Use of VIIRS AOT in Hierarchical Autoregressive Model to Predict Daily $PM_{2.5}$

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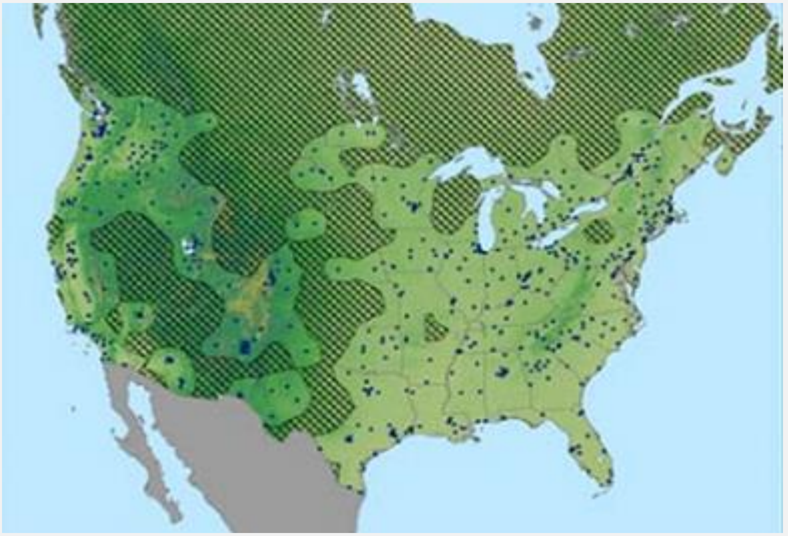
Motivation

- Spatial and temporal coverage of existing $PM_{2.5}$ monitoring - significant data gaps resulting in over 36 million Americans (~40% of the area) not covered by a monitoring network

- Demand for accurate air quality characterization in community surveillance/human health analyses

- Chemical Transport Models require extensive emission inventories for model predictions – often do not capture high $PM_{2.5}$ concentrations associated with wildfires

- Daily AOT is a measure of the true state of the atmosphere for aerosols



Additional information needed for spatial prediction of $PM_{2.5}$ in the hatched areas

Challenges with AOT and surface PM2.5 in fusion models

- Correlation between the two data sources varies both in time and in space
- Data sources are temporally and spatially misaligned
- Extensive missing data in both the monitoring data and satellite data
  - AOT observed at 64% of grid cells with monitoring stations
  - Daily observations rate for study period 45% - 83%

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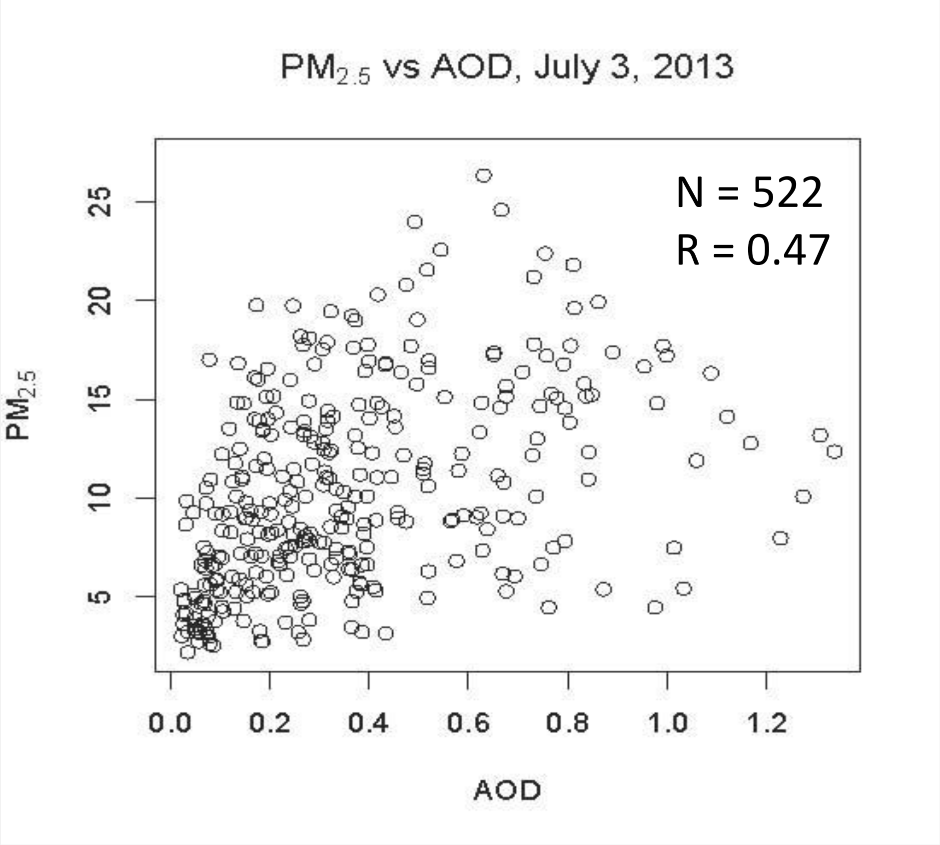

