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

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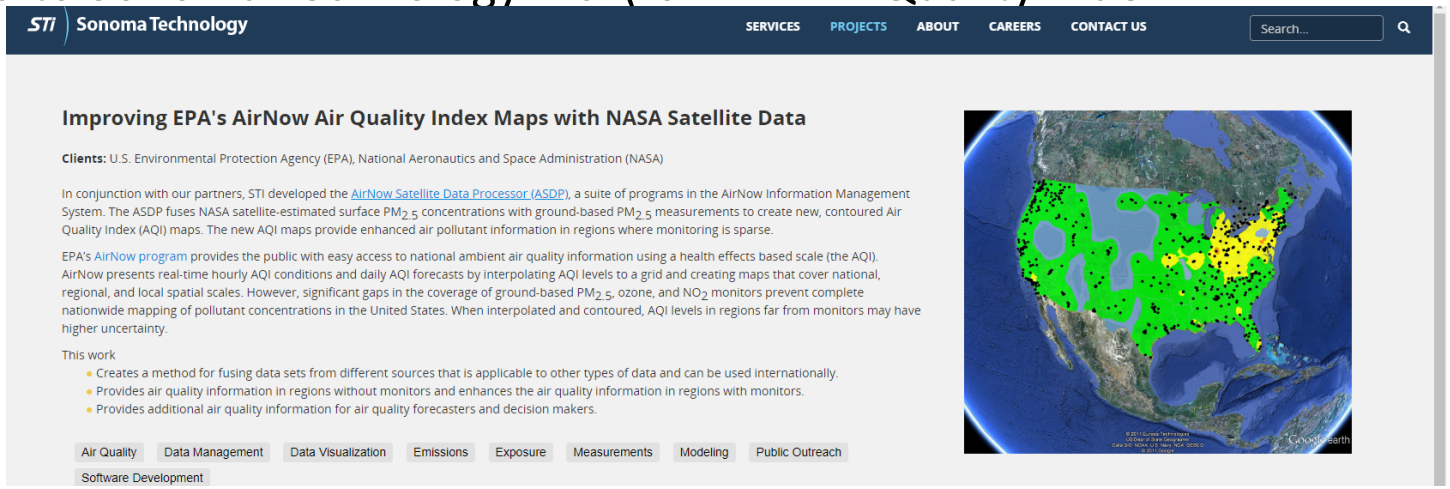
Introduction

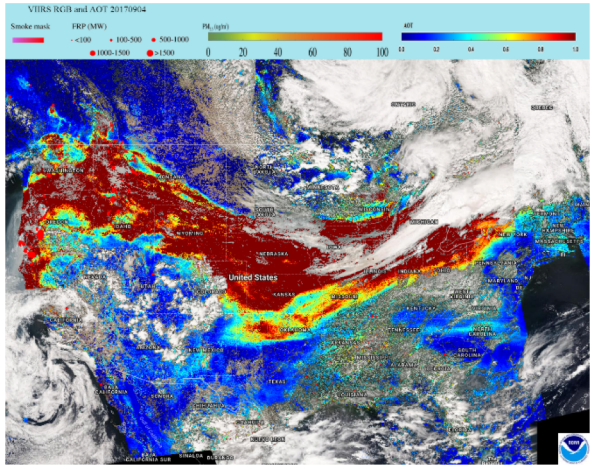
- Satellite retrieved aerosol optical depth (AOD) can help monitor and forecast PM2.5
  - Fill spatial gaps in ground observations
  - Track aerosol transport
- Estimates of surface PM2.5 using MODIS and VIIRS AOD are displayed at NOAA near real time websites
  - https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/
  - 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)

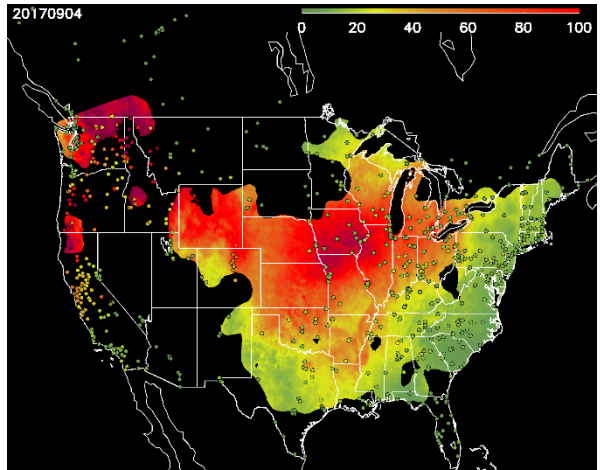
https://asdp.airnowtech.org/



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 PM2.5=A×AOD+B
Daily temporal resolution and 4 km spatial resolution on fixed grid

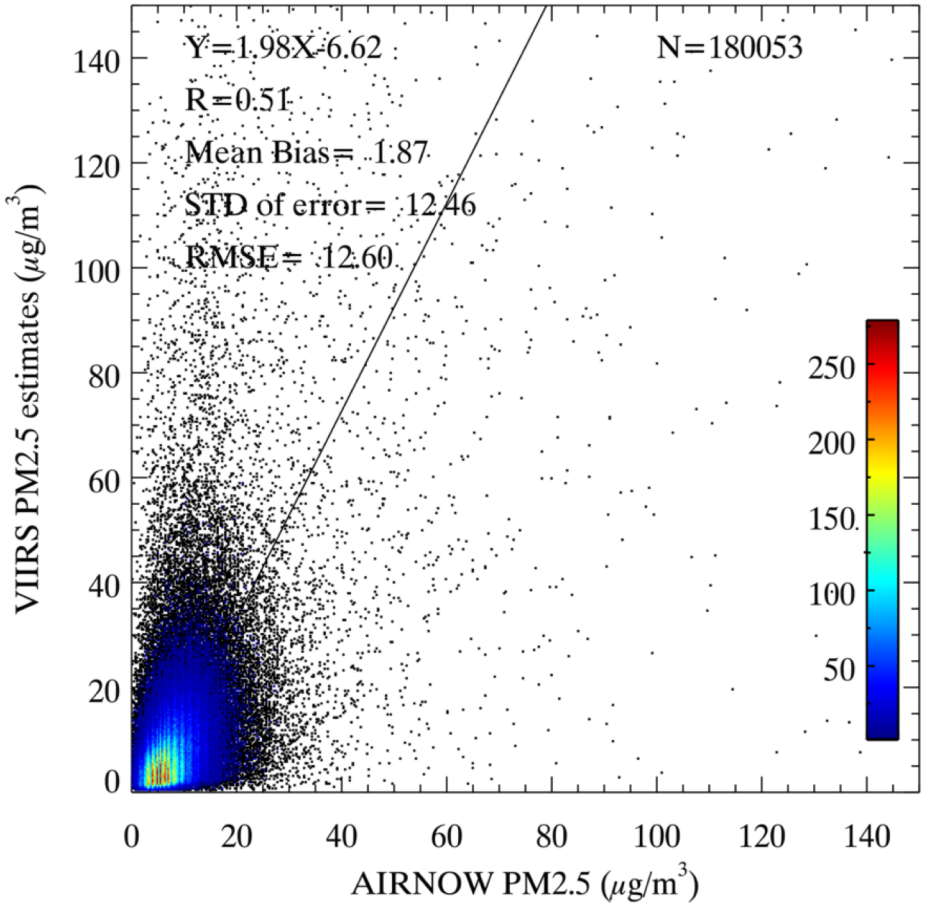
Smooth the estimated PM2.5 using inverse distance weighting and PM2.5 climatology

