Slowing Declines in U.S. NOx Emissions Reductions Detected With OMI

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Mapping NO$_2$ trends with OMI

Russell et al. 2012

Lamsal et al. 2015

Duncan et al. 2016
Corroborating satellite NO₂ trends with bottom-up inventories

NO₂ column (summer) from GOME & SCIA, and bottom-up NOx emissions

Krotkov et al., 2016

NO₂ column (black) from OMI, and bottom-up power-plant emissions (red)

Kim et al., 2006
Changes in trends observed in OMI and AQS data

Tong et al., 2015

de Foy et al., 2016
Global chemical data assimilation using OMI NO2 from Miyazaki et al. (2017) included results over the U.S.

Results also show a decline in the rate of NOx emissions reductions post 2009.
Declining trends have been decreasing, in contrast to inventories

“top-down NOx” from inverse modeling study of Miyazaki et al., ACP, 2017

“EPA NOx” from EPA trends report

“CEMS+MOVES” is EPA trends report but using CEMS and MOVES for egu and transport, respectively.

“Fuel-Based NOx” our bottom-up estimate (see SI)

Jiang et al., PNAS, 2018
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DOMINO, NASA, and BEHR are different satellite retrievals (the process of converting OMI’s spectroscopic measurements to column concentrations of NO2) processed by different groups. They can differ owing to assumptions about clouds, vertical distributions of gases and aerosols in the atmosphere, etc.

Jiang et al., PNAS, 2018
Retrieval variability at the 10 km scale makes it difficult to evaluate trends in many individual locations (and hence associate trends with particular sectors), but the broader trends are consistent. Jiang et al., PNAS, 2018
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Urban vs rural? The declining trends are similar if we look CONUS wide, rural, or just urban sites that have AQS measurements.
The decades-long decline in NOx and CO emissions is slowing.

- NOx concentrations dropped by 7 percent yearly from 2005 to 2009 but just 1.7 percent yearly from 2011 to 2015—a 76% slowdown.
- EPA emission inventories put the slowdown at only 16% for same period.

Slowdown likely caused by a number of reasons:

- The decreasing relative contributions of gasoline cars, due to the ongoing effectiveness of three-way catalytic converters
- The increasing relative emissions of nitrogen oxides from such sources as off-road vehicles and industrial, residential, and commercial boilers, and off-road vehicles
- Slower-than expected reductions in emissions by heavy-duty diesel trucks that have newer (and still maturing) catalytic converter technologies

Note: The study concluded that emissions from China not playing a role

Jiang et al., PNAS, 2018
Next Steps: Constraints on NOx emissions from OMI and GEOS-Chem 4D-Var

- Extending analysis to the entire OMI record using combination of mass-balance and 4D-Var techniques (aka “hybrid inversion” Qu et al., 2017)
- Global (2°x2.5°) and NA (0.5° x 0.67°) inversions of NO₂ and SO₂
- Examining sensitivity of inversions to satellite retrievals
Year 2 Progress Update, PI Henze, Co-I’s Anenberg, Kinney

Supporting health impact assessment tools using remote sensing and earth system models

• Source-receptor (SR) coefficients for \( PM_{2.5} \) and \( O_3 \) to CCAC impact toolkit (LEAP-IBC)
  • \( PM_{2.5} \) SR coefficients delivered to CCAC for all countries in Asia, Africa, most countries in Caribbean, Central & South America.
  • \( O_3 \) coefficients for each CCAC member nation
  • LEAP-IBC applied in Nepal (Nakarmi et al., submitted)
  • Impacts of cookstoves (Lacey et al., 2017) and fugitive diesel NOx (Anenberg et al., 2017)
  • High-resolution SR calculations for urban regions
    • In progress for Africa, West Africa
  • Expand health impacts
    • Global burden of ambient air pollution on asthma (Anenberg et al., submitted)

Tiger Team Participation

• Hi-Res \( PM_{2.5} \) (Kinney, Tong)
  • Health impacts of different \( PM_{2.5} \) estimates (Anenberg)
  • Low-cost monitors deployed in NYC, Boston, SF (Kinney)
• NOx constraints (Pierce, Tong)
  • US July 2011 0.5x0.667 NOx emissions, comparison to CMAQ DA (Pierce) and impact of retrieval choice (SP vs DOMINO)
• SIPS (Fiore)
  • Contribute to / review technical guidance documents
  • \( NO_2 \) trends from OMI (Zhang et al., 2018)
  • Review of background \( O_3 \) (Jaffe et al., 2018) and satellite \( PM_{2.5} \) (Diao et al, in prep.)
• Trends (Duncan, West)
  • \( SO_2 \) and \( NO_x \) emission constraints from OMI and associated \( \Delta PM_{2.5} \) and \( O_3 \) in progress
• Long-range pollution transport (AQAST TT)
  • Contributed to 6 papers in ACP special issue
Extra slides
### Table 1. Trends and uncertainties for all NO\textsubscript{x} datasets

<table>
<thead>
<tr>
<th>Period</th>
<th>EPA NO\textsubscript{x}</th>
<th>Top-down NO\textsubscript{x}</th>
<th>OMI (NASA)</th>
<th>OMI (DOMINO)</th>
<th>OMI (BEHR)</th>
<th>AQS NO\textsubscript{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005–2009 (CONUS)</td>
<td>−6.4%</td>
<td>−7.0 ± 1.4%</td>
<td>−8.8 ± 1.0%</td>
<td>−8.6 ± 0.9%</td>
<td>−5.4 ± 1.0%</td>
<td>−5.4 ± 1.0%</td>
</tr>
<tr>
<td>2011–2015 (CONUS)</td>
<td>−5.3%</td>
<td>−1.7 ± 1.4%</td>
<td>−1.9 ± 0.8%</td>
<td>−1.0 ± 0.9%</td>
<td>−1.0 ± 0.8%</td>
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</tr>
<tr>
<td>2005–2009 (sampled)</td>
<td>−10.2 ± 1.8%</td>
<td></td>
<td>−9.6 ± 1.7%</td>
<td>−8.5 ± 1.8%</td>
<td>−6.6 ± 1.4%</td>
<td>−6.6 ± 1.4%</td>
</tr>
<tr>
<td>2011–2015 (sampled)</td>
<td>−3.2 ± 1.6%</td>
<td></td>
<td>−2.6 ± 1.8%</td>
<td>−2.1 ± 1.6%</td>
<td>−2.6 ± 1.5%</td>
<td>−2.6 ± 1.5%</td>
</tr>
</tbody>
</table>

All trends are relative to the average of each data period (2005–2009 and 2011–2015) cover the whole US and based on a linear trend model. Uncertainties represent 1 σ and include the error budget discussed in *Si Appendix*. OMI (sampled) represents OMI NO\textsubscript{2} measurements sampled at AQS NO\textsubscript{2} measurement locations and times based on monthly averages.