
20+ Years of Cloud-to-ground Lightning Observations in the U.S., and Comparison with Climatological Co-variates

Kenneth L. Cummins^{1,4}



Michael K. Tippett²



William J. Koshak³

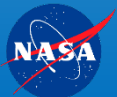


¹University of Arizona, Tucson, Arizona

⁴Florida Institute of Technology, Melbourne, Florida

²Department of Applied Physics and Applied Mathematics, Columbia University, New York, New York

³NASA Marshall Space Flight Center, Huntsville, Alabama



ILDC/ILMC ILDC/ILMC March 2018

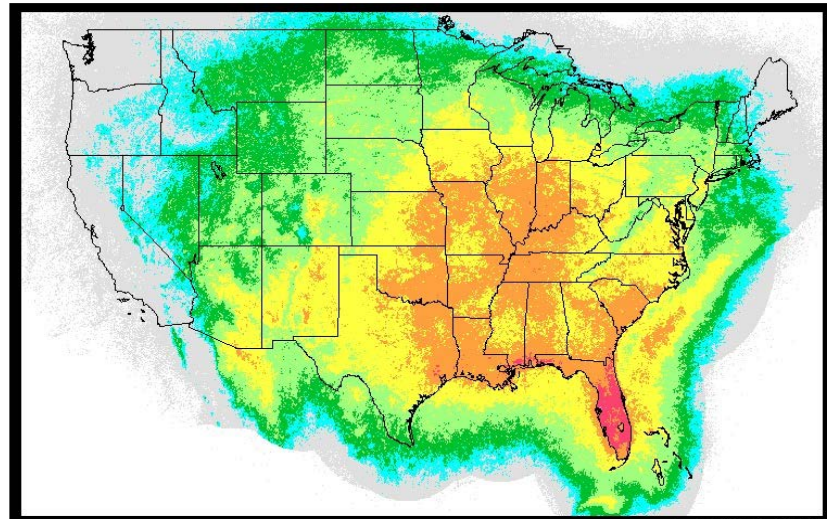


Why This Topic Now?

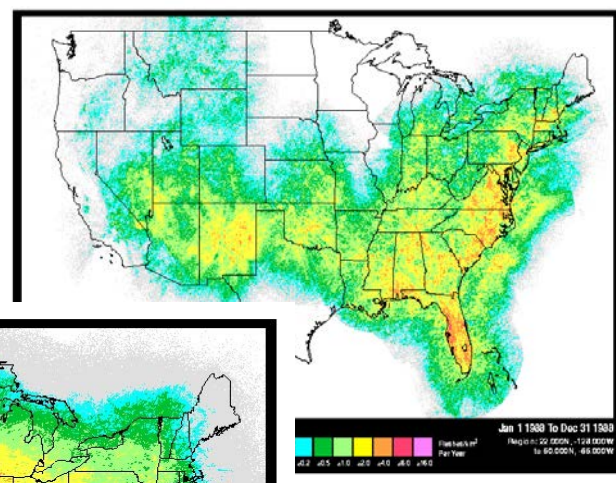
- ▶ We are working to make CG lightning incidence and impacts a part of the National Climate Assessment (NCA)
 - Koshak et al., 2015 – (referenced in our abstract)
- ▶ NLDN provides the longest time-contiguous, wide-area (CONUS) CG lightning dataset
 - twice the duration of most decadal variations
 - long enough to assess year-to-year temporal correlations
- ▶ Lots of changes to the NLDN over the last 23 years
 - We need to correct for network effects in order to tease-out underlying weather and climate variation

Evolution Towards a National Network

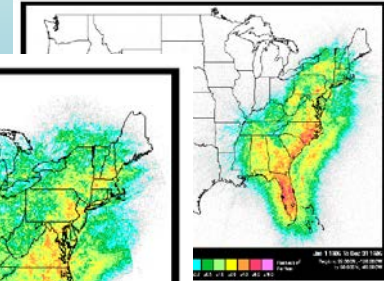
1995...



