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

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Cynthia Garcia (California Air Resource Board)
Sang-Mi Lee (South Coast Air Quality Management District)
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HAQAST
NASA Health and Air Quality Applied Sciences Team

AMS meeting, January 9 2019, Phoenix, Arizona

SAN JOSE STATE UNIVERSITY

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.

Outline

1. *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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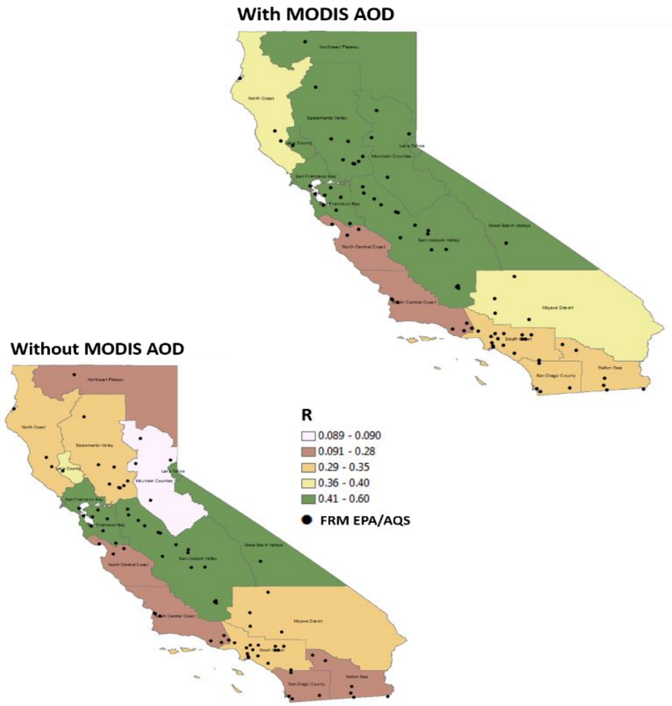
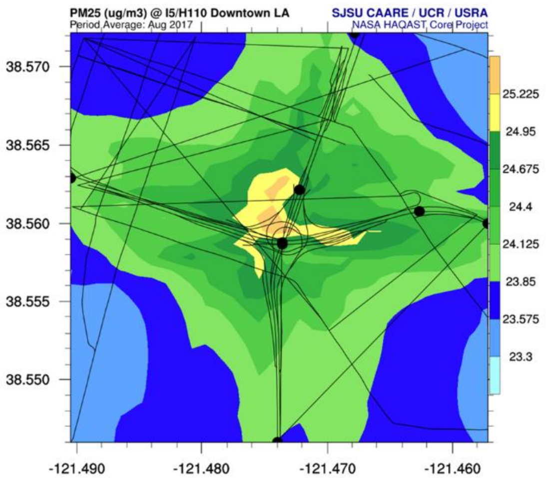
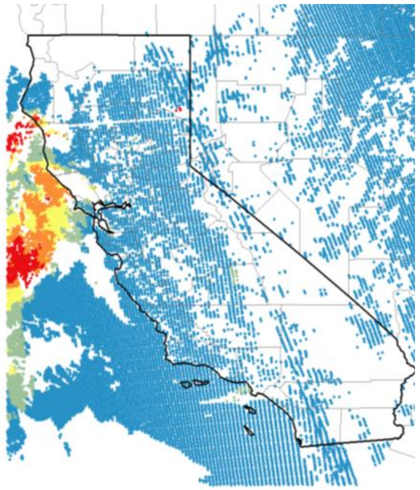
2. *Added value of satellite information to derive surface PM2.5*



3. *A fused PM2.5 field of satellite data, ground monitors, further downscaled to 100 meter scale*



