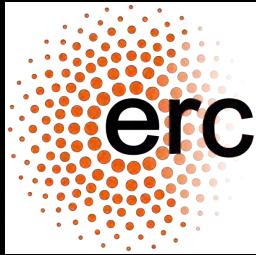
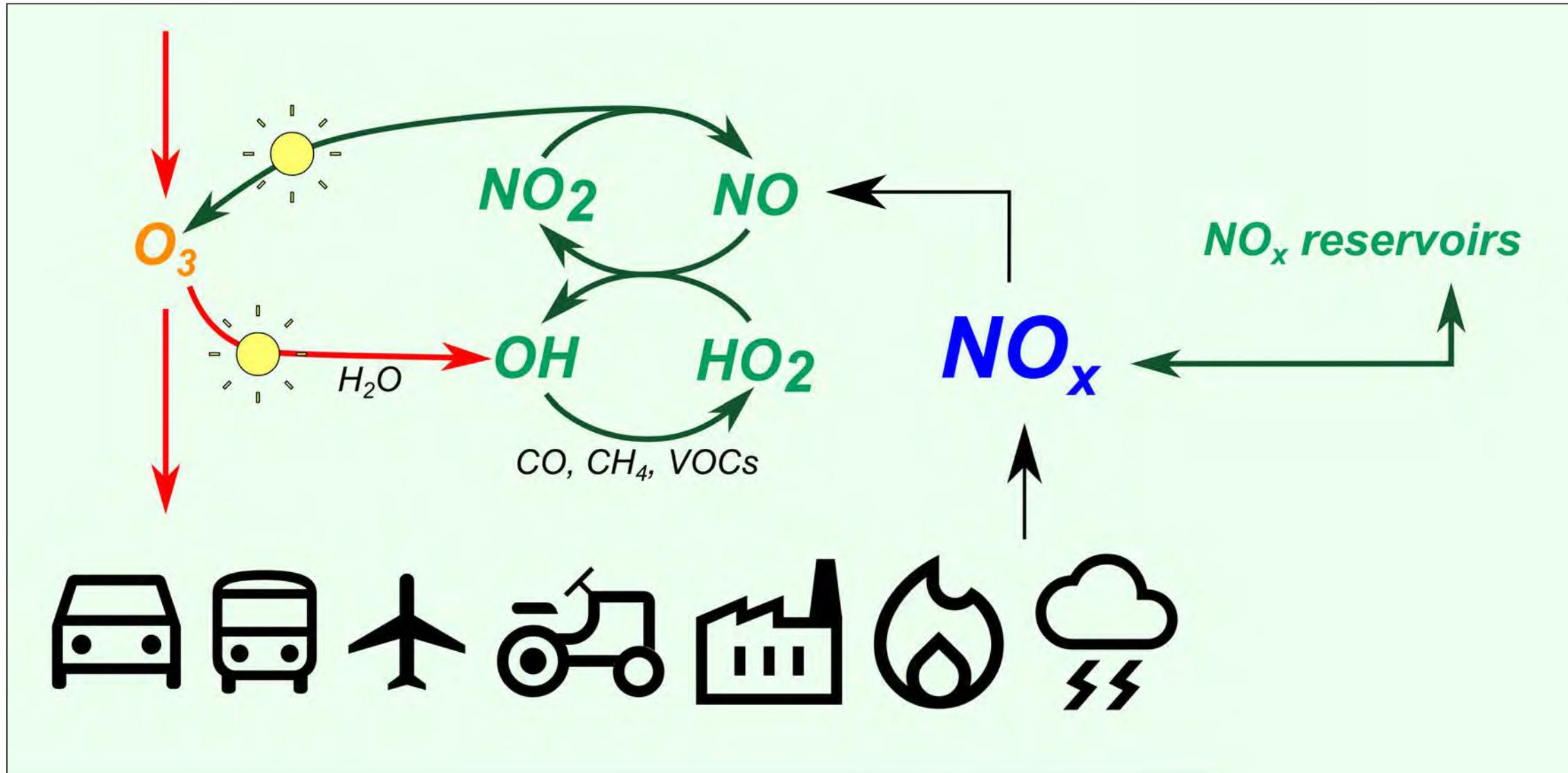


Global vertical profiles of tropospheric NO₂ from cloud-sliced TROPOMI observations