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

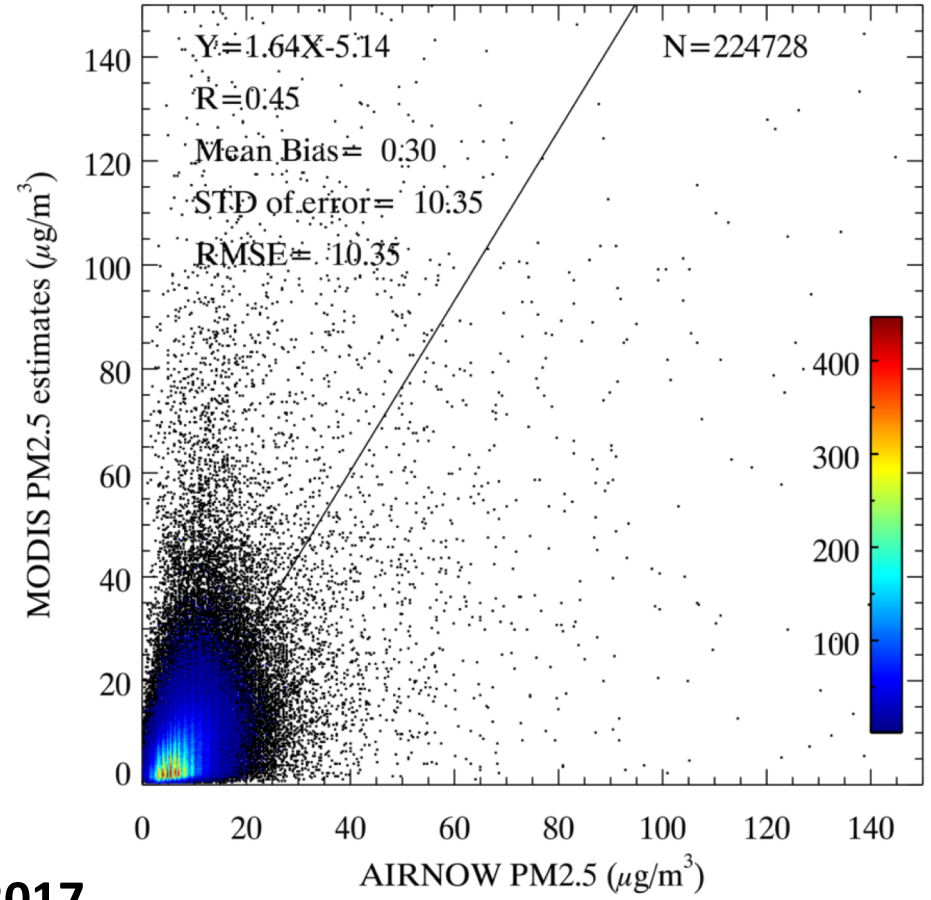
Apply weight threshold map to remove areas with small weights or bad performance

Evaluation of Current Method

VIIRS



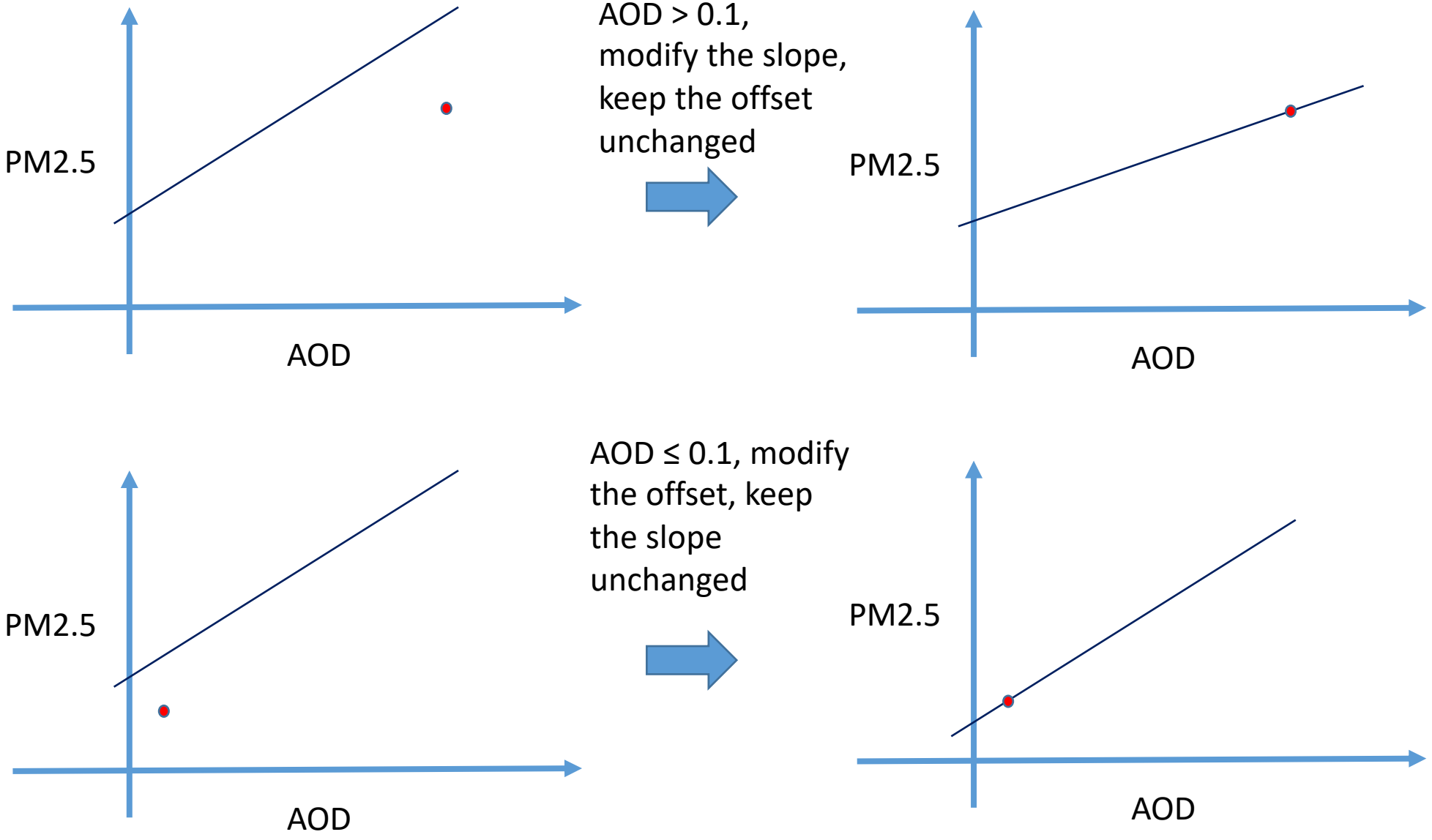
MODIS (Terra + Aqua)