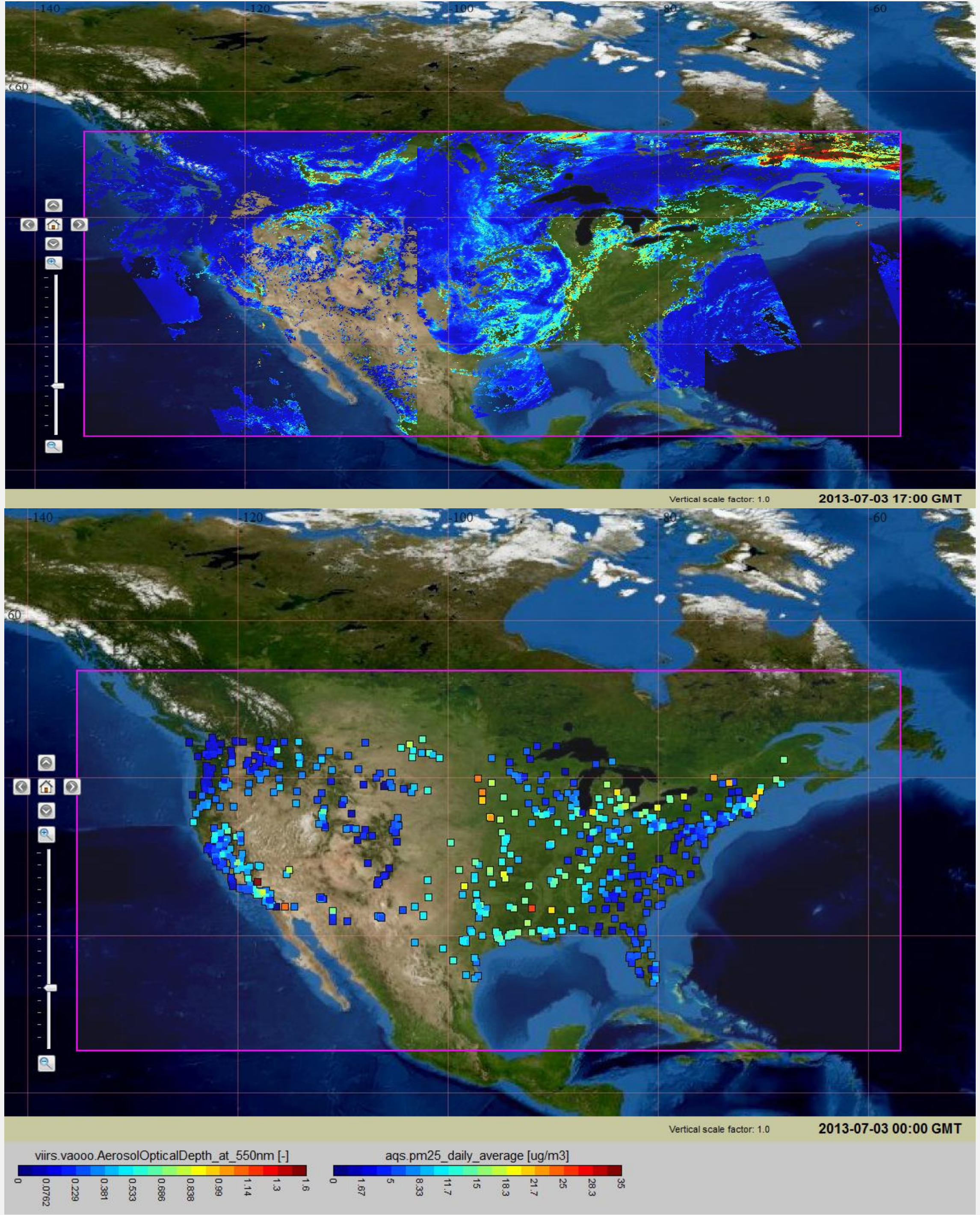

Hierarchical Autoregressive Model

Model consecutive day average $PM_{2.5}$ across CONUS using daily spatially-varying coefficients:

- VIIRS AOT data - day-specific spatially-varying intercept and coefficient
- Account for missingness in AOT data via model-based imputation at missing grid cells
- Autoregressive term based on previous day surface $PM_{2.5}$ concentrations
- Meteorological covariates (daily avg. T and RH)

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Autoregressive Model

$$P_t(s) = \alpha_{0,t} + \beta_{0,t}(s) + (\alpha_{1,t} + \beta_{1,t}(s))A_{i,t} + X_t(s)\gamma + \rho P_{t-1}(s) + E_t(s) \quad \text{(M1)}$$

$\alpha_{0,t}$ and $\alpha_{1,t}$ - global intercept and AOT coefficients for day t

