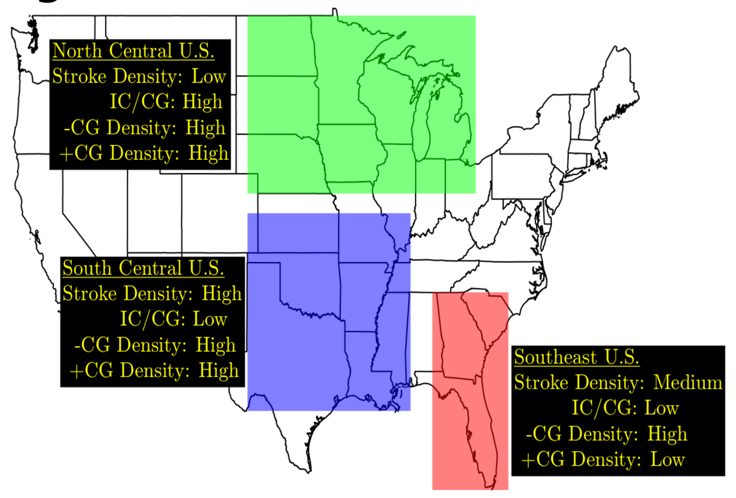
Variability in lightning NO_x production rates due to regional differences in lightning type and polarity

Jeff Lapierre[1,2] (jlapierre@earthnetworks.com), Joshua Laughner[3], Sally Pusede[2], William Koshak[4]
[1] Earth Networks, Germantown, MD, [2] University of Virginia, Charlottesville, VA, [3] University of California, Berkely, CA, [4] NASA Marshal Space Flight Center, Huntsville, Alabama

Introduction

- The concentration of nitrogen oxides (NO_x) largely controls the production of upper tropospheric (UT) ozone.
- Lightning contributes to as much as 70% of UT NO_x
- Current estimates of NO_x production range from ~10-10^3 mol NO_x per stroke. There remains disagreement as to whether cloud-to-ground (CG) strokes produce more or the same amount of NO_x per stroke as intracloud (IC) strokes
- We focus on three regions in the U.S. that typically exhibit specific lightning characteristics as illustrated below.



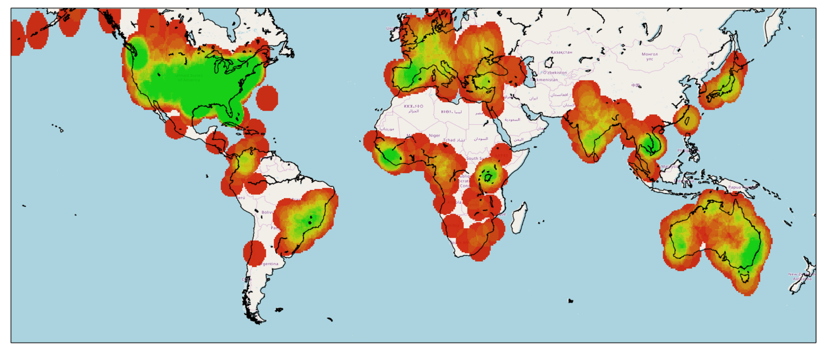
- **The goal of this study is to determine if regional variations in lightning characteristics play a dominant role in the large variational observations of LNO_x**

Data

- **Timeframe:** May - August 2014-15
- **Earth Networks Total Lightning Network (ENTLN)**

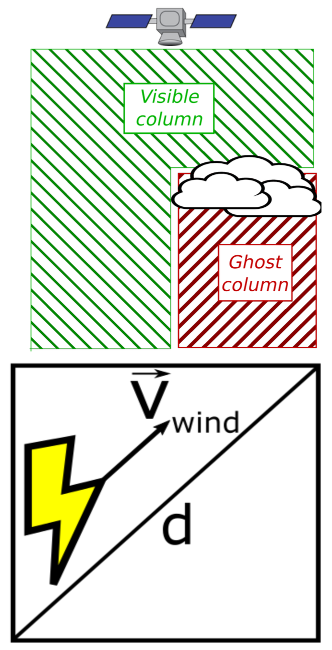
Global network that provides stroke time, location, type, and peak current

ENTLN Coverage



- **Berkely High Resolution (BEHR) product**
Daily Global Tropospheric NO_2 profiles from the Ozone Monitoring Instrument (OMI)
- **ECMWF Climate Reanalysis (ERA5)**
Hourly winds at 37 pressure levels and 31 km resolution accross North America

