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Abstract EGU24-8441:

Improved lightning NO_x emission inventory evaluated with vertical profiles of NO_2 and ozone obtained by cloud-slicing TROPOMI

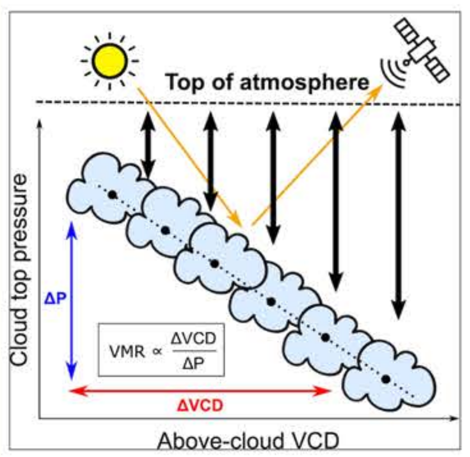
Rebekah P. Horner[1](rebekah.horner.20@ucl.ac.uk), Eloise A. Marais[1], Nana Wei[1]

[1]Department of Geography, University College London, London, UK

We derive global vertical profiles of tropospheric NO_2 and O_3 from TROPOMI that we use to identify the need to improve representation of lightning NO_x

1 Cloud-slicing to yield vertical profiles of pollutants

Schematic of cloud-slicing

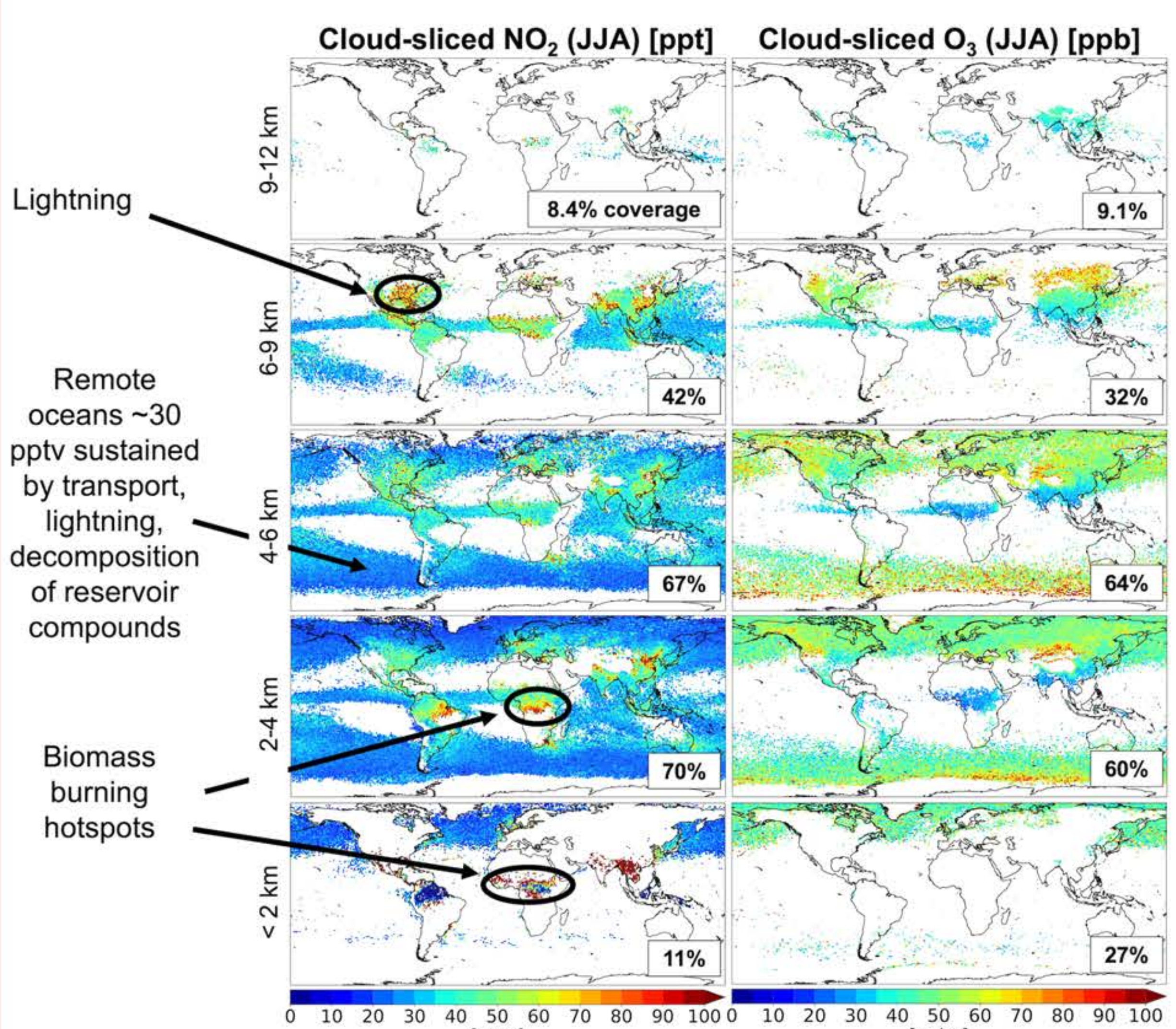


- Nitrogen oxides (NO_x) are key contributors to tropospheric ozone (O_3).
- Observations of the vertical profiles of tropospheric NO_x and O_3 are severely limited.
- Cloud-slicing (left) addresses this by taking advantage of satellite partial columns separated by optically thick clouds[1].