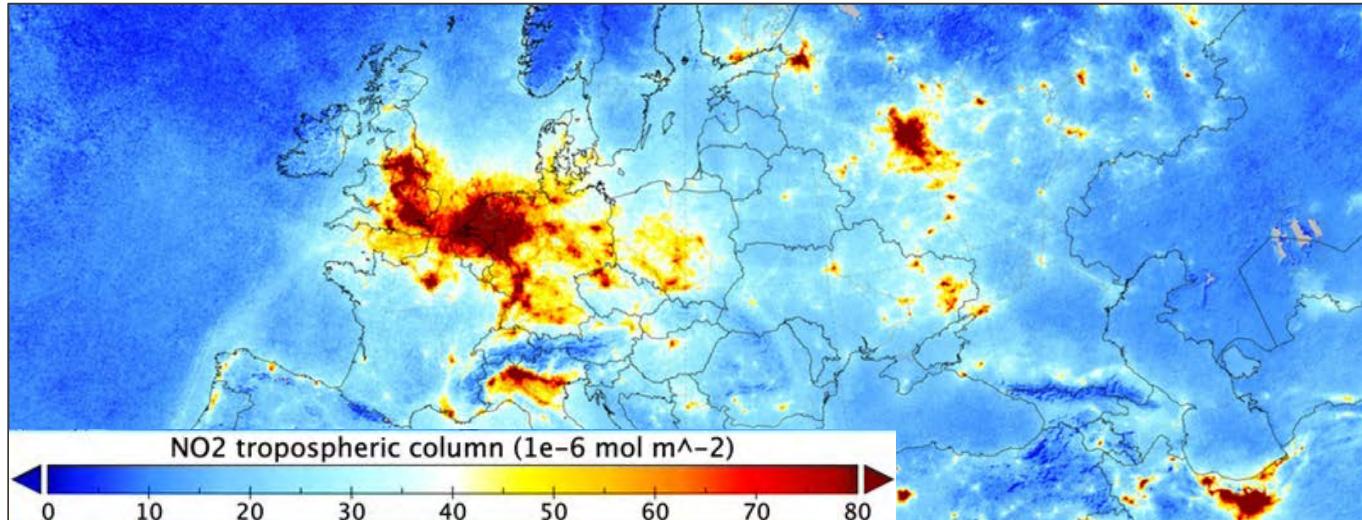


The importance of NO_x in the troposphere

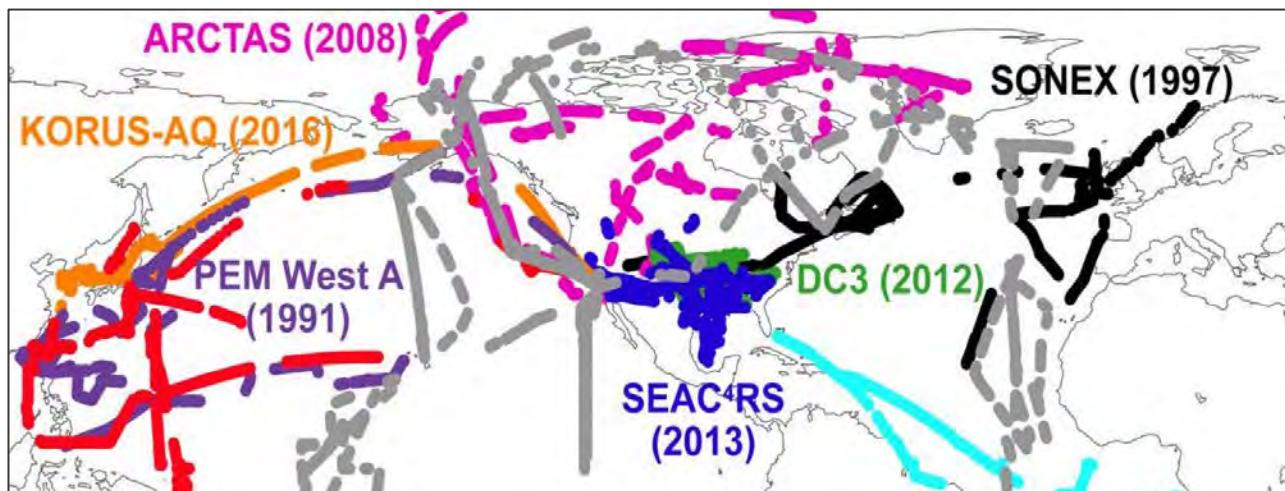


Why do we use cloud-slicing?

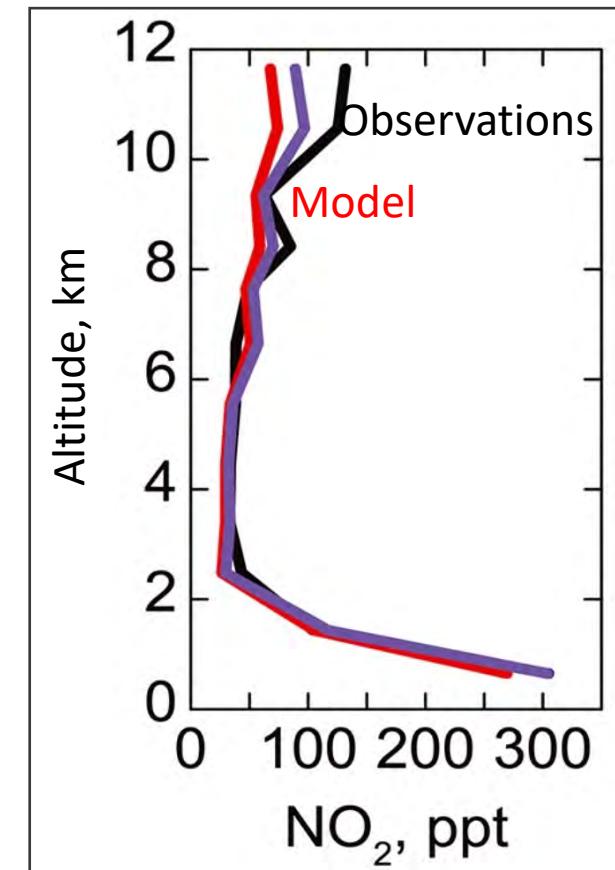
TROPOMI NO₂ column – April to September 2018



