

Applications of satellite data in analyses of surface PM_{2.5}

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Collaborators: Robert Chatfield and Meytar Sorek-Hamer (NASA ARC)



HAQAST-5 meeting, January 3, 2019, Phoenix, Arizona



Motivation

(Satellite Regional PM2.5 fields and Downscaling to Near-Road scale)

Fine particulate is among the most harmful air pollutants for human health. There is ongoing interest in developing reliable methods to estimate PM2.5 concentrations 1) at unmonitored locations and 2) at finer horizontal resolution for improved health risk assessment and public health tracking.

We aim to develop an efficient system that can reliably estimate PM2.5 at unmonitored locations and at finer horizontal resolution at important locations.

- **MODIS aerosol optical depth (AOD)** provides an input for particulate levels at **unmonitored locations** in methods used to construct regional PM2.5 fields.
- **Dispersion model** fields can be fused into portions of these regional fields for **increased horizontal resolution** where high PM gradients can be anticipated, for example near major roadways.

Some of the highlights

A review article on $PM_{2.5}$ exposure estimates submitted to ES&T

Methods, availability, and applications of $PM_{2.5}$ exposure estimates derived from ground measurements, models, and satellite datasets

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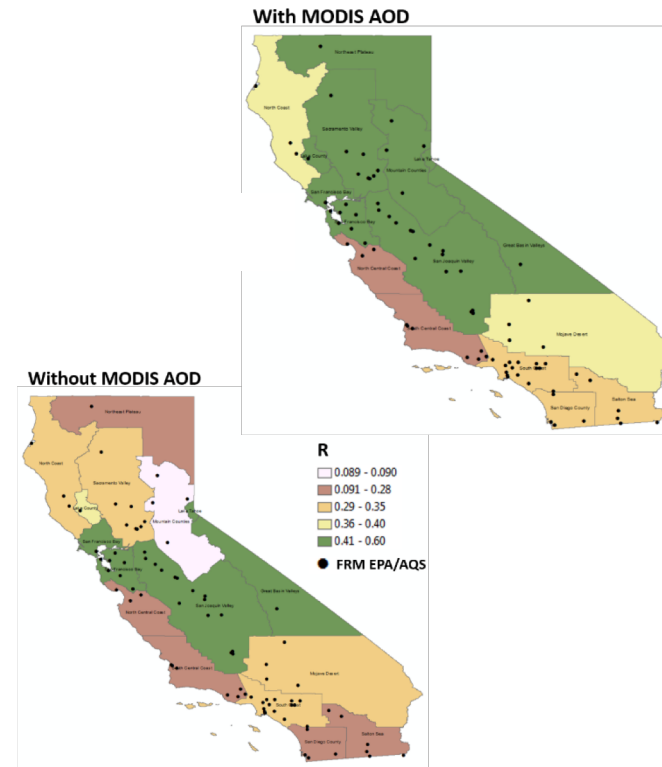
^hNational Center for Atmospheric Research, Atmospheric Chemistry Observations and Modeling, 3450 Mitchell Ln, Boulder, CO, USA, 80301;

ⁱBoston University School of Public Health, Department of Environmental Health, 715 Albany Street, Talbot 4W, Boston, Massachusetts, USA, 02118;

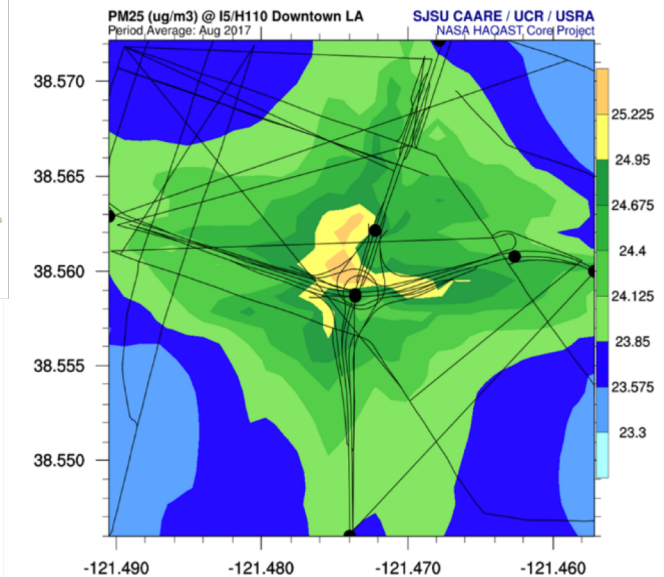
^jCenters for Disease Control and Prevention, 1600 Clifton Road, Mail Stop E-19, Atlanta, Georgia, USA, 30333.

^kUniversity of Washington, School of Environmental and Forest Sciences, Anderson Hall, Seattle, WA, USA, 98195;

Added value of satellite information to derive surface $PM_{2.5}$



A fused $PM_{2.5}$ field of satellite data, ground monitors, further downscaled to 100 meter scale



A survey on publicly available PM_{2.5} exposure data sets

1. What are the publicly available PM2.5 exposure data sets?

2. How are they generated?

3. What are the general guidelines for using these data?

Source of Dataset	Region	Time Period	Spatial Resolution	Temporal Resolution	Monitor	Model	Satellite	Reference
GBD	Global	1990 - 2013	*0.1°× 0.1°	Annual	X	X	X	<u>Brauer</u> et al., [2016]
Dalhousie Dataset V4.GL.02	Global	1998 - 2016	1 km ²	Annual	X	X	X	(1)
GBD	Global	2014	*0.1°× 0.1°	Annual	X	X	X	Shaddick et al., [2018]
Berkeley Dataset	Global	2016 - 2017	*0.1°× 0.1°	Daily	X	X		(2)
EST 2014	China	2012 – 2013	50 km ²	Annual & Seasonal	X	X	X	Ma et al., [2014]
Dalhousie Dataset V4.NA.01	CONUS	1998 - 2012	1 km ²	Annual	X	X	X	(1)
EPA <u>AirData</u>	CONUS	1999 - 2018	County	Daily	X			(3)
EST 2013	CONUS	2001 - 2006	8.9 km ²	Monthly	X	X	X	Beckerman et al., [2013]
CDC EPHTN	CONUS	2001 - 2014	County	Daily	X	X		(4)
CDC WONDER	CONUS	2003 - 2011	County	Daily	X		X	(5)
<u>AirFire</u> Dataset	CONUS	2014 - 2018	3 & 12 km ²	Daily		X		(6)
AQAH 2018	NC, USA	2006 - 2008	12 km ²	Monthly & Annual	X	X		Huang et al., [2018]

