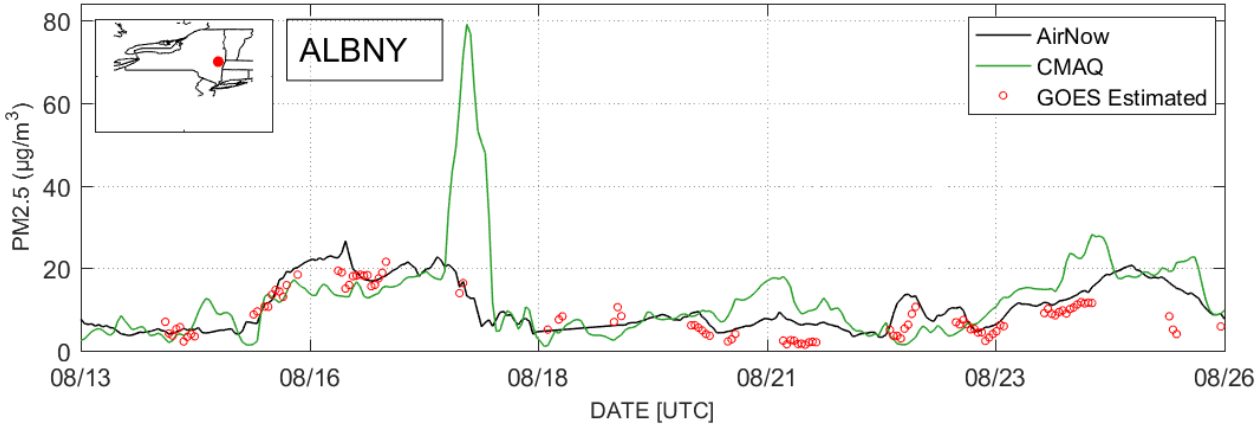


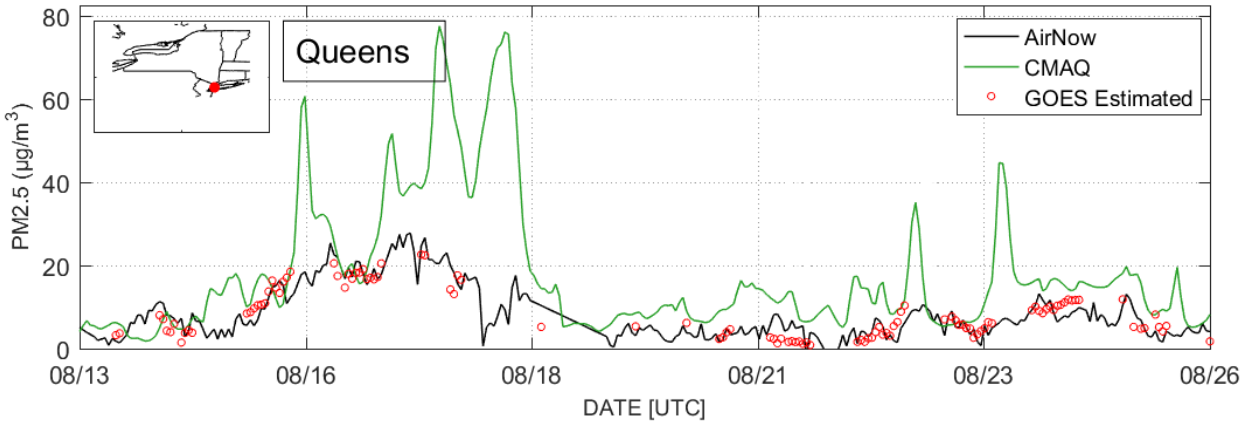
12km domain:
(472x312 cells) covering the CONUS
(172x172 cells) covering CMAQ domain

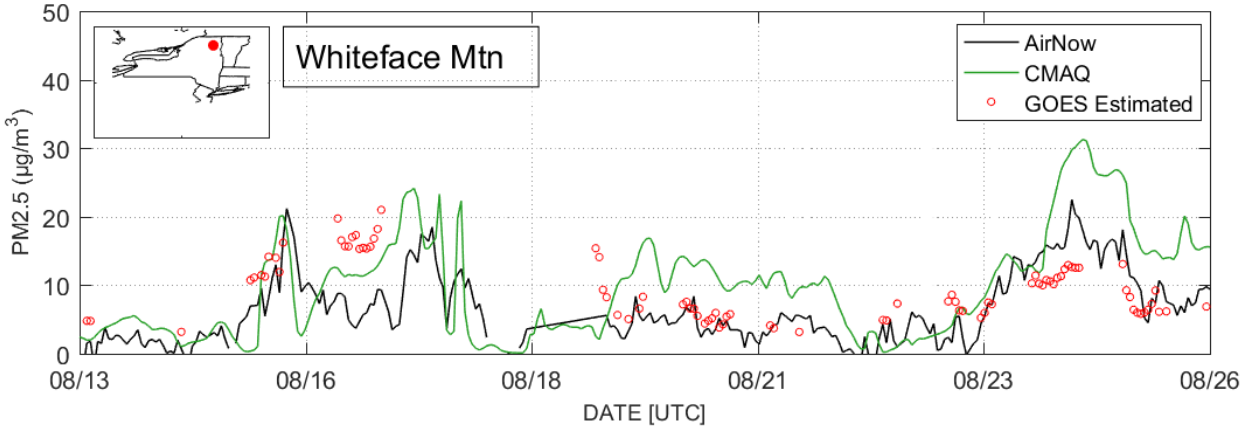
Model version	CMAQ v5.2.1
Domain	N.E. US; 12km
Meteorological Model	WRF v3.7.1
Anthropogenic Emissions	ARL (NEI 2011 v2 using GMU scheme)
Biogenic Emissions	BEIS v3.6.1 with BELD b4
Wind-blown Dust	No
OMI Data	Yes (column ozone)
Photolysis	Inline
AERO Version	AERO6
Chemical Mechanism	CB6r3
Boundary Conditions	ARL (CMAQ 5.2.1 para run)
Gravitational Setting	Yes

