RECENT ADVANCEMENTS IN DERIVING NO$_X$ EMISSION ESTIMATES FROM SATELLITE DATA

Presentation by: Dan Goldberg$^1$

Co-Authors: Lok Lamsal$^2$, Christopher Loughner$^3$, Pablo Saide$^4$, Greg Carmichael$^5$, Meng Gao$^5$, Benjamin de Foy$^6$, Daven Henze$^7$, Jung-Hun Woo$^8$, Zifeng Lu$^1$ & David Streets$^1$

$^1$University of Chicago & Argonne National Laboratory, Argonne, IL
$^2$NASA Goddard Space Flight Center, Greenbelt, MD
$^3$NOAA Air Resources Laboratory, College Park, MD
$^4$University of California-Los Angeles, Los Angeles, CA
$^5$University of Iowa, Iowa City, IA
$^6$Saint Louis University, Saint Louis, MO
$^7$University of Colorado – Boulder, Boulder, CO
$^8$Konkuk University, Seoul, South Korea

Image from: http://earthobservatory.nasa.gov
DERIVING NO\textsubscript{X} EMISSIONS FROM SATELLITE INFORMATION OVER LONG TIMESCALES

Using a methodology first pioneered by Beirle et al., 2011, and enhanced by Valin et al., 2013, de Foy et al., 2015 and Lu et al., 2015, we can derive NO\textsubscript{X} emissions from OMI.

Using an exponentially modified Gaussian function fit:

\[ \text{NO}_\text{X} \text{ Emissions} = 1.33 \left( \frac{\alpha}{\tau_{\text{effective}}} \right) \]

where \( \tau_{\text{effective}} = \frac{x_0}{w} \)

1.33 = \text{NO}_\text{X}/\text{NO}_2 \text{ ratio} \\
\( \alpha \) = observed OMI NO\textsubscript{2} burden \\
\( \tau_{\text{effective}} \) = effective lifetime \\
\( x_0 \) = e-folding distance \\
w = wind speed

\*\( \alpha \) and \( x_0 \) are derived from the exponentially modified Gaussian fit
ENHANCED OMI NO₂ PRODUCTS

(a)→(b): Use CMAQ instead of GMI to calculate the Air Mass Factor (AMF)

(b)→(c): Scale CMAQ based on D-AQ aircraft observations, and then calculate AMF

(c)→(d): Spatial weighting based on the variability within CMAQ [Kim et al., 2016; GMD]

(d) Is much better than (a) when compared to in situ observations!

Key takeaways:
- Model resolution plays a significant role in the calculation of air mass factors (high resolution = better)
- Accuracy of model simulation is critical in generating robust satellite observations
  - If model emissions or chemistry are way off, satellite will be unrealistic
- Spatial weighting helps satellite match urban-scale variability better

Goldberg et al., 2017; ACP

Showing a June & July 2008 – 2012 average; \( r^2 \) denotes correlation with ground monitors
Bottom-up \( \text{NO}_x \) emissions inventory appears to be underestimated by:

- 36% using standard product
- 53% by using the enhanced product

\[ \text{Bottom-up: 198 kton/yr} \]

\[ \text{Standard OMI NO}_2 \]

\[ \text{Enhanced OMI NO}_2 \]

Top-down \( \text{NO}_x \) emission estimates:

\[ \text{Top-down: 353 kton/yr} \]

\[ \text{NO}_x \text{ lifetime: 4.2 hrs} \]

\[ \text{Top-down: 484 kton/yr} \]

\[ \text{NO}_x \text{ lifetime: 3.4 hrs} \]
USING AN ENHANCED SATELLITE PRODUCT TO DERIVE NO\textsubscript{X} EMISSIONS FROM THE FORT MCMURRAY WILDFIRE, MAY 2016

Use parameterization derived by Bousserez, 2014 to re-process OMI NO\textsubscript{2} retrieval:

\[ CF_{NO2} = \log_e(3.4 \Delta NO_2 + 2.2) \]

where \( CF = \) Correction factor and \( \Delta NO_2 = (NO_2 \text{ wildfire} - NO_2 \text{ background}) / NO_2 \text{ background} \)

New OMI NO\textsubscript{2} top-down estimate shows better agreement with bottom-up inventory!

Biggest discrepancies will be for anomalous wildfires in rural regions.
FUTURE WORK: LOOKING FORWARD TO USING TROPOMI DATA!

TROPOMI tropospheric NO2, April 2018

Image acquired from: http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-5P/Copernicus_Sentinel-5P_releases_first_data

NOX emission inventories data can be evaluated on much shorter timescales! Monthly, if not weekly!
Funding Acknowledgments

- EPA Air Climate and Energy (ACE) Research Program
- U.S. Department of Energy, Fossil Energy
- NASA KORUS-AQ Science Team
- NOAA FIREX Science Team
- NASA Air Quality Applied Sciences Team (AQAST)

A portion of this presentation was developed under Assistance Agreement No. RD83587101 awarded by the U.S. Environmental Protection Agency to Yale University. It has not been formally reviewed by EPA. The views expressed in this document are solely those of the authors and do not necessarily reflect those of the Agency. EPA does not endorse any products or commercial services mentioned in this presentation.