Applications of GLM Data for National Climate Assessment (NCA) Studies

W. J. Koshak[1]

[1]Earth Science Branch, NASA Marshall Space Flight Center, Huntsville, AL USA.

Paper # AE11A-3181

1. OVERVIEW

The Geostationary Lightning Mapper (GLM) offers a new and exciting way to probe lightning/climate inter-relationships, and therefore supports the National Climate Assessment (NCA) program. In particular, there is a desire to use GLM to estimate lightning nitrogen oxides (LNOx) since trace quantities of NOx affect greenhouse gas concentrations (e.g., ozone).

2. RELATIVE ESTIMATES OF LNOx

LNO_x Production P in moles:

$$P = \left[\frac{Y}{N_A}\right] E = \left[\frac{Y}{\beta N_A}\right] Q \,, \qquad Q \text{ in Joules}$$

$Y \sim 10^{17}\ molecules\ J^{-1}$ (Thermochemical Yield)

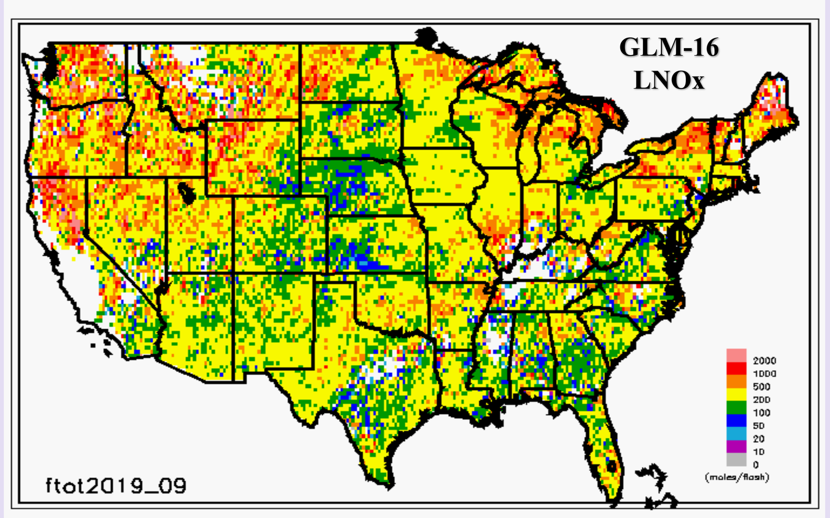
$N_A = 6.022 \times 10^{23}\ molecules\ mol^{-1}$ (Avogadro's Number)