NASA DC-8 aircraft flight tracks



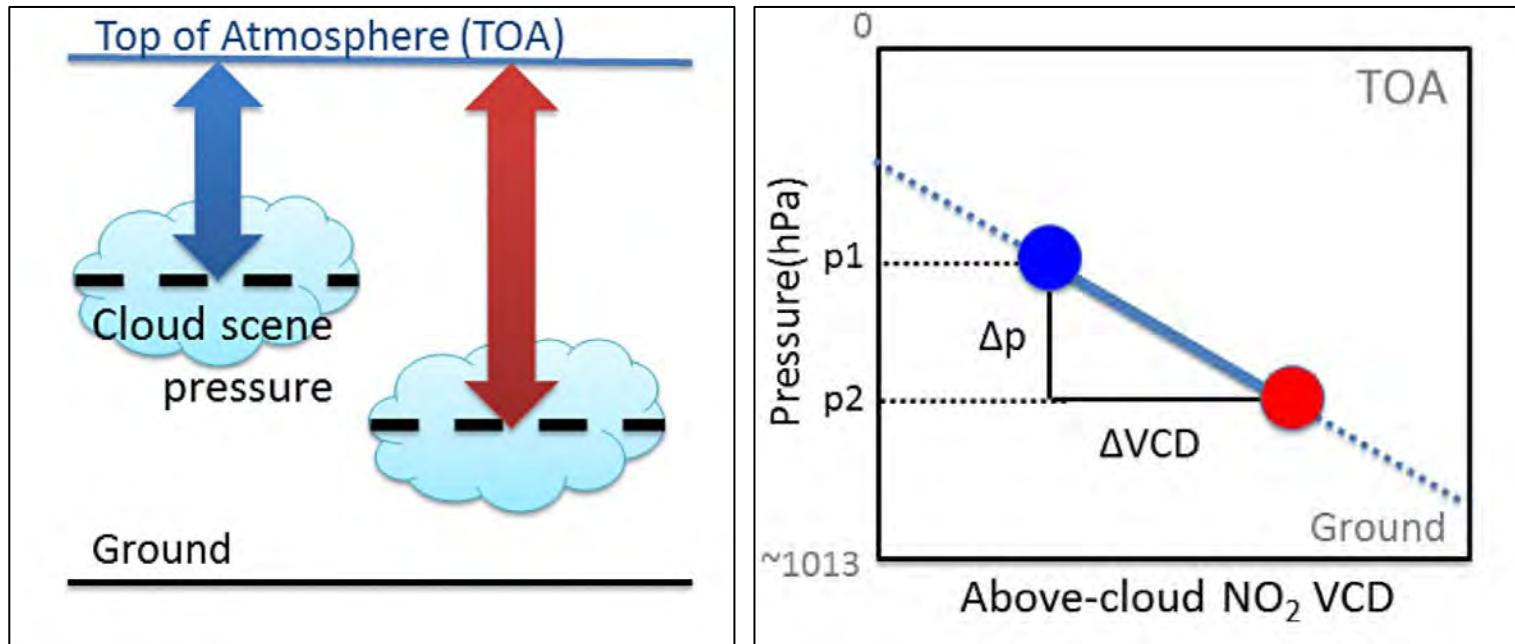
Modelled NO₂ vertical profile



(Silvern et al., 2018)

TROPOMI data retrieval and the cloud-slicing technique

Derives the NO₂ volume mixing ratio using partial NO₂ columns above optically thick clouds.



(S. Choi et al., 2014)

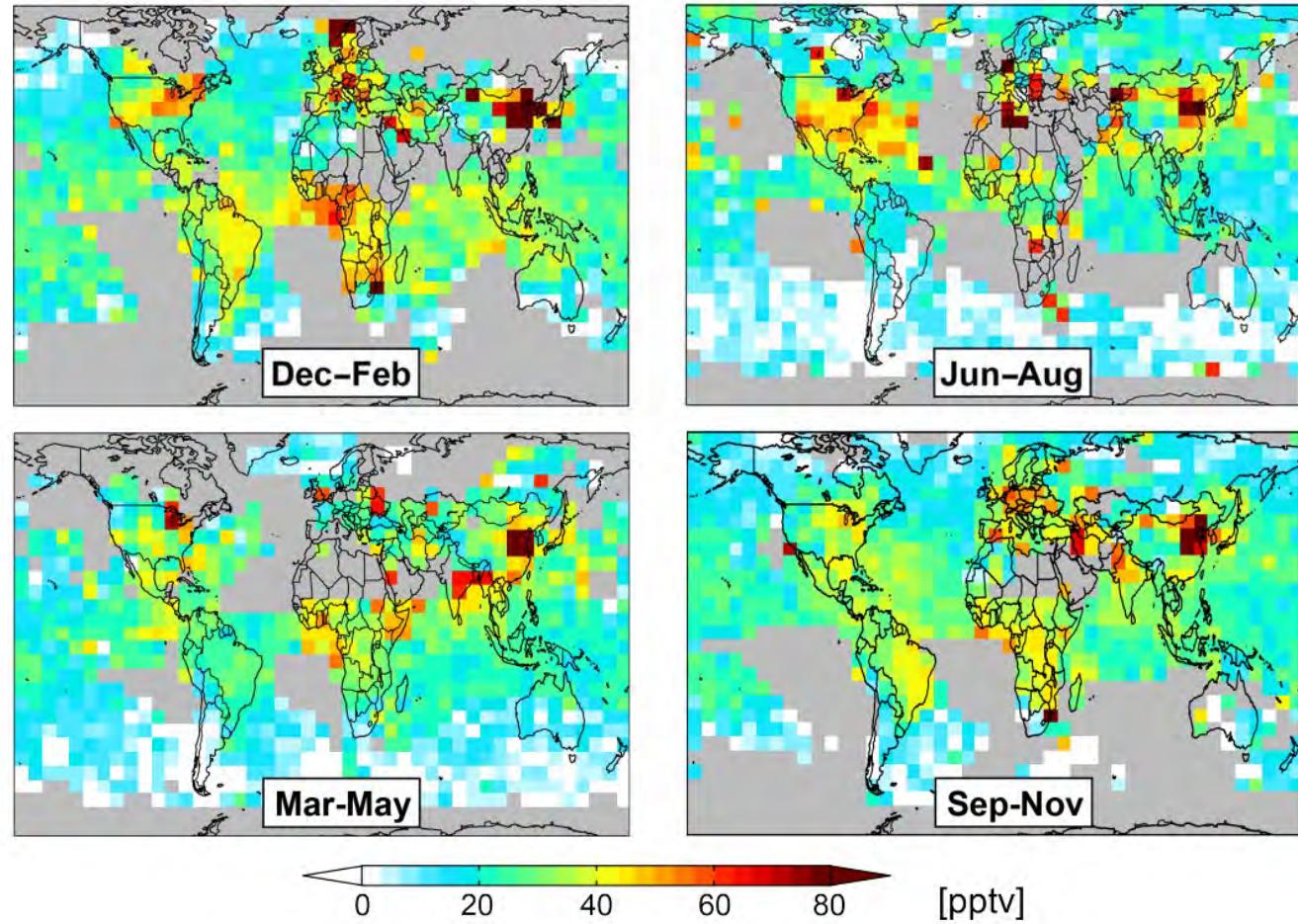
$$NO_2 \text{ VMR} = \frac{\Delta VCD}{\Delta p} \frac{k_B g}{R_{air}}$$