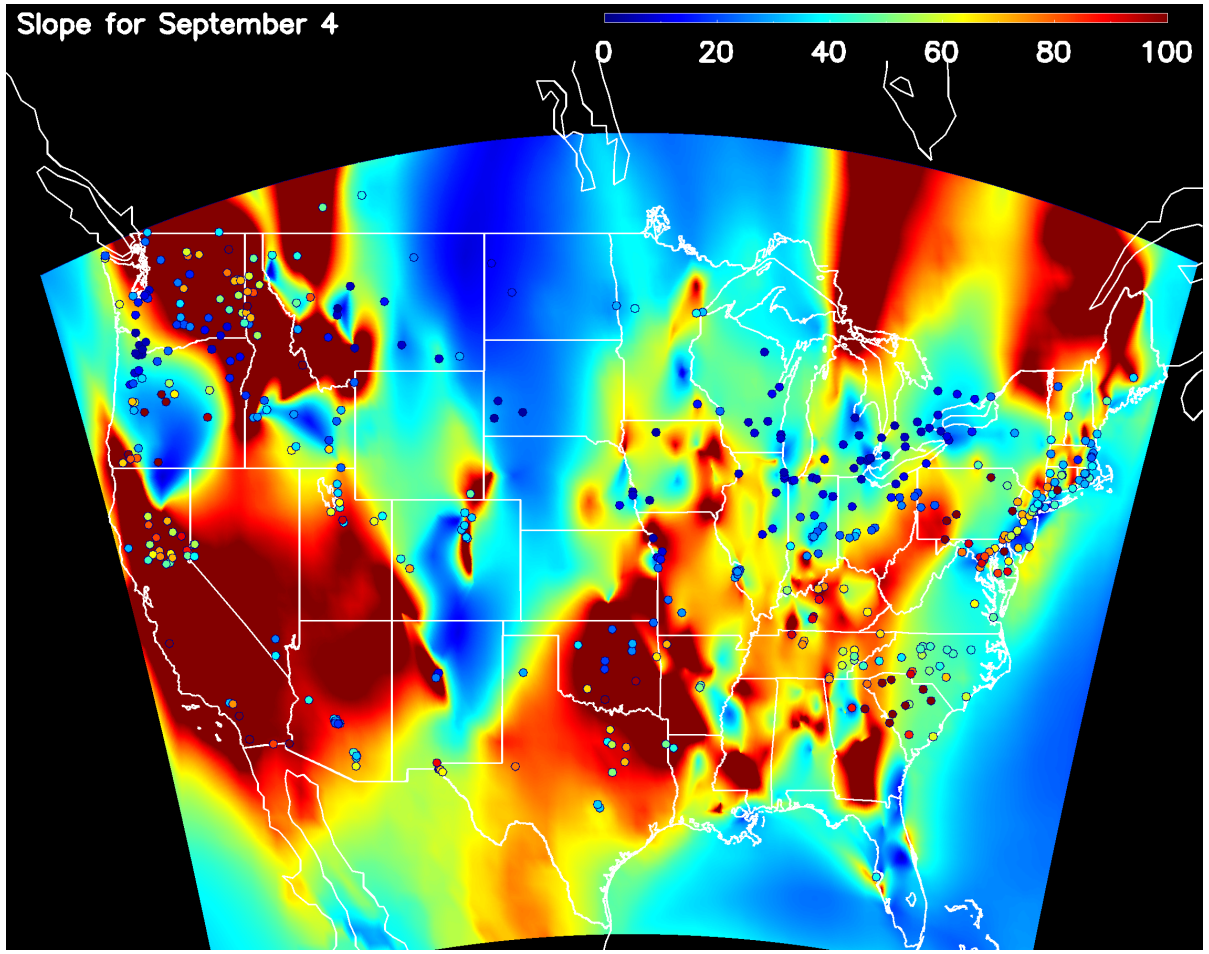
2015 - 2017

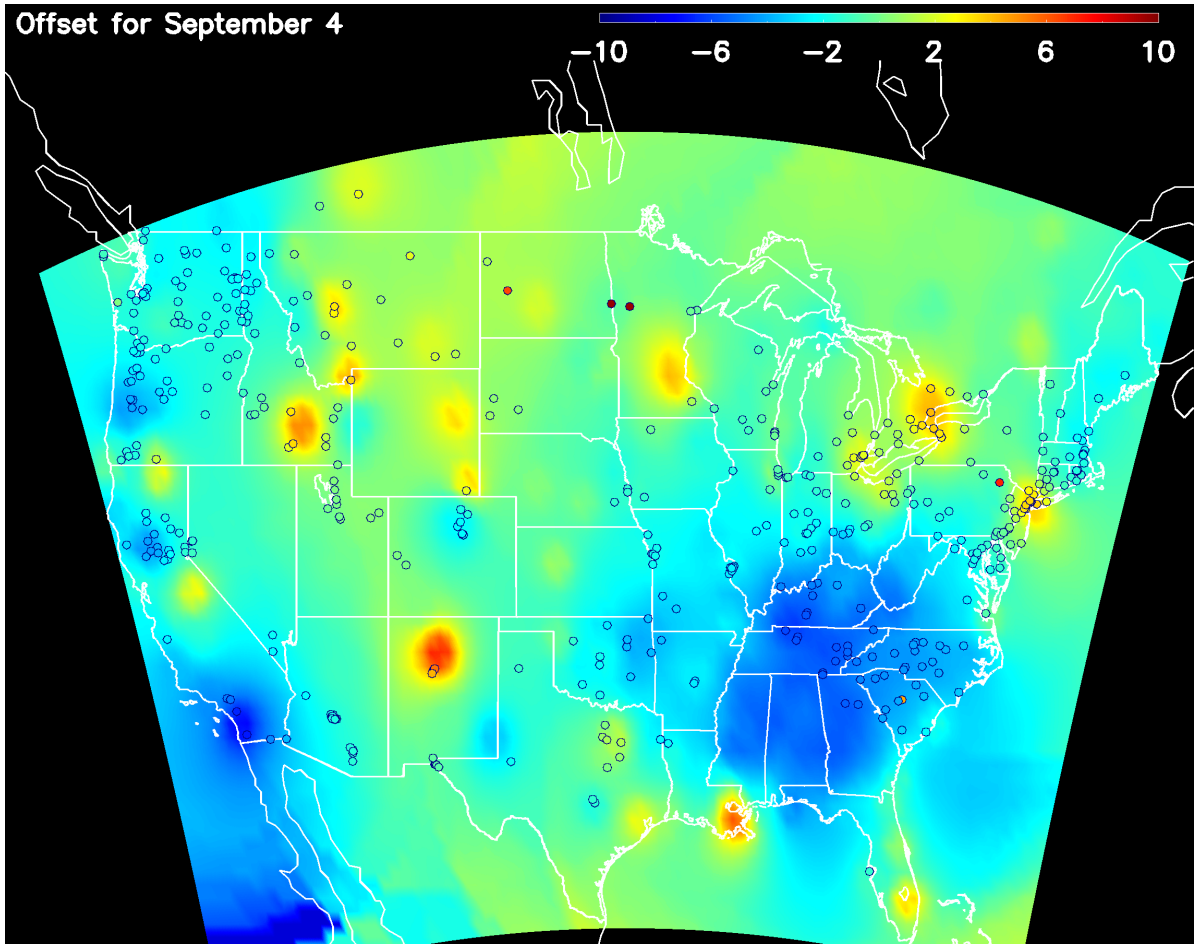
Improve AOD to PM2.5 conversion

- 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)

