Global free tropospheric NO_2 Abundances Derived using a Cloud Slicing Technique from Aura OMI

S. Choi, J. Joiner, Y. Choi, B. N. Duncan,
A. Vasilkov, N. Krotkov and E. J. Bucsela

GEMS Science Team Meeting
2014. 10. 8.

Free Tropospheric NO_2

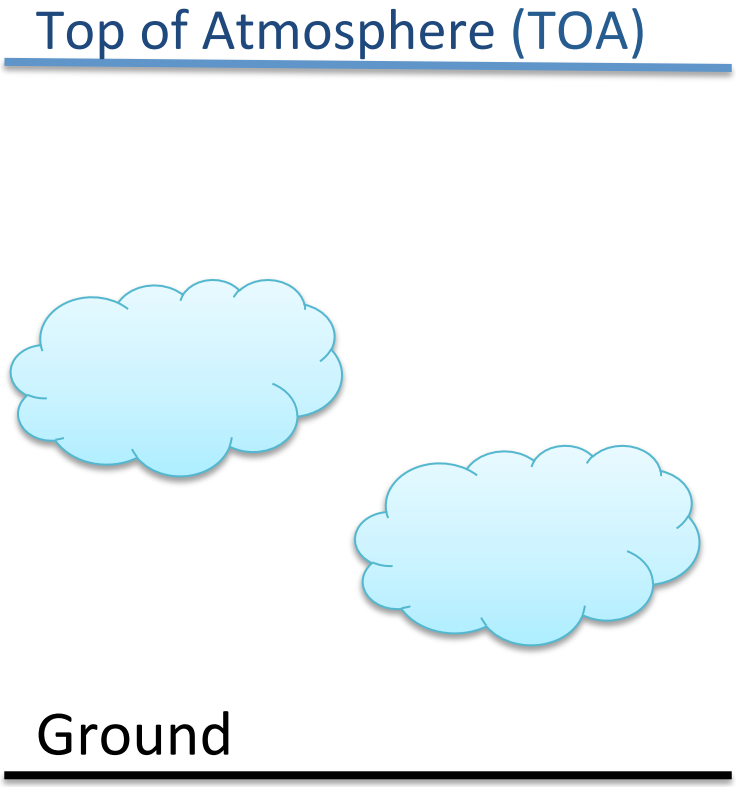
- Atmospheric NO_2
  - Produced by combustion, lightning, and in soil
- Indirect radiative impacts in troposphere
  - Ozone has largest warming effect in upper-troposphere
  - Impacts methane concentrations
- A few types of **free-**tropospheric NO_2 measurements available
  - Aircraft in situ measurements, MAX-DOAS, NO_2 sondes, etc.

Cloud Slicing Technique

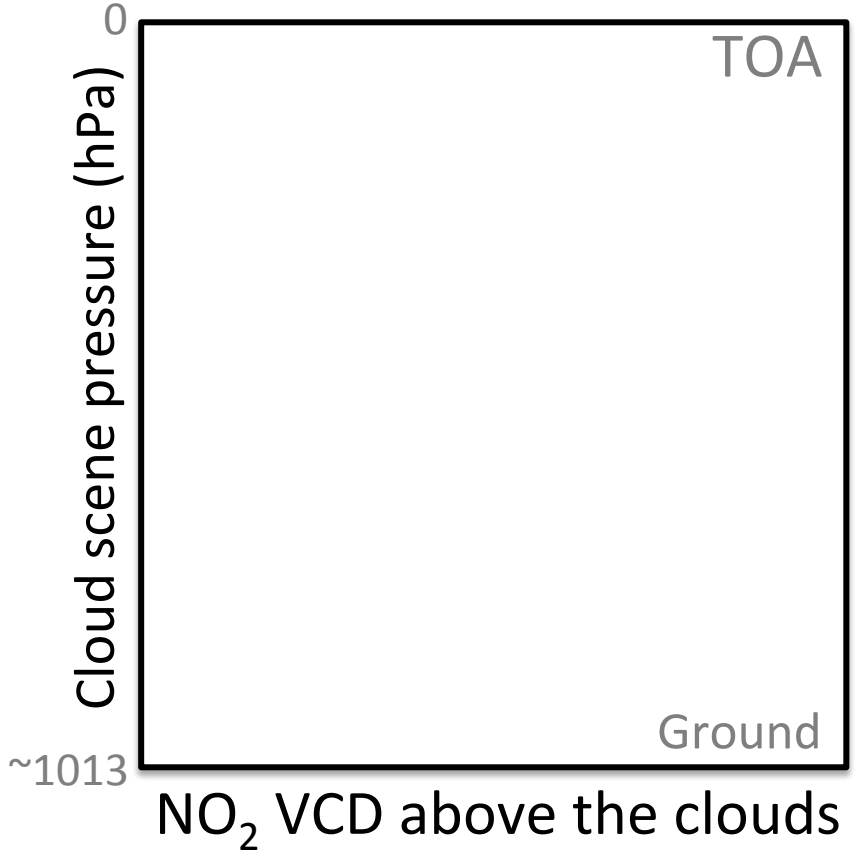
- Utilize **above-cloud** NO_2 column (where CRF > 0.9)
  - Cloudy measurements are usually neglected in the view of surface pollution
  - Good quality column measurements as clouds provide bright surface
- Data obtained
  - Free tropospheric NO_2 volume mixing ratio (VMR)
- Independent of prescribed stratospheric column estimate