GOES estimated and CMAQ simulated PM2.5 vs AirNow observations

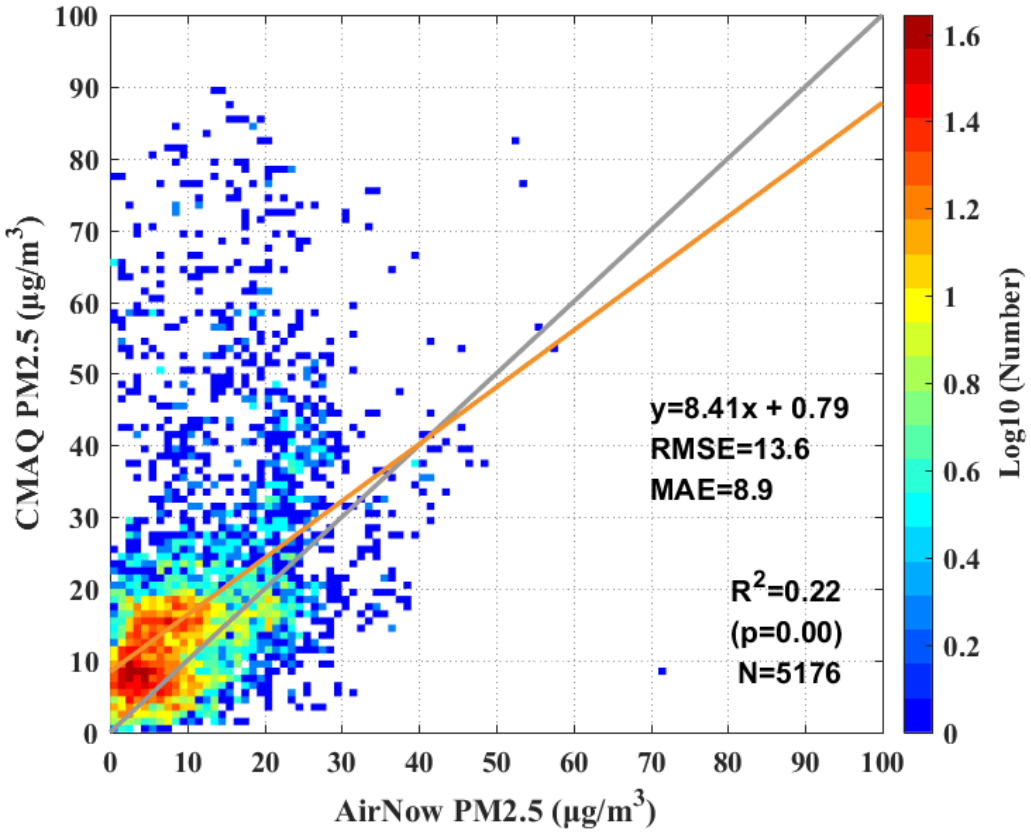


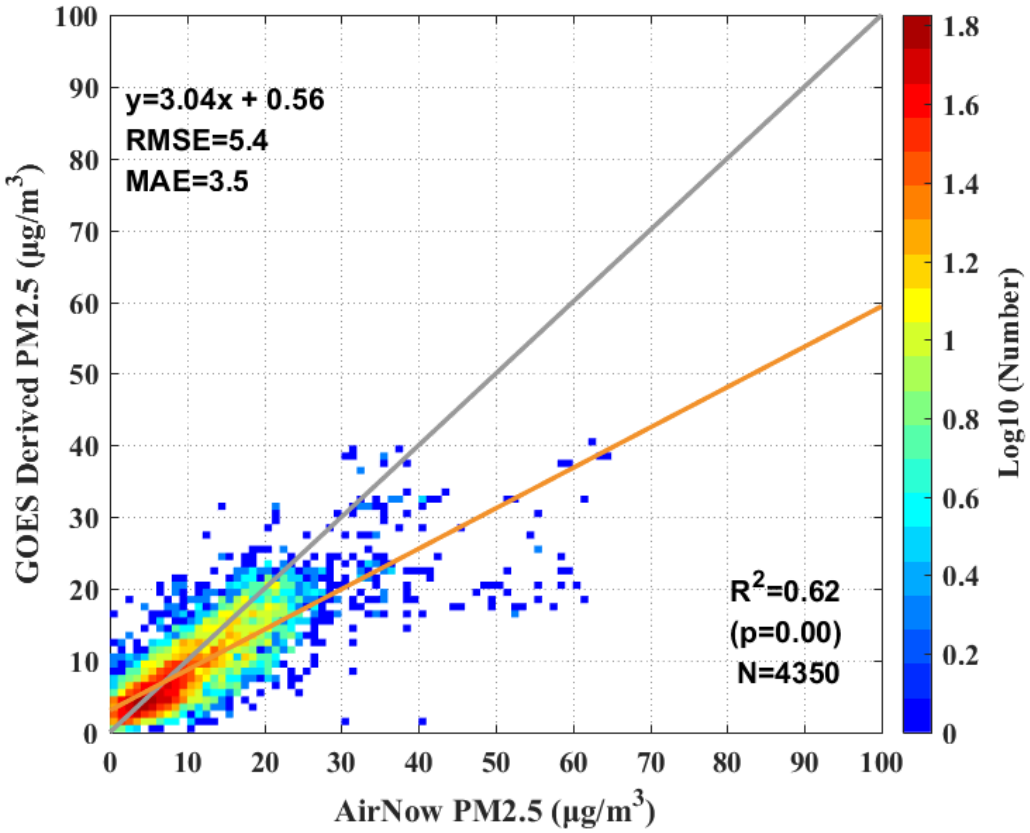






GOES estimated and CMAQ simulated PM2.5 vs AirNow observations





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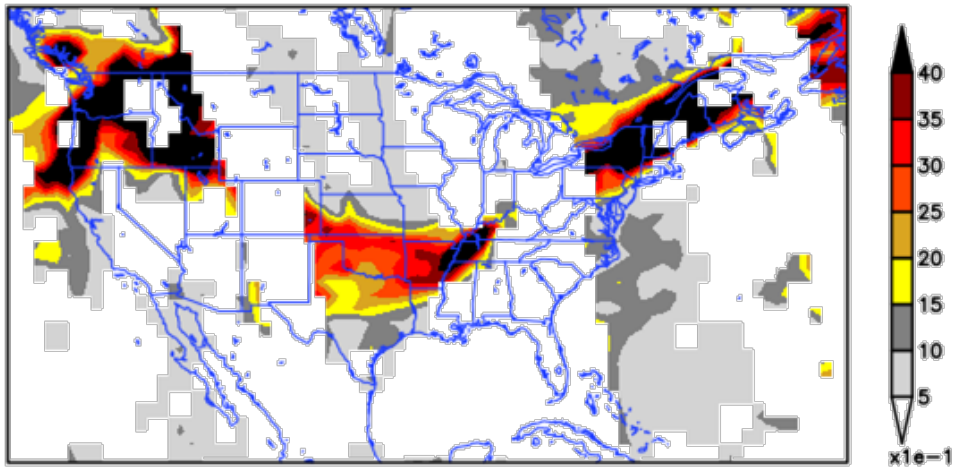
