A Satellite-Dispersion Modeling System to Downscale Fine Particulate Fields to Near-Road Scale

Frank Freedman\textsuperscript{1,2}, Mohammad Al-Hamdan\textsuperscript{3,2}, Akula Venkatram\textsuperscript{4}, Seyedmorteza Amini\textsuperscript{4}, Ana Rivera\textsuperscript{5}, Sen Chiao\textsuperscript{1,2}

\textsuperscript{1}Department of Meteorology and Climate Sciences, San Jose State University
\textsuperscript{2}Center for Advanced Atmospheric Research and Education
\textsuperscript{3}Universities Space Research Association
\textsuperscript{4}Department of Mechanical Engineering, University of California Riverside
\textsuperscript{5}Department of Geography, San Jose State University

November 28, 2017
Presented at HAQAST3
Lamont Doherty Earth Observatory (Palisades, NY)
Stakeholders (1)

• **California Air Resources Board**
  - Cal EnviroScreen 3.0
  - U.S. Mexican border issues
  - Cynthia Garcia, Hyung-Joo Lee, Jin Xi (Research Division)

• **California Department of Public Health**
  - Imperial Valley & U.S. Mexican Border Issues (IVAN Network support)
  - UNC Passive Sampling (Bay Area)
  - Paul English (Environmental Health Investigations Branch), Jeff Wagner (Environmental Health Laboratory Branch)
Stakeholders (2)

- **South Coast Air Quality Management District**
  - MATES V Planning Support (Long-term health risk study ...)
  - Sang-Mi Lee (Planning, Rule Development & Area Sources)

- **Bay Area Air Quality Management District**
  - Model evaluation, emissions determination, BenMAP health risk assessment
  - Saffet Tanrikulu (Planning & Climate Protection)
  - Collaboration w Meytar Sorek Hamer and Bob Chatfield (NASA AMES)
  - See poster
Use of Satellite-derived PM2.5 Fields for California (Precedent ...)

Current version PM2.5 fields, annual averages at census tract level ...

- PM2.5 values for census tracts with centers more than 50 kilometers from the nearest monitor were assigned a concentration based on satellite observations for the years 2006-2012, with the exception of the monitor in Portola (Plumas County), California. Satellite data was used for areas beyond 10 kilometers from the Portola monitor due to the localized nature of the pollution in Portola.

Employs Lee et al. (2016) satellite-derived PM2.5 for areas more than 50 km from monitor (2006 – 2012, Deep Blue 10-km)

Update to current years...
Higher resolution satellite products ...

Questions

- Can dispersion modeling downscaling system provide a useful, direct estimate of underlying PM2.5, diesel and ultrafine particulate fields at census tract scale?
- Can system be designed to be practical for end-user application?
Satellite-Informed PM2.5 Fields for California (Procedure)

• Al-Hamdan et al. (2009, 2014)
• Based on AOD->PM2.5 regression model
• 3-km resolution fields for California for 2016
• Dark Target 3-km satellite AOD product (MODIS, AQUA satellite)
• Meteorological co-variates in regression
• Bias Correction, QA/QC, B-spline smoothing
Satellite-Informed PM2.5 Fields for California (by Census Tract)


2006 - 2012 Fields (Lee et al. 2016) (Deep Blue 10-km derived)

DRAFT Results (2016)

2016 Field (DRAFT) (Al-Hamdan, in progress ...) (Dark Target 3-km derived)
Dispersion Modeling Downscaling
(Procedure)

• **Define area of interest**: single or set of daily, gridded satellite-derived PM25 concentrations

• **PM25$_{SAT}$**: Satellite-derived PM25 concentration (24-hour avg.) over area of interest

• **PM25$_{DM}$**: Dispersion model estimated PM25 concentration (24-hour avg.) over area of interest

• **<>**: - spatial average over area of interest

(1) **Dispersion model estimated field...**

\[
PM25_{DM}(x,y) = PM25_{REG,DM,P} + PM25_{REG,DM,S} + PM25_{LOC,DM,P}(x,y) .
\]

- **Regional**: LBM Model
- **Local**: Line-source model

(2) **Scale dispersion model field to match satellite**

\[
PM25(x,y) = PM25_{DM}(x,y) \times [PM25_{SAT} / <PM25_{DM}>]
\]

Dispersion model field sum of *regional & local* contributions

Regional: LBM model
Local: Line-source model

Scale dispersion model field
So average over area of interest
Matches satellite-derived value.
Dispersion Modeling Downscaling
(Example: December 8, 2016 @ Riverside CA)

Given ...

Satellite-derived value @ area of interest on December 8, 2016 = 19.6 μg/m³

Step 1
• LBM Model
• Regional PM2.5

Step 2:
• Line Source Model: Local PM2.5
• Scaling to match satellite-value

LBM calculated back-trajectories (example: hour 0700 LST Dec. 8, 2016)

Downscaled Dec. 8 field
Satellite PM2.5 Field Generation

- Meteorology (NLDAS-2, ~12km)
- Satellite AOD (MODIS AQUA) (DT 3-km)

PM2.5 Measurements (EPA FRM)

Surfacing Model (Multi-Regression & B-Spline Interpolation)

Satellite-Informed PM2.5 Grids (Daily 3-km) (PM$_{2.5}^{\text{SAT}}$)

Dispersion Model Downscaling

- Regional Emissions (4-km, 2012)
- Meteorology (HRRR 3km)
- Roadway Emissions (CALTRANS AADT) (EMFAC2014)

- Lagrangian Background Model (LBM)
- Line Source Model

Merge

Regional PM2.5 (PM$_{2.5}^\text{REG,DM,P}$) (PM$_{2.5}^\text{REG,DM,S}$)

Local PM2.5 (PM$_{2.5}^\text{LOC,DM,P}$)

Downscaled PM2.5 (~ 10-100 m resolution)
Next steps ...

System up and running, onward ...

- **Fine-tune internal physics**: Satellite AOD-PM2.5 & Dispersion Modeling
- **Increase computational efficiency** (implement on multi-processors)
- **Define case-studies** for evaluation & applications
Further details ...

• “A Satellite-Dispersion Modeling System to Generate High-Resolution Downscaled PM2.5 Field”. Presented at the 16th Annual CMAS Conference, Chapel Hill, NC, October 23-25, 2017.