Cloud Slicing Technique

Measurement at Cloudy Scenes

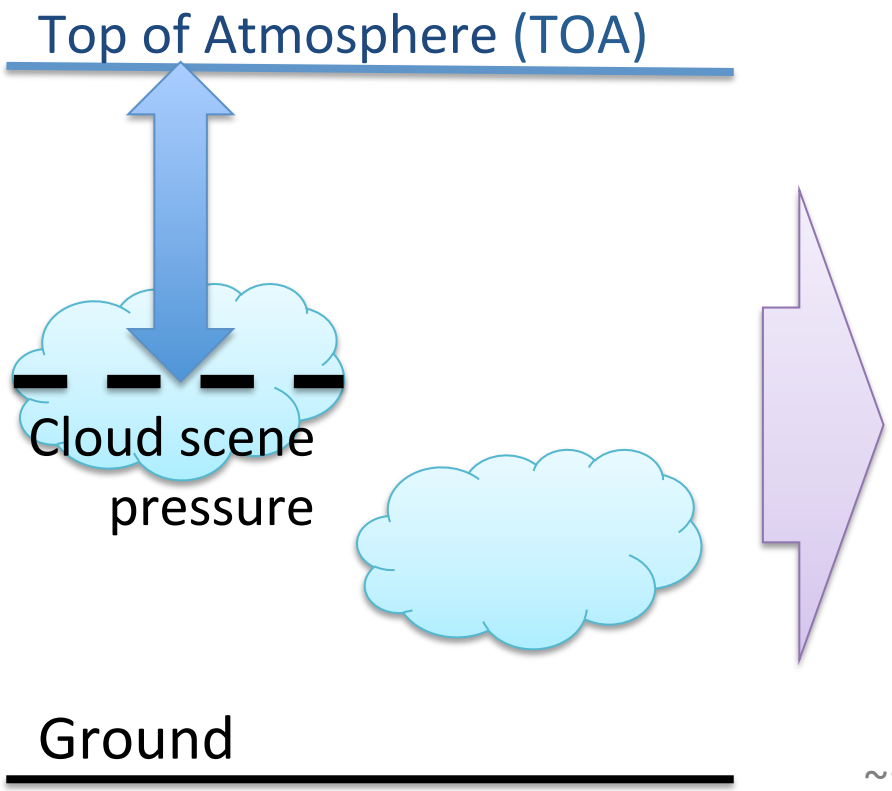


Observed Column vs Pressure

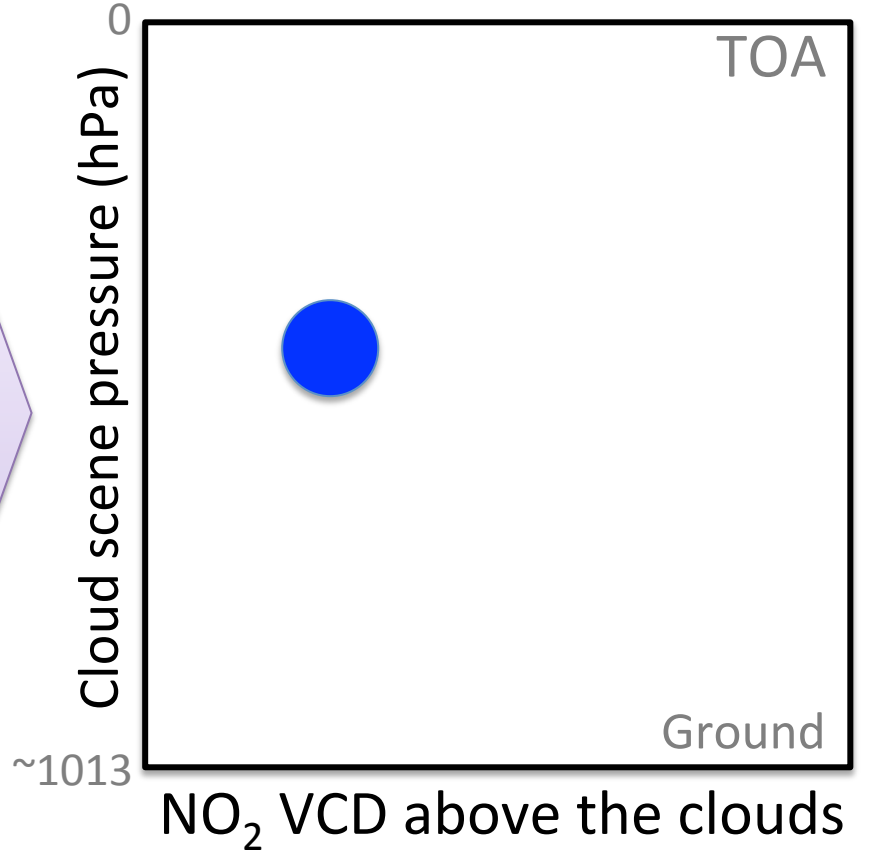


Cloud Slicing Technique

Measurement at Cloudy Scenes

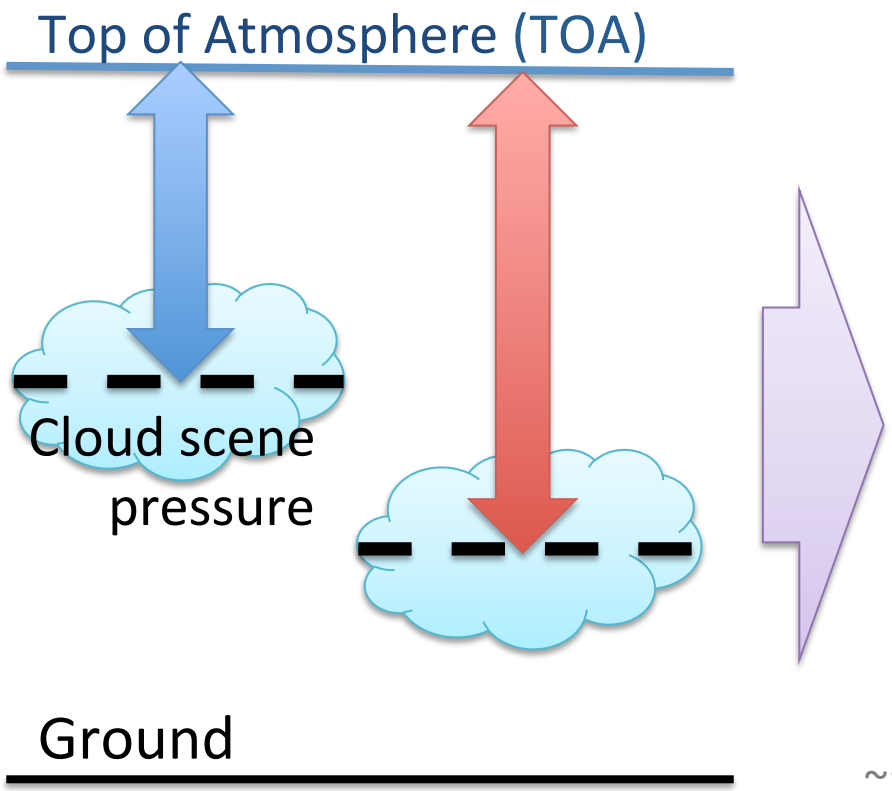


Observed Column vs Pressure

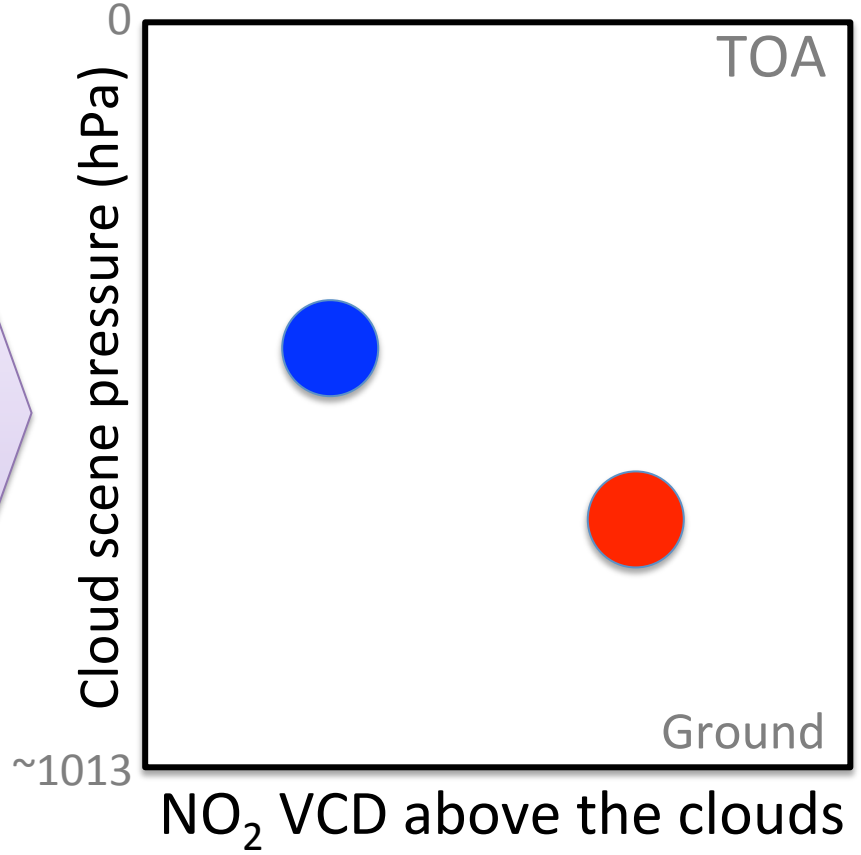


Cloud Slicing Technique

Measurement at Cloudy Scenes

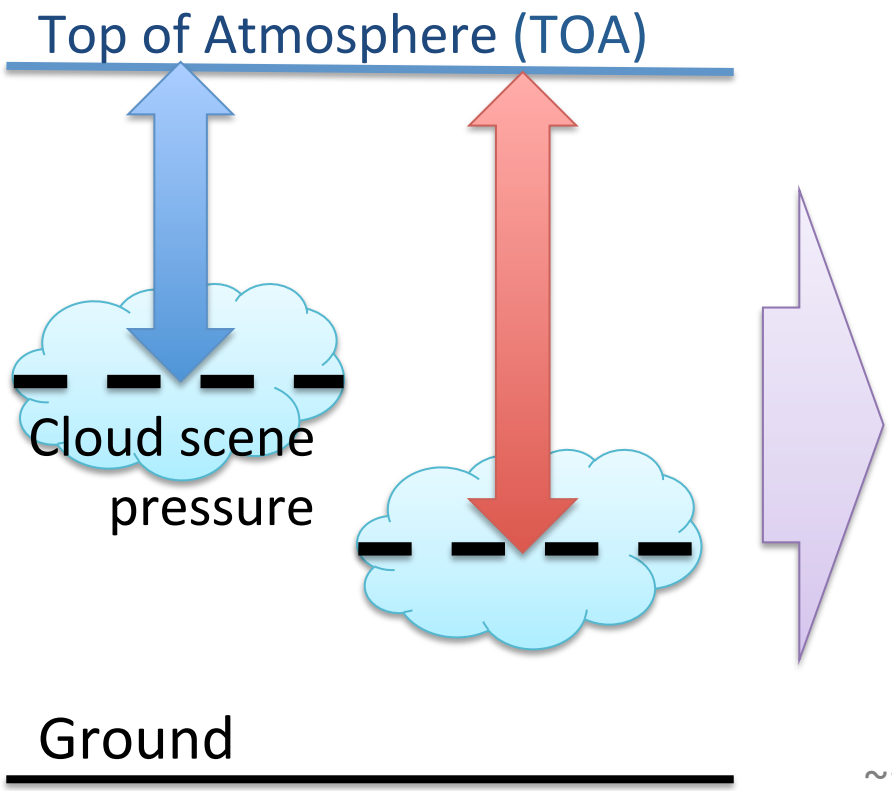


Observed Column vs Pressure

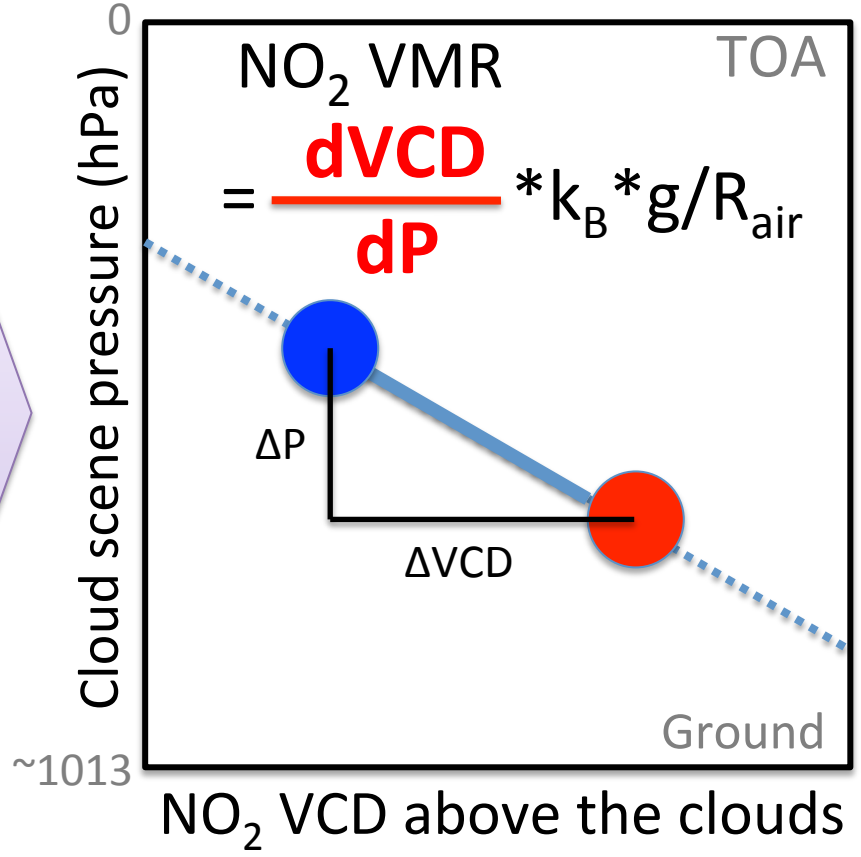


Cloud Slicing Technique

Measurement at Cloudy Scenes

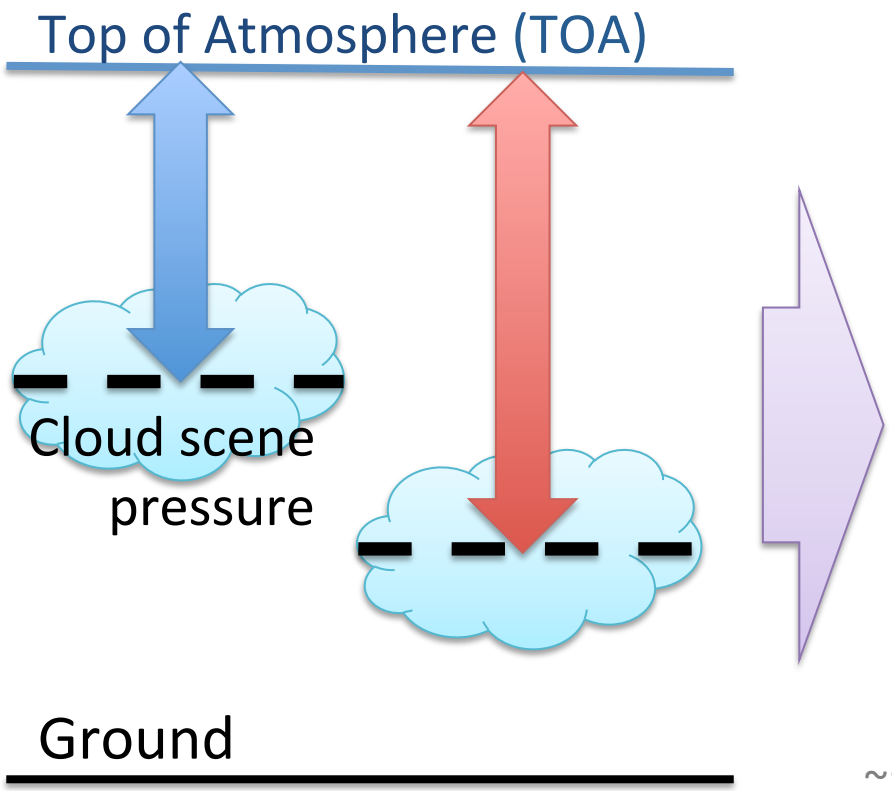


Observed Column vs Pressure

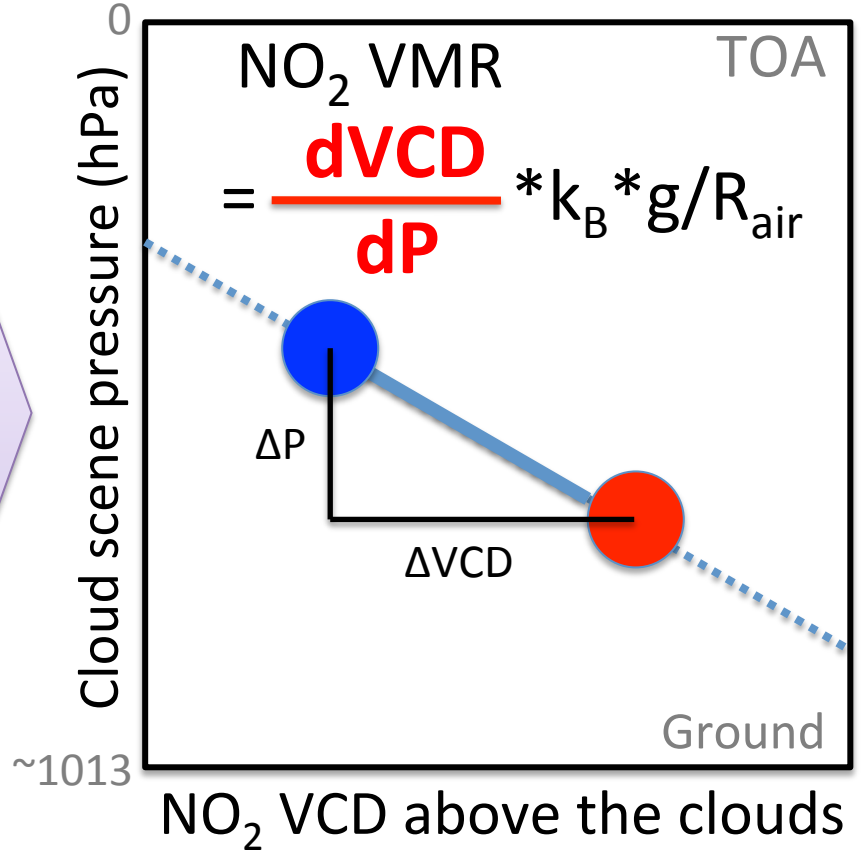


