NO_2 Stratosphere-Troposphere Separation Estimated from UV and Visible Retrievals

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GeoXO ACX NO_2 Algorithm Development

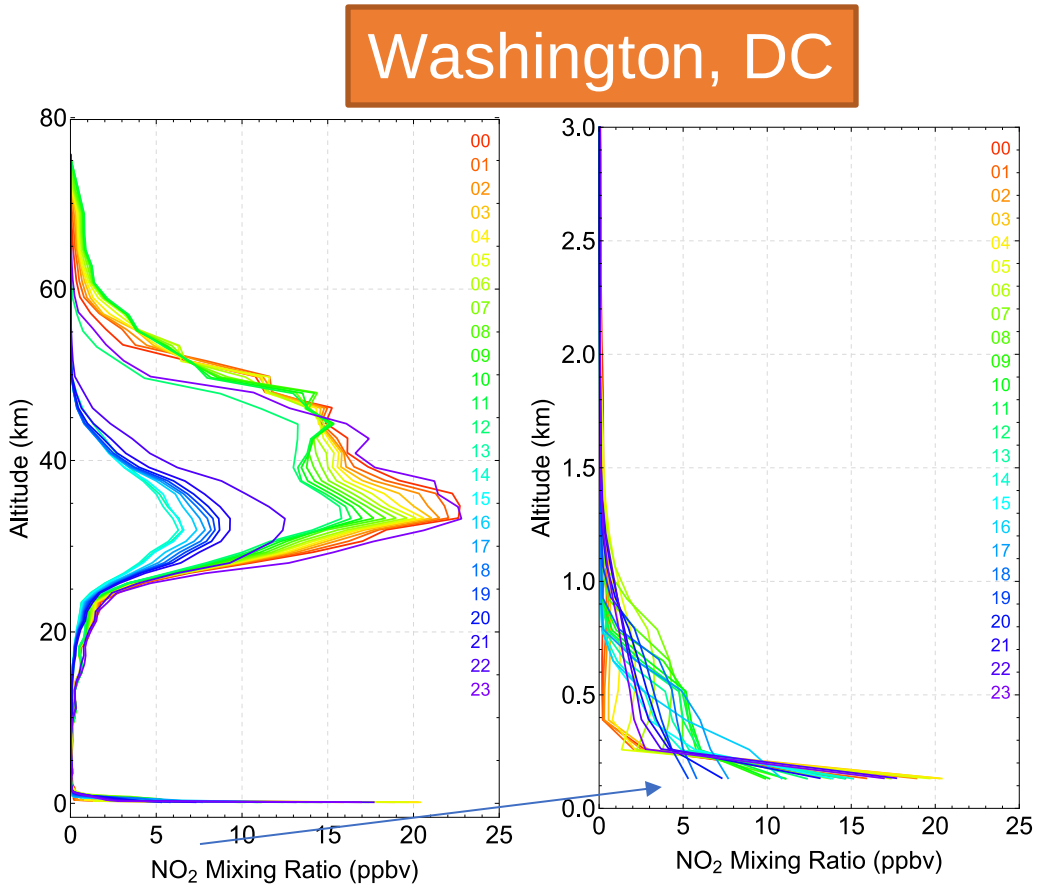
- We are developing an advanced NO_2 algorithm for GeoXO ACX processing and demonstrating its accuracy using proxy data.
- We plan to make a series of algorithm advancements, from correcting imperfections in spectral measurements to enhancing algorithmic physics:
  - Perfecting techniques to correct spectral measurements
    - wavelength registrations
    - instrument spectral responses
    - anomalous pixels
    - calibration biases
    - common mode spectra
  - Accurate algorithm physics implementation
    - Stratosphere-troposphere separation (STS)
    - Surface reflection (inclusion of BRDF)
    - Explicit treatment of aerosols

Proxy Data

Review of STS

STS Schemes

1. Estimated from stratospheric NO_2 columns over regions with negligible tropospheric NO_2 columns (e.g., reference sectors, STREAM, Geddes et al., 2018, …)
2. Stratospheric NO_2 fields from chemical transport models (CTMs) (e.g., GEOS-CF, TM5, CAMS, ….)



