Estimates of Lightning NO_x Production based on High Resolution OMI NO_2 Retrievals over the Continental US

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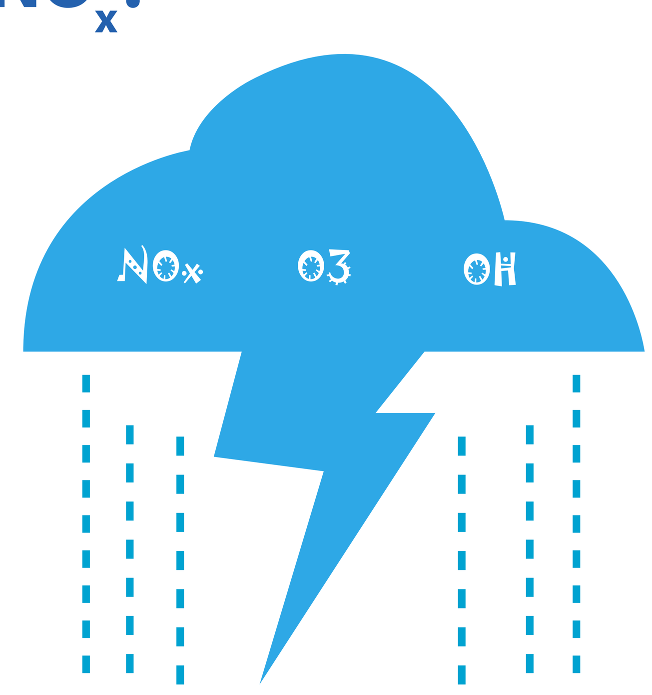
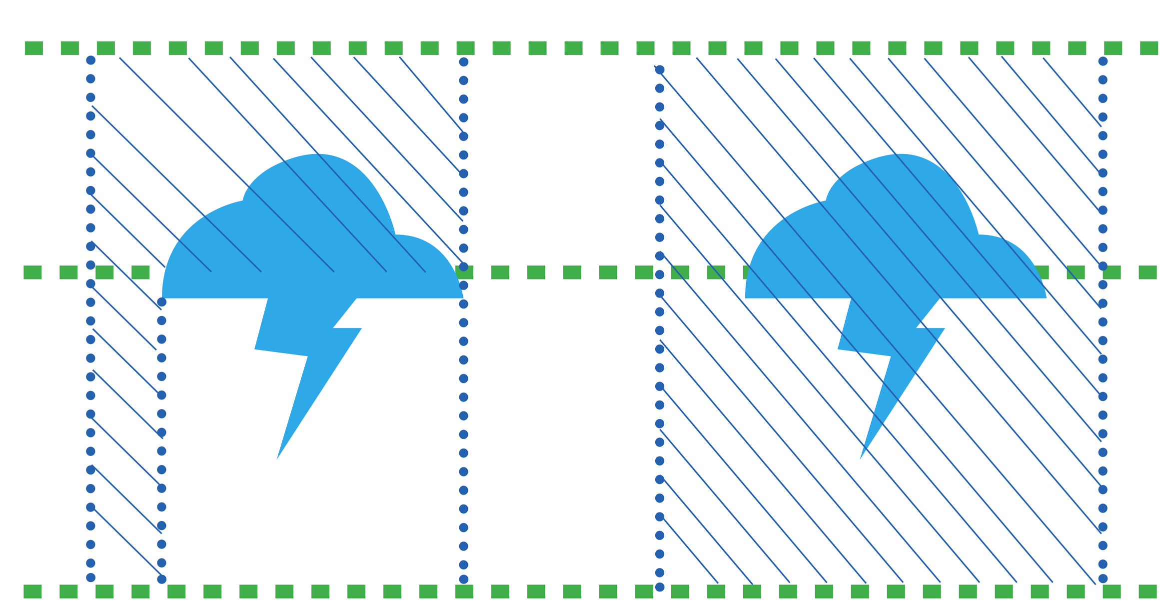
The new algorithm for retrieval of **LNO_x** from **OMI,** including LNO_x **below the cloud**, has been developed for application over **active convection**, whether in **clean** or **polluted** regions.

Why Study LNO_x?

