A New Phase in Validation of Satellite NO$_2$ products—Berkeley Contribution to DISCOVER-AQ and preparation for GEO-CAPE

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Validation of NO$_2$ products to date

1) Spirals in nadir
2) Comparison to seasonal and interannual trends observed from surface stations
3) Comparison to models—sanity checks
In situ constraints for satellite observations of NO2 from OMI.

At the detection limit.

Flight of 4 March, Spiral #1

1s data
Mean for 100m bin

Integrated column density = $1.8 \times 10^{15}$ mols/cm$^2$

Flight of 4 March, Spiral #2

1s data
Mean for 100m bin

Integrated column density = $0.54 \times 10^{14}$ mols/cm$^2$
In situ vs. Satellite NO2 Comparison
Buscela et al. JGR 2009

MILAGRO
Flight #3 March 2006

Aerosol Index and Cloud Fraction:
- Land
- Ocean
- AI > 1.0
- CF > 0.1
- Both

\[ \text{Slope} = 0.93 \pm 0.03 \]
\[ \text{y-int} = 0.09 \pm 0.08 \]
\[ \text{CorrCoef} = 0.837 \]

In Situ \( (10^{15} \text{ cm}^{-2}) \)
\[ \text{NO}_2 \]
\[ \Sigma \text{PNs} \]
\[ \Sigma \text{ANs} \]
\[ \text{HNO}_3 \]
A.R. Russell, et al.,
*Space-based Constraints on Spatial and Temporal Patterns of NOx Emissions in California, 2005-2008*


Trends in OMI match trends at surface stations
OMI: ~7%/year decrease
Inventory: ~4% / year
Lessons learned from validation of NO$_2$ products to date

1) The NO$_2$ products from GOME, SCIAMACHY, OMI and GOME-2 are accurate to better than a factor of two. Long term precision of OMI is better than a few %. The relative accuracy of the different instruments also appears to be quite high, in the neighborhood of 10%.

2) the high spatial resolution of OMI presents different challenges/opportunities than do the lower res instruments.
Lessons learned from validation of NO$_2$ products to date

3) Time varying a priori profile shapes are needed—a single annual profile introduces biases estimated to be as large as 60%—but these introduce significant model information into the experimental product making it challenging to understand how it is possible—if at all—to use the observational product as an independent test of models.

4) High resolution albedo, terrain and profiles does produce a product that is has a narrower spread compared to reference data.
R.C. Hudman, et al.

*Interannual variation in soil NOx emissions observed from Space*

ACPD 10, 13029-13053, 2010. ACP, in press

Report a difference between standard product and DOMINO product in the vicinity of thunderstorms that affects magnitude of pulsing. Stratosphere?
L.C. Valin, et al. *Observation of slant column NO2 using the super-zoom mode of AURA OMI*, in preparation

**OMI observations at a spatial scale comparable to the GEO-CAPE target of 13 x 6 km**
Some of the things that are missing from the validation of NO$_2$ products to date

1) There has been essentially no validation off of nadir, and certainly no systematic comparison of the retrievals at nadir with those at larger angles.

2) There has been no systematic comparison to profiles at different times of day—that would provide an independent reference for the relative accuracy of the different instruments.
All have a Tropospheric Column of $1 \times 10^{15}$ mol. NO$_2$ cm$^{-2}$

Profile Shapes
Summary of profiles from INTEX-A

(10 second observations)
What controls NO$_2$ gradients at the edge of and within urban and other plumes?
high winds  
low NO$_2$  
high OH

low winds  
high NO$_2$  
low OH
Four Corners Power Plant

Emissions (CEMS)
Low (50-75%)  High (75-100%)

High Winds

Low Winds

High OH

Low OH
OMI SP & Berkeley 1:00 and 1:30-1:00
Percent Decrease on Weekends

OMI Column NO$_2$

$E_{VOC}=1x$

$E_{VOC}=2x$

$E_{VOC}=4x$
Application in 3-d: WRF-CHEM

4km met emissions at different resolutions compare NO$_2$ column

Gray biases of more than +25%
Black biases more than -25%
4 and 12 km

48 and 192 km
Thank you!
Columns and Mixing ratio

$1 \times 10^{15} \sim 400$ ppt, 1 km PBL

$1 \times 10^{16} \sim 4$ ppb, 1 km PBL
Effects of model spatial resolution on coupling of NO$_2$ mixing ratio, OH and therefore feedback on the NO$_2$ lifetime
A plume in 1-d

A point source advected by constant winds at constant noon and constant VOC
Effects of Spatial resolution of a model

\( E_{\text{NO}_2} = 7.8 \times 10^4 \text{ mole hr}^{-1} \)

\( E_{\text{NO}_2} = 7.8 \times 10^3 \text{ mole hr}^{-1} \)

\( E_{\text{NO}_2} = 7.8 \times 10^2 \text{ mole hr}^{-1} \)
A point source in 2-d
Black Constant OH
\(5 \times 10^6 / \text{cm}^3\)
4 and 12 km

48 and 192 km
Conclusions

Deriving OH from the shape of NO$_2$ plumes is promising

We have many pieces of information:

- variation with day of week
- variation with met (wind speed, pbl height)
- trends over multiple years
- variation with time of day

But we have more to learn before we know how to use all of these pieces of information.