USING MODIS AOD AND WRF-CHEM TO INFER DAILY $PM_{2.5}$ CONCENTRATIONS AT 1 KM RESOLUTION IN THE EASTERN US

SEARCH
Solutions for Energy Air, Climate & Health

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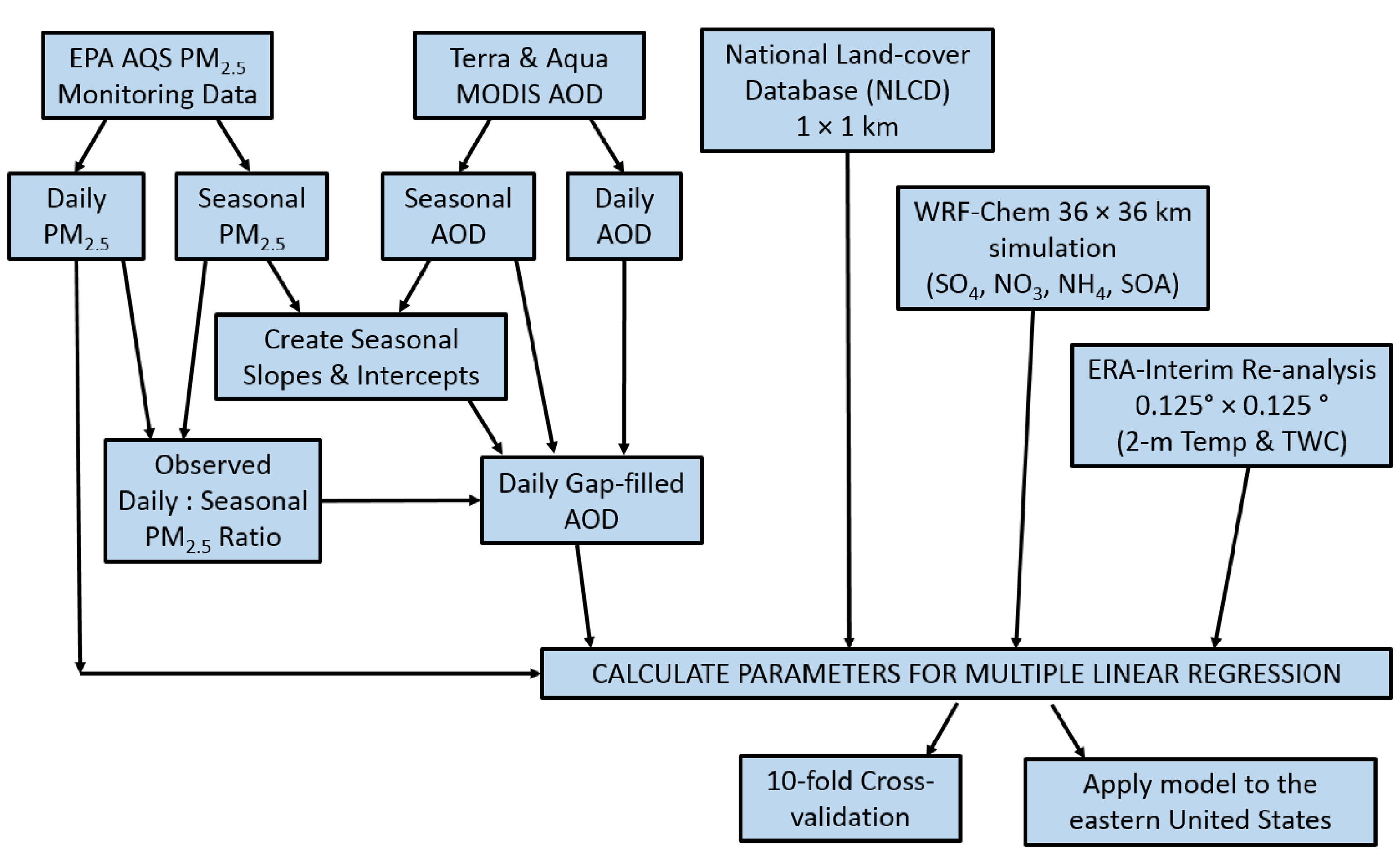
INTRODUCTION

- High temporal and spatial resolution estimates of $PM_{2.5}$ concentrations are critical to the assessment of health effects in epidemiological studies.
- Satellite information can be helpful by providing aerosol optical depth (AOD) in regions with few monitors, but it alone cannot quantify surface $PM_{2.5}$ concentrations.
- We develop a daily $PM_{2.5}$ product at 1 × 1 km spatial resolution across the eastern United States with the aid of satellite AOD and WRF-Chem output.