4. *California wildfire analyses using MODIS AOD and ground monitor data*



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?***

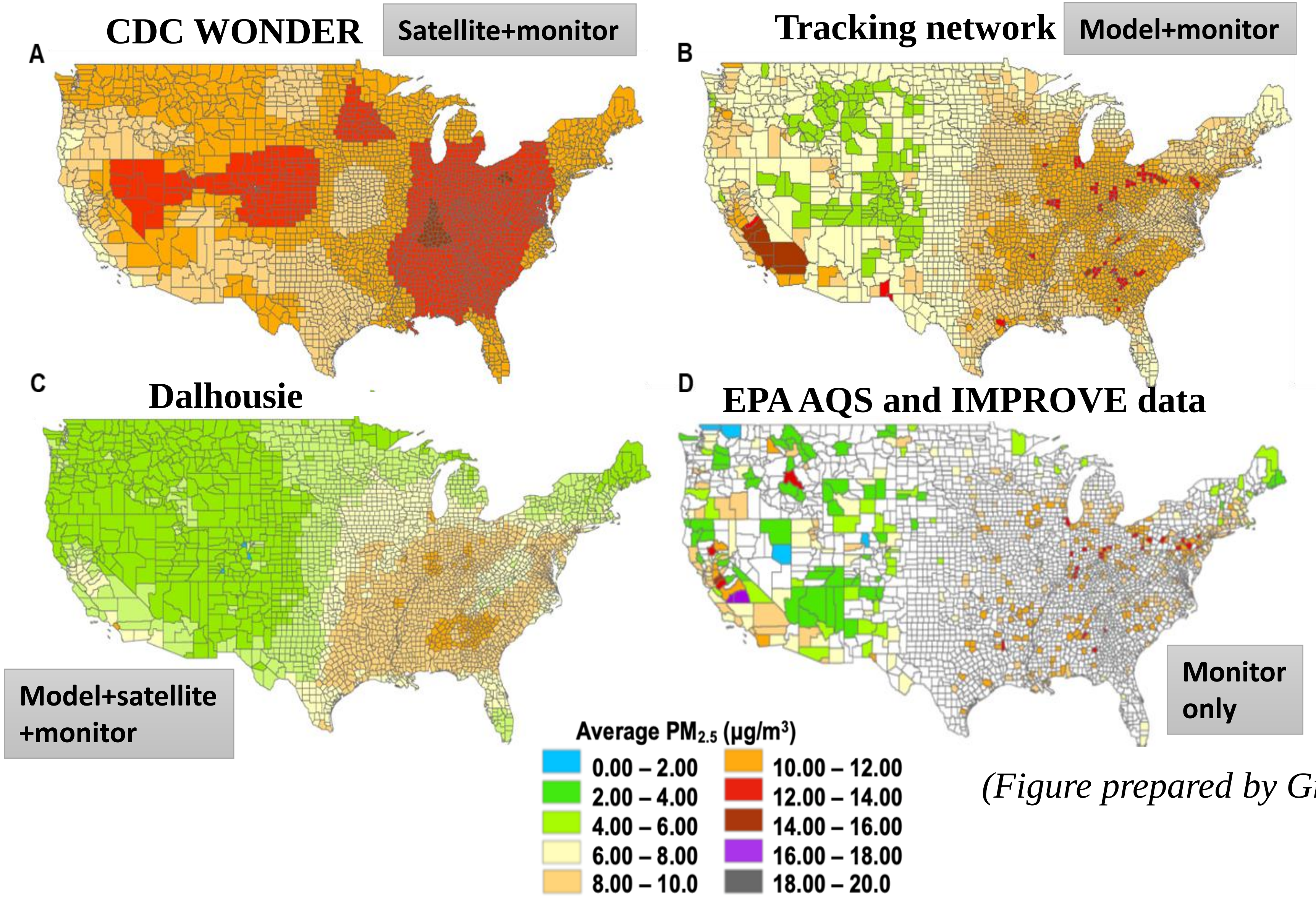
Source of Dataset	Region	Time Period	Spatial Resolution	Temporal Resolution	Monitor	Model	Satellite	Reference
GBD	Global	1990 - 2013	*0.1°× 0.1°	Annual	X	X	X	Brauer et al., [2016]
Dalhousie Dataset V4.GL.02	Global	1998 - 2016	1 km^2	Annual	X	X	X	(1)
GBD	Global	2014	*0.1°× 0.1°	Annual	X	X	X	Shaddick et 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 AirData	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)
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 PM2.5 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

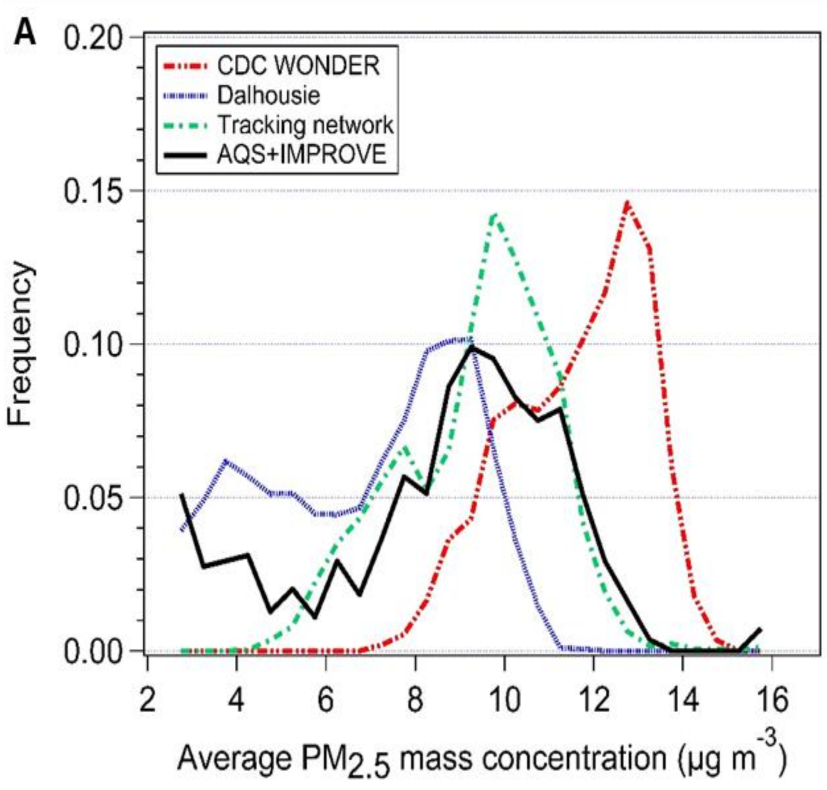
(1) CDC WONDER exhibits higher $PM_{2.5}$ and a large regional maximum over the central U.S.