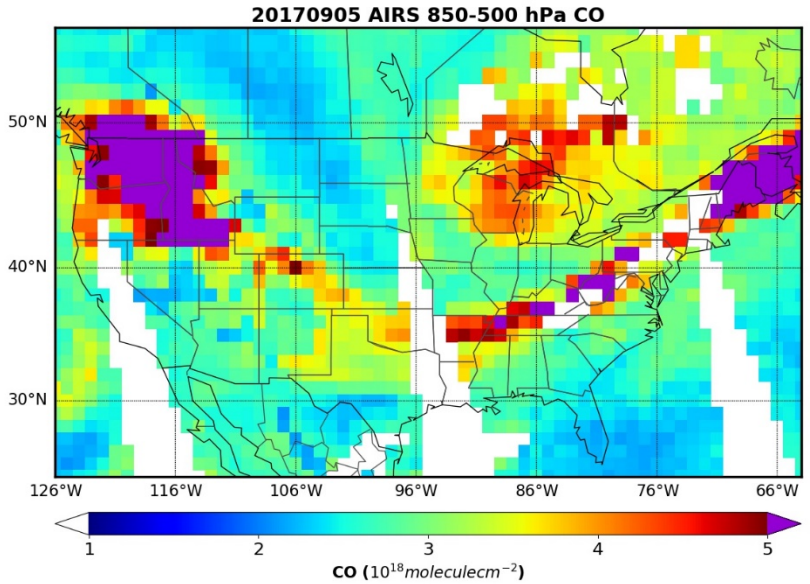
- Limitation in AOD products: chemical composition and vertical structure
- Solution: AOD observations are used in conjunction with aerosol model/reanalysis, surface network, and other satellite retrievals

OMI UV Aerosol Index (2017-09-05)

