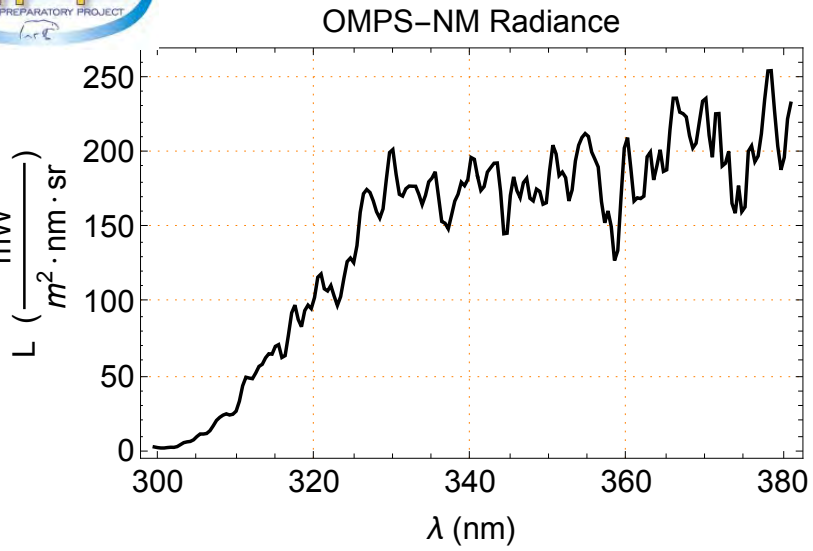
OMPS Additional Trace Gases: NO_2 and SO_2 Products

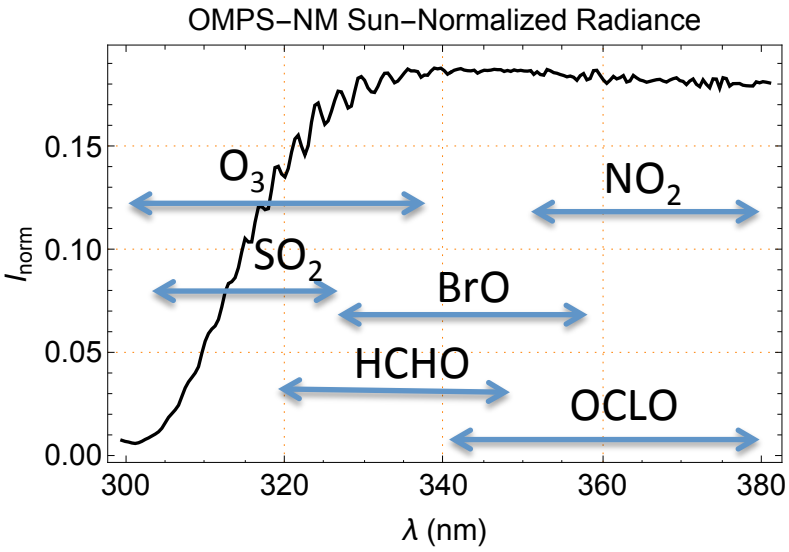
Kai Yang
University of Maryland College Park

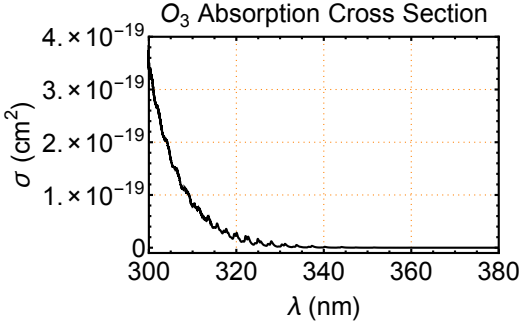


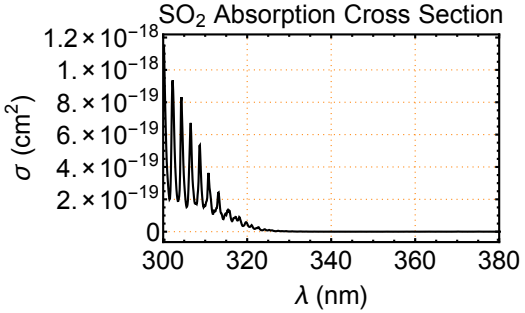
JPSS Annual Science Team Meeting, August 26, 2015

