Improving surface PM$_{2.5}$ forecast using an ensemble of satellite data, chemistry transport model outputs, and surface observations

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An era of multiple operational forecasts & satellite data of aerosols

- NAVAL NAAPS
- NAAPS + FLAMBE; ECMWF NOAA NAQFC-smoke
- NAAPS + DT Land AOD DA; NAQFC-dust
- NAAPS + Ocean AOD DA
- NASA GEOS-FP & Radiance DA
- NAQFC PM$_{2.5}$
- MODIS/Terra; MISR/Terra; MOPITT/Terra
- MODIS/Aqua, AIRS/Aqua
- CALIPSO
- OMI/Aura
- VIIRS, OMPS/NPP, GOCI
- Himawari-8
- GOES-16
- JPSS-1
- TEMPO, MAIA
- NAAPS + Ocean AOD DA
- NAAPS + DT Land AOD DA; NAQFC-dust
- NAAPS + FLAMBE; ECMWF NOAA NAQFC-smoke
- NAVAL NAAPS

Timeline:
- 2000: MODIS/Terra; MISR/Terra; MOPITT/Terra
- 2002: MODIS/Aqua, AIRS/Aqua
- 2004: CALIPSO
- 2006: OMI/Aura
- 2012: VIIRS, OMPS/NPP, GOCI
- 2015: Himawari-8
- 2016: GOES-16
- 2017: JPSS-1
- 2020: TEMPO, MAIA
- ~2018: NASA GEOS-FP & Radiance DA
- 2009: NAAPS + Ocean AOD DA
- 2012: NAAPS + DT Land AOD DA; NAQFC-dust
- 2016: NAQFC PM$_{2.5}$
Global forecast scheduling cycle

- Delay time period
- 24-hr forecasts that are ahead of clock time

Observation

different models ensembles

Analysis

$t - 24$
$t - 12$
$t - 3$
t
$t + 3$
$t + 6$
$t + 12$
$t + 24$
Enabling single best and rapid AQ forecast and advisory through model output statistics (MOS) techniques

24-hr forecasts that are ahead of clock time
Different models have different strengths and weakness

Case study: June, 2012

Monthly EPA: $8.80 \pm 3.65 \mu g \text{ m}^{-3}$

Monthly GC: $6.61 \pm 3.28 \mu g \text{ m}^{-3}$ (-25%)

Monthly WC: $4.37 \pm 2.57 \mu g \text{ m}^{-3}$ (-50%)

Monthly CMAQ: $6.94 \pm 3.30 \mu g \text{ m}^{-3}$ (-21%)
Step 1. forecast bias correction at surface observation sites with Kalman-Filter (KF) ensemble approach

<table>
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<th>GC</th>
<th>WC</th>
<th>CMAQ</th>
<th>En-raw</th>
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<td>Model</td>
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<td>NMB</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
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<tr>
<td>R</td>
<td>0.51</td>
<td>0.36</td>
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<tr>
<td>y</td>
<td>0.43x + 3.0</td>
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<tr>
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<td>7.6</td>
<td>5.9</td>
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<tr>
<td>y</td>
<td>6.9 ± 5.1</td>
<td>4.5 ± 4.2</td>
<td>7.4 ± 5.2</td>
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Normalized Standard Deviation

Correlation

NMB (%)

Model

KF-Model

Ensemble

Ground PM$_{2.5}$

Expected
Step II. **Forecast** bias and pattern correction at locations that have no ground-based sites

- Iteration 1, $R = 125$ km
- Iteration 2, $R = 63$ km
- Iteration 3, $R = 15$ km
- ...
KF-SCM sites

Evaluation sites
Remote Sensing Information Gateway

A webservice & application for quick easy access to subsets of Petabytes of air quality data.

https://www.epa.gov/hesc/remote-sensing-information-gateway
Thank you!