A satellite-dispersion modeling system to generate high-resolution downscaled PM2.5 fields

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Motivation

There is growing interest in knowing air pollution levels at finer resolution and at locations not currently monitored. PM2.5 and finer-sized particulate are among the most harmful air pollutants for human health.

We aim to develop an efficient system that can reliably estimate PM2.5 at unmonitored locations at fine-resolution. MODIS AOD retrievals can provide PM2.5 fields continuously in space. Dispersion models can downscale these fields to fine resolution.

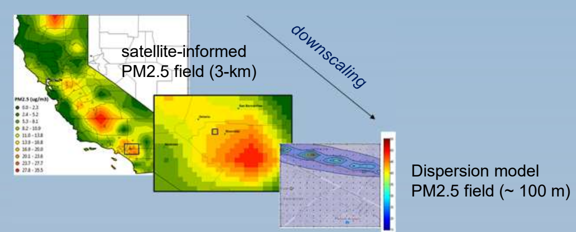
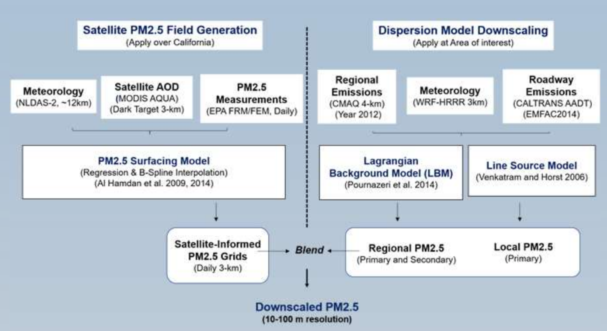


Figure 1: Illustration of downscaling in area around Riverside, California for Dec. 8, 2016. Procession from satellite-informed PM2.5 fields from MODIS Dark Target 3-km AQUA retrievals to downscaled fields using a near-road line-source dispersion model.

System Design

Flowchart



Downscaling Procedure

Given a satellite-derived PM2.5 field

$PM2.5_{sat}$

Calculate local dispersion model PM2.5 field

$$PM2.5_{mod}(x,y) = PM2.5_{pri,reg} + PM2.5_{sec,reg} + PM2.5_{pri,loc}(x,y)$$

Scale field so its average equals satellite-derived value

$$PM2.5_{downscaled}(x,y) = PM2.5_{mod}(x,y) \times \frac{PM2.5_{sat}}{\langle PM2.5_{mod}(x,y)\rangle}$$

Satellite-Informed PM2.5

Sample PM2.5 Surfaces (California 2016)

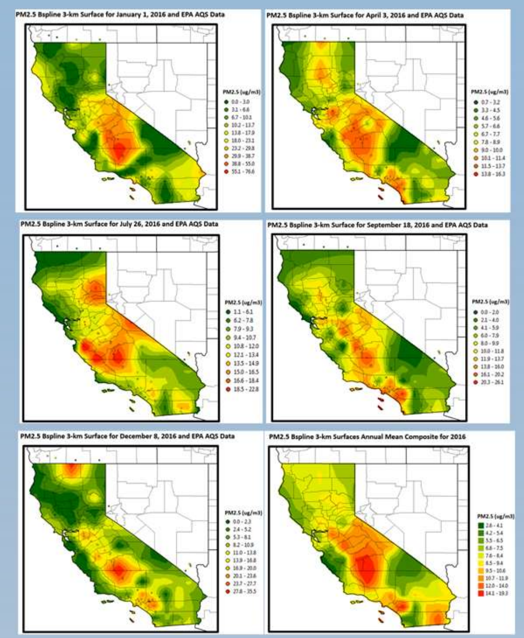


Figure 2. PM2.5 surfaces based on daily AOD retrievals from MODIS AQUA Dark Target (3-km) on selected days and annually for California 2016. Based on procedure of Al-Hamdan et al. (2009, 2014).

