Using space-based observations to understand urban emissions and chemistry

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$ NASA
Sensor array for CO₂, NO₂, O₃, …
Nodes deployed on school rooftops

http://beacon.berkeley.edu/
1. We need a retrieval that is accurate at spatial scales of ~10 km
Berkeley High Resolution Retrieval (BEHR)

<table>
<thead>
<tr>
<th></th>
<th>NASA standard</th>
<th>BEHR</th>
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</thead>
<tbody>
<tr>
<td><strong>Terrain pressure</strong></td>
<td>High-res terrain database, center of OMI footprint</td>
<td>High-res terrain database, average over OMI footprint</td>
</tr>
<tr>
<td><strong>Terrain reflectivity</strong></td>
<td>Monthly $1^\circ \times 1^\circ$</td>
<td>MODIS, 8 day $0.05^\circ \times 0.05^\circ$</td>
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<tr>
<td><strong>NO$_2$ profile shape</strong></td>
<td>Annually $2^\circ \times 2.5^\circ$</td>
<td>WRF-Chem, Monthly $4 \times 4$ km$^2$ (CA&amp;NV) $12 \times 12$ km$^2$ U.S.</td>
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<tr>
<td><strong>Clouds</strong></td>
<td>OMI cloud product</td>
<td>MODIS cloud product</td>
</tr>
</tbody>
</table>

Russell et al., Atmos Chem & Phys 11, 8543-8554, 2011
Summer 2011

http://behr.cchem.berkeley.edu
2. Resolving chemistry and emissions from space
OH is nonlinear with NO$_2$
Rural — Suburban — Urban

0 — 0.5 — 0.5 — 4 — 4 — 100 ppb

NO$_2$ (ppb)

Background — Plume edge — Plume Core

[OH] (molecules cm$^{-3}$)

$\tau_{NO_x}$ (hours)

$2 \times 10^7$
2-d (or 3-d WRF)

- constant emissions
- advection
- dilution
- chemical feedback.

L Valin et al., Atmos. Chem. Phys. 2011
Prediction: lifetime of NO$_x$ depends on wind speed

L Valin et al., *GRL* 2013
Prediction: lifetime of NO$_x$ depends on wind speed.

L Valin et al., GRL 2013
Riyadh
Riyadh urban plume (OMI)

Winds
15-20 km hr⁻¹

Riyadh

L Valin et al., GRL 2013
A model plume

L Valin et al., *Atmos. Chem. Phys.* 2011
L Valin et al., GRL 2013
Rotate winds to x direction
(see also Beirle et al. Science, 2011)

Sort by wind speed

L Valin et al., GRL 2013
The NO$_2$ lifetime

$150 \text{km}$

$30 \text{ km/hr}$

L Valin et al., GRL 2013
Integral of the entire plume

NOx lifetime and OH_{effective}

\[ E = 145 \text{ moles s}^{-1} \]

\[ \begin{align*} 
7.5h & \quad \text{OH} = 5.6 \times 10^6 \\
5h & \quad \text{OH} = 8.4 \times 10^6 \\
2.5h & \quad \text{OH} = 17 \times 10^6 
\end{align*} \]
The same ideas hold true for variations in $\text{H}_2\text{O}$—the source of the OH
Riyadh

Low water, less OH, more NO$_2$

High water, more OH, less NO$_2$

Valin and Cohen in prep
$\text{H}_2\text{O}$ longer lifetime shorter

Valin and Cohen in prep
Conclusions:

TEMPO, GEOCAPE, TROPOMI, ...
Thank you

Luke Valin
PhD November 2012

$$ NASA$$