Previous cloud-slicing of satellite data

Seasonal mean upper tropospheric NO₂ from NASA OMI with a spatial resolution of 5° x 8° (2005-2007).

OMI = Ozone Monitoring Instrument

- OMI has a horizontal resolution of 13 km x 24 km.
- TROPOMI has a horizontal resolution of 5.6 km x 3.5 km since August 2019.

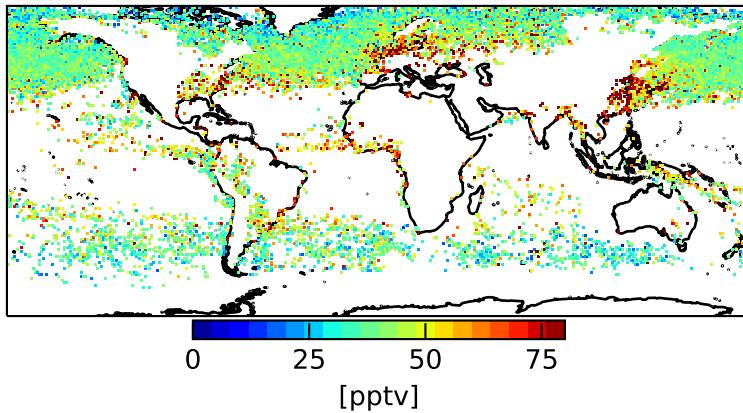


(Marais et al., 2018)

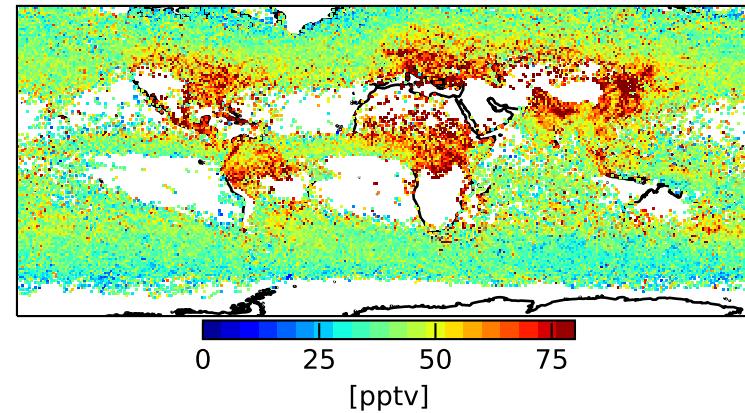
TROPOMI vertical columns from cloud-slicing

Mean TROPOMI NO₂ for Jun-Aug 2019 with a resolution of 1°x 1°.

