



Scaling Satellite-derived Aerosol Optical Depth (AOD) to Surface PM2.5: Opportunities and Challenges

Shobha Kondragunta¹ and Hai Zhang^{1,2}

¹NOAA NESDIS Center for Satellite Applications and Research

²I. M. Systems Group

Introduction

- Satellite retrieved aerosol optical depth (AOD) can help monitor and forecast PM2.5
 - Fill spatial gaps in ground observations
 - Track aerosol transport
- Estimates of surface PM2.5 using MODIS and VIIRS AOD are displayed at NOAA near real time websites
 - <https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/>
 - <https://www.star.nesdis.noaa.gov/smcd/spb/aq/eidea/>
- Surface PM2.5 estimates are also piped to Sonoma Technology Inc. (for EPA Air Quality Index updates)



<https://asdp.airnowtech.org/>

STI Sonoma Technology

SERVICES PROJECTS ABOUT CAREERS CONTACT US

Search...

Improving EPA's AirNow Air Quality Index Maps with NASA Satellite Data

Clients: U.S. Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA)

In conjunction with our partners, STI developed the [AirNow Satellite Data Processor \(ASDP\)](#), a suite of programs in the AirNow Information Management System. The ASDP fuses NASA satellite-estimated surface PM_{2.5} concentrations with ground-based PM_{2.5} measurements to create new, contoured Air Quality Index (AQI) maps. The new AQI maps provide enhanced air pollutant information in regions where monitoring is sparse.

EPA's [AirNow program](#) provides the public with easy access to national ambient air quality information using a health effects based scale (the AQI). AirNow presents real-time hourly AQI conditions and daily AQI forecasts by interpolating AQI levels to a grid and creating maps that cover national, regional, and local spatial scales. However, significant gaps in the coverage of ground-based PM_{2.5}, ozone, and NO₂ monitors prevent complete nationwide mapping of pollutant concentrations in the United States. When interpolated and contoured, AQI levels in regions far from monitors may have higher uncertainty.

This work

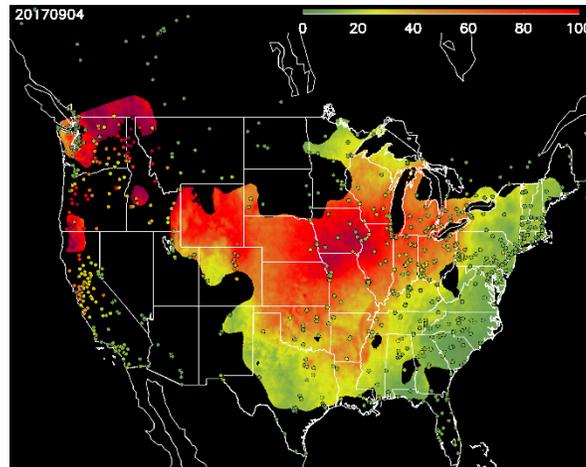
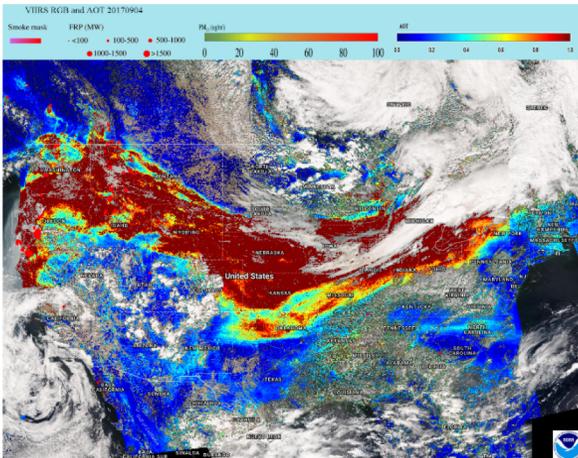
- Creates a method for fusing data sets from different sources that is applicable to other types of data and can be used internationally.
- Provides air quality information in regions without monitors and enhances the air quality information in regions with monitors.
- Provides additional air quality information for air quality forecasters and decision makers.

Air Quality Data Management Data Visualization Emissions Exposure Measurements Modeling Public Outreach

Software Development

Background

- The AOD to PM2.5 conversion algorithm currently used at NOAA is based on van Donkelaar et al., Env.Sci.Tech., 2012
- Method originally developed for MODIS now adapted for VIIRS



Re-grid AOD into fixed grid with 4km spatial resolution covering CONUS region



Apply predefined AOD filter to remove areas with poor AOD accuracy (based on validation with AERONET)



AOD to PM2.5 conversion using Look-up-table:
Linear relation $PM_{2.5} = A \times AOD + B$
Daily temporal resolution and 4 km spatial resolution on fixed grid



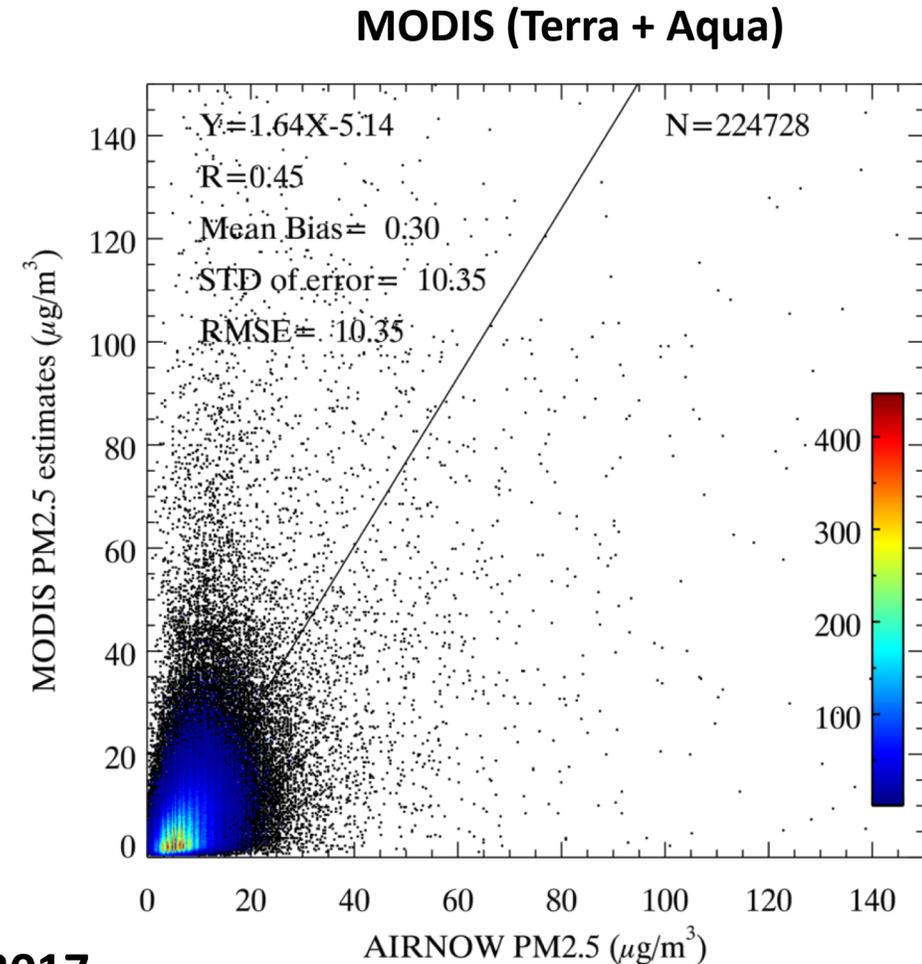
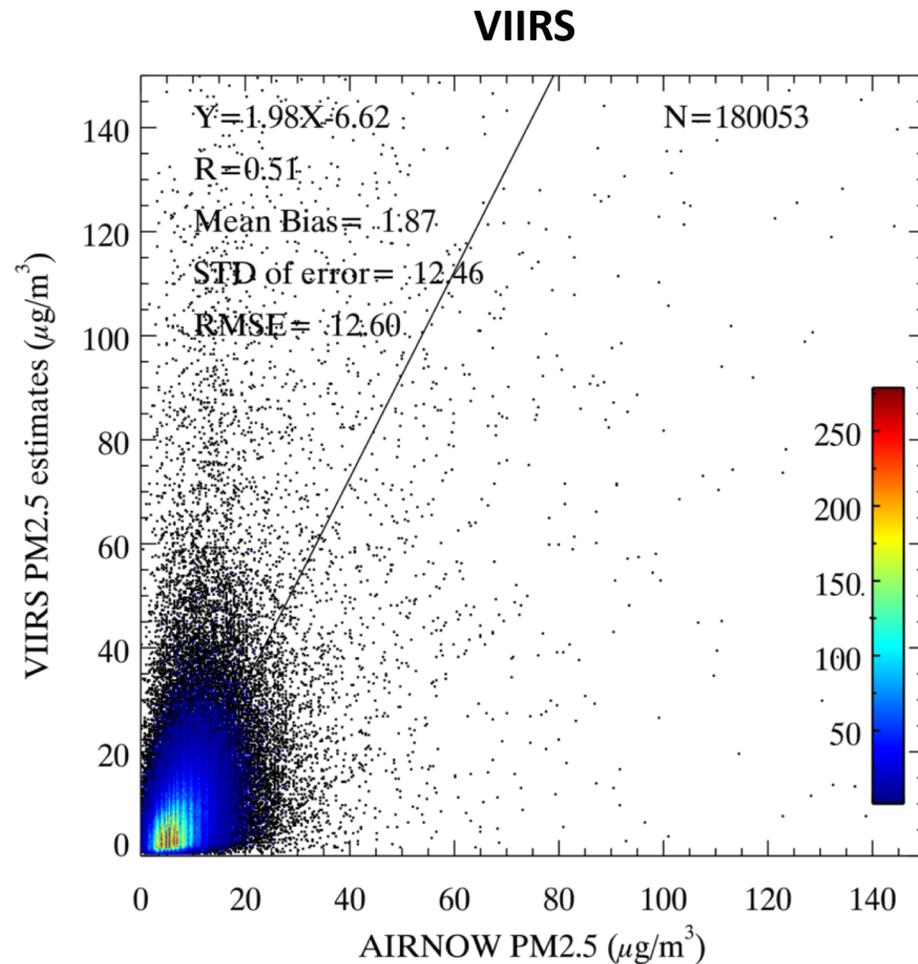
Smooth the estimated PM2.5 using inverse distance weighting and PM2.5 climatology