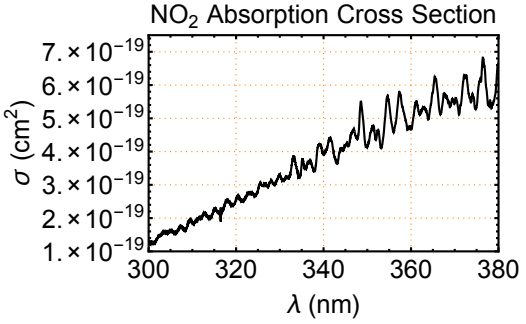
Suomi NPP/OMPS-NM

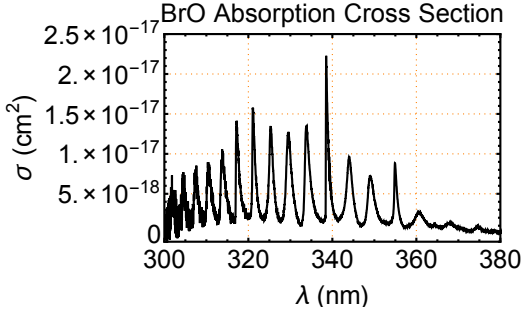


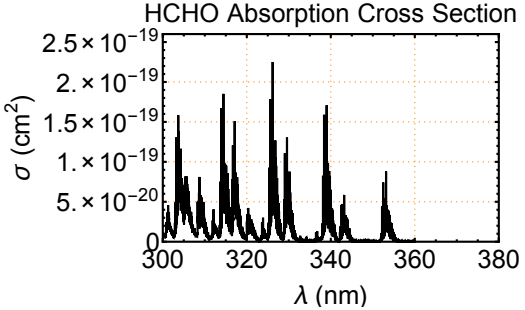


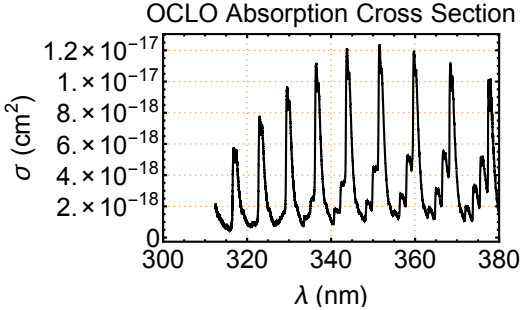






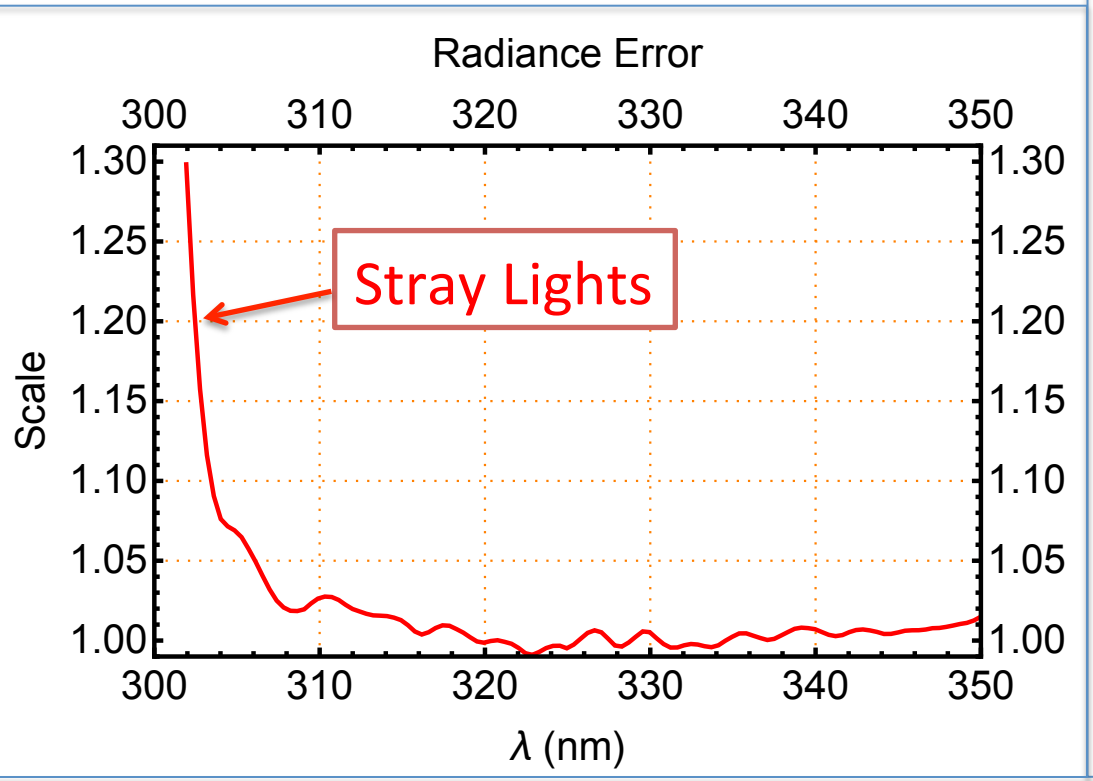




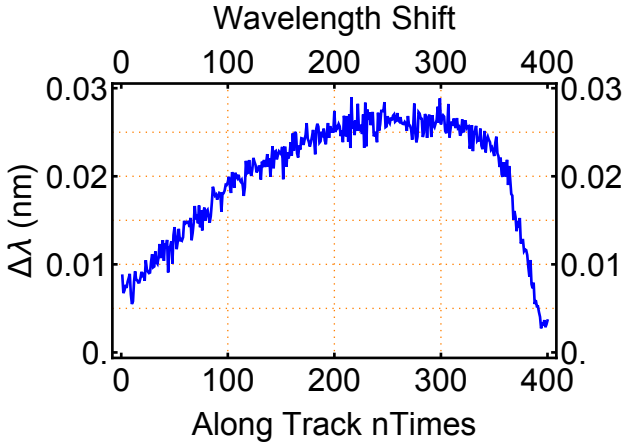


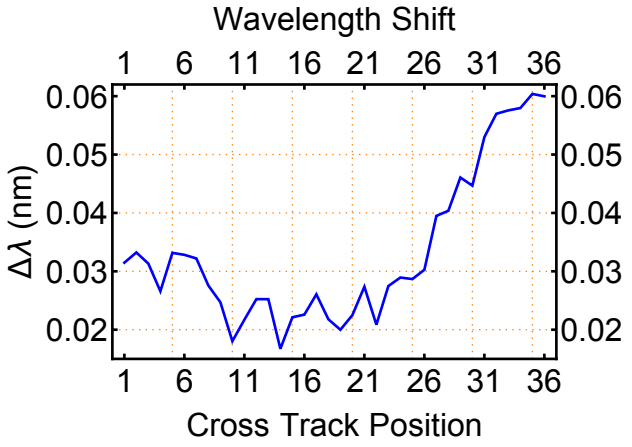
Suomi NPP/OMPS-NM

- Stable performance
- high signal-to-noise ratio
- But significant stray lights, and other instrumental artifacts



Wavelength Variation





Objectives

Retrieve NO_2 and SO_2 from SNPP/OMPS with sufficient quality to extend Aura/OMI record.

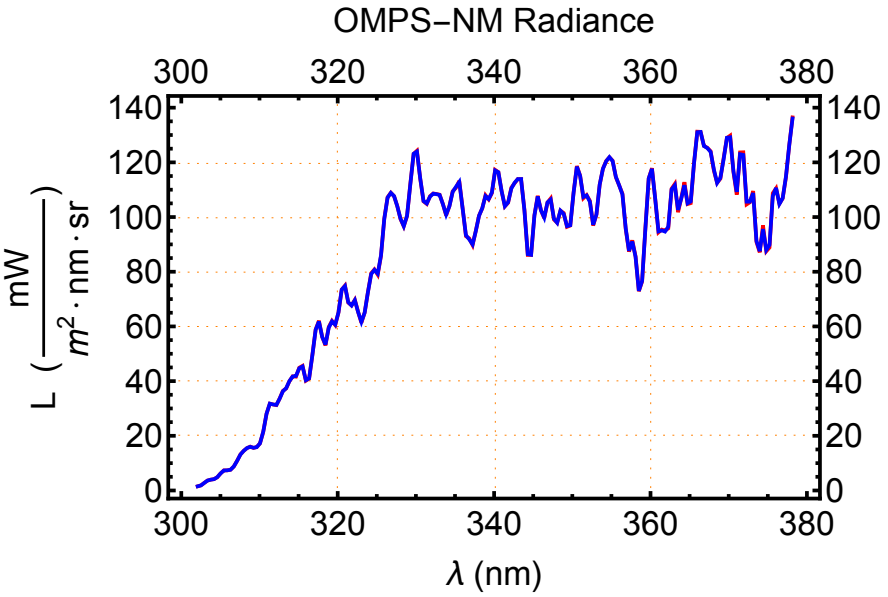
- Standard Products
  - SO_2 Vertical Columns
    - Volcanic SO_2 at various altitudes
    - Boundary Layer SO_2
  - NO_2 Vertical Columns
    - Tropospheric, Stratospheric, and Total NO_2
- Near-Real-Time (NRT) Products
  - SO_2 Vertical Columns

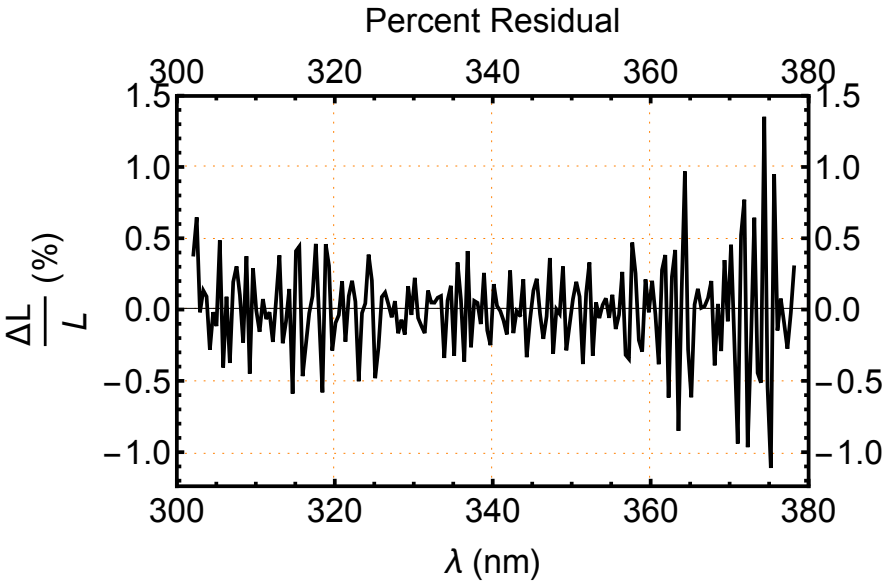
Retrieval Algorithm

To achieve high product quality, Direct Vertical Column Fitting (DVCF) Algorithm:

- State-of-the art algorithm physics: accurate of radiative transfer including RRS scattering (Ring effect)
- Effective schemes to account for varying instrumental effects: wavelength registration, spectral response, under sampling, and spectral interferences

Direct Radiance Fitting





Radiance:
Model (Blue) vs. Measurement (Red)

Residual Standard Deviation: 0.3%

Spectral Ranges

Direct Vertical Column Fitting (DVCF)

1. O_3 and SO_2 : 308 – 360 nm
- SO_2/O_3 : 308 – 333 nm
- Reflectivity/cloud fraction, aerosol index : 333 – 360 nm

2. NO_2 :345 – 378 nm
- Full range: NO_2: 345 – 378 nm
- reflectivity/cloud fraction, pressures, aerosol index: 350 – 378 nm

