Vertical profiles of global tropospheric nitrogen dioxide (NO_2) obtained via cloud-slicing TROPOMI partial columns

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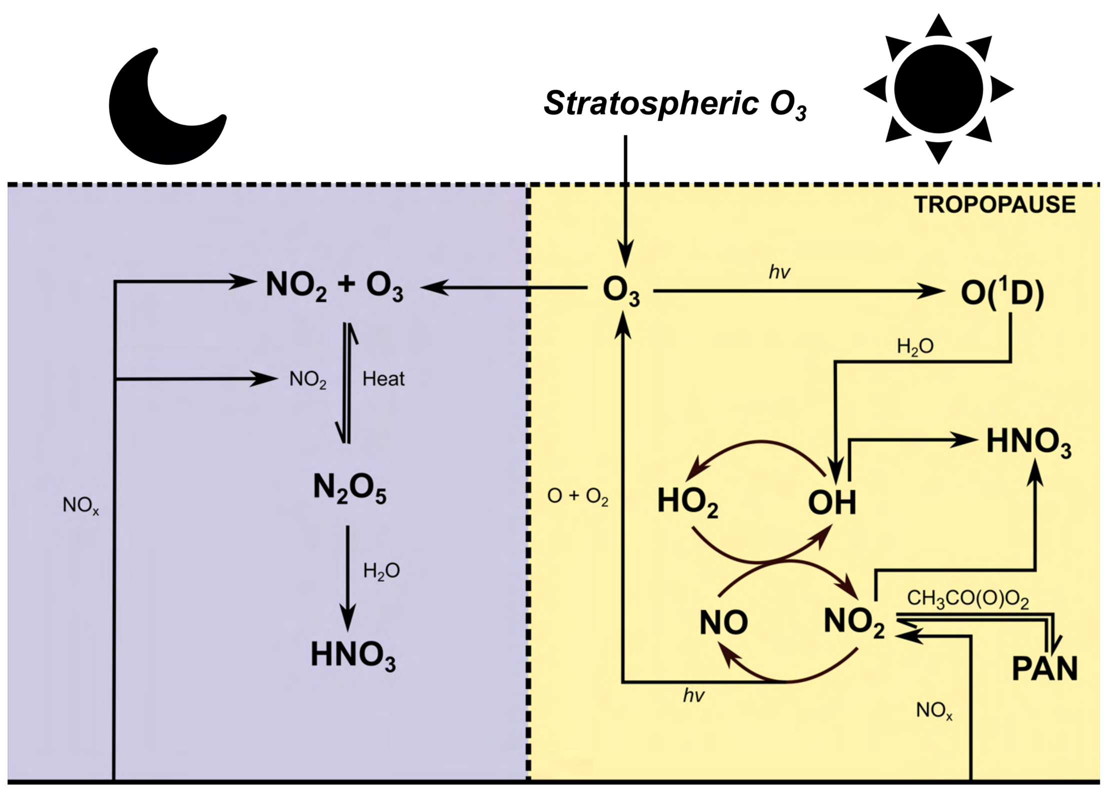
Major Finding: Cloud-slicing of TROPOMI NO_2 performs well globally between 320-800 hPa when compared to NASA DC-8 aircraft observations and GEOS-Chem underestimates by ~60% in this region of the troposphere.