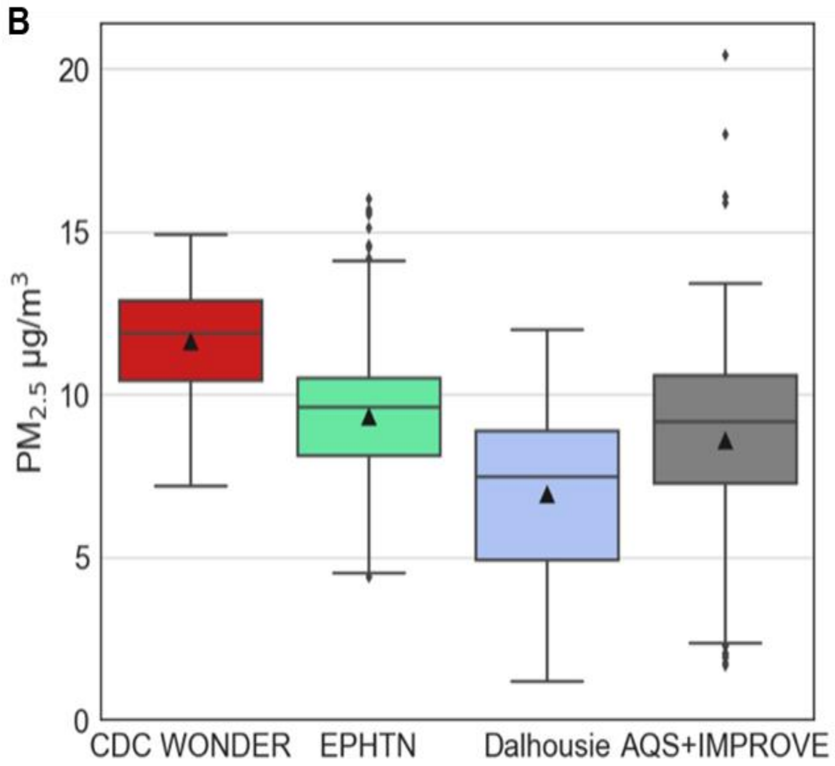
(2) For Southern California, EPHTN shows the highest $PM_{2.5}$ (over 14 µg/m3)

(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

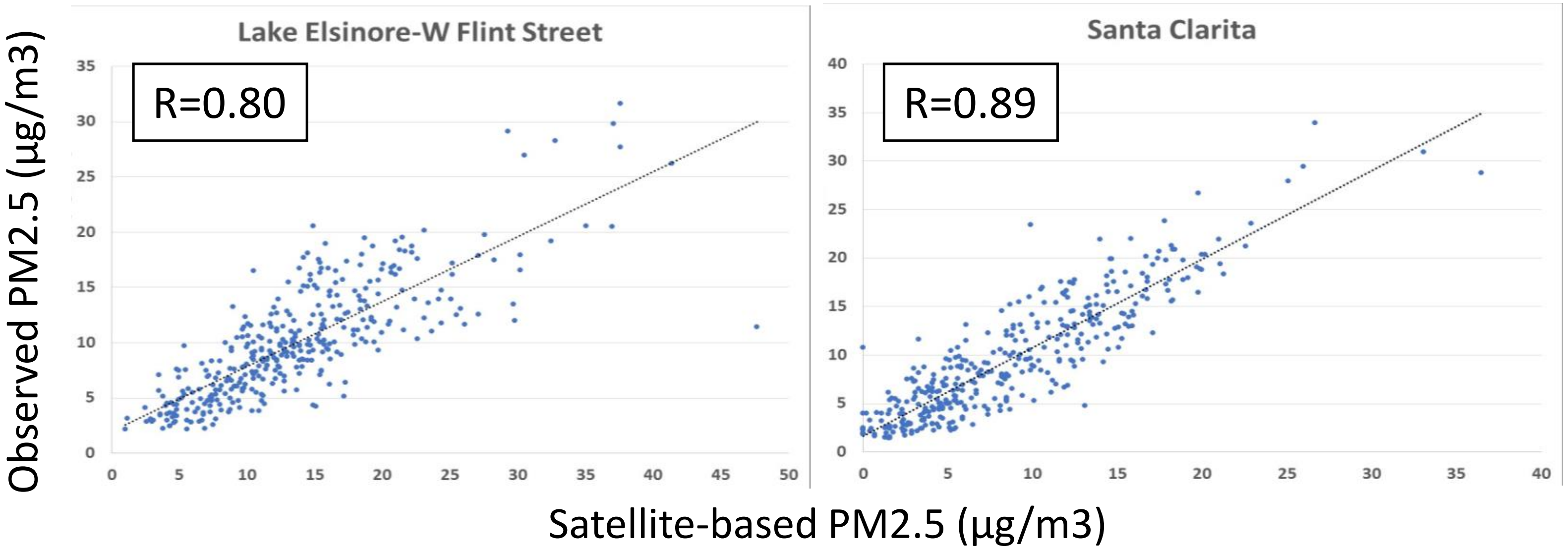
(2) Dalhousie: the lowest mean values of $PM_{2.5}$ overall, and the largest standard deviation

(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

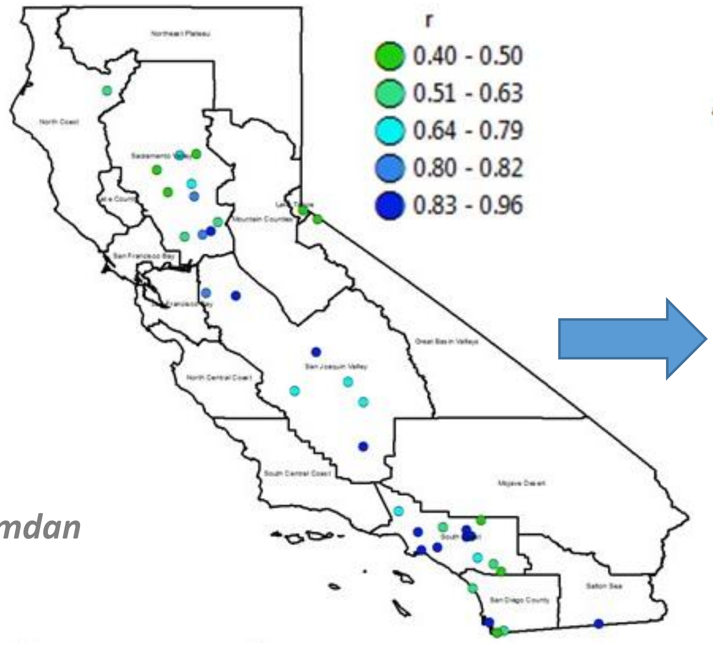
Diao M., T. Holloway, S. Choi, S.M. O'Neill, M.Z. Al-Hamdan, A.van Donkelaar, R.V. Martin, X. Jin, A.M. Fiore, D.K. Henze, F. Lacey, P.L. Kinney, F. Freedman, N.K. Larkin, Y. Zou, A. Vaidyanathan Methods, availability, and applications of $PM_{2.5}$ exposure estimates derived from ground measurements,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