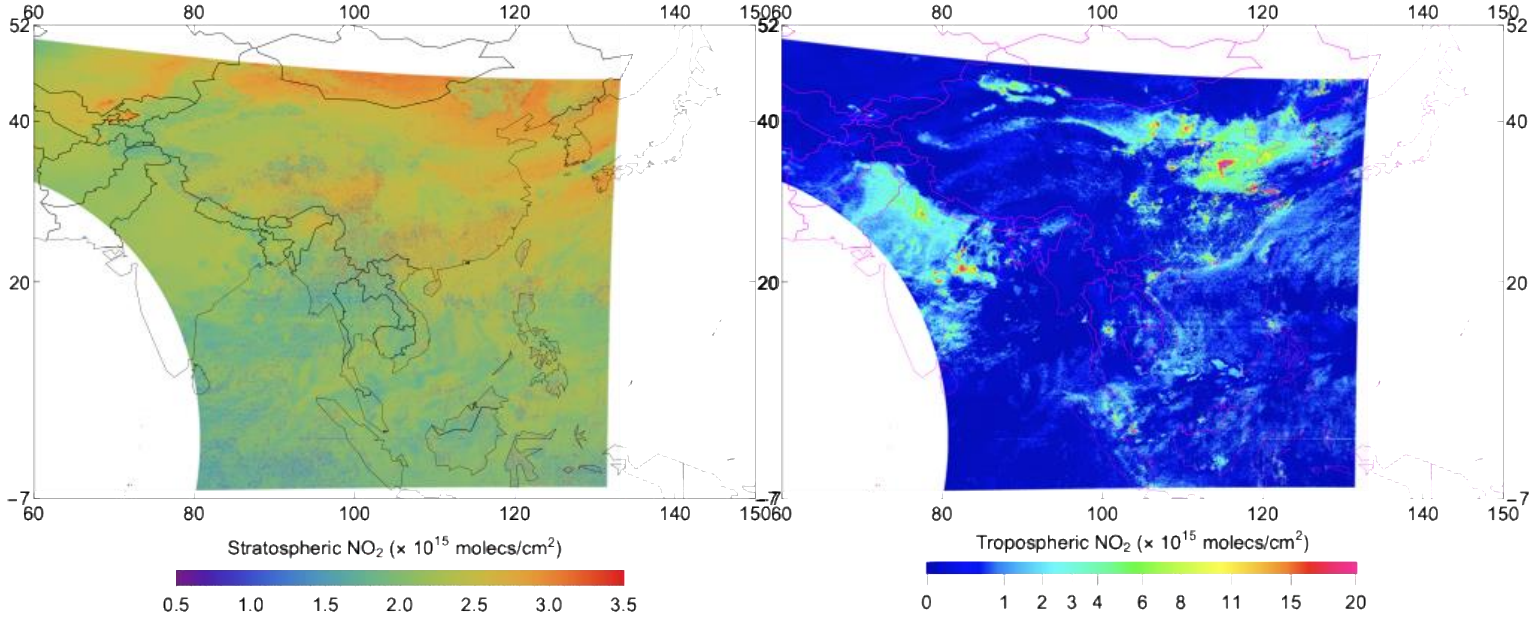
Diurnal variations of NO_2 profiles
2023-01-01, GEOS-CF

Stratosphere-Troposphere Separation (STS)

Deficiencies

1. Small-scale variations in stratospheric NO_2 fields; insufficient nearby clean regions
2. Biases often exist in the stratospheric NO_2 fields from CTMs and satellite retrievals.