- We apply cloud-slicing to TROPOMI NO_2 and O_3 total columns in 2018 to 2022.

Cloud-slicing yields global vertical profiles of seasonal mean NO_2 and O_3 volumetric mixing ratios (VMRs) in 5 tropospheric layers

2 Vertical profiles of NO_2 and O_3 from TROPOMI

Global cloud-sliced multiyear mean NO_2 and O_3 obtained at high resolution (1° x 1°) in 5 discrete layers: 2 upper troposphere (6-9 km & 9-12 km), 2 mid-troposphere (2-4 km & 4-6 km), and 1 boundary layer (BL) (< 2 km).

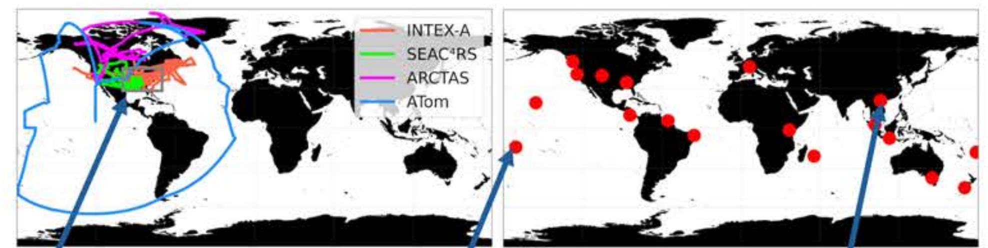


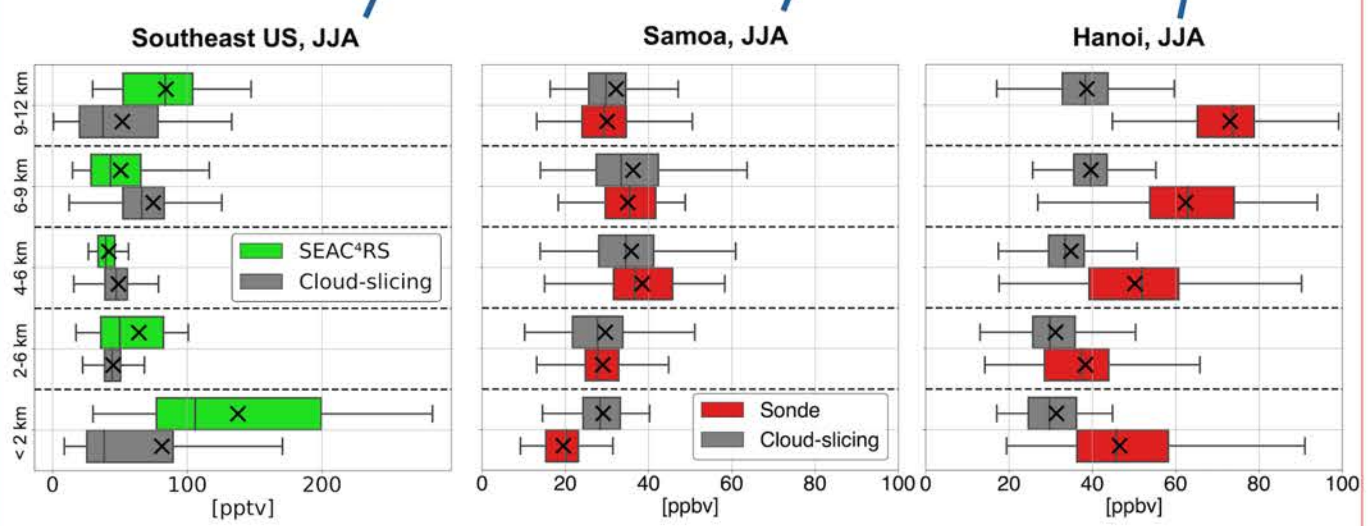
Greatest **coverage** in the mid troposphere where clouds are abundant. Data **range** from ~ 30 ppt (remote oceans) to > 100 ppt (BL and mid troposphere over biomass burning locations) for NO_2 and ~35 ppb (tropics) to >200 ppb (northern midlatitudes influenced by pollution) for O_3.