$$PM_{2.5,SBC} = \frac{\sum_{i=1}^m \left(\frac{N}{d^2} \right)_i \times \left(\frac{PM_{2.5,BC}}{PM_{2.5,c}} \right)_i}{\sum_{i=1}^m \left(\frac{N}{d^2} \right)_i} \times PM_{2.5,c}$$



Apply weight threshold map to remove areas with small weights or bad performance

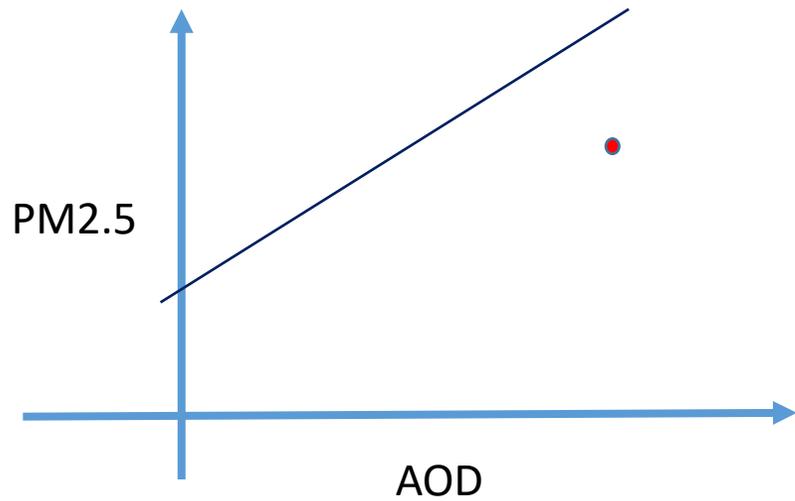
Evaluation of Current Method



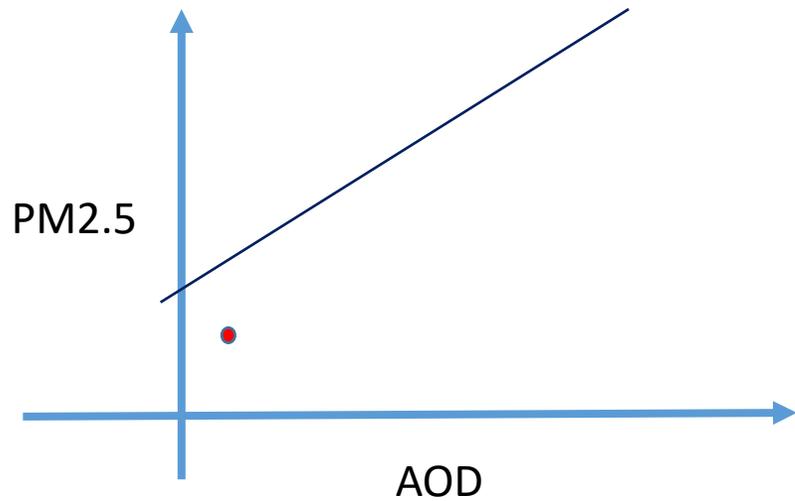
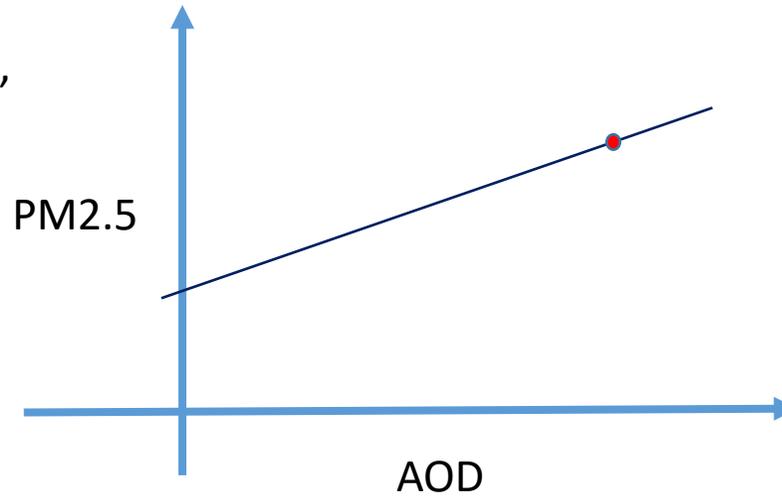
2015 - 2017

Improve AOD to PM2.5 conversion

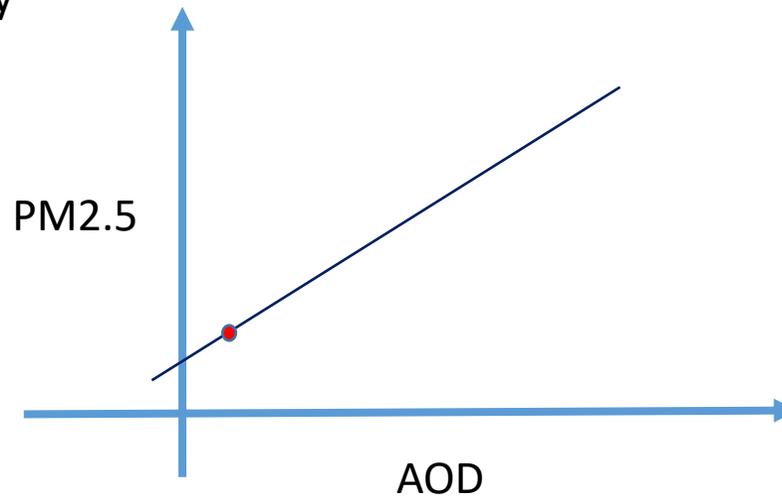
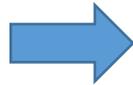
- AOD vs PM2.5 relationship is dynamic
- A new method with dynamic updates of slopes and intercepts developed
 - PM2.5 known at the stations (obtained within 2 hrs of observation)
 - **Modify slopes and intercepts at each station using PM2.5 and AOD matchup data**
 - **Interpolate slopes and offsets across the domain**
 - **Use the new slopes and offsets to calculate PM2.5 using AOD**
- Daily PM2.5 (for AOD from polar-orbiting satellites) or hourly PM2.5 (for AOD from geostationary satellites)