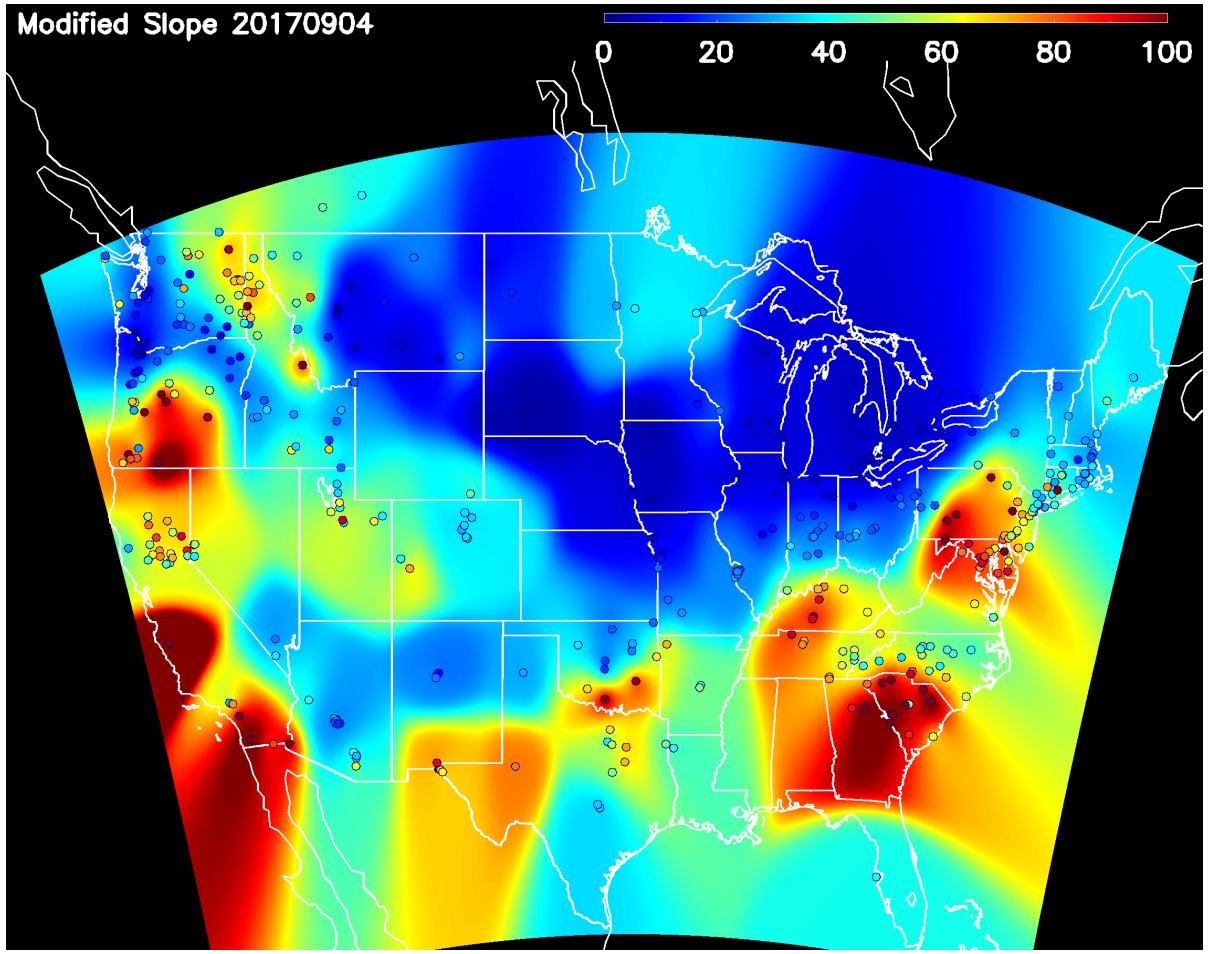


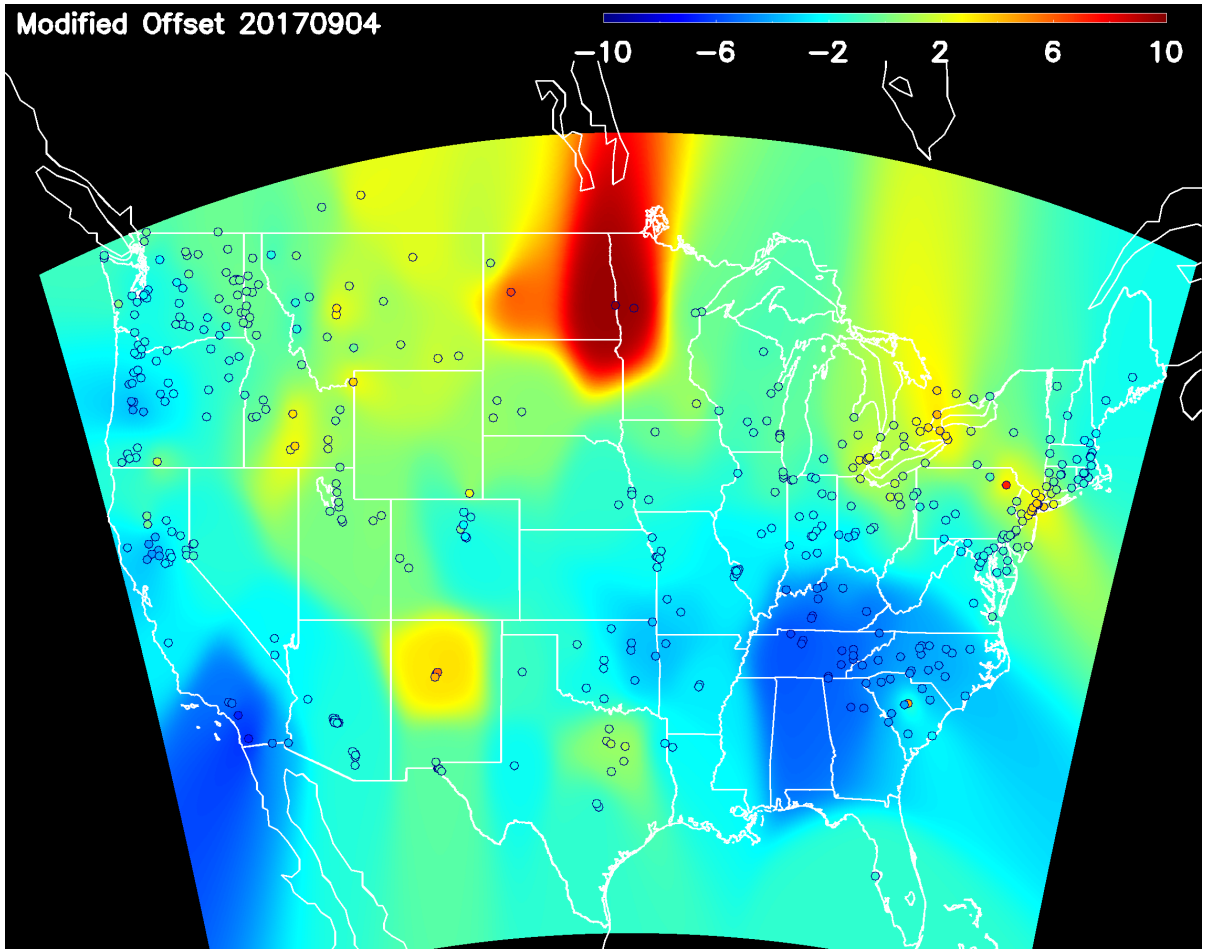
Schematic of Near Real Time Tuning of Regression Parameters





- Slope for the regression equation shown on the left
- Intercept for the regression equation shown on the right
- Overlaid or 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