Diao M., T. Holloway, S. Choi, S.M. O'Neill, M.Z. Al-Hamdan, A.van Donkelaar, R.V. Martin, X. Jin, A.M. Fiore, D.K. Henze, F. Lacey, P.L. Kinney, F. Freedman, N.K. Larkin, Y. Zou, A. Vaidyanathan Methods, availability, and applications of PM_{2.5} exposure estimates derived from ground measurements, models, and satellite datasets, **submitted to ES&T**.

Four main methods of generating PM_{2.5} datasets

- **1. Ground-based monitor data**

- EPA archived monitoring data can be accessed at the AirData website (<https://www.epa.gov/outdoor-air-quality-data>)
- U.S. EPA initiated the Chemical Speciation Monitoring Network (CSN)
- Temporary PM_{2.5} monitors are deployed as a part of the Wildland Fire Air Quality Response Program (WFAQRP, <https://wildlandfiresmoke.net/>)

- **2. Ground-based monitor + model simulations**

- Atmospheric chemical transport models (CTMs)
- EPA Fused Air Quality Surfaces Using Downscaling (FAQSD)
- CDC National Environmental Public Health Tracking Network (EPHTN)

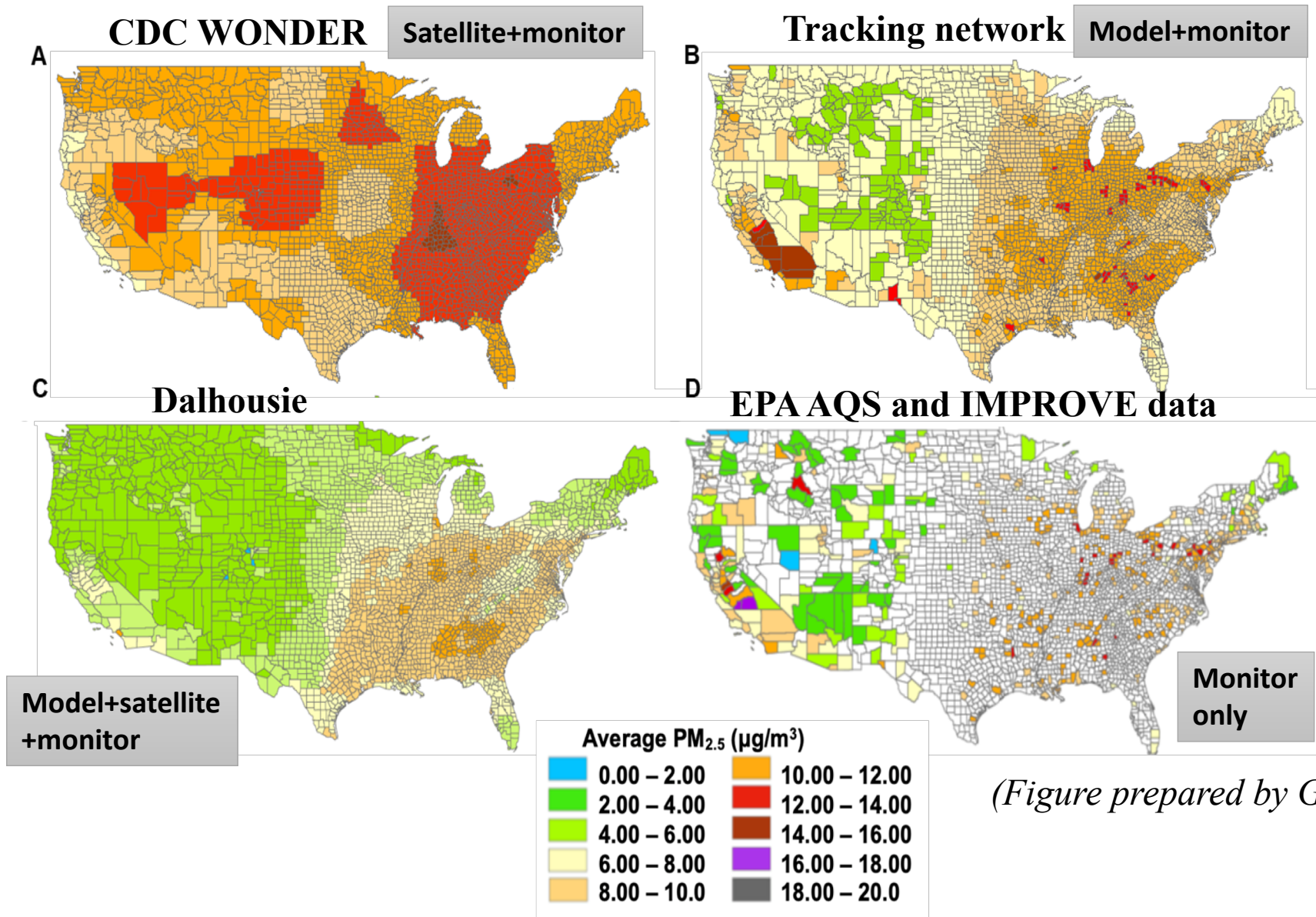
- **3. Ground-based monitor + satellite data**

- Linear regression models for estimating PM_{2.5} concentrations from remotely-sensed AOD;
- Adding meteorological parameters to develop multiple regression models or generalized additive models

- **4. Ground-based monitor + satellite data + model simulations**

- Example: van Donkelaar et al. (2015, 2016)

Comparisons of three commonly-used publicly available PM_{2.5} datasets in the contiguous U.S.

