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

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\textit{Stakeholder Groups: SCAQMD, BAAQMD, CARB, CalDPH}

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Fused Modeling
(Background)

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

NOx Annual Avg (2005)

Atlanta

Bates et al. (2018)
Fused Modeling: Envisioned Area-of-Interest (AOI)
(Example, Alma Neighborhood, Downtown San Jose, CA)
Geostatistical Model: Regional PM2.5*
(Adapted for CA: HAQAST)

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

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)


**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)

\[
PM2.5(x,y) = \text{Geostatistical}(x,y) + \text{Dispersion Model}(x,y) - \text{Dispersion Model}(x,y)
\]

\[
\text{Fused field over AOI} \quad \text{regional background} \quad \text{local variability across AOI} \quad \text{subtract avg of dispersion model field across AOI}
\]

( ) Spatial average over AOI
(can cover single or multiple regional grids)
Fused PM2.5
(Regional + Finescale)
(100 – 1000 m)

System Flowchart

One-day time lag

MODIS AOD (DT-3km)

Hours time lag

Ground PM2.5 (AIRNOW)

AOD-PM2.5 Regression Relationships (A Priori)

MODIS PM2.5 Model (Geostatistical) (USRA-MSFC)

Dispersion Model Setup for AOI (A Priori)

Line / Area Source Dispersion Model (UC Riverside)

Daily PM2.5 (Regional 3-km)

Daily PM2.5 (Finescale) (100s – 1000 m)

Fusion

Source, emissions, monitor data

HRRR Meteorology (hourly 3-km)
Applications to Date ...

- **Fused PM2.5 (Freeway Interchange)**
  - Downtown San Jose (H101/I280/I680)
  - 3 km AOI
  - 100 m resolution

- **MODIS-Derived PM2.5 (Geostatistical Model)**
  - (California, 3-km)
  - 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 (Freeway Traffic)**
  - Downtown Los Angeles (I5/H110)
  - 3 km AOI
  - 100 m resolution

- **Fused PM2.5 (Freeway Traffic)**
  - Downtown Sacramento (I80/H99)
  - 3 km AOI
  - 100 m resolution
Fused PM2.5 Field
(I80/H99 Interchange, Sacramento) (December 2017)

100 m resolution

H99

~ 25 ug/m³

~ 23 ug/m³

Observations

HRRR Model

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)

strong WSW winds

Fusion Domain
Brawley / El Centro area

“high PM”

“low PM”

MAIAC

BAMS PM10

IVAN PM2.5 (small symbols)

AIRNOW PM2.5 (large symbols)
Dispersion Model Setup

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)

\[ y = 0.66x + 5.7 \]
\[ r^2 = 0.53 \]

\[ Emissions = c_1 \times Area_1(t) + c_2 \times Area_2(t) + c_3 \times Area_3(t) \]
\[ c_1 = 0.06, \quad c_2 = 0.41, \quad c_3 = 0.13 \]
Fused Modeling: Fitted Dispersion Model
(Example Day: May 25, 2017)

Geostatistical

Fused: Geostatistical & Dispersion

AIRNOW Monitors
Niland (N)
Calexico (C)

Daily PM2.5 (µg/m3)
Model vs. IVAN PM2.5*
(Imperial Valley Windblown Dust Event, May 25, 2017)

The graphs compare the Geostatistical Model and the Fused Model: Geostatistical & Dispersion against the IVAN PM2.5 measurements. The Geostatistical Model shows a more scattered distribution, while the Fused Model has a tighter clustering around the diagonal line, indicating a better fit to the IVAN data.
Fused Modeling: Envisioned Area-of-Interest (AOI)
(Example, Alma Neighborhood, Downtown San Jose, CA)
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
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