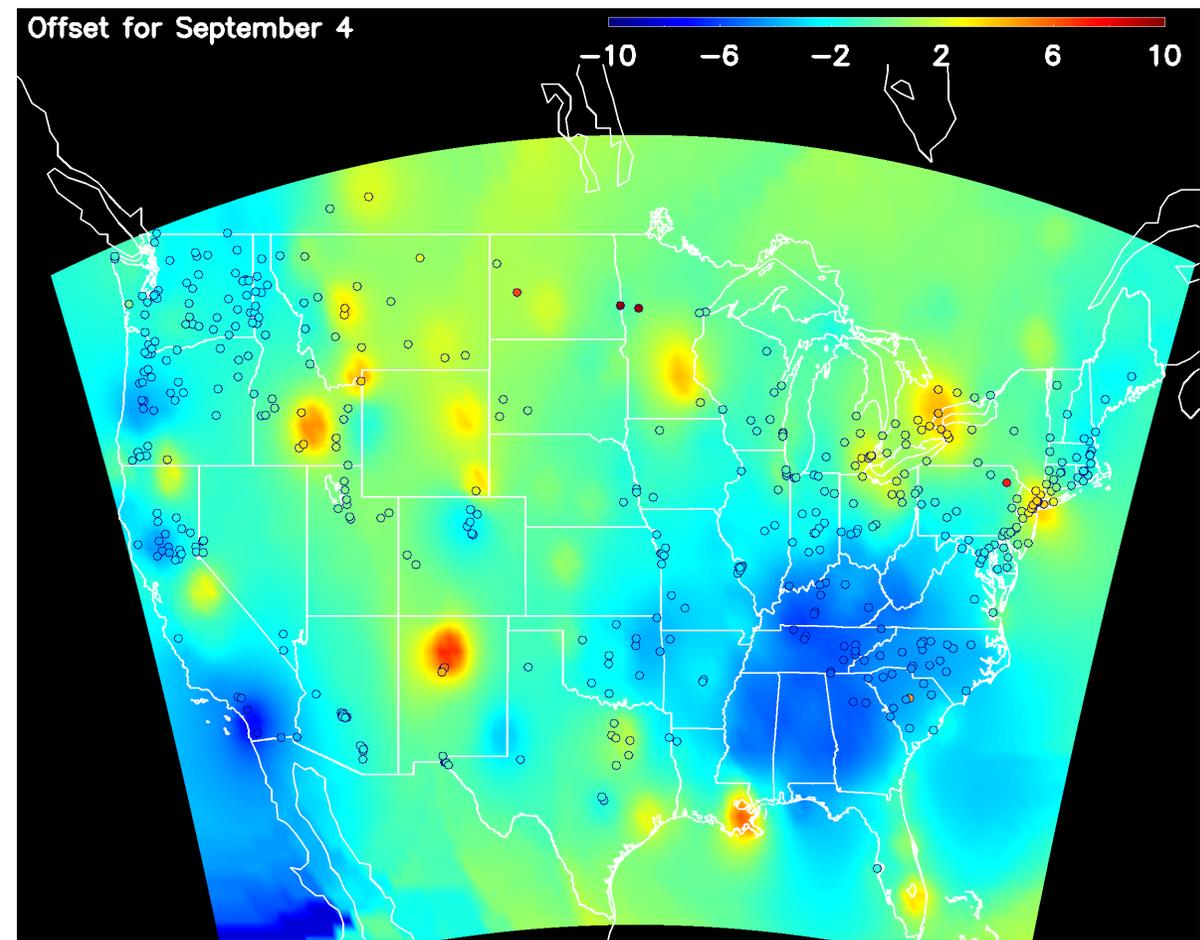
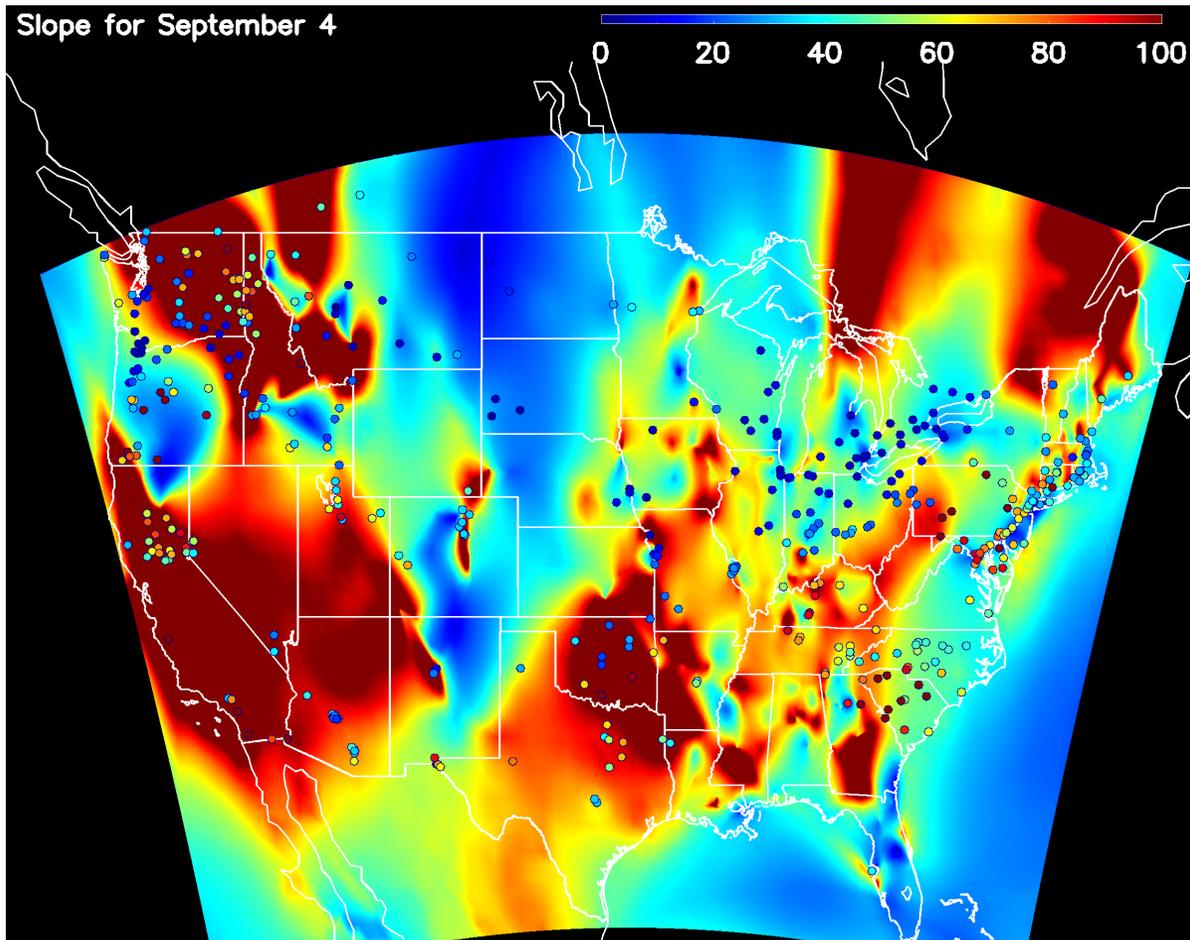
AOD > 0.1,
modify the slope,
keep the offset
unchanged



