Assessing Global Change Impact on the US Using National Lightning Data

National Climate Assessment PI Meeting
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Overview of Project Goals

Develop <u>Assessment Capabilities & Products</u> to monitor, quantify, and provide alerts of climate-induced changes in lightning, and resulting impacts:

- **Evaluate the Sensitivity of <u>Lightning Characteristics</u> to Climate Change**
  - lightning flash counts
  - peak return stroke current
  - multiplicity (# strokes per flash)
  - lightning nitrogen oxides (LNOx)
  - diurnal variations (counts, peak current)

- **Determine & Examine Lightning-Caused <u>Impacts</u> to Several Economic Sectors**
  - Human Health (lightning-caused injury/death)
  - Agriculture (lightning-caused crop damage)
  - Forestry (lightning-caused wildland fires)
  - Personal Property (lightning-caused personal property damage)

Achievement of Goals

- **Lightning Analysis Tool (LAT) Developed & Applied**
  A sustaining assessment tool that provides the assessment capabilities & products for monitoring climate-induced changes in lightning characteristics, and lightning impacts.

- **Science Results Discussed in:**
  - **Journal Articles**
    - Koshak, W. J., K. L. Cummins, D. E. Buechler, B. Vant-Hull, R. Blakeslee, E. R. Williams, and H. S. Peterson, Variability of CONUS Lightning in 2003-2012 and Associated Impacts, submitted to *J. Appl. Meteorol. & Climatol.*, 2014.
    - Chronis, T., R. Said, K. Cummins, W. Koshak, E. McCaul, E. Williams, G. Stano, and M. Grant, Climatological Diurnal Variation of CG Lightning Peak Current, submitted to *Geophys. Res. Lett.*, 2014.
  - **Conference Paper**
    - Koshak, W. J., B. Vant-Hull, E. W. McCaul, and H. S. Peterson, Variation of a Lightning NOx Indicator for National Climate Assessment , *International Conference on Atmospheric Electricity*, June, 2014.
  - **Book Chapter**
    - Koshak, W. J., Global Lightning Nitrogen Oxides Production, to appear in Chapter 19 of the upcoming 2nd edition of The Lightning Flash, editor Vernon Cooray, IEE Power & Energy Series.

Achievement of Goals (cont.)

Examined all upgrades to national lightning network.

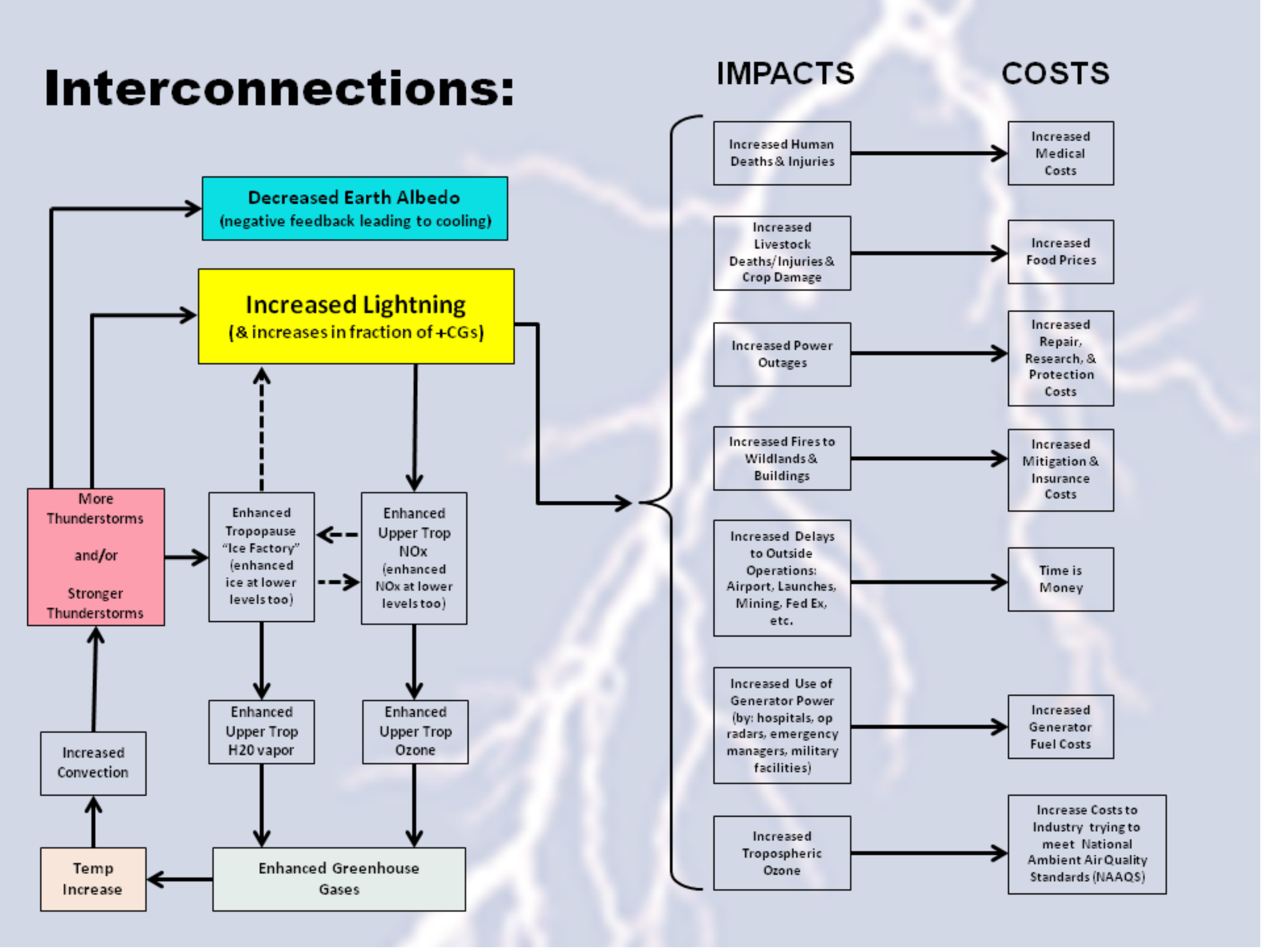
Only +CG multiplicity affected.