1. Motivation

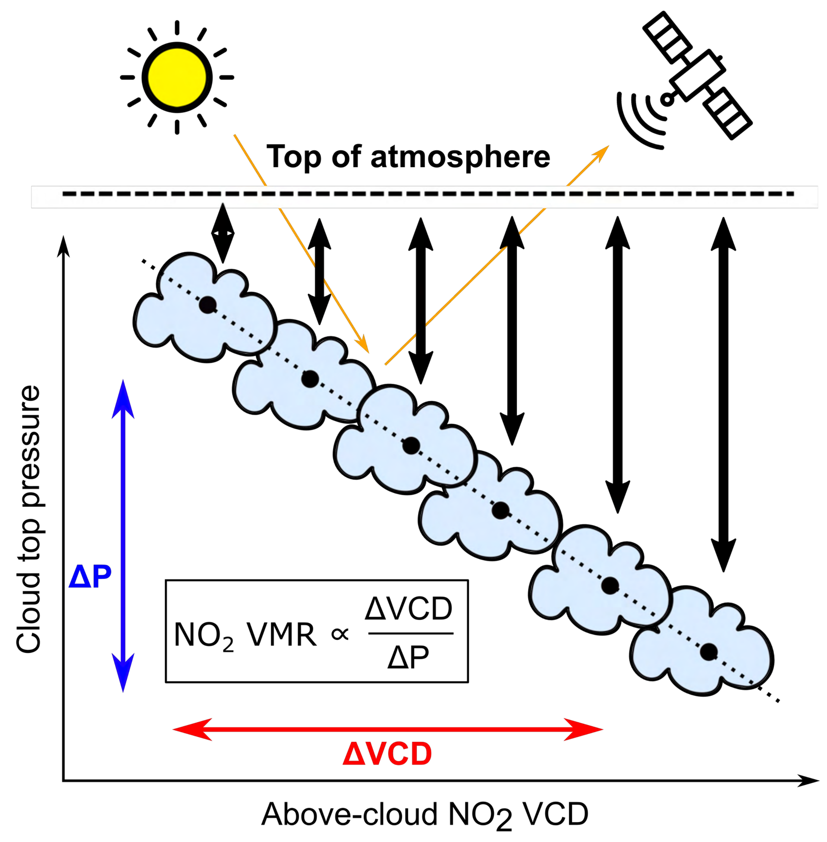
Cycle of NO_x in the troposphere during the day and at night



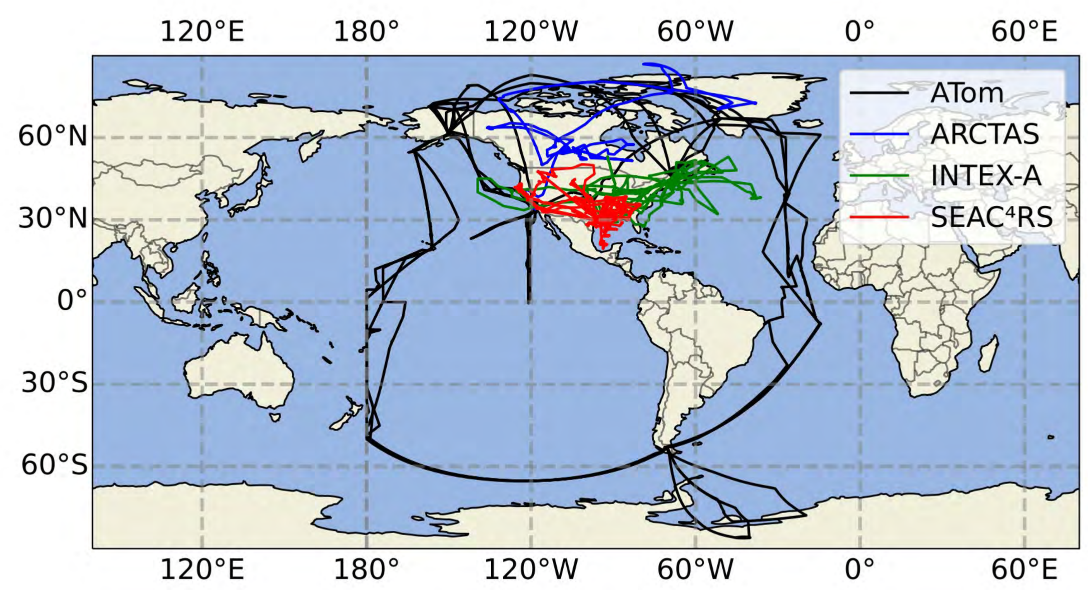
- Nitrogen oxides ($NO_x \equiv NO + NO_2$) are strongly linked to the formation of ozone (O_3) in the NO_x-limited regions of the troposphere.
- O_3 is a key contributor to the oxidation state of the atmosphere and maintaining the oxidation capacity of the troposphere.
- Well-mixed greenhouse gases have been responsible for a radiative forcing of 2.45 W/m² and O_3 is responsible for 26% of this.