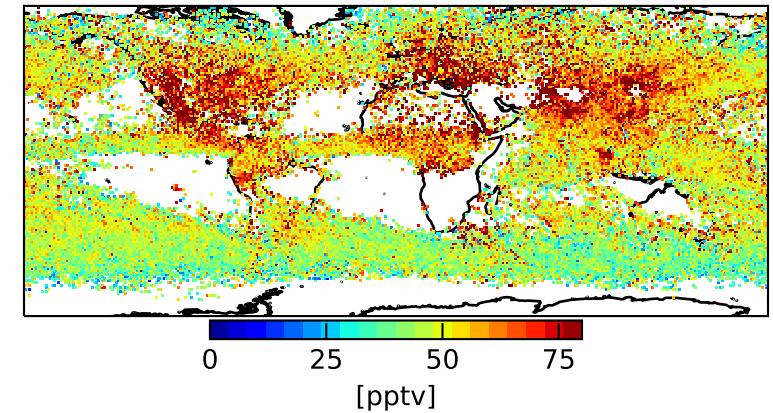
800-1100 hPa: 17.4% filled



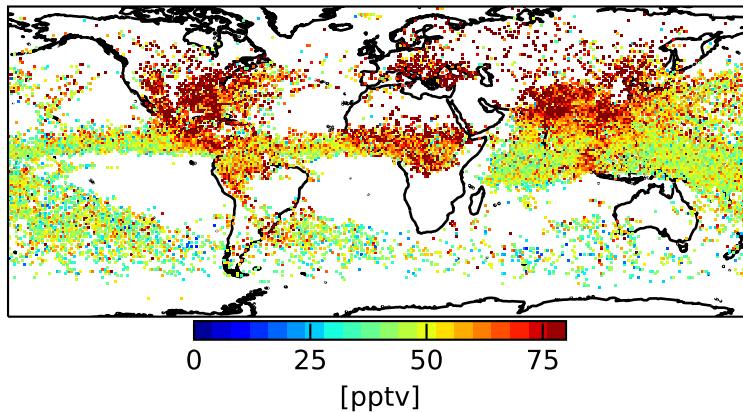
600-800 hPa: 55.0% filled



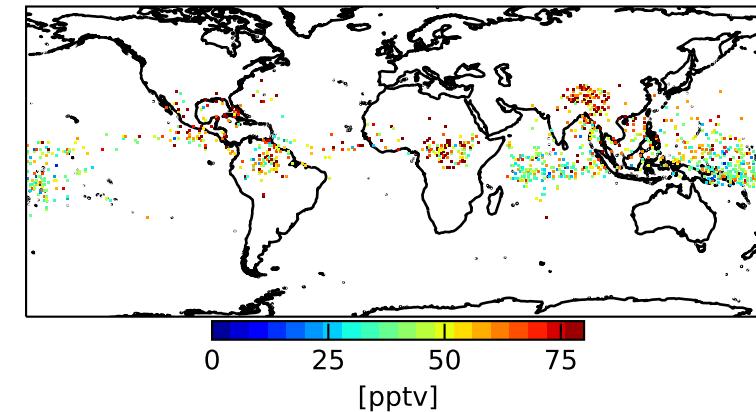
450-600 hPa: 49.0% filled



320-450 hPa: 20.4% filled



180-320 hPa: 1.68% filled



Datasets used in tropospheric vertical profiles

TROPOMI aboard Sentinel-5P



2 retrieval products from TROPOMI
(*TROPOMI 1* & *TROPOMI 2*)