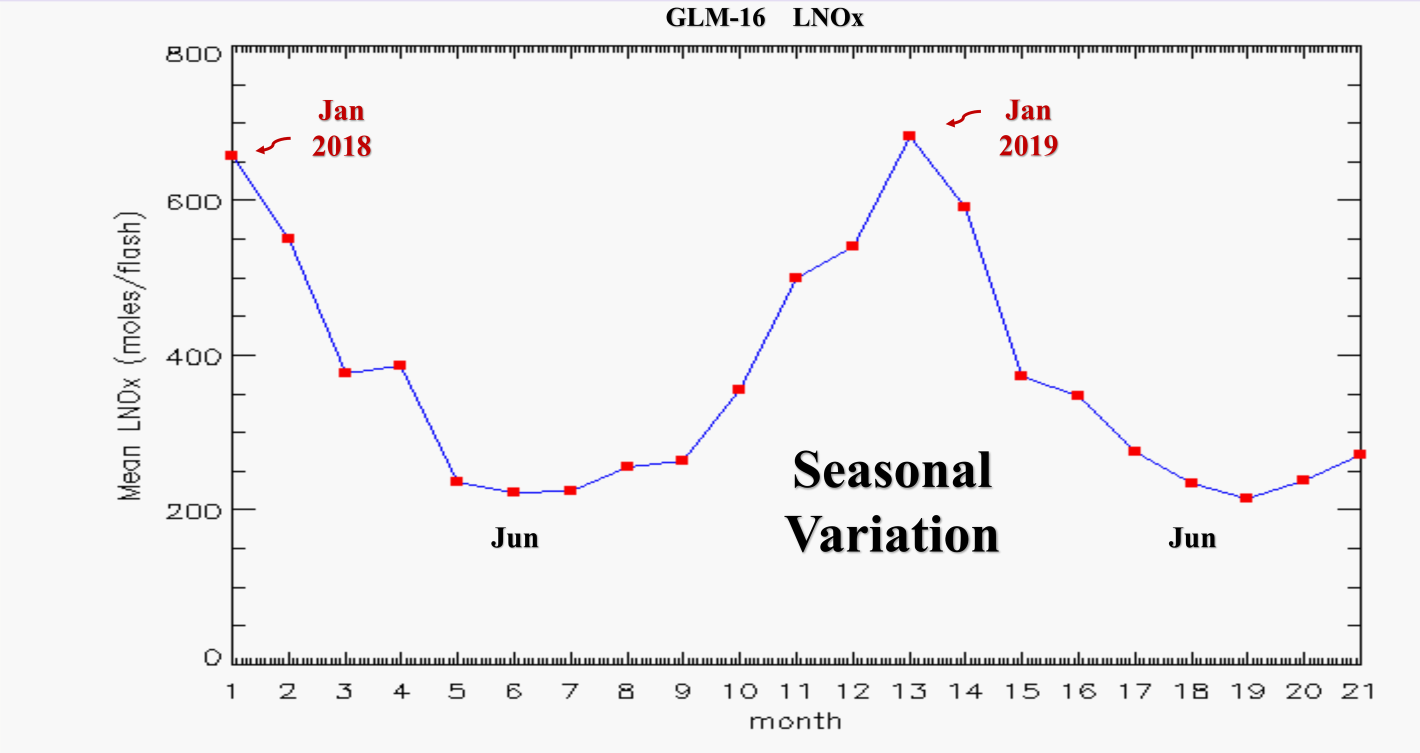
$\beta \sim 1.35997 \times 10^{-22} \Rightarrow$ ave $P = 250$ moles/flash over 1st 10 mo of 2018 reference year

Flash Energy E when $P = 250$ moles is:

$$E = \frac{N_A P}{Y} = 1,505,500,000\ J \sim 1.5\ GJ$$

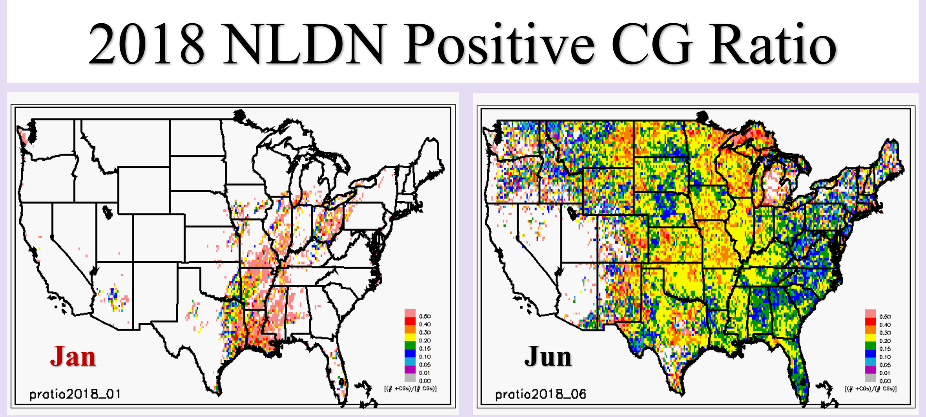
Geographical Variation
(sample month)