2. The cloud-slicing technique

- The cloud-slicing technique was first used to derive upper tropospheric ozone measurements from the TOMS satellite instrument[1].
- This takes advantage of the optically thick clouds present in the troposphere.
- The NO_2 volume mixing ratio (VMR) is calculated using the relationship between the cloud top pressure and the vertical column density (VCD).
- This technique allows us to eliminate the contribution of the stratosphere.



3. NASA DC-8 aircraft campaigns



INTEX-A - Summer 2004

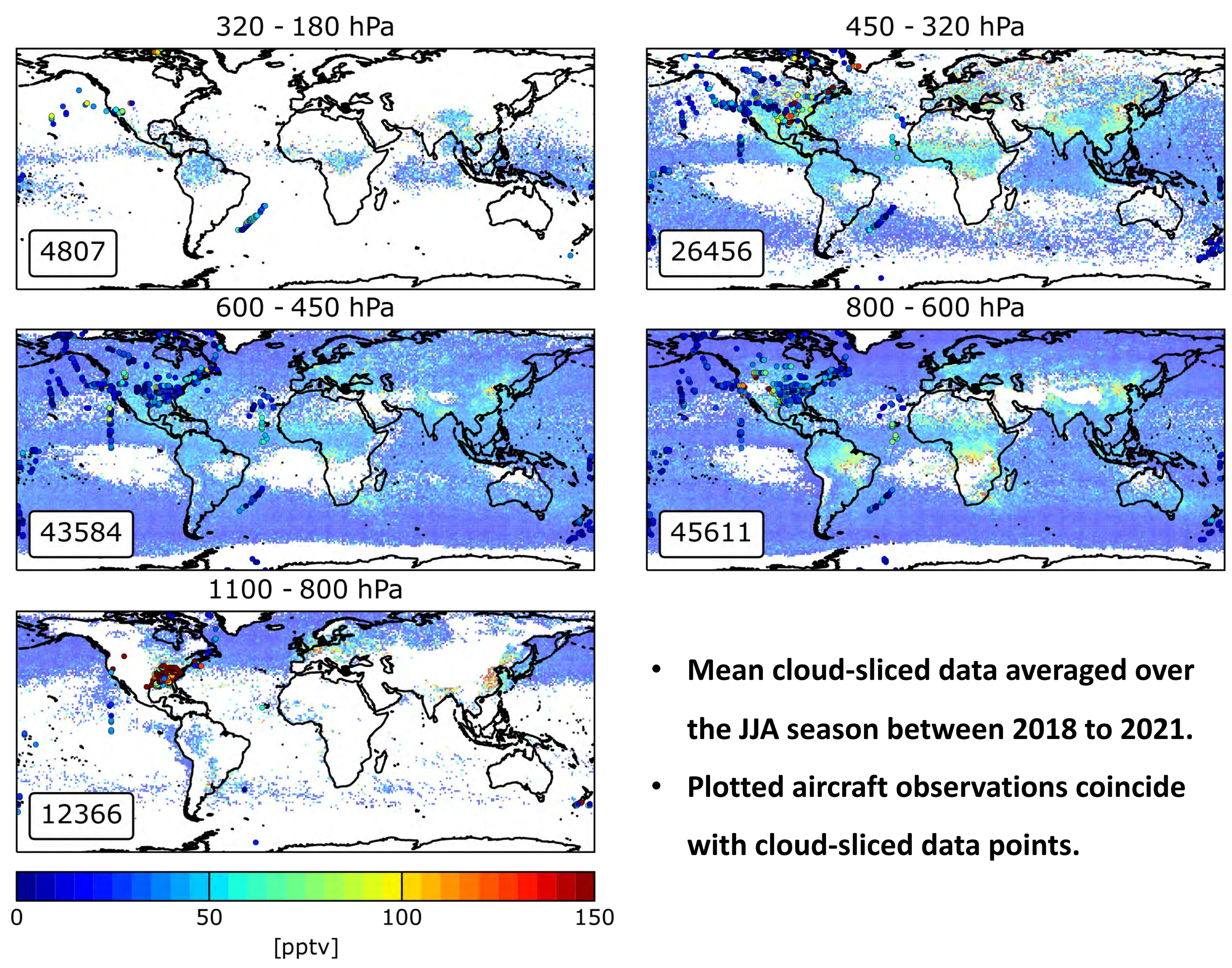
SEAC⁴RS - Summer 2013