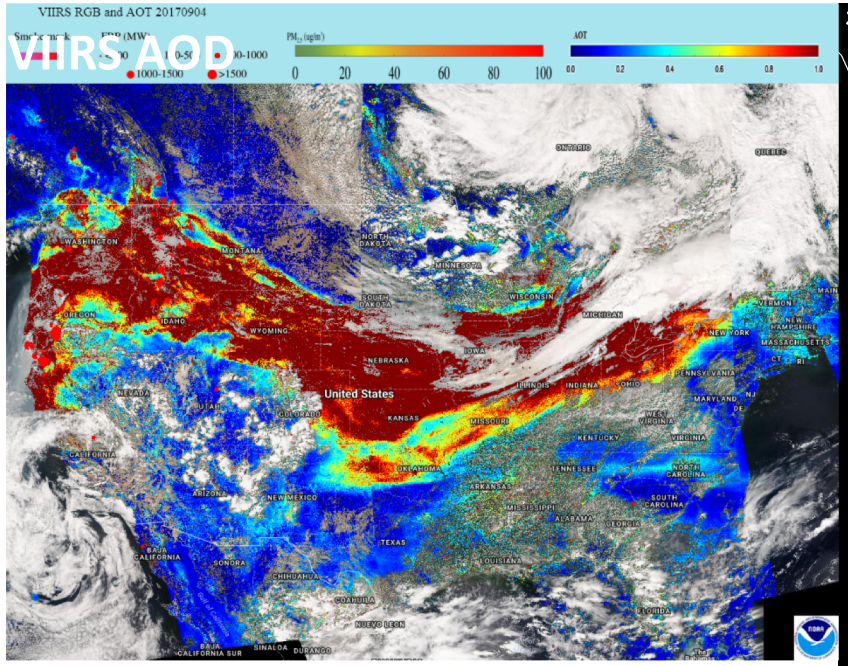


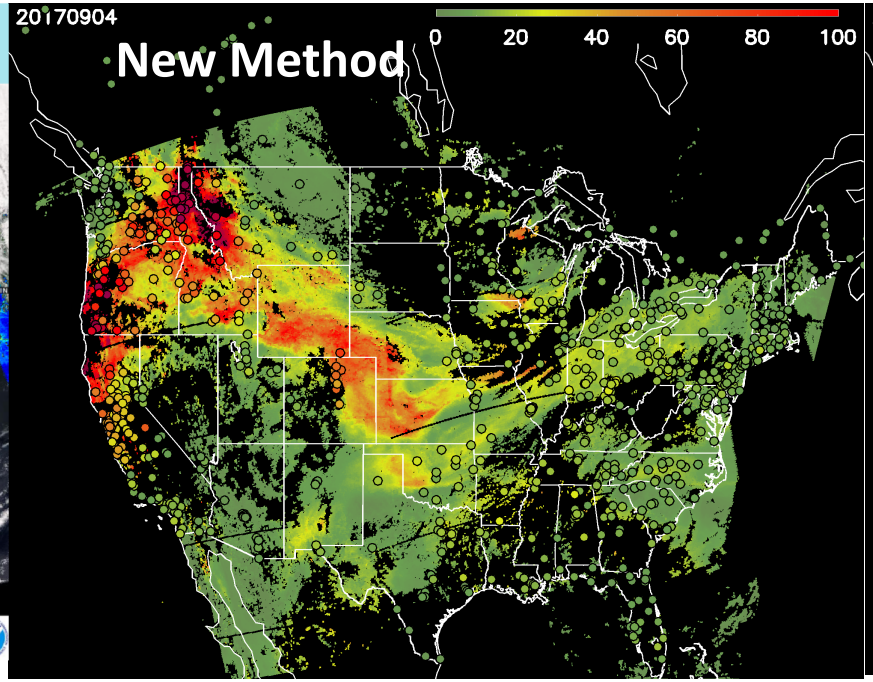


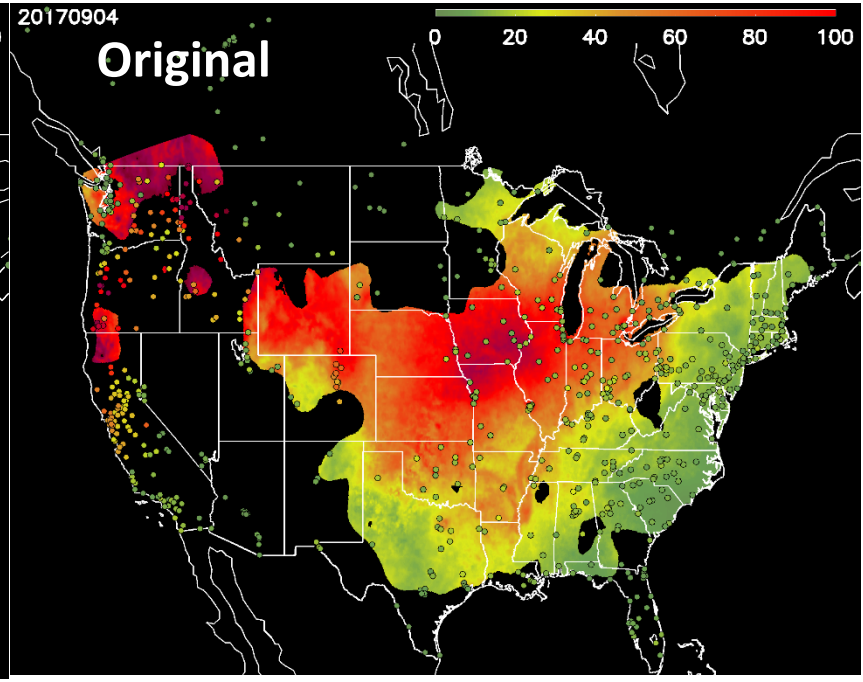
Near time slopes (left panel) and intercepts (right panel) at AIRNOW stations interpolated