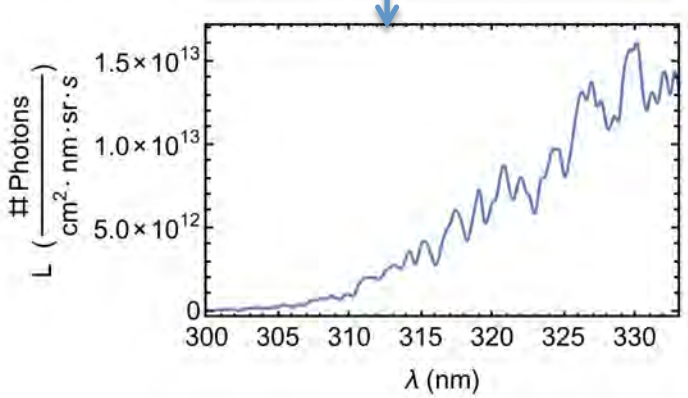
By-Products: O_3 profile and column, and surface parameters: reflectivity/cloud fraction, aerosol index, and pressure

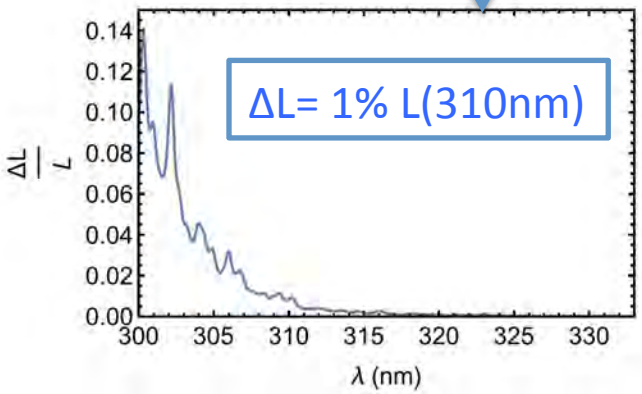
Spectral interference

- Due to measurement imperfection and instrumental artifacts, such as stray lights, ghosting, etc.
- Spectral interference is the main factor limiting the sensitivity and accuracy of the retrieved trace gas columns.

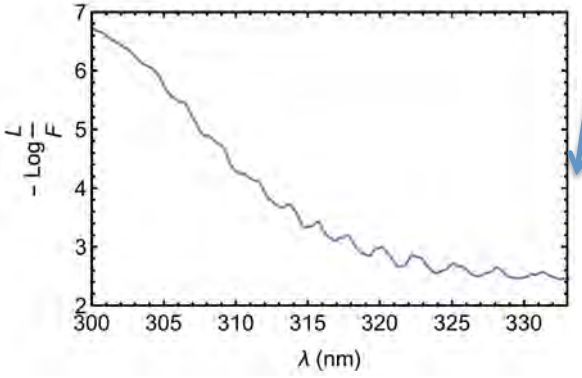
Spectral interference: Signal Dependence

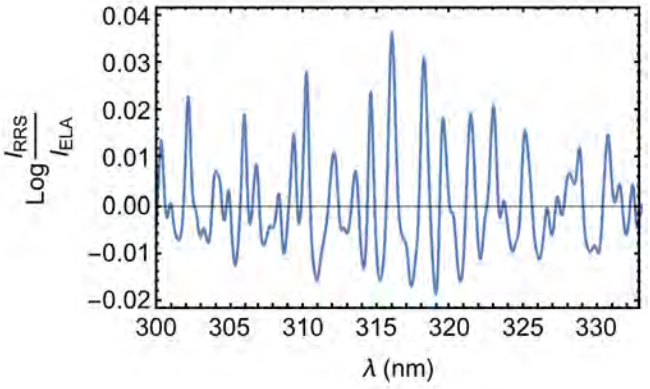
$$Log\left[\frac{L+\Delta L}{F}\right] = Log\left[\frac{L}{F}\right] + \frac{\Delta L}{L}$$





ΔL= 1% L(310nm)





Ring Spectrum

Characterizing Spectral interference

Error Covariance Matrix:

$$Cov[i,j] = \langle \varepsilon(\lambda_i) \cdot \varepsilon(\lambda_j) \rangle$$

where $\varepsilon(\lambda_i)$ is the residual:

$$\varepsilon(\lambda_i) = \mathrm{Log}[\, I_{measured}(\lambda_i)/I_{modeled}(\lambda_i)]$$

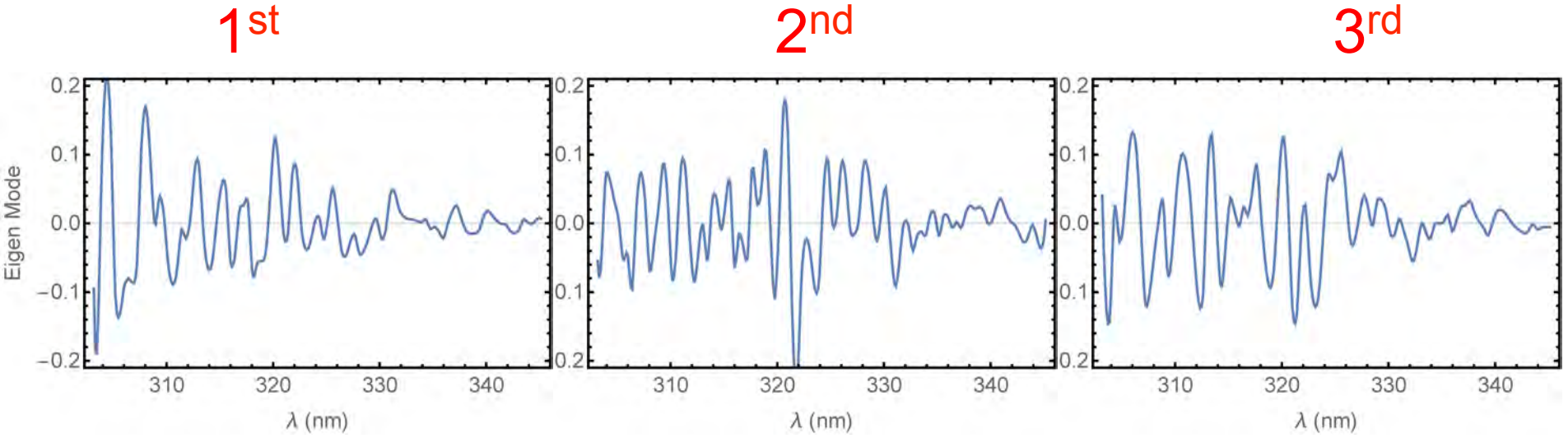
$I_{measured}$: Sun-normalized radiance measurements

$I_{modeled}$: Radiance from accurate RT modeling

Covariance Matrices : constructed for various conditions, such as solar and viewing angles, and scene reflectivity