ARCTAS – Spring & Summer 2008

- ATom-1 (Jul-Aug 2016)
- ATom-2 (Jan-Feb 2017)
- ATom-3 (Sep-Oct 2017)
- ATom-4 (Apr-May 2018)

4. Implementing the cloud-slicing technique between 180-1100 hPa

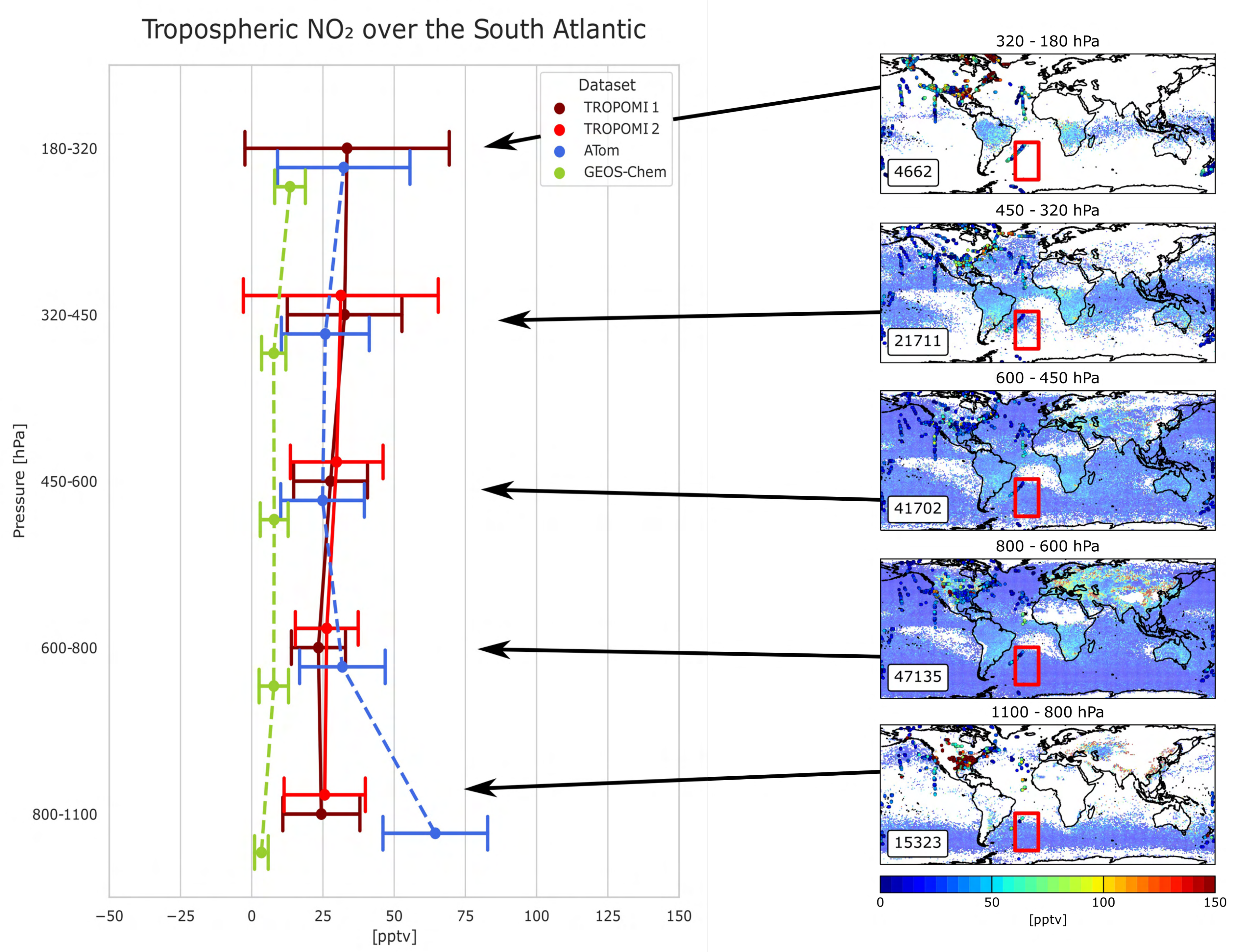
- Previous studies have used cloud-sliced OMI total columns of NO_2 to obtain NO_2 mixing ratios between 650-900 hPa[2] and between 280-450 hPa[3] as well as on TROPOMI measurements between 180-450 hPa[4].
- This has been expanded here using TROPOMI data at five pressure intervals between 180-1100 hPa and compared to measurements from the NASA DC-8 aircraft campaigns.