Results

- Expanded coverage
- Improved surface PM2.5 estimates



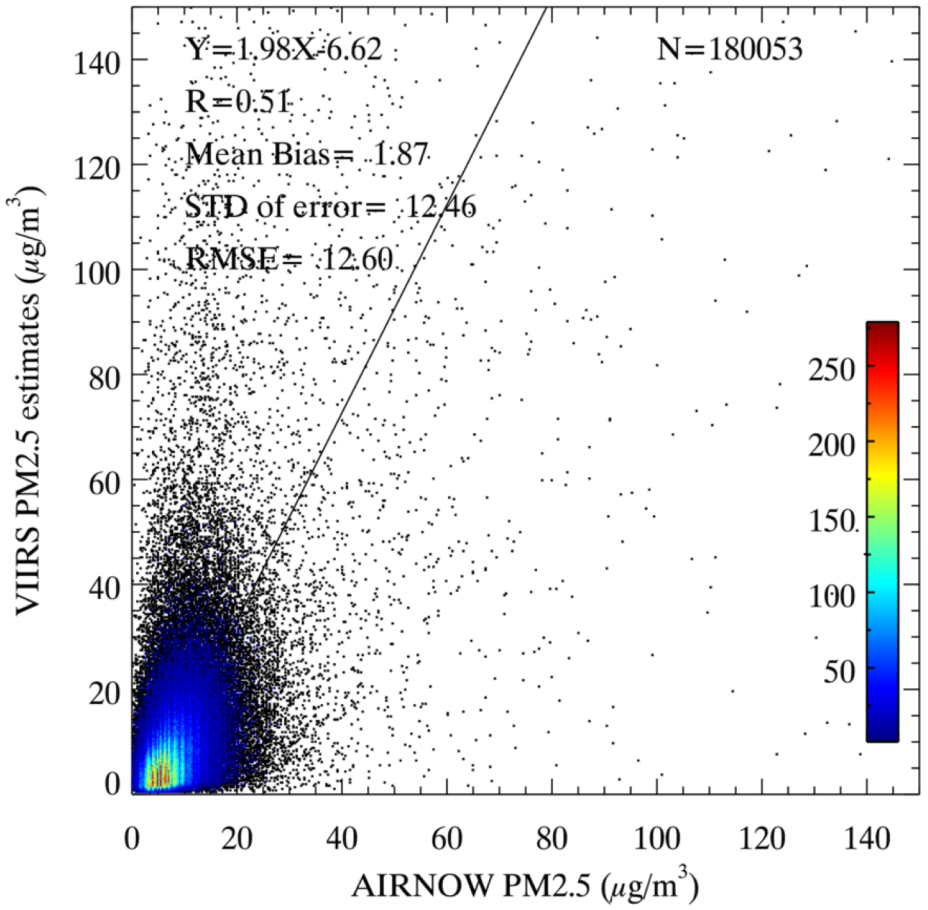




Evaluation of New Method

- 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

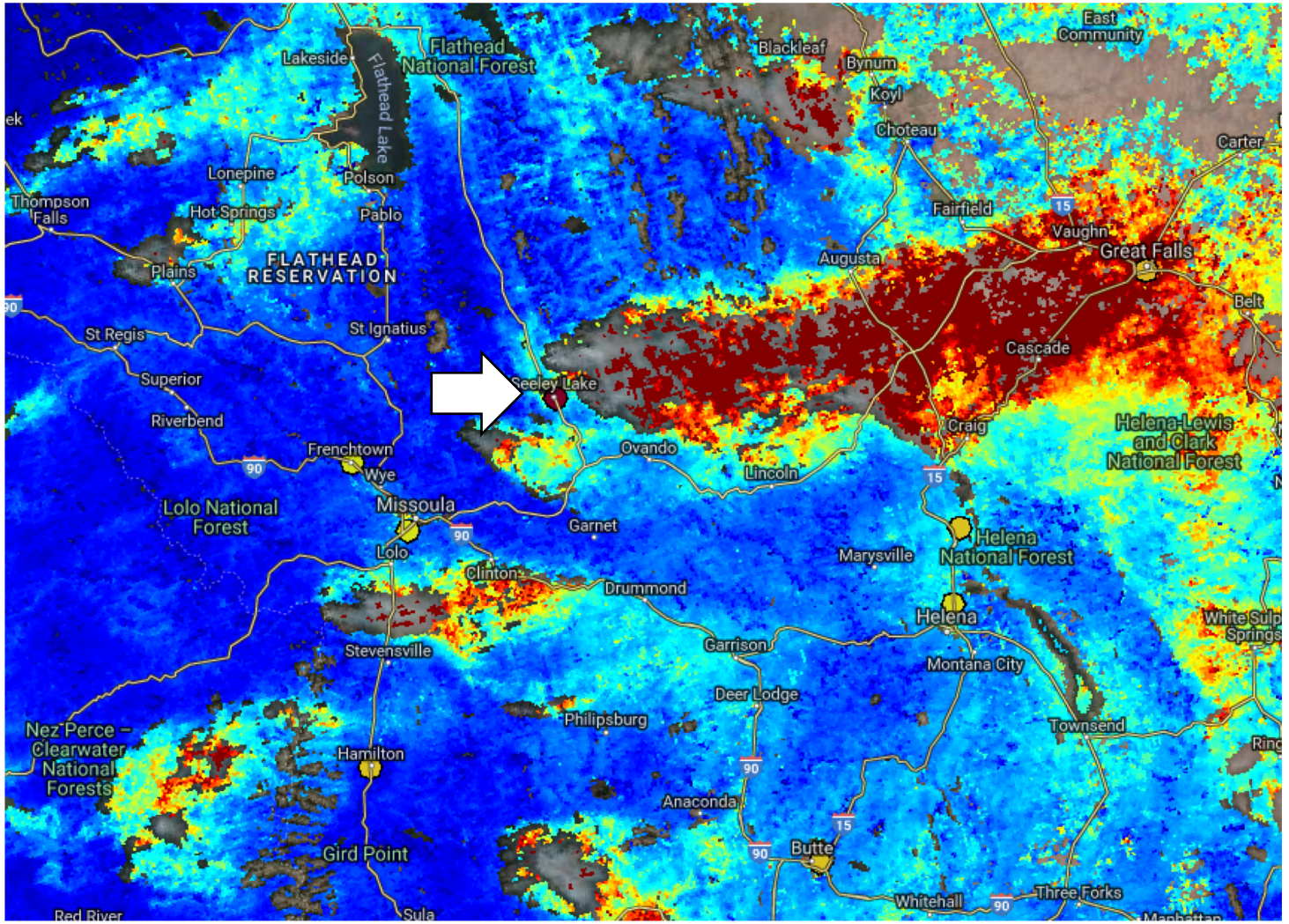
2015 - 2017



AOD-PM2.5 Issues

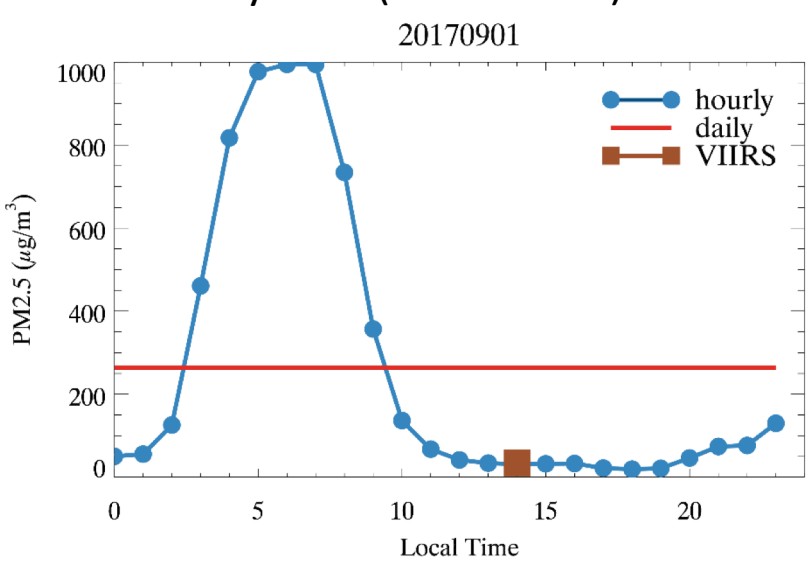
- Traditional concerns are:
  - Boundary layer height
  - Aerosol composition
  - Relative humidity
  - Etc.
- Issues we think that are also important
  - Diurnal variation of PM2.5
  - High AODs (>2.0) that are not reported or flagged as out of range
  - Spatial averaging of AOD around a ground station

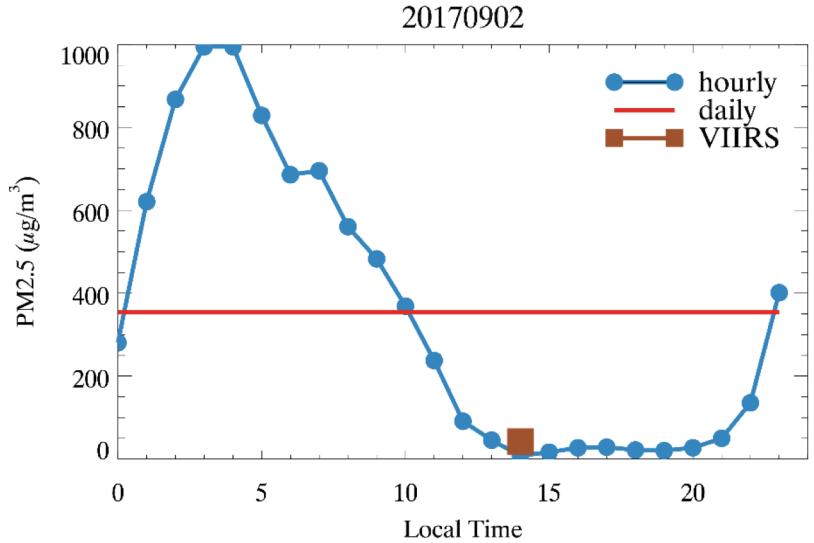
Seeley Lake (300630038) 20170901

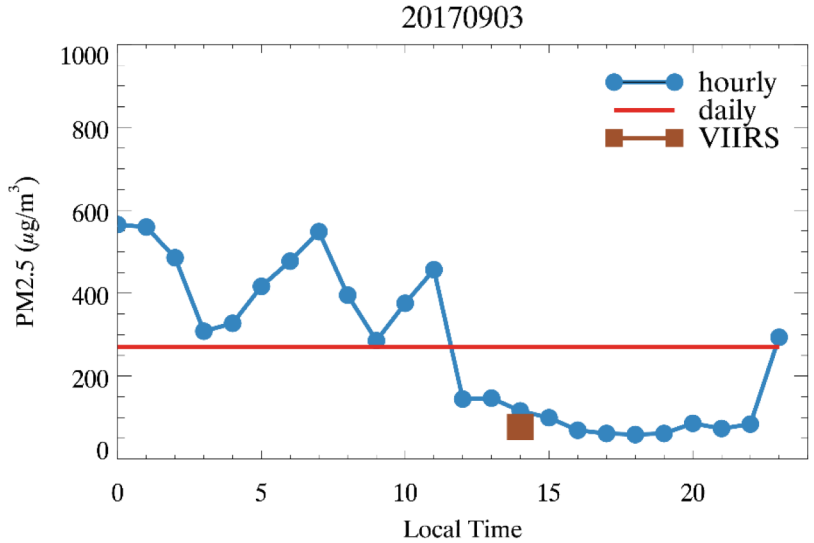


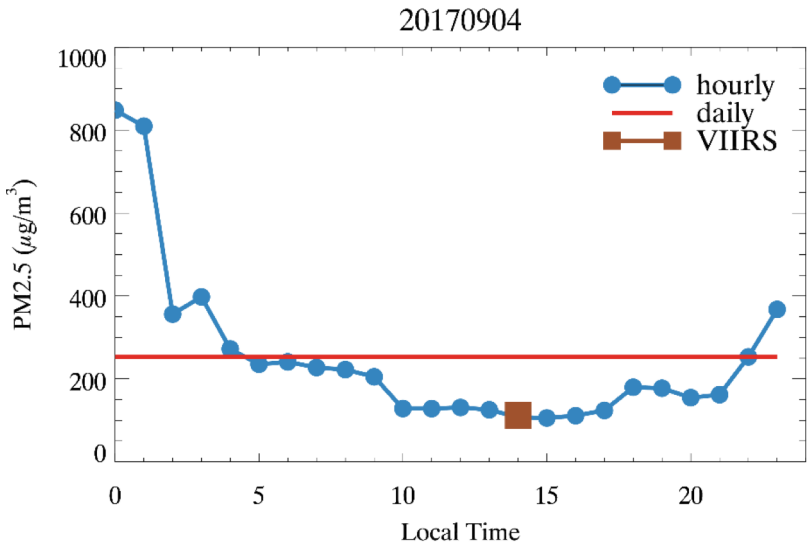
SNPP VIIRS AOD and AIRNOW PM2.5

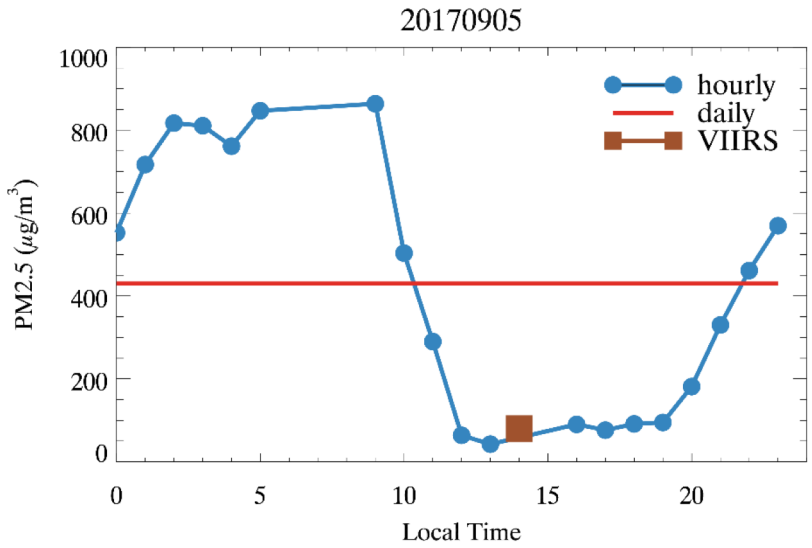
Seeley Lake (300630038)