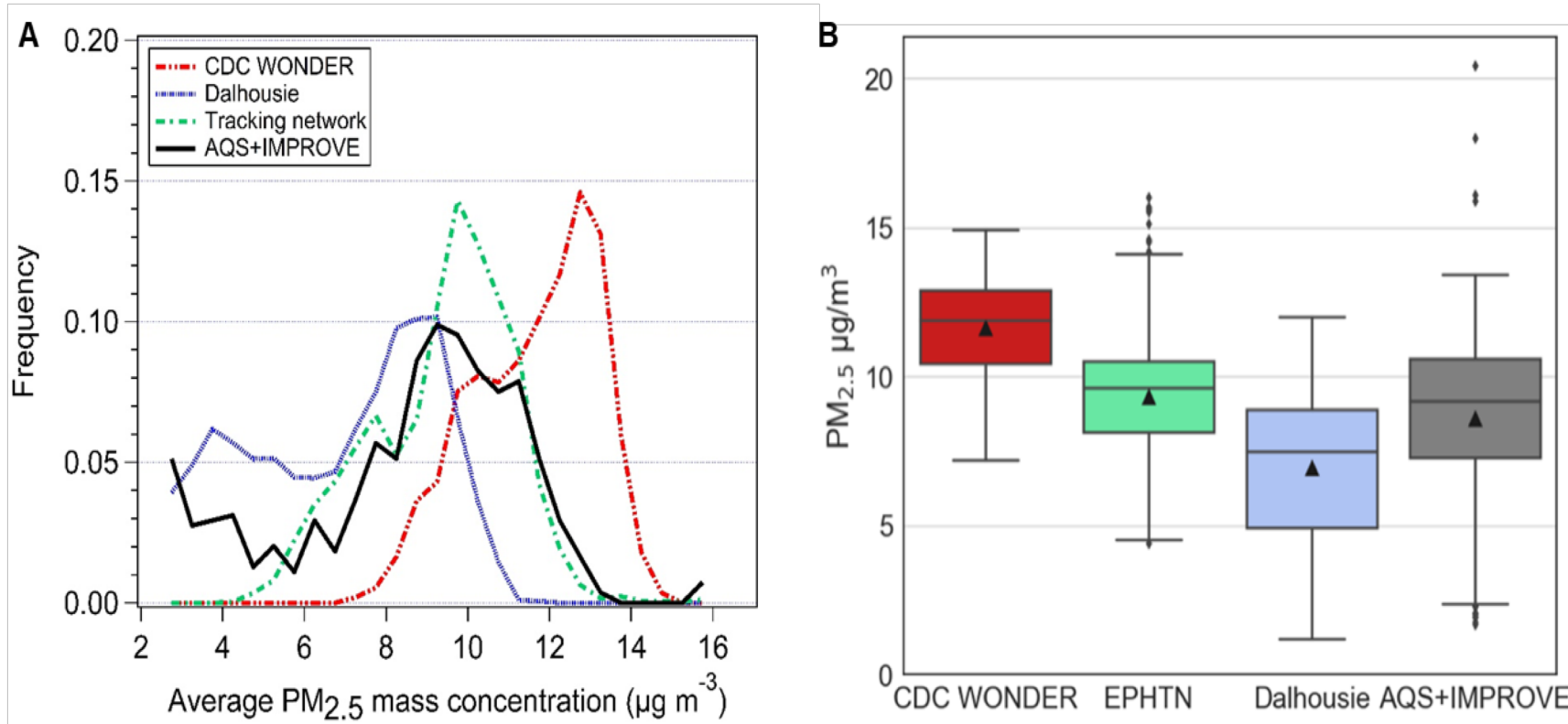


ArcGIS-generated county-level maps of PM_{2.5} in 2011

- (1) CDC WONDER exhibits higher PM_{2.5} and a large regional maximum over the central U.S.
- (2) For Southern California, EPHTN shows the highest PM_{2.5} (over 14 μg/m³)
- (3) Dalhousie exhibits lower PM_{2.5} overall, and is more spatially homogeneous over the western U.S.

(Figure prepared by Grace Choi and Tracey Holloway)

Statistical distributions of three PM_{2.5} datasets in the contiguous US in 2011



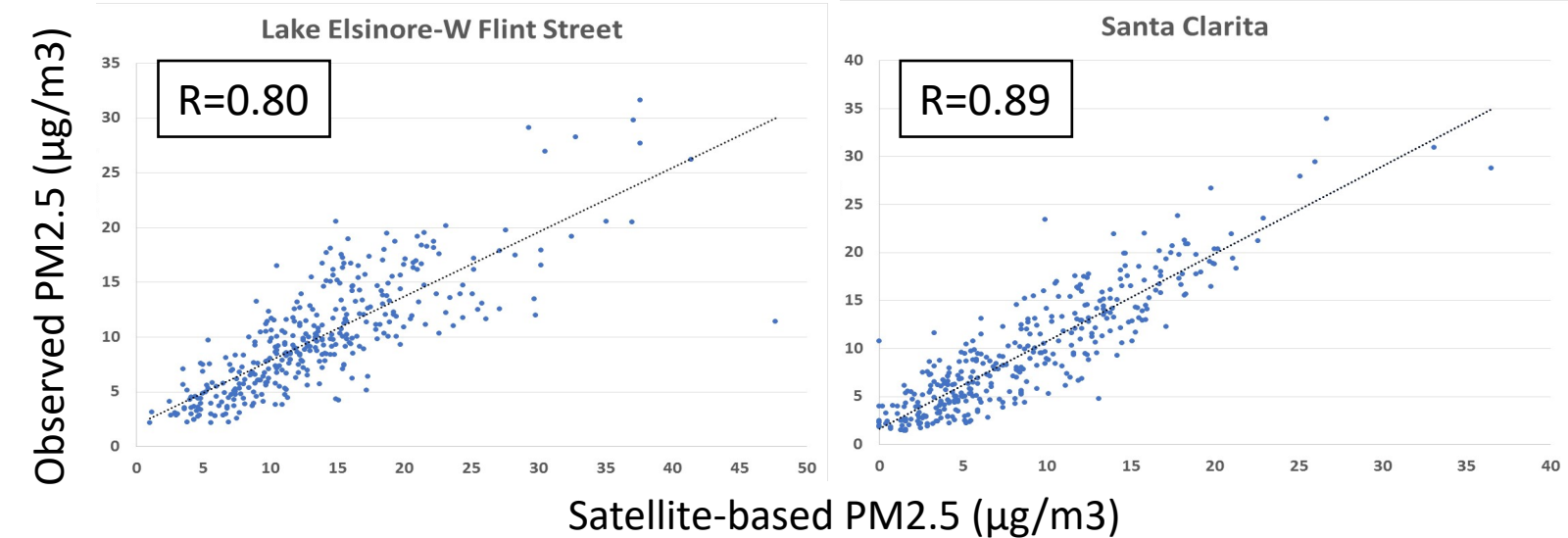
Findings:

- (1) CDC WONDER: overall higher values
- (2) Dalhousie: the lowest mean values of PM_{2.5} overall, and the largest standard deviation
- (3) More detailed comparisons are needed to track down the reasons behind the differences

Figure prepared by Minghui Diao, Xiaomeng Jin, Grace Choi and Tracey Holloway

Diao M., T. Holloway, S. Choi, S.M. O'Neill, M.Z. Al-Hamdan, A. van Donkelaar, R.V. Martin, X. Jin, A.M. Fiore, D.K. Henze, F. Lacey, P.L. Kinney, F. Freedman, N.K. Larkin, Y. Zou, A. Vaidyanathan Methods, availability, and applications of PM_{2.5} exposure estimates derived from ground measurements, models, and satellite datasets, **submitted to ES&T**.

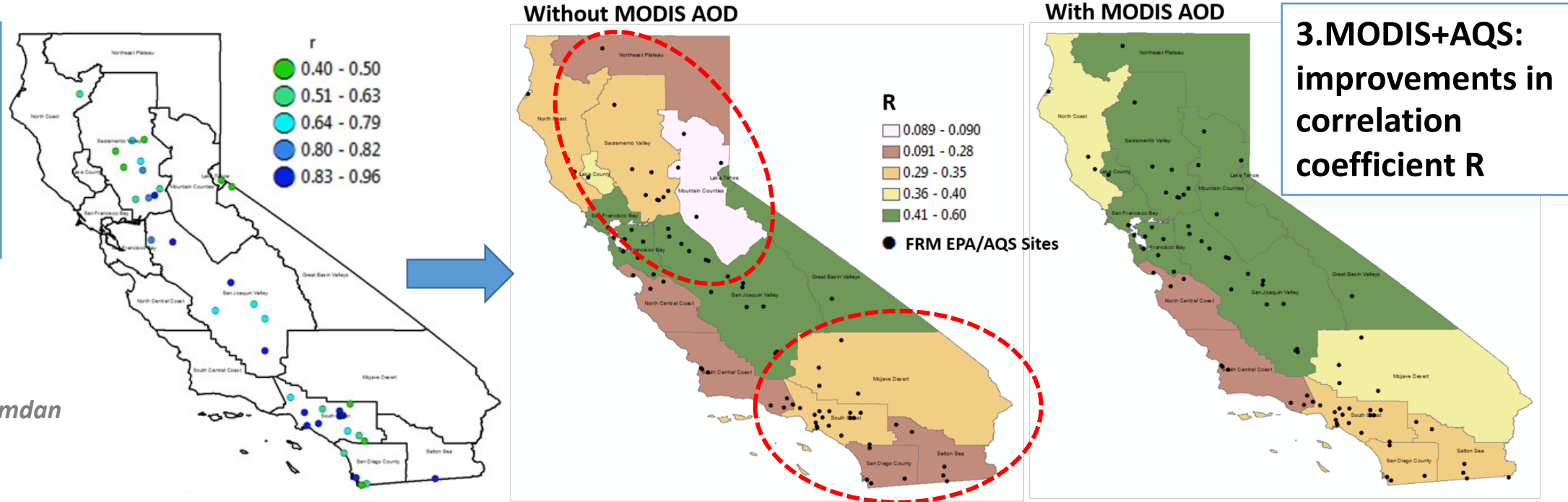
Added value of satellite information of aerosol optical depth (AOD)



1. Satellite-based PM_{2.5} grid-mean values compared with the observations at two non-Federal Reference Monitor (FRM) stations in 2016

