Application of satellite observations for timely updates to global anthropogenic NO\textsubscript{x} emission inventories

Lok Lamsal, Randall Martin, Akhila Padmanbhan, Aaron van Donkelaar, Qiang Zhang, Chris Sioris, Kelly Chance, Thomas Kurosu, Mike Newchurch
Changes in tropospheric NO$_2$ columns reflect the changes in NO$_x$ emissions

Richter et al., 2005
Inventory compilation is a huge undertaking, frequent updates not feasible

<table>
<thead>
<tr>
<th>Extension</th>
<th>Inventory</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>GEIA</td>
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</tr>
<tr>
<td></td>
<td>EDGAR</td>
<td>2000</td>
</tr>
<tr>
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<td>2002, 2005</td>
</tr>
<tr>
<td></td>
<td>Europe</td>
<td>1980-2006</td>
</tr>
<tr>
<td></td>
<td>USA</td>
<td>1999, 2002, 2005</td>
</tr>
<tr>
<td></td>
<td>Mexico</td>
<td>1999</td>
</tr>
<tr>
<td></td>
<td>East Asia</td>
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Available NO\textsubscript{x} emissions inventory implemented in GEOS-Chem

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**Inventory compilation is a huge undertaking, frequent updates not feasible**

**Emission factor**

**Emission control**

**Available NO\textsubscript{x} emissions inventory implemented in GEOS-Chem**

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Overlap of satellite observations to historical bottom-up NO\textsubscript{x} emission inventories helpful for method validation

Bottom-up NO\textsubscript{x} emission inventories

- World
- Canada
- Europe
- USA
- Mexico
- East Asia

Satellite observations of tropospheric NO\textsubscript{2}

SCIAMACHY

OMI

~70%
Applying GEOS-Chem high resolution capability to SCIAMACHY and OMI tropospheric NO₂

SCIAMACHY

Dalhousie product

OMI

DOMINO product (DP) with stripes correction and GEOS-Chem profiles

\[
\Omega_{v,trop}^{DP_{GC}} = \frac{\Omega_s - \Omega_{s,strat}^{DP}}{\sum_i M_i^{DP} \times K_i^{DP} \times X_i^{GC}} \times \sum_i X_i^{GC}
\]

Comparison of DP and DP_GC with in situ surface measurements

GEOS-Chem

Version: v8-01-04

Resolution: 1°x1.25° (GEOS-4)
Sensitivity of changes in NO$_2$ columns to changes in NO$_x$

\[ \frac{\Delta E}{E} = \beta \times \frac{\Delta \Omega}{\Omega} \]

\[ \beta = \frac{\Delta E}{E} \times \frac{\Delta \Omega}{\Omega} \]

Area with annual mean trop. NO$_2$ < $1 \times 10^{15}$ molec.cm$^{-2}$ and with anthr. contribution <50% excluded

Lamsal et al., GRL, submitted
Significant agreement between SCIAMACHY-derived hindcast and bottom-up inventories

\[ E_j = \left(1 + \beta \frac{\Omega_j - \Omega_i}{\Omega_i} \right) \times E_i \]

\[ r^2 = 0.9 \]

Lamsal et al., GRL, submitted
Significant agreement between SCIAMACHY-derived hindcast and bottom-up inventories

Emission changes from 2003 to 2006

<table>
<thead>
<tr>
<th>Region</th>
<th>Bottom-up</th>
<th>SCIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>5.5%</td>
<td>13%</td>
</tr>
<tr>
<td>USA</td>
<td>-5.3%</td>
<td>-9.0%</td>
</tr>
<tr>
<td>E. Asia</td>
<td>22%</td>
<td>23%</td>
</tr>
<tr>
<td>China</td>
<td>28%</td>
<td>26%</td>
</tr>
</tbody>
</table>

Lamsal et al., GRL, submitted
Discrepancy in satellite NO$_2$ and bottom-up NO$_x$ trends in China

Part of differences for not accounting for $\beta$

See Poster by Sicong Kang et al

Zhang et al., 2007
Inventory forecast for 2009 using SCIAMACHY and OMI observations are consistent.
Conclusions

• Bottom-up inventory requires years to compile and becomes quickly outdated.

• Developed a method to update bottom-up NO\textsubscript{x} inventory using satellite observations of tropospheric NO\textsubscript{2} column

• Emission changes consistent in bottom-up inventory and satellite observations.

• Forecast inventory for 2009 similar from SCIAMACHY and OMI: Chinese NO\textsubscript{x} emissions increase by \~6%/year and North American NO\textsubscript{x} emissions decrease by \~2%/year during 2006-2009.