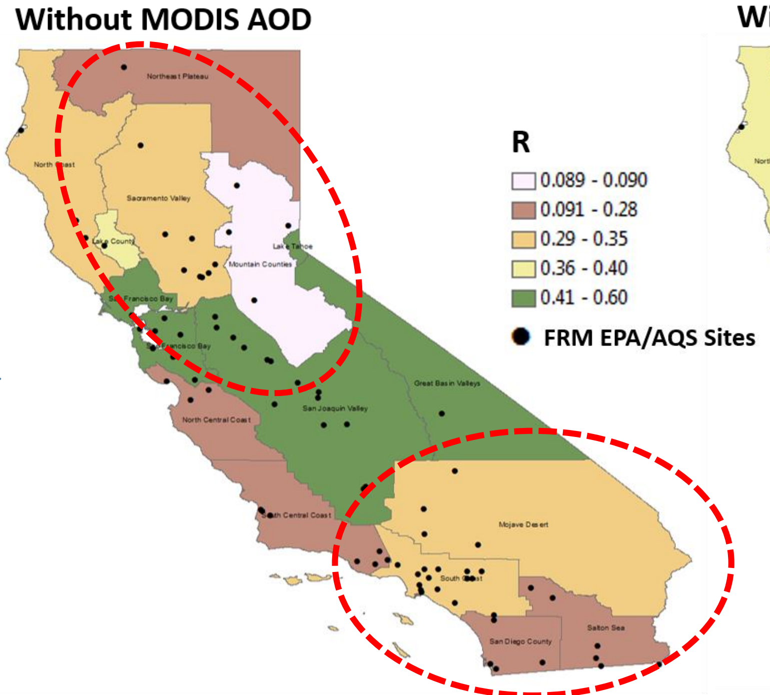
Added value of satellite information of aerosol optical depth (AOD)

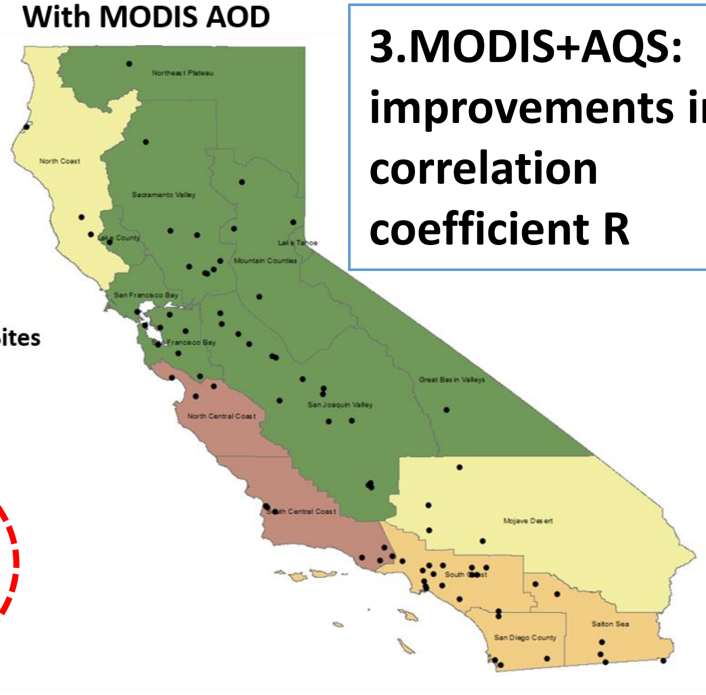


1. Satellite-based $PM_{2.5}$ grid-mean values compared with the observations at two non-Federal Reference Monitor (FRM) stations in 2016 (These non-FRM monitors are provided by EPA AQS)