2. Validation correlation coefficients at 44 non-FRM locations

Figure prepared By:
Dr. Mohammad Al-Hamdan
USRA at NASA/MSFC



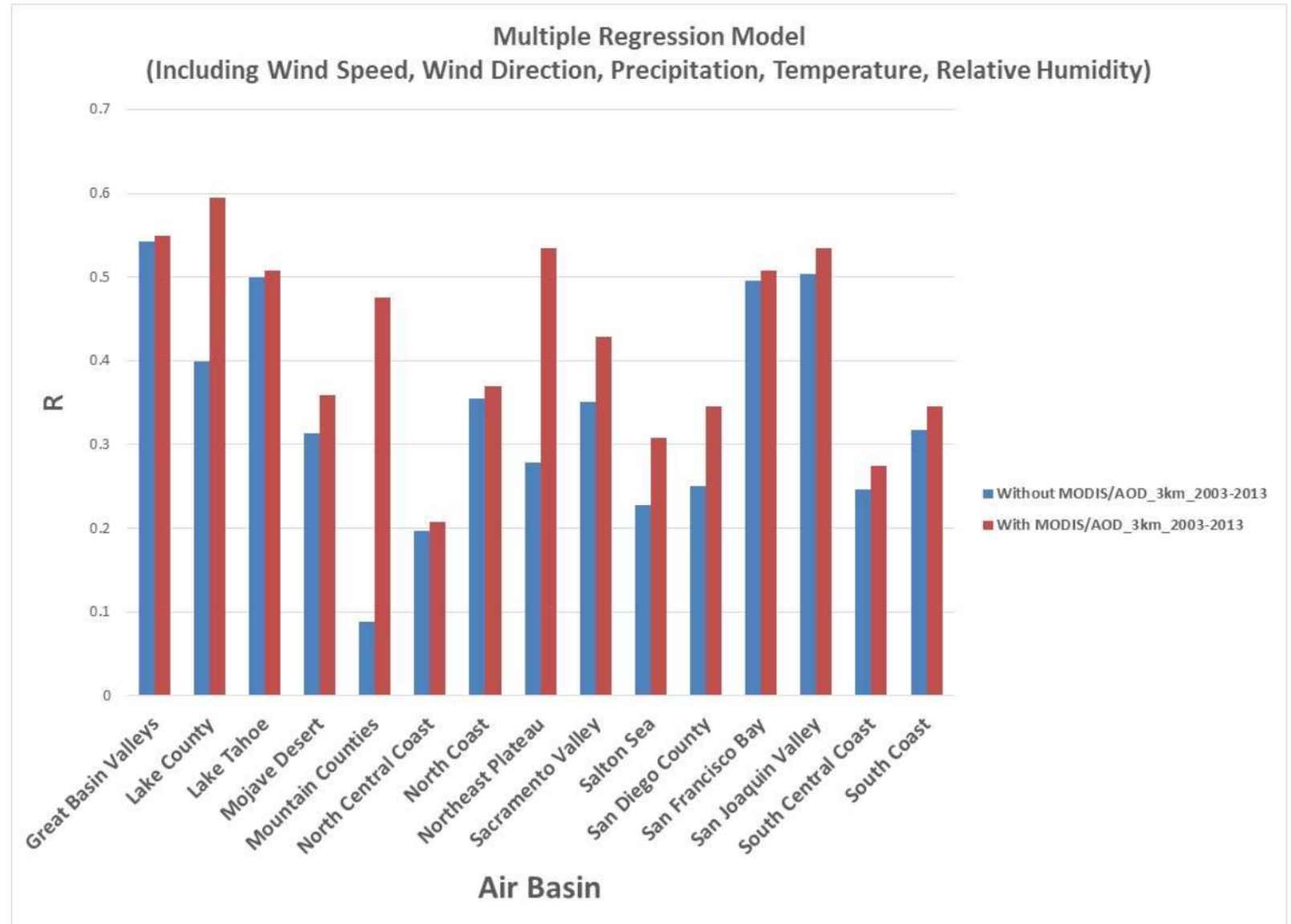
3. MODIS+AQS: improvements in correlation coefficient R

Added value of satellite data

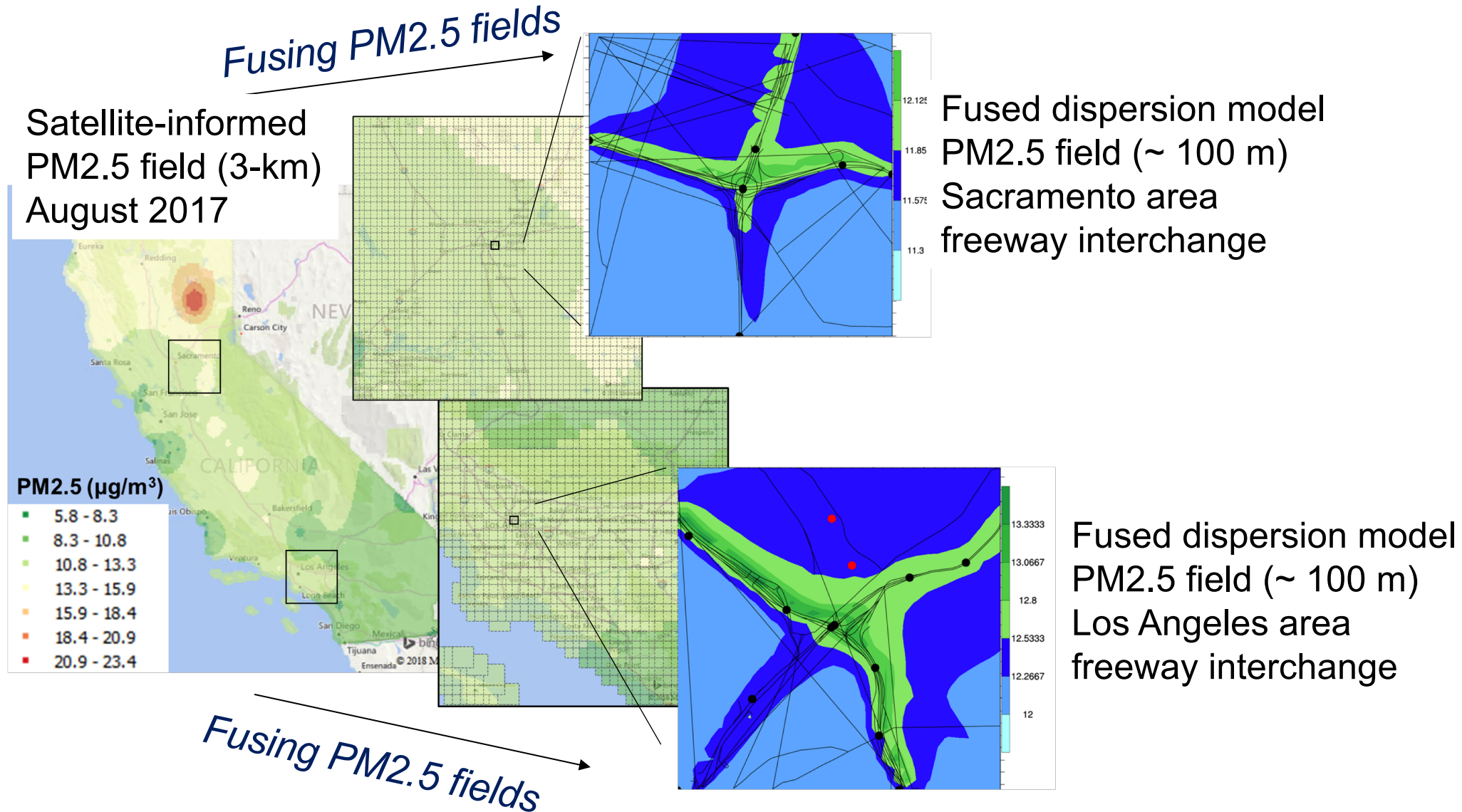
This evaluation shows the improvement/value added to the multiple regression model (R Improvement) by including the MODIS/AOD in the multiple regression model