Cloud Slicing Technique

Measurement at Cloudy Scenes



Observed Column vs Pressure

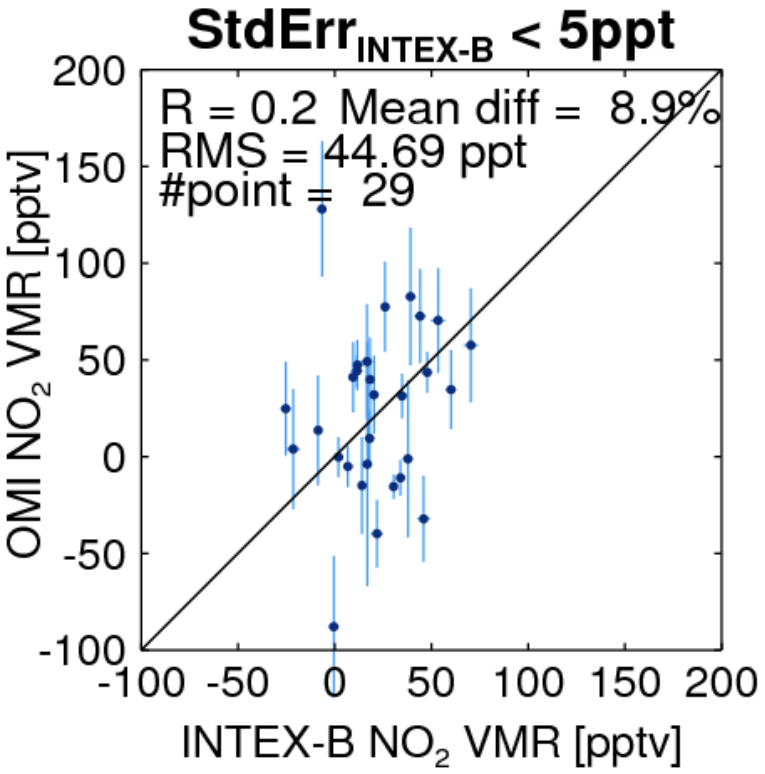


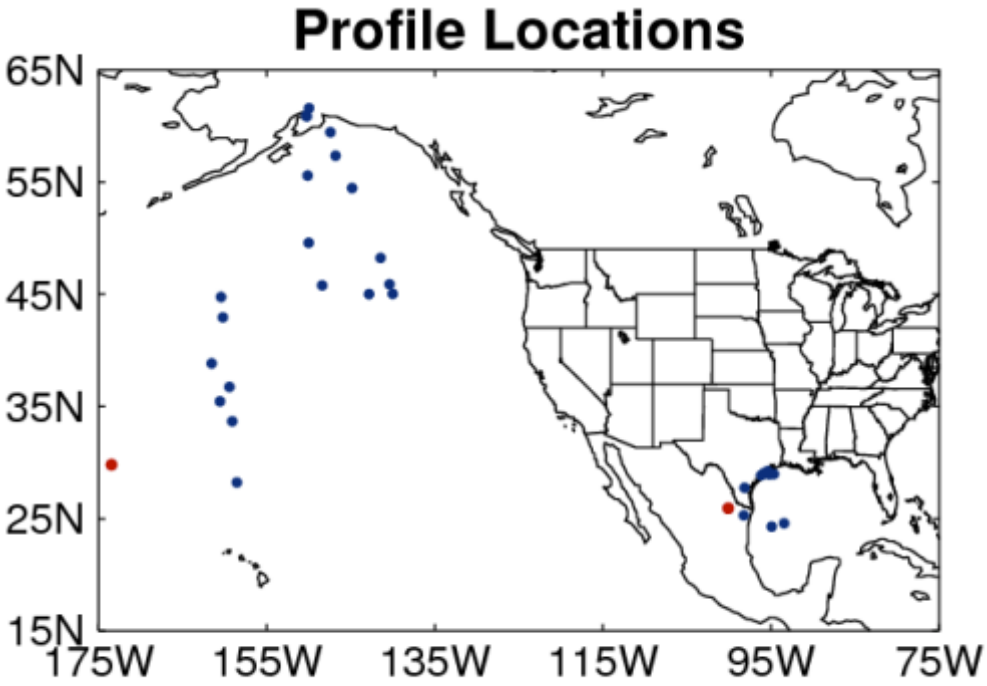
The slope between NO_2 VCD and cloud pressure is proportional to NO_2 volume mixing ratio (VMR)

Cloud Slicing Technique

- Using near-Lambertian cloudy AMF instead of geometric AMF
- Assumptions
  - Uniform NO_2 VMR in the sampling pressure ranges
  - No stratospheric variation in the sampling spatial/ temporal ranges (6^ox 8^o, calculated per orbit)
- Limitations
  - Represent cloudy conditions only
  - Magnitudes only as accurate as above-cloud NO_2 VCD
    - Uncertainties in SCD, cloudy AMF