ACX NO_2 Algorithm on GEMS 2023-03-30_0045



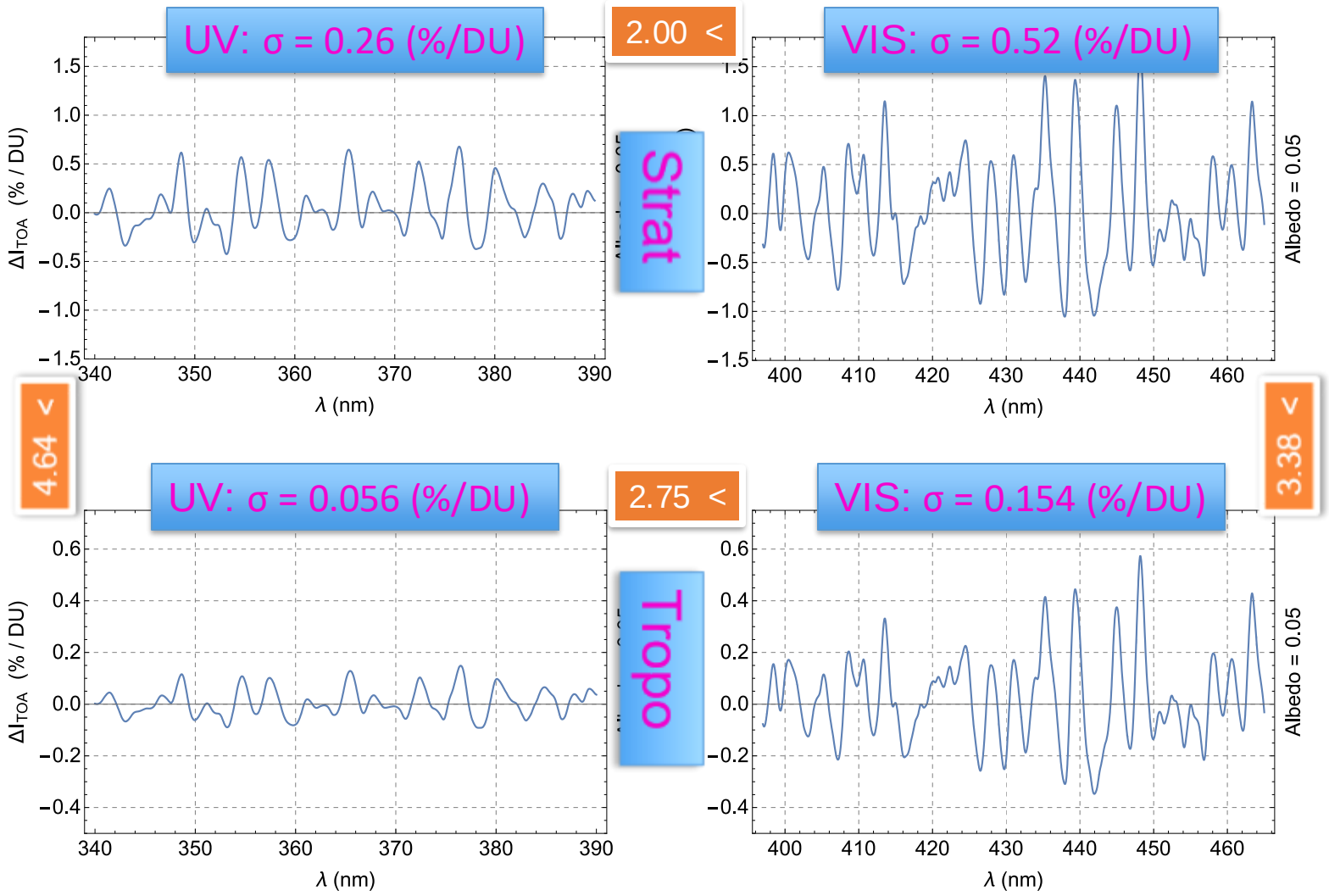
Stratospheric NO_2

Tropospheric NO_2

Theoretical Basis for NO_2 STS from Joint UV-VIS Retrievals

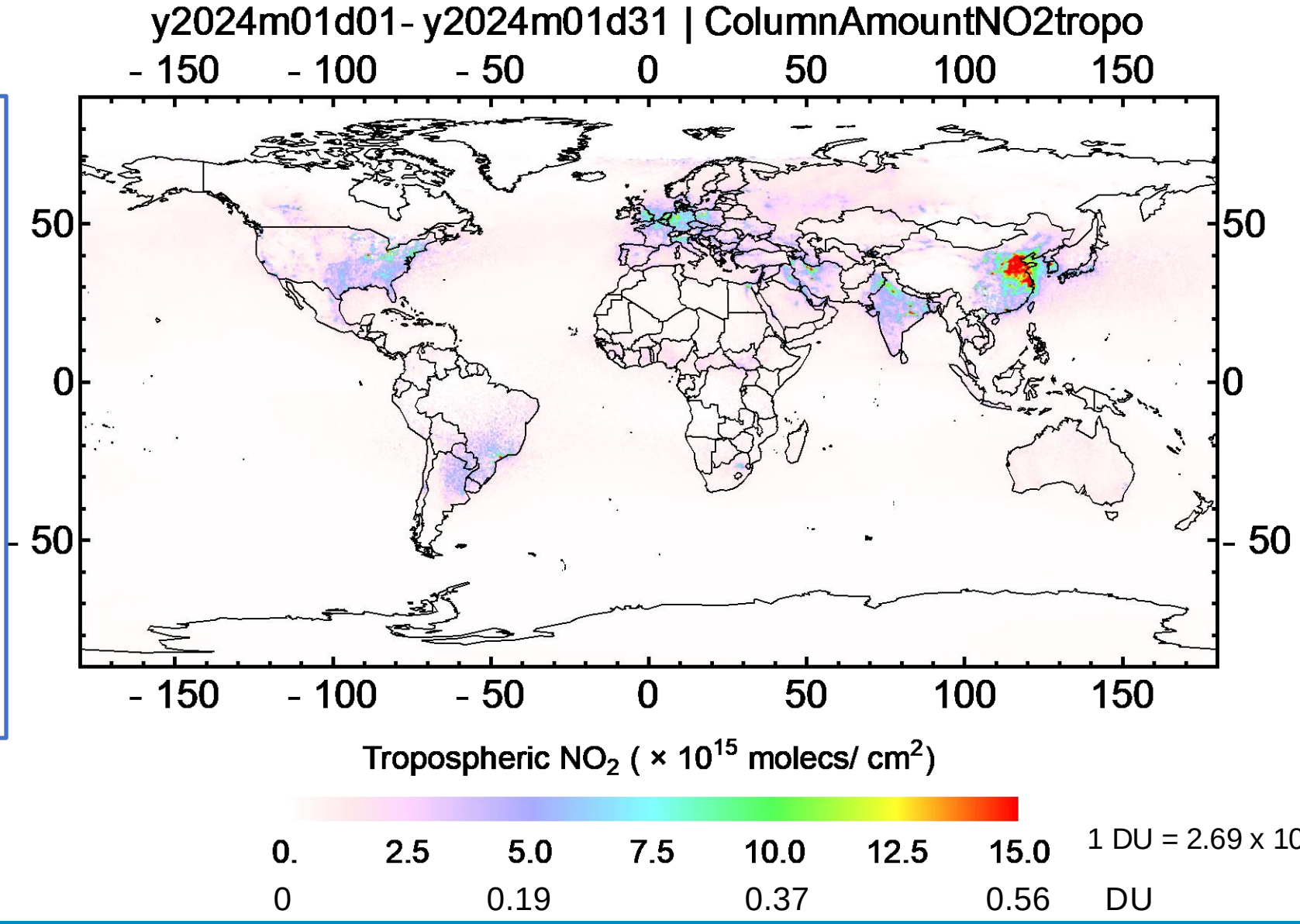
NO_2 Measurement Sensitivity:

1. VIS and UV more sensitive to strat NO_2 than tropo NO_2
2. UV strat NO_2 sensitivity is 4.6 times that of tropo NO_2 (low reflectivity scenes)
3. UV provide closer estimates of strat NO_2
4. VIS slant NO_2 >= UV slant NO_2 (low reflectivity scenes)



Tropospheric NO_2 from UV (NOAA-20 OMPS)

Monthly means of January 2024 show significant enhancements of NO_2 over major industrial and densely populated areas. This result illustrates the OMPS's capability in capturing spatial-temporal variations of tropospheric NO_2 accurately, therefore its usefulness for various applications.