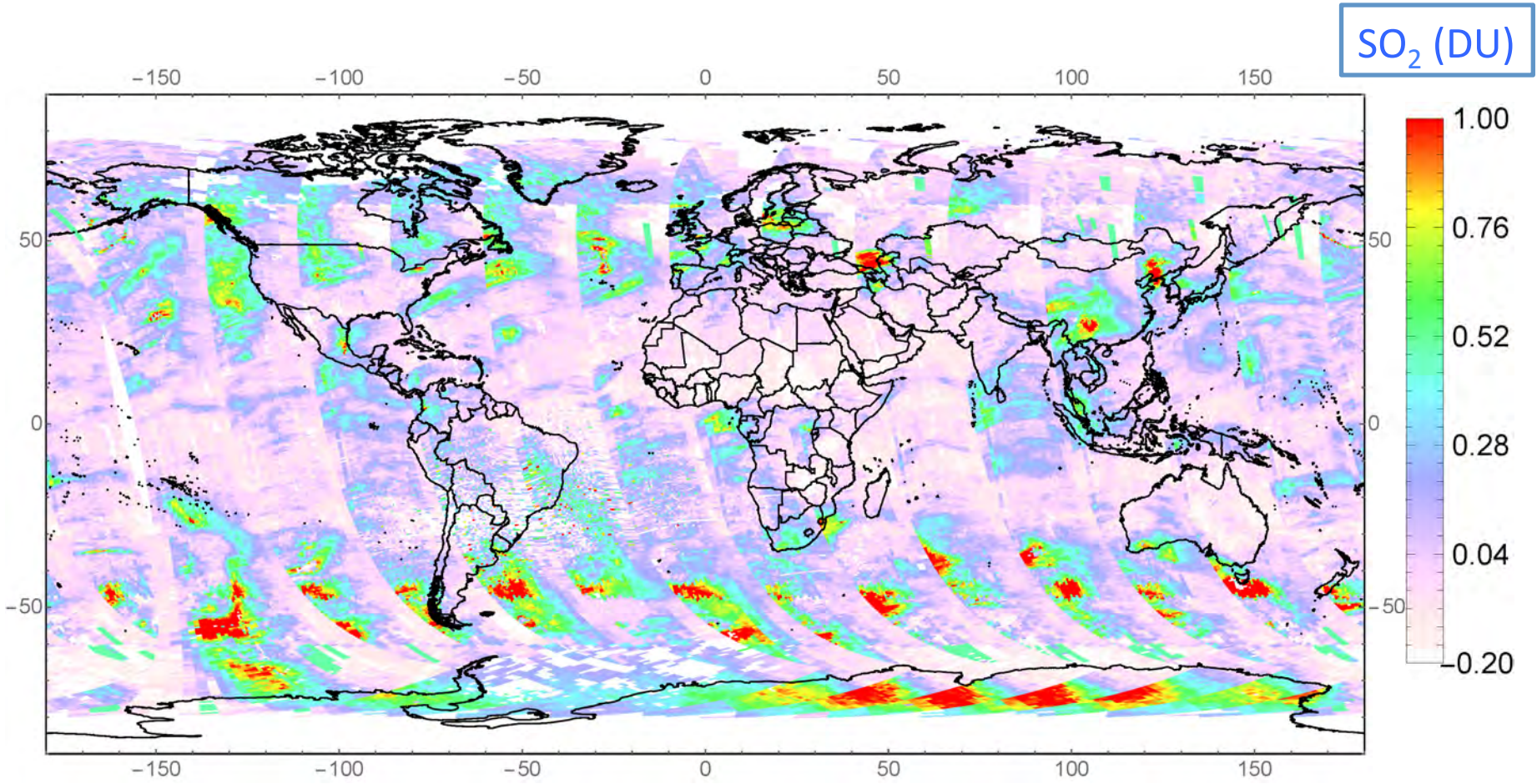
Mitigating Spectral Interference

Eigen functions of the Covariance Matrix

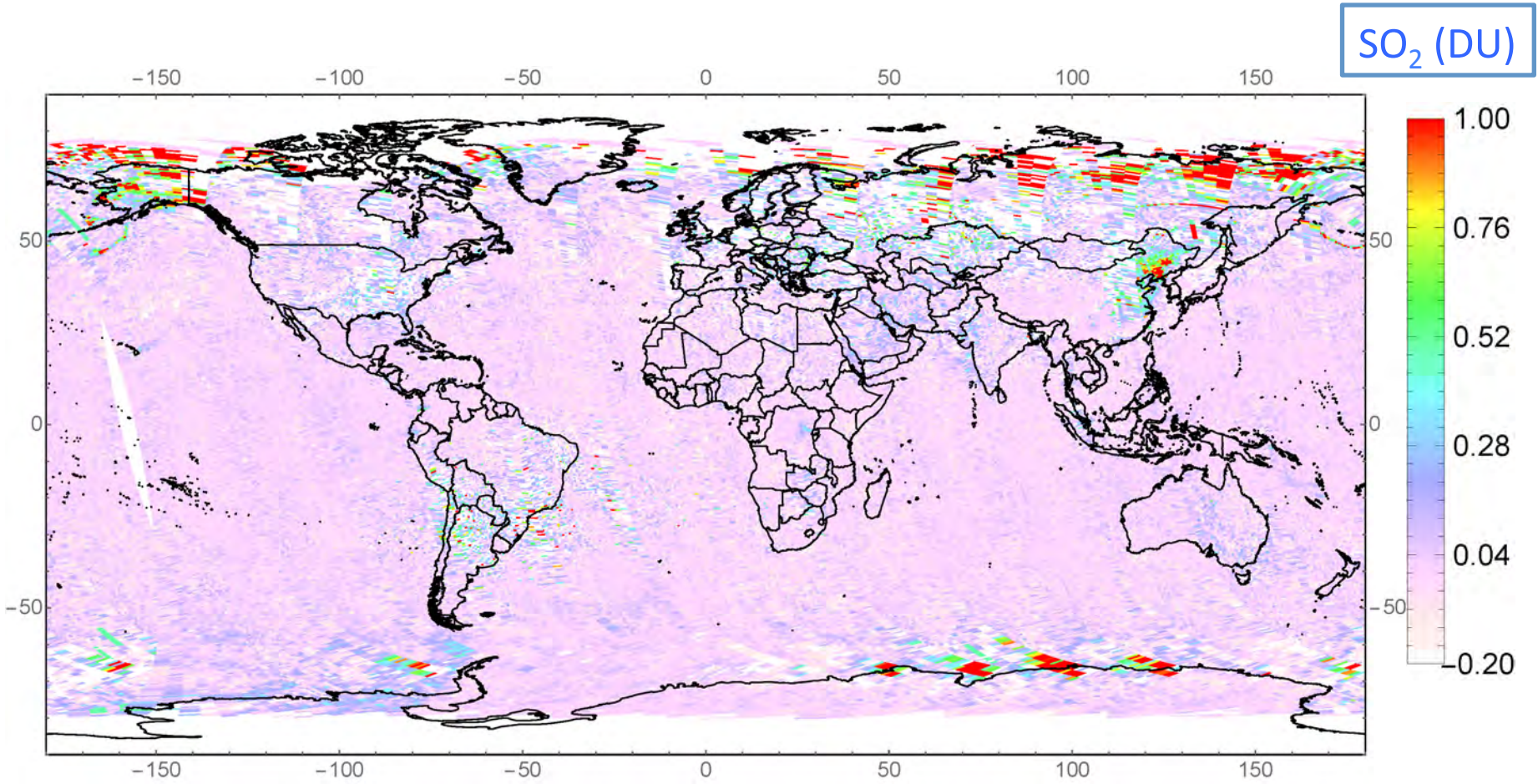


- Fitting of the first few Eigen functions would significantly reduce the impacts of spectral interference

