A Real-Time System for Fusing Regional and Dispersion Model PM2.5 Fields

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Stakeholder Groups: SCAQMD, BAAQMD, CARB, CalDPH

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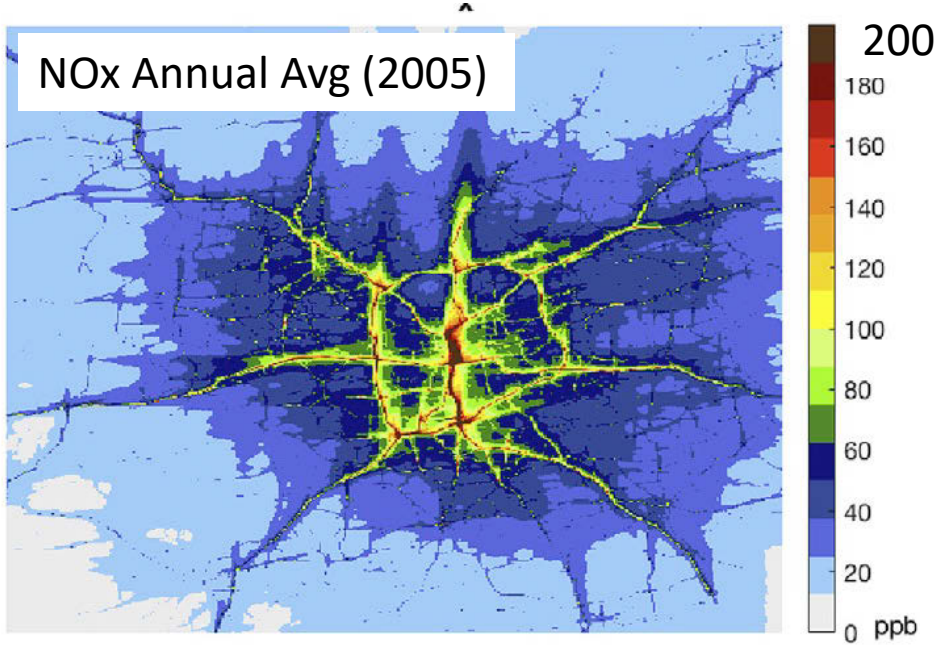
Presented at HAQAST6
(Pasadena, CA)

HAQAST
NASA Health and Air Quality Applied Sciences Team

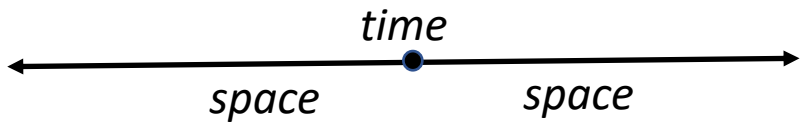
Fused Modeling
(Background)

- Combined regional & finescale modeled AQ fields
- 10s – 100s meter resolution
- Past Applications: CMAQ regional + AERMOD & R-LINE dispersion models



Atlanta

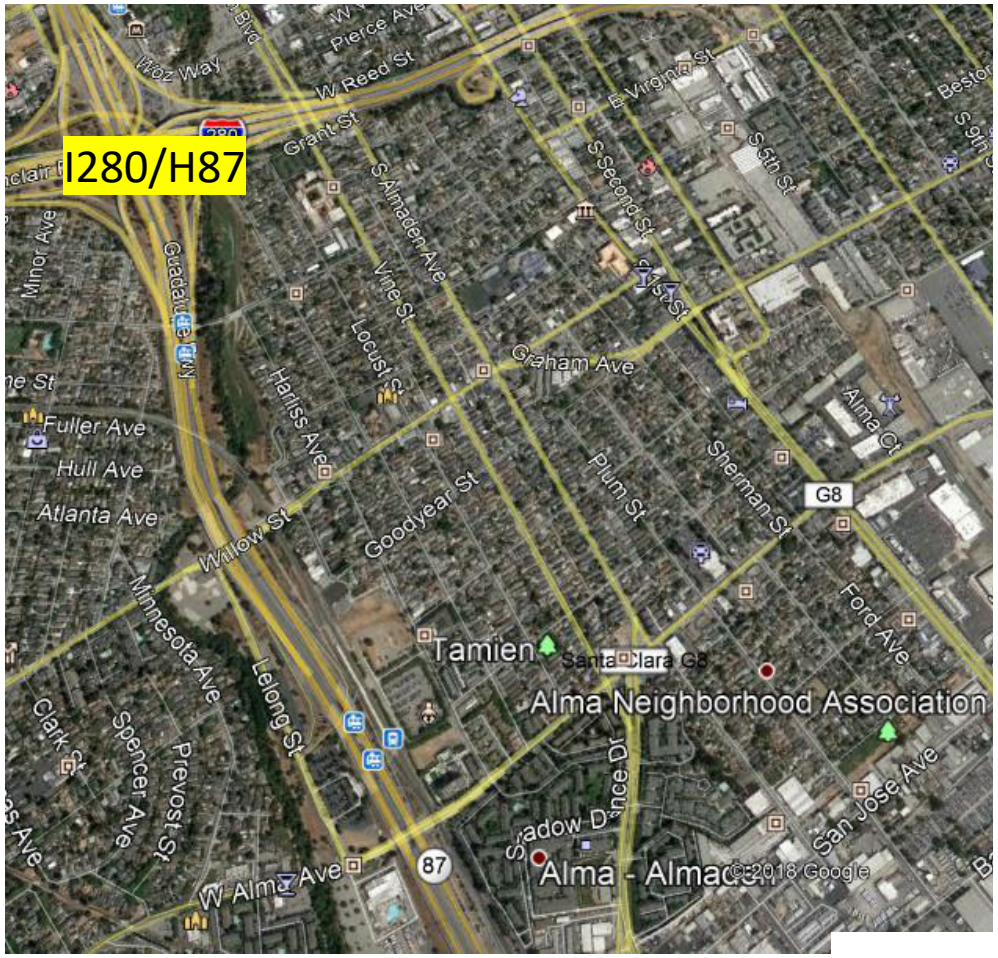
Bates et al. (2018)

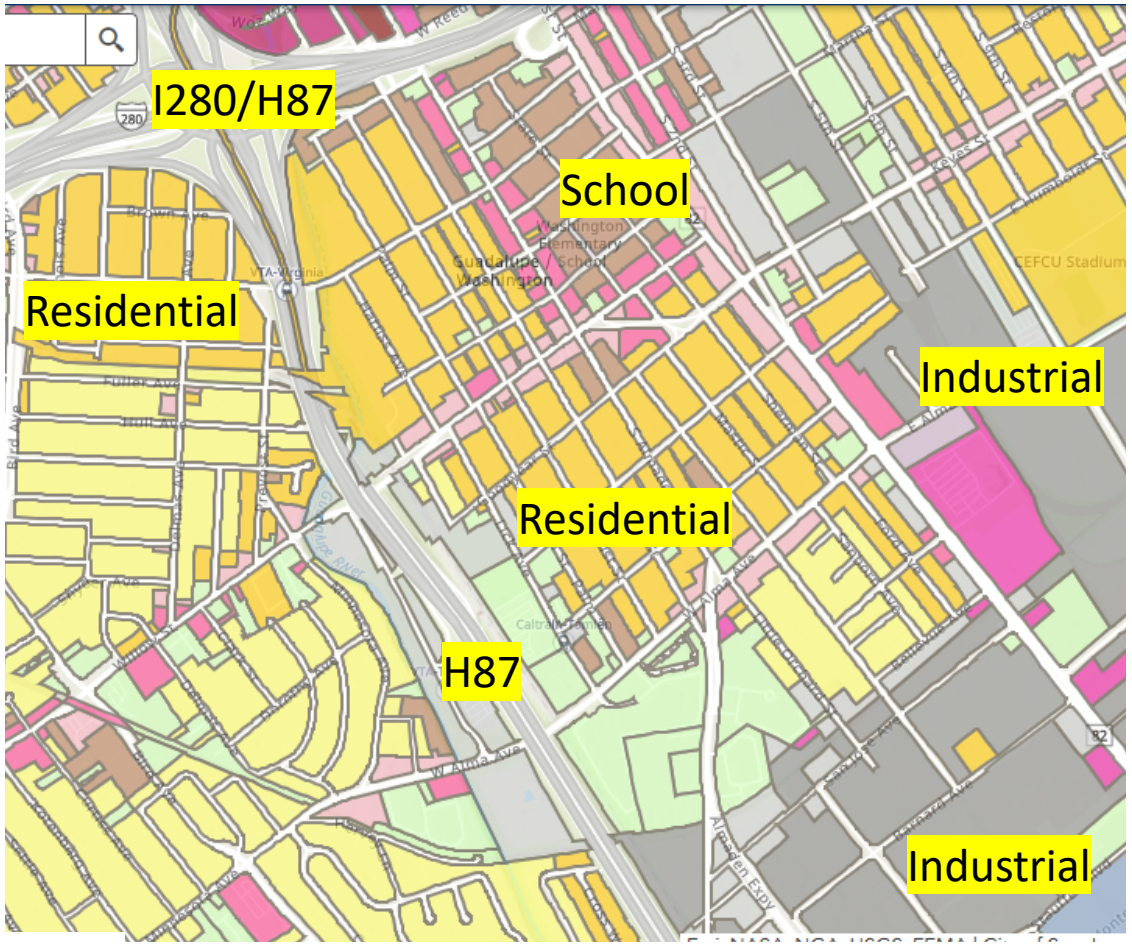


Fused Modeling: Envisioned Area-of-Interest (AOI)