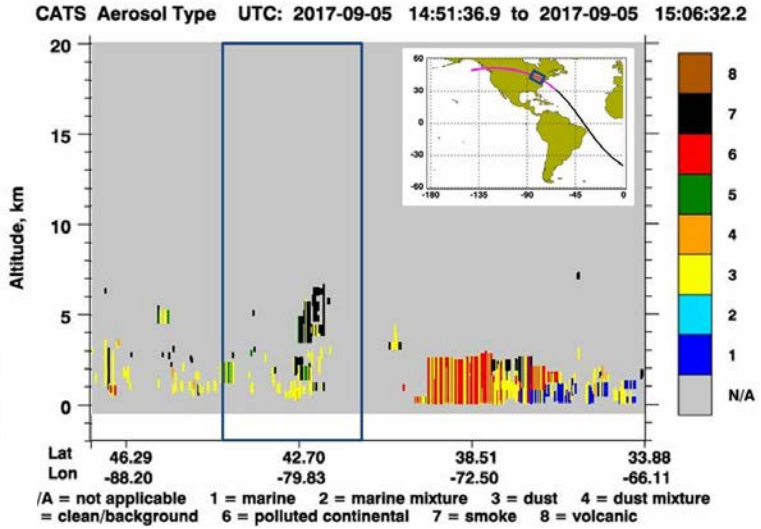


Ratio of measured backscattered UV radiation versus calculated Rayleigh scattering

AIRS CO (850-500 mb)



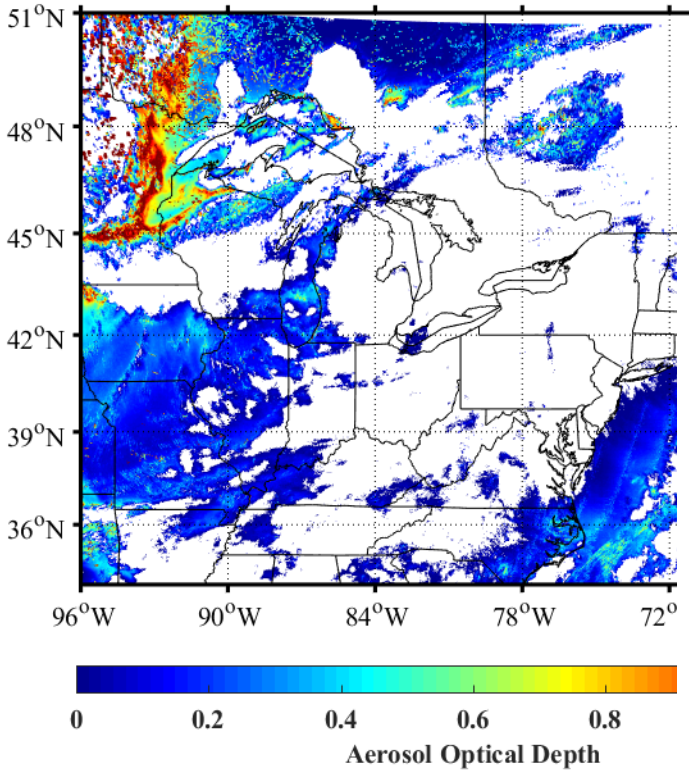
CATS aerosol subtype



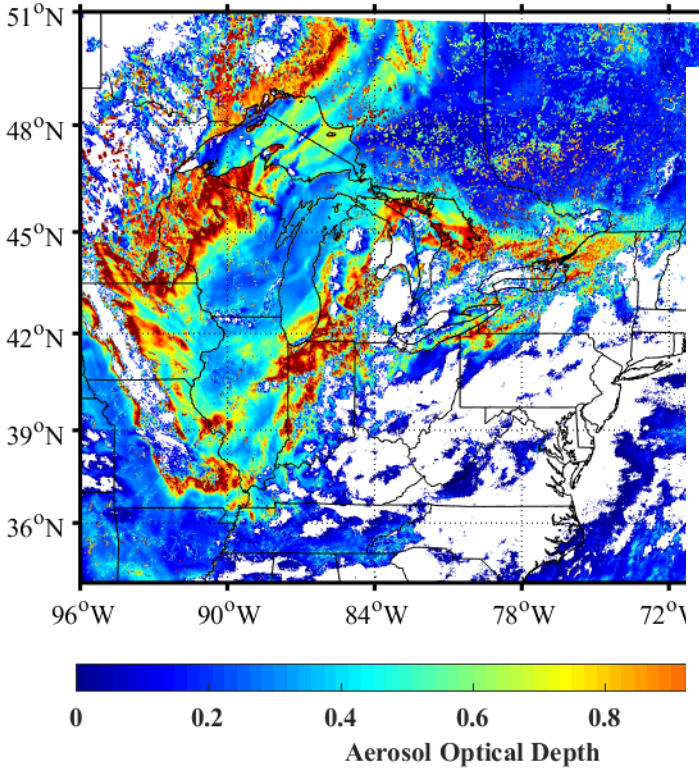
Space-borne aerosol lidar measuring backscatter