OMPS Boundary Layer SO_2: Without Correction

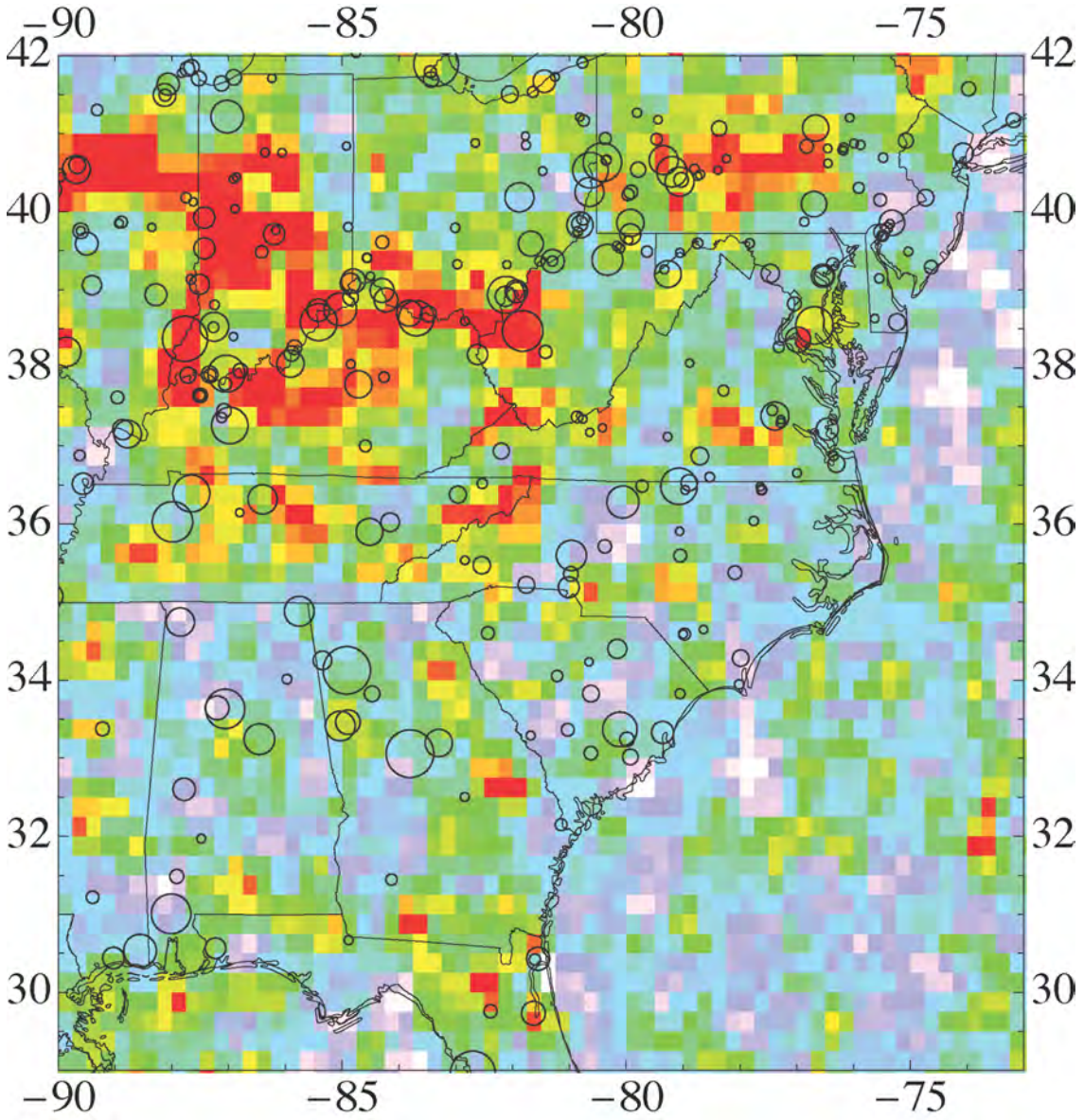


OMPS Boundary Layer SO_2: With Correction

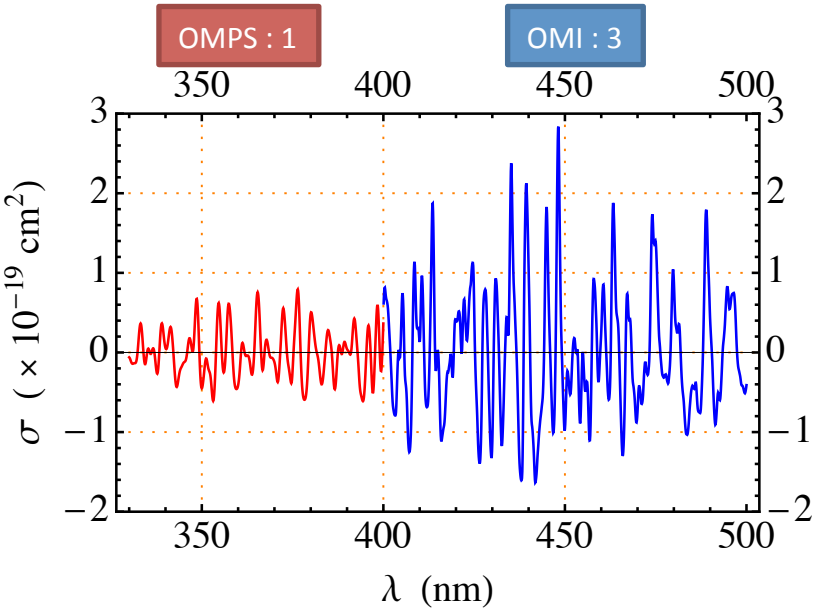


Unprecedented SO_2 Sensitivity: Pollution over US

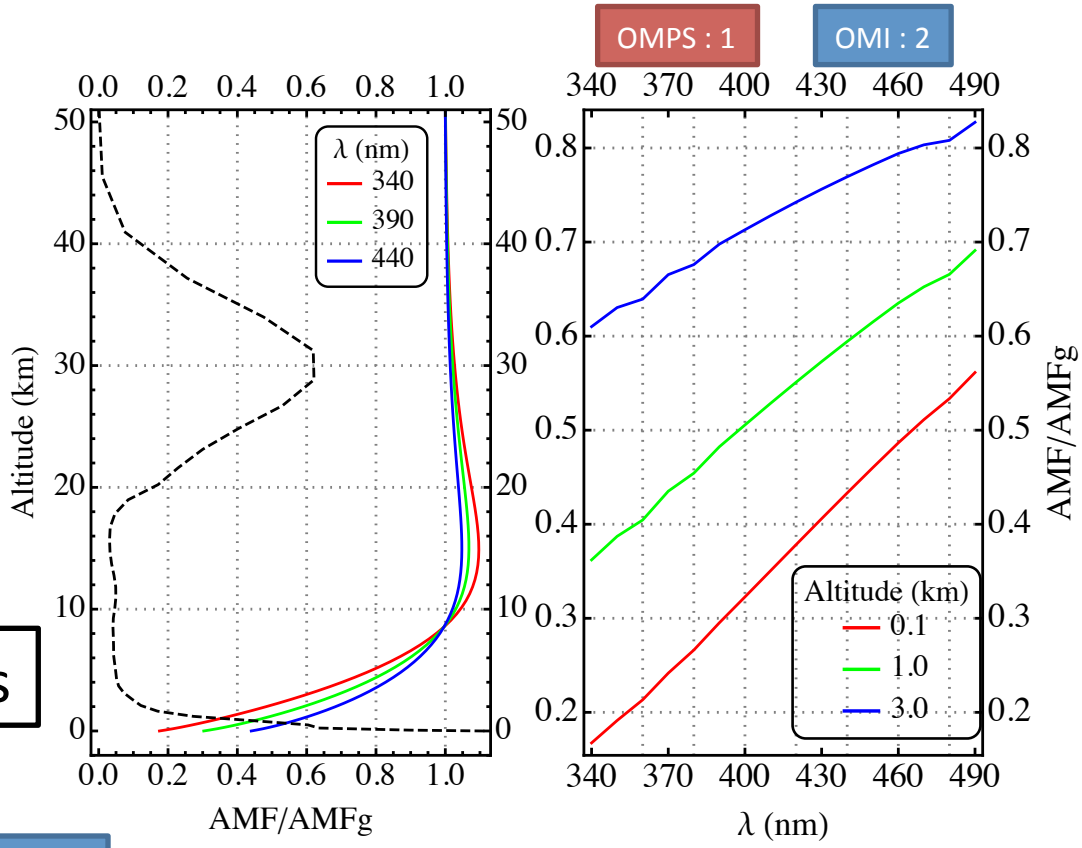
SNPP/OMPS
October 2013
Monthly Mean
DVCF Algorithm



