Advancing Measurements of Tropospheric NO$_2$ from Space: New Techniques and Application to OMPS

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Outline

• Algorithm Basis: NO$_2$ Measurement Sensitivity
• New NO$_2$ Retrieval Technique: Direct Vertical Column Fitting Algorithm
• New Strat-Trop Separation Technique: Sliding Median
• Application to S-NPP/OMPS and Comparisons with Aura/OMI
• Future Development
**NO₂ Measurement Sensitivity:**

**Cross Section × Air Mass Factor**

**NO₂ Differential Cross Sections**

Sensitivity to tropospheric NO₂:
OMI 4 to 8 times > OMPS

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New NO$_2$ Algorithm:
Direct Vertical Column Fitting (DVCF)

Basic approach: Iterative spectral fitting to minimize the difference between measurements and radiative transfer simulations

\[
\ln I_m(\lambda) - \ln I_{TOA}(\lambda) = V \int_0^\infty \frac{\partial \ln I_{TOA}(\lambda)}{\partial \tau_z} S_z \sigma(\lambda, T_z) d\tau - \sum_i \xi_i \sigma_i(\lambda, T_i) + \epsilon.
\]

- NO$_2$ vertical column : $V$
- NO$_2$ Shape factor : $S_z$
- Other absorber slant column : $\xi_i$
- Altitude-resolved Air Mass Factor : $-\frac{\partial \ln I_{TOA}}{\partial \tau_z}$

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Improvements over DOAS

New algorithm allows more complete treatment of algorithm physics

• Self consistency: surface reflection, cloud (MLER) parameters, and their spectral dependence are retrieved from the same spectral range. Enable better handling of surface reflectance variation and cloud/aerosol conditions.

• More accurate in accounting for the effects of spectral and altitude variations in measurement sensitivity

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Artifact and Bias Correction

Radiance correction schemes developed with the new algorithm:

• Soft calibration of measured radiance based on internal consistency
• Residual analysis to derive static and dynamics corrections to remove biases and spectral interferences
• Stable instrument performance allows corrections derived from one time period to be effective for other time periods.

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New Strat-Trop Separation (STS): Orbit-Based Technique

Basic idea

• Localized (small scale) features in the strat fields are attributed to tropospheric signals due to shape factor prescription mismatch.

• Smoothing out these localized features improve both strat and trop NO$_2$ fields.
Orbit-Based STS: Procedures

- Initial STS done using tropopause and shape factor
- Two smoothed strat fields from sliding median of each cross-track position of an orbit: ~2° and ~20° latitude bands
- The excesses (+) and deficits (−) of strat NO₂ are the difference between the two smoothed fields.
- Trop columns adjustment: strat excesses are added to and deficits are subtracted from the trop fields, whilst accounting for their different measurement sensitivities.
Orbit-Based Example: Tropospheric Adjustment

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Orbit-Based STS: Advantages

• Each cross track done independently: without mixing measurements at different local time
• Measurement characteristics preserved: without increasing tropospheric NO$_2$ noise
S-NPP OMPS NO$_2$

New techniques applied to OMPS observations in the spectral range: 345 – 378 nm

First Global NO$_2$ Measurements form UV
OMPS: NO$_2$ Total Slant Columns

03/21/2013

09/22/2013

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OMPS: NO$_2$ Stratospheric Vertical Columns

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OMPS: NO$_2$ Tropospheric Vertical Columns

03/21/2013

09/22/2013

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Comparisons with OMI

OMPS tropospheric NO$_2$ measurement sensitivity is similar to that of OMI achieved with standard operational (DOAS-based) algorithm:

- OMPS slant column precision is better than $10^{15}$ molecules/cm$^2$, but slightly less than OMI
- Tropospheric column precision $\sim 3\times10^{14}$ molecules/cm$^2$, better than OMI

OMPS continues and extends Aura/OMI long-term data records
Comparison: OMI vs OMPS
Monthly Mean: July 2013

OMPS

OMI

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Comparison: OMI vs OMPS
Monthly Mean: December 2013

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Comparison: OMI vs OMPS
Monthly Mean: December 2013

Latitude = 36 Degree
Summary

• A new algorithm for improved NO$_2$ retrieval from space-based UV/Vis spectral measurements: OMI, GOME-2, OMPS, TROPOMI, TEMPO, and ...

• A new strat-trop separation approach, suitable for near-real-time application

• New correction schemes enabled by the new algorithm, for bias reduction and sensitivity enhancement.
Algorithm Advances Enable Daily Global Pollution Monitoring with OMPS

SO₂ (DU)

NO₂ (10¹⁵ cm⁻²)

UV Alₜ
Unprecedented SO$_2$ Sensitivity

OMPS October 2013 Monthly Mean ISF Algorithm

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