METHODOLOGY

- We use a statistical multiple-linear regression model trained to surface $PM_{2.5}$ observations from the EPA Air Quality System (AQS) monitoring network to re-construct $PM_{2.5}$ across the eastern US.
- We apply a gap-filling technique described by Lv et al. (2016) to construct robust daily estimates of AOD when satellite data is missing.
- A block flow diagram of our methodology is below:



MODIS AOD GAP-FILLING

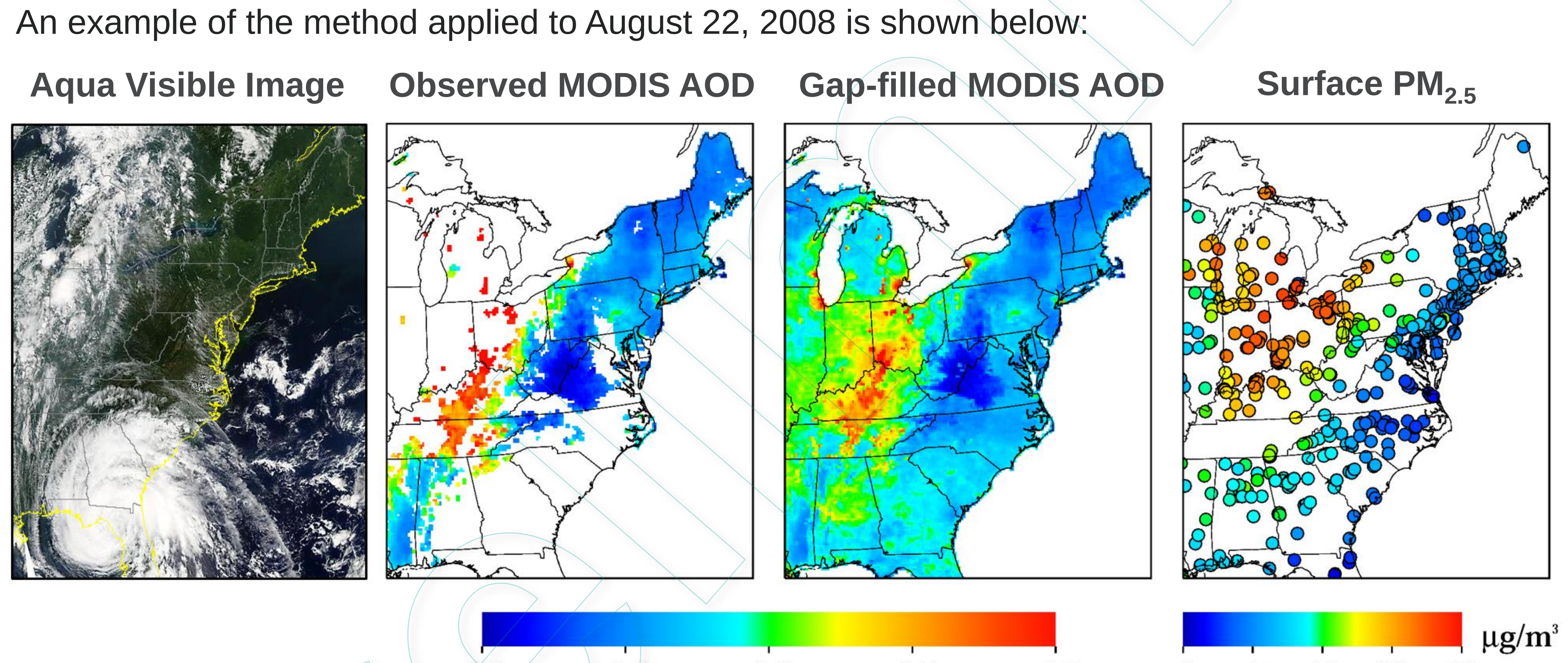
- We use a gap-filling procedure described by Lv et al., 2016 to estimate MODIS AOD when it is missing:

$$AOD_{d,j} = a_{s,j}\left[\frac{PM_{d,j}}{PM_{s,j}} \times AOD_{s,j}\right] + b_{s,j}$$