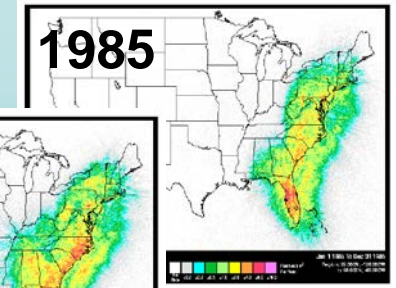
1988



1987



1985



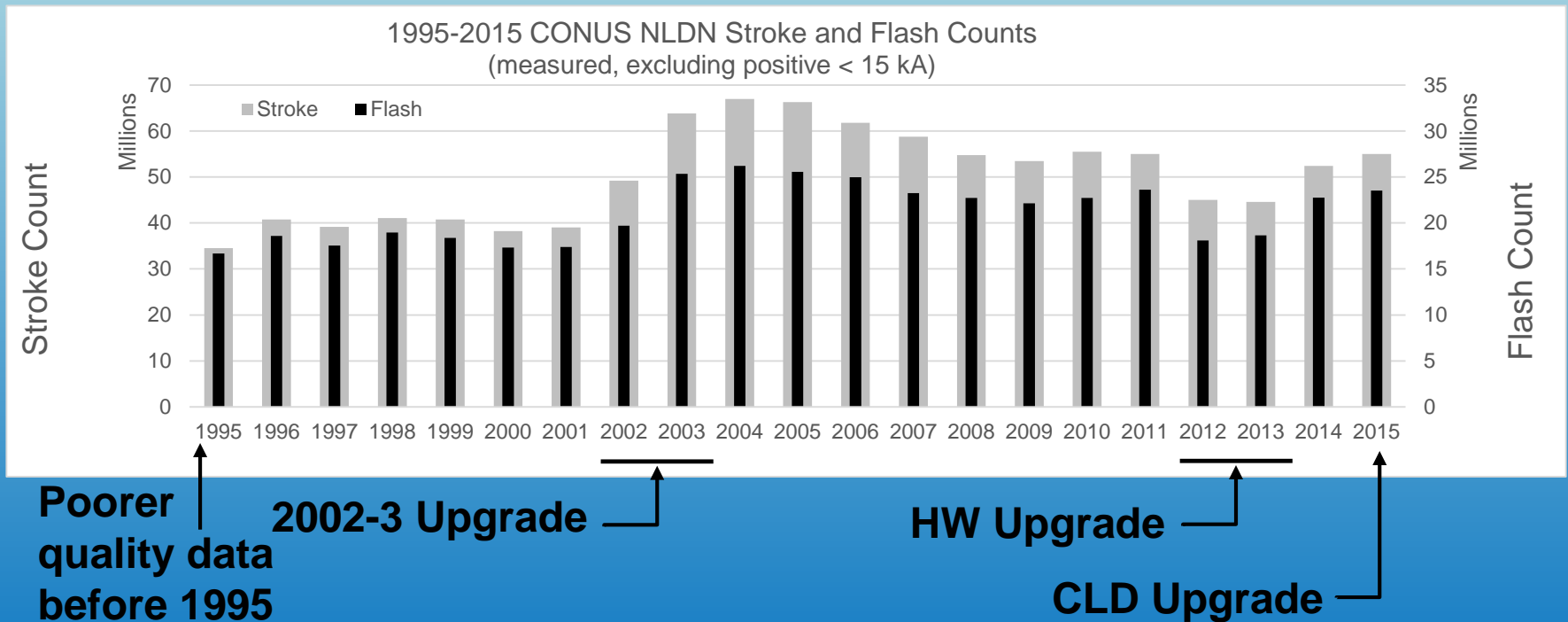
SUNYA
LLP
NSF

SUNYA
NASA
EPRI

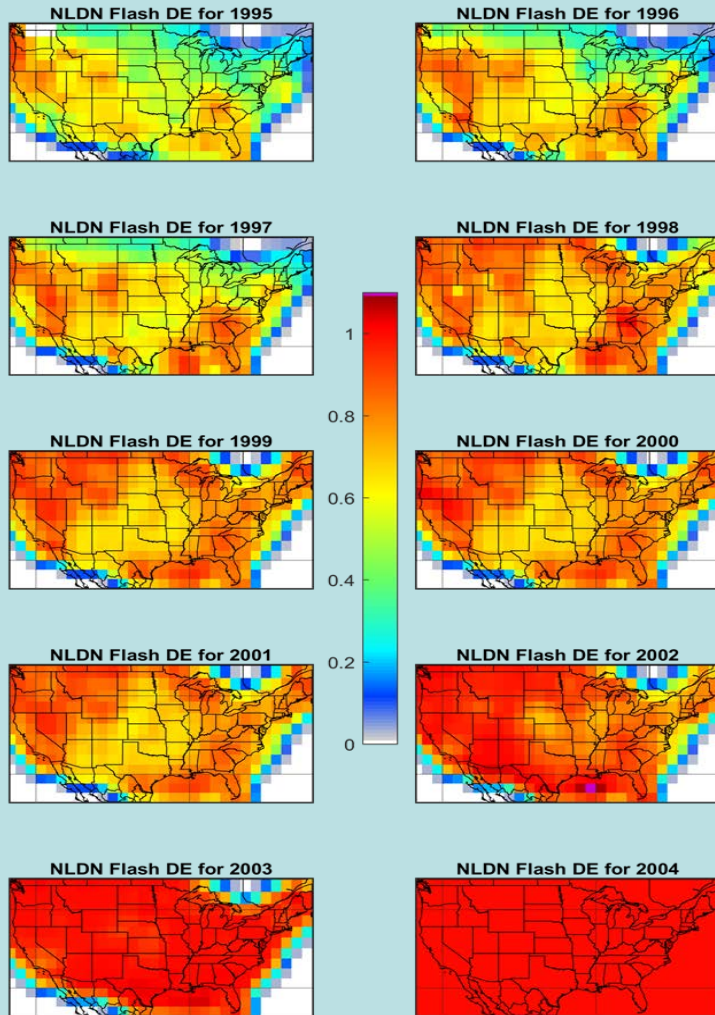
NOAA
EPRI
RSCAN/ARSI
LLP/GDS
ARSI
Global Atmospherics

Background/Motivation

