# Improved representation of lightning $NO_x$ in GEOS-Chem informed by vertical profiles of $NO_2$ from cloud-slicing TROPOMI

Bex Horner[1] (rebekah.horner.20@ucl.ac.uk) & Eloise A. Marais[1]

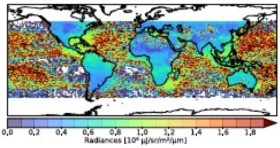
[1]Department of Geography, University College London, London, UK

**We use lightning flash energy data to develop time- and space-resolved lightning NOx production rates**

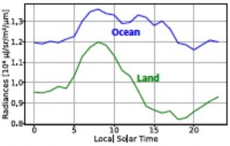
## 1 Lightning parameterisation in GEOS-Chem

Lightning $NO_x$ production rate in GEOS-Chem is currently set to 500 moles per flash north of 35°N and 280 moles per flash everywhere else.

**Lightning flash radiances from TRMM and ISS**




**Diurnal lightning flash radiances from TRMM and ISS**

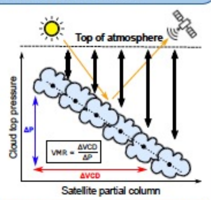



- Flash radiances (flash energy) vary spatially and diurnally.
- Radiances are greatest over oceans and peak in the morning over land → lightning $NO_x$ should vary spatially and diurnally in the GEOS-Chem model.

**Lightning data from the Lightning Imaging Sensor (LIS) satellite instrument show that the energy per flash varies spatially and diurnally.**

## 2 Cloud-slicing TROPOMI partial columns

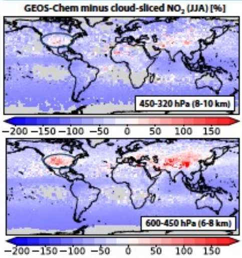
- Nitrogen oxides ($NO_x$) are key contributors to tropospheric ozone ($O_3$).
- Observations of the vertical profiles of tropospheric $NO_x$ are severely limited.
- Cloud-slicing (right) addresses this by taking advantage of satellite partial columns separated by optically thick clouds[1].
- We apply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




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

## 3 Using cloud-slicing to evaluate GEOS-Chem

**GEOS-Chem minus cloud-sliced $NO_2$ (JJA) [%]**




We use **GEOS-Chem v13.3.4** as state-of-knowledge of tropospheric $NO_x$ and $O_3$ and compare it to our cloud-sliced $NO_2$ data product on the **model grid (2° x 2.5°)**[2]. Model updated to include liberation of $NO_x$ via peroxypropionyl nitrate (PPN) photolysis and particulate nitrate photolysis[3].

**GEOS-Chem overestimates $NO_2$ in the upper troposphere over northern mid-latitudes, especially in the summer months where the production of lightning $NO_x$ dominates.**

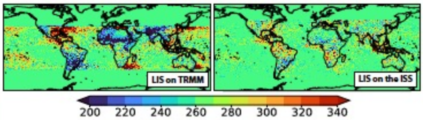
## 4 Lightning $NO_x$ production rates from LIS radiances

The parameterisation by Wu et al.[4] is applied to LIS flash radiances to calculate the gridded lightning $NO_x$ production rates.

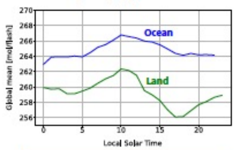
$$\frac{y}{N_A} \times \frac{\Sigma E}{N_{fl} \times \bar{P}}$$

$y$ = thermochemical $NO_x$ yield (9.0 x $10^{16}$ molec/J)
$N_A$ = Avogadro's constant
$E$ = LIS flash radiances
$N_{fl}$ = LIS flash counts
$\bar{P}$ = Mean global $LNO_x$ production rate (265 mol/fl)

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

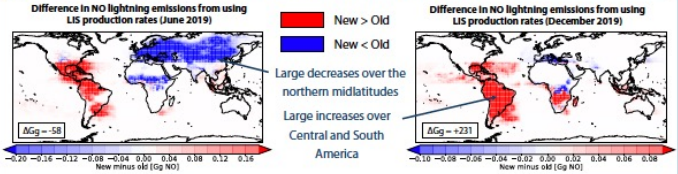


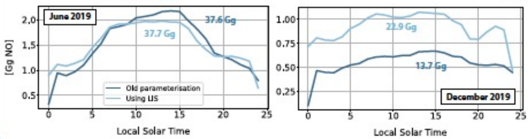

**Diurnal lightning $NO_x$ production rates**




**Far more variable $NO_x$ per flash than fixed values currently used.**

## 5 Implications for lightning NO emissions simulated by HEMCO



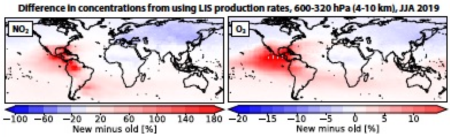

**Large spatial changes, but similar hourly variability, as latter governed by variability in flashes.**

## 6 Changes to concentrations in the mid-troposphere

Simulations over the TROPOMI satellite overpass time (12:00-15:00 Local Solar Time)

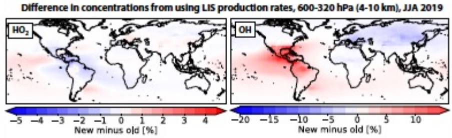
New > Old    New < Old

**Difference in concentrations from using LIS production rates, 600-320 hPa (4-10 km), JJA 2019**




- Large increases over Central America and modest increases over remote oceans where $LNO_x$ production rates increase (see Box 5).
- Decreases over Eurasia where production rates were set to 500 mol/fl.

**Difference in concentrations from using LIS production rates, 600-320 hPa (4-10 km), JJA 2019**




**Changes in oxidants and atmospheric composition leads to implications for model estimates of climate change attributable to tropospheric $O_3$ and the persistence of VOCs and $O_3$ precursors.**

## 7 Ongoing work

- Assess the impact of a more mechanistic lightning $NO_x$ parameterisation in other seasons and years.
- Use cloud-sliced vertical profiles to assess our new lightning $NO_x$ parameterisation in GEOS-Chem.

## Acknowledgements

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## References

[1] **Ziemke J.R.** et al. (2001) JGR 106(D9) [2] **Horner R.P** et al. (2024) ACP in review [3] **Shah V.** et al. (2023) ACP 23(2) [4] **Wu Y.** et al. (2023) JGR 128(4)