Lightning-Related Indicators for National Climate Assessment (NCA) Studies

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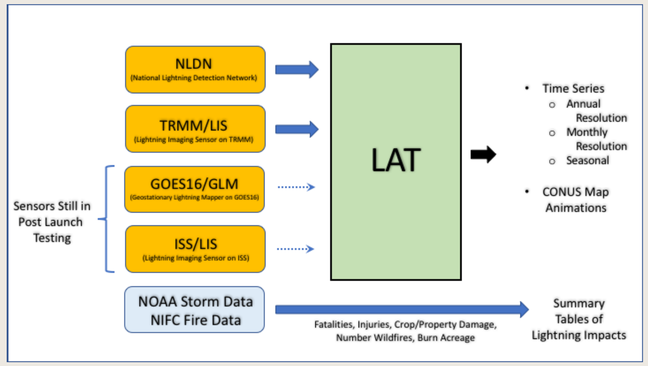
1. OVERVIEW

Changes in climate can affect the characteristics of lightning (e.g., number of flashes that occur in a region, return stroke current and multiplicity, polarity of charge deposited to ground, and the lightning cloud-top optical energy emission). The NASA/MSFC Lightning Analysis Tool (LAT) monitors these and other quantities in support of the National Climate Assessment (NCA) program. Changes in lightning characteristics lead to changes in lightning-caused impacts to humans (e.g., fatalities, injuries, crop/property damage, wildfires, airport delays, changes in air quality).

2. LIGHTNING ANALYSIS TOOL (LAT)



The LAT analyzes both ground- and space-based lightning data. It computes different types of lightning flash energy indicators derived from the space-based lightning observations, and demonstrates how these indicators can be used to estimate trends in lightning nitrogen oxides (LNOx) across the continental US. LNOx affect greenhouse gas concentrations such as ozone that influences changes in climate.

19 NLDN-derived Variables

```
;   NLDN  (nvar=19)
;       0  NUMALL:  CG count
;       1  NUMNEG: -CG count
;       2  NUMPOS: +CG count
;       3  PRATIO:  NUMPOS/NUMALL = +CG fraction
;       4  FLDALL:  CG flash density (#/km2)
;       5  FLDNEG: -CG flash density (#/km2)
;       6  FLDPOS: +CG flash density (#/km2)
;
;       7  PCURALL:  production of (absolute value)  CG peak current (kA)
;       8  PCURNEG:  production of (absolute value) -CG peak current (kA)
;       9  PCURPOS:  production of +CG peak current (kA)
;      10  PMULALL:  production of  CG multiplicity (# of strokes)
;      11  PMULNEG:  production of -CG multiplicity (# of negative strokes)
;      12  PMULPOS:  production of +CG multiplicity (# of positive strokes)
;
;      13  CURALL:  PCURALL/NUMALL = absolute value of  CG peak current per flash (kA/CG)
;      14  CURNEG:  PCURNEG/NUMNEG = absolute value of -CG peak current per flash (kA/-CG)
;      15  CURPOS:  PCURPOS/NUMPOS = +CG peak current per flash (kA/+CG)
;      16  MULALL:  PMULALL/NUMALL =  CG multiplicity (# strokes per CG)
;      17  MULNEG:  PMULNEG/NUMNEG = -CG multiplicity (# negative strokes per -CG)
;      18  MULPOS:  PMULPOS/NUMPOS = +CG multiplicity (# positive strokes per +CG)
```

15 LIS-derived Variables

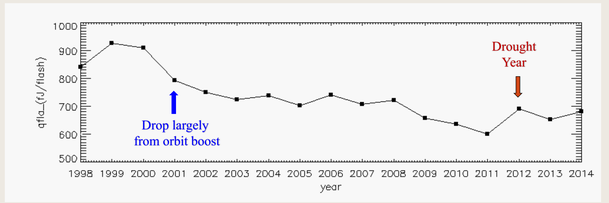
```
;   TRMM/LIS (nvar=15)
;       0  NRAW:  raw flash count (#)
;       1  NTOT:  total (i.e. DE & Viewtime Corrected) flash count (#)
;       2  JRAW:  NRAW/Area = Flash density from the nraw flashes (#/km2)
;       3  JTOT:  NTOT/Area = Flash density from the ntot flashes (#/km2)
;       4  VTIM:  LIS viewtime (hours)
;
;       5  QENG:  Q energy production from the nraw flashes (picoJoules)  ... pico = 1.0D-12
;       6  GENG:  G energy production from the nraw flashes (Joules)
;       7  QFLA:  Q energy/flash for the nraw flashes (femtoJoules/flash) ... femto = 1.0D-15
;       8  GFLA:  G energy/flash for the nraw flashes (milliJoules/flash) ... milli = 1.0D-03
;
;       9  PRAW:  LNOx production from the nraw flashes (kilomoles)
;      10  PTOT:  LNOx production from the ntot flashes (megamoles)
;      11  DRAW:  PRAW/Area = LNOx production density from the nraw flashes (moles/km2)
;      12  DTOT:  PTOT/Area = LNOx production density from the ntot flashes (moles/km2)
;      13  FRAW:  PRAW/NRAW = LNOx production per flash from the nraw flashes (moles/flash)
;      14  FTOT:  PTOT/NTOT = LNOx production per flash from the ntot flashes (moles/flash)
```