Joint UV-Vis Retrieval to Separate Stratospheric and Tropospheric NO_2 Columns

S	Slant Column
V	Vertical Column
AMF	Air Mass Factor
u	UV
v	VIS
s	stratosphere
t	troposphere

Slant Column Equations for UV and VIS

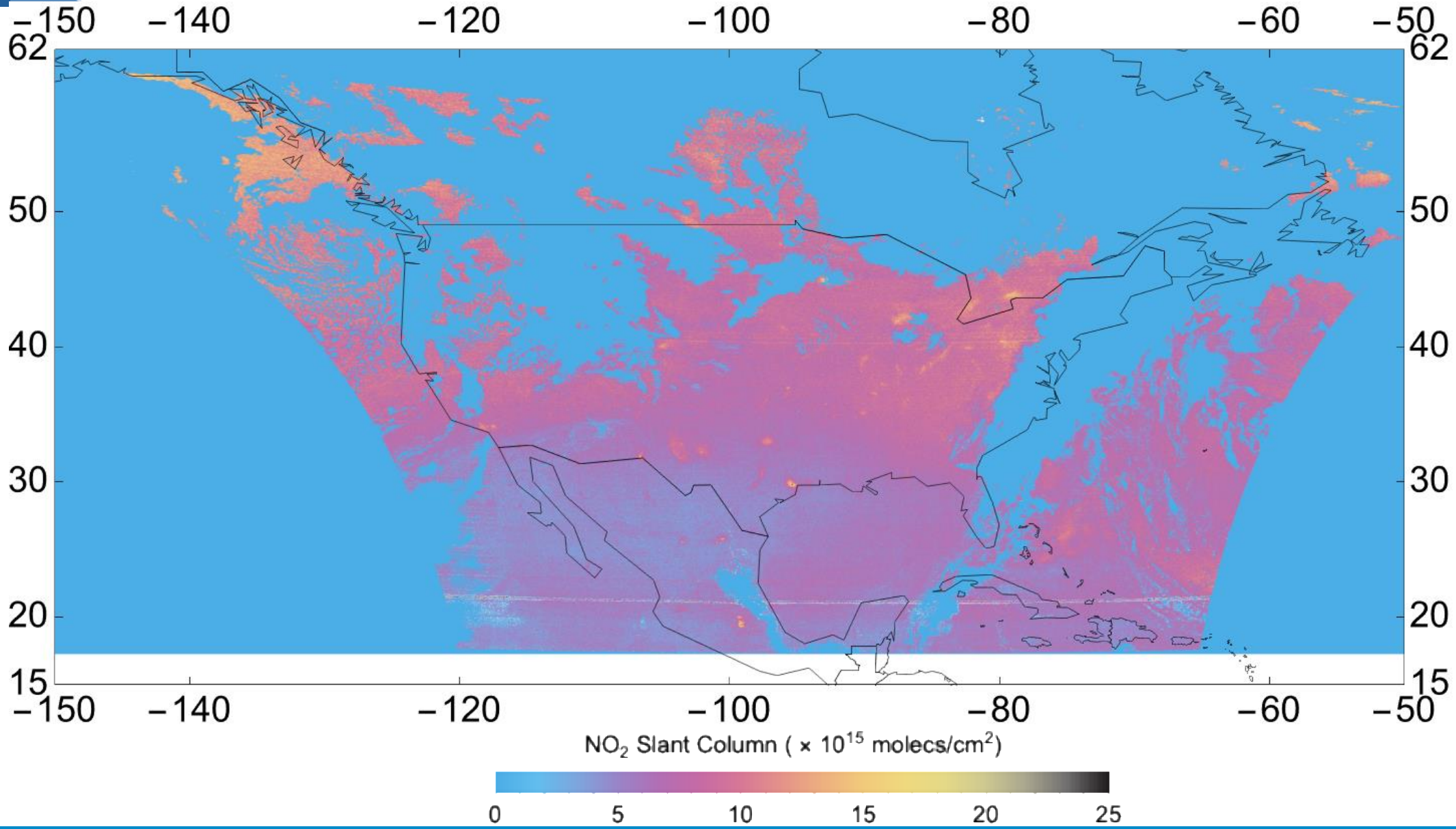
$$S_u = V_s\ \mathrm{AMF}_u^s + V_t\ \mathrm{AMF}_u^t$$

$$S_v = V_s\ \mathrm{AMF}_v^s + V_t\ \mathrm{AMF}_v^t$$

$$V_t = \frac{S_v\ \mathrm{AMF}_u^s - S_u\ \mathrm{AMF}_v^s}{\mathrm{AMF}_u^s\ \mathrm{AMF}_v^t - \mathrm{AMF}_v^s\ \mathrm{AMF}_u^t} = \frac{S_v\ - S_u}{\mathrm{AMF}_v^t - \mathrm{AMF}_u^t}$$

$$V_s = \frac{S_v\ \mathrm{AMF}_u^t - S_u\ \mathrm{AMF}_v^t}{\mathrm{AMF}_v^s\ \mathrm{AMF}_u^t - \mathrm{AMF}_u^s\ \mathrm{AMF}_v^t}$$