(Example, Alma Neighborhood, Downtown San Jose, CA)

zoning map





~ 2 x 2 km

space

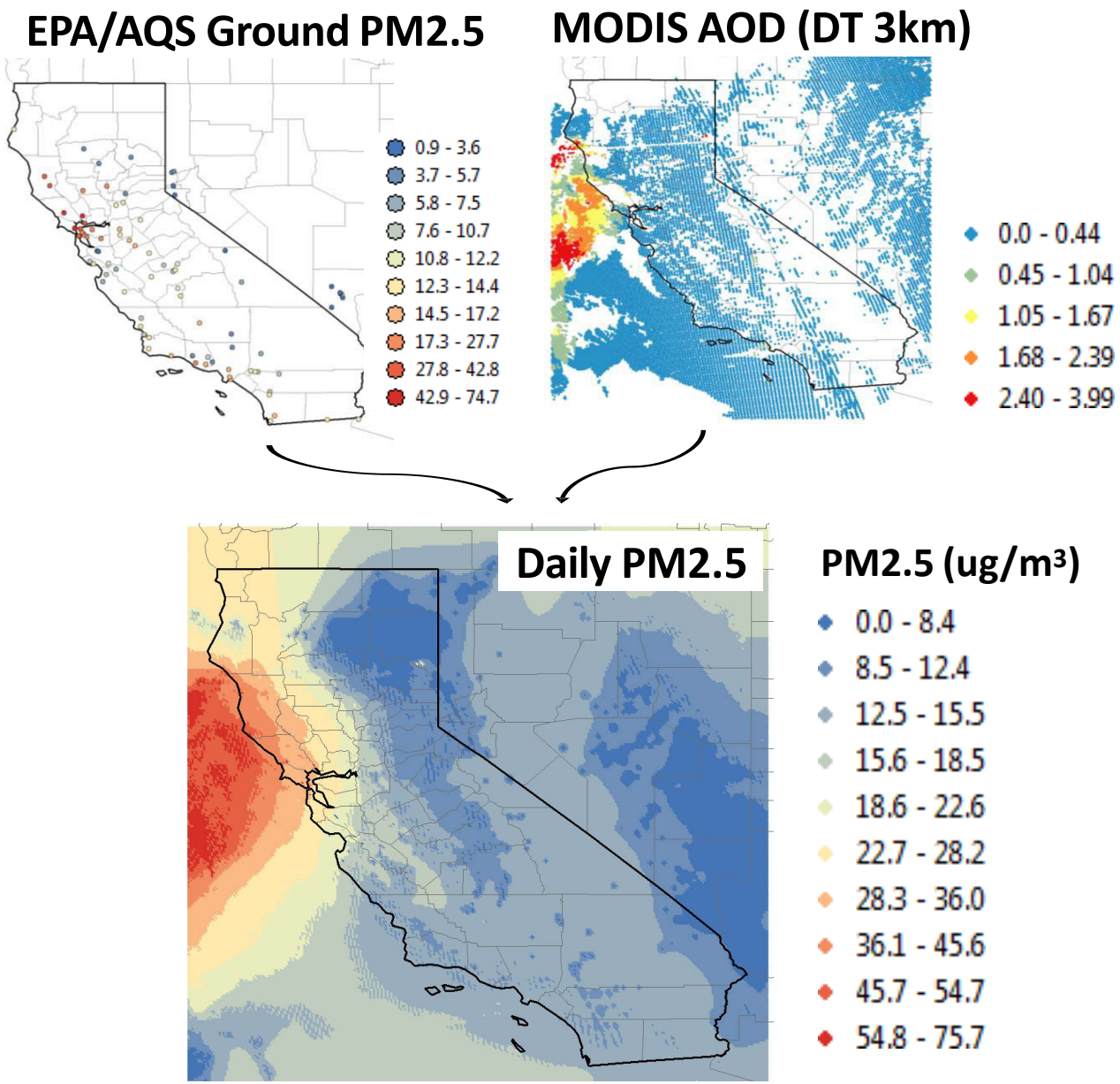
time *time*

Geostatistical Model: Regional PM2.5*

(Adapted for CA: HAQAST)

Approach

- Ground PM2.5 obs + MODIS AOD
- Daily 3-km PM2.5 Fields
- Computationally efficient



Example: October 9, 2017
HAQAST TT2 (work in progress …)

Al-Hamdan et al. (2009), Al-Hamdan et al. (2014)
https://wonder.cdc.gov/nasa-pm.html

Modeling System: Components

- **Regional PM2.5: Geostatistical Model (USRA-MSFC)**
  - AIRNOW ground PM2.5 & MODIS Dark Target 3-km AOD
  - 3-km fields using over California
- **Finescale PM2.5: Steady-State Dispersion Model (UC Riverside)**
  - Area and line sources
  - Same basic formulations as EPA AERMOD & R-LINE
  - Driven by hourly meteorology
- **HRRR Model Meteorology (NOAA ESRL): Real-Time Met Inputs**
  - 3-km CONUS, operational real-time
  - Drive dispersion model w initial fields of hourly 18-hour HRRR forecast runs
  - Archived at University of Utah Department Atmospheric Science (since mid 2016)

Geostatistical model: Al-Hamdan et al. (2009), Al-Hamdan et al. (2014), https://wonder.cdc.gov/nasa-pm.html

Dispersion model: Cimorelli et al. (2005), Snyder et al. (2013), Venkatram et al. (2013), https://www.mdpi.com/1660-4601/16/7/1252

HRRR Archive: Blaylock et al. (2017), http://hrrr.chpc.utah.edu/

Fusion Method
(Applied over a local AOI)

$$PM2.5(x,y) = \overline{Geostatistical(x,y)} + Dispersion\ Model(x,y) - \overline{Dispersion\ Model(x,y)}$$

Fused field over AOI (background + local)