3 Cloud-slicing assessed with independent measurements

We compare cloud-sliced data to NASA DC-8 aircraft data for NO_2 and SHADOZ, WOUDC and NOAA ozonesondes for O_3 coincident with TROPOMI overpass.

NASA DC-8 aircraft tracks (left) and ozonesonde locations (right)



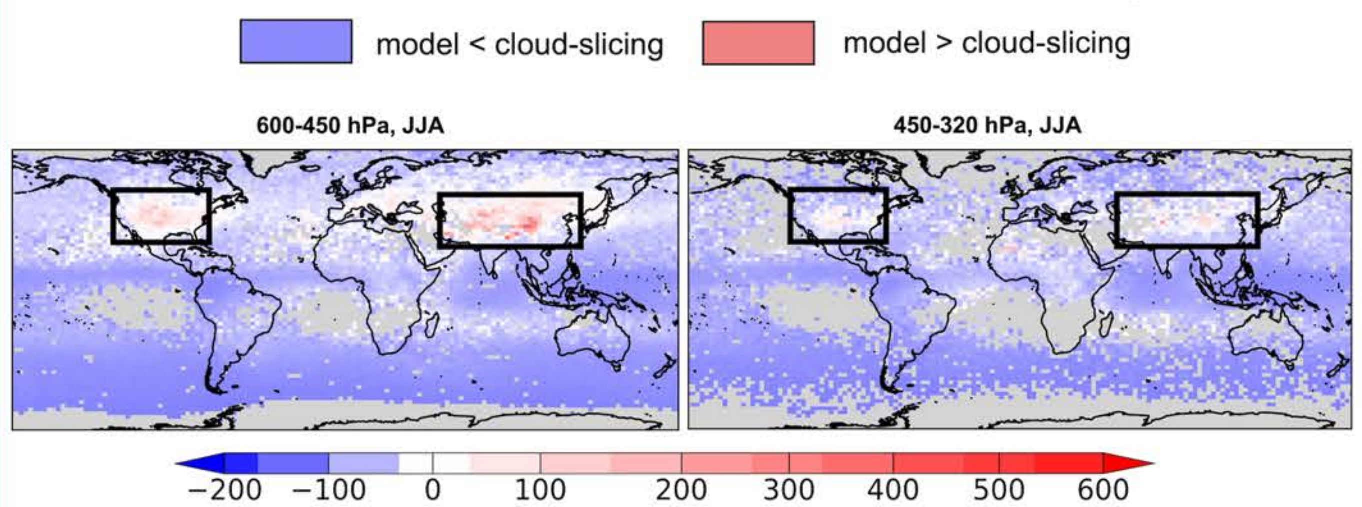


NO_2 data differences are small (10-15 ppt) when data density and sampling are consistent, but this is rare. O_3 data is consistent at most sites (see Samoa above), but a few sites exhibit large differences in the upper troposphere (see Hanoi above).

4 Assessing understanding of tropospheric NO_x and O_3

We use GEOS-Chem as state-of-knowledge of tropospheric NO_x and O_3 and compare it to the cloud-sliced data on the **global model grid (2° x 2.5°)**. The model is updated to include liberation of NO_x via peroxypropionyl nitrate (PPN) photolysis and particle nitrate photolysis.[2]