NO_2 Slant Column from TEMPO UV



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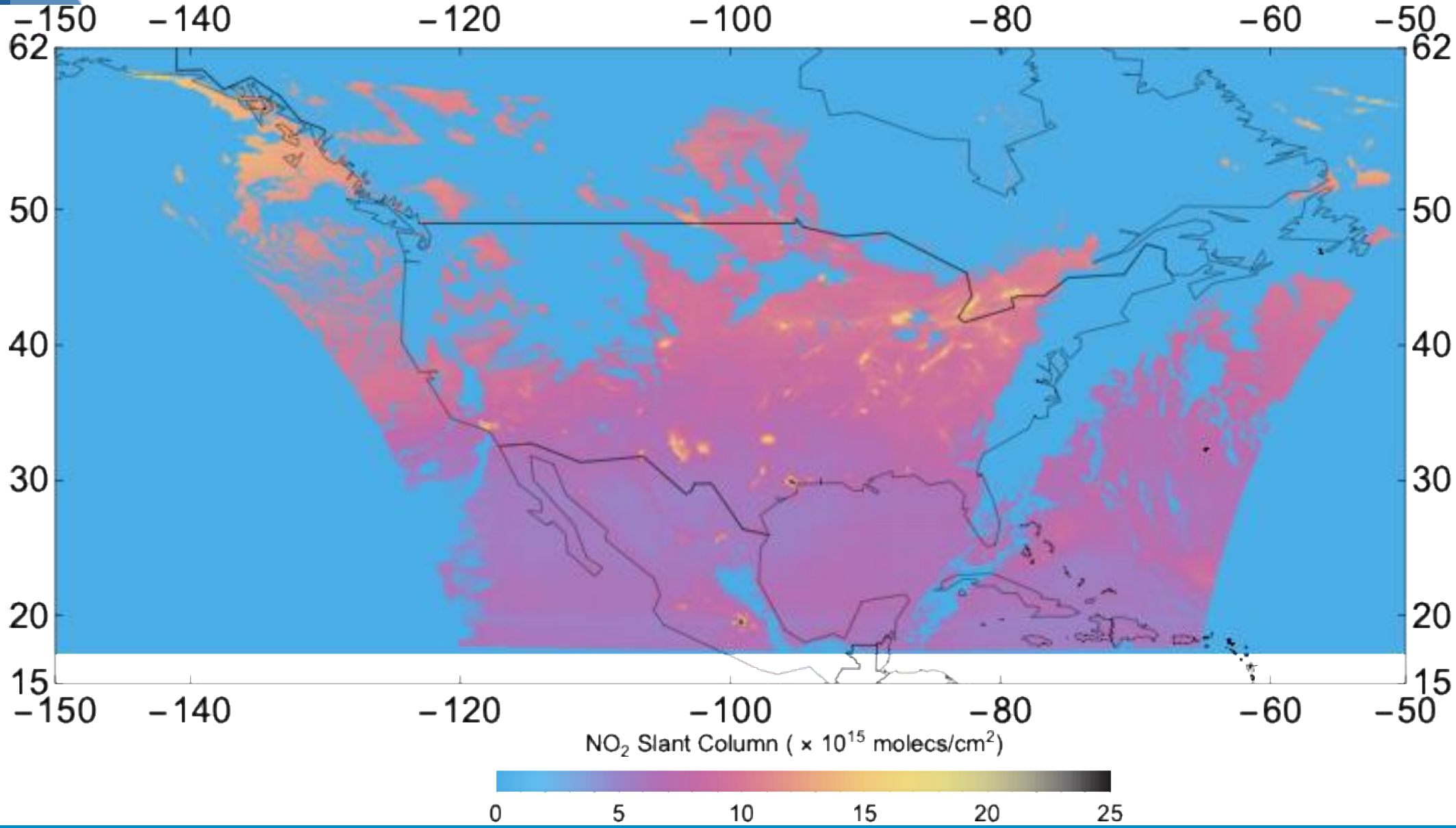
NO_2 Slant Column from TEMPO VIS