- ▶ Quality control of NLDN cloud-to-ground lightning data
 - Numerous upgrades since inception in 1989
 - Modest changes can confound interpretation of climate impact



NLDN DE Corrections



- ▶ 2x2 degree analysis grid

- ▶ 2004 Reference Year

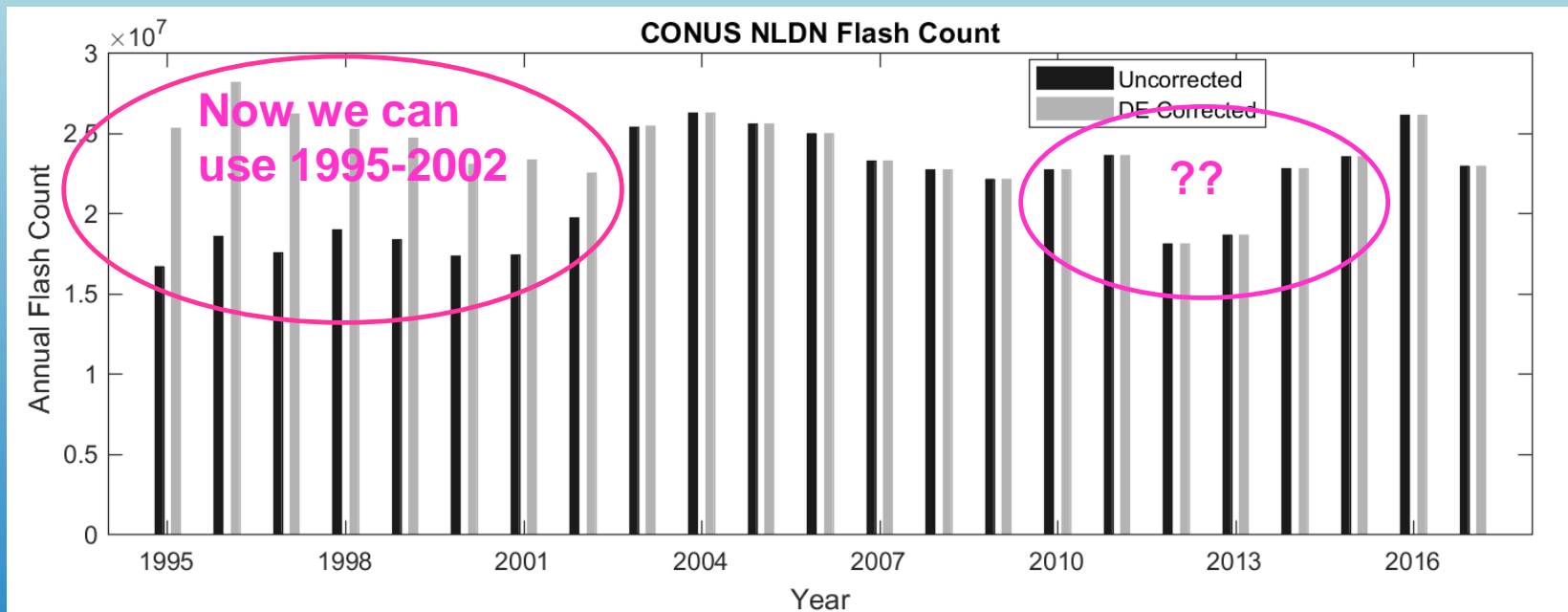
- ▶ Method:

Medici G., K.L. Cummins, D. Cecil, W. Koshak, S. Rudlosky (2017), **The Intra-cloud lightning fraction in the contiguous United States**, *Monthly Weather Review*, 145, 4481-4498

- ▶ See [public access Supplemental Material](#) for further [details](#) and to [obtain the corrections](#)

Annual CONUS Flash Counts: 1995-2017

Uncorrected and Corrected Counts



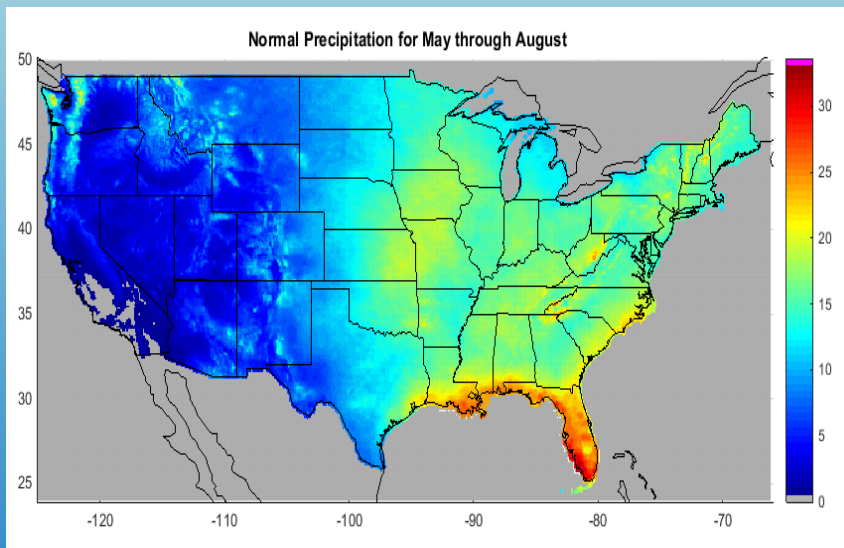
Was there an underlying weather issue?

- ▶ No change in peak current distributions
- ▶ No change in flash multiplicity
- ▶ Left with asking about a significant weather change

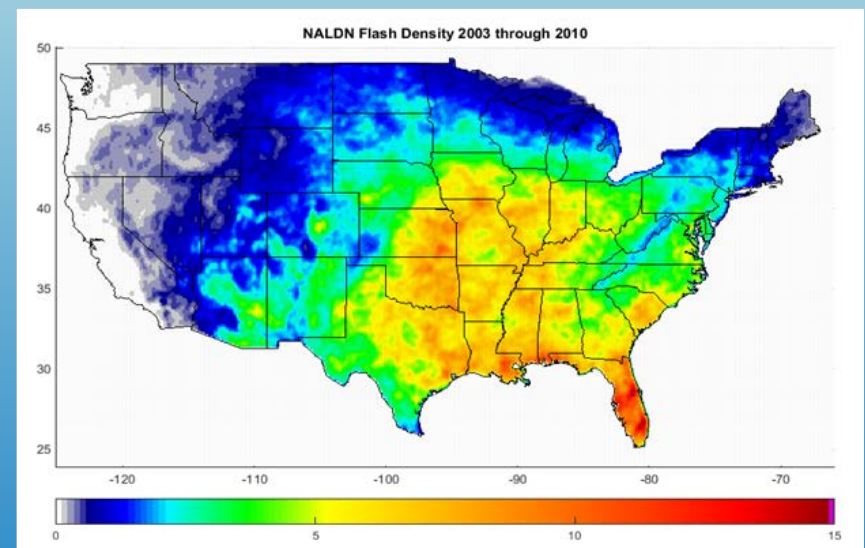
- ▶ The most-likely correlate is **convective precipitation**
 - Occurs most-frequently in May through August
 - Use PRISM Monthly precipitation product
 - ▶ 30-year climatology as a reference
 - ▶ Gauge-corrected and QC's hourly NEXRAD estimates
 - ▶ Elevation model and storm trajectory assistance in inter-mountain west