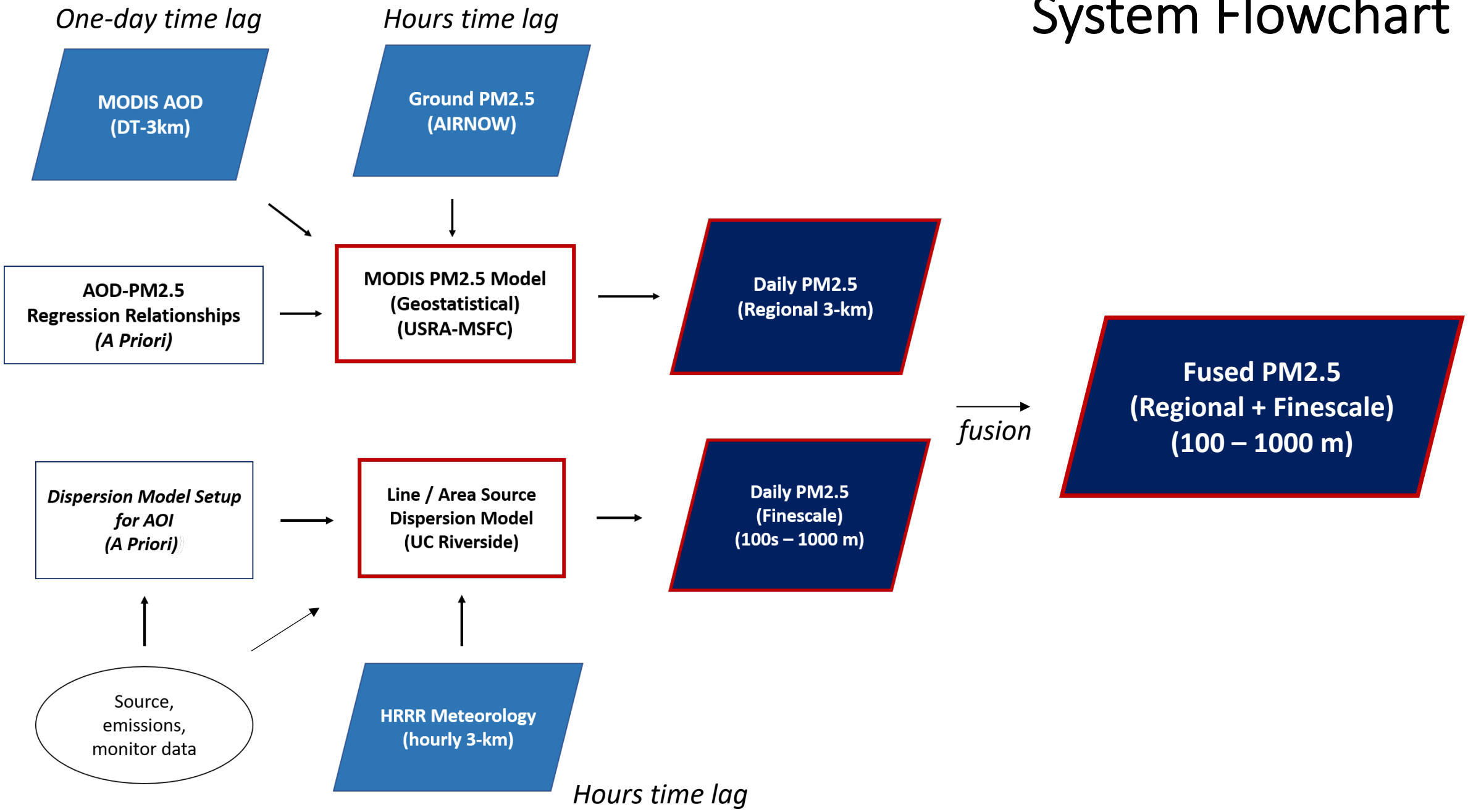
regional background

local variability across AOI

subtract avg of dispersion model field across AOI

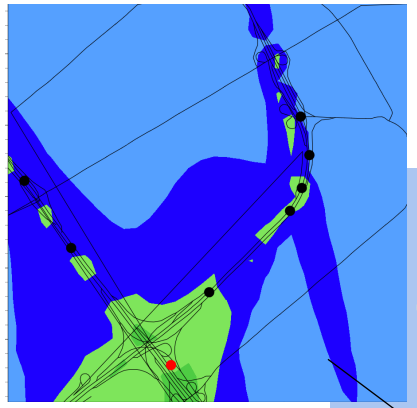
$\overline{(\ )}$ Spatial average over AOI
(can cover single or multiple regional grids)

System Flowchart

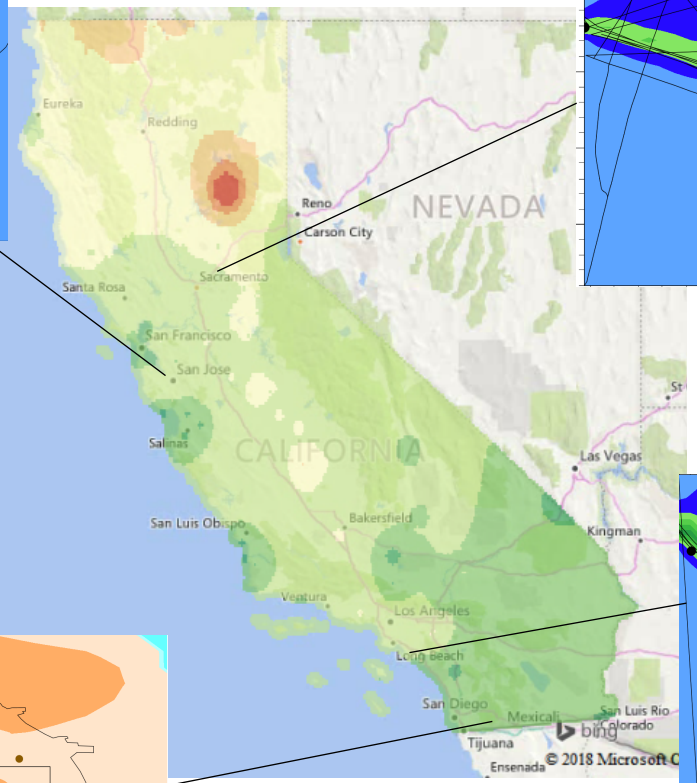


Applications to Date …

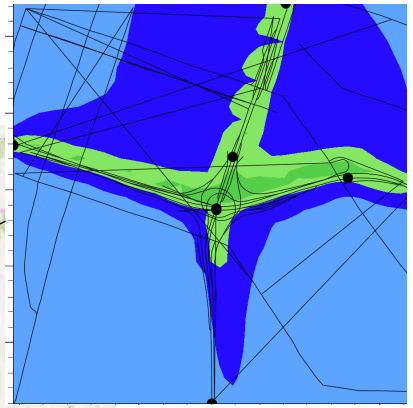
3 km AOI
100 m resolution



MODIS-Derived PM2.5
(Geostatistical Model)
(California, 3-km)



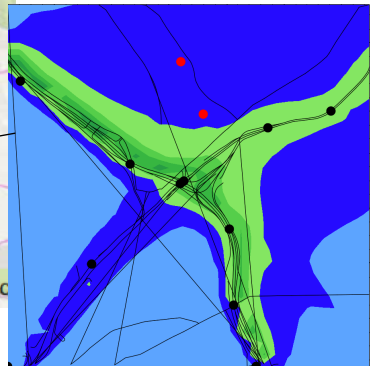
Fused PM2.5 (Freeway Interchange)
Downtown Sacramento (I80/H99)



3 km AOI
100 m resolution

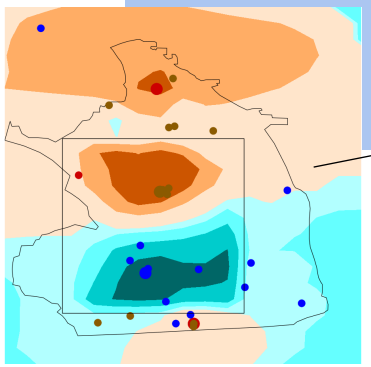
Fused PM2.5 (Freeway Interchange)
Downtown San Jose (H101/I280/I680)

Fused PM2.5 (Freeway Traffic)
Downtown Los Angeles (I5/H110)



3 km AOI
100 m resolution

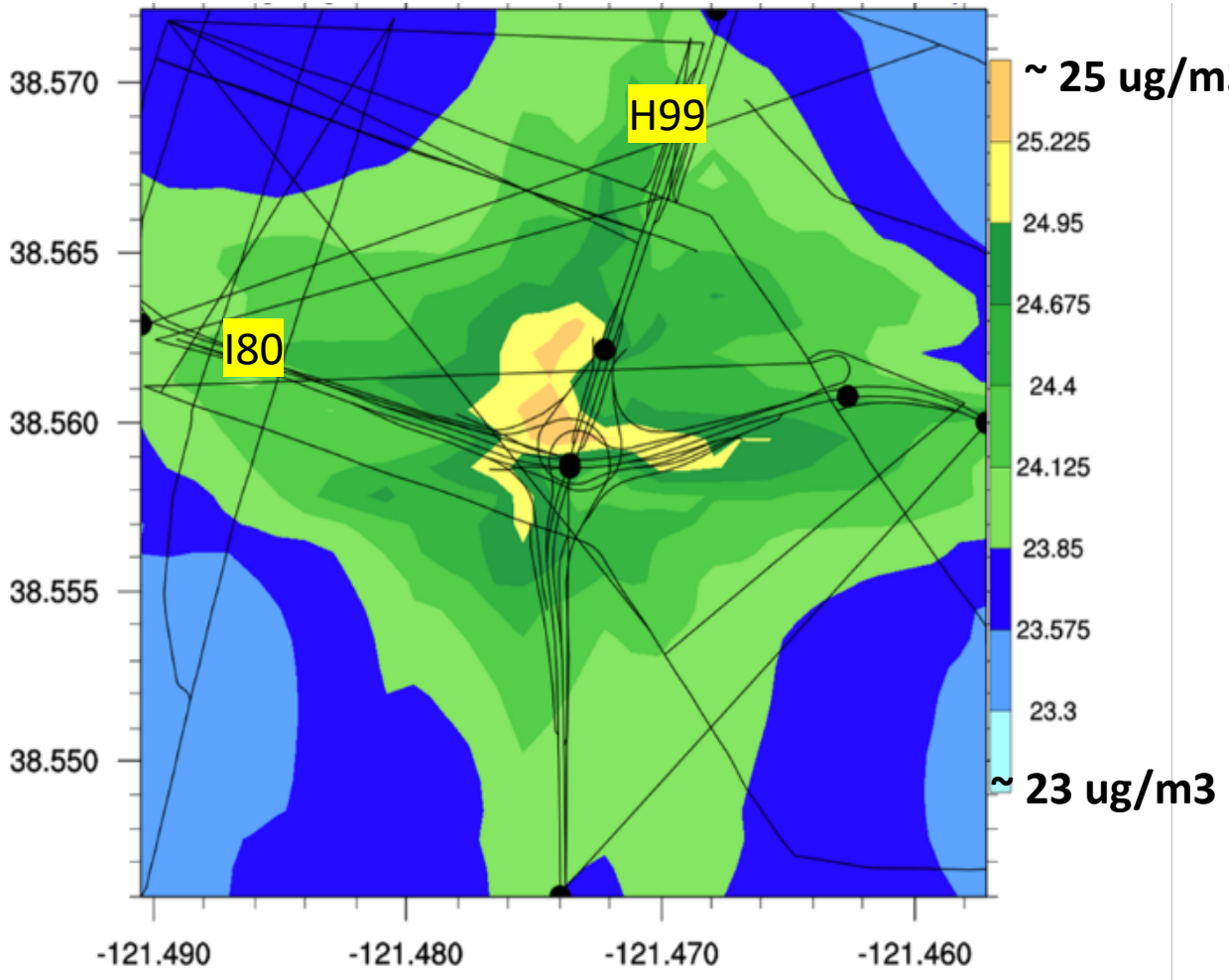
Fused PM2.5: Windblown Dust)
Imperial Valley (CA)