$X_t(s)$ - vector of location and day specific meteorological covariates

γ - vector of coefficients

$\beta_{0,t}(s)$ and $\beta_{1,t}(s)$ - spatially varying intercept and AOT coefficients for day t

$E_t(s)$ - error

Schliep E. M., A. E. Gelfand, and D. M. Holland, *Autoregressive spatially-varying coefficient models for predicting daily PM2:5 using VIIRS satellite AOT*, Adv. Stat. Clim. Meteorol. Oceanogr, submitted Aug 2015

Model Comparison

Competing submodels nested within model

Global intercept:

$$P_t(s) = \alpha_{0,t} + \beta_{0,t}(s) + (\alpha_{1,t} + \beta_{1,t}(s))A_{i,t} + X_t(s)\gamma + \rho P_{t-1}(s) + E_t(s) \qquad (S1)$$

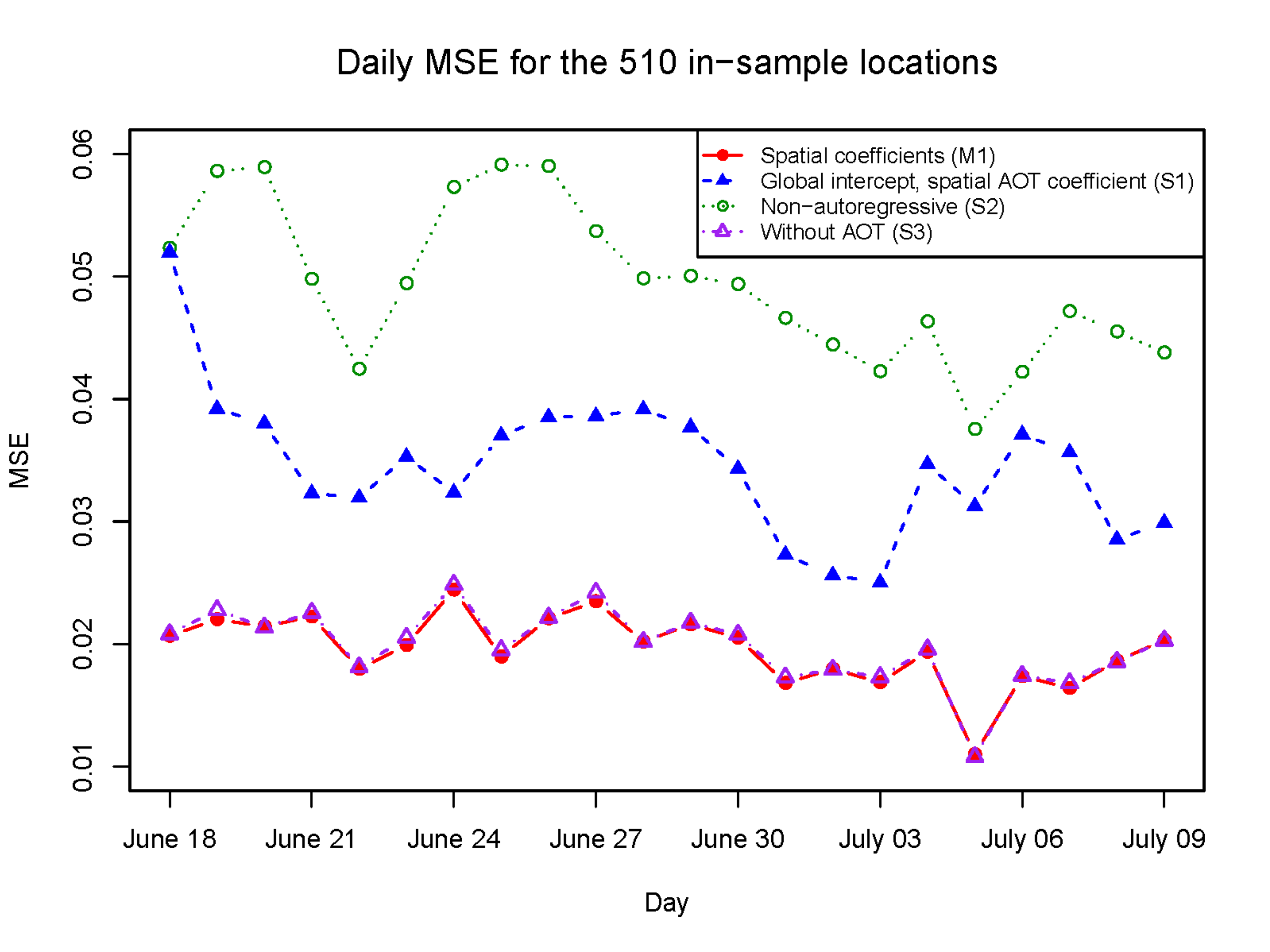
Non-autoregressive:

$$P_t(s) = \alpha_{0,t} + \beta_{0,t}(s) + (\alpha_{1,t} + \beta_{1,t}(s))A_{i,t} + X_t(s)\gamma + \rho P_{t-1}(s) + E_t(s) \qquad (S2)$$

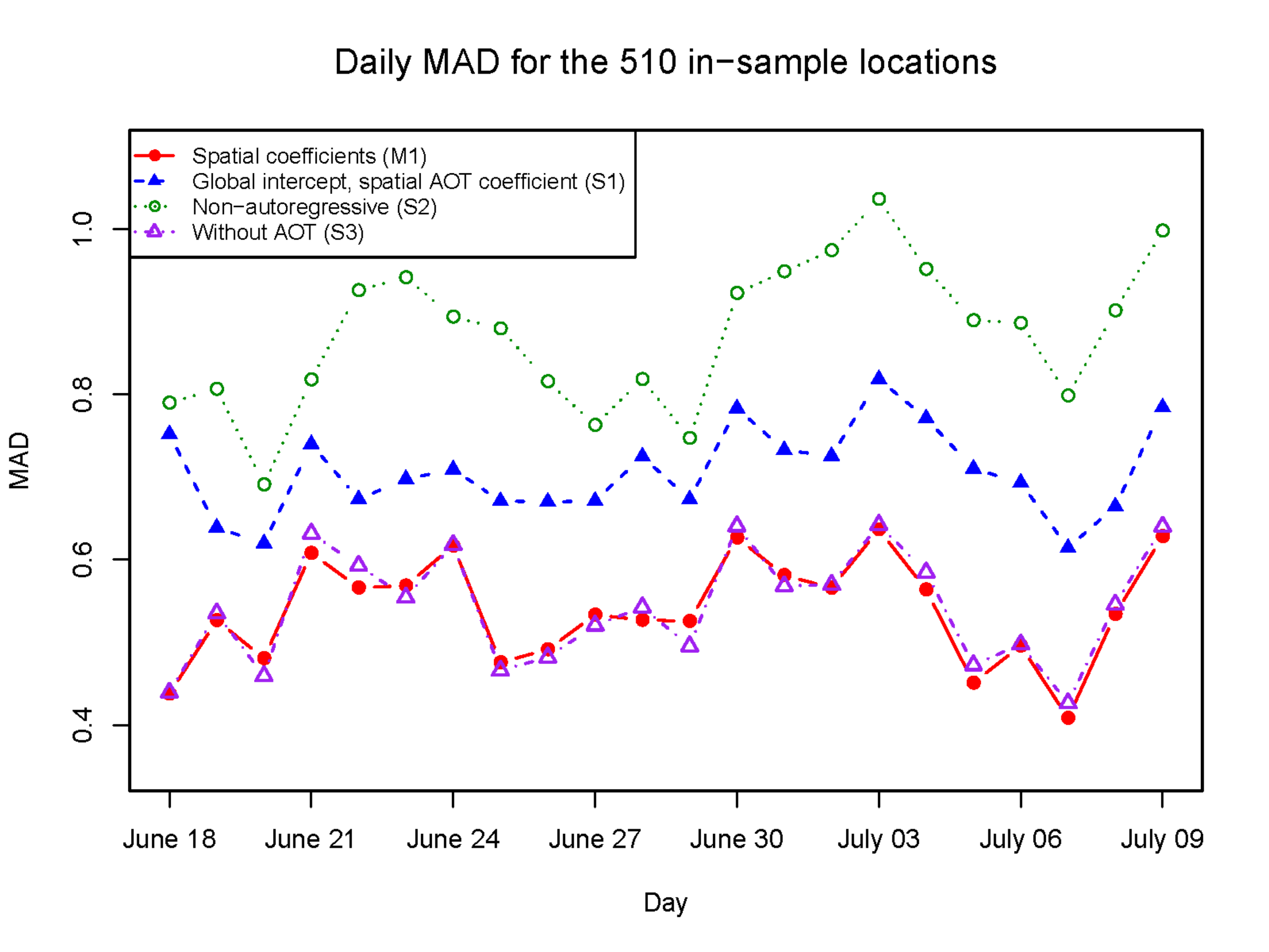
Without AOT:

$$P_t(s) = \alpha_{0,t} + \beta_{0,t}(s) + (\alpha_{1,t} + \beta_{1,t}(s))A_{i,t} + X_t(s)\gamma + \rho P_{t-1}(s) + E_t(s) \qquad (S3)$$

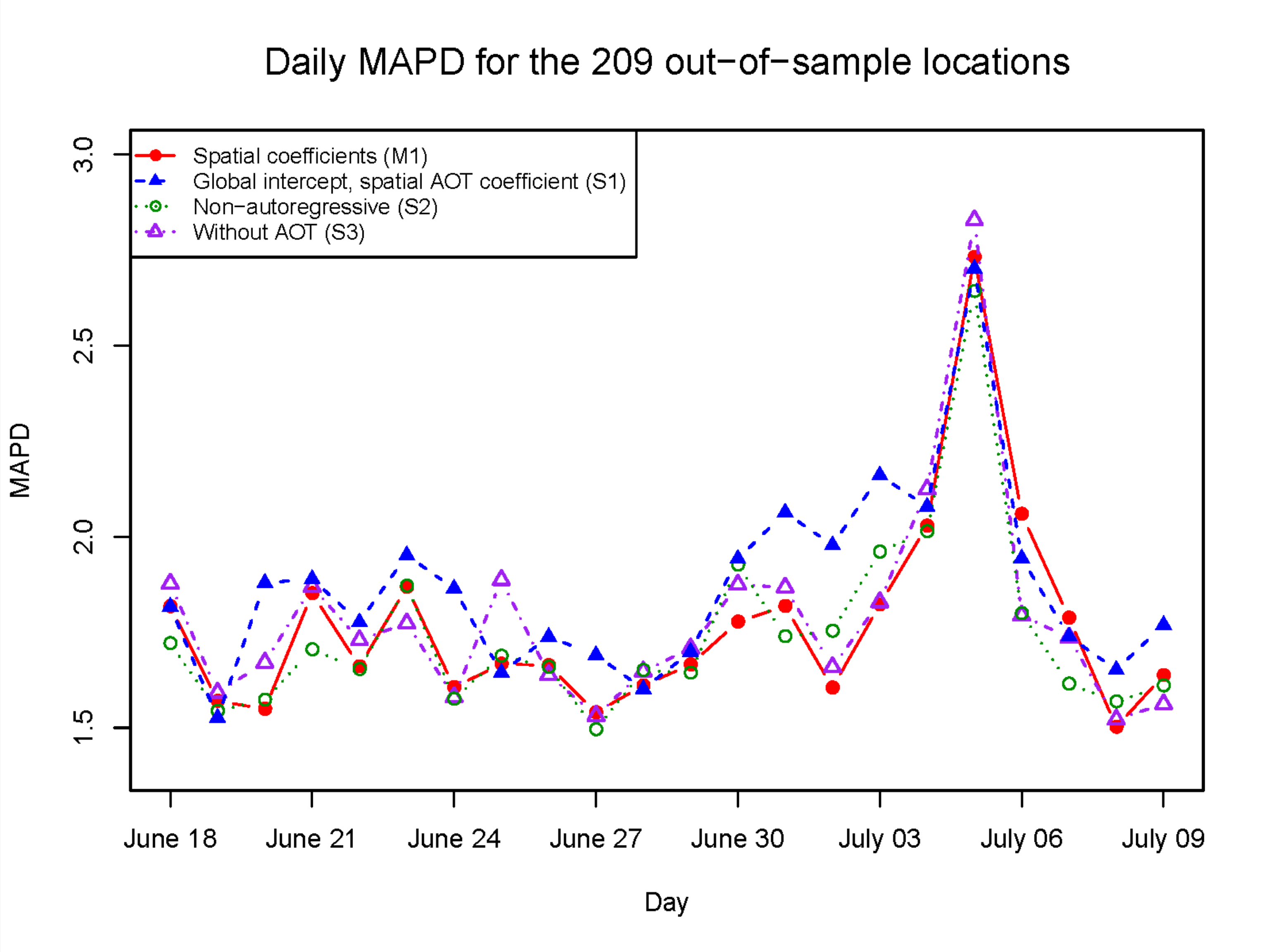
Model Comparison



Model Comparison



Model Comparison



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Summary and Conclusion

- Use of VIIRS AOT in hierarchical autoregressive model to model daily average $PM_{2.5}$ concentration across CONUS

- Several submodels considered to quantify improvement in daily $PM_{2:5}$ prediction using AOT