Comparison with INTEX-B Data



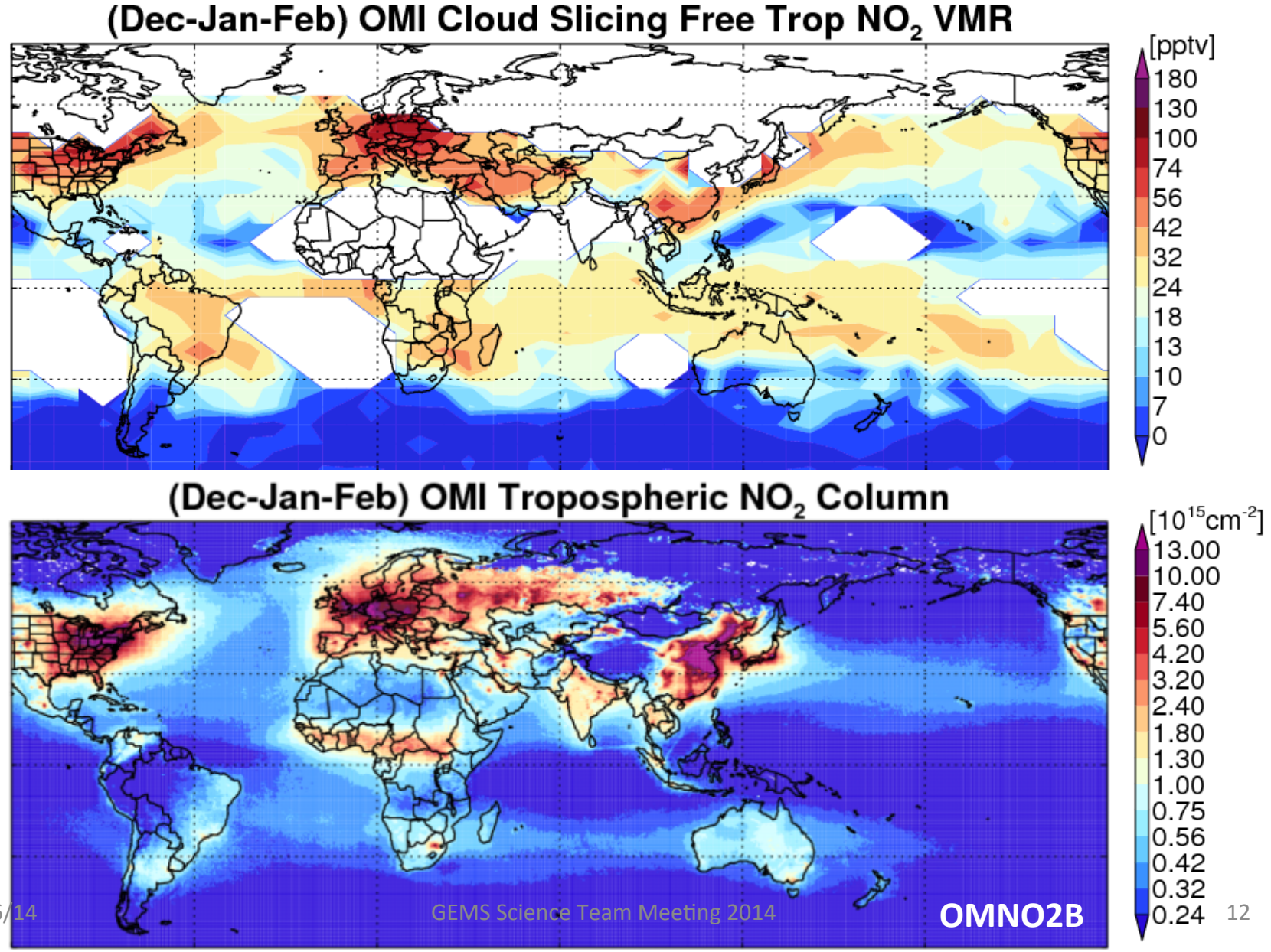


- INTEX-B VMR standard error < 5 pptv
- Similar magnitude but very weak correlation
- Reasonable agreement despite the intrinsic limits:
  - Poor collocation, small scale features, clear/cloudy conditions

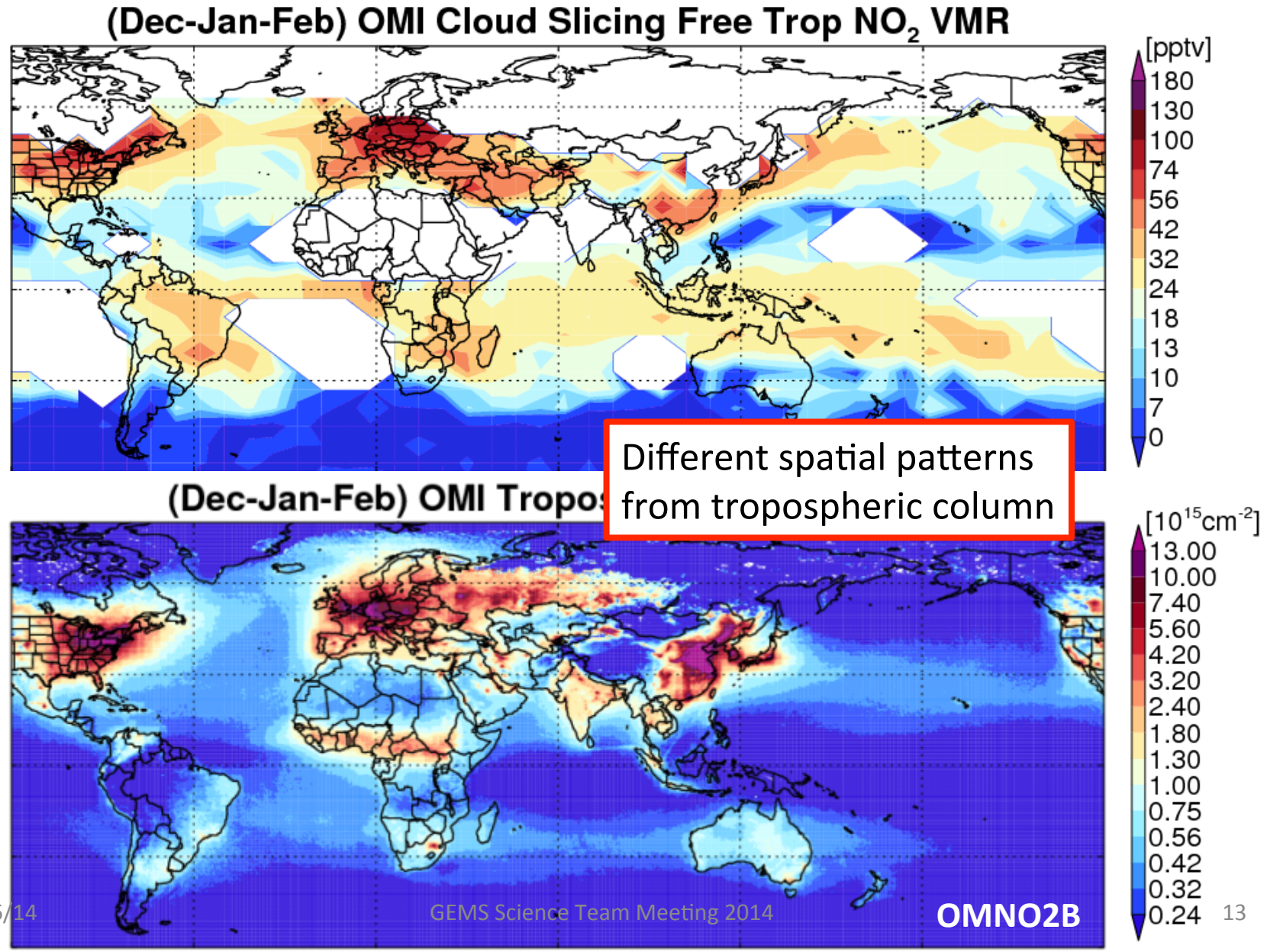
Global Seasonal Climatology

- Global seasonal free-tropospheric NO_2 climatology
  - Take advantage of high spatial/temporal coverage of satellite measurements
  - Concentrate on spatial and seasonal patterns
- Large volume of data required for reasonable results
  - 3-year OMI data accumulated (2005-2007)
  - Coarse resolution (6^o latitude x 8^o longitude)
- Distinct patterns in the free tropospheric VMR
  - Independent source of data to study free troposphere