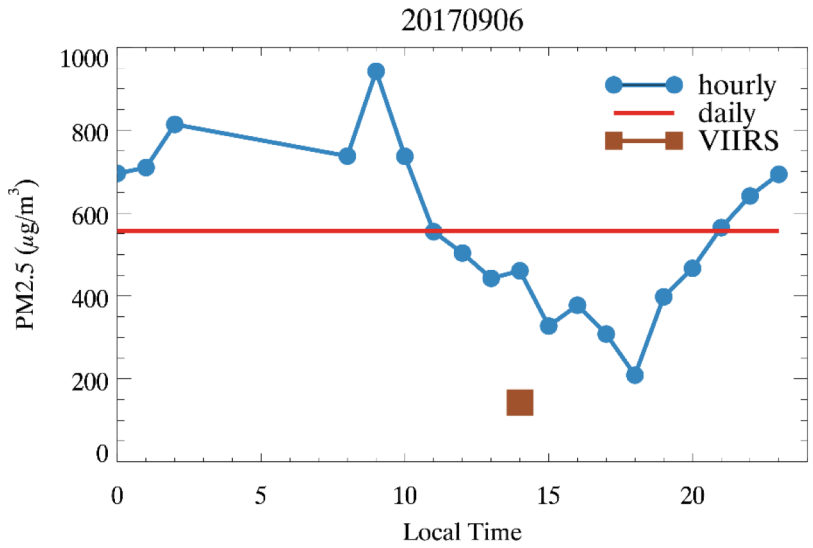




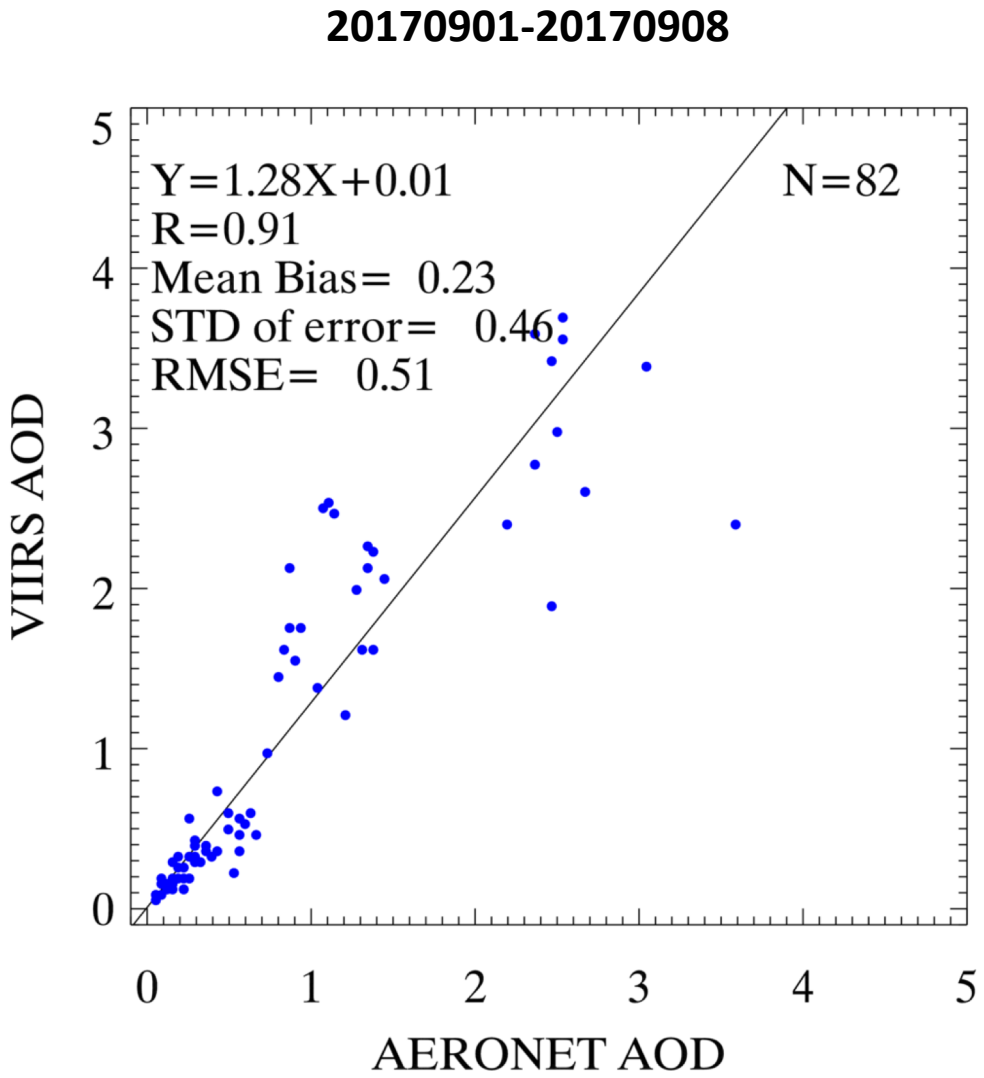




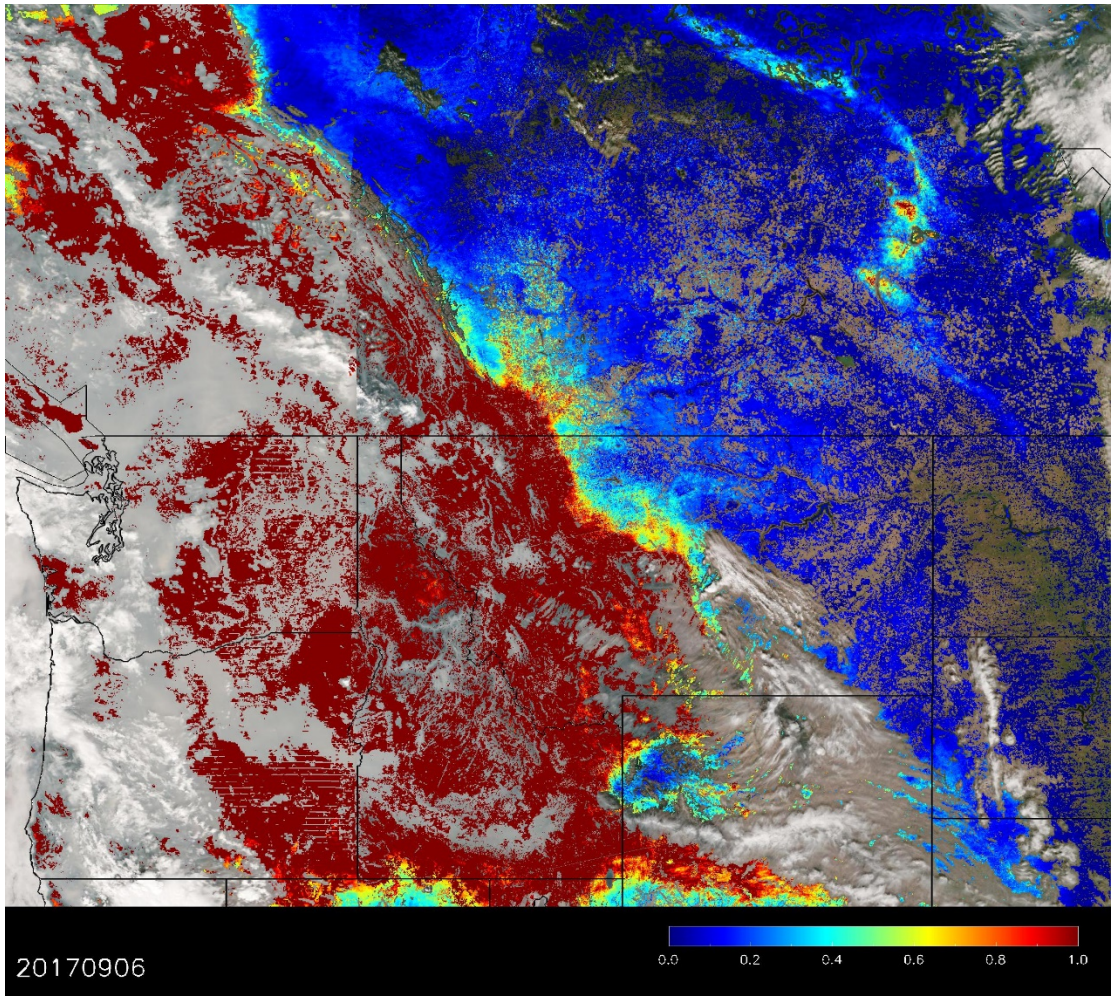




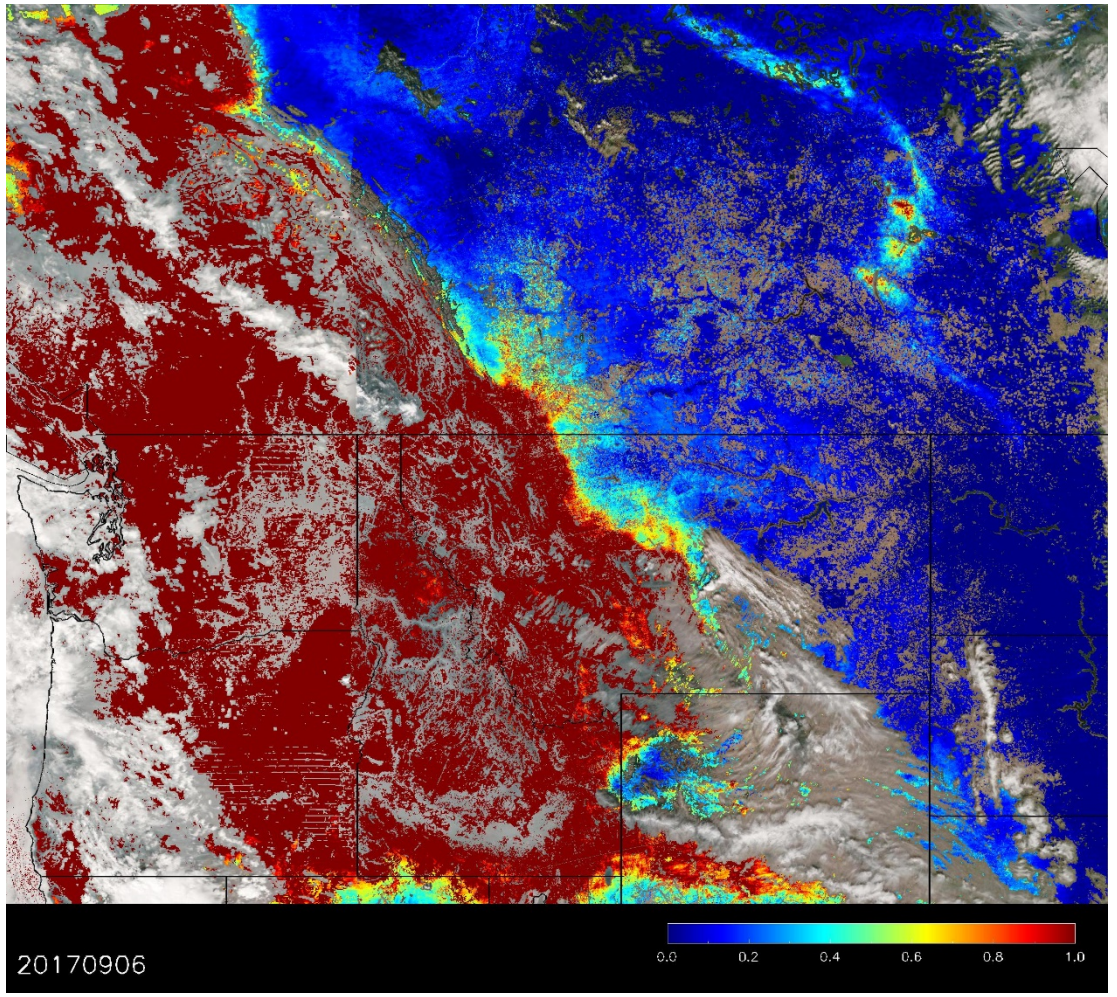
- Seven stations over Pacific NorthWest during a smoke event
- AODs from both AERONET and VIIRS have a big dynamic range