- Model comparison results show limited predictive capability with AOT, results consistent Paciorek and Liu (2009)

- Factors likely influencing use of AOT in model
  - Missing AOT data
  - Vertical structure of aerosols – need to develop improved scaling of AOT for aerosol aloft.

EPA considering use of ceilometer (CL-51) as viable technology for PAMS mixing layer measurement

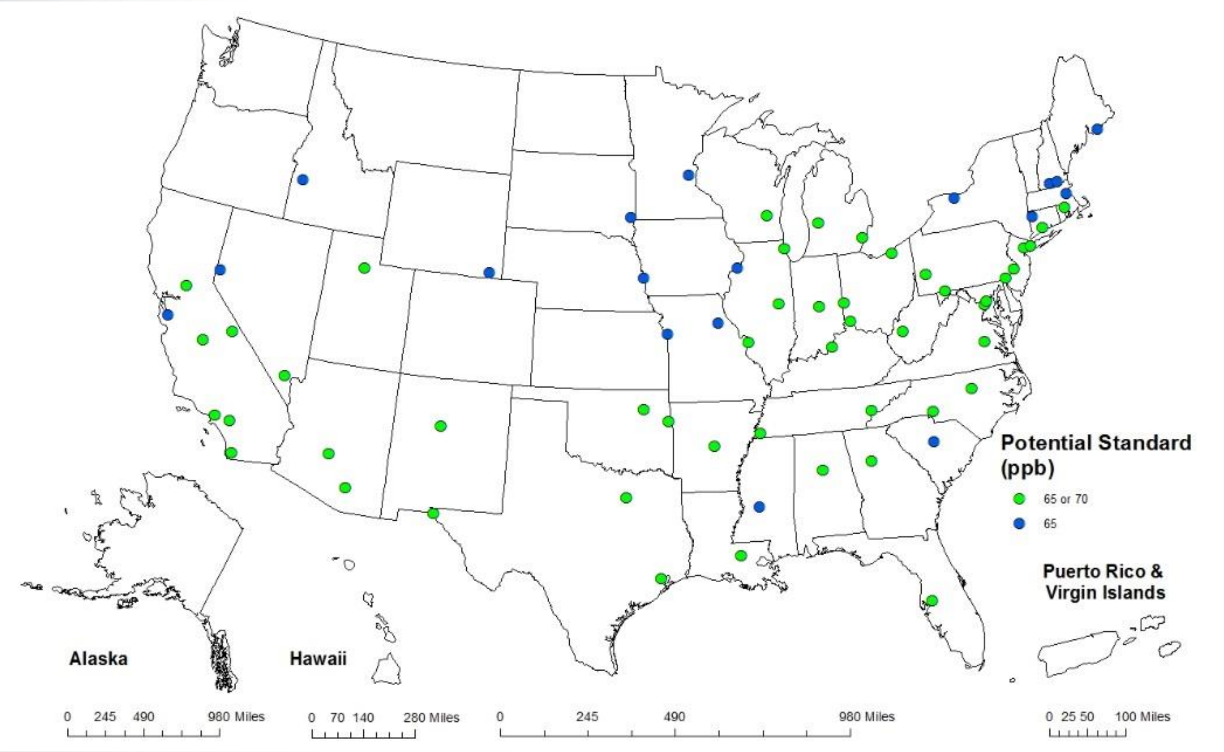
Vaisala CL-51 Ceilometer Stated Characteristics:

- Cloud reporting range: 0…43,000 ft (0…13km)
- Backscatter profiling range: 0…49,200 ft (0…15km)
- Can operate in all weather
- Fast measurement - 6 second measurement cycle
- Reliable automatic operation
- Good data availability
- Eye safe diode laser (LIDAR)


CL-51 positioned next to Space Science and Engineering Center, University of Wisconsin Mobile Lab

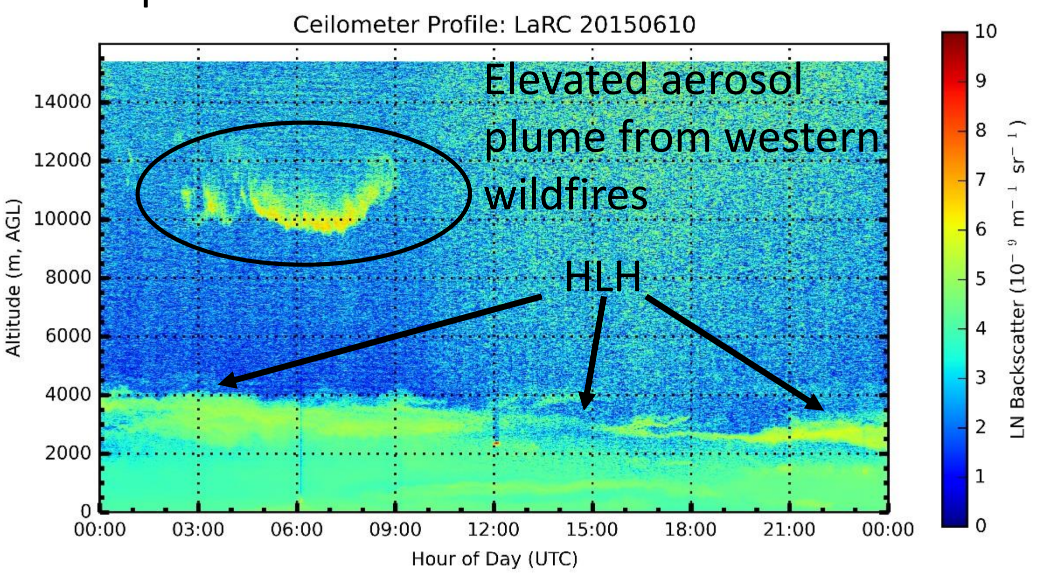
EPA Photochemical Assessment Monitoring Station (PAMS) program

Potential Site Locations for ceilometer (CL-51) Network



Map based on 2011-2013 ozone design values
PAMS requirements will be based on 2014-2016 data

- Future CL-51 Network would allow for continuous aerosol profile measurement to define HLH on a regional basis
- CL-51 provides backscatter profile (~910 nm) up to 15.4 km



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