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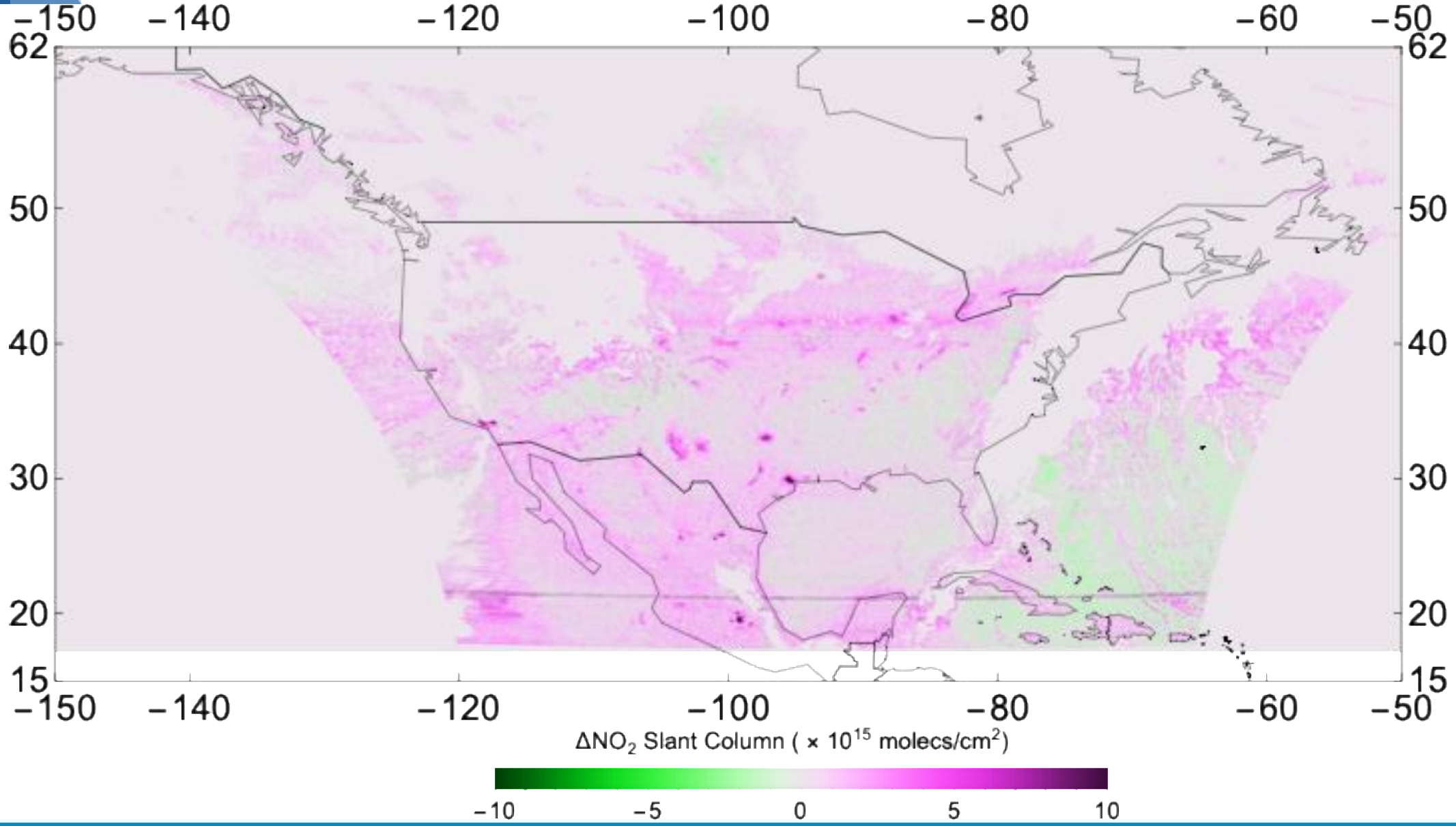
NO_2 Slant Column Difference (VIS – UV)



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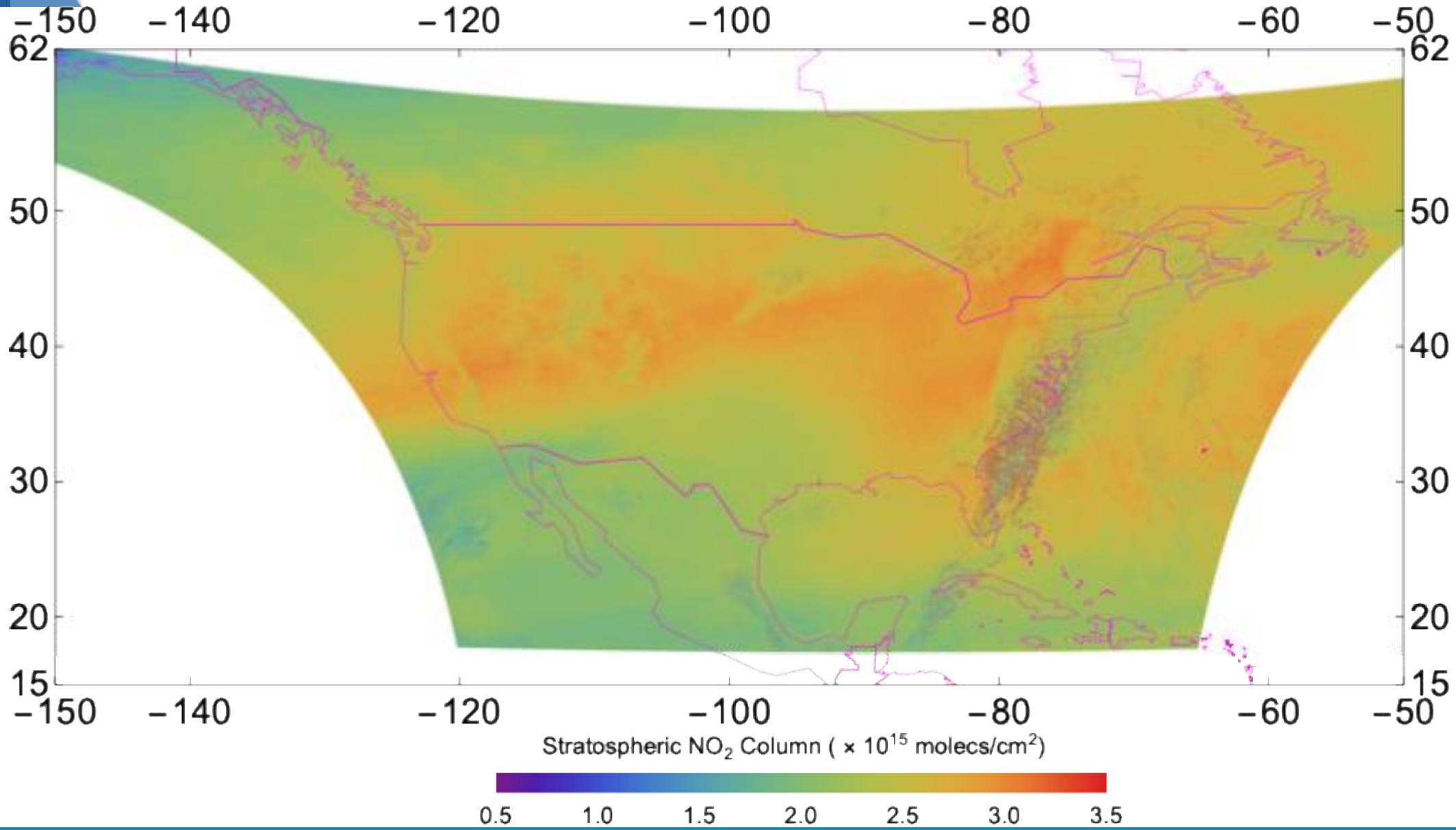
NO_2 Stratospheric Column from TEMPO