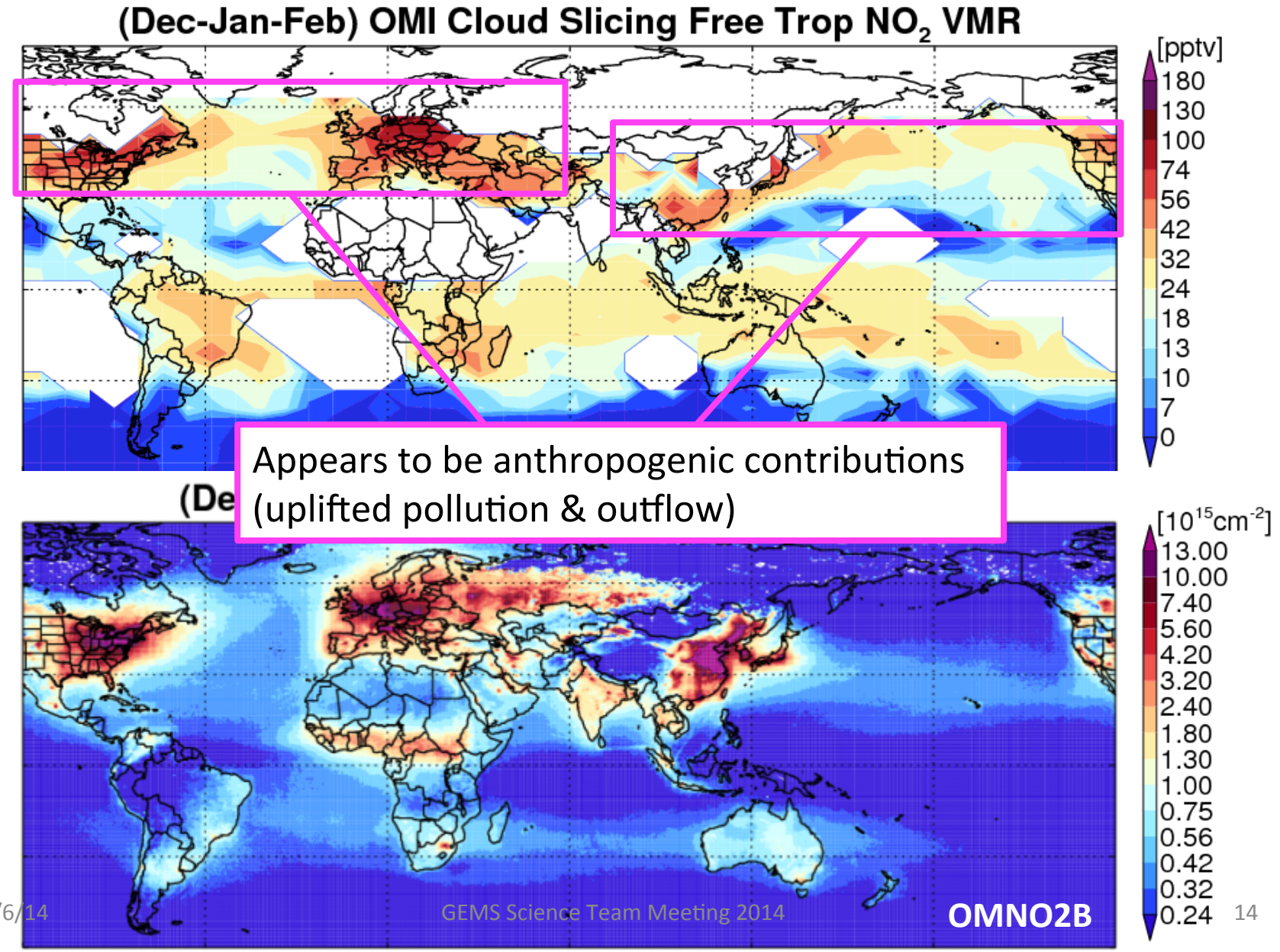
Global Seasonal Climatology



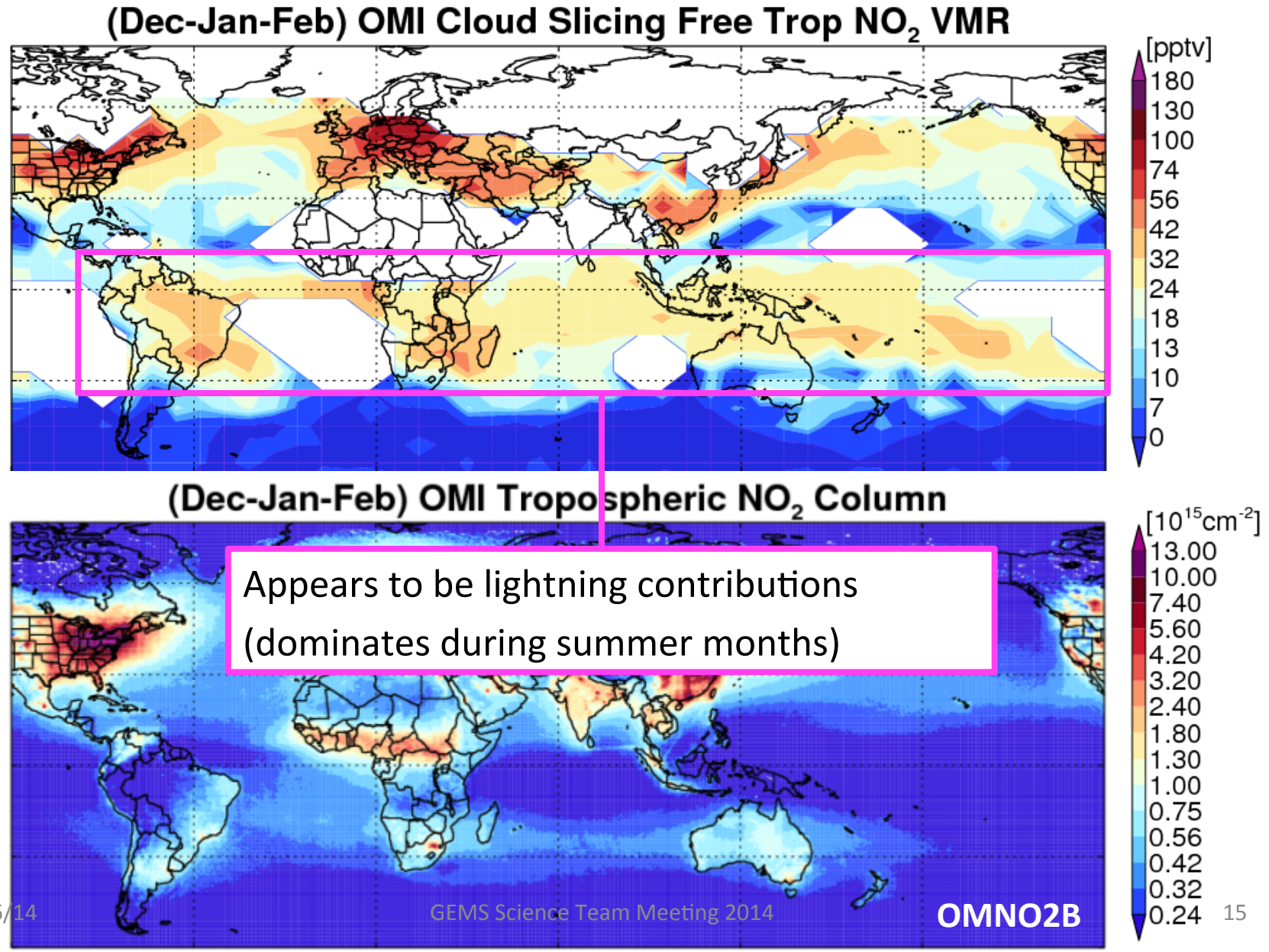
Global Seasonal Climatology



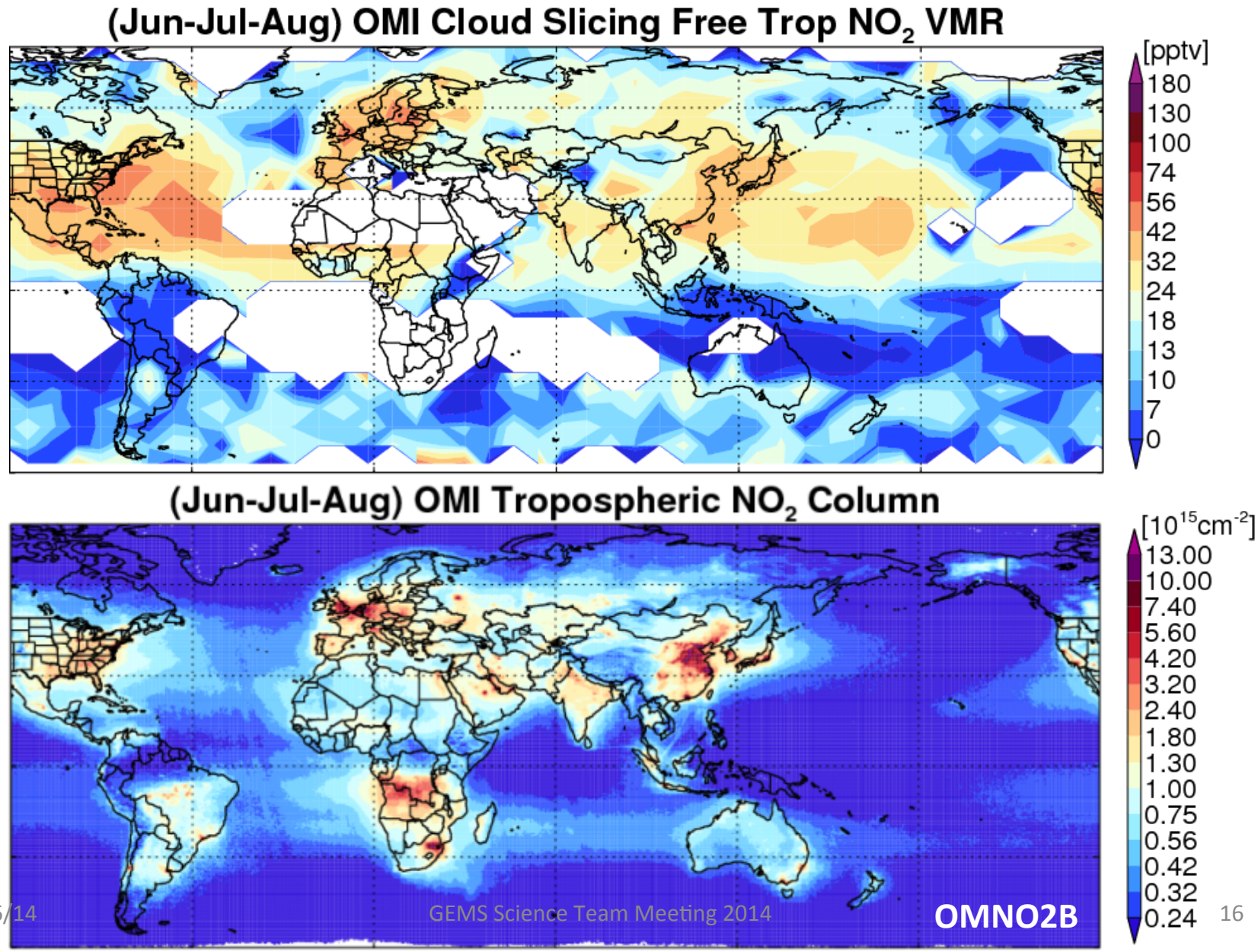
Global Seasonal Climatology



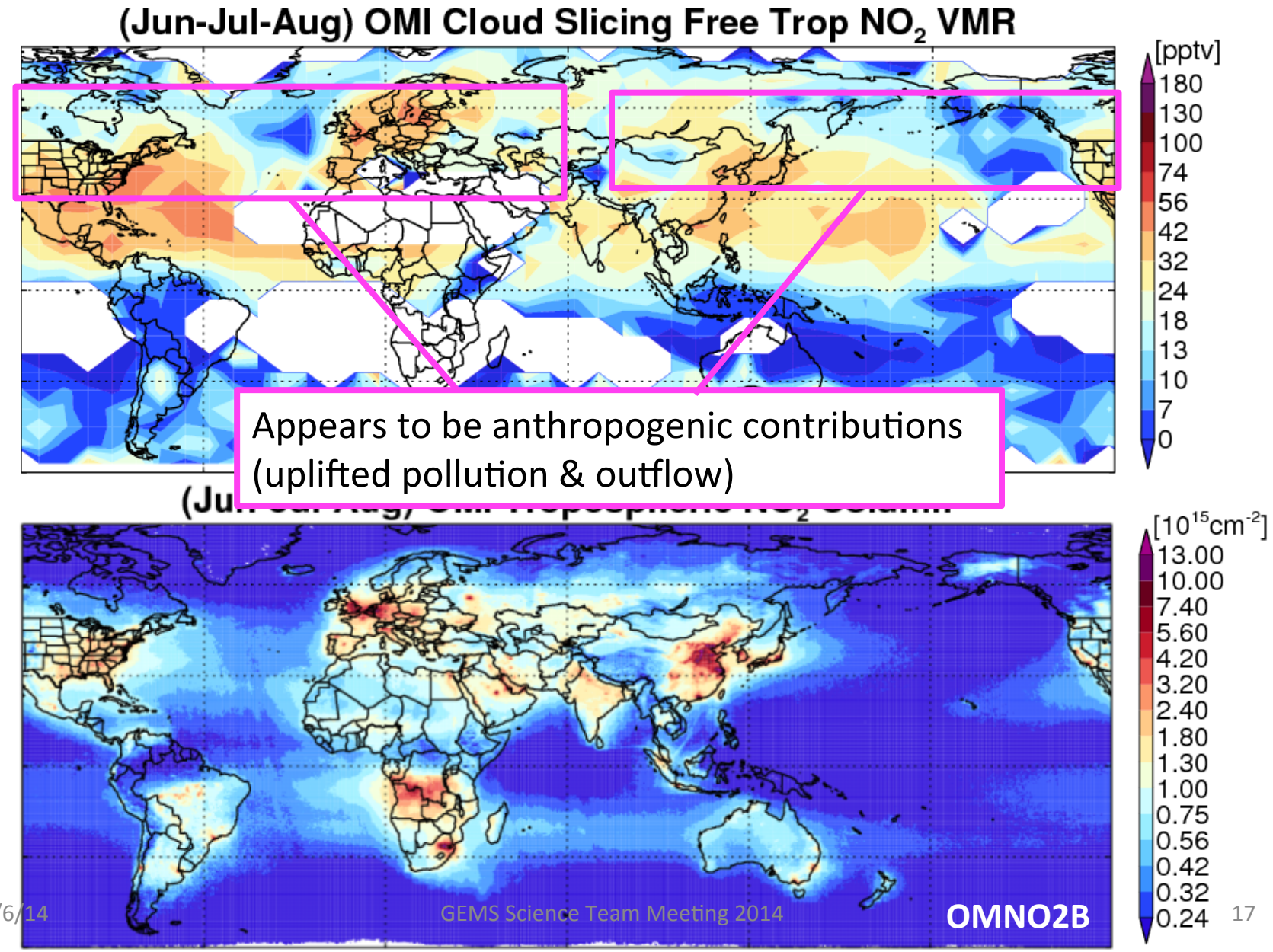
Global Seasonal Climatology



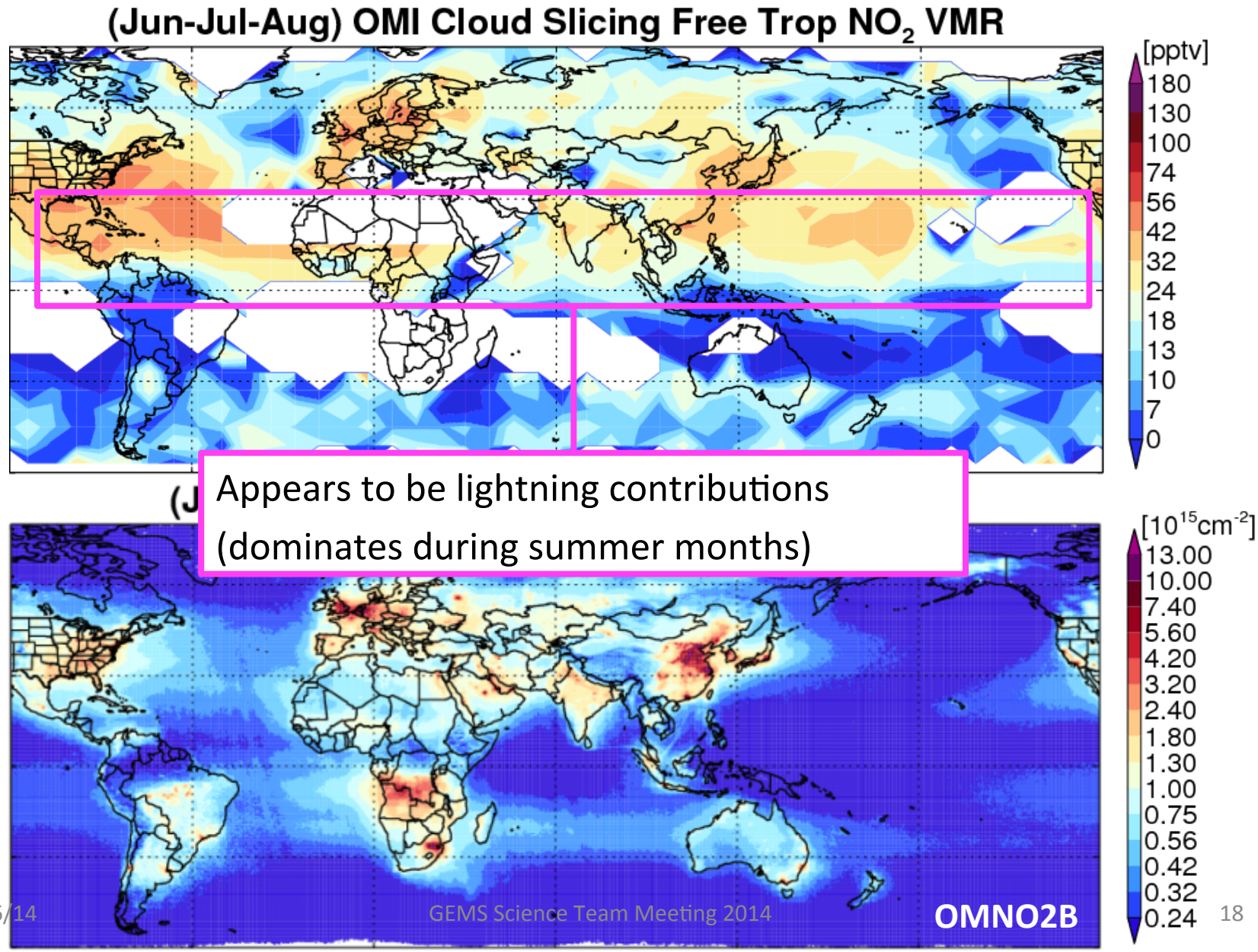
Global Seasonal Climatology