Percent difference between GEOS-Chem and cloud-sliced NO_2

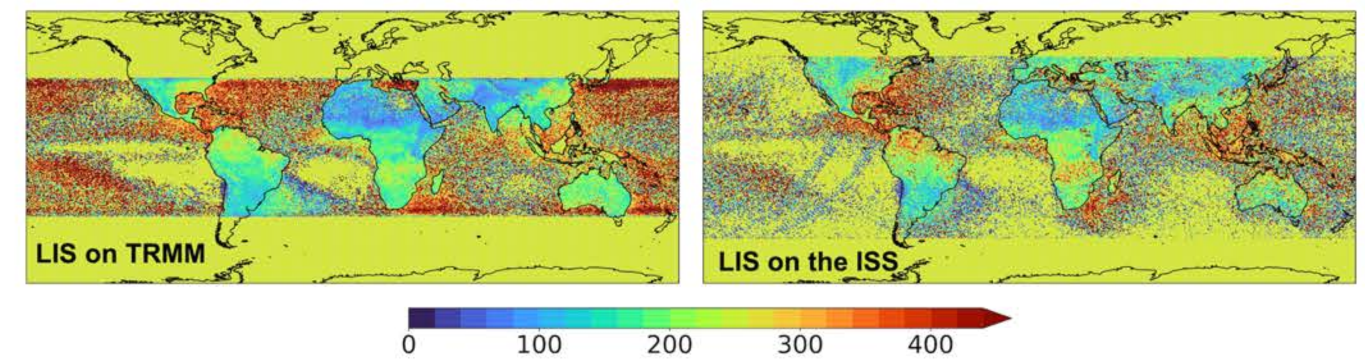


GEOS-Chem overestimates NO_2 in the mid and upper troposphere over northern mid-latitudes, as lightning NO_x production is double (500 mol/fl) everywhere else (260 mol/fl).

5 Lightning NO_x production rates from flash energy proxies

Lightning imaging sensor (LIS) flash energies (radiances) are used with observationally-constrained global mean lightning NO_x production (280 mol/fl) to calculate spatially resolved values for input to models[3].

Gridded (0.5° x 0.625°) lightning NO_x production rates in moles per flash



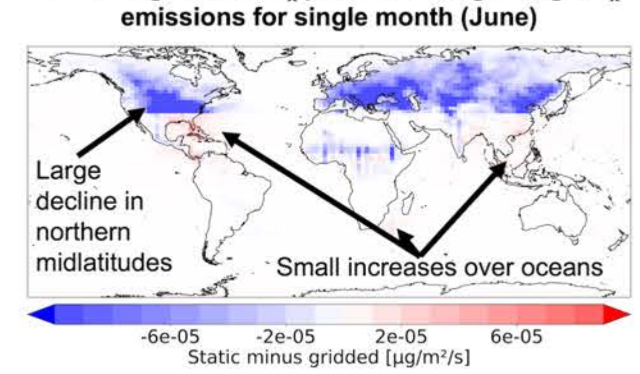
NO_x per flash is far greater over oceans (250-500 mol/fl) than land (35-200 mol/fl), but differences between ISS and TRMM over oceans needs to be resolved to exploit greater latitudinal extent of ISS.

NO_x per flash for use in CTMs is far more variable than fixed values currently invoked. Greater NO_x per flash over oceans may resolve remote ocean low bias shown in Box 4.

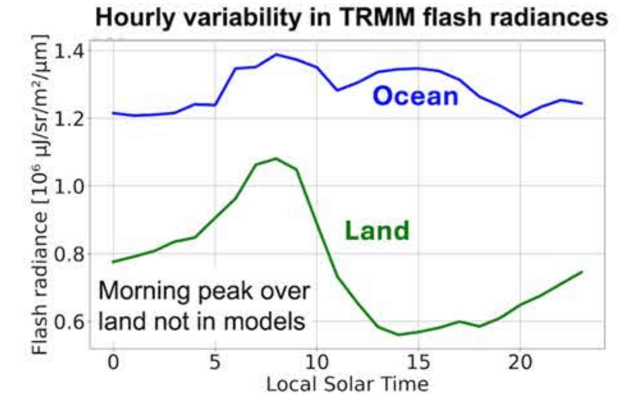
6 Implications of gridded NO_x per flash on lightning NO_x emissions

We incorporate gridded NO_x per flash in the emissions component (HEMCO) of GEOS-Chem (left plot), yielding annual emissions (6.5 Tg N) greater than the original model version (5.8 Tg N).

Effect of gridded NO_x per flash on lightning NO_x emissions for single month (June)



Hourly variability in TRMM flash radiances



Mass of nitrogen emitted by lightning is relatively unaffected, but spatial distribution (shift from land to ocean) is. Hourly variability effects on atmospheric composition needs to be tested.

7 Ongoing work

- Resolve TRMM and LIS differences
- Account for hourly variability in lightning NO_x production rates, as LIS data indicate greatest NO_x production in the morning.
- Assess the impact of more mechanistic lightning NO_x parameterisation on tropospheric NO_x, O_3, oxidants, and compounds affected by oxidant abundance.

Acknowledgements

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Key references

[1] **Ziemke J.R.** et al. (2001) JGR: Atmospheres 106(D9) [2] **Shah V.** et al. (2023) ACP 23(2) [3] **Chronis T. & Koshak W.J.** (2017) BAMS 98(7)