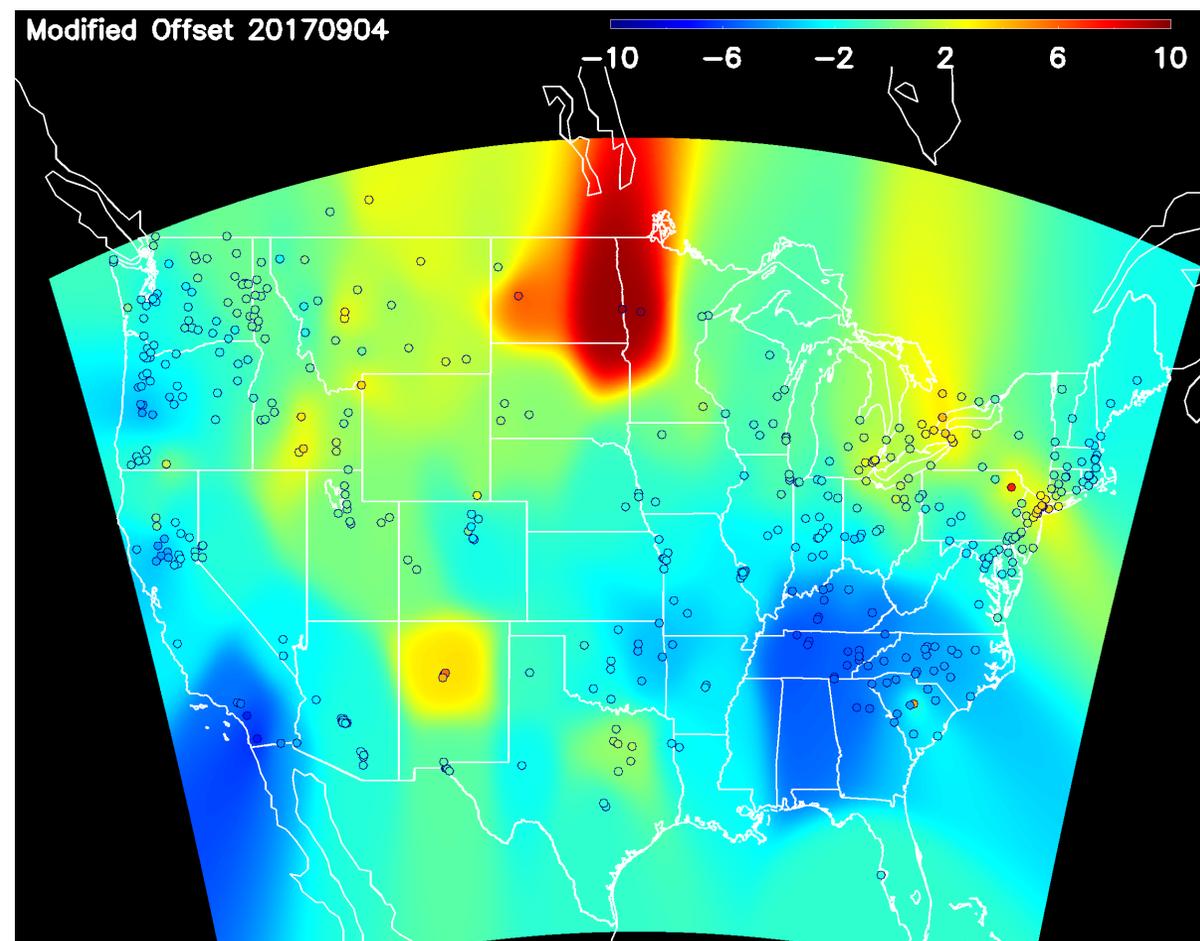
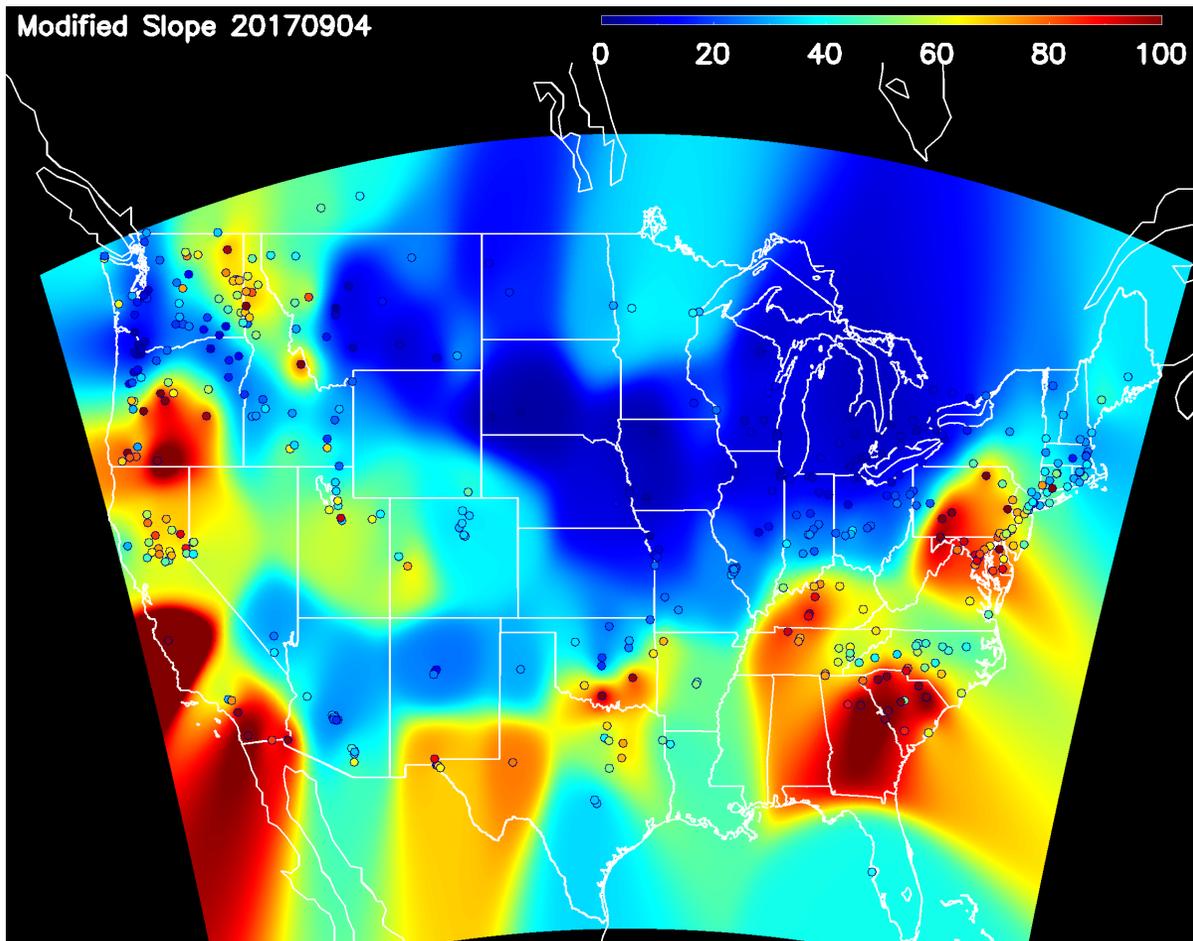
AOD ≤ 0.1, modify
the offset, keep
the slope
unchanged



Schematic of Near Real Time Tuning of Regression Parameters



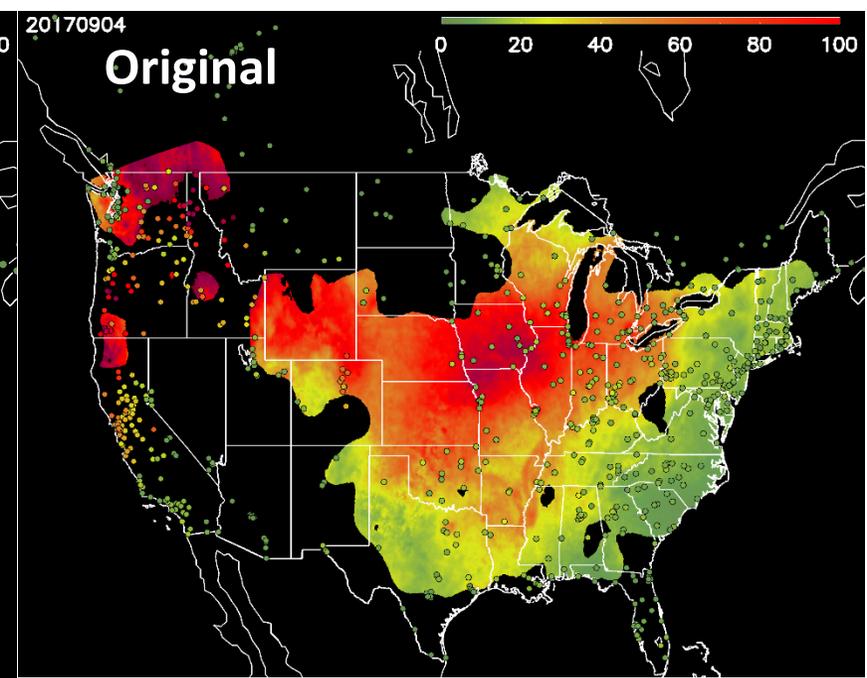
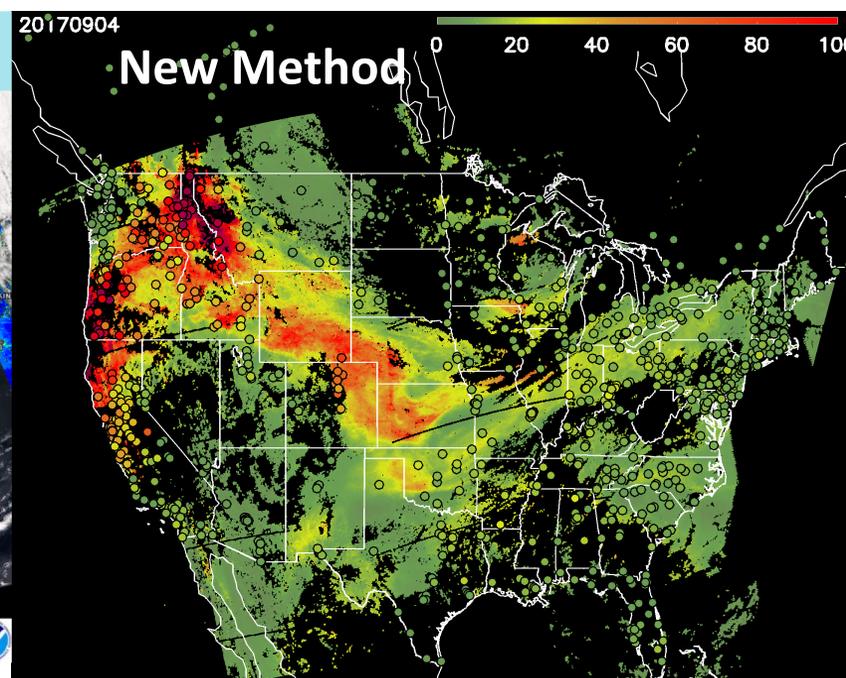
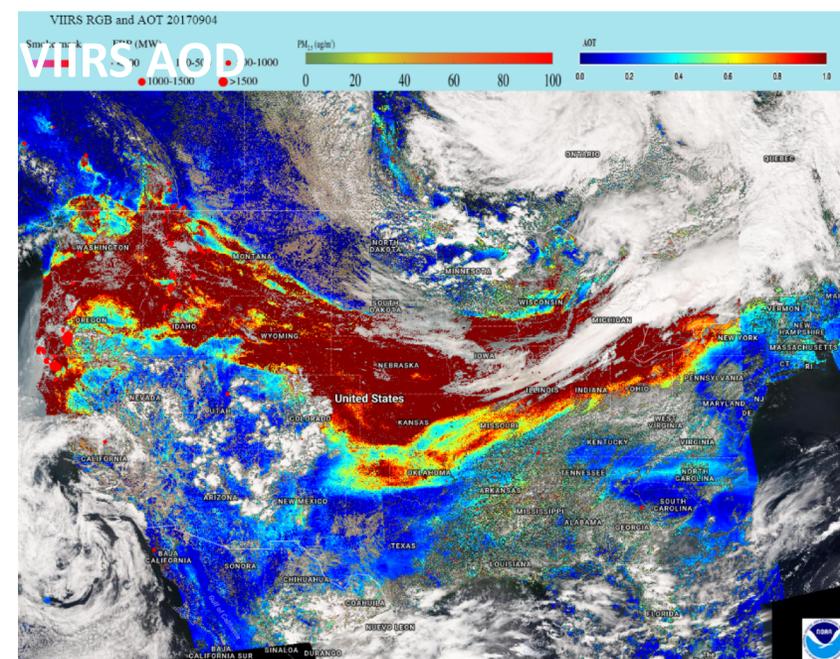
- Slope for the regression equation shown on the left
- Intercept for the regression equation shown on the right
- Overlaid on the real time slopes and intercepts for AIRNOW stations to highlight how different they are from the ones we have based on Donkelaar et al. method