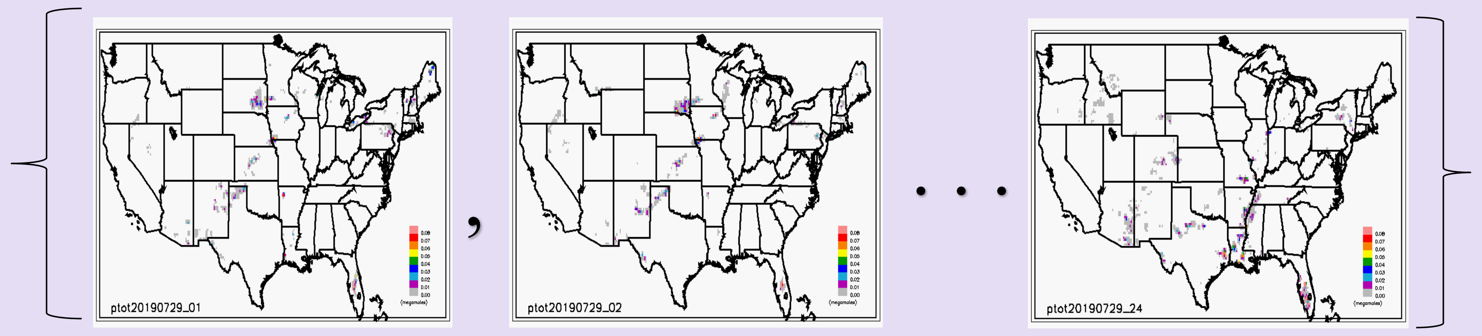


A Simple Model for Initial Insight:

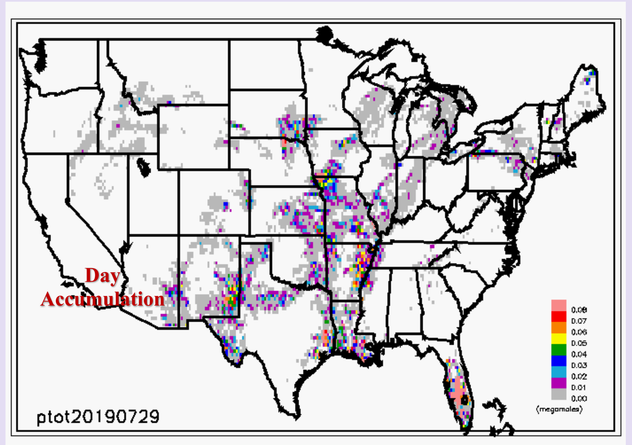
- LNOx production P is proportional to total flash energy E (good assumption).
- **GLM Flash Optical Energy Q** detected is proportional to E (reasonable assumption; cloud complicates) .
- Provides first GLM-estimates of LNOx (sample month shows **Geographical Variation**).
- **Seasonal Variation** shows peak in LNOx/flash in winter (shallower clouds, lower flash rates, higher +CGs ratio). Consistent with results found with TRMM/LIS over 17+ year period.
- Approach also useful for hourly **Air Quality Applications** (such as CMAQ ozone forecasts) .