National Lightning Detection Network Upgrades

- **2002-2003** Upgrade (all sensors replaced w/new IMPACT-ESPs + 8 sensors added)
- **2004** Propagation Model Upgrade (increases peak current values)
- **2006** Sensor Addition Upgrade (2 sensors added SE of Florida)
- **2006** E-Field Waveform Detection Criteria Upgrade (short PTZ waveforms admitted to allow limited IC detection; increases CG count but some are cloud flashes)
- **2006** 15kA Rule Upgrade (no effect since already accounted for)
- **2008** Location Algorithm Upgrade (extend range to offshore & N. Mexico)
- **2008** Duplicate/Misplaced Events Upgrade (improvements in removing these)
- **2011-2012** Upgrade to LS7001 Sensors (appropriately decreases +CG multiplicity)

Achievement of Goals (cont.)

Surveyed & compiled main interconnections.

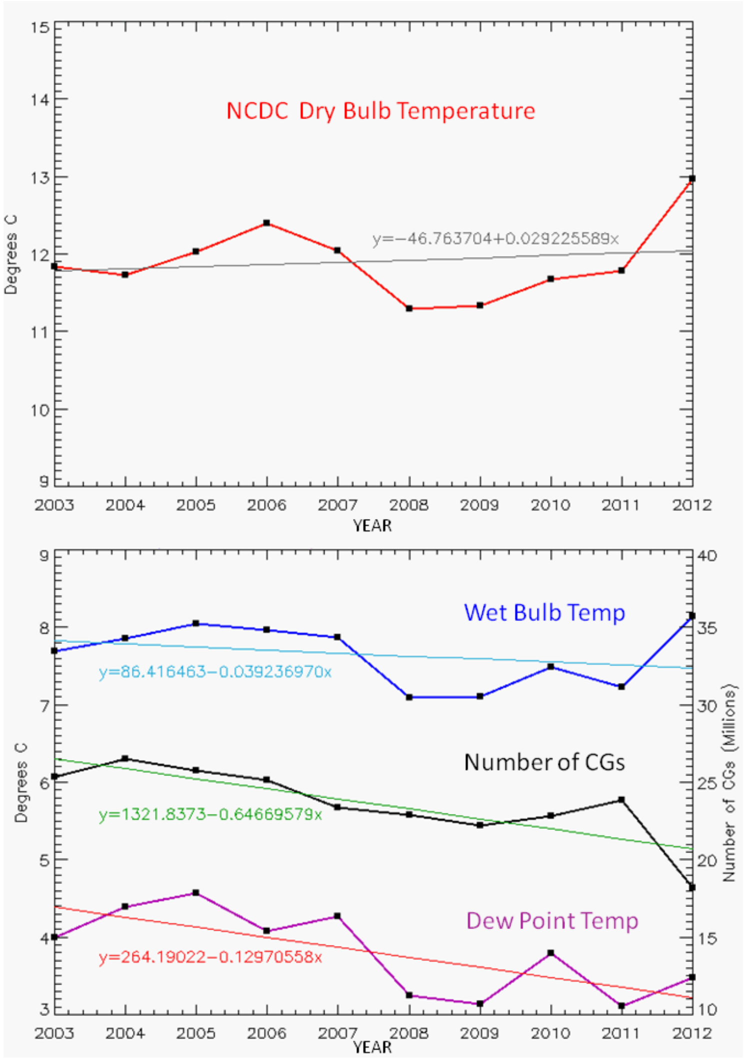


Achievement of Goals (cont.)

Found that CG lightning is decreasing!

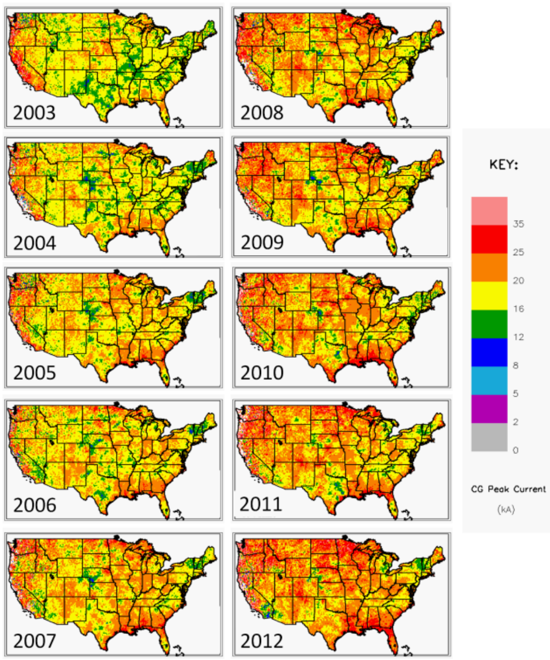
Why does CG lightning drop by 12.8% when T is trending up?

Answer: Lightning needs heat & moisture. So use long-term Tw (instead of T) to obtain positive correlation.

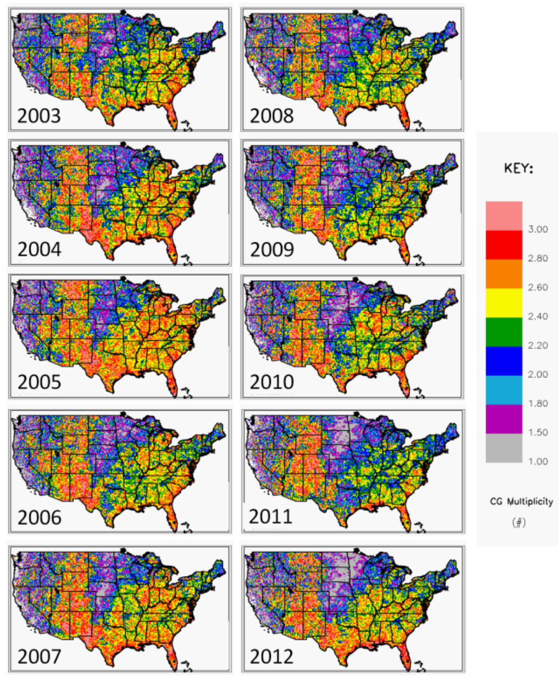


Achievement of Goals (cont.)

