LNOx Estimates Directly from LIS Data

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1. BACKGROUND

Lightning nitrogen oxides (LNOx) are important because they indirectly influence our climate by controlling the concentration of ozone (O_3) and hydroxyl radicals (OH) in the atmosphere [Huntrieser et al., 1998]. In support of the National Climate Assessment (NCA) program, satellite Lightning Imaging Sensor (LIS; Christian et al. [1999]; Cecil et al. [2014]) lightning optical data is used to directly estimate LNOx production over the southern portion of the conterminous US for the 16 year period 1998-2013.

2. RETRIEVAL METHOD

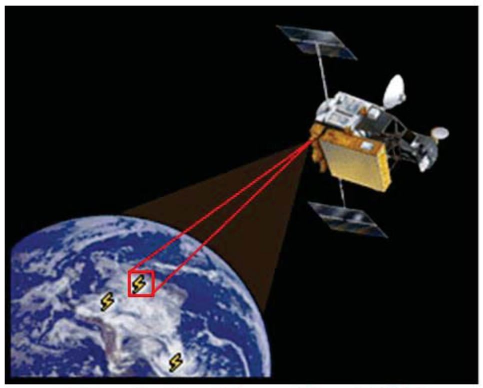
LIS measures a small fraction of flash energy from k^{th} flash:

$$\beta_k = \frac{Q_k}{E_k} = \frac{\text{LIS-detected Flash Optical Energy}}{\text{Total Energy of the Flash}}$$

Flash LNOx Production:

$$P_k = \frac{Y}{N_A} E_k = \frac{Y}{N_A}\frac{Q_k}{\beta_k} \sim \frac{Y}{N_A}\frac{Q_k}{\beta}$$

Yield: $Y \sim 10^{17}$ *molecules / J*
Fraction: $\beta \sim 1.87 \times 10^{-19}$
N_A = Avogadro's constant



LIS shown detecting optical energy Q_k from the k^{th} flash.

Total LNOx Production P_t in a Region:
(Sum over all N_o observed flashes & account for LIS detection efficiency and viewtime to extrapolate to total # flashes N_t)

$$P_t = \sum_{k=1}^{N_o} P_k + (N_t - N_o)\left(\frac{1}{N_o}\sum_{k=1}^{N_o} P_k\right)$$

Ancillary Details

$$Q_k = CA\Delta\lambda \sum_{i=1}^{m_k}\sum_{j=1}^{n_k}\left[\frac{a_{jk}\cos\alpha_{jk}}{r_{jk}^2}\right]\bar{\xi}_{ijk} = \text{LIS-detected optical energy of kth flash}$$

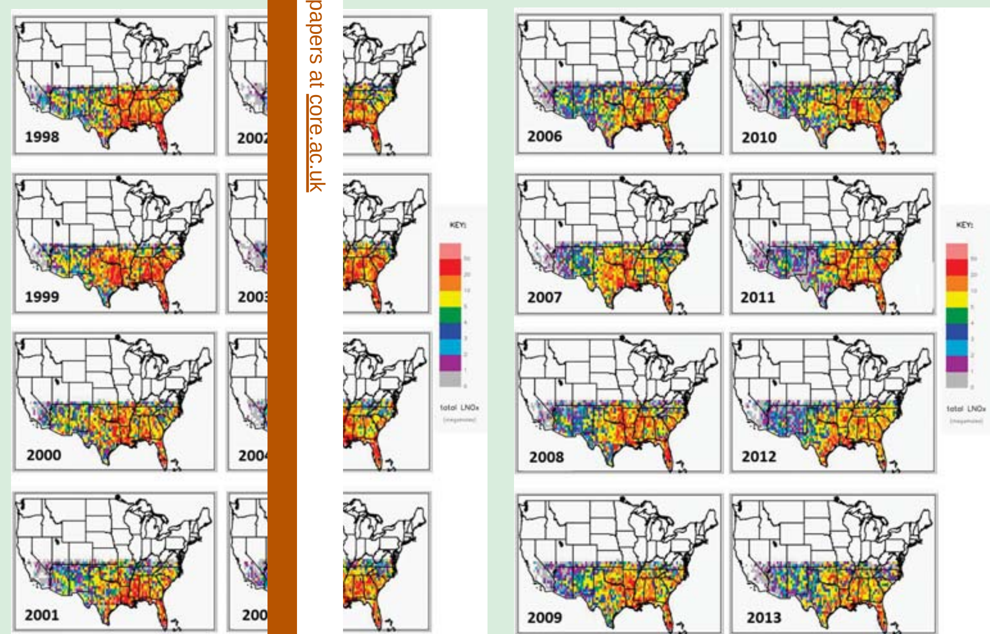
$$\alpha_{jk} = \sin^{-1}\left[\left(\frac{R+z}{R+H}\right)\sin\theta_{jk}\right] = \text{foreshortening angle}$$

$$r_{jk} = (R+H)\frac{\sin(\alpha_{jk}-\theta_{jk})}{\sin\theta_{jk}} = \text{range (from event footprint to LIS)}$$

R = Earth Radius, z = LIS orbital altitude, θ_{jk} = event boresight angle, C = conversion factor,
A = LIS entrance aperture area, $\Delta\lambda$ = LIS bandwidth, $\bar{\xi}_{ijk}$ = event energy density,
m_k = # frames occupied by kth flash, n_k = # pixels illuminated by kth flash,
a_{jk} = LIS event footprint area (in km^2).

3. GEOGRAPHICAL VARI S OF LNOx

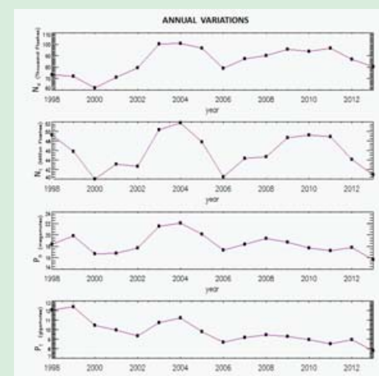
Annual geographical variations of the x production P_t described in the previous section are provided below. The value of beta has been calibrated so that the mean LNO n per flash in 1998 (the reference year) is 250 moles.



4. TREND OF SOUTHERN US LNOx

The trend in the total LNOx (summed the entire southern CONUS region) and associated flash provided here.
LIS is regarded as a very stable instru chler et al., 2014], but note that there appears to be a downw the LIS-inferred total LNOx production.. Additionally analy ded to insure that the trend is a real/natural occurrence.

Downward Tre LNOx



5. REFERENCES

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