- Mean cloud-sliced data averaged over the JJA season between 2018 to 2021.
- Plotted aircraft observations coincide with cloud-sliced data points.

5. Creating vertical profiles of cloud-sliced NO_2 TROPOMI data

The mean of all the cloud-sliced data points within a given area is calculated and plotted to create a profile and the error bars represent the standard deviation. GEOS-Chem v13.3.4 is used at a resolution of 4° x 5°. GEOS-Chem simulations are shown here for the period DJF 2015/2016 and cloud-slicing observations averaged over the DJF season between 2018 and 2021.

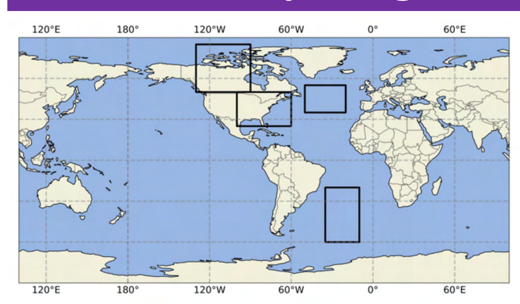


- TROPOMI 1: Uses cloud top height and cloud fraction information from the FRESCO product that minimises the difference between measured and simulated spectra in the O2 A-band between 752-766 nm.
- TROPOMI 2: Uses cloud top height and cloud fraction information from the O22CLD product that measures oxygen absorption in the O2-O2 band between 460-490 nm.