Near time slopes (left panel) and intercepts (right panel) at AIRNOW stations interpolated

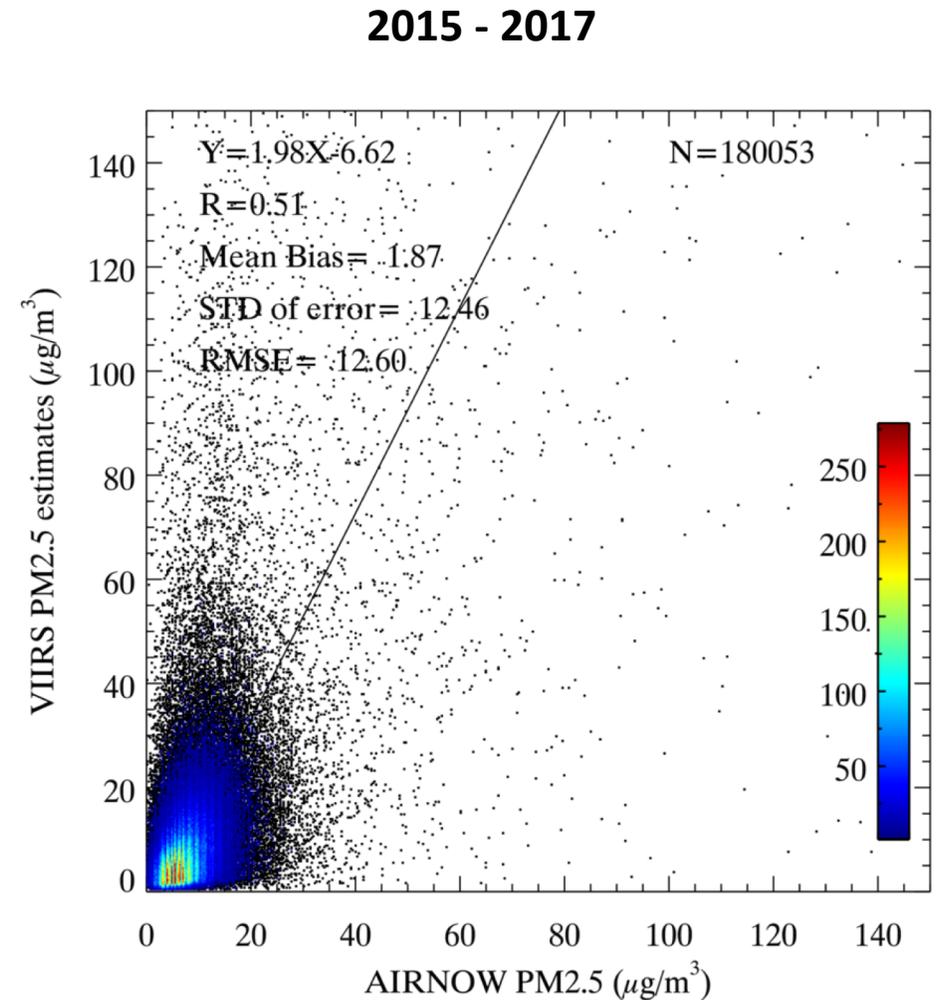
Results

- Expanded coverage
- Improved surface PM2.5 estimates



Evaluation of New Method

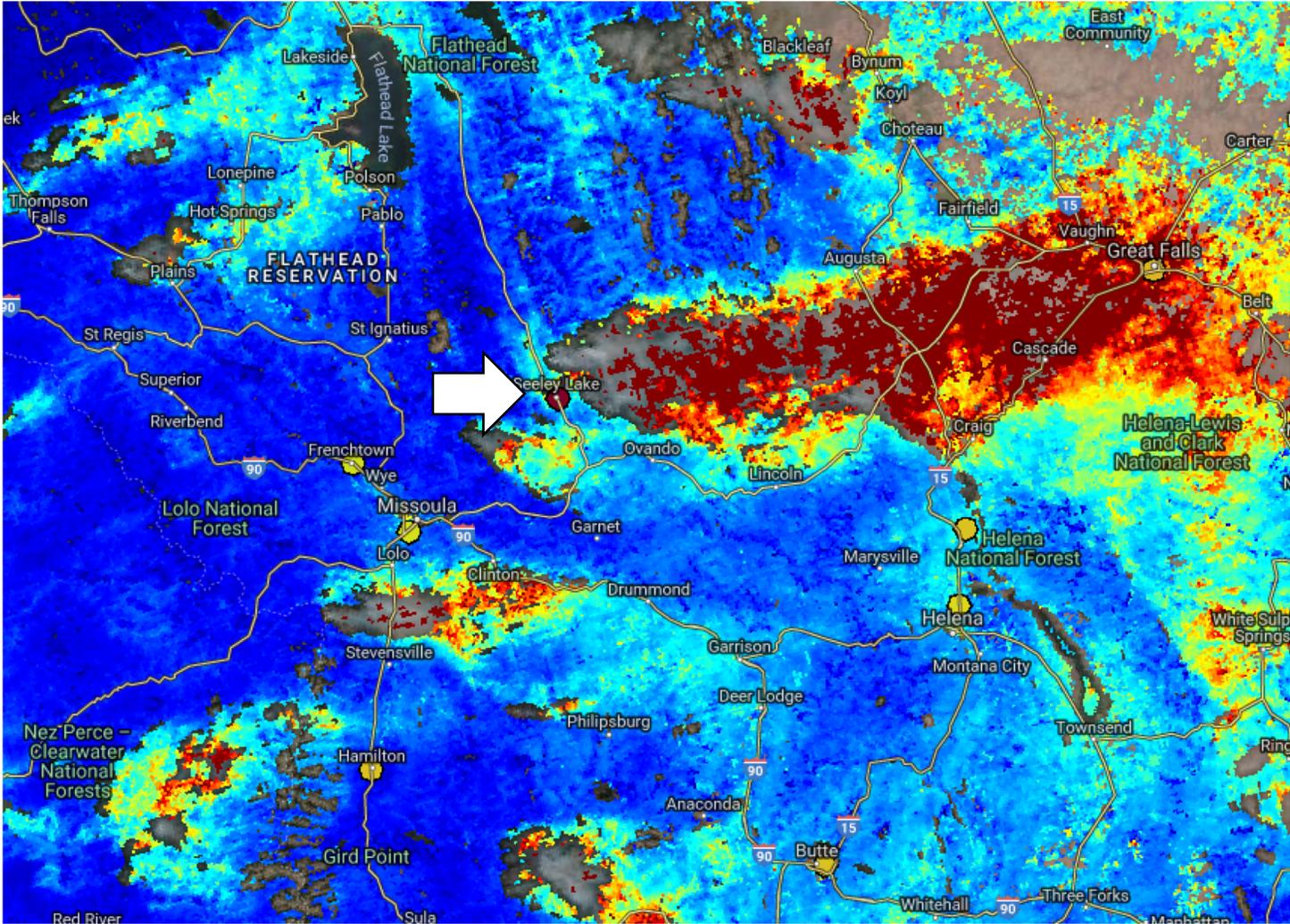
- At each site used for validation
 - obtain slope and offset through interpolation from other sites. (The slopes and intercepts at the other sites are obtained through PM2.5-AOD matchup)
 - Estimate PM2.5 from AOD at this site using the interpolated slope and offset
 - Compare estimated PM2.5 and AIRNOW PM2.5 (surface measurements)
- Repeat the above procedure for every site