Figure prepared By:
Dr. Mohammad Al-Hamdan
USRA at NASA/MSFC

Multiple Regression Models Evaluation (For With and Without MODIS AOD)



Fusion of satellite-derived PM_{2.5} and a downscale model



~ 100 m resolution over 3 km regional grid

Figures prepared by:
Frank Freedman, SJSU

Fusion of satellite data and a downscale model

Initialization

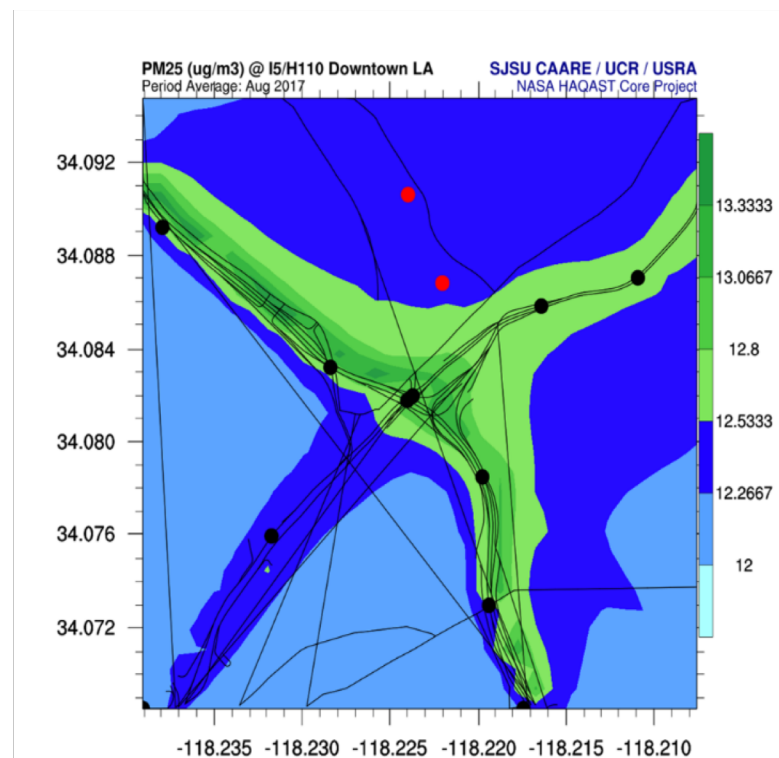
- 1) Regional PM2.5 concentration value at some grid within the regional field, $PM2.5_{Reg}$
- 2) Fine-scale PM2.5 field computed by dispersion model within the grid, $PM2.5_{FS}(x,y)$

Remove spatial average of fine-scale field from regional value and add fine-scale field back in ...

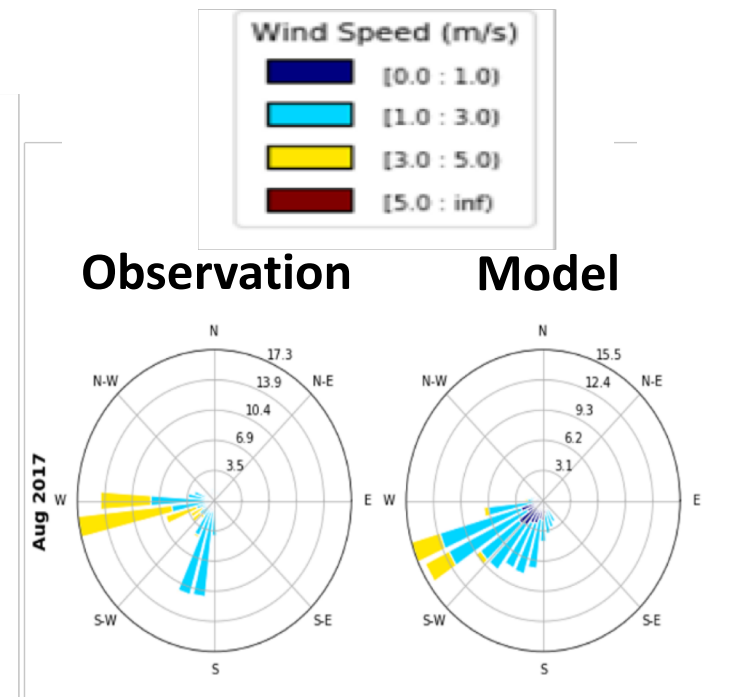
$$PM2.5_{Fused}(x,y) = PM2.5_{Reg} - \overline{PM2.5_{FS}(x,y)} + PM2.5_{FS}(x,y)$$

Case study: Fused PM2.5 Field (I5/H110 Downtown Los Angeles, August 2017)

Regional PM2.5
field value = $12.4 \mu\text{g}/\text{m}^3$



Downscaled to ~100 m around interchange.
+ regional average = $12.4 \mu\text{g}/\text{m}^3$



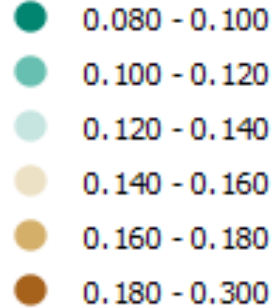
SCAQMD North Main St
August 2017 hourly winds

HRRR model vs. nearby monitor wind rose
comparison (August 2017 hourly winds)