NO_2 Measurement Sensitivity :
Cross Section × Air Mass Factor



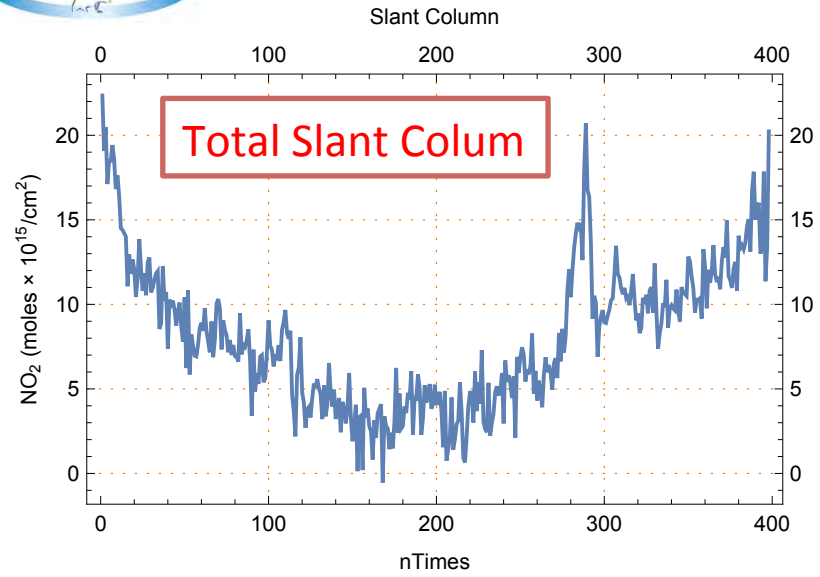
NO_2 Differential Cross Sections



Sensitivity to tropospheric NO_2 :
OMI 4 to 10 times > OMPS

Altitude-Resolved AMFs

OMPS NO_2 Measurement Sensitivity



Precision of slant column:

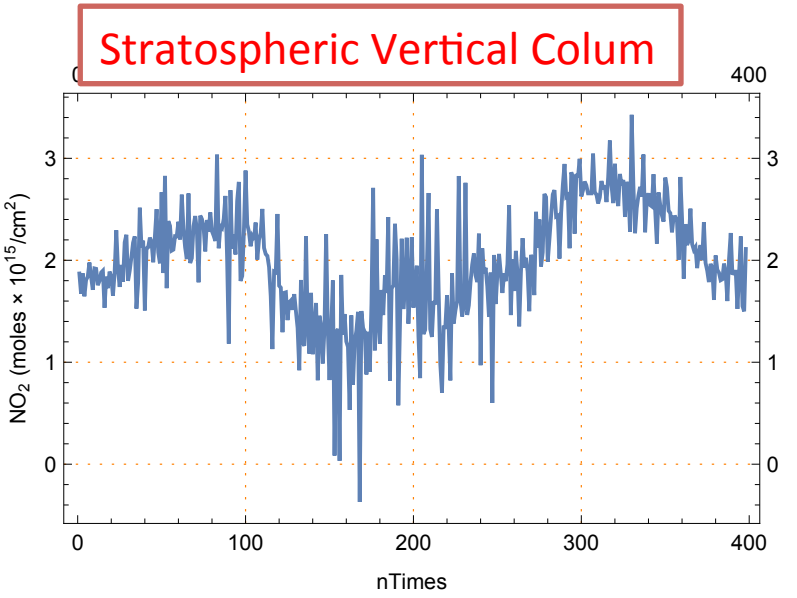
OMPS ~ 1×10^{15} molecules/cm^2

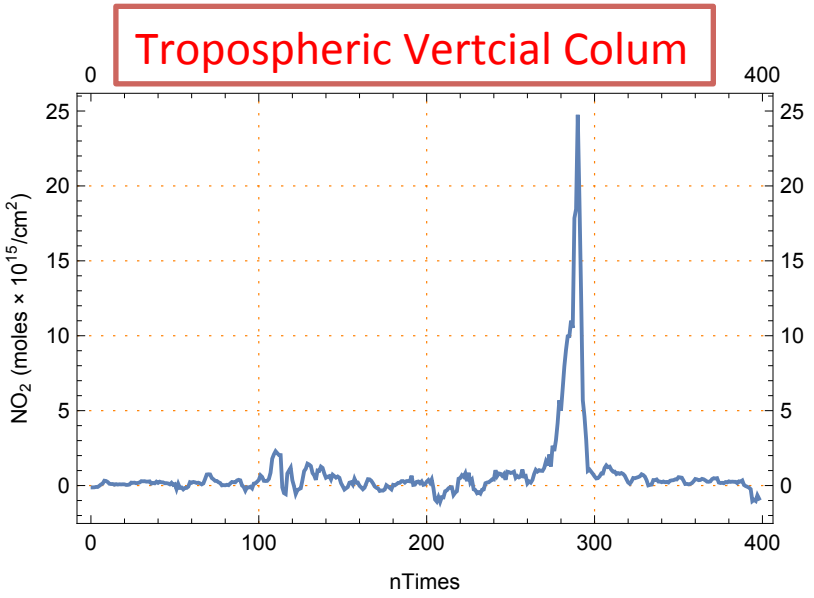
OMI ~ 1×10^{15} molecules/cm^2

Precision of vertical tropospheric column:

OMPS ~ 0.5×10^{15} molecules/cm^2

OMI ~ 1.0×10^{15} molecules/cm^2





NO_2 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.

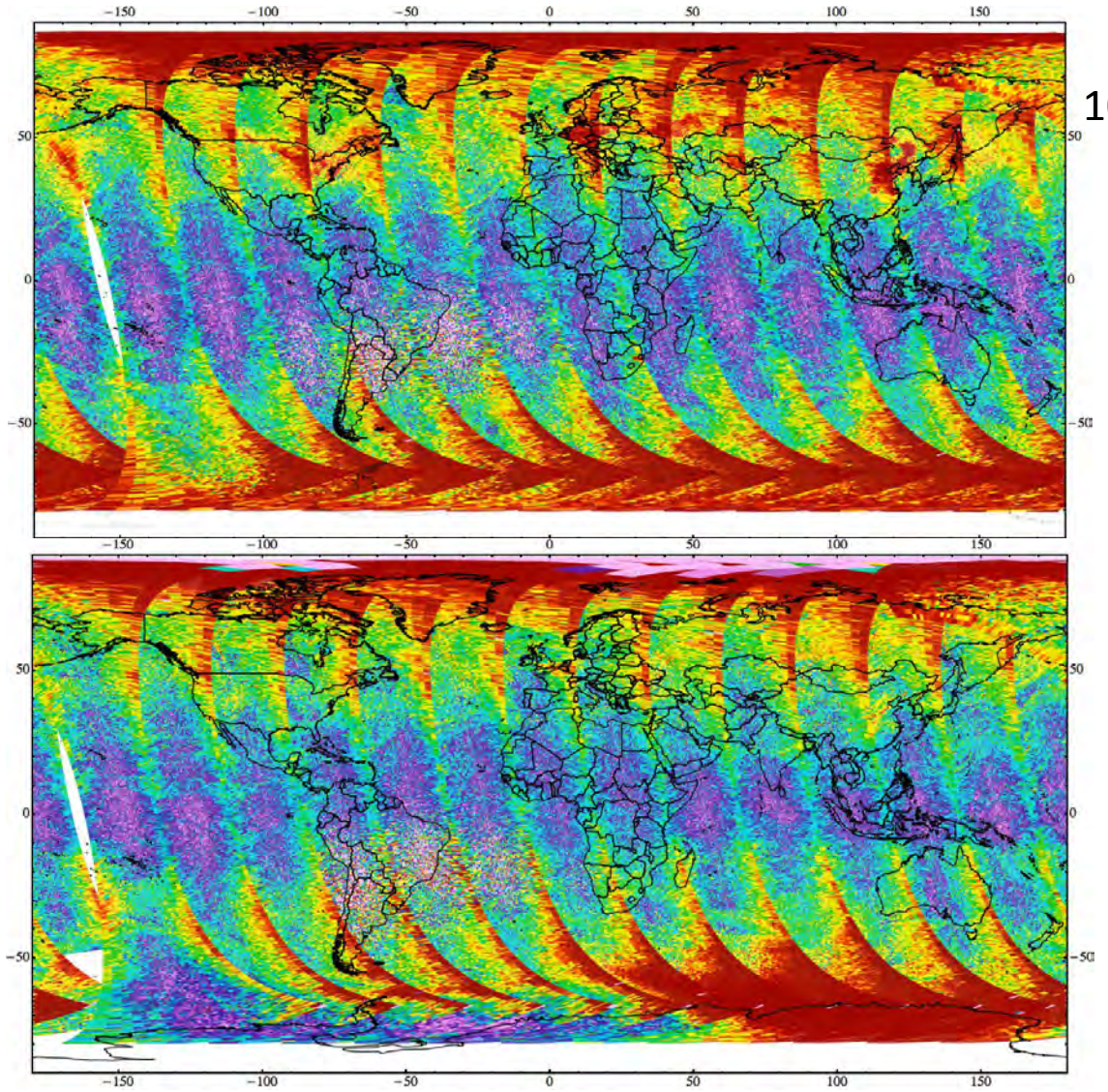
Procedure

- 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 NO_2 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.