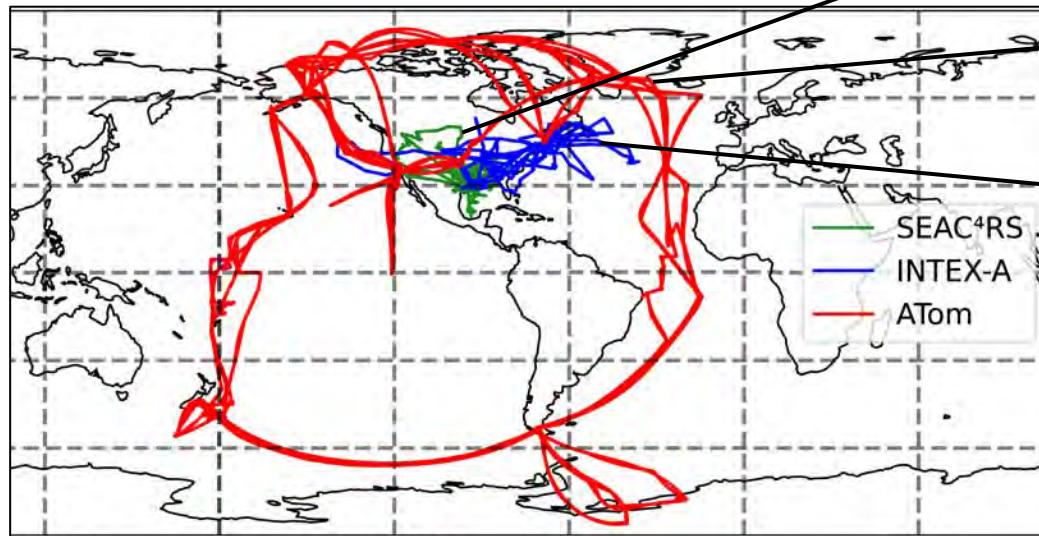
SEAC⁴RS - Summer 2013



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

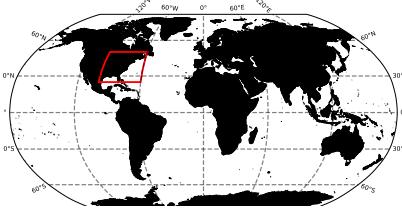


INTEX-A - Summer 2004

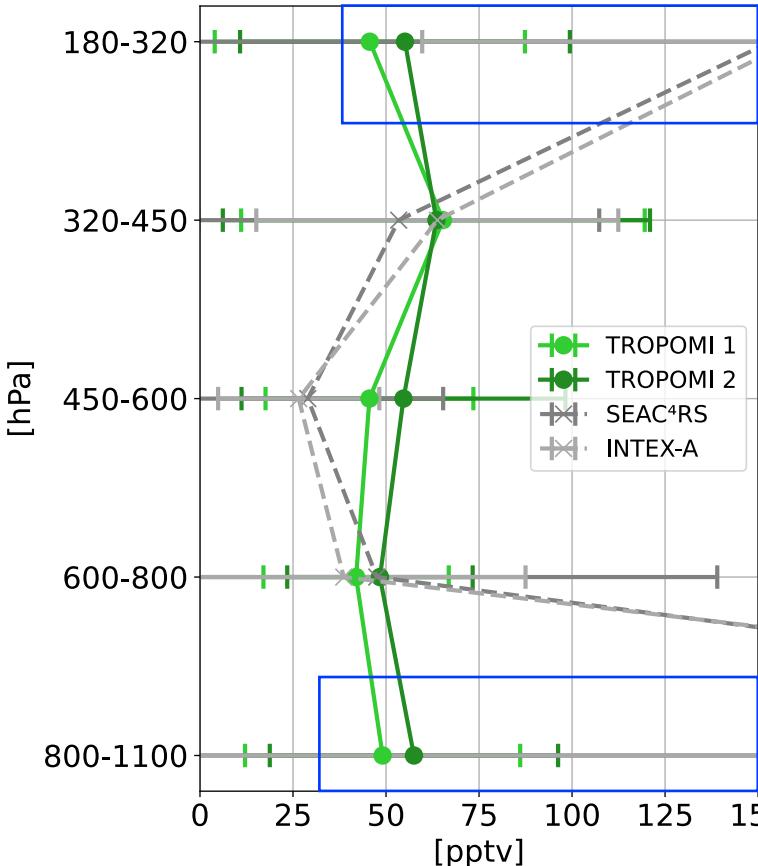


Multi-year tropospheric vertical profiles from TROPOMI

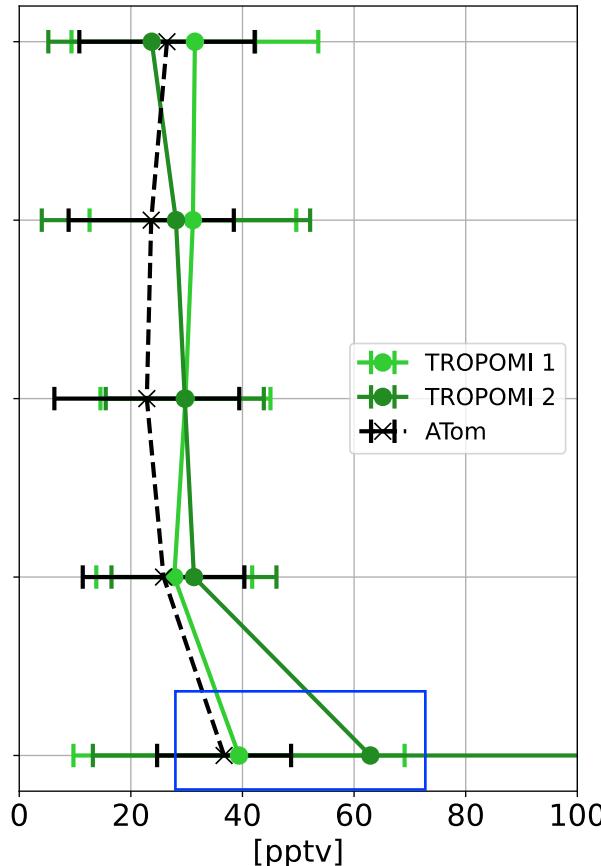
June to August: 2018 to 2021



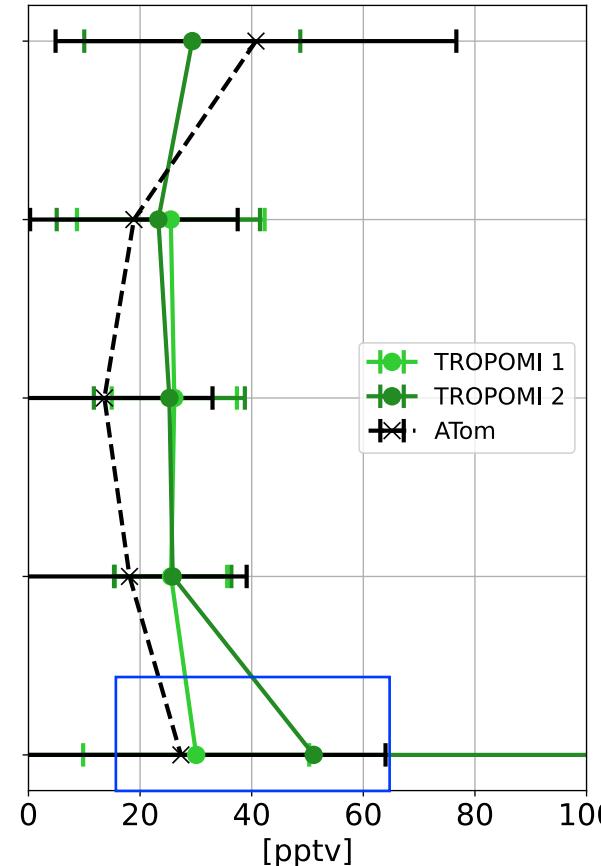
Eastern North America



Central Pacific



South Atlantic



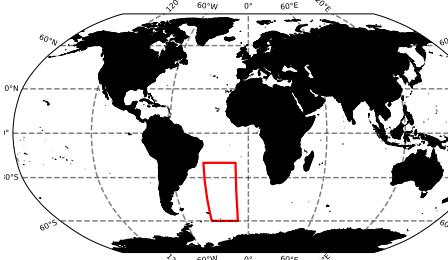
Over North America:

- > 350 pptv difference in the boundary layer.
- Decreases between 180 and 320 hPa to < 110 pptv.