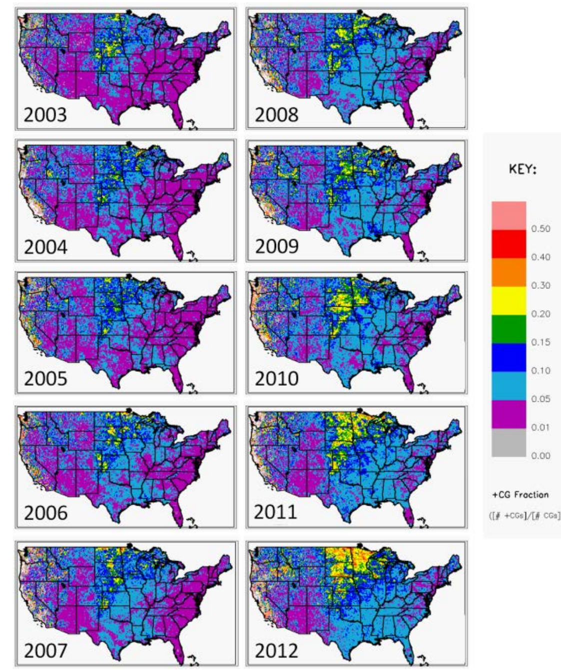
CG peak current up by 8.0%



CG multiplicity down by 4.1%



Fraction of +CGs up by 41.5%



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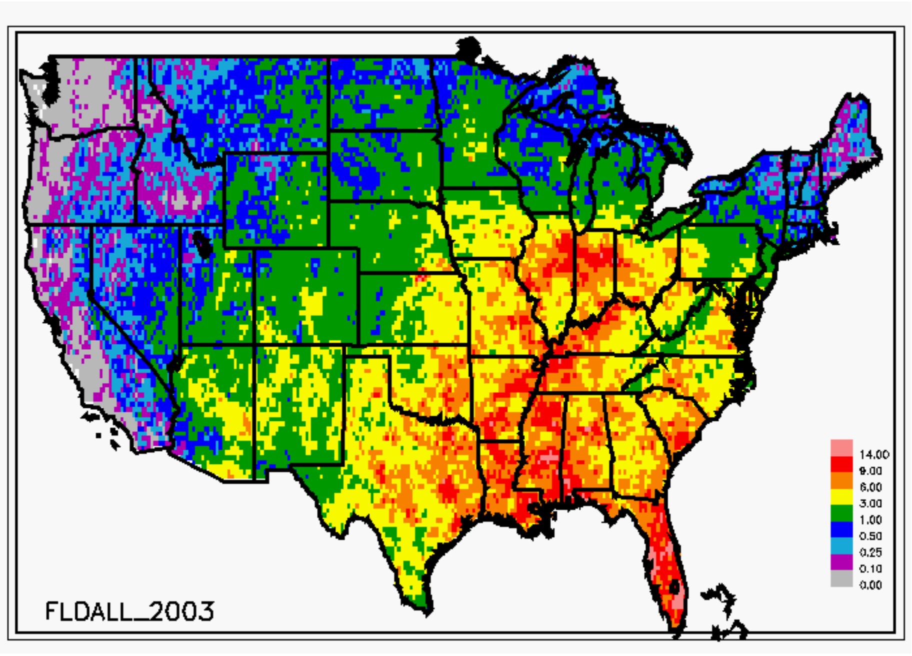
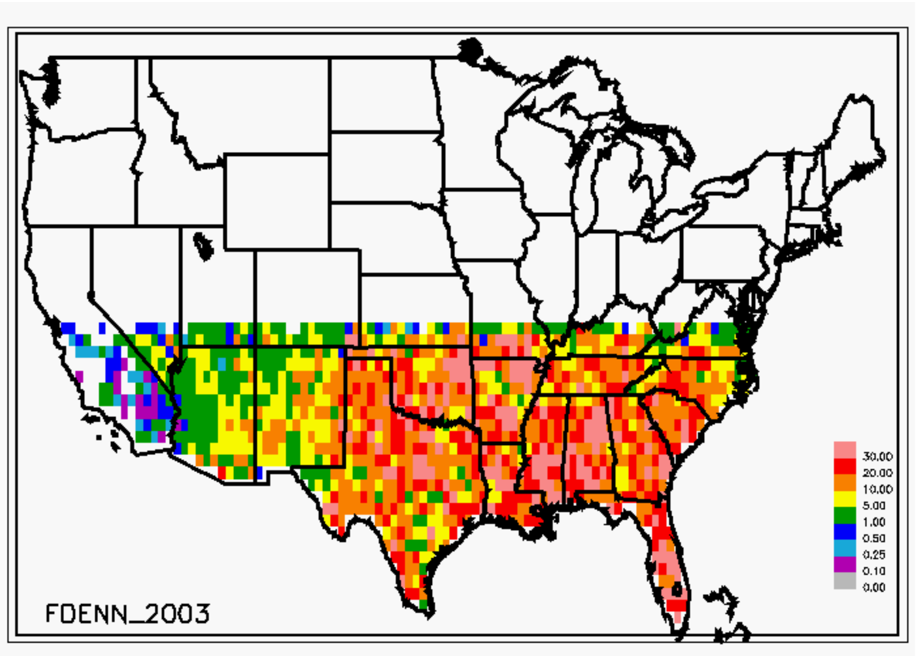
NLDN Flash Density (2003-2012)