2. Validation correlation coefficients at 44 non-FRM locations







3.MODIS+AQS: improvements in correlation coefficient R

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

Added value of satellite data for deriving surface PM2.5

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

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

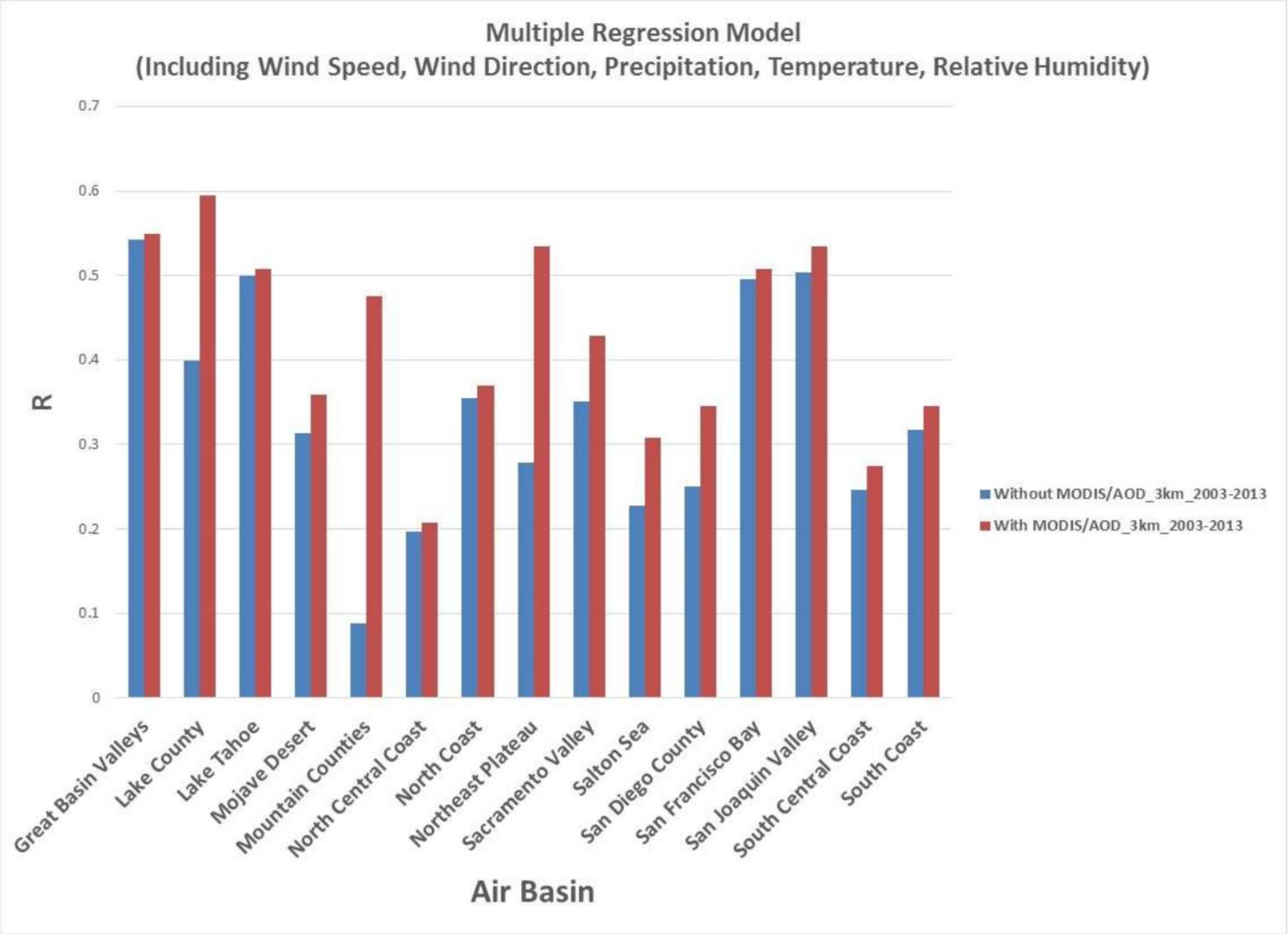


Figure prepared By:
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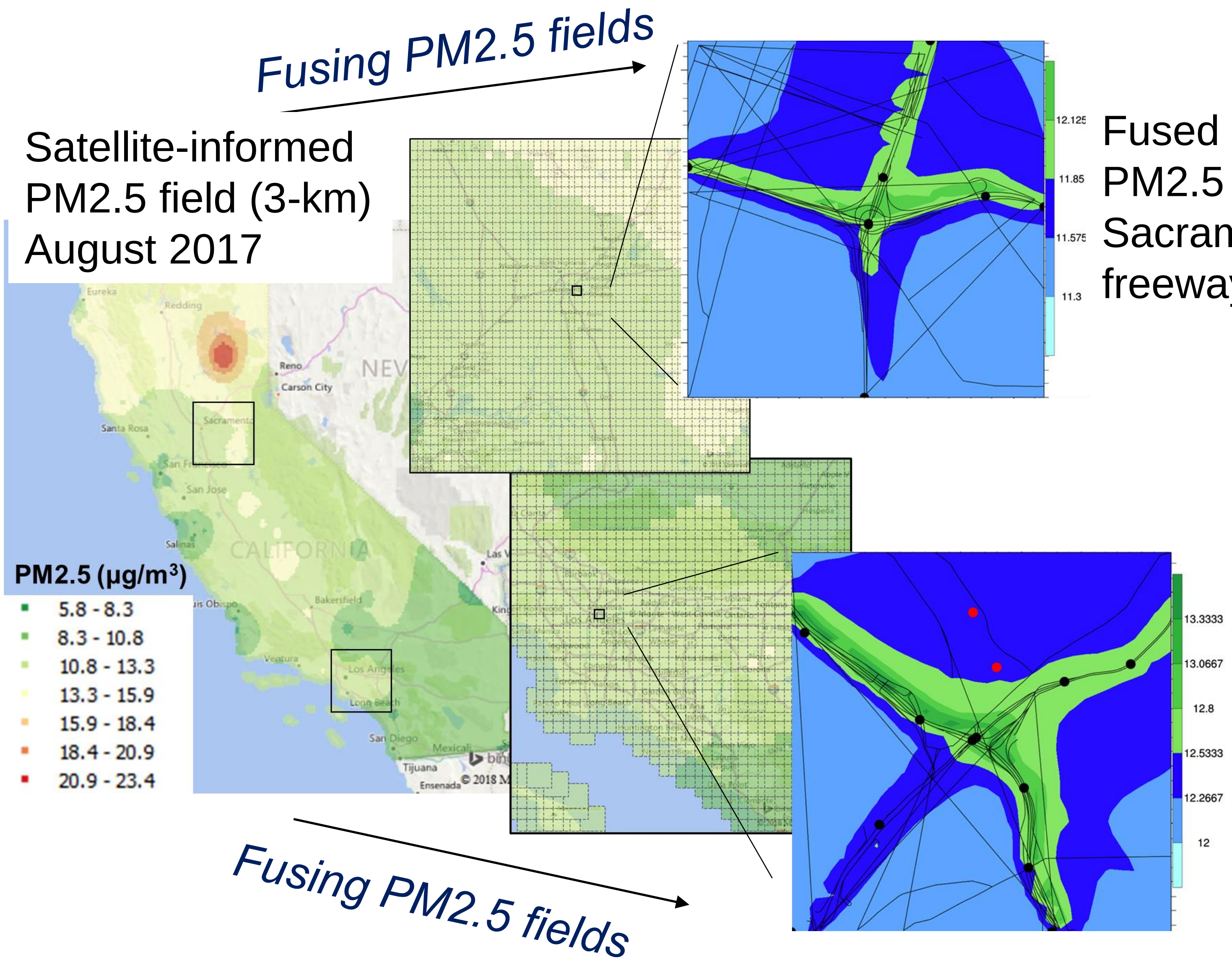
USRA at NASA/MSFC