Global Seasonal Climatology



Global Seasonal Climatology

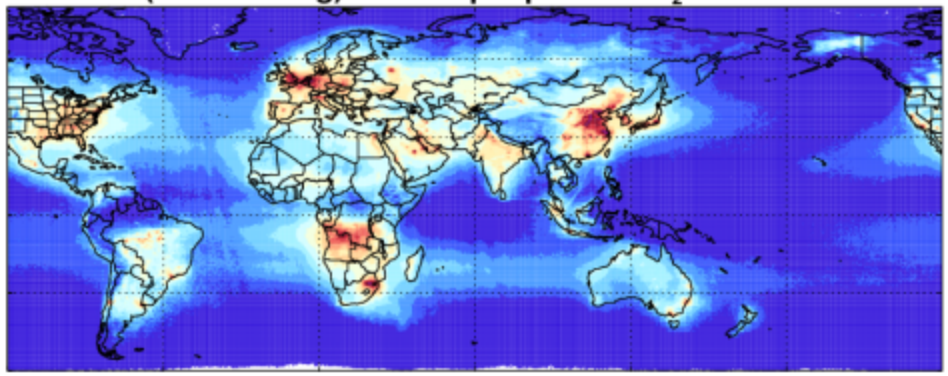


Tropospheric Column NO_2 (OMI vs GMI)

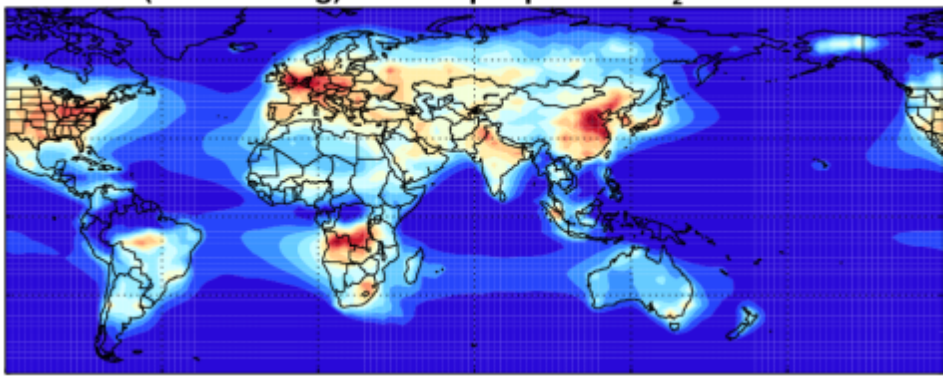
OMI

GMI

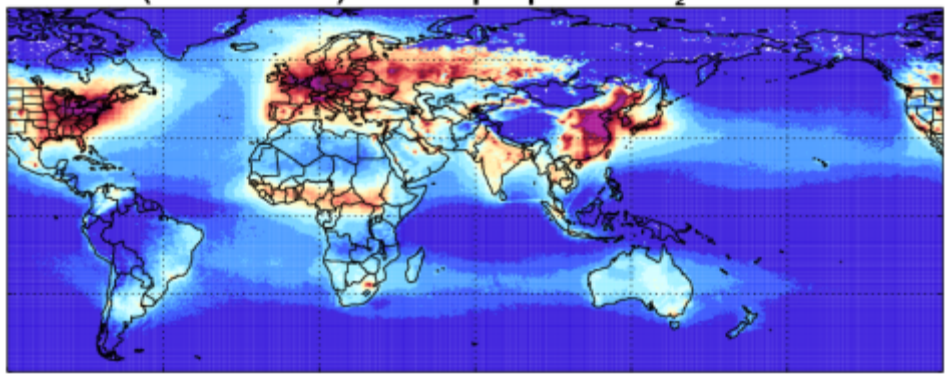
(Jun-Jul-Aug) OMI Tropospheric NO_2 Column



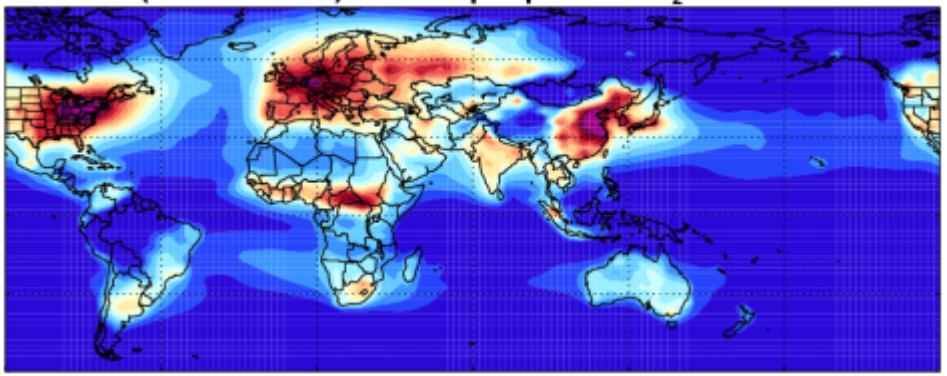
(Jun-Jul-Aug) GMI Tropospheric NO_2 Column