Air Quality Applications

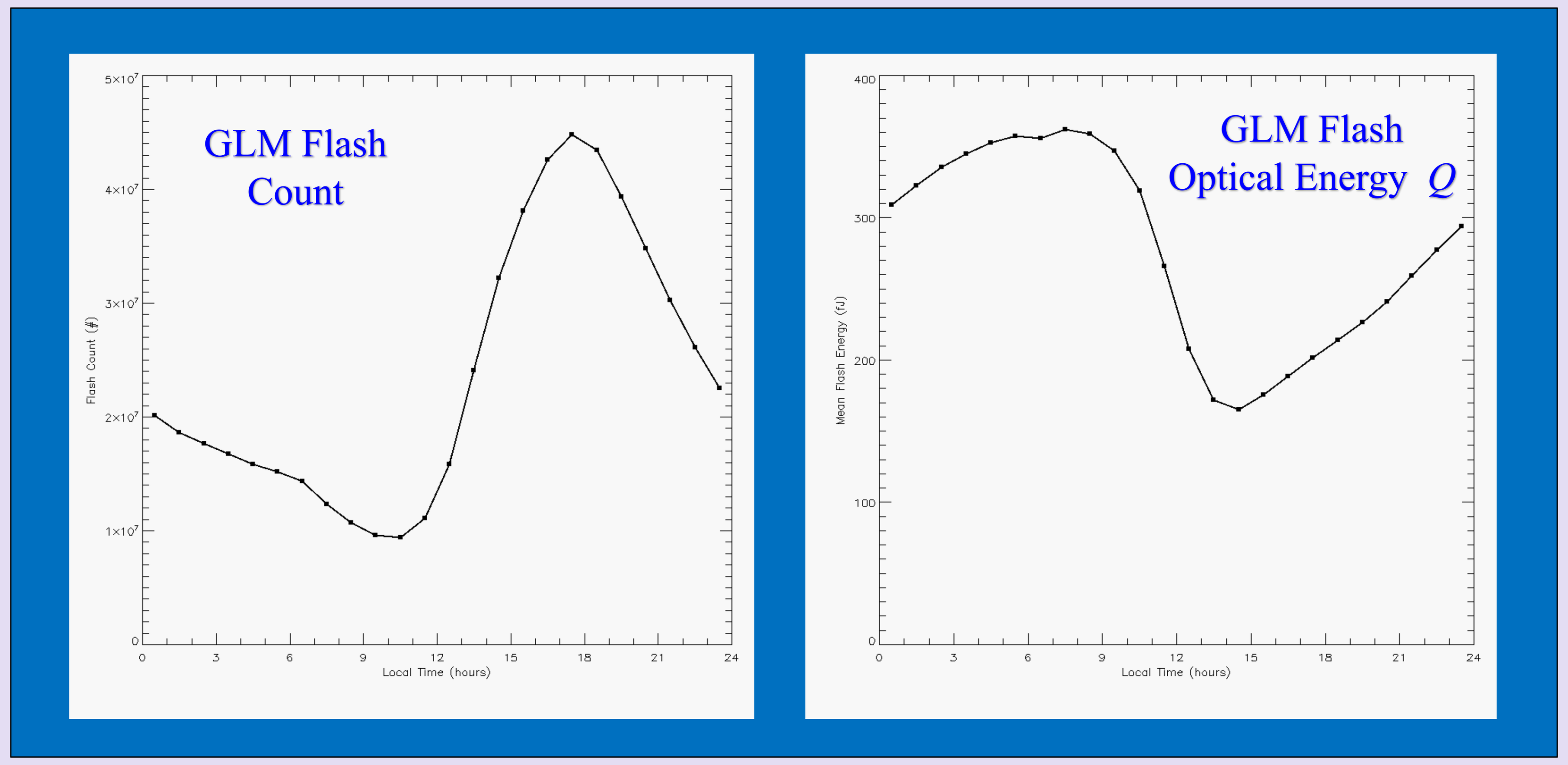


Hourly GLM LNOx Maps



Daily Map

3. DIURNAL VARIATIONS



An interesting result is that when flash count is low the optical energy per flash is high, and visa-versa. Consistent with Bruning & MacGorman (2013). Therefore, one expects **Diurnal Variation** in LNOx per flash.

Period: 1 Jan 2018 – 12 Aug 2019
Sample Size: 565M+ flashes

4. ABSOLUTE ESTIMATES OF LNOx (in progress)

As a thundercloud grows, Q likely decreases since:

- Cloud becomes optically thicker (cloud-top height H and graupel density ρ increase).
- Flash rate f increases, channel length L decreases (Bruning & MacGorman, 2013).

Q varies:

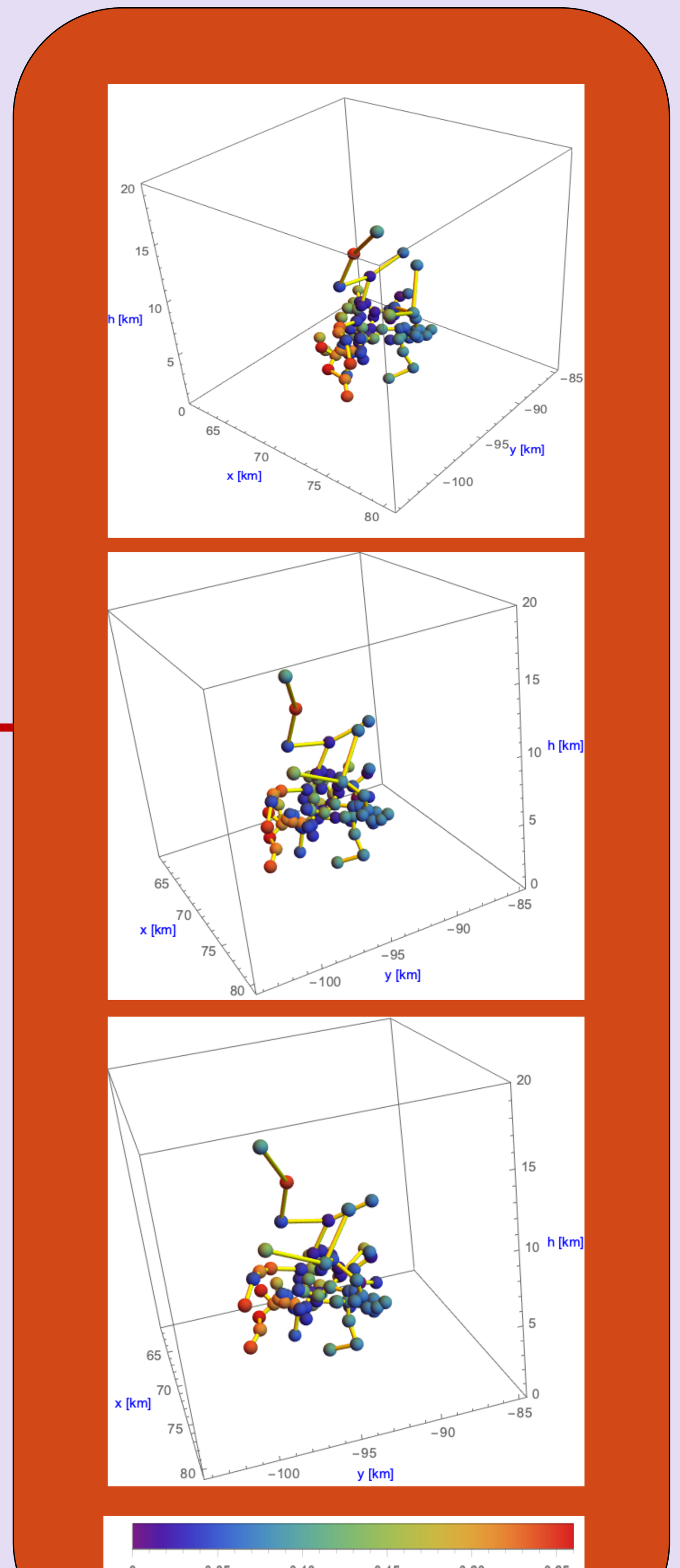
- Geographically (esp. land/ocean difference).
- Seasonally.
- Diurnally (see also Chronis & Koshak, 2017).
- with Storm Polarity (e.g., inverted Colorado storms).
- with Storm Severity (i.e., with +CG ratio).
- with Flash-type (CG, IC) & other flash specifics

Nvhf = 84
L (km) = 110.022
δ (sec) = 0.260351
Range (km) = 117.563
hmax (km) = 17.0602
hmin (km) = 1.3951

22 Dec 2013
1st VHF: 14:5:11.8945

Therefore, LNOx Production P estimates presently being developed by:

- Determining the empirical relationships between GLM observables (e.g., Q, flash area A, flash duration δ), and LMA-derived channel length L which is tied to LNOx production.
- Applying **Mathematica V12.0** to LMA data (Fig. to Right):
  - Graph Theory to find Spanning Tree computation of L.
  - 4D Rendering to closely examine physics.
- For example: $P = P[L(Q, A, \delta)$; location, season, local time, flash type] w/ flash type obtained from GLM using Koshak & Solakiewicz (2015).



5. REFERENCES

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2019 Fall American Geophysical Union (AGU) Meeting, San Francisco, CA December 9-13, 2019.