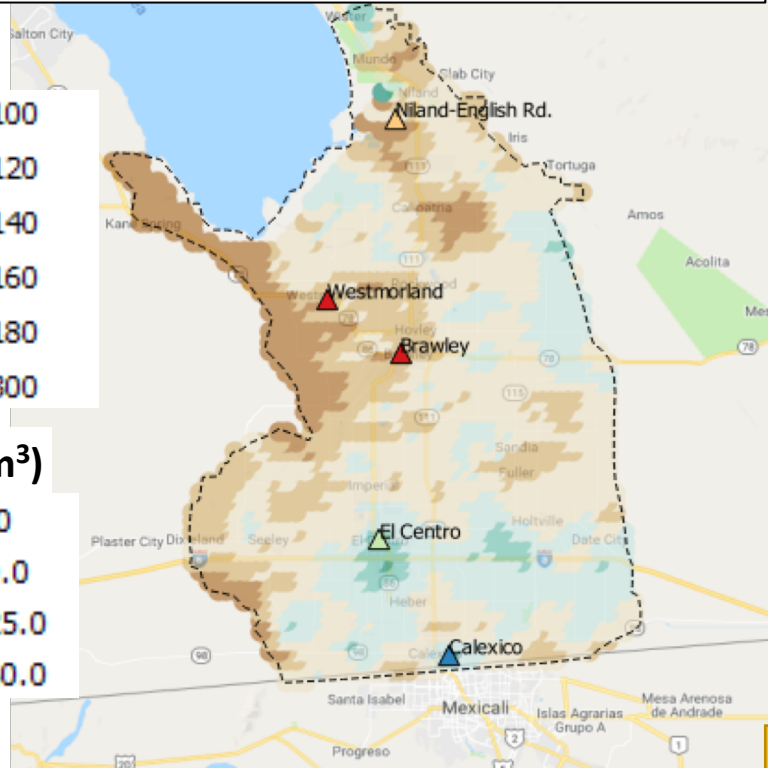
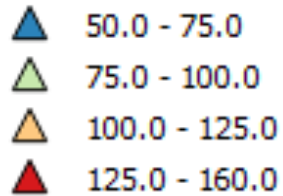
Tiger Team 1 project on Imperial Valley in California

Routine PM10 measurements overlaid

AOD

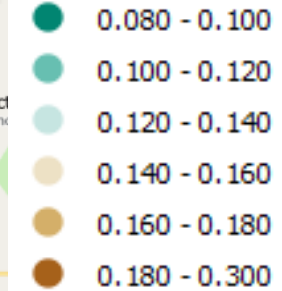


PM10 ($\mu\text{g}/\text{m}^3$)

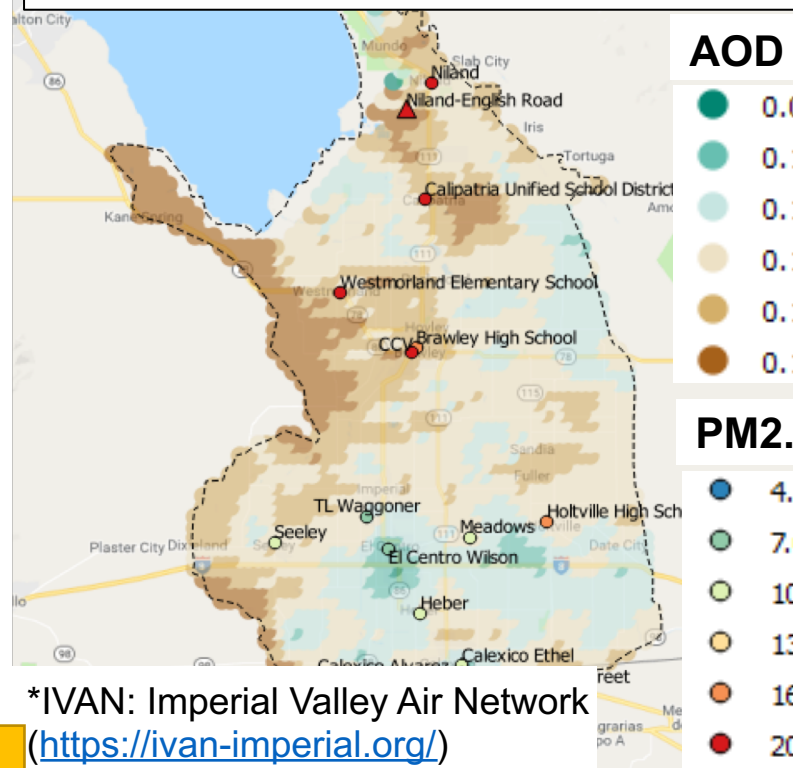
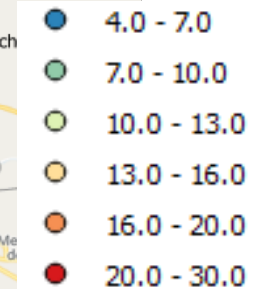


IVAN* PM2.5 measurements overlaid

AOD



PM2.5 ($\mu\text{g}/\text{m}^3$)



*IVAN: Imperial Valley Air Network
(<https://ivan-imperial.org/>)

A composite of 11 days in 2016 of high windblown dust in Imperial Valley.

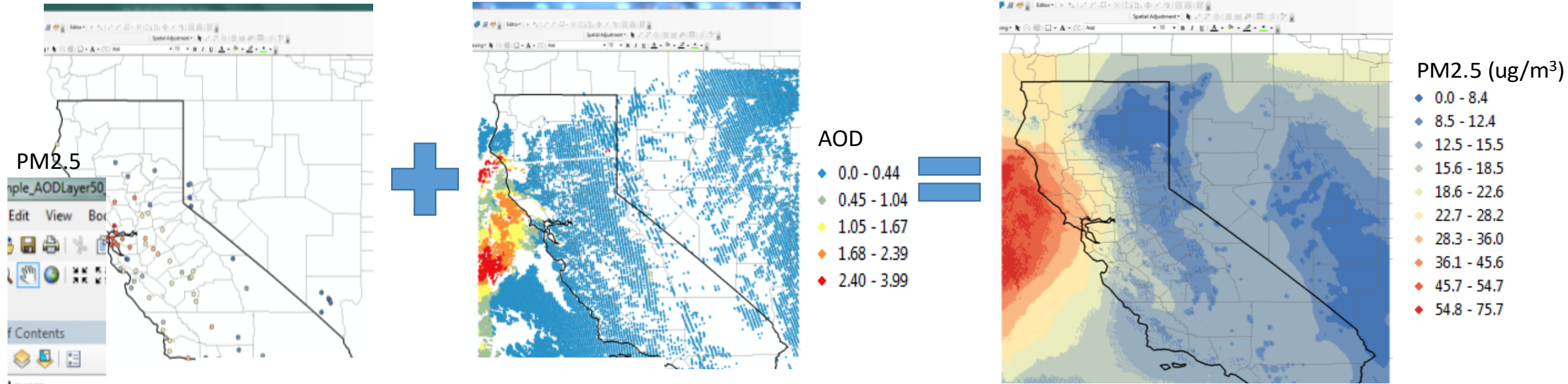
- Average of MAIAC Aqua AOD fields (<https://arcg.is/1n0Tjn>).
- Number of Days: 11 (Mar 22, Mar 28, Apr 25, Apr 27, May 5, May 15, May 20, May 21, May 24, May 25, Jun 15)

Faraz Ahangar, Frank Freedman, and Akula Venkatram, Using Low-Cost Air Quality Sensor Networks to Improve the Spatial and Temporal Resolution of Concentration Maps, to be submitted.