LIS Flash Density (2003-2012)



Compared CGs to total lightning from LIS

Year	NLDN	LIS (Raw)	LIS (DE & VT Corrected)
2003	25,312,151	100,090	50,435,202
2004	26,515,549	100,695	51,831,376
2005	25,733,836	96,522	47,837,176
2006	25,110,025	78,787	40,511,787
2007	23,350,168	87,181	44,373,486
2008	22,888,321	90,307	44,772,072
2009	22,233,574	95,793	48,724,951
2010	22,793,791	93,751	49,250,190
2011	23,825,025	96,680	48,989,029
2012	18,192,183	86,766	44,139,720

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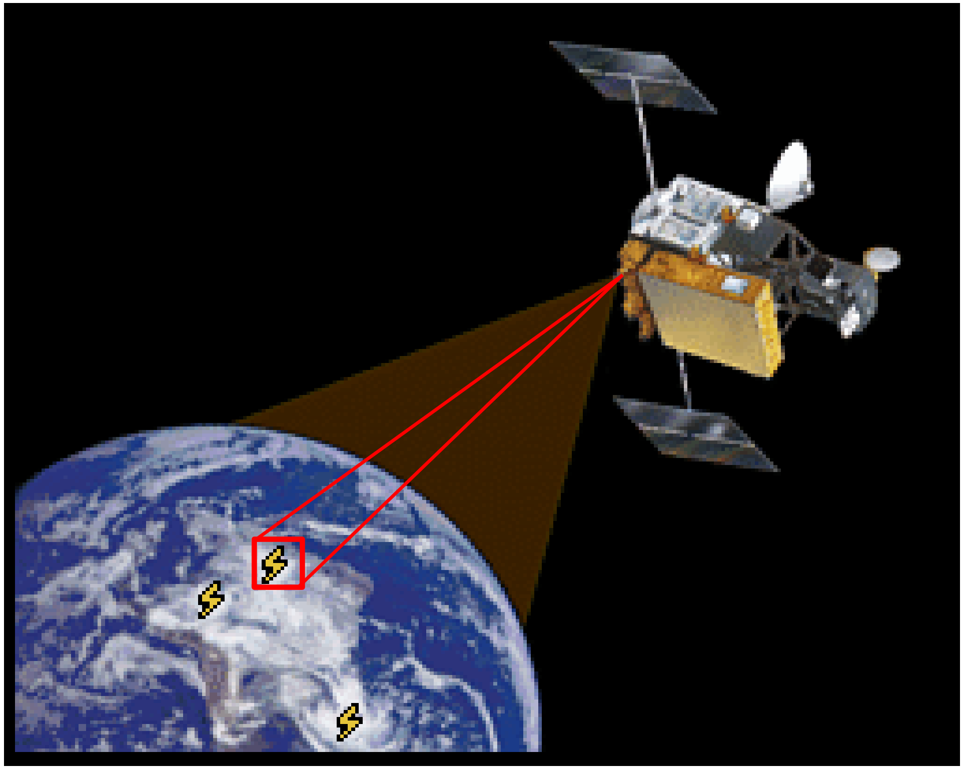
Achievement of Goals (cont.)

Significant Challenge!
Wanted to go beyond the simple Lightning NOx Indicator

$$\mathrm{LNI} = \sum_{i=1}^{N} A_i B_i \quad .$$

Solution:
Derived a way to use TRMM/LIS data to estimate flash energy and then convert this energy to Lightning NOx Production P.