OMPS: NO_2 Total Slant Columns

03/21/2013

09/22/2013



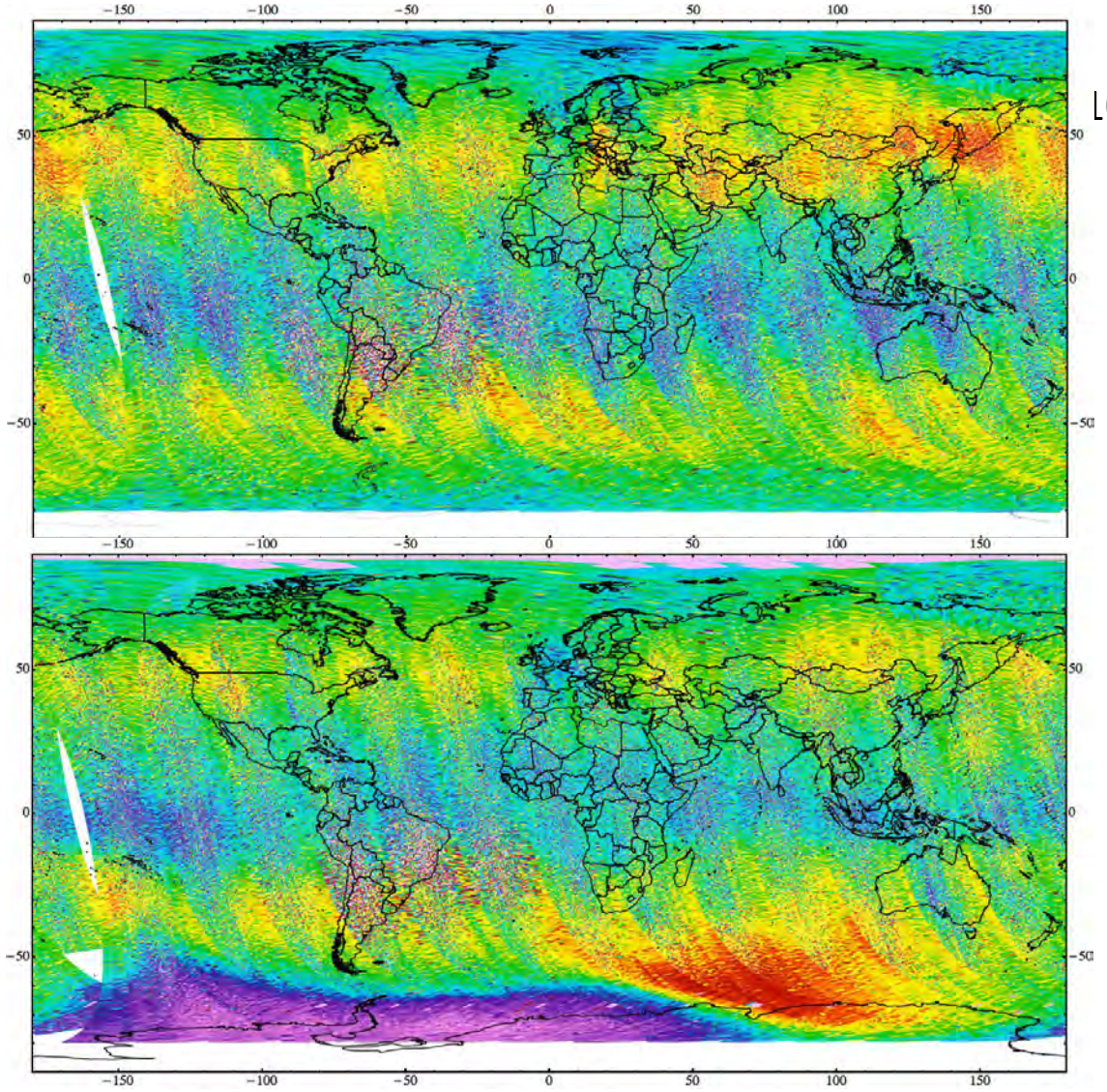
NO_2
10^{15} molecules/cm^2

15.00
12.50
10.00
7.50
5.00
2.50
0.00

OMPS: NO_2 Strat Vertical Columns

03/21/2013

09/22/2013



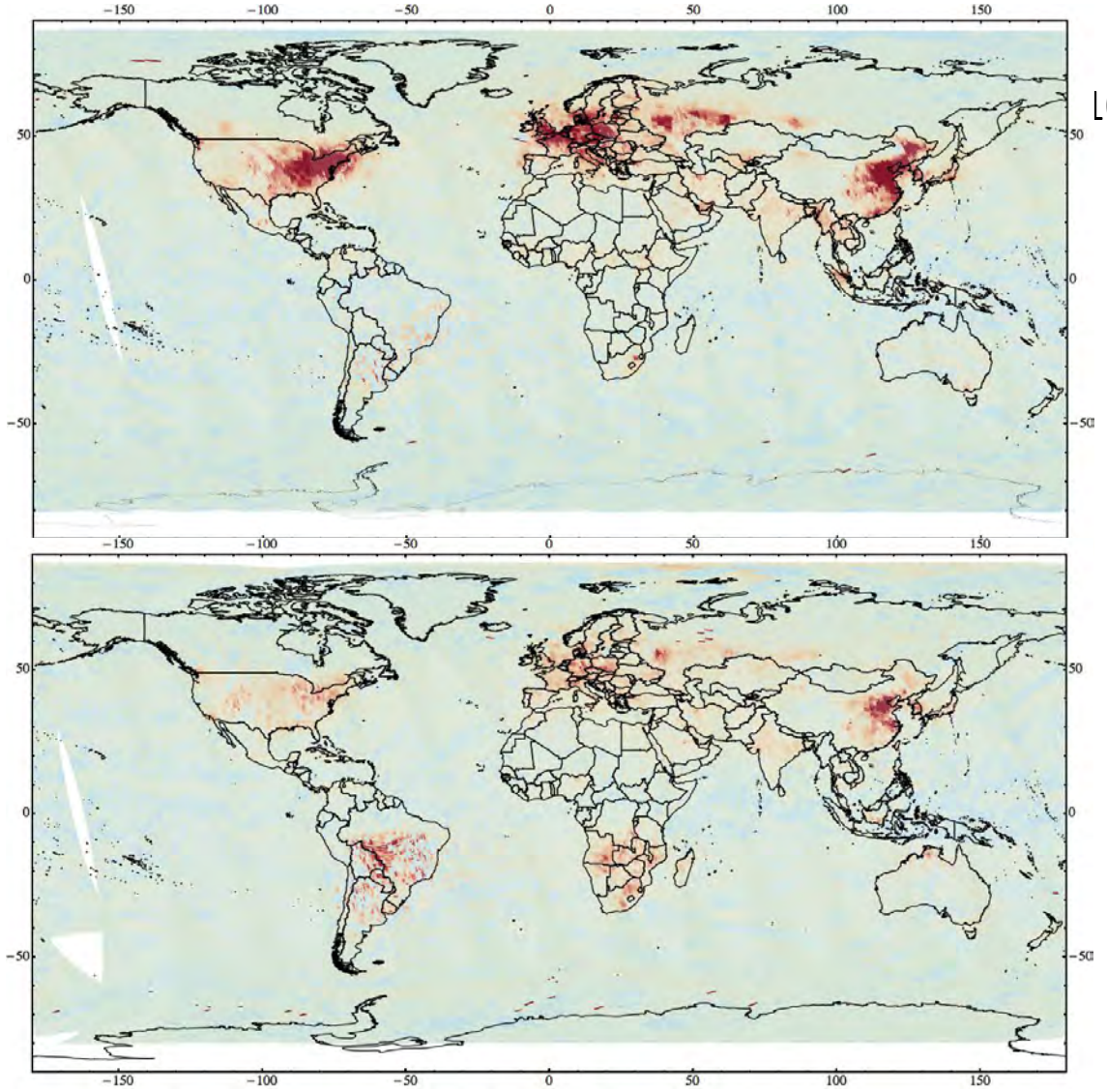
NO_2
10^{15} molecules/cm^2

5.00
4.00
3.00
2.00
1.00
0.00

OMPS: NO_2 Trop Vertical Columns

03/21/2013

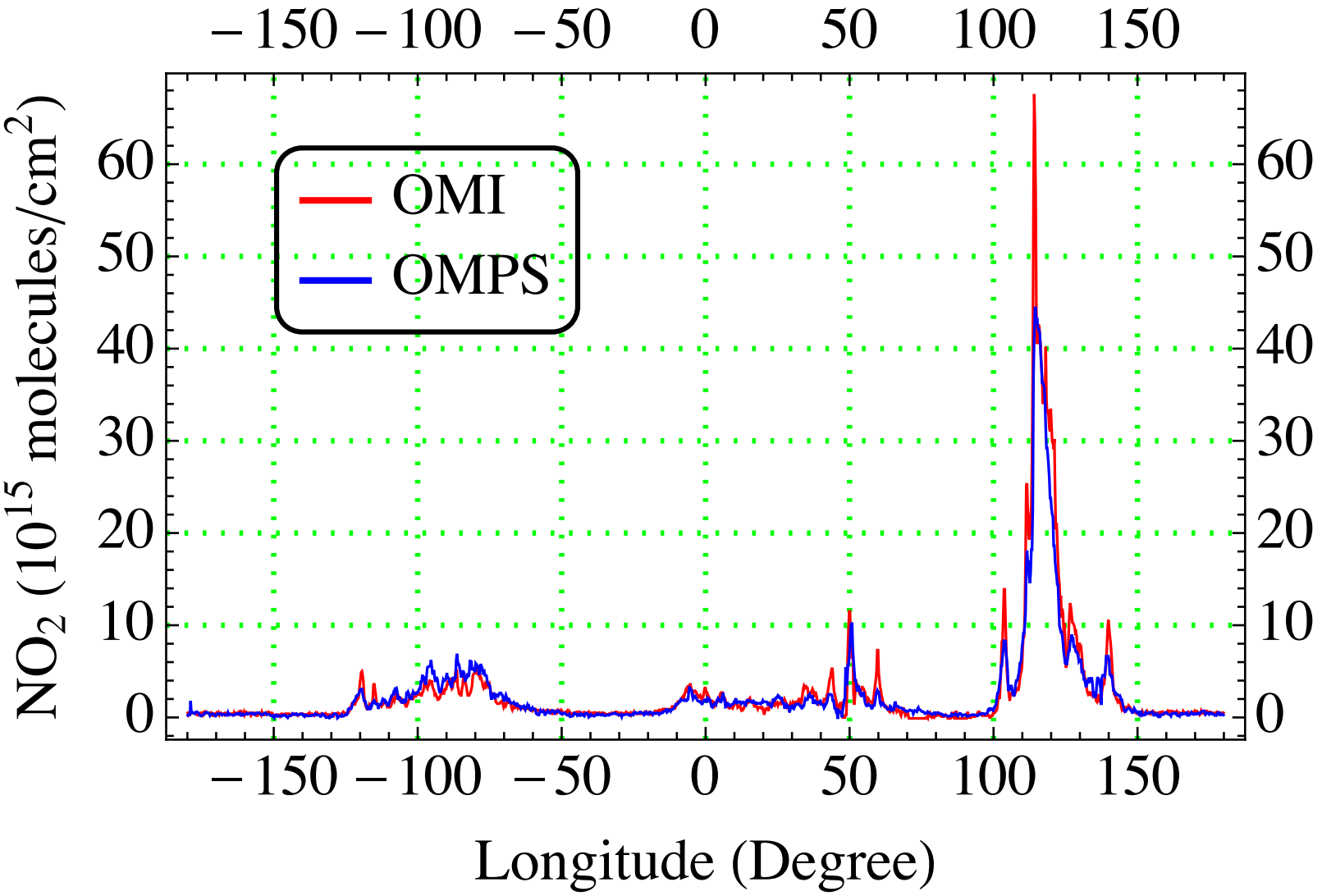
09/22/2013



NO_2
10^{15} molecules/cm^2

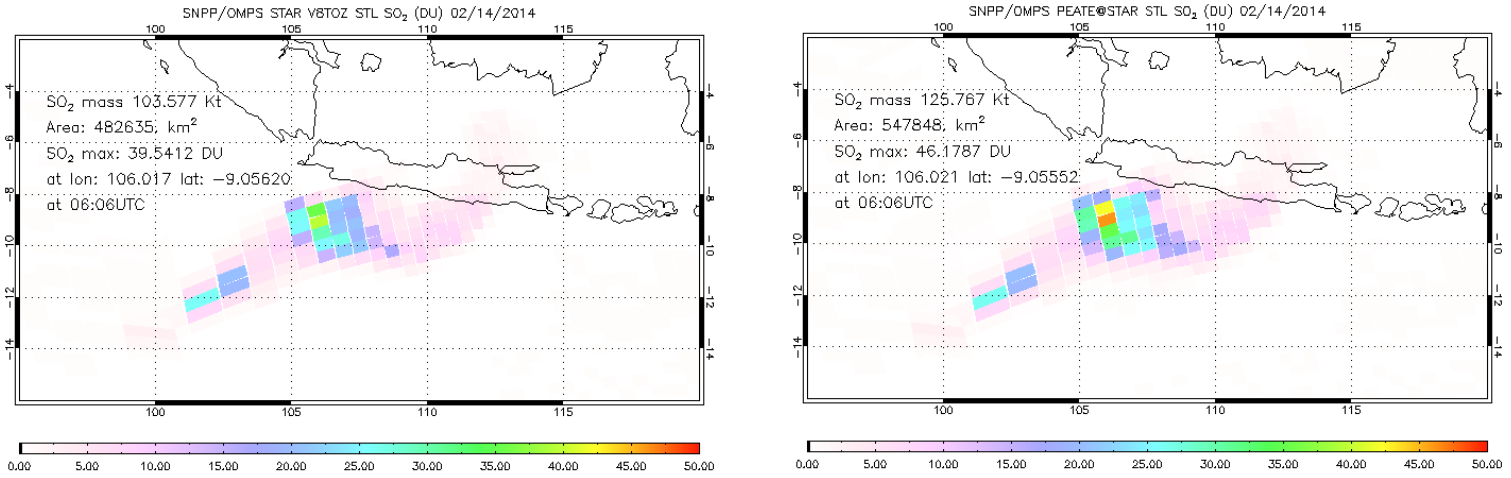
10.00
8.00
6.00
4.00
2.00
0.00

Comparison: OMI vs OMPS
Monthly Mean: December 2013



Near-Real-Time SO_2 Product

- NRT SO_2/Ash are processed with the reliable Linear Fit (LF) algorithm. Data available at Ozone SIPS and LANCE.
- LF algorithm successfully transferred to NOAA.



Eruption of Kelud 2014/02/14. Figures from J. Niu (NOAA STAR)

Summary

- Advanced algorithm with more complete algorithm physics treatment and many improvements, including state-of-the-art radiative transfer modeling, accurate treatment of instrumental effect, and advanced soft calibration, have been developed and implemented for OMPS processing.
- These advances have enabled sensitive and unbiased measurements of tropospheric SO_2 and NO_2 from SNPP/OMPS-NM, achieving data quality that matches or exceeds those of its predecessors.

Acknowledgement

This work is supported by NASA.