AOD from GEOS-16

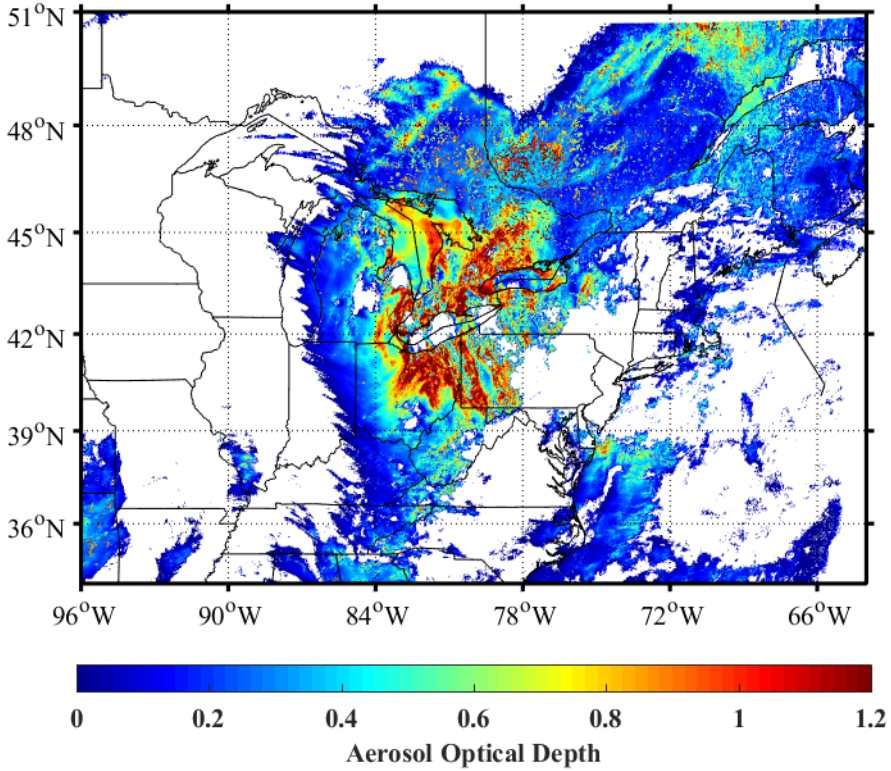
2018-08-17 23:02:30 - 2018-08-17 23:57:30