(Dec-Jan-Feb) OMI Tropospheric NO_2 Column



(Dec-Jan-Feb) GMI Tropospheric NO_2 Column

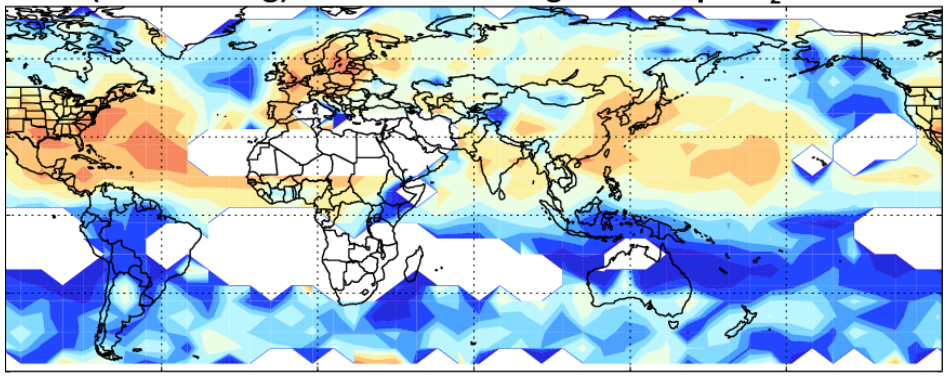


Free Trop. NO_2 VMR (OMI vs GMI)

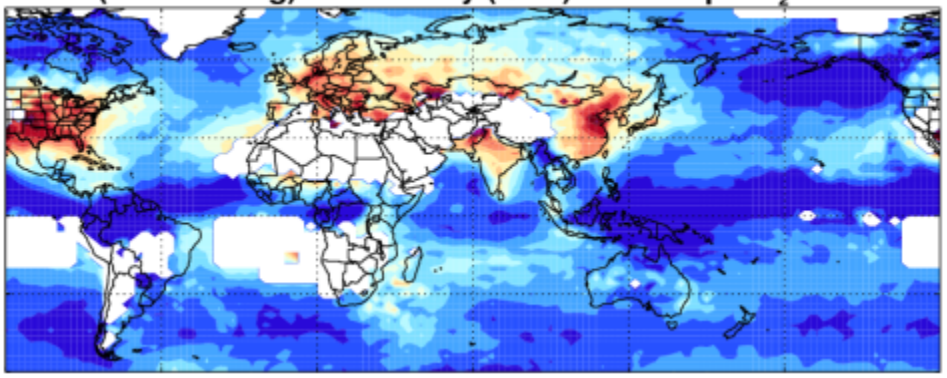
OMI

GMI

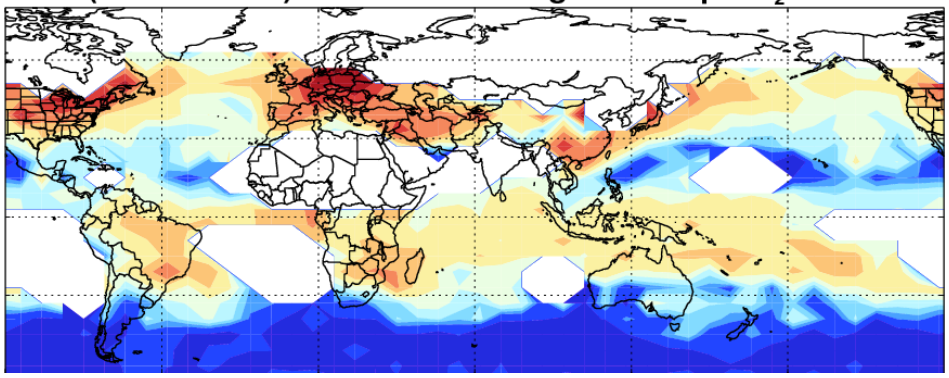
(Jun-Jul-Aug) OMI Cloud Slicing Free Trop NO_2 VMR



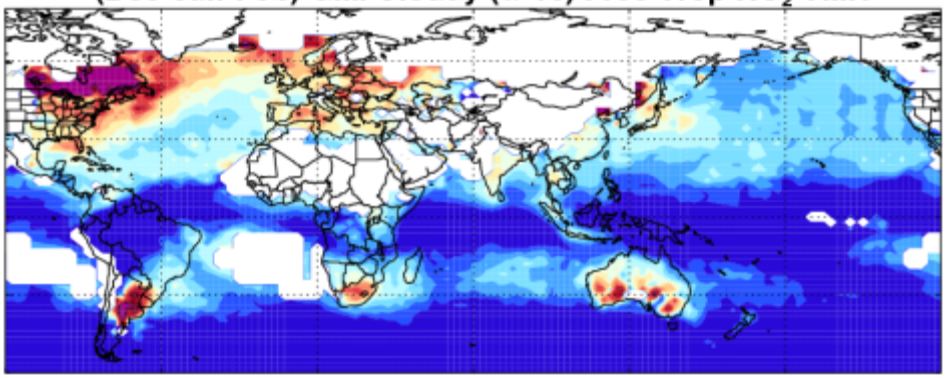
(Jun-Jul-Aug) GMI Cloudy (τ>10) Free Trop NO_2 VMR