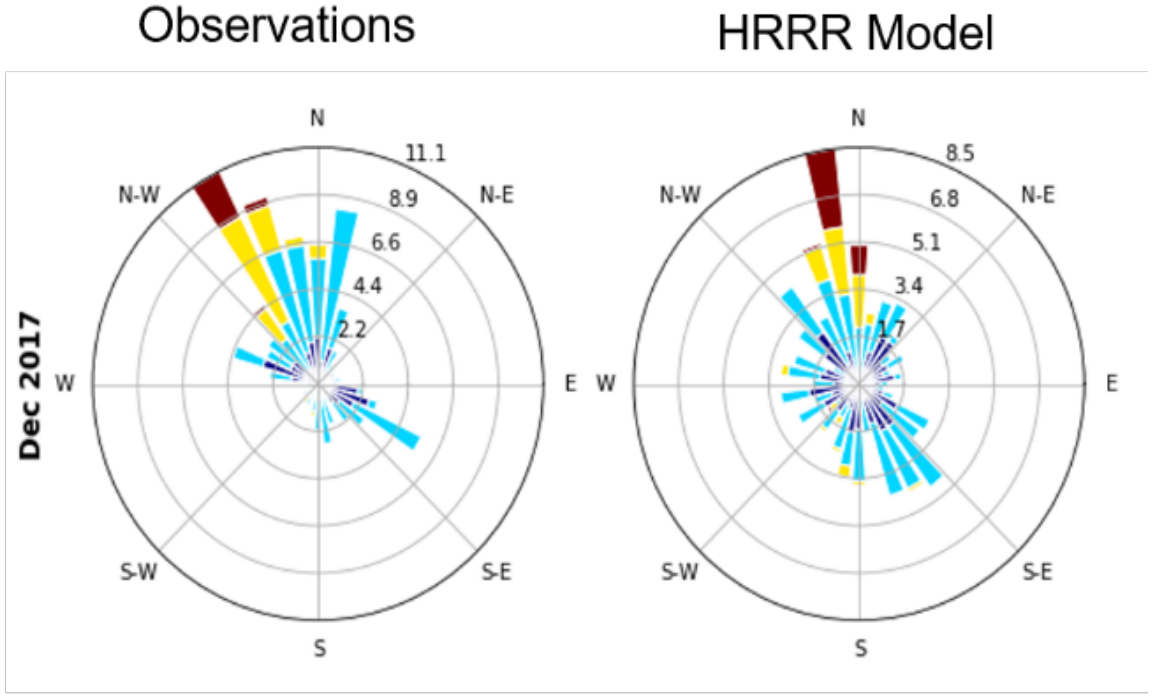
20 x 30 km AOI
3 km resolution

Fused PM2.5 Field

(I80/H99 Interchange, Sacramento) (December 2017)



100 m resolution



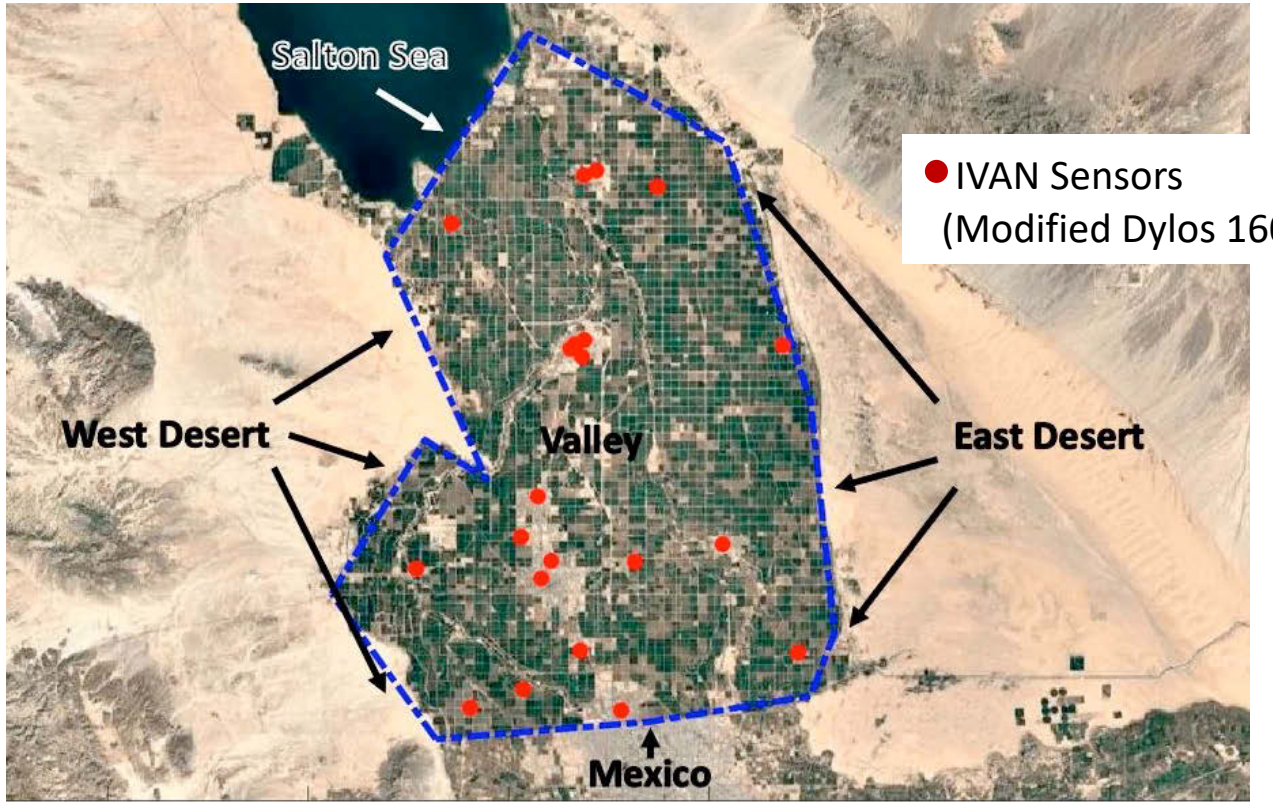
Wind Rose Comparison: Model vs. Observations
(CARB Sacramento T St.; December 2017)

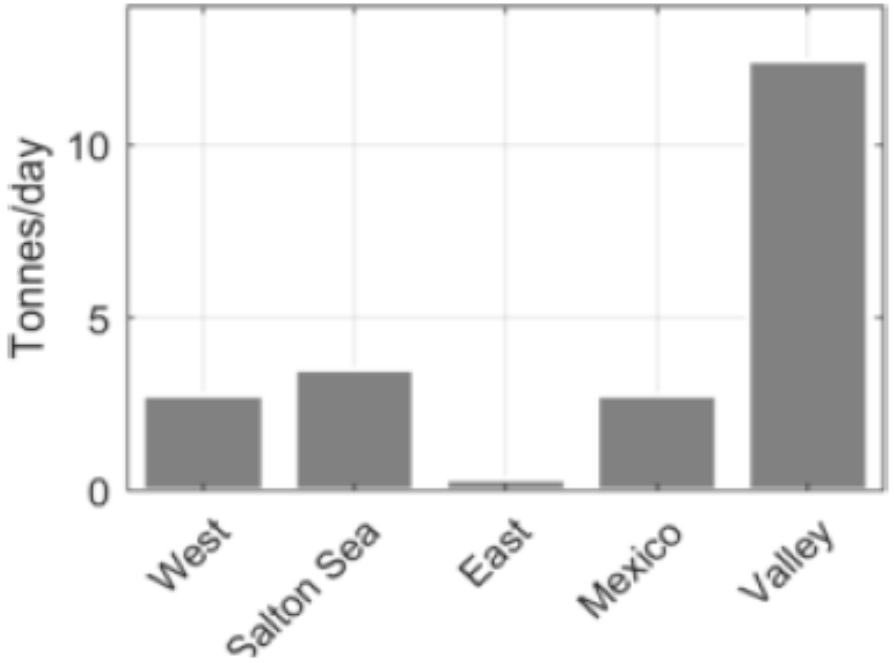
Implementation w IVAN Low-Cost Sensors
(Windblown Dust Events, Imperial Valley CA)