- Global lightning NO_x (LNO_x) production: 2 - 8 Tg N yr^{-1}
- ~ 80% of NO_x in the middle to upper troposphere has a lightning source
- -> O_3 and OH
- Satellites measurements are a powerful tool to estimate LNO_x directly
- In this study, we develop the new algorithm for calculating LNO_x production efficiency (PE) and compare it with former methods.



Method



TropVis, LNO_xVis | LNO_x

$$V_{LNOx} = \frac{S_{Trop} \longleftarrow S - S_{Strat}}{AMF_{LNOx} \dashleftarrow S_{Trop} / V_{LNOx}} \qquad V_{LNOxClean} = \frac{S_{LNO2} \longleftarrow S - S_{Strat}}{AMF_{LNOxClean} \dashleftarrow S_{LNO2} / V_{LNOx}}$$

$$V_{LNO2Vis} = \frac{S_{Trop} \longleftarrow S - S_{Strat}}{AMF_{LNO2Vis} \dashleftarrow S_{Trop} / V_{LNO2Vis}} \qquad V_{TropVis} = \frac{S_{Trop} \longleftarrow S - S_{Strat}}{AMF_{TropVis} \dashleftarrow S_{Trop} / V_{TropVis}}$$

V: vertical column density; S: slant column density; AMF: air mass factor

$\longleftarrow$: the Ozone Monitoring Instrument (OMI) data $\dashleftarrow$: combined OMI and WRF-Chem data

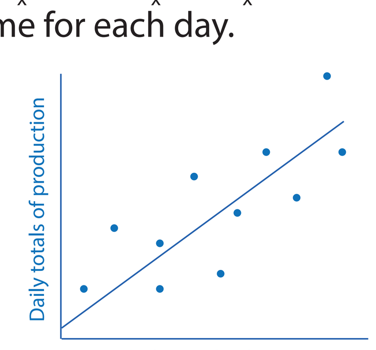
- **$V_{LNOxClean}$ and $V_{TropVis}$ assume that all retrieved NO_2 originates with lightning [Pickering et al. 2016];**

The definition of AMF is the only difference. The former is based on a priori LNO_2 and LNO_x profiles while the later depends on NO_2 profiles which includes lightning production.

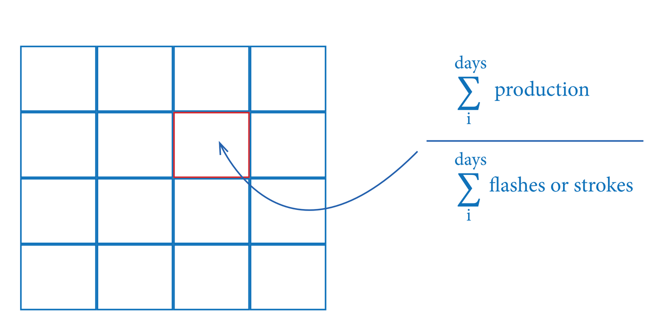
- **V_{LNOx} and $V_{LNO2Vis}$ distinguish LNO_x and LNO_2Vis from other sources respectively;**

TropVis, LNO_xVis, LNO_x, LNO_xClean, flashes and strokes are calculated for all 1° × 1° grids 2.4 h before OMI overpass time for each day.

Linear regression analysis



Summation analysis



$$\frac{\sum_i^{days} \text{production}}{\sum_i^{days} \text{flashes or strokes}}$$

Criteria

OMI: Cloud radiative fraction (CRF) ≥ 70%, 90% or 100%, Cloud pressure (CP) ≤ 650 hPa

Earth Networks Total Lightning Network (ENTLN):
Flashes ≥ 2400 per 1° × 1° grid, Strokes ≥ 8160 per 1° × 1° grid

WRF-Chem: $CF_{max[350 - 400 hPa]}$ ≥ 40%, LNO_2Vis/NO_2Vis ≥ 50%, Flashes >= 1000 (2.4 h before OMI overpass time)