- VIIRS AODs are biased high but



High quality AOD



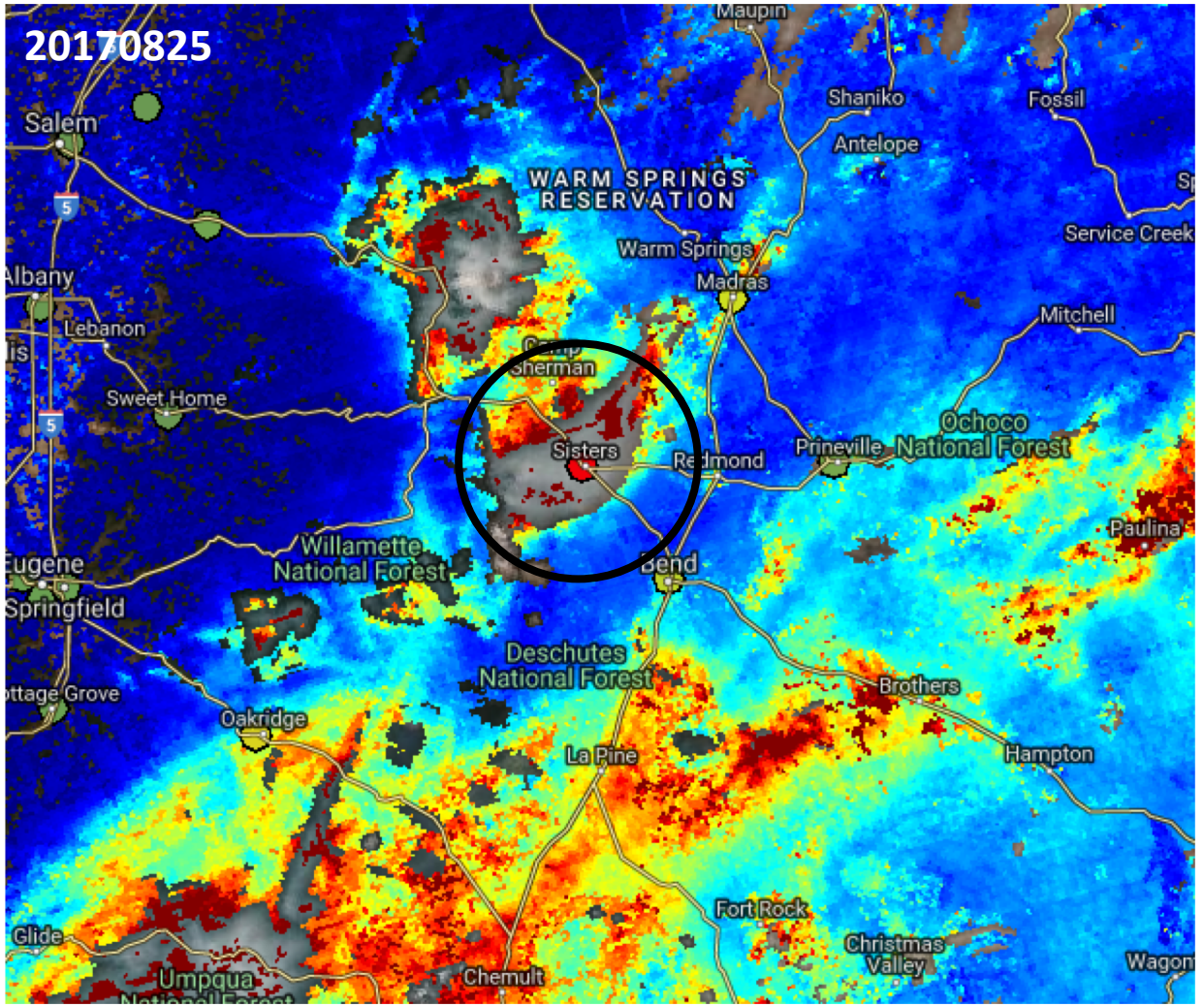
High quality AOD + out of range AOD



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 PM2.5



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