Over the oceans:

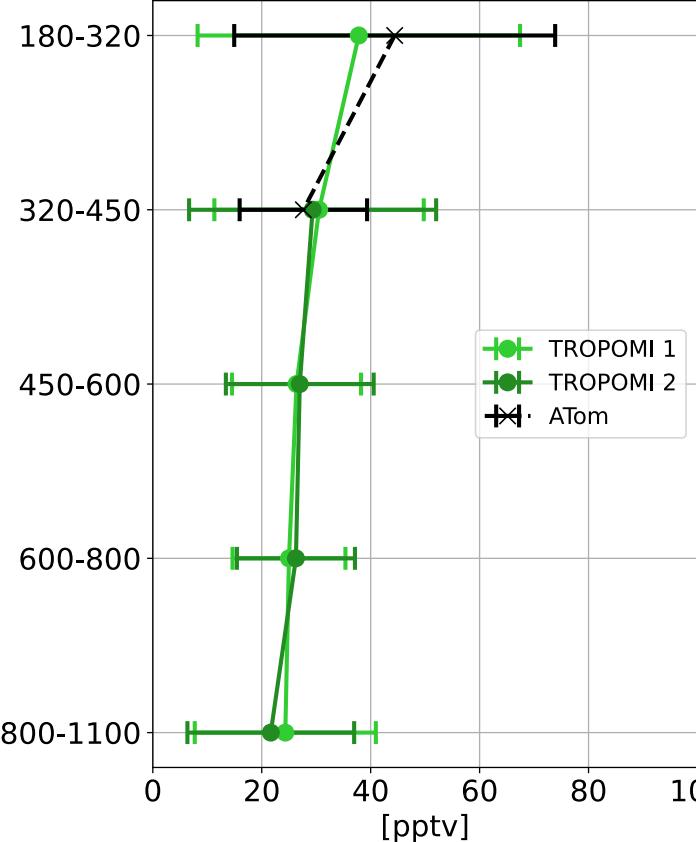
- < 30 pptv difference in the boundary layer.
- Discrepancy of 10 pptv between 180 and 320 hPa.

Comparison of seasonal vertical profiles to ATom measurements

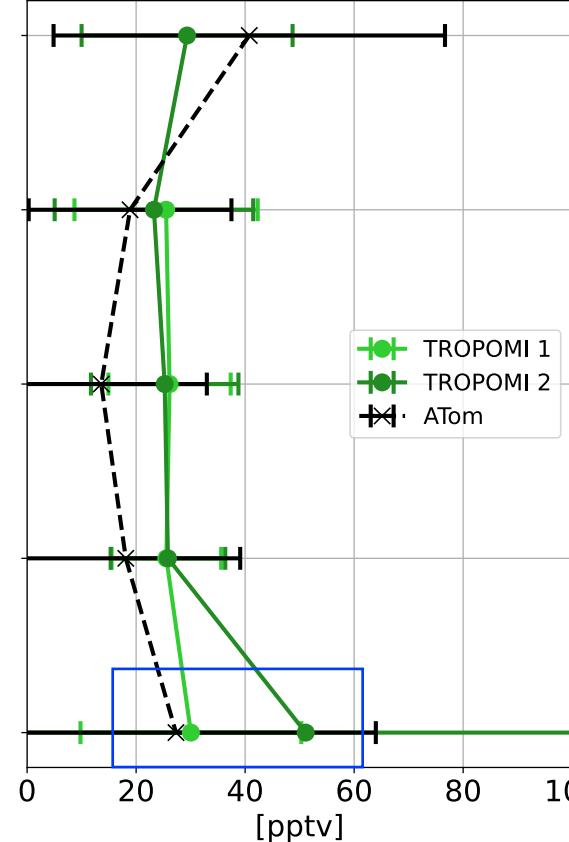


This technique enables us to obtain information on the composition of the troposphere where aircraft observations are lacking.