Evaluation against non-FRM monitor data

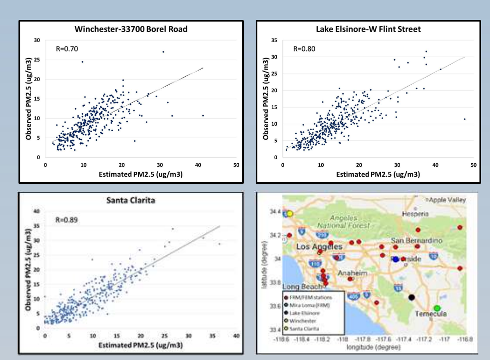


Figure 3. Validation analysis comparing satellite-informed PM2.5 grid cell values to observed daily PM2.5 from non-FRM stations in the cell. Non-FRM stations data are not used in constructing PM2.5 surfaces, and therefore provide independent measurements for evaluation. Map of site locations on lower right.

Dispersion Modeling

Lagrangian Background Model

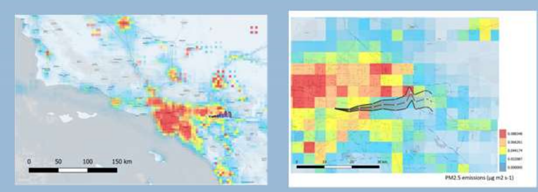


Figure 4: Lagrangian Background Model (LBM) back trajectories from the Mira Loma station for simulation of 0700 LST on December 8, 2016 overlaid on annual average primary emission field (year 2012, supplied by SCAQMD). Simulations driven by HRRR model field downloaded from http://hrrr.chpc.utah.edu/.

Line Source Model
Integration of CALTRANS Road Traffic Data

Figure 5: Major roadway line sources implemented into the line-source dispersion model for the South Coast Air Basin. Circles indicate locations of mileposts where AADT is measured. Left panel, entire area; Right panel, zoomed-in over area around Riverside, CA. Data from CALTRANS: http://www.dot.ca.gov/hq/tsip/gis/datalibrary/#Highway

Line Source Model
Downscaling Daily Satellite PM2.5 Value

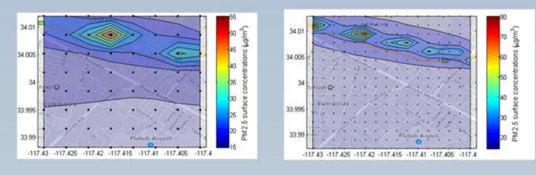


Figure 6: Downscaled PM2.5 field within the 3-km satellite PM2.5 grid containing the Mira Loma station on December 8, 2016. Left Panel: downscaled into 8 x 8 sub-grids (375 m), Right Panel: downscaled to 16 x 16 sub-grids (187.5 m). Dots on map using the line-source model of Venkatram and Horst (2006),

Implementing HRRR

Wind Rose Comparisons

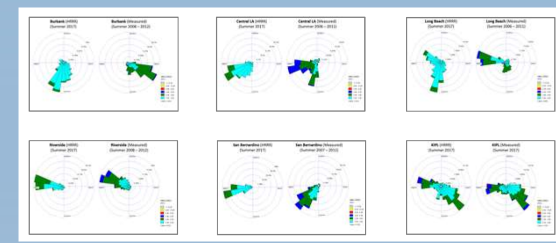


Figure 7: Comparison of summer 2017 wind roses from the NOAA WRF-HRRR model versus summer-month observations at Southern California sites. HRRR information found at https://rapidrefresh.noaa.gov/hrrr/.

Driving LBM with the HRRR

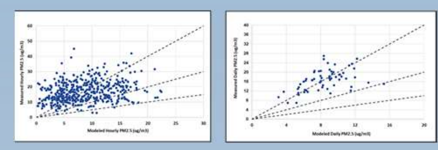


Figure 8: Hourly (left panel) and daily-average (right panel) LBM model driven by the HRRR for primary PM2.5 vs. measured for SCAQMD Mira Loma site. Runs for June 2 – Sept 20, 2017 at three-hourly intervals (1,4,7,10,13,16,19,22 local time, n = 480 hours, 60 days).

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