AOD-PM2.5 Issues

- Traditional concerns are:
 - Boundary layer height
 - Aerosol composition
 - Relative humidity
 - Etc.
- Issues we think that are also important
 - Diurnal variation of PM2.5
 - High AODs (>2.0) that are not reported or flagged as out of range
 - Spatial averaging of AOD around a ground station

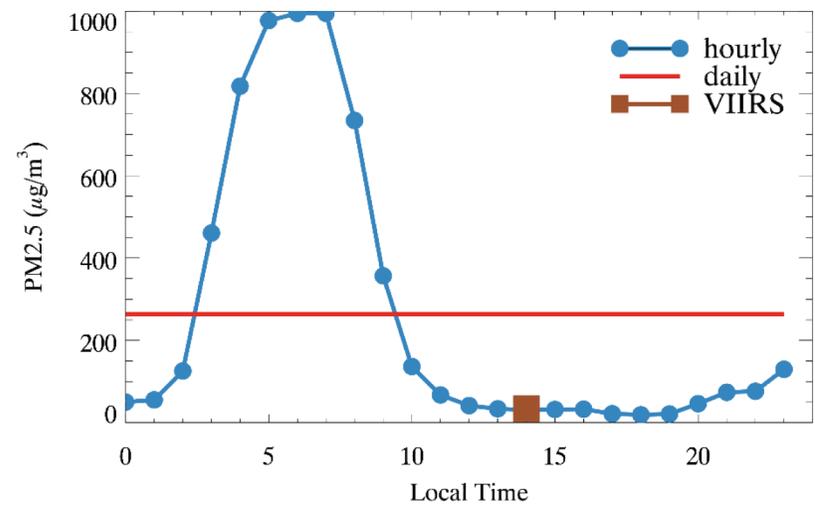
Seeley Lake (300630038) 20170901



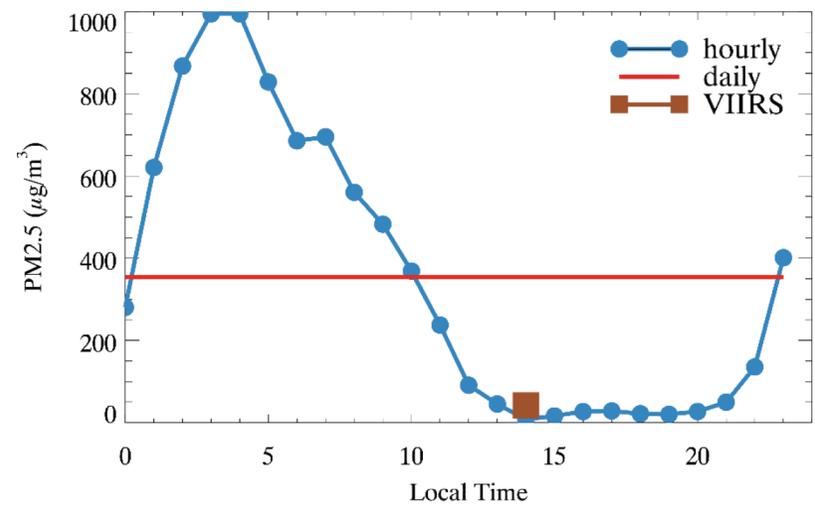
SNPP VIIRS AOD and AIRNOW PM2.5

Seeley Lake (300630038)