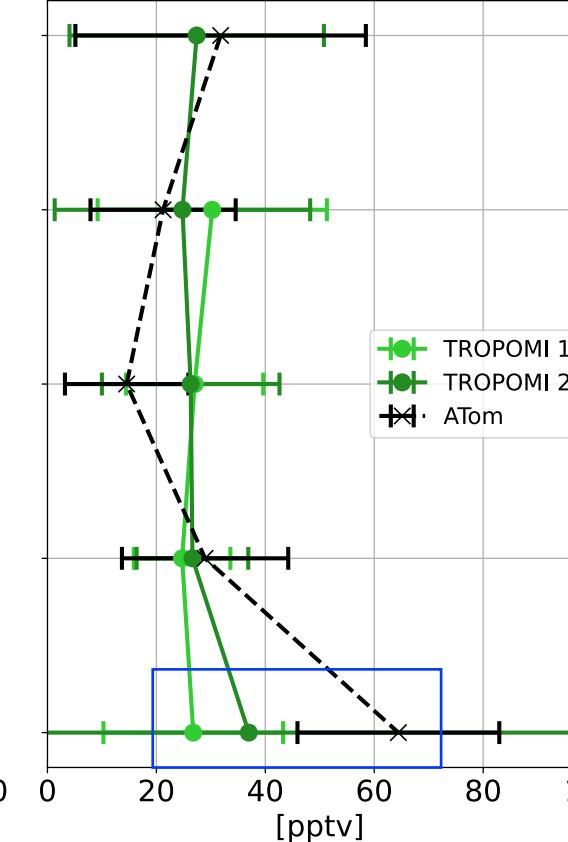
Mar to May: 2018 to 2021



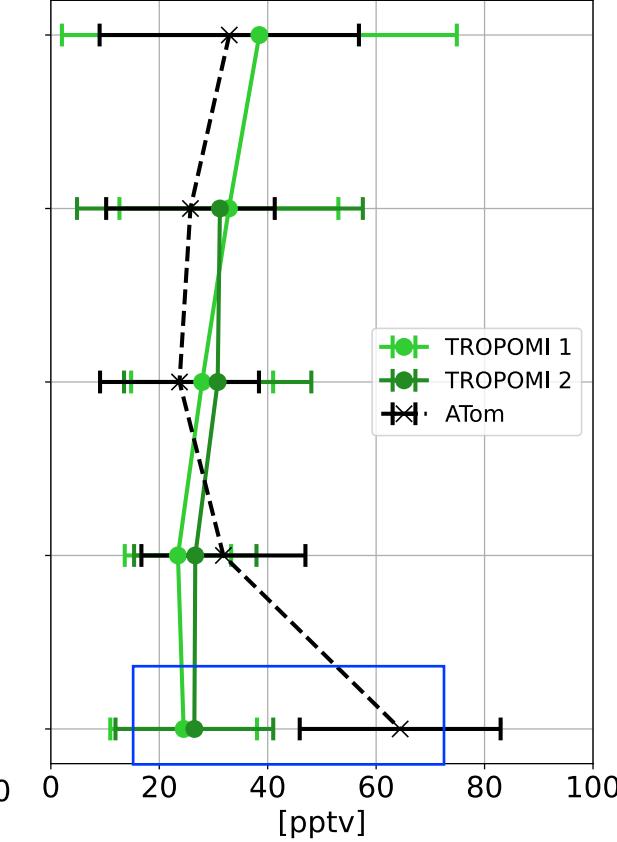
Jun to Aug: 2018 to 2021



Sept to Nov: 2018 to 2021

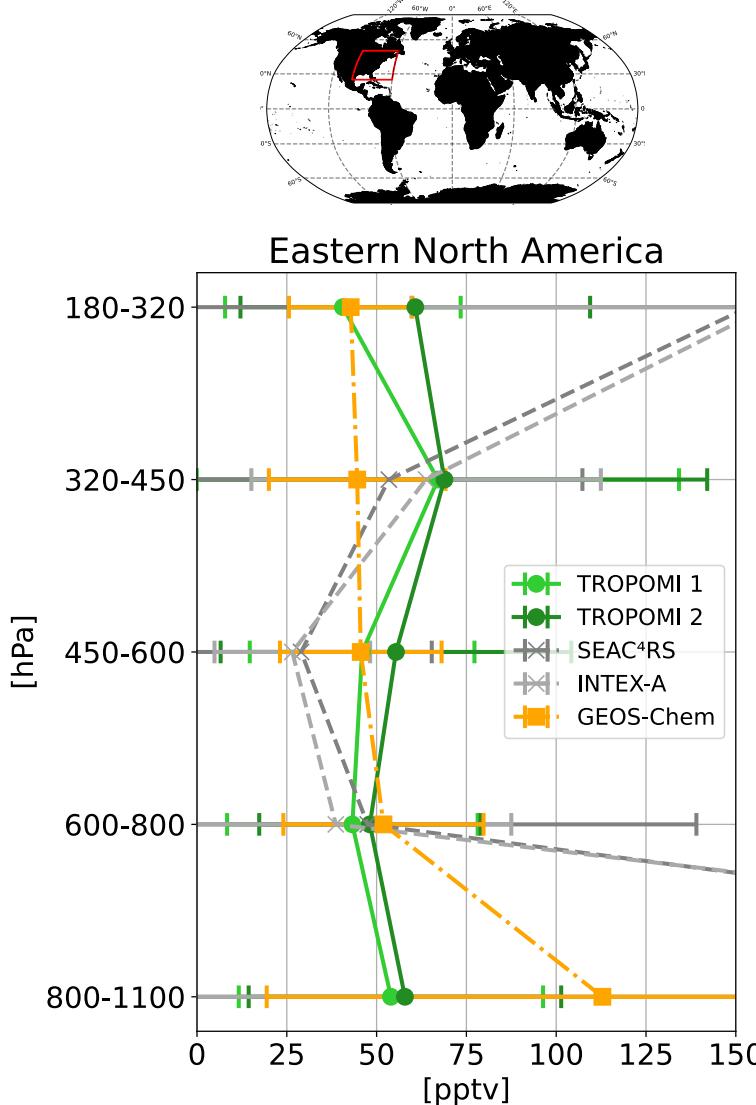


Dec to Jan: 2018 to 2020



Summary

Jun - Aug 2019



- Provides a method for creating vertical profiles from global cloud-sliced satellite data.
- Reasonable agreement in most areas of the globe between TROPOMI and aircraft observations between 180-800 hPa.
- Enables analysis of vertical distribution of NO₂ in areas where aircraft observations are sparse.

Next steps:

1. Use GEOS-Chem to attribute any other uncertainties.
2. Continue to test the robustness of these results.
3. Identify whether the cloud-slicing technique is functional in the boundary layer.