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

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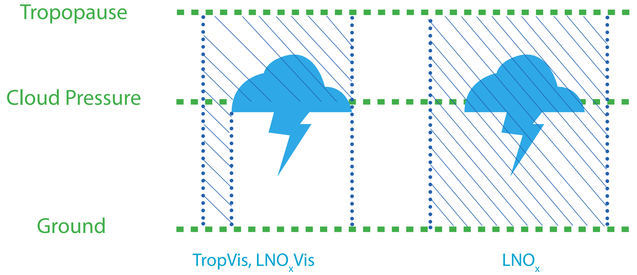
Photography encouraged

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



$$V_{LNOx} = \frac{S_{Trop}}{AMF_{LNOx}} \quad \begin{matrix} \leftarrow S - S_{Strat} \\ \leftarrow\!- - S_{Trop} / V_{LNOx} \end{matrix}$$

$$V_{LNOxKen} = \frac{S_{LNO2}}{AMF_{LNOxKen}} \quad \begin{matrix} \leftarrow S - S_{Strat} \\ \leftarrow\!- - S_{LNO2} / V_{LNOx} \end{matrix}$$

$$V_{LNO2Vis} = \frac{S_{Trop}}{AMF_{LNO2Vis}} \quad \begin{matrix} \leftarrow S - S_{Strat} \\ \leftarrow\!- - S_{Trop} / V_{LNO2Vis} \end{matrix}$$

$$V_{TropVis} = \frac{S_{Trop}}{AMF_{TropVis}} \quad \begin{matrix} \leftarrow S - S_{Strat} \\ \leftarrow\!- - S_{Trop} / V_{TropVis} \end{matrix}$$

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

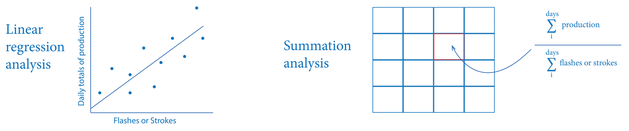
⟵: the Ozone Monitoring Instrument (OMI) data ← –: combined OMI and WRF-Chem data

- **$V_{LNOxKen}$ 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_2Vis, LNO_x, LNO_xKen, flashes and strokes are calculated for all 1° × 1° grids 2.4 h before OMI overpass time for each day.



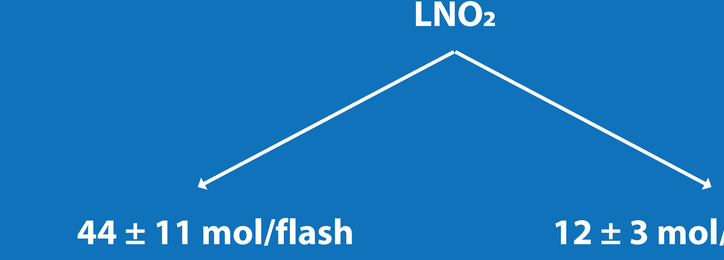
Criterion

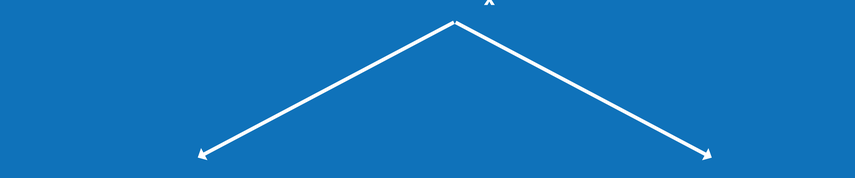
OMI: Cloud radiative fraction (CRF) ≥ 70% or 100%, Cloud pressure (CP) ≤ 650 hPa

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)

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.





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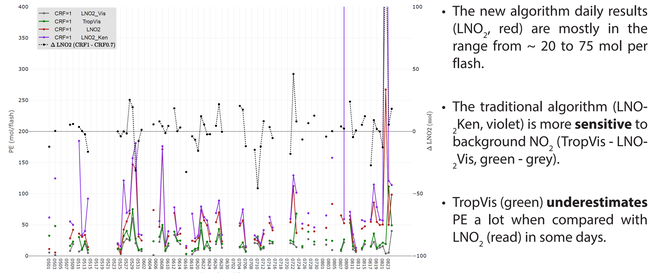
Results



- The new algorithm daily results (LNO_2, red) are mostly in the range from ~ 20 to 75 mol per flash.
- The traditional algorithm (LNO_2Ken, violet) is more **sensitive** to background NO_2 (TropVis - LNO_2Vis, green - grey).
- TropVis (green) **underestimates** PE a lot when compared with LNO_2 (read) in some days.

Figure 1. Time series plot of LNO_2Vis, TropVis, LNO_2 and LNO_2Ken productions per day over continental U.S. for MJJA 2014 with CRF ≥ 100% and a flash threshold of 2400 flashes per 2.4 h. Black dots are differences between LNO_2 with CRF ≥ 100% and LNO_2 with CRF ≥ 70%.

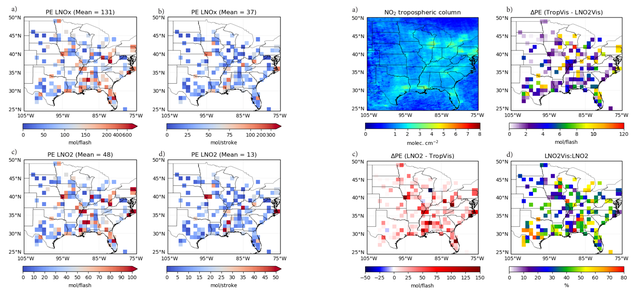
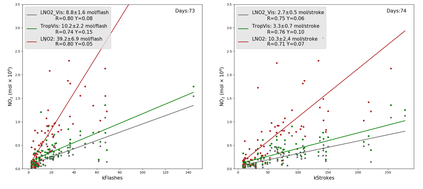


Figure 2. (a) and (c) Maps of 1° × 1° gridded values of mean LNO_x and LNO_2 production per flash with CRF ≥ 100% for MJJA 2014; (b) and (d) are as same as (a) and (c) except for stroke.

Figure 3. (a) Mean (MJJA 2014) NO_2 tropospheric column; (b) and (c) Differences of mean LNO_2 production per flash with CRF ≥ 100% based on different methods; (d) The ratio of LNO_2Vis to LNO_2.

- For the summation analysis (Fig. 2), the PE distribution based on flash is **different** from that based on stroke, which is related to the charge structure of thunderclouds.
- TropVis **overestimates** PE 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 LNO_2Vis to LNO_2 ranges from ~ 20% to 70% (Fig. 3d). **Uncertainty** of PE based on TropVis would be **higher at lower ratio** regions.



For the linear regression analysis:

- Similar to Fig. 3b, PE (slope) based on TropVis (**green**) is **larger** than that based on LNO_2Vis (**grey**).
- Similar to Fig. 3c, PE (slope) based on LNO_2 (**red**) is **larger** than that based on TropVis (**green**).

References

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Acknowledgments

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