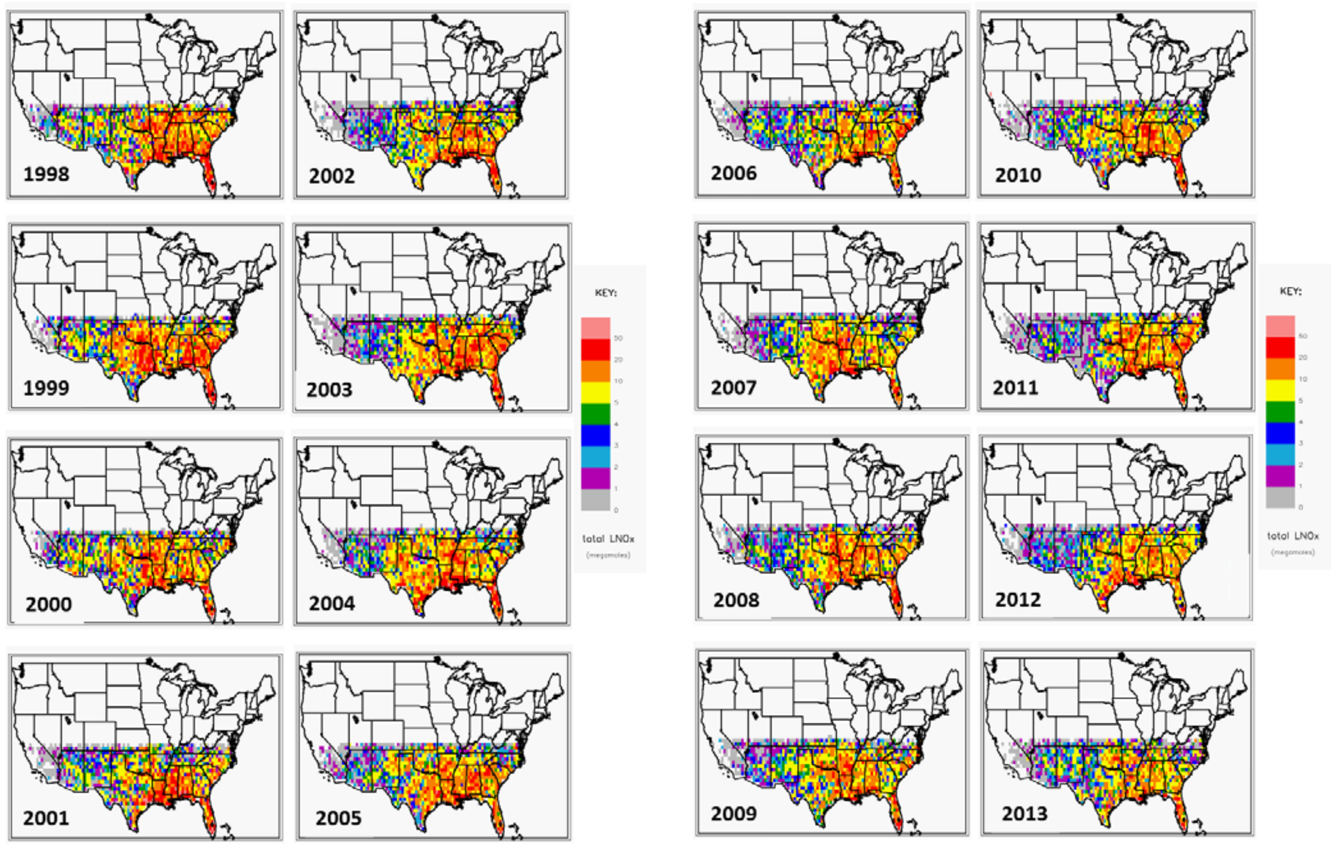


Lightning Nitrogen Oxides (LNOx) affect greenhouse gases & hence climate.

$$P = \sum_{k=1}^{N_O} P_k + N_u \left(\frac{1}{N_o} \sum_{k=1}^{N_o} P_k \right) \quad , \qquad P_k = \frac{CYA\Delta\lambda}{\beta N_A} \sum_{i=1}^{m_k} \sum_{j=1}^{n_k} \left[\frac{a_{jk} \cos \alpha_{jk}}{r_{jk}^2} \right] \bar{\xi}_{\lambda ijk}$$