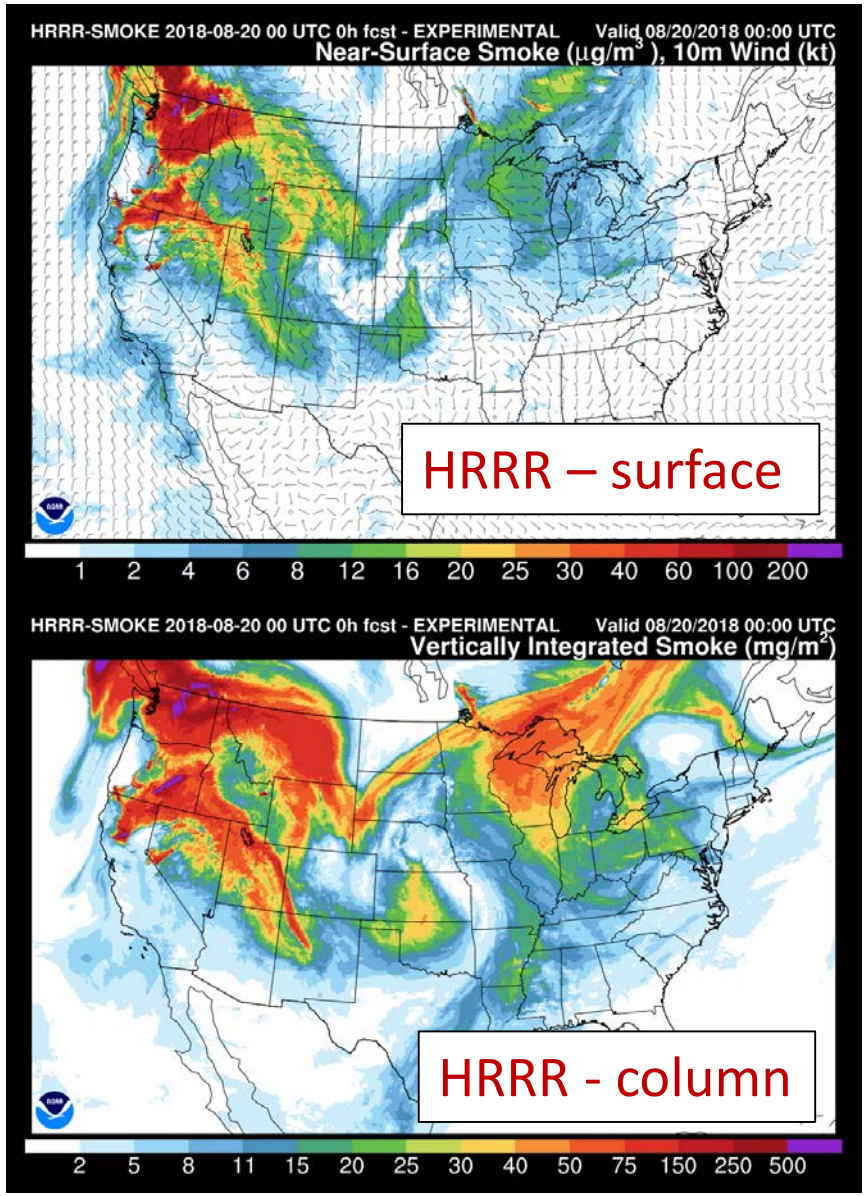


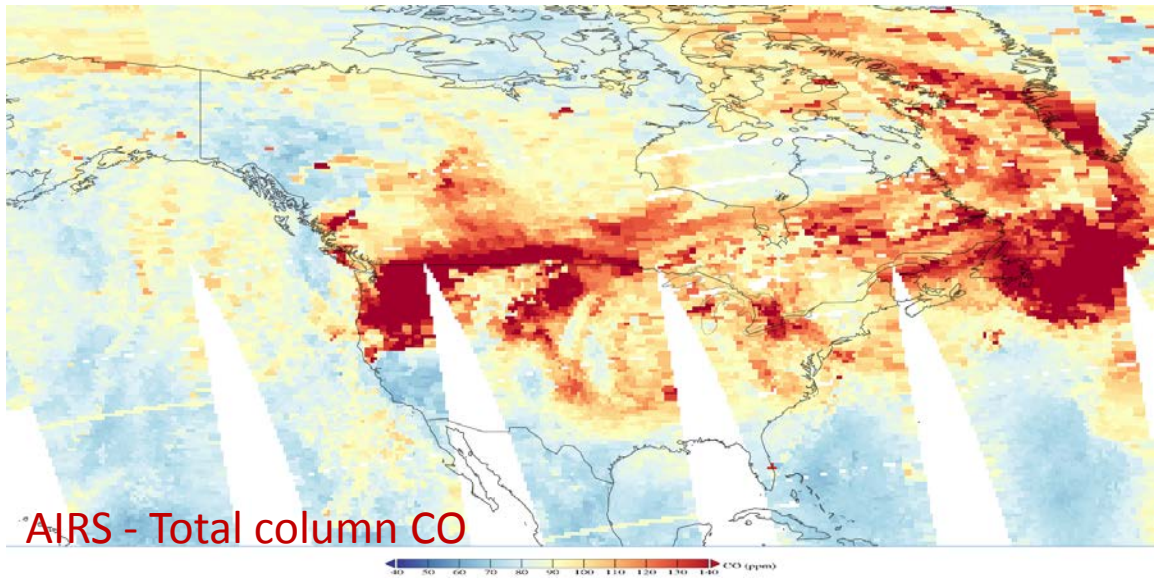
2018-08-18 23:02:31 - 2018-08-18 23:57:31



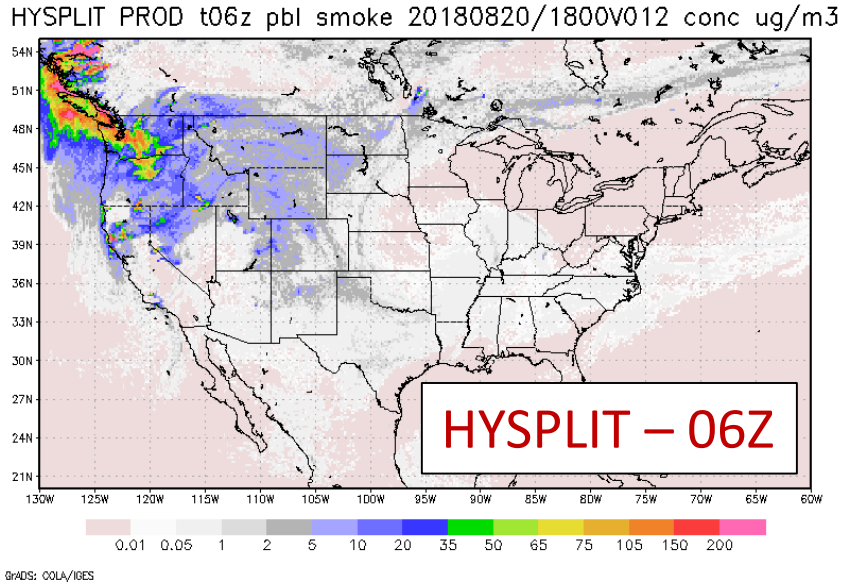
2018-08-19 23:02:31 - 2018-08-19 23:57:31