Climatology

30-year PRISM Precipitation (May through August)



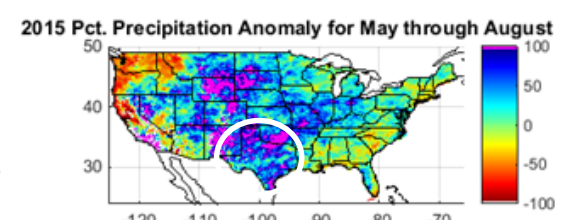
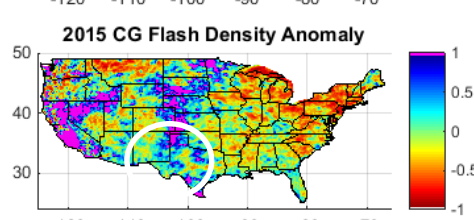
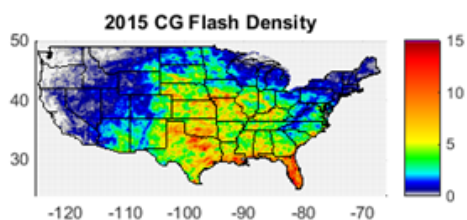
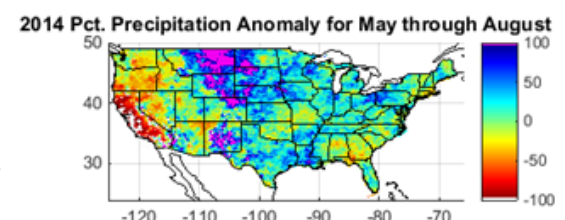
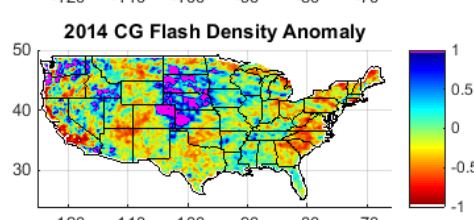
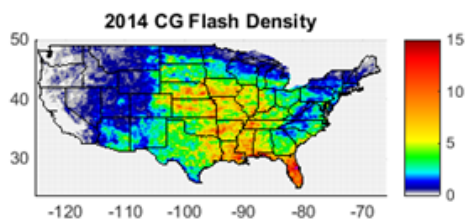
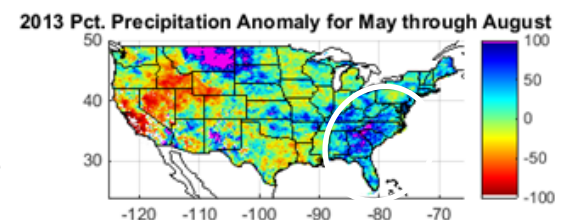
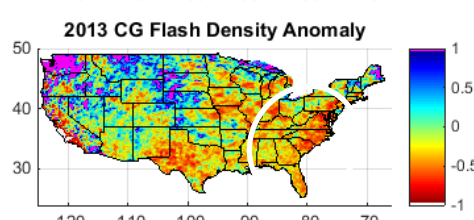
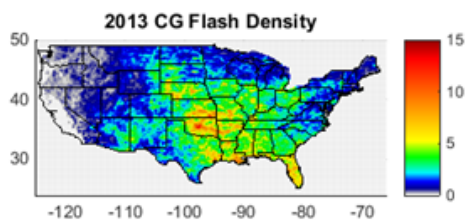
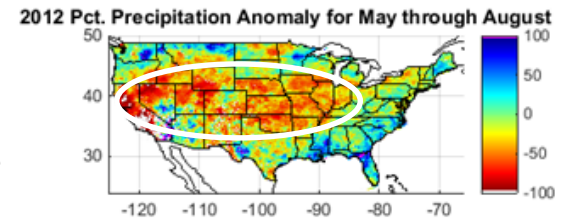
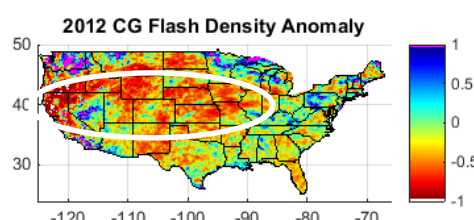
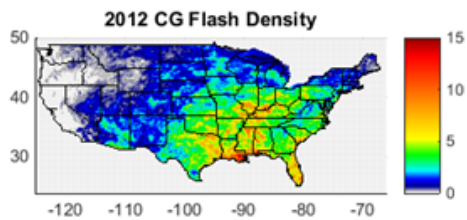
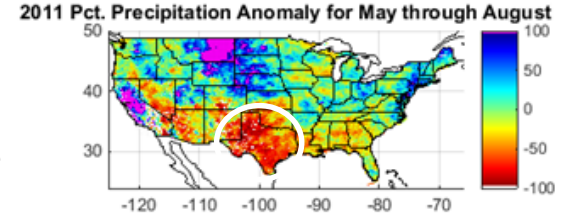
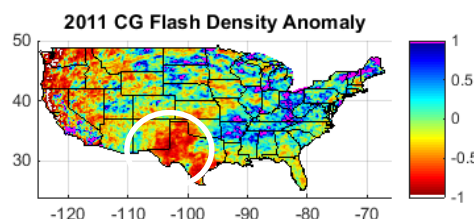
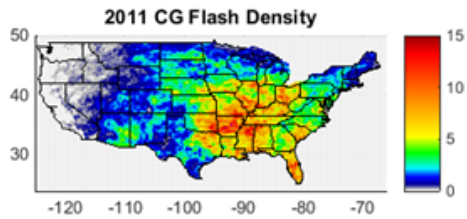
2003-2010 NLDN CG Flash Density