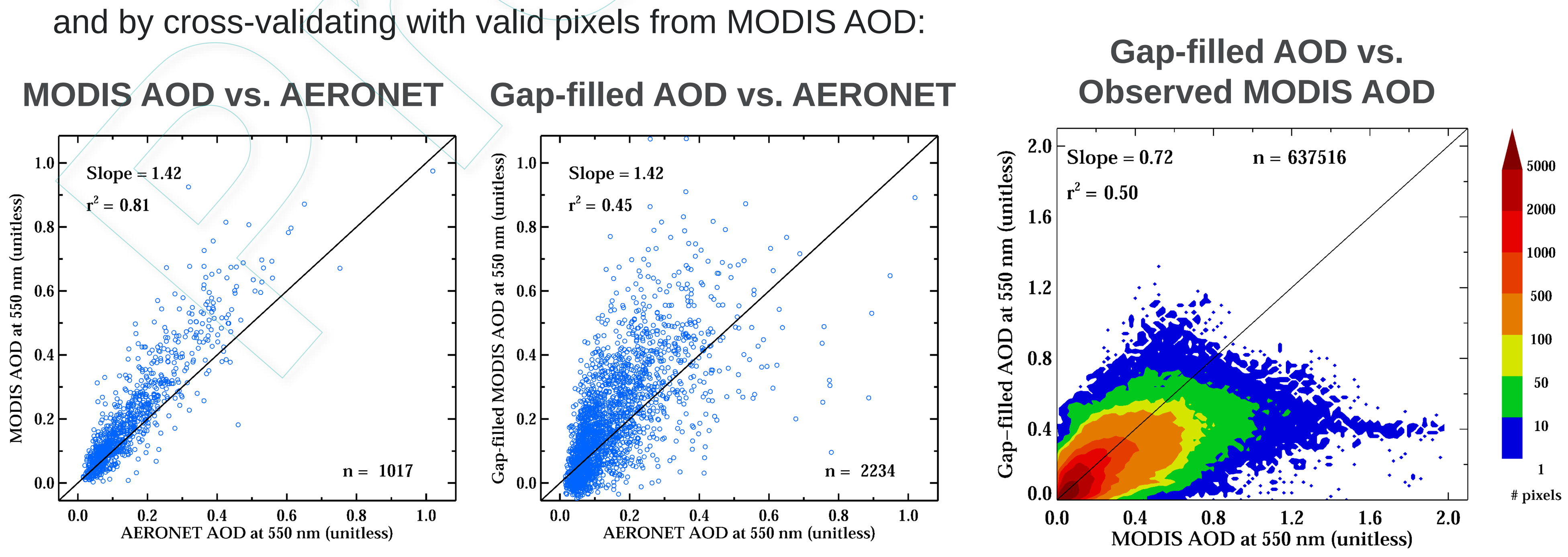
$d = day, \quad j = grid\ cell, \quad s = season$

$AOD_{d,j} = daily\ estimated\ AOD$
$a_{s,j} = slope\ derived\ from\ seasonal\ fit$
$b_{s,j} = intercept\ derived\ from\ seasonal\ fit$
$PM_{d,j} = daily\ PM_{2.5}\ concentration$
$PM_{s,j} = seasonal\ PM_{2.5}\ concentration$
$AOD_{s,j} = seasonal\ AOD$

- An example of the method applied to August 22, 2008 is shown below:

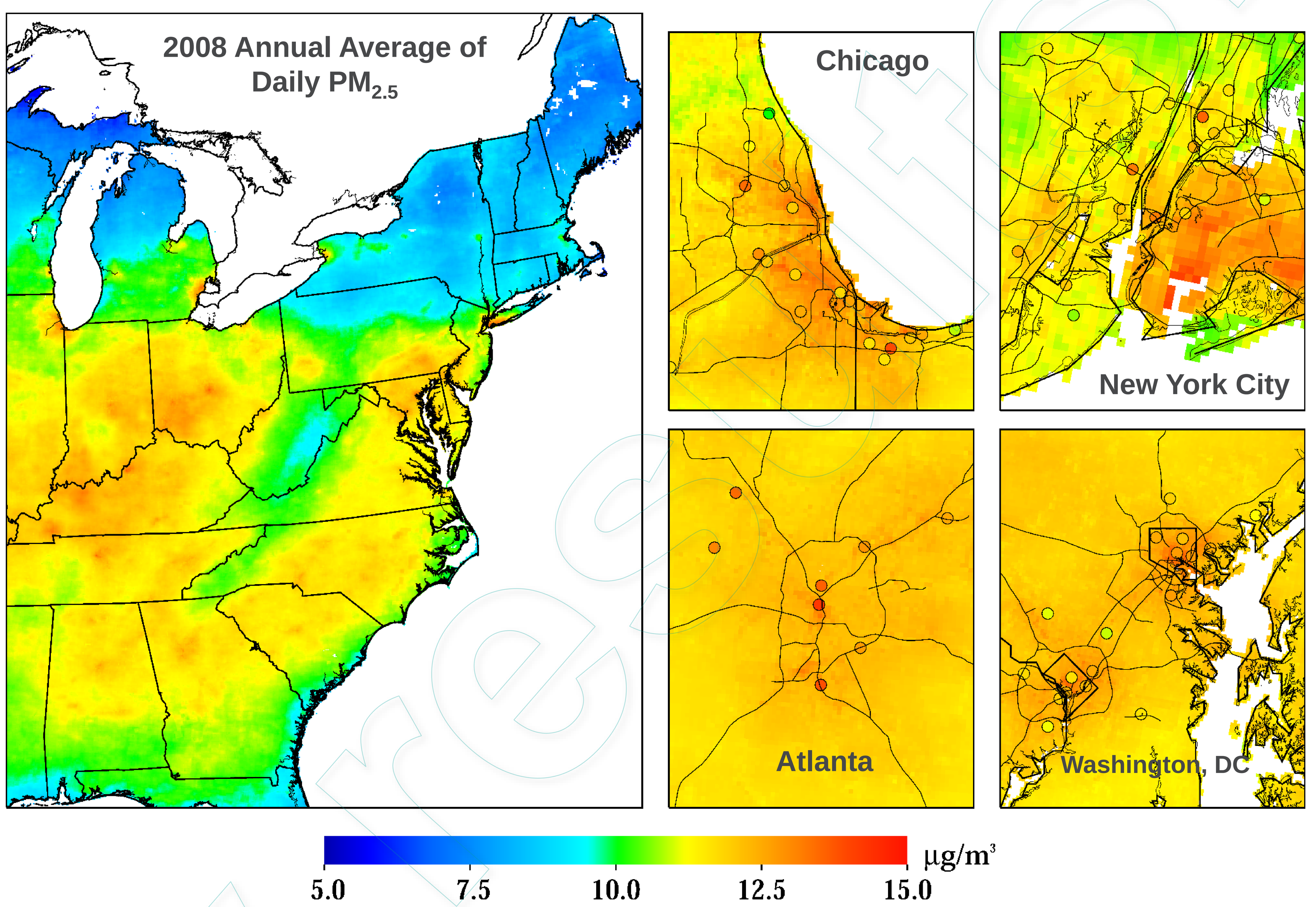


- The performance of the gap-filling methodology is measured by comparing to AOD from AERONET and by cross-validating with valid pixels from MODIS AOD:

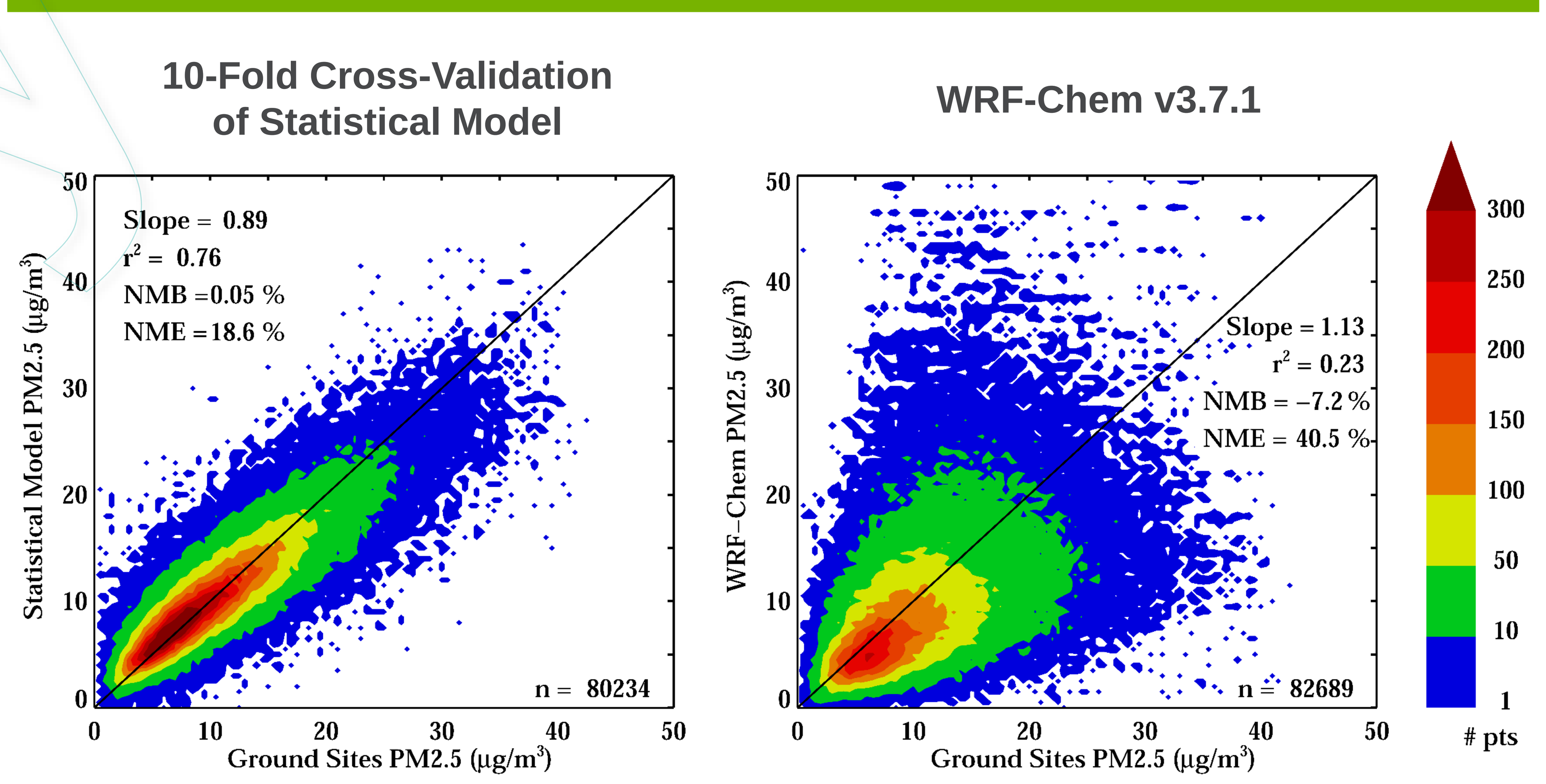


DAILY $PM_{2.5}$ AT 1 KM RESOLUTION

- $PM_{2.5\ i,j} = \alpha_i + \beta_{1,i}x_{1,i,j} + \beta_{2,i}x_{2,i,j} + \ldots + \beta_{n,i}x_{n,i,j}$ for day i, and grid cell j, where α = constant, β = coefficient, x = independent predictor of $PM_{2.5}$
- Model is initially trained daily to 24-hour averaged $PM_{2.5}$ observations, and then applied at 1 km resolution to the eastern United States.



MODEL PERFORMANCE



Name of run	Daily fit R²	Daily fit Slope	Daily fit NME
Met	0.46	0.68	29.2%
LUT	0.41	0.66	30.5%
WRF-Chem	0.66	0.80	22.3%
Met, LUT & WRF-Chem	0.72	0.87	20.0%
AOD	0.59	0.77	25.1%
AOD, Met, LUT & WRF-Chem	*0.76*	*0.89*	*18.6%*
AODallgf, Met, LUT & WRF-Chem	0.78	0.90	17.9%
WRF-Chem-PM2.5	0.23	1.13	40.5%

Met= Meteorological variables (2-m afternoon temperature & total water column from ERA-Reanalysis)
LUT= Land-use Type; forest and urban percentages from the 2011 National Land Cover Database
WRF-Chem = Concentrations of particulate NH_4, NO_3, and SO_4 from the WRF-Chem simulation
AOD = MODIS Aerosol Optical Depth from Terra & Aqua; for the daily fit, the gap-filling technique is used
AODallgf = Daily observed Aerosol Optical Depth is overwritten with gap-filled Aerosol Optical Depth
WRF-Chem-PM2.5 = PM2.5 from the WRF-Chem simulation
NME = Normalized Mean Error

- The model (*in italics*) predicts daily $PM_{2.5}$ with high skill ($r^2 = 0.76$)
  - WRF-Chem is the strongest predictor
  - MODIS is also a strong predictor
  - Meteorology and land-use are secondary contributors

CONCLUSIONS

- The model developed herein generates a high-fidelity estimate ($r^2 = 0.76$ using a 10-fold cross-validation) of daily $PM_{2.5}$ throughout the eastern United States.
- Information from WRF-Chem is the most important contributor to the performance of the statistical model.
- Gap-filled satellite AOD is also a substantial contributor to the skill of the model.
- Meteorological information and land-use data are secondary contributors to model skill.
- The statistical model performs better than WRF-Chem as a stand-alone product.

This poster was developed under Assistance Agreement No. RD83587101 awarded by the U.S. Environmental Protection Agency to Yale University. It has not been formally reviewed by EPA. The views expressed in this document are solely those of the authors and do not necessarily reflect those of the Agency. EPA does not endorse any products or commercial services mentioned in this poster.

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