Methods

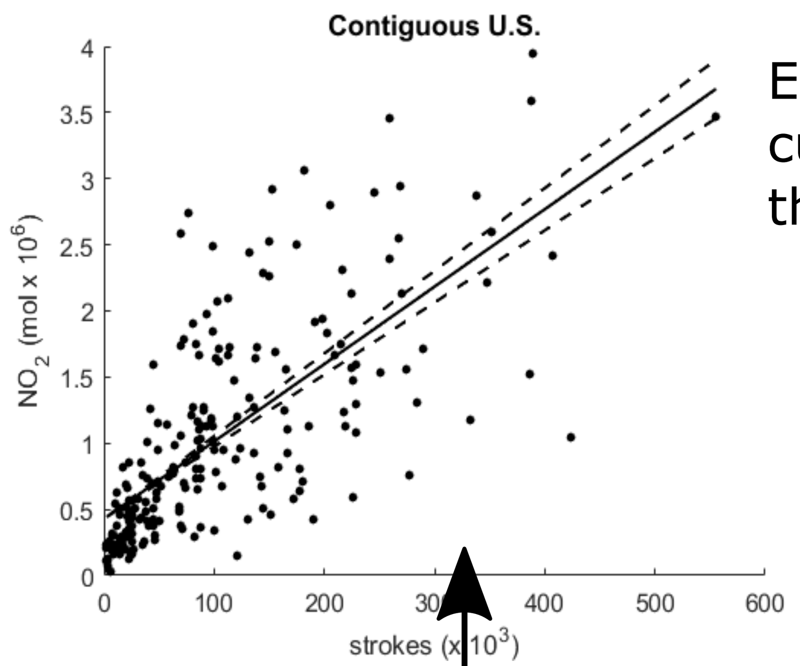


- We only use visible column data for high cloud radiative fraction (>70%). This acts as a filter for boundary layer NO_2 [1].
- Only want LNO_2 within a single pixel. We use the wind speed and cross pixel distance to determine the time window of pixel correlated LNO_2. For U.S., this is **2.4 hours**.
- Sum up NO_2 and # of strokes for all 1x1 degree pixels over entire region for each day.
- For Total (IC+CG) LNO_2 we find slope of NO_2 vs stroke #. For IC and CG LNO_2, we use linear regression to solve the equation below:

$$Total\ NO_2 = \#IC \times IC_{prod} + \#CG \times CG_{prod} + C$$

- We correct for NO_x lifetime near thunderstorms, which has been shown to be ~3 hours [2].
- NO:NO_2 is largely uncertain due to short lifetime of NO_x as well as O_3 production from lightning [3]. For this reason, we report results as NO_2 instead of NO_x. Approximate conversion: **LNO_x ~ LNO_2 x 10**

Results: U.S.



Estimated LNO2 using current data is ~25% lower than with stroke data.

LNO2 CG:IC 5.5

	US (mol NO_2 stroke^{-1})	
	Stroke	Current
Total	6.8 ± 0.4	5.2 ± 0.4
IC	5.5 ± 0.6	4.0 ± 0.6
CG	30.5 ± 9.1	22.2 ± 10.4

Results: Regions

	LNO_2 (mol NO_2 stroke^{-1})		
	SE	SC	NC
Total	4.3 ± 0.4	6.6 ± 0.7	5.0 ± 0.6
IC	2.5 ± 0.8	5.2 ± 1.3	3.8 ± 1.3
CG	42.3 ± 15.1	37.8 ± 25.0	36.2 ± 28.4
CG:IC	16.9	7.3	9.5

Red means highest of regions, blue means lowest.

Parameter	Region	Total	IC	CG
Stroke Density (# km^{-2})	SE	2.13	2.04	0.097
	SC	1.79	1.7	0.097
	NC	1.69	1.62	0.071
Stroke Current (kA stroke^{-1})	SE	4.2	3.1	24.3
	SC	5.3	3.9	27.3
	NC	4.9	4.1	20.5

Lightning Characteristics that match LNO_2 results:

- **SE:** Lowest total and IC stroke current.
- **SC:** Highest total stroke current
- **NC:** Lowest CG stroke density and stroke current

Conclusions

- We estimate an overall LNO_2 production of **6.8 mol NO_2 stroke^{-1}**, which is in agreement with current literature.
- **LNO_2 estimates using current data are consistently lower than for stroke data**. This may indicate that using stroke data overestimates LNO_2.
- We find that **CG strokes produce 5-17 times more LNO_2 than IC strokes**.
- **Regions in this study do show different LNO_2 results** and are partially explained by lightning characteristics. Variation between regions is ~30%. This does not completetly explain the large variation of LNO_x in the literature.

References

[1]Pickering, K. E., et. al. (2016). Estimates of lightning NOx production based on OMI NO2 observations over the Gulf of Mexico., doi:10.1002/2015JD024179.
[2]Nault, B. A., et. al. (2017). Lightning NOx Emissions: Reconciling Measured and Modeled Estimates With Updated NOx Chemistry. Geophysical Research Letters, doi: 10.1002/2017GL074436.
[3]Minschwaner, et. al. (2008). Observation of enhanced ozone in an electrically active storm over Socorro, NM: Implications for ozone production from corona discharges. doi: 10.1029/2007JD009500