Tiger Team 2 project on California wildfire in Oct-Nov 2017

EPA/AQS PM2.5

NASA/MODIS AOD

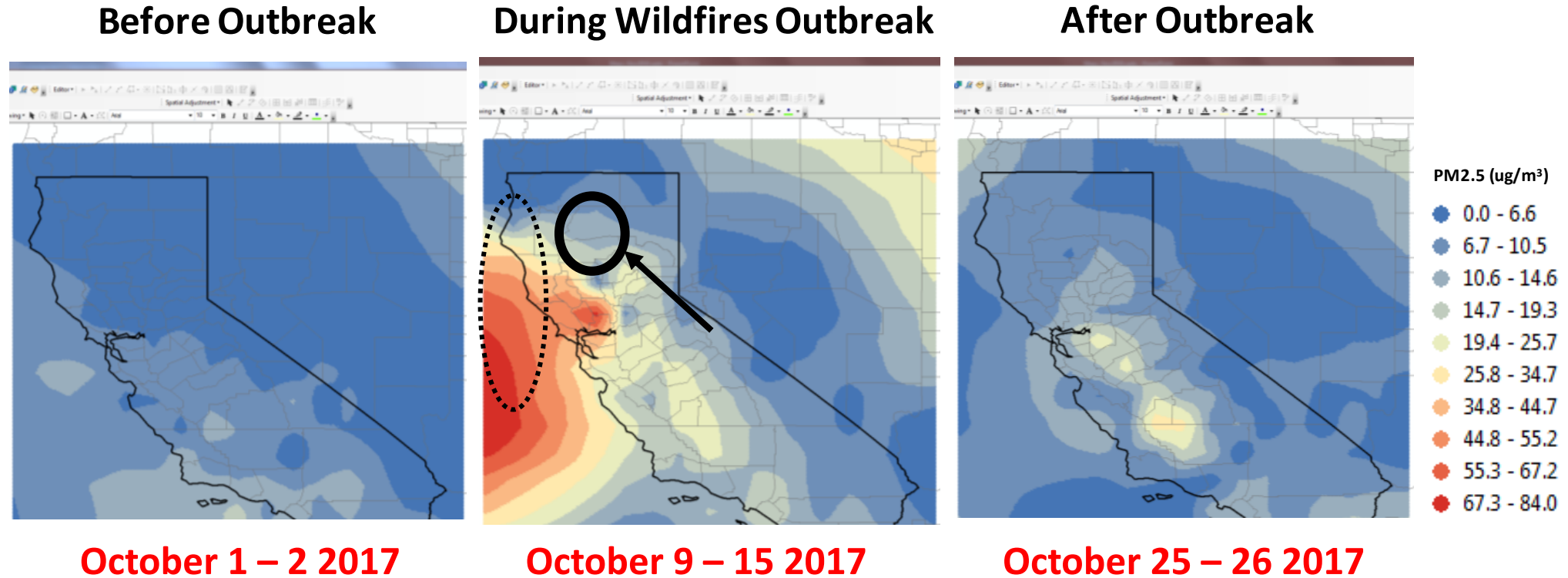


Example of October 9, 2017

Using satellite data to provide a more extensive coverage of surface PM2.5 during the wildfire event in California

Figures prepared by:
Dr. Mohammad Al-Hamdan
USRA at NASA/MSFC
mohammad.alhamdan@nasa.gov

TT2: Evolution of the surface PM_{2.5} concentrations



1. NASA satellites and ground monitors combined to provide daily estimates of PM_{2.5} before and after the Northern California Wildfires outbreak of October 9-15, 2017.
2. Issues with the off-shore high concentrations due to B-spline smoothing method in the algorithm. Currently working on removing B-spline in the surfacing model.





Year 2.5 Progress Update, PI Minghui Diao

Integrating Satellites into Health and Air Quality Management

- 1. Satellite-derived PM_{2.5} grids
 - Develop, apply and evaluate regression model for California;
 - Construct AOD-PM_{2.5} surfaces for California for 2016 and 2017;
- 2. Visualization of satellite-derived PM_{2.5} grids (complete)
 - Develop visualization of MAIAC AOD and derived PM_{2.5} on selected days (LA, Bay Area, Imperial Valley);
 - Analysis and incorporation of HRRR wind fields.
- 3. Dispersion model simulation
 - Development and evaluation of the dispersion model simulations
 - **Incorporate satellite-derived surface PM_{2.5} into a dispersion model, which are further downscaled to 100 meter scale (mostly finished)**
- 4. *A review paper submitted to ES&T* on PM_{2.5} data availability, method and analyses, led by Minghui Diao

Tiger Team Participation

- TT#1 led by Patrick Kinney (complete)
 - Deploy low-cost sensors in three Bay Area sites;
 - MAIAC AOD and dispersion modeling analysis of PM₁₀ and PM_{2.5} fields across Imperial Valley
- TT#2 led by Susan O'Neill (PI) and Minghui Diao (co-I) (on-going)
 - Developing surface PM_{2.5} derived from satellite data for the duration of the California wildfire in October – November 2017
 - Conducting dispersion model simulations for wildfire plume distribution
- 11+ academic talks; 5 stakeholders; Research website on HAQAST project at SJSU:
 - <https://www.cloud-research.org/haqast-project>
 - 1 paper submitted, 2 papers in preparation