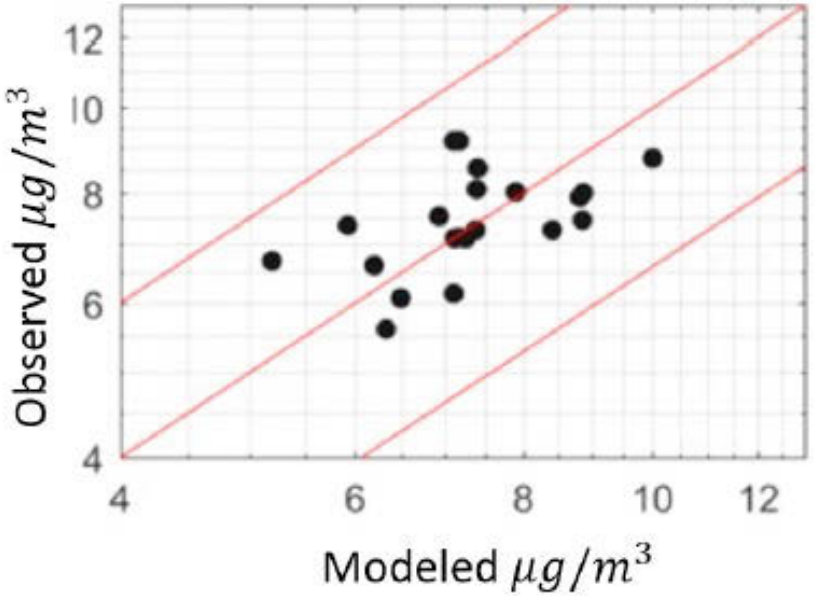
Dispersion Model Emissions Fitting

(Imperial Valley, Tiger Team 1)

https://www.mdpi.com/1660-4601/16/7/1252







IVAN data: https://ivan-imperial.org/

Comite Civico Del Valle; Luis Olmeda, Paul English, Edmund Seto, Jeff Wagner; English et al. (2017), Carvlin et al. (2017), Wong et al. (2018)

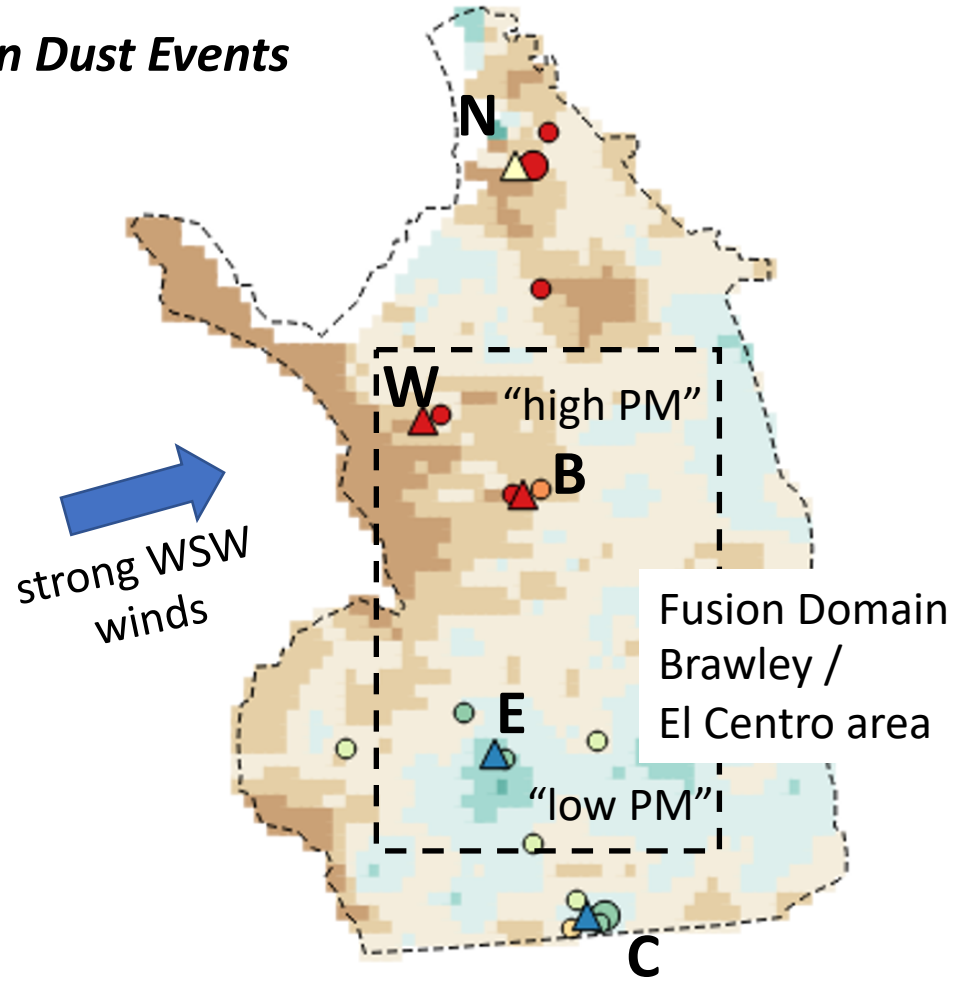
MAIAC AOD atop IVAN Low-Cost PM2.5

(Windblown Dust, Imperial Valley, HAQAST TT1)

Composite: Windblown Dust Events (11 days, Spring 2016)

State Agency Monitors

Niland (N)
Westmorland (W)
Brawley (B)
El Centro (E)
Calexico (C)



AOD

- 0.080 - 0.100
- 0.100 - 0.120
- 0.120 - 0.140
- 0.140 - 0.160
- 0.160 - 0.180
- 0.180 - 0.300

MAIAC

PM_{10} (µg/m³)

- 50 - 70
- 70 - 90
- 90 - 110
- 110 - 130
- 130 - 160

BAMS PM10

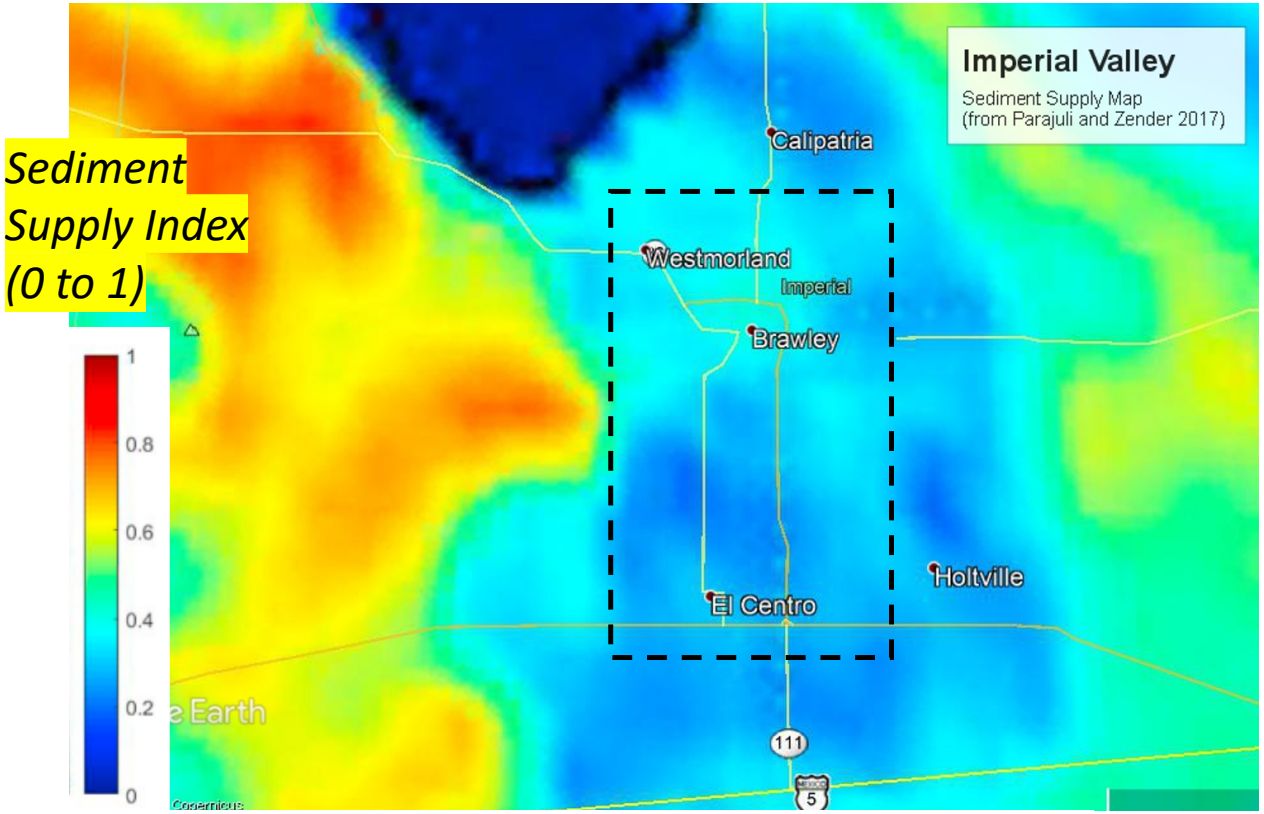
$PM_{2.5}$ (µg/m³)