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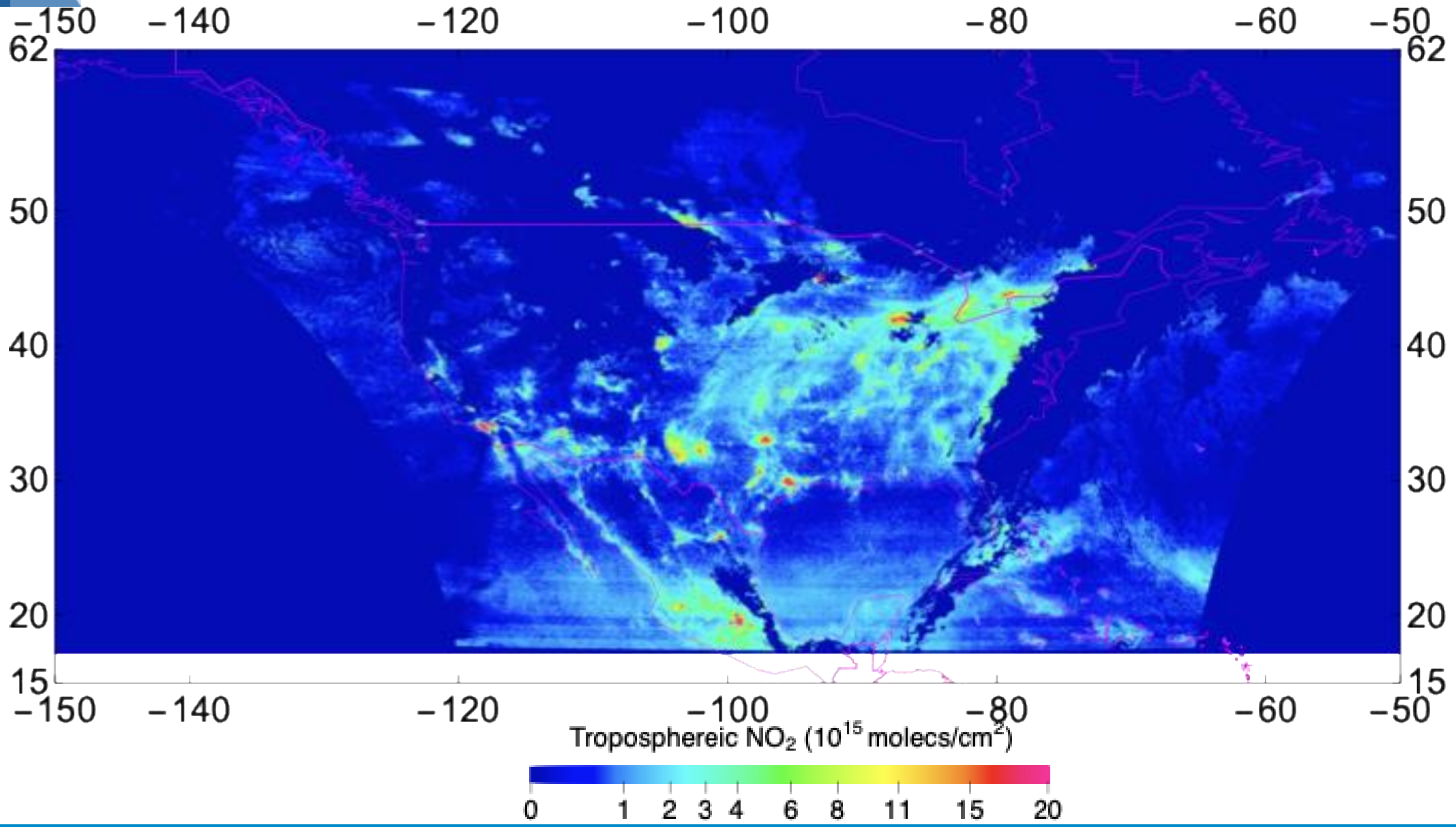
NO_2 Tropospheric Column from TEMPO