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



Fused dispersion model
PM2.5 field (~ 100 m)
Sacramento area
freeway interchange

Fused dispersion model
PM2.5 field (~ 100 m)
Los Angeles area
freeway interchange

~ 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, $PM2.5_{Reg}$

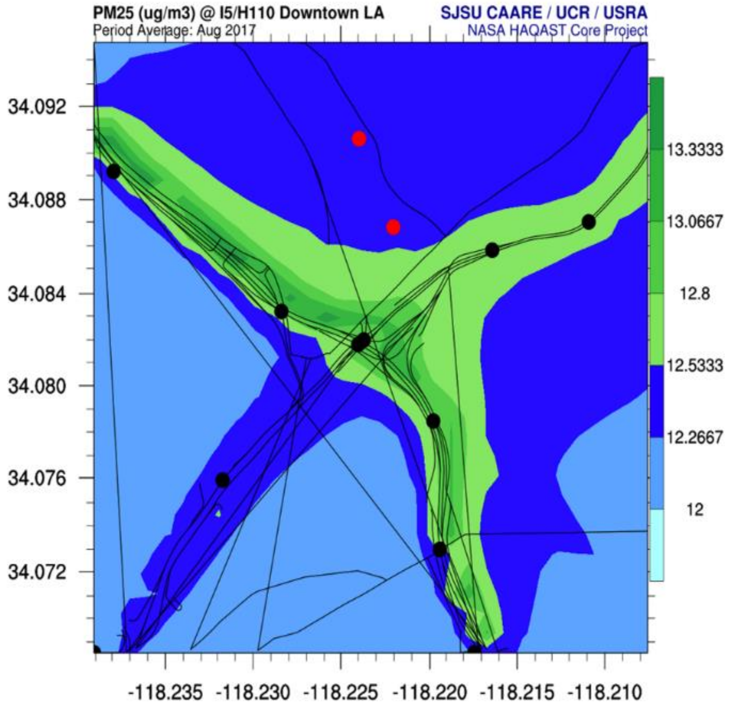
2) Fine-scale PM2.5 field computed by dispersion model within the grid, $PM2.5_{FS}(x,y)$

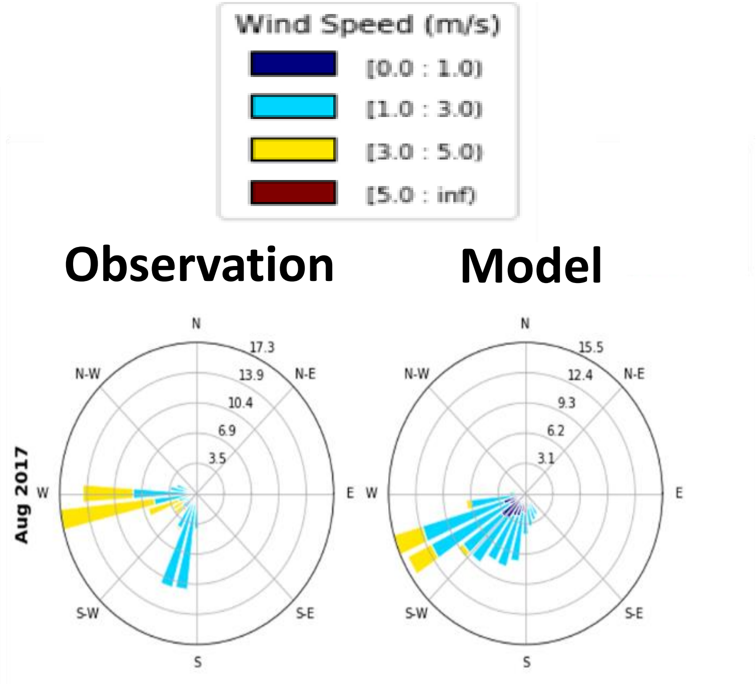
Remove spatial average of fine-scale field from regional value and add fine-scale field back in …