- 4.0 - 7.0
- 7.0 - 10.0
- 10.0 - 13.0
- 13.0 - 16.0
- 16.0 - 20.0
- 20.0 - 30.0

IVAN PM2.5 (small symbols)
AIRNOW PM2.5 (large symbols)

Dispersion Model Setup

Sediment supply field

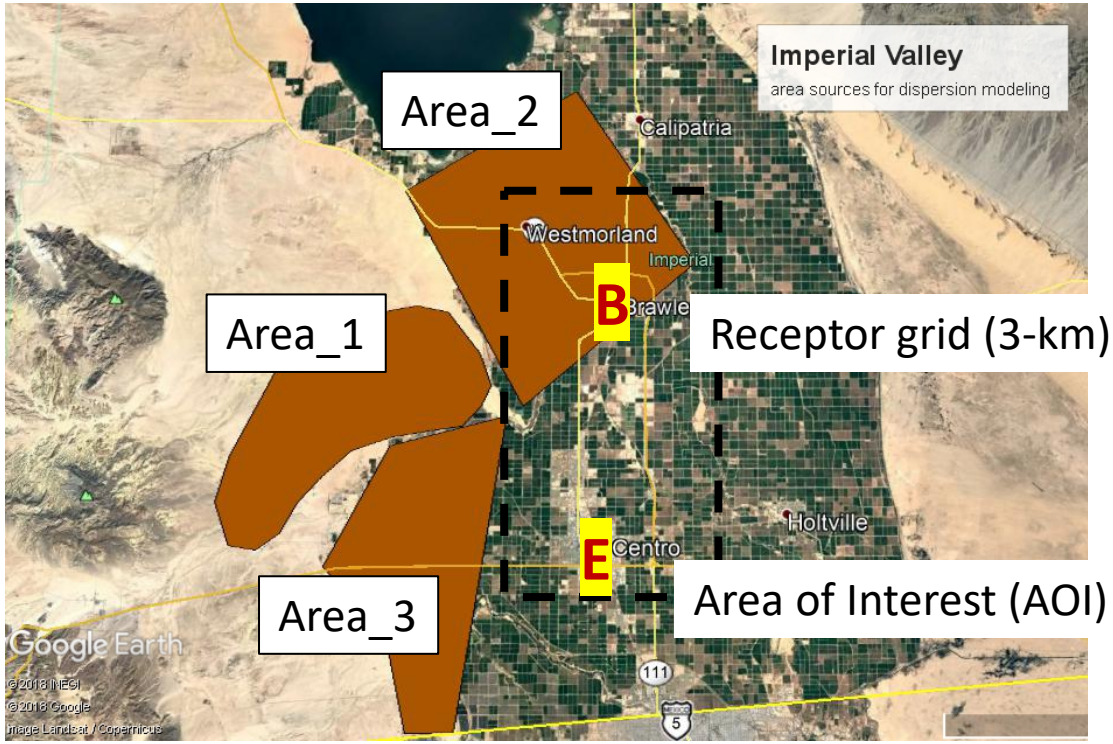


Sediment supply field

Parajuli and Zender, 2017

https://doi.org/10.1016/j.aeolia.2018.05.004

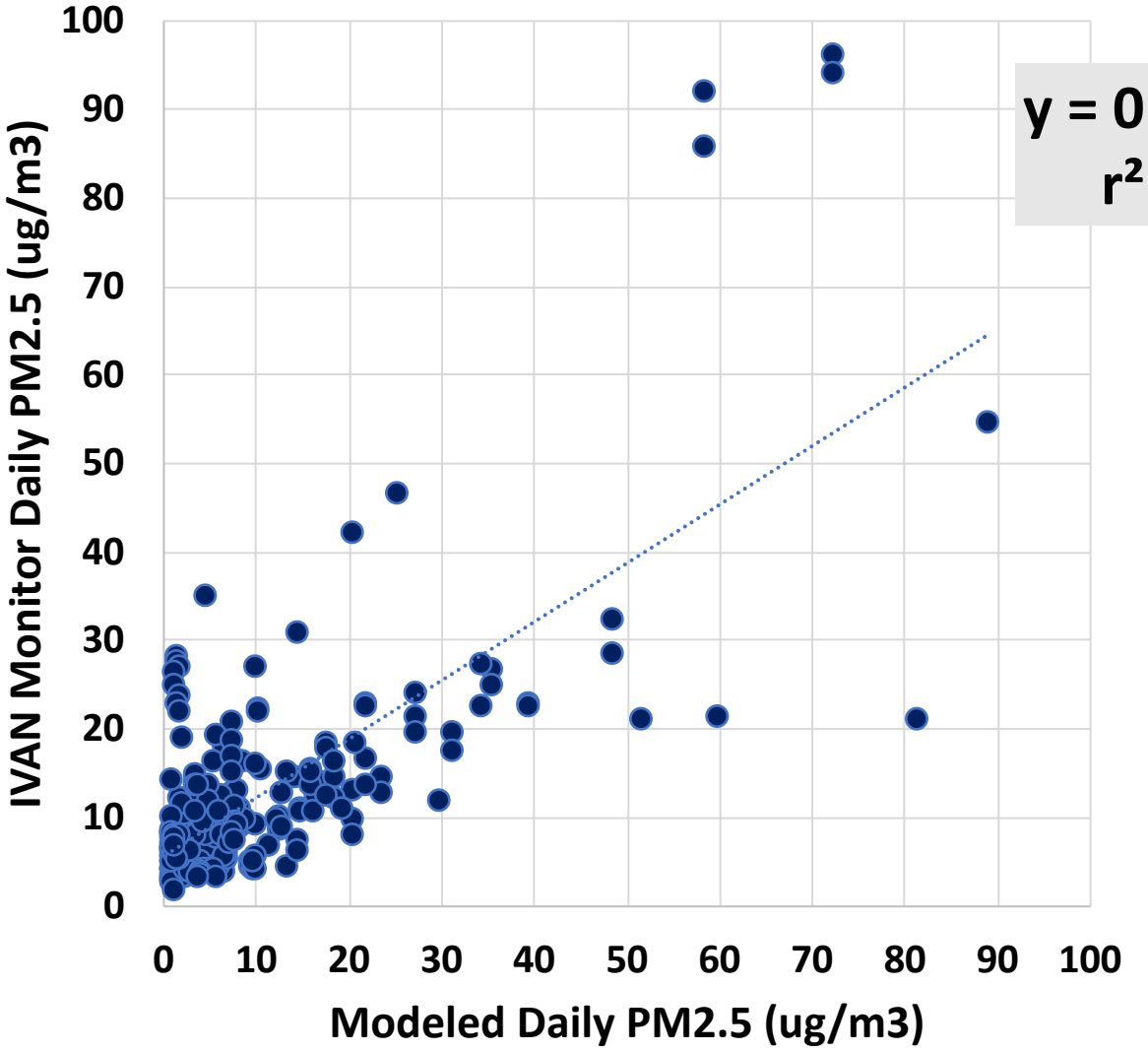
Model Area Sources



DUSTRAN Model Emissions: Area_1(t), Area_2(t), Area_3(t)
Regress against IVAN PM2.5: determine c1, c2, c3
(independent set of 2017 springtime windblown dust days)

Fitted Dispersion Model PM2.5

(Imperial Valley, 20 Wind Blown Dust Days, March - June 2017)