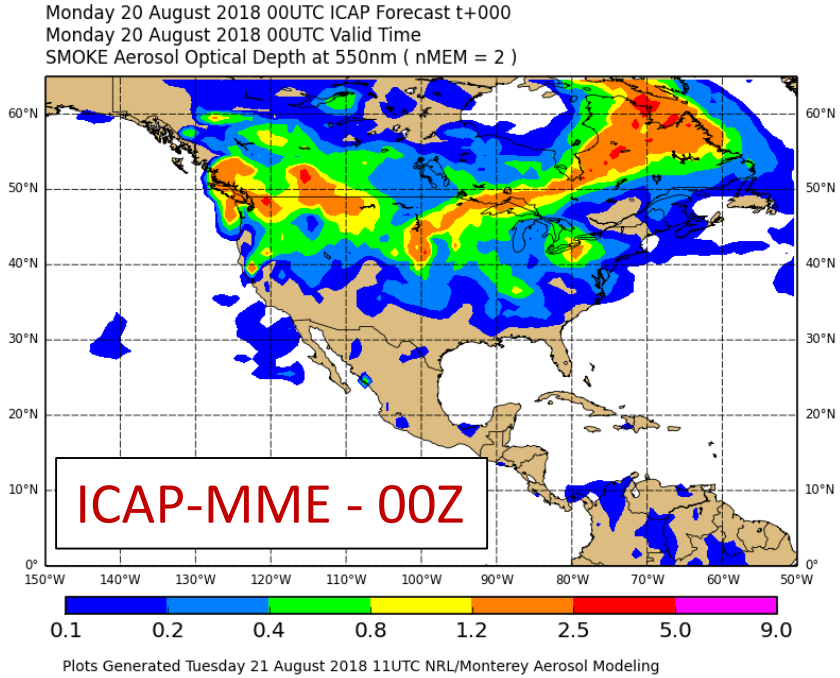



HRRR-SMOKE 2018-08-20 00 UTC 0h fcst - EXPERIMENTAL
Valid 08/20/2018 00:00 UTC
Near-Surface Smoke (µg/m³), 10m Wind (kt)
1 2 4 6 8 12 16 20 25 30 40 60 100 200
HRRR – surface
HRRR-SMOKE 2018-08-20 00 UTC 0h fcst - EXPERIMENTAL
Valid 08/20/2018 00:00 UTC
Vertically Integrated Smoke (mg/m²)
2 5 8 11 15 20 25 30 40 50 75 150 250 500
HRRR - column

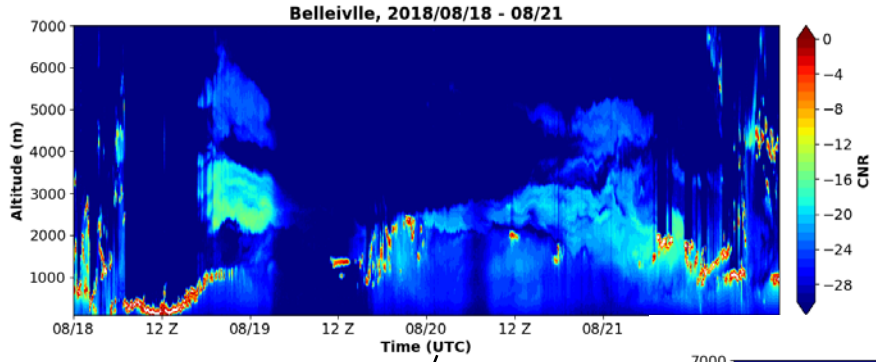

AIRS - Total column CO

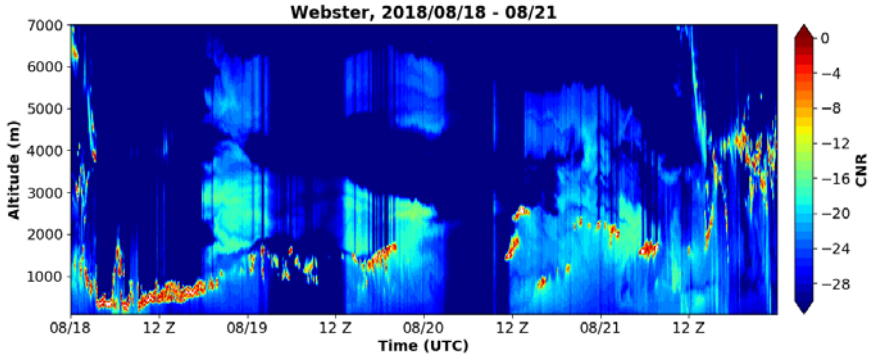
Aug 20, 2018

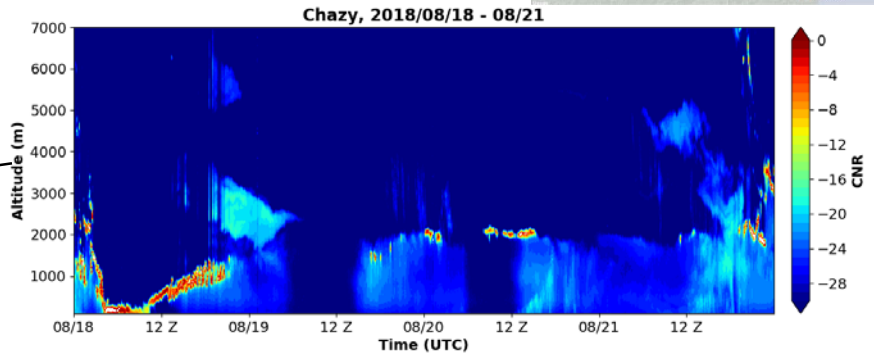

HYSPLIT PROD t06z pbl smoke 20180820/1800V012 conc ug/m3
0.01 0.05 1 2 5 10 20 35 50 65 75 105 150 200
GrADS: COLA/IGES
HYSPLIT – 06Z