Results

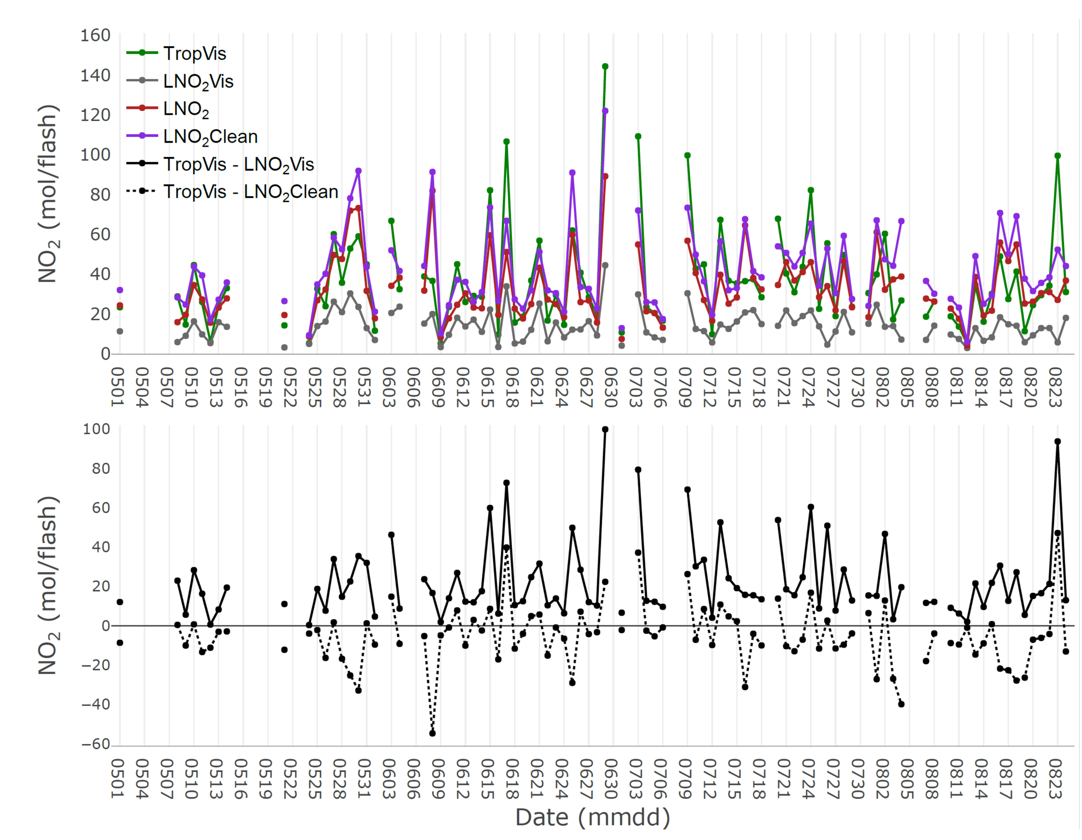


Figure 1. (top) Time series of TropVis, LNO2Vis, LNO2 and LNO2Clean production per day over the Continental U.S. for MJJA 2014 with CRF ≥ 70% and a flash threshold of 2400 flashes per 2.4 h. (bottom) Time series of differences between TropVis and LNO2Vis and differences between TropVis and LNO2Clean with CRF ≥ 70%.

- The new algorithm daily results (LNO_2, red) are mostly in the range from 20 to 80 mol per flash.
- LNO2Vis productions (grey) are **fewer** than LNO2 productions (red) which contain LNO2 **below the cloud**.
- The difference between TropVis production and LNO2Vis production (solid black) indicates how many **background NO2** exists above the cloud.
- TropVis and LNO_2Clean is more **sensitive** to background NO_2.
- The extent of the **overestimation** of TropVis is larger than that of LNO2Clean in polluted regions, while it is opposite in relatively clean regions.