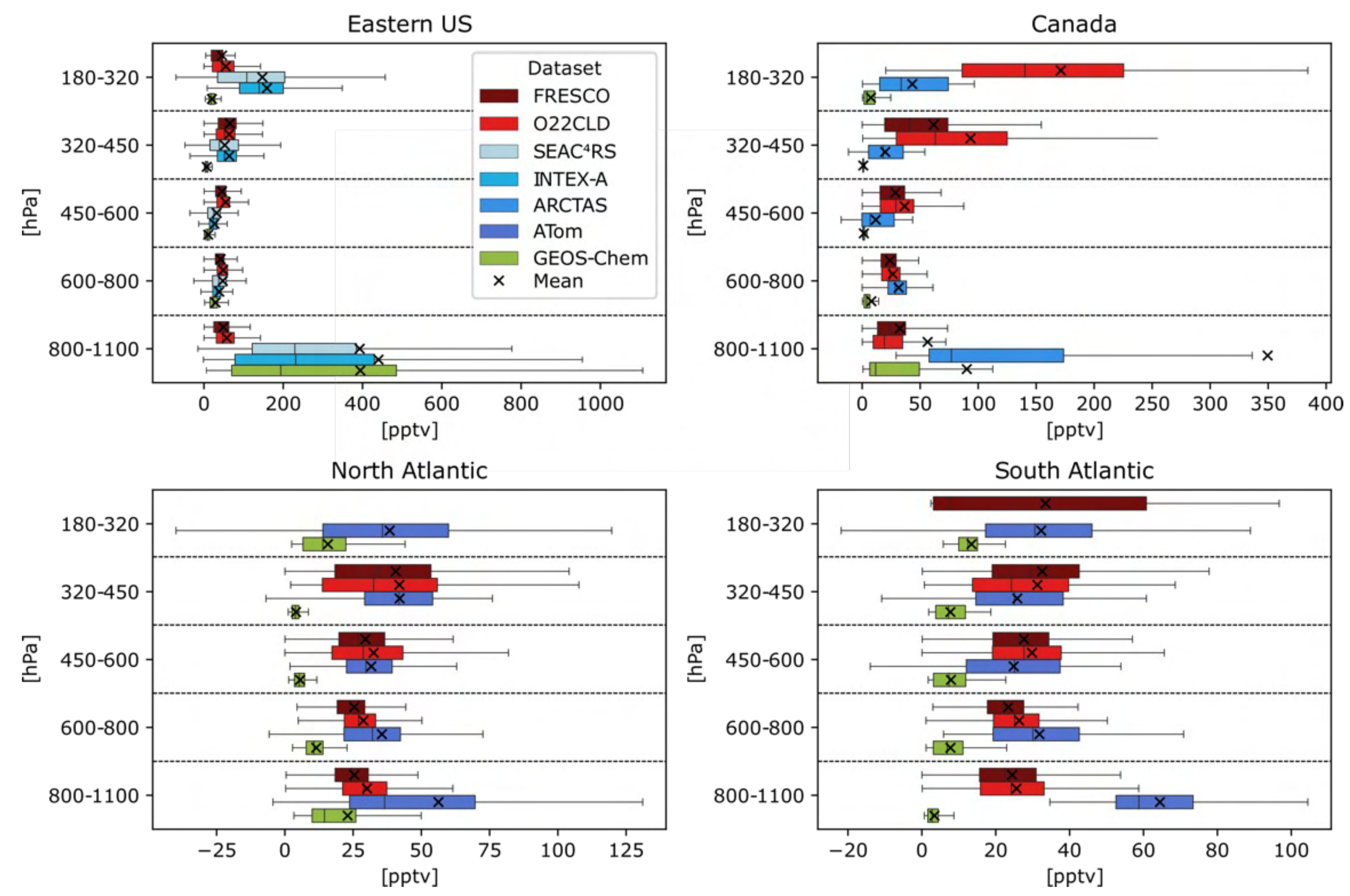
Next Steps

Explore the cause of inconsistencies in the boundary layer using AMF data and evaluating the correlation between ΔVCD and ΔP. Apply cloud-slicing to the OMPS instrument, as OMPS missions are sustained to 2040.

6. Comparing vertical profiles between different global regions



Mean and median cloud-sliced NO_2 data for summer 2018 to 2021 is shown here with the box plots representing the median value with the 5th, 25th, 75th and 95th percentiles.



- Concentrations of NO_2 deviate by less than 15% between cloud-slicing and aircraft observations in the mid-troposphere where data density is increased.
- Cloud-slicing results underestimate NO_2 concentrations compared to aircraft observations in the boundary layer where cloud-slicing is up to 300 pptv below aircraft observations.
- Differences of up to 150 pptv in the upper troposphere (320–180 hPa) may be due to the low sampling frequency here (see Box 3).

Acknowledgements

- This work is funded by the European Research Council.
- We are grateful to the NASA DC-8 Science Teams for for access to aircraft observations.

References

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