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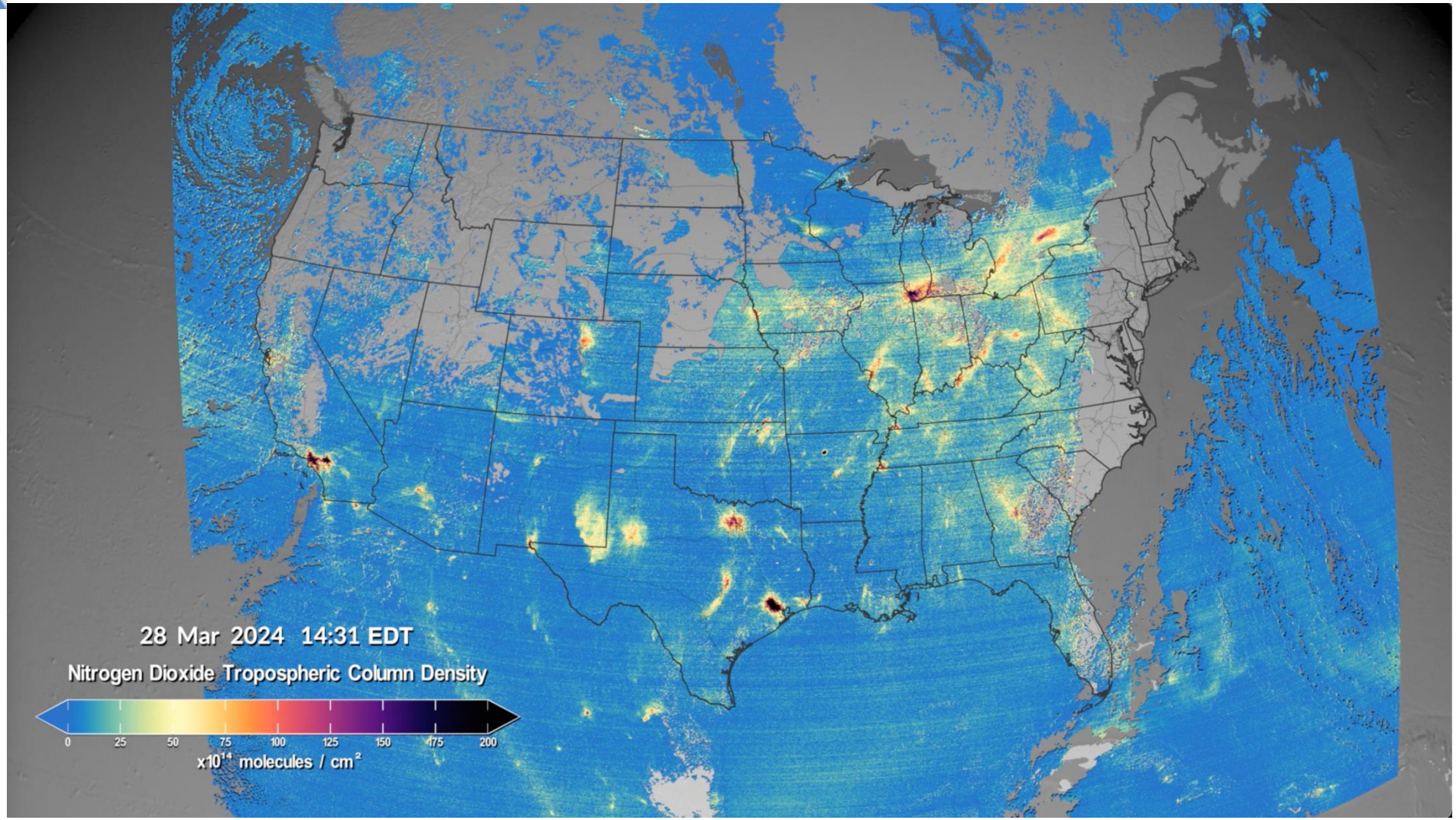
Comparisons with TEMPO Standard NO_2 Product



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Screenshot of https://svs.gsfc.nasa.gov/5303/

Summary

- We describe the theoretical basis of the STS scheme based on joint UV and Vis retrievals. We construct the STS equation and provide the solution based on the DOAS approach.
- This new STS scheme is successfully demonstrated with TEMPO observations, showing stratospheric NO_2 can be estimated without relying on the traditional STS scheme based on CTMs simulation or interpolation from clean regions.
- This is quite robust scheme, insensitive to calibration biases. However, it requires well characterized UV and Vis measurements to achieve consistent quantification NO_2 slant columns in UV and Vis.
- The likely deficiency is the relative NO_2 biases between UV and Vis, due to different spectral bands are affected by spectral interferences differently.
- The tropospheric NO_2 enhancements agree well with the standard TEMPO product.