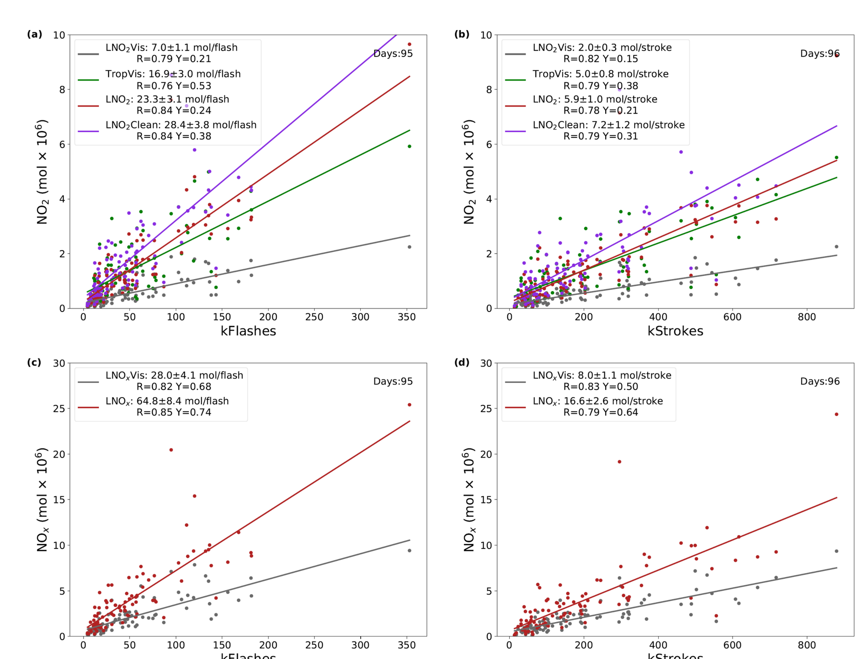


Figure 2. (a) Daily TropVis, LNO2Vis, LNO2 and LNO2Clean versus ENTLN total flashes data. (b) Same as (a) but for strokes. (c) Daily LNO_xVis and LNO_x versus total flashes. (d) Same as (c) but for strokes.

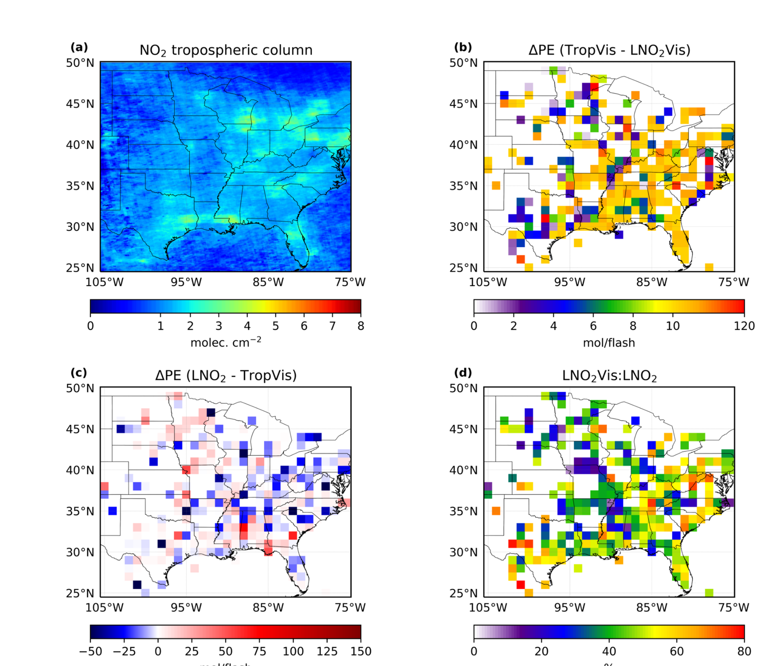


Figure 3. (a) Mean (MJJA 2014) NO2 tropospheric column. (b) and (c) Differences of mean LNO2 production efficiency with CRF ≥ 70% based on different methods. (d) The ratio of LNO2Vis to LNO2.

- For the linear regression analysis (Fig. 2), because the amount of polluted grid boxes is **fewer** than relatively clean parts, TropVis production is **smaller** than LNO2Clean production.
- LNO2 production is between LNO2Clean production and TropVis production, which coincides with the results in Fig. 1.
- TropVis **overestimates** production at **polluted** regions when compared with LNO_2Vis because of other sources above clouds (Fig. 3a and Fig. 3b).
- LNO_2 is larger than TropVis at most regions, which indicates that **LNO_2 below clouds** is more than other sources above clouds (Fig. 3c).
- The ratio of LNO2Vis to LNO2 ranges from 10% – 80% (Fig. 3d). This may be caused by the height of the clouds and the profile of LNO2. **Uncertainty** of production based on TropVis would be **higher at lower ratio** regions.

LNO2		**LNO_x**	
29 ± 13 mol/flash	**8 ± 4 mol/stroke**	**79 ± 36 mol/flash**	**22 ± 10 mol/stroke**

References

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