Note: All mapped data are accumulated into 0.5°x0.5° grids and trimmed to CONUS

Good coherence with the interesting exception in the Appalachians

Annual CG Lightning and Related Anomalies



How About Lightning Type Classification?

► Sequence of Classification Changes

Change Date

Before April, 2006

April 2006

May-Aug 2012

Aug 18, 2015

March 23, 2016

***** NLDN Change *****

Waveform Width only

Waveform Width; $+I_p < 15$ kA set to CG

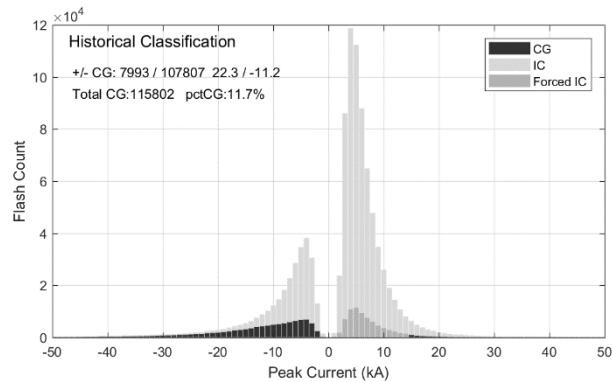
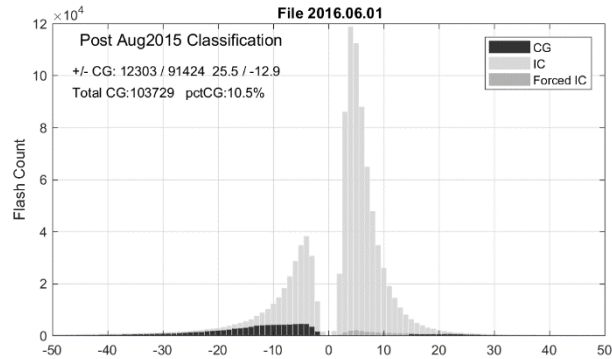
Increase sensor sensitivity

New multi-parameters classification