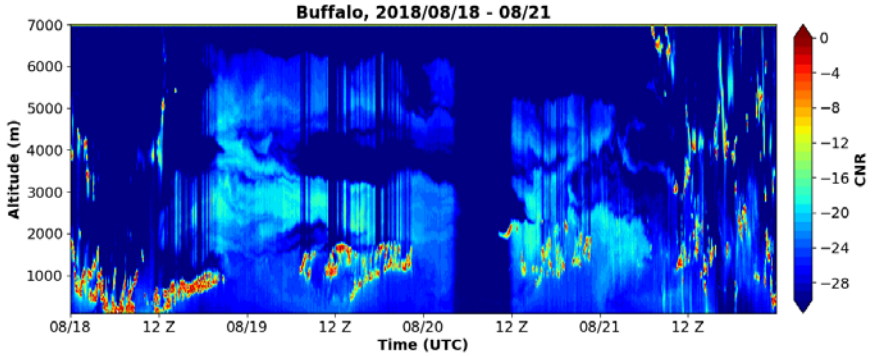

Monday 20 August 2018 00UTC ICAP Forecast t+000
Monday 20 August 2018 00UTC Valid Time
SMOKE Aerosol Optical Depth at 550nm (nMEM = 2)
0.1 0.2 0.4 0.8 1.2 2.5 5.0 9.0
Plots Generated Tuesday 21 August 2018 11UTC NRL/Monterey Aerosol Modeling
ICAP-MME - 00Z

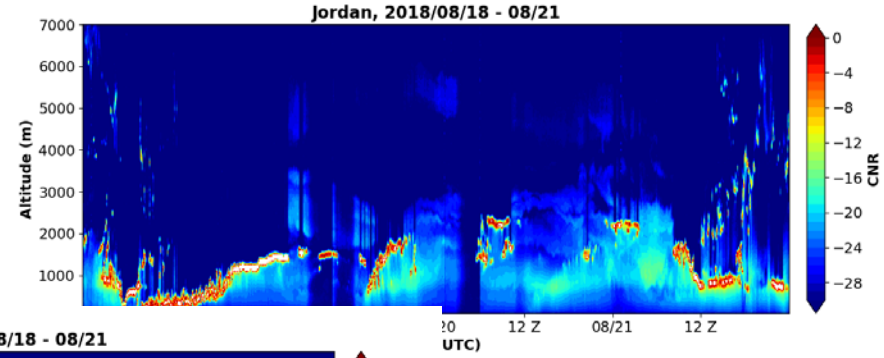
Profiler observations (Aug 18-20, 2018)

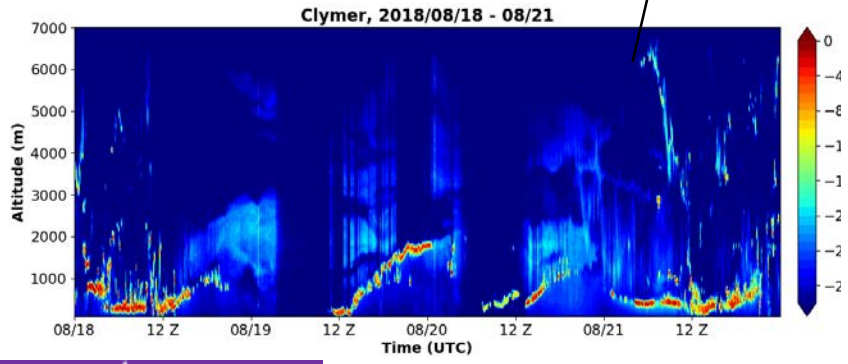


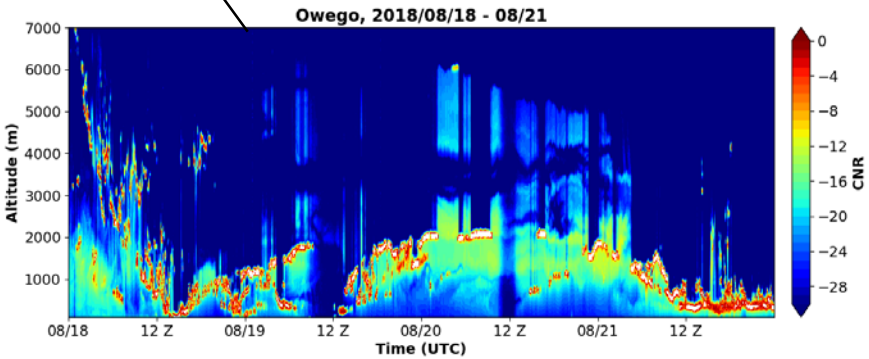


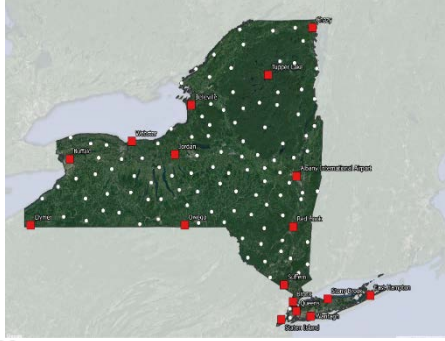












Concluding Remarks

- Critical contributions by VIIRS and GOES-16 aerosol products for air quality applications over NYS
- Synergistic activities -- AOD observations in conjunction with aerosol model/reanalysis, surface network, and other satellite retrievals

Thanks.

Questions or comments?