(Dec-Jan-Feb) OMI Cloud Slicing Free Trop NO_2 VMR



(Dec-Jan-Feb) GMI Cloudy (τ>10) Free Trop NO_2 VMR

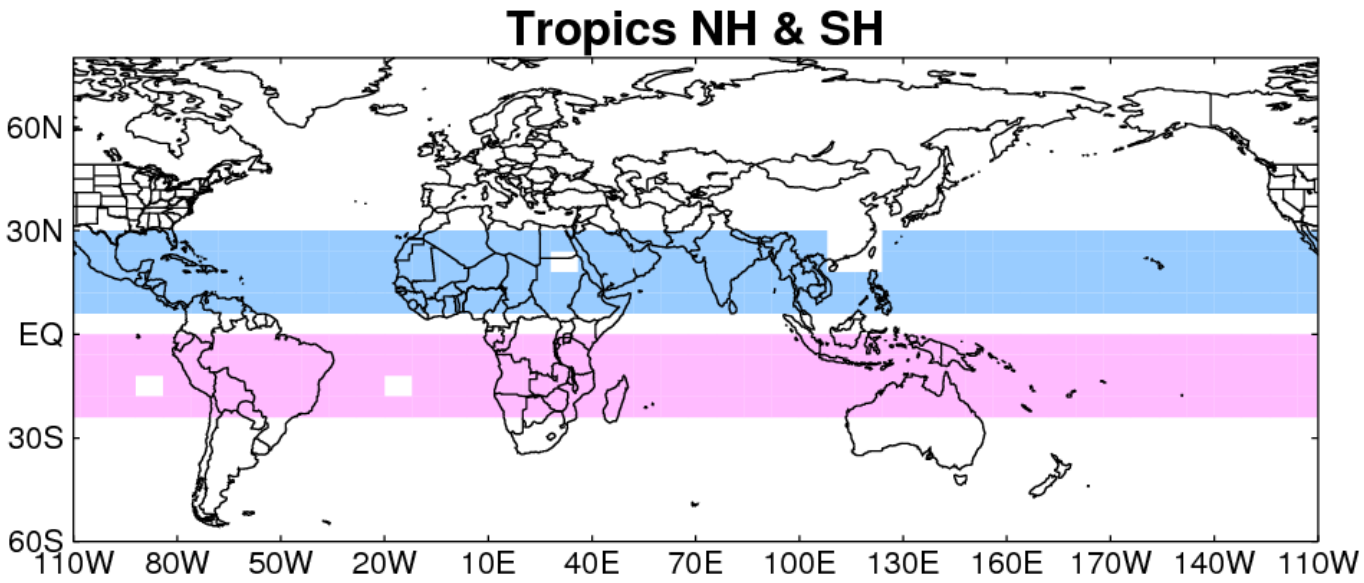


Collaboration with chemical transport models is anticipated

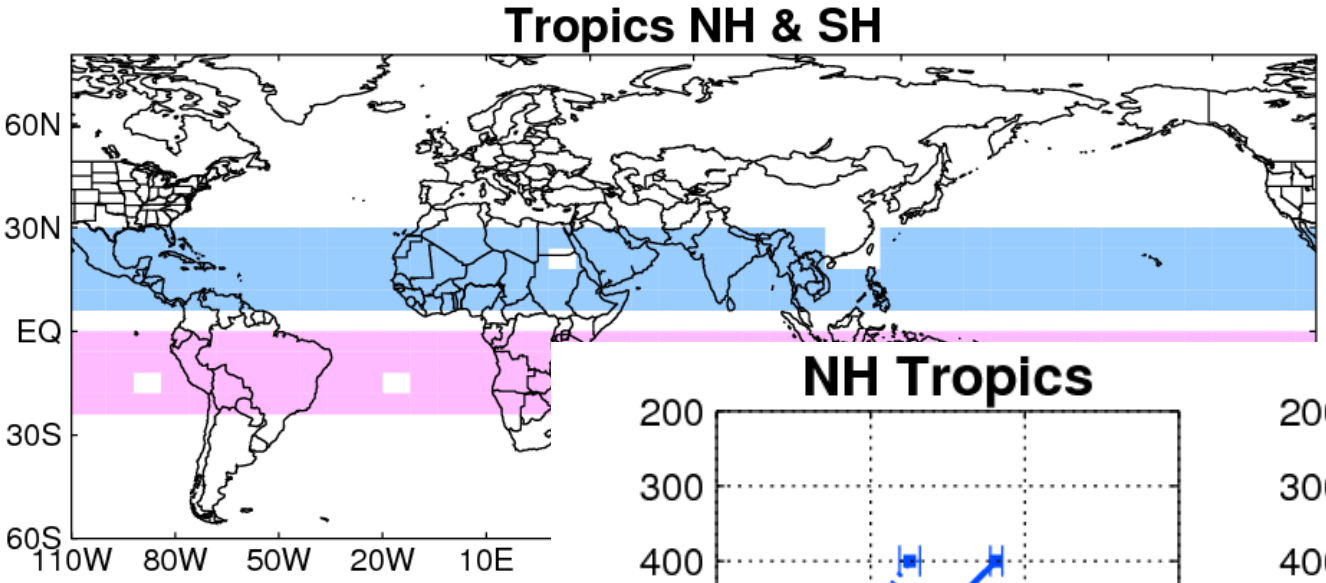
Profile Analysis

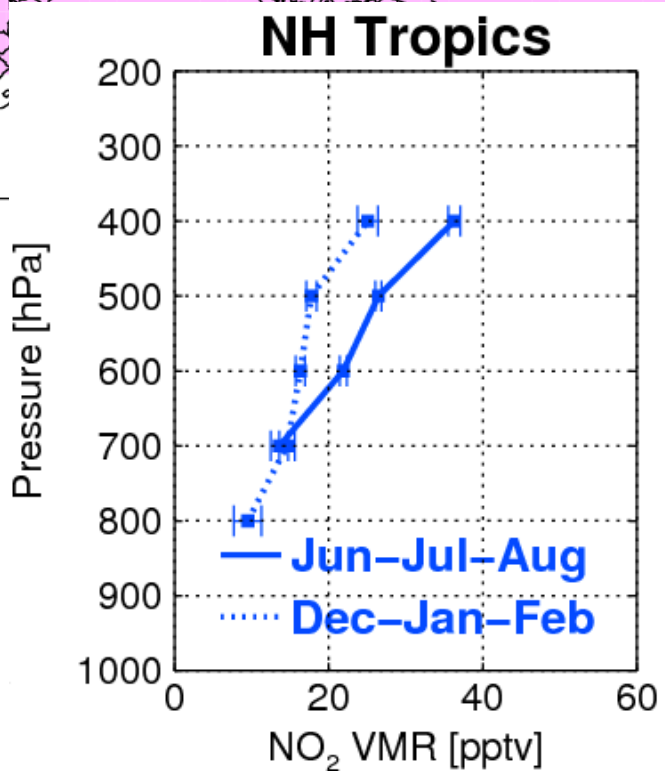
- Coarse profile analysis (~100 hPa resolution)
- Requires even more data with significant cloud pressure variability
- Example cases
  - Tropical oceans of NH and SH for lightning NO_2

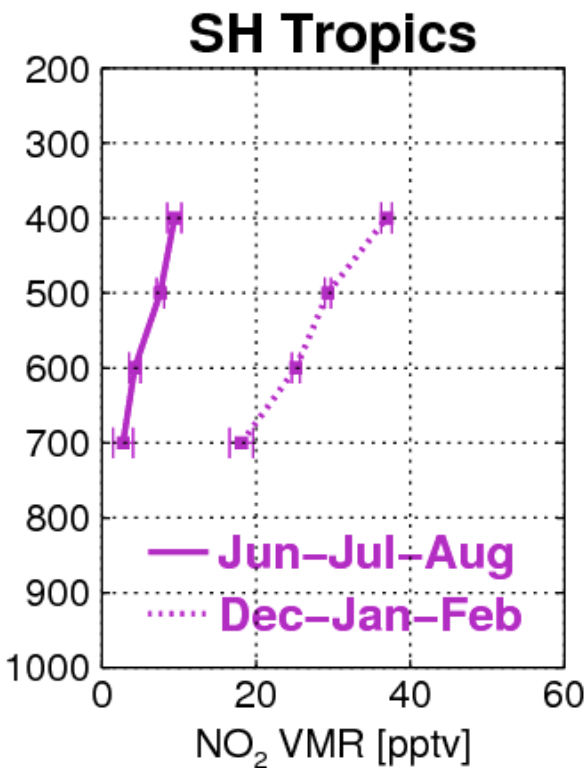
Profile Analysis



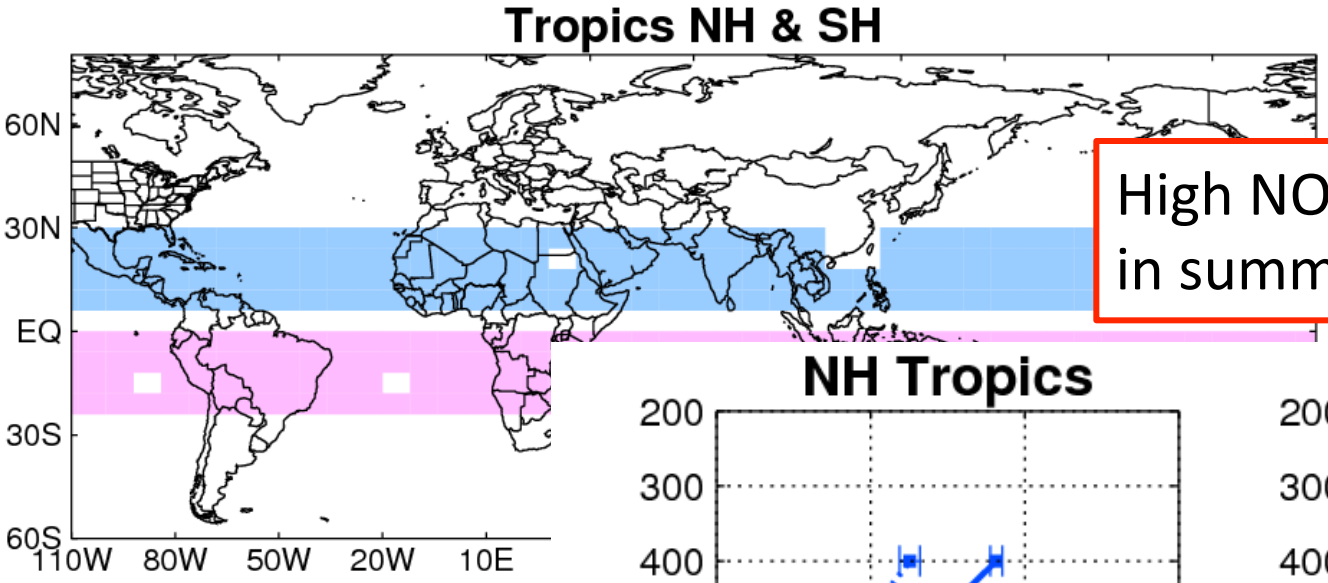
Profile Analysis



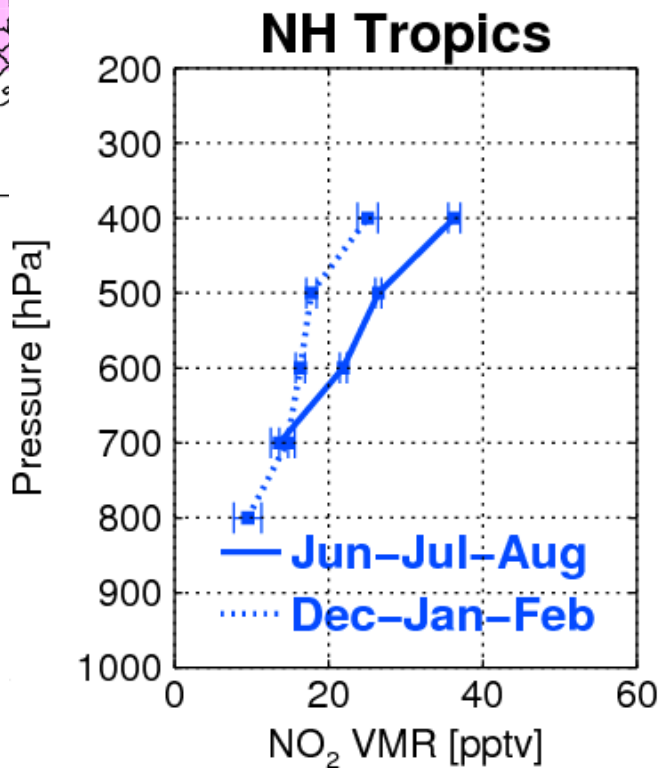


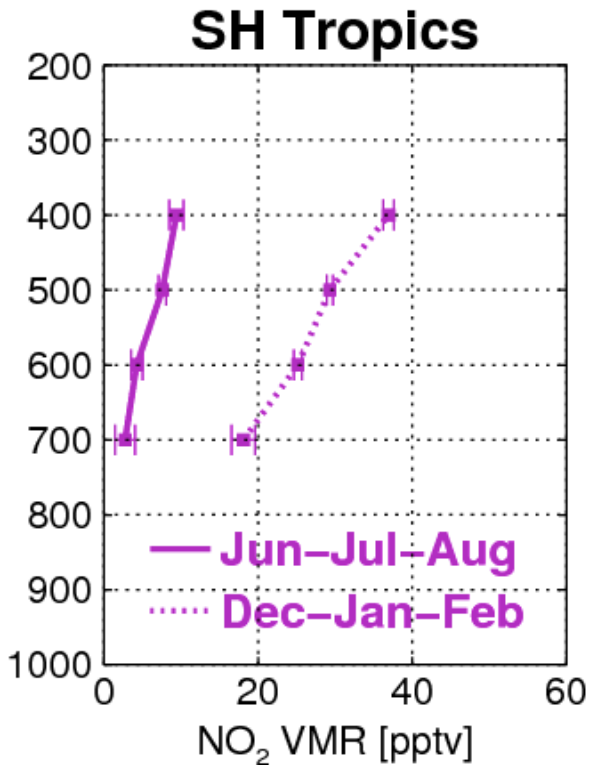


Profile Analysis



High NO_2 above 500 hPa in summer





Conclusions

- Free tropospheric NO_2 VMR derived using cloud slicing
- Comparison with INTEX-B measurements shows reasonable agreement
- Global seasonal climatology and profile analysis show anthropogenic and natural (lightning) distinct features of free tropospheric NO_2, independent of the tropospheric column
- Expect collaborations with various free tropospheric NO_2 measurements and models including geostationary missions (GEMS and TEMPO)

Thank you!

S. Choi et al.: First Estimates of Global Free-tropospheric NO_2 Abundances Derived using a Cloud Slicing Technique from Aura OMI, *Atmos. Chem. Phys.*, *accepted*

Backup slides

Detail/Data Screening Criteria

- Use slant column density (OMNO2A) and geometric AMF

- Cloud radiance fraction > 0.9
- Aerosol index < 1.0
- No snow/ice surface
- Solar zenith angle < 80 degree
- Gradient of NO2 VMR < 0.33 pptv / hpa (profiles from GMI model or INTEX-B measurements)

Example of Calculated NO_2 Climatology