Recent Improvements to LAT:

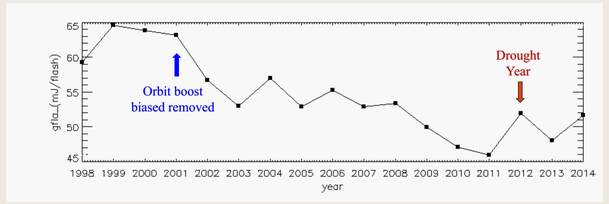
- Code generalized to admit GLM and ISS/LIS data ingests & processing.
- Employs new flash optical energy metric *G* that is invariant to sensor parameters (orbit altitude, entrance pupil area) … see LIS-derived variables (lower left list).
- TRMM/LIS lightning optical amplitudes were corrected for sensitivity roll-off with boresight angle incidence to lens system.
- Monthly resolution time-series plots added.
- Analysis period extended 1 yr (ie, thru 2014)

3. RECENT LAT RESULTS FOR TRMM/LIS

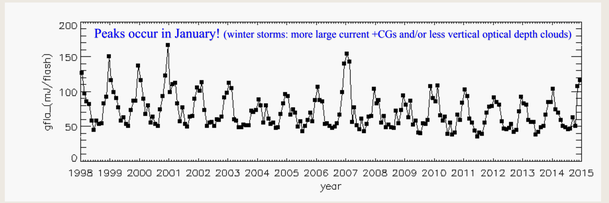
The LAT results provided below represent only a tiny fraction of all results obtained (i.e., there are time-series and CONUS maps for all 19 NLDN- and 15 LIS- derived variables shown in the listings in panel to the left). The results represent extensions and improvements to earlier LAT results provided in Koshak et al. (2015). For more details on how space-based flash optical energy is converted to LNOx estimates see Koshak (2017).



Trend in TRMM/LIS incident optical energy per flash, *Q*.



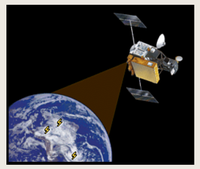
Trend in TRMM/LIS upward optical energy per flash, *G*.



Trend in *G* when the averaging is done over monthly intervals.

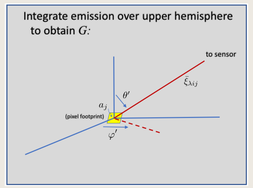
Incident Flash Optical Energy:

$$Q = \sum_{i=1}^{m}\sum_{j=1}^{n} A_j \Delta\lambda_j \Delta\omega_j \bar{\xi}_{\lambda ij}$$



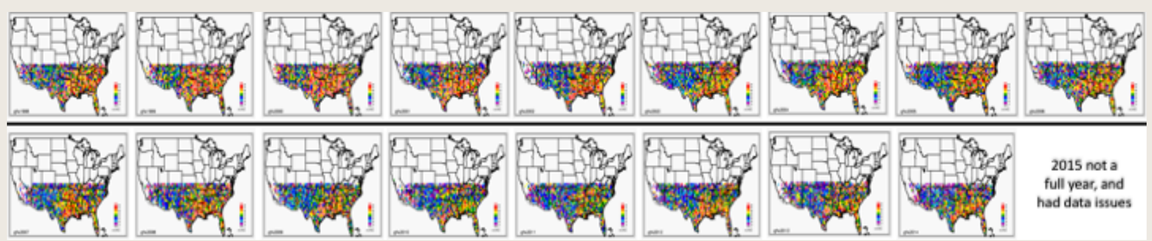
Upward Flash Optical Energy:

$$G = \Delta\lambda \sum_{i=1}^{m}\sum_{j=1}^{n} \pi \bar{\xi}_{\lambda ij} a_j$$



Summary:

- Confirmed downward trend in flash optical energy upto 2011, then upward turn.
- Interesting peak in energy/flash in January.
- *G* is an optimal parameter for LNOx estimation since invariant to orbit altitude.
- LAT greatly expanded & improved.



Geographical trend in *G*.

4. REFERENCES

Koshak, W. J., K. L. Cummins, D. E. Buechler, B. Vant-Hull, R. J. Blakeslee, E. R. Williams, H. S. Peterson, 2015: Variability of CONUS Lightning in 2003-12 and Associated Impacts, *J. Appl. Meteorol. Climatology*, **54**, No. 1, 15-41.

Koshak, W. J., 2017: Lightning NOx estimates from space-based lightning imagers, *16th Annual Community Modeling and Analysis System (CMAS) Conference*, Chapel Hill, NC, October 23-25.