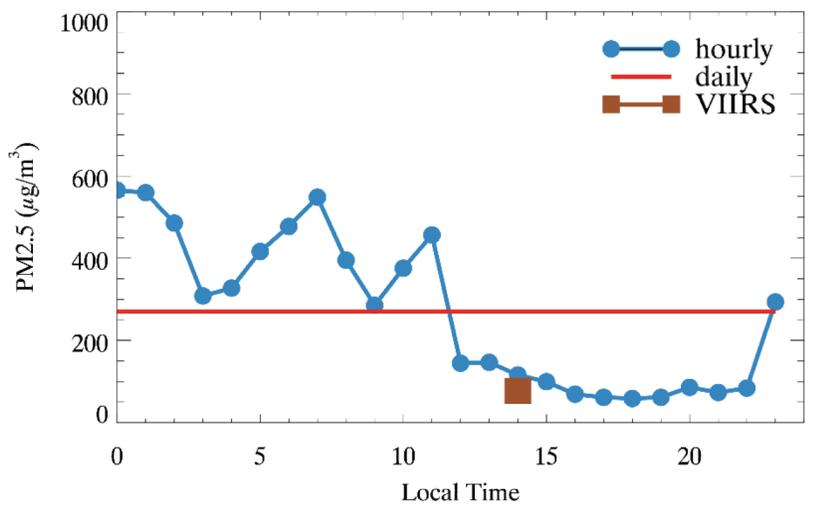
20170901



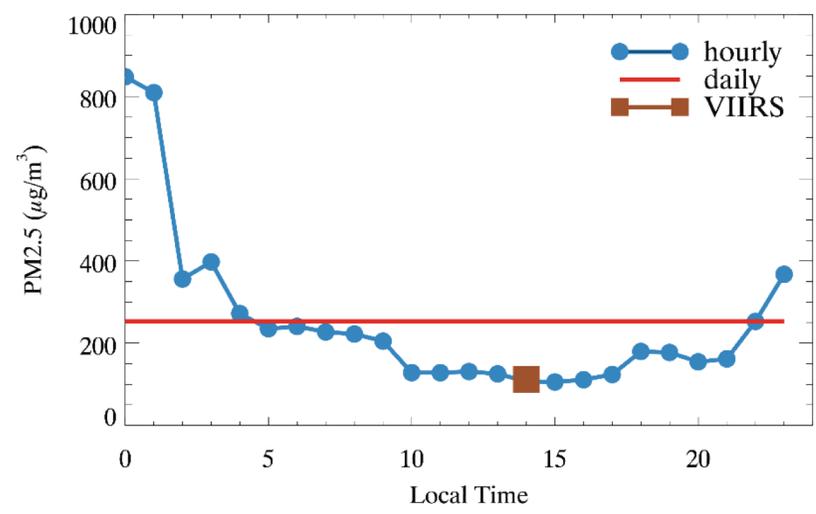
20170902



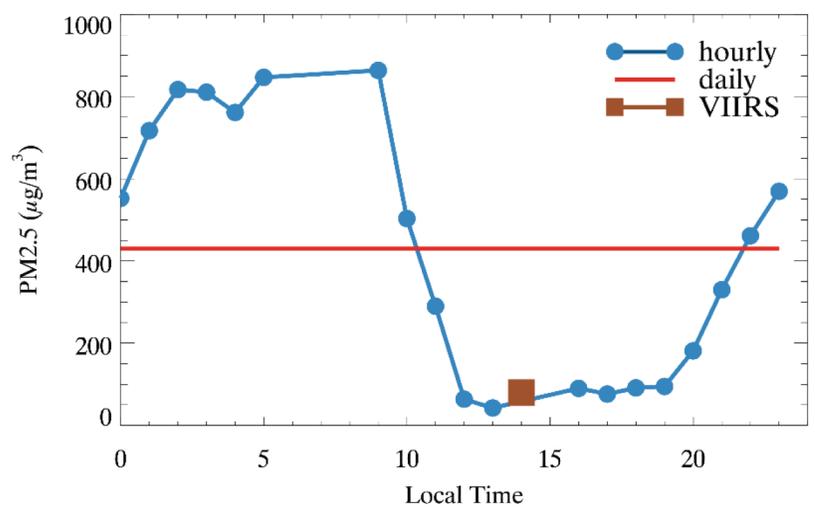
20170903



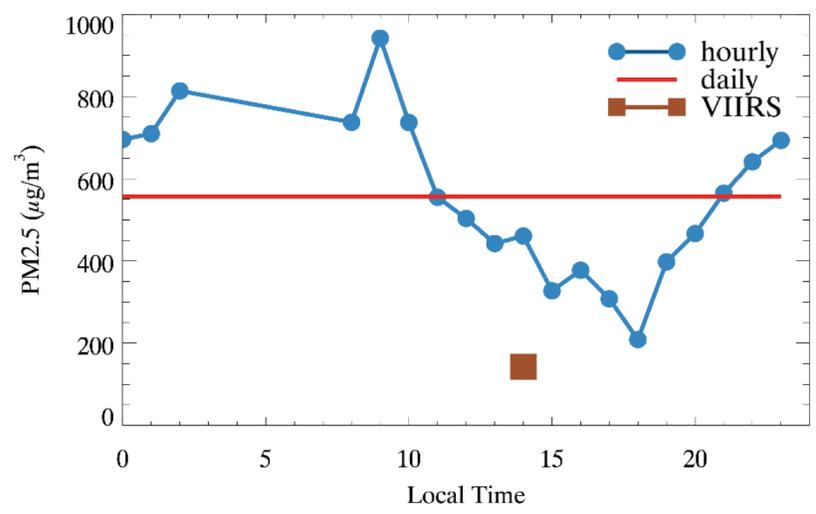
20170904



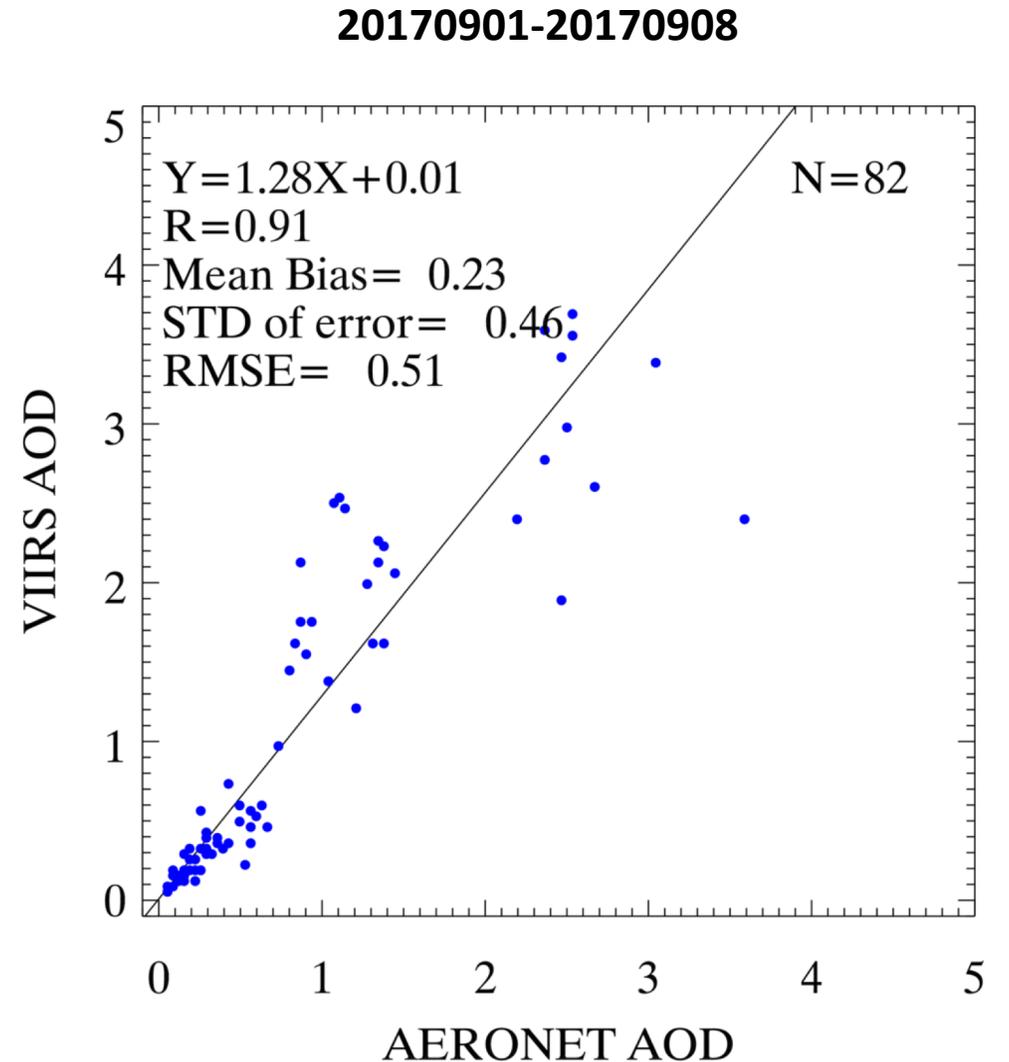
20170905



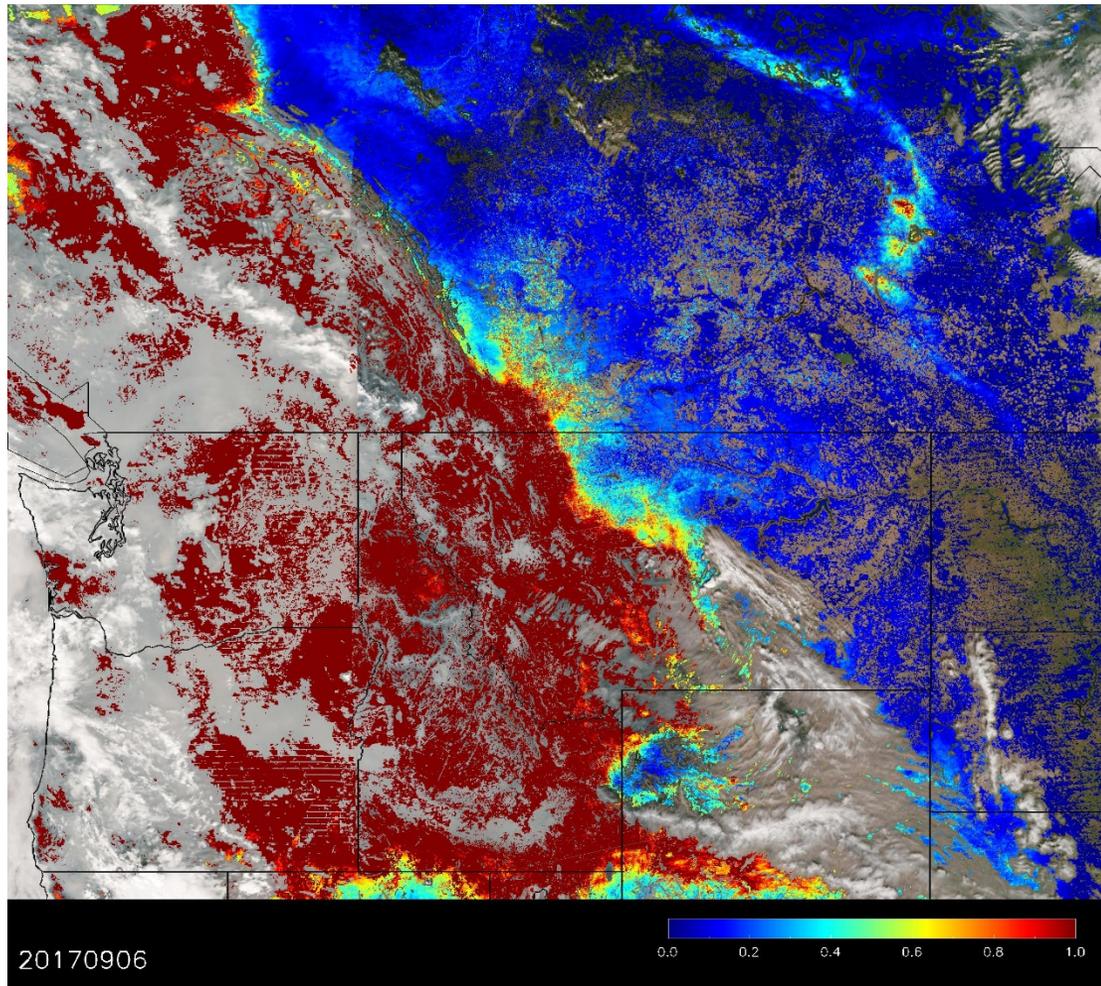
20170906



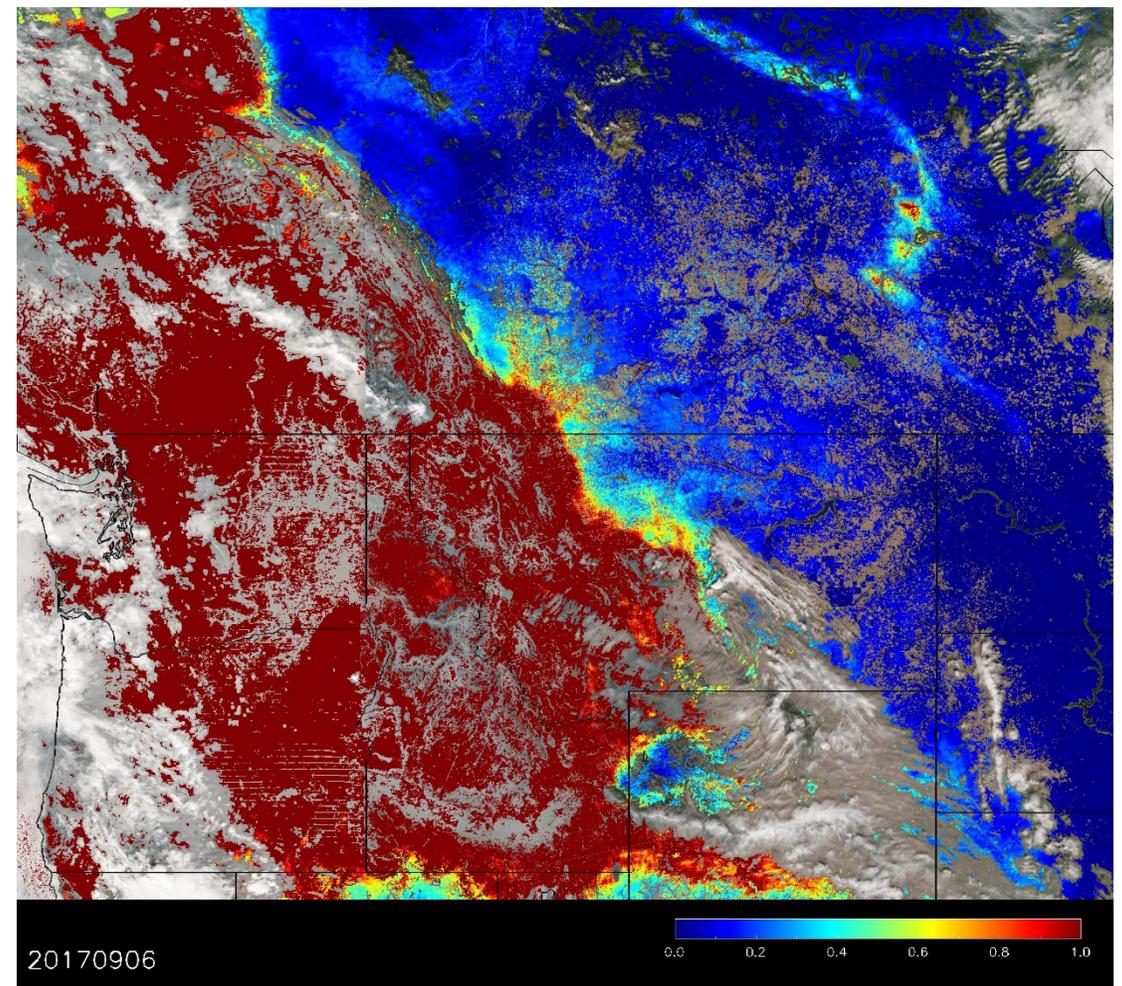
- Seven stations over Pacific NorthWest during a smoke event
- AODs from both AERONET and VIIRS have a big dynamic range
- VIIRS AODs are biased high but



High quality AOD



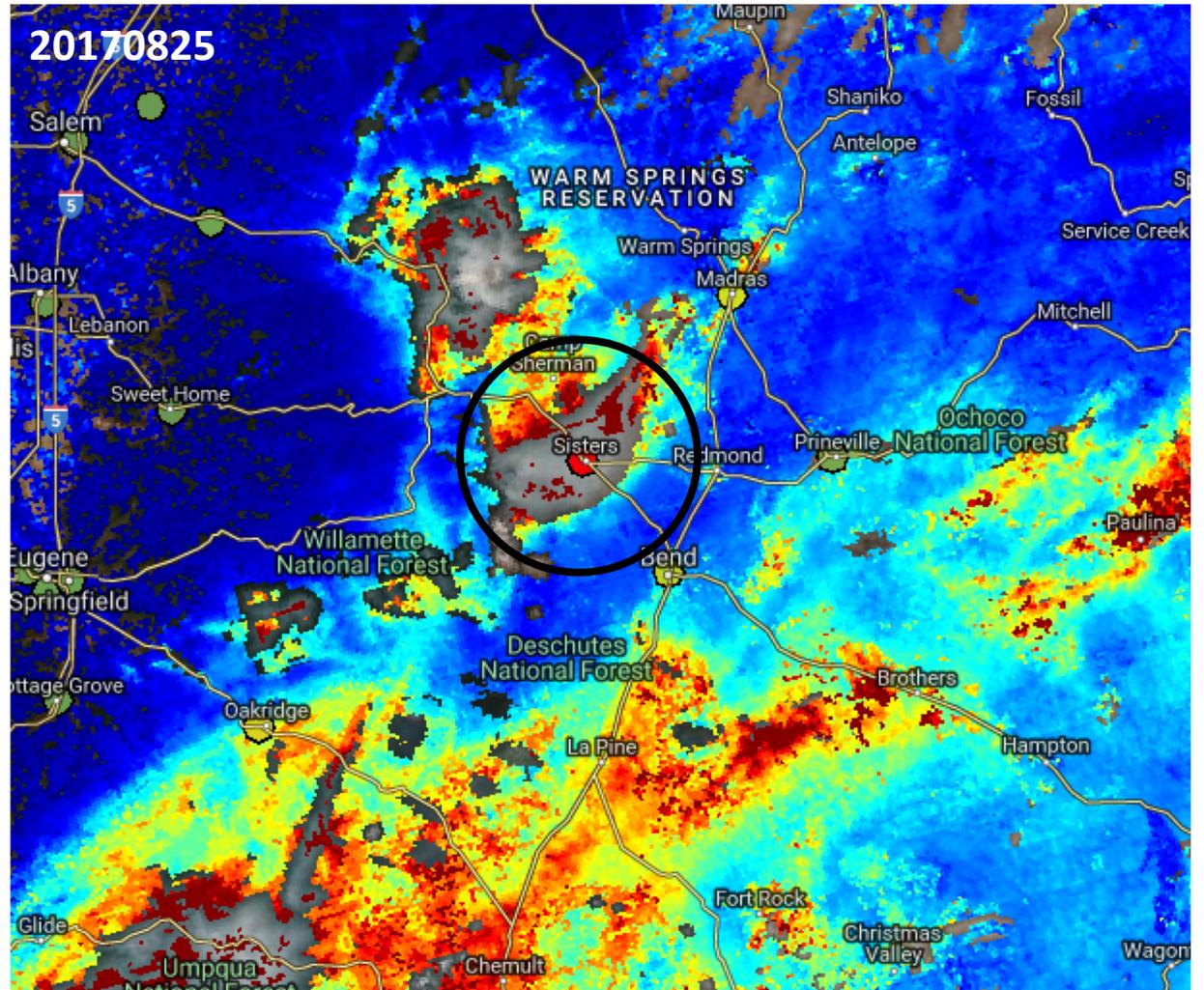
High quality AOD + out of range AOD



Adding out of range VIIRS AOD can improve AOD retrieval coverage and therefore expected to improve PM2.5 estimates coverage.

Spatial Sampling

- 27.5 km circle contains low AOD area for small scale smoke plume
- Very few AOD retrievals in the middle of the plume
 - Results in lower AOD for the smoke plume to be paired with high surface PM_{2.5}



Conclusions

- The use of a climatological relationship to convert AOD to PM2.5 tends to have large errors
 - The modified algorithm generates near-real-time AOD-PM2.5 relation. It can improve the PM2.5 estimates from AOD
- Using VIIRS or MODIS AOD (instantaneous values) to get daily average surface PM2.5 is not a reliable approach
 - Diurnal variation of PM2.5 is substantial, especially when events are episodic (high PM2.5 values) and boundary layer dynamics is varying during the day
- GOES-16 AOD is available now and will be applied to the United States region to test the estimates with high temporal resolution