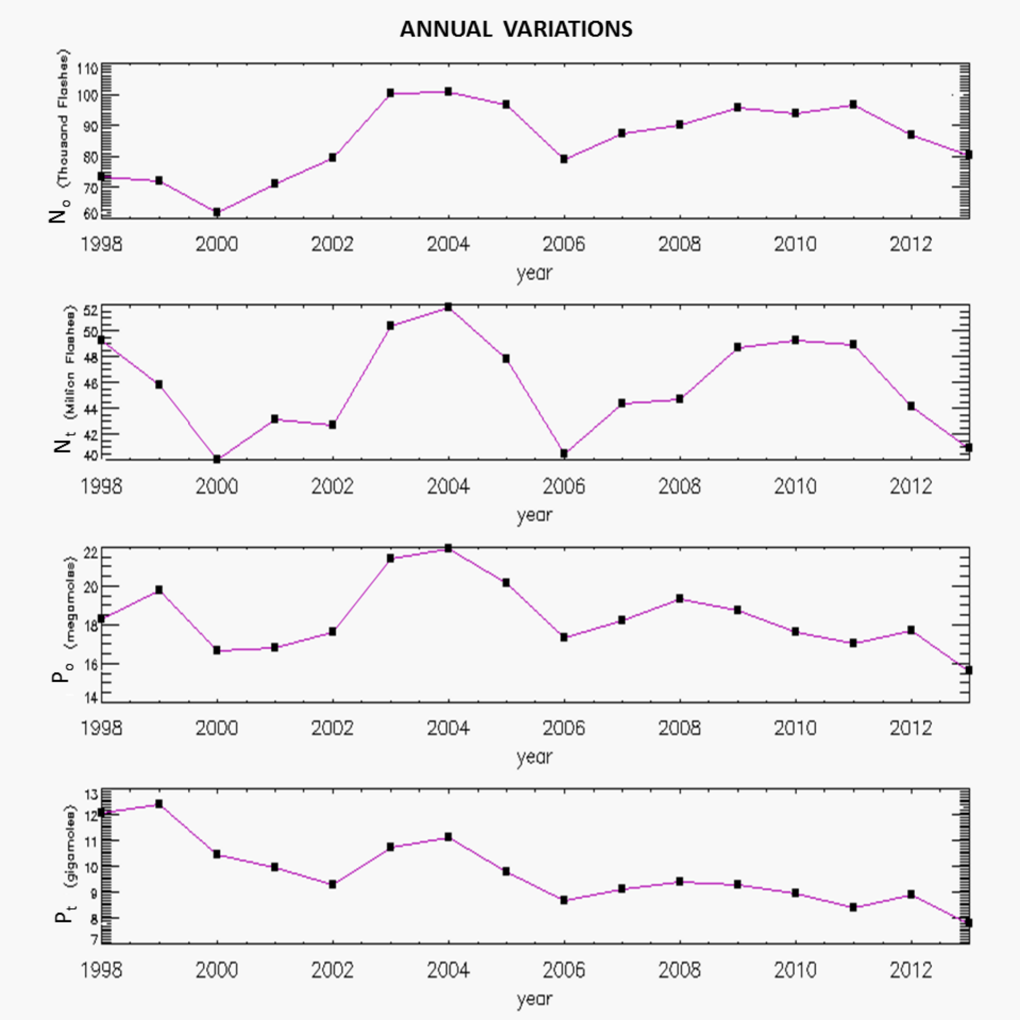
Achievement of Goals (cont.)

Obtained
LIS-inferred
LNOx
1998-2013
(megamoles)



Achievement of Goals (cont.)

Obtained LIS-Inferred Flash Count & LNOx 1998-2013



LNOx is dropping

Achievement of Goals (cont.)

Completed Assessment of Climate-Induced Changes in CG Lightning-Caused Impacts.

$$\text{Sensitivity} = \frac{\partial I}{\partial T_w} = \frac{\partial I}{\partial N}\frac{\partial N}{\partial T_w}$$