$y = 0.66x + 5.7$

$r^2 = 0.53$

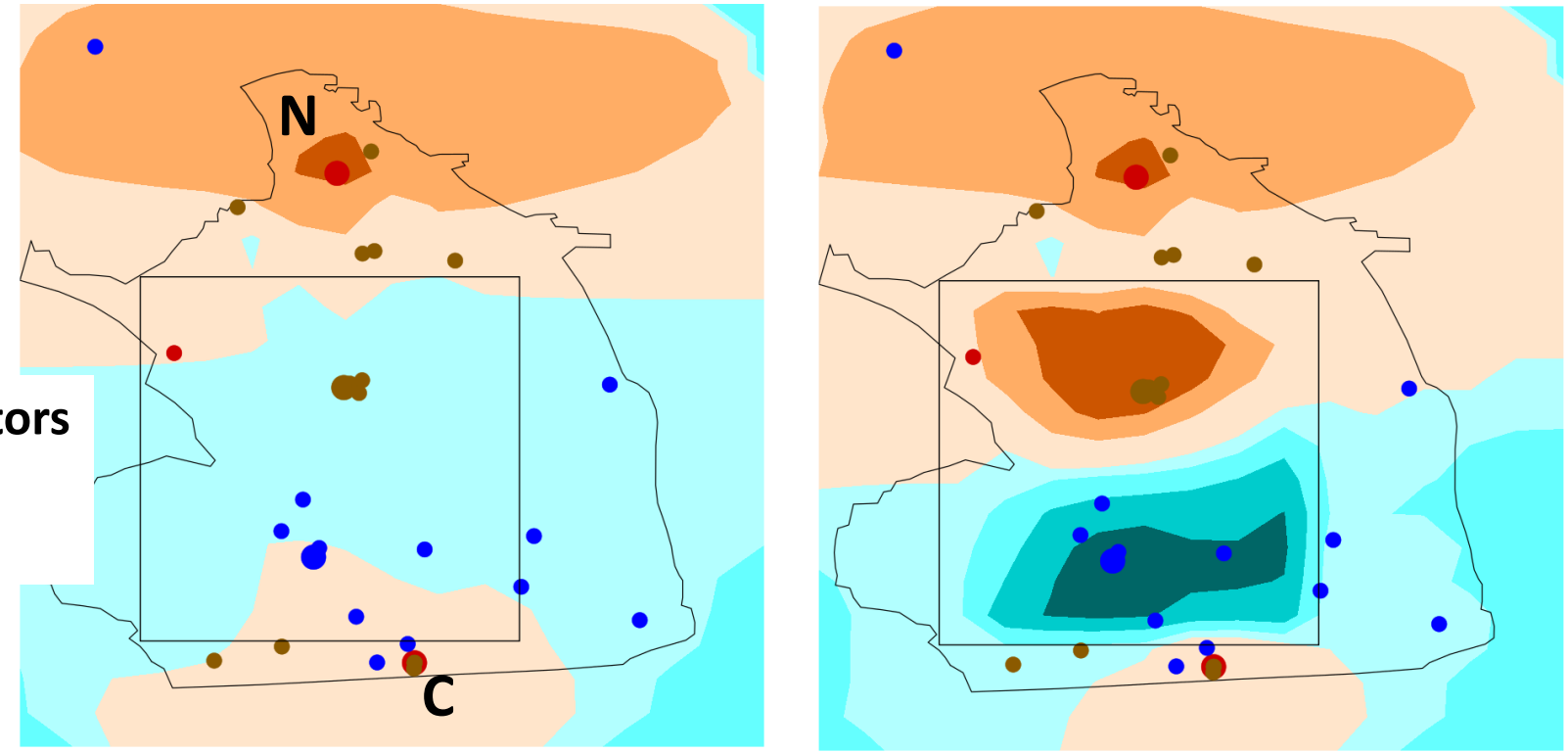
Emissions = c1*Area_1(t) + c2*Area_2(t) + c3*Area_3(t)

c1 = 0.06, c2 = 0.41, c3 = 0.13

Fused Modeling: Fitted Dispersion Model
(Example Day: May 25, 2017)

Geostatistical

Fused: Geostatistical & Dispersion



AIRNOW Monitors
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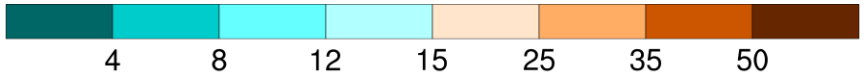
Calexico (C)

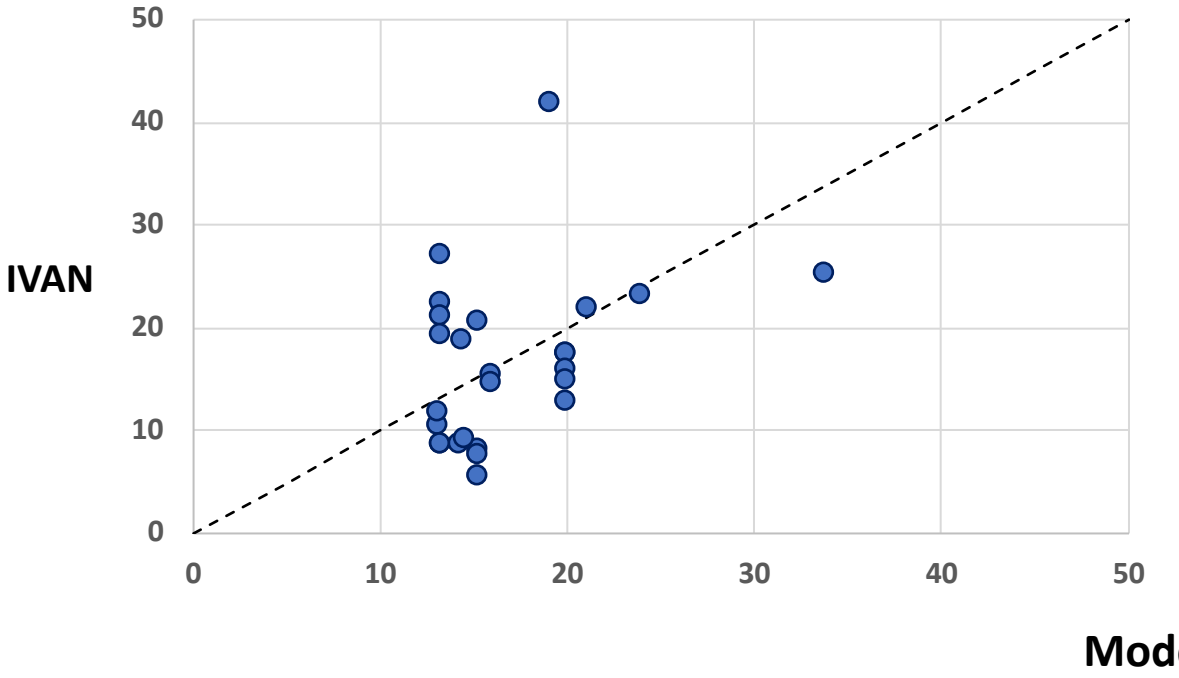


Daily PM2.5 (µg/m3)

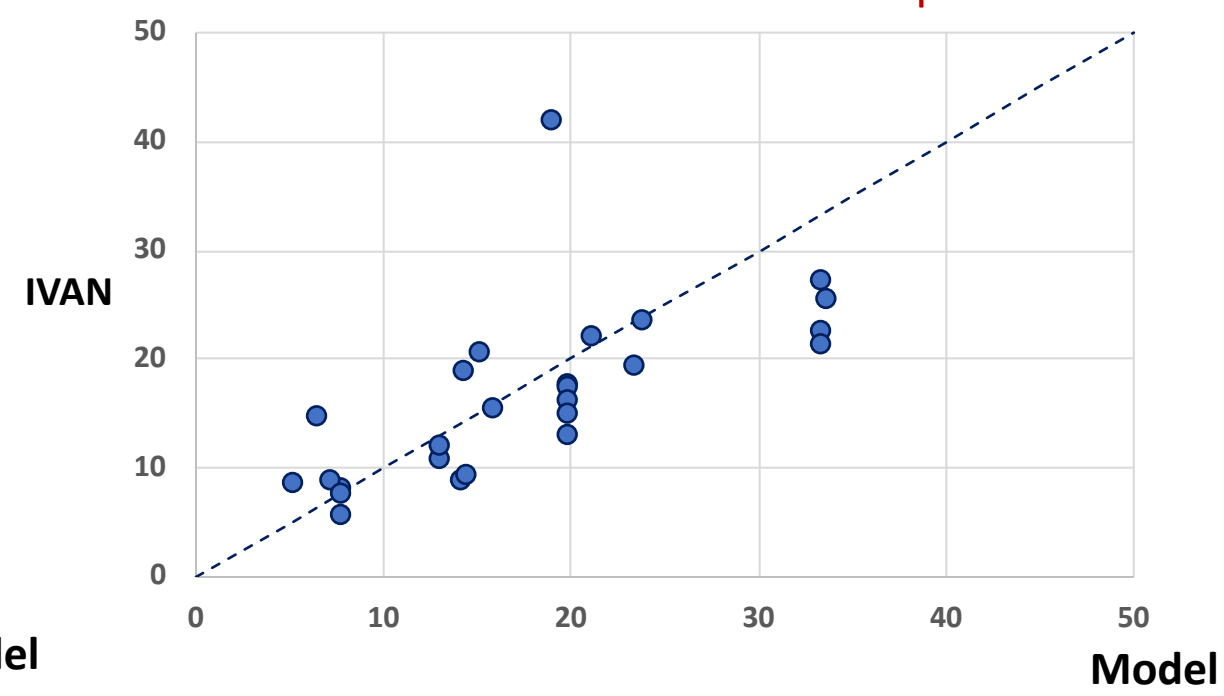
Model vs. IVAN PM2.5*

(Imperial Valley Windblown Dust Event, May 25, 2017)