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

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

Regional PM2.5
field value = 12.4 μg/m^3





SCAQMD North Main St
August 2017 hourly winds

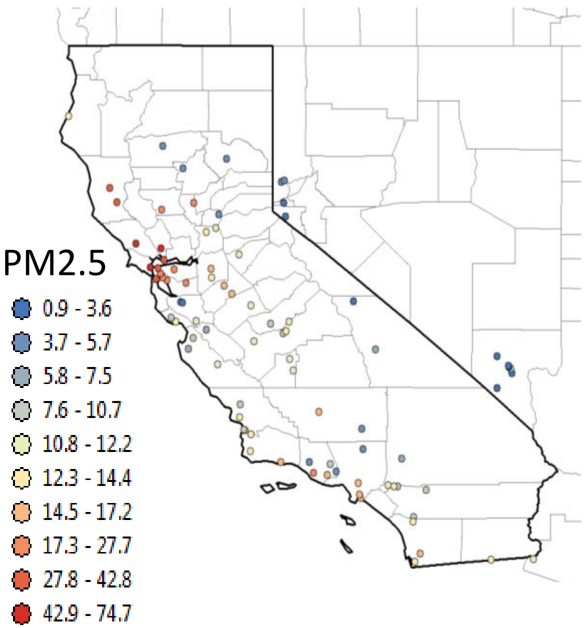
Downscaled to ~100 m around interchange.
+ regional average = 12.4 μg/m^3

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

Frank Freedman, Mohammad Al-Hamdan, Muhammad Barik, Seyedmorteza Amini, Faraz Ahangar, Akula Venkatram, Isa Cruz, and Minghui Diao. A Modeling System for Fused Satellite-Derived Regional and Near-Roadway PM2.5 Fields: Status and Future Directions. To be submitted to ***Environmental Modeling and Software***.

Tiger Team project on California wildfire in Oct-Nov 2017

EPA/AQS PM2.5



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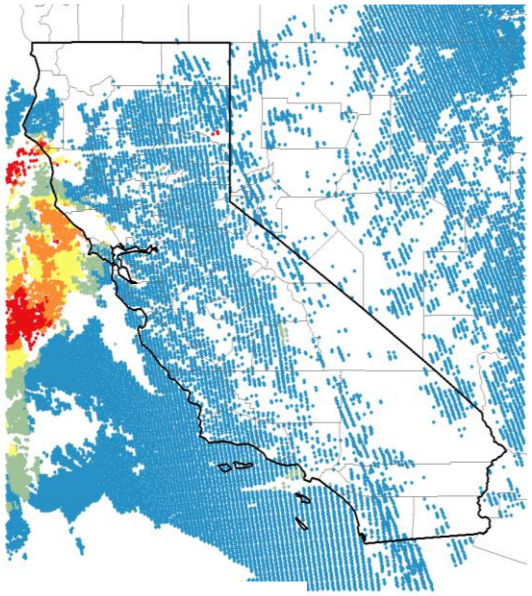
NASA/MODIS AOD



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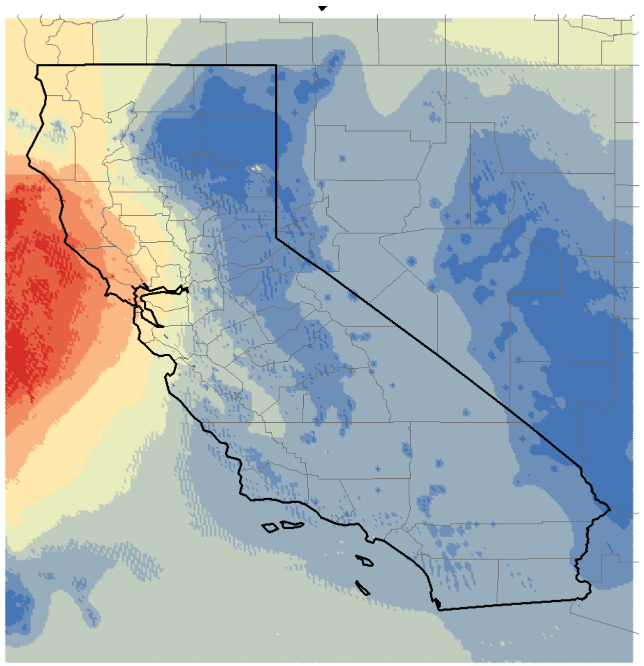
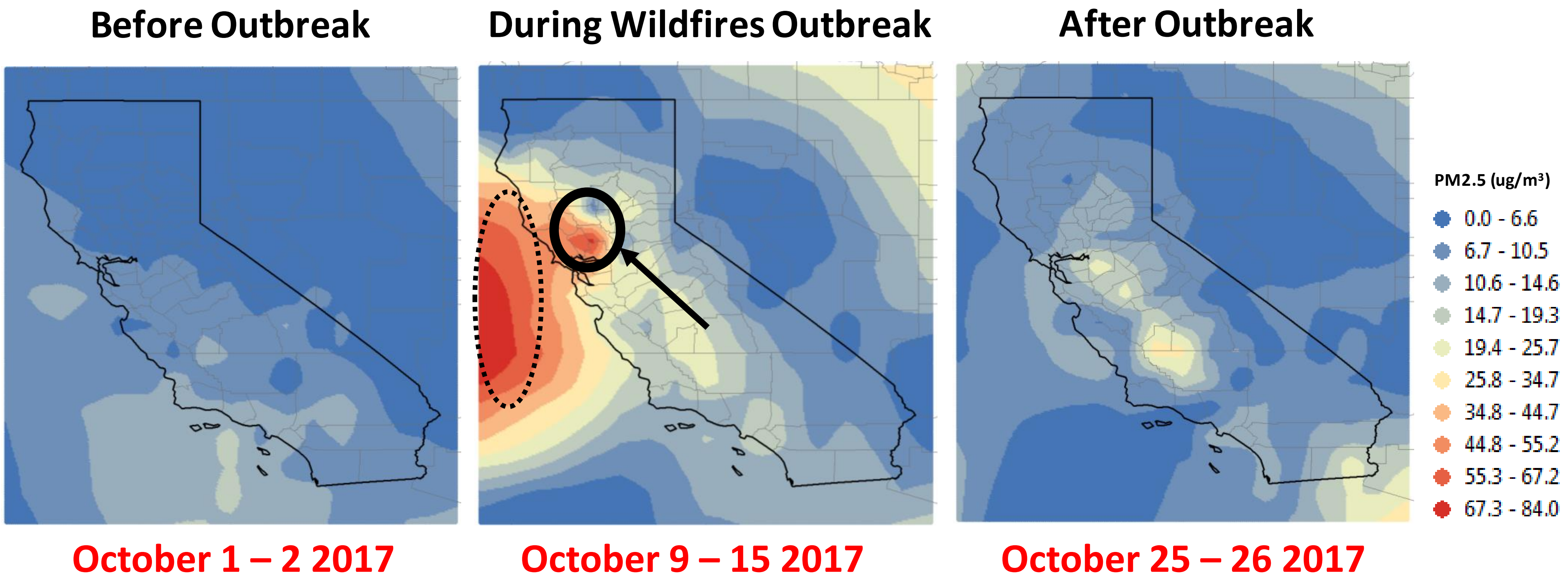