$$I = \text{Impact to a Sector}$$

$$N = \text{CG Lightning Count}$$

$$T_w = \text{Wet-Bulb Temperature}$$

Human Health

Fatalities: 13.7 deaths/°C

Injuries: 85.4 injuries/°C

Agriculture

Crop Damage: $63,198/°C

Personal Property

Homeowners Insurance Claims: $367.3M/°C

Forestry

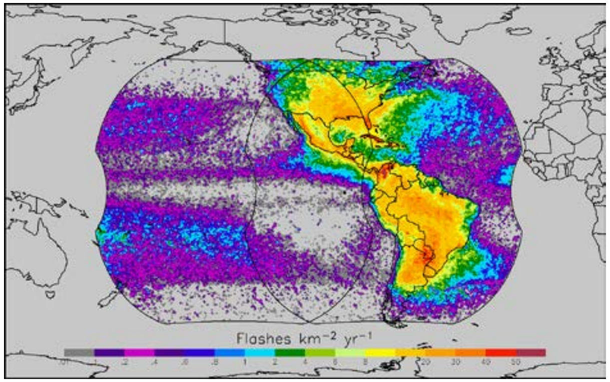
Wildfires (number): 4158/°C

Wildfires (acres): 1.2M/°C

Future Evolution & Benefits

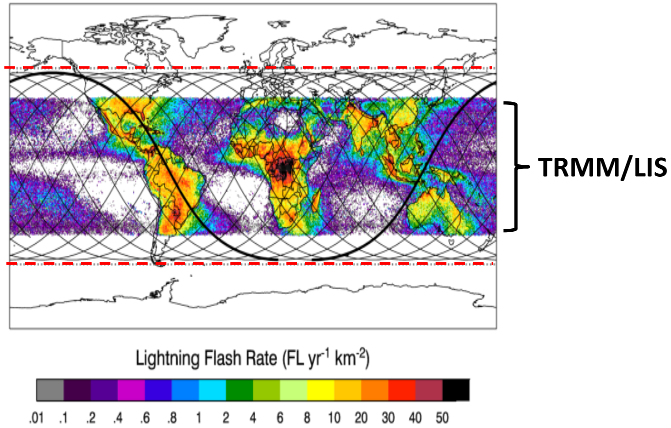
- **Employ GOES-R Geostationary Lightning Mapper (GLM) Data**
  - Launch early 2016.
  - Offers continuous monitoring of total lightning over all of CONUS.
  - Data will be implemented into this project's Lightning Analysis Tool (LAT) for NCA studies.
  - Will apply LNOx production *P* equation for improved (i.e. continuous) LNOx monitoring.

GLM field-of-view (East park better)



- **Employ International Space Station Lightning Imaging Sensor (ISS/LIS) Data**
  - Launch early 2016.
  - Views all of CONUS (TRMM/LIS only up to 38°N).
  - Data will be implemented into this project's Lightning Analysis Tool (LAT) for NCA studies.
  - Will apply LNOx production *P* equation for improved & cross-sensor LNOx monitoring.

ISS/LIS field-of-view (red-dotted)



… Present NCA work represents important preparation & proving ground for analyzing these future data!

User Community & Decision Makers

- **Chattanooga Hamilton County Air Pollution Bureau**
  - Address: 6125 Preservation Dr, Chattanooga, TN 37416.
  - Monitors Air Quality, and proceeds with enforcement actions if air quality violations are determined.
- **Point-Of-Contact**
  - Kathy Jones – Air Monitoring Manager.
  - She would like to know better to what extent ozone exceedances are attributable to lightning.

Sample of Jone's estimates of lightning-caused exceedances
… but desire is to improve accuracy of these analyses.

OZONE	Exceedance of 75 STD 8-Hour		Association with Significant Lightning
2012			
June 28-July 1	Yes		Yes
2011			
June 7, 8	Yes		No
August 17,18	Yes		No
September 2	Yes		No
2010			
May 5,6	Yes		No
April 2	No	Day before	Yes
April 13,14	Yes		Yes for 4/14
August 4	Yes		Yes
August 10,11	Yes		Yes
September 15	Yes		No
2009			
March 22,23	No		No
April 9	No		Yes for 4/10
June 1,2	Yes		Yes
August 7	No		Yes
June 25, 26	No		Yes
2008			
June 25	Yes		No- West of Chatt
July 18,19	Yes		No-West of Chatt
August 4	Yes	Day Before	Some
August 19	Yes	Day Before	Some

User Community & Decision Makers (cont.)

- **Harpeth Valley Utilities District**
  - Address: 5838 River Road, Nashville, TN 37209
  - Serves the water and wastewater needs of customers in portions of Davidson, Williamson and Cheatham counties.
  - Provides water service to more than 16,000 customers and wastewater service to more than 13,000 customers.
  - Over eight billion gallons of drinking water pumped per year.
  - 385+ miles of drinking water lines in place
  - **When storms approach they switch to generator power. Power outage due to lightning stops service pumps producing large water pressure gradients that bust water lines.**

- **Point-of-Contact**
  - Kevin Snider – Engineer Technician.
  - He would like more lightning data/statistics to better prepare for lightning, and avoid turning on generator power when possible … for cost savings.

Thank You !