Geostatistical



Fused Model: Geostatistical & Dispersion



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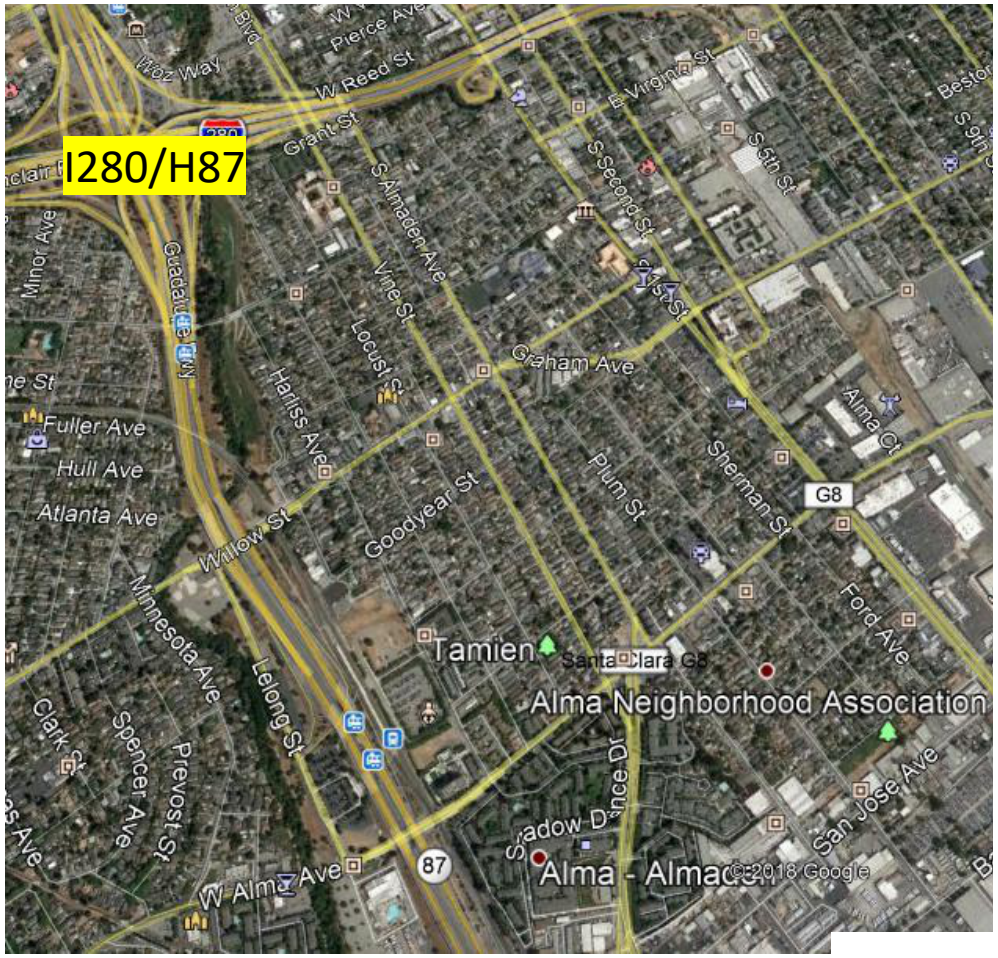
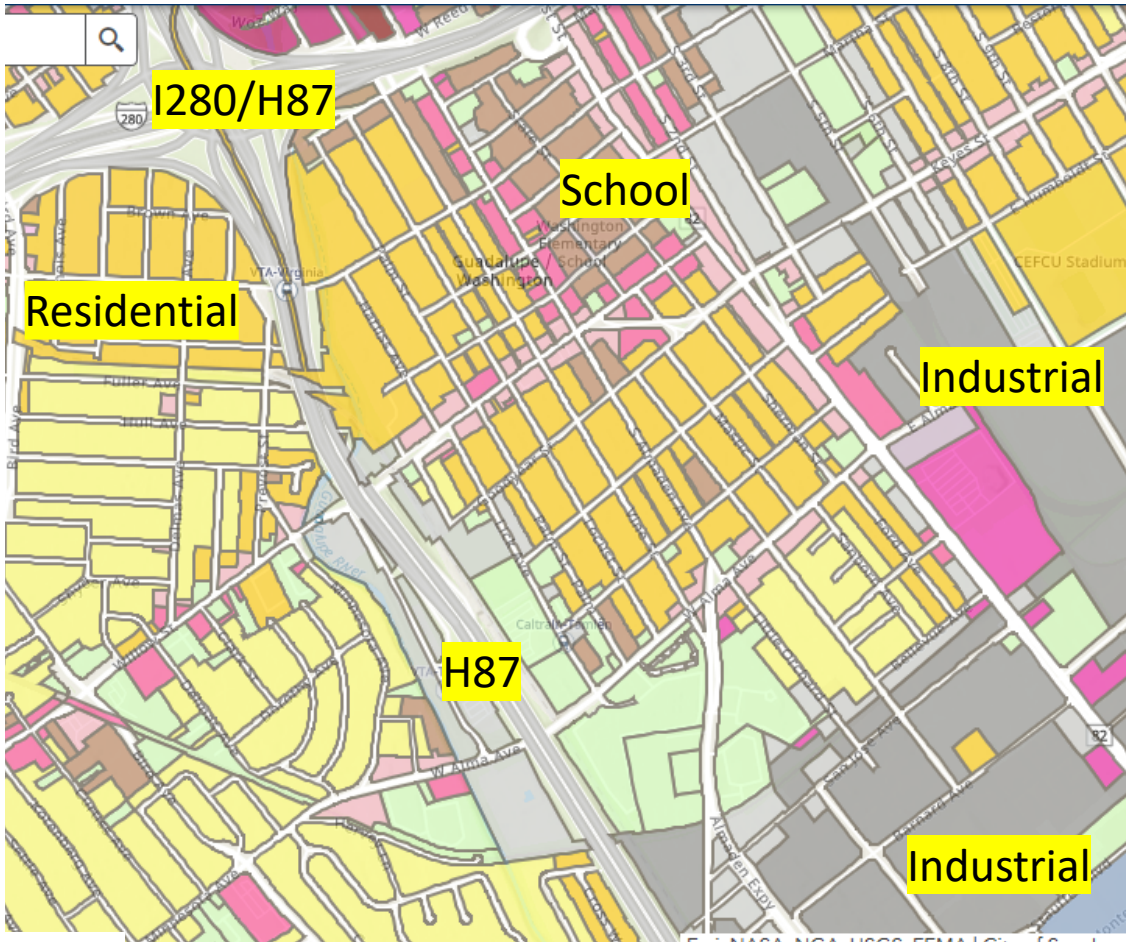
(Example, Alma Neighborhood, Downtown San Jose, CA)

zoning map





~ 2 x 2 km

space

time *time*

Summary

- System is developed & running
- Results to date promising (limited & ongoing evaluation …)
- Main challenges & future work
  - AOD-PM2.5 relationship for geostatistical model
  - Configuration of dispersion model for an AOI (Emissions? Sources?)
  - Long-term field evaluation at fine scale
  - Ongoing low-cost sensor development & deployments

Year 3 Progress Update, PI Minghui Diao

Core Project: Downscaling Satellite Derived PM2.5 Fields for California using Dispersion Modeling

- 1. Satellite-derived $PM_{2.5}$ grids
  - Constructed preliminary daily AOD-derived $PM_{2.5}$ surfaces for California for 2006 - 2017;
  - System running in real-time at SJSU (http://www.met.sjsu.edu/weather/HAQAST/)
  - *A review paper of satellite PM2.5 fields is in revision stage (JA&WMA)* led by Minghui Diao w HAQAST co-authors.
- 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);
  - https://www.cloud-research.org/haqast-project
- 3. Dispersion model Downscaling
  - System running in real-time at SJSU (http://www.met.sjsu.edu/weather/HAQAST/)
  - Published important developmental work: https://www.mdpi.com/1660-4601/16/7/1252
  - Conference paper on approach: http://www.met.sjsu.edu/weather/HAQAST/articles/Freedman_CMAS2017_Technical_Abstract.pdf

Tiger Teams

- TT#1: Community Scale PM2.5 Exposure (complete)
  - Completed UNC PAS low-cost samplers study w Maria Castillo, Pat Kinney, Jeff Wagner. Paper in revision stage (Atmos. Environ.)
  - Imperial Valley: Published article on dispersion modeling of 2017 PM2.5 using IVAN low-cost sensors https://www.mdpi.com/1660-4601/16/7/1252
  - Imperial Valley: A paper submitted to Remote Sensing of Environment on MAIAC AOD detection of windblown dust events
- TT#2 led by Susan O'Neill (PI) and Minghui Diao (co-I) (on-going)
  - Developing surface PM2.5 derived from satellite data for the duration of the California wildfire in October – November 2017 (finished)
  - Developing plume injection height product from satellite (finished)
  - A paper in preparation for wildfire projects with multiple groups

1 paper published
2 papers submitted (1 in revision stage)
3 in preparation