Example of October 9, 2017

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

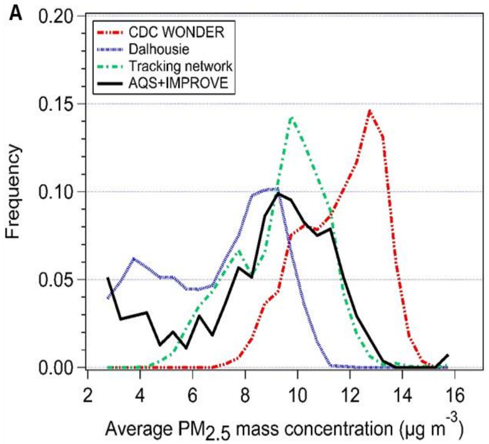
TT2: Evolution of the surface $PM_{2.5}$ concentrations

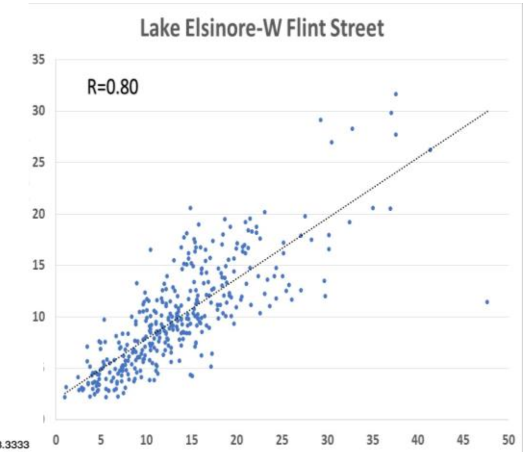


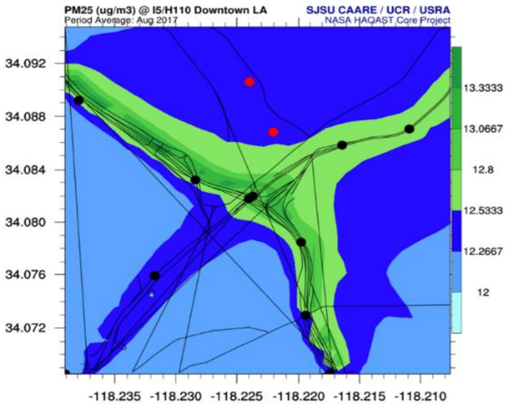
1. NASA satellites combined with ground monitors are able to provide an evolutionary trend for surface $PM_{2.5}$ before and after the Northern California Wildfires outbreak of October 9-15, 2017.
2. Issues with the off-shore contours of high concentrations due to B-spline smoothing in the algorithm. Currently working on testing other smoothing methods in the surfacing model.

Conclusions

- **1. Review article on publicly available $PM_{2.5}$ exposure estimates data sets** *(in review)*
  - Differences are shown in Year 2011 among several data sets (CDC WONDER, Dalhousie data, Tracking network, and AQS+IMPROVE)
- **2. Added value of satellite data for deriving surface $PM_{2.5}$**
  - Improved correlation coefficients are shown for AQS+MODIS data versus AQS only;
  - 44 non-FRM monitors are used in the validation
- **3. Fused data set among satellite-derived $PM_{2.5}$, ground monitor data, and a dispersion model**
  - Developed a software that incorporates regional averages from satellite-derived $PM_{2.5}$ into a dispersion model
  - Downscaled to 100-m scale for health impact analyses on community scales
- **4. California wildfire and applications of satellite data**
  - MODIS AOD data can be used to identify high concentrations of $PM_{2.5}$ during the wildfire outbreak
  - Ongoing development of better algorithms of combining monitor and satellite data

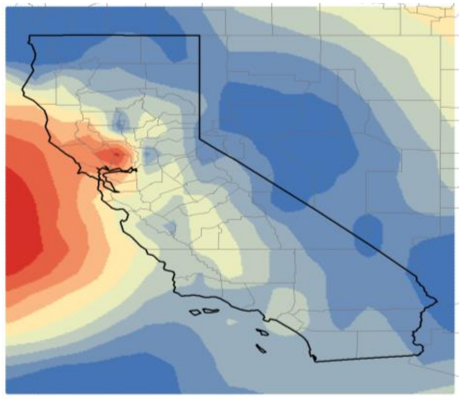






Acknowledgement
NASA HAQAST grant
NNX16AQ91G

During Wildfires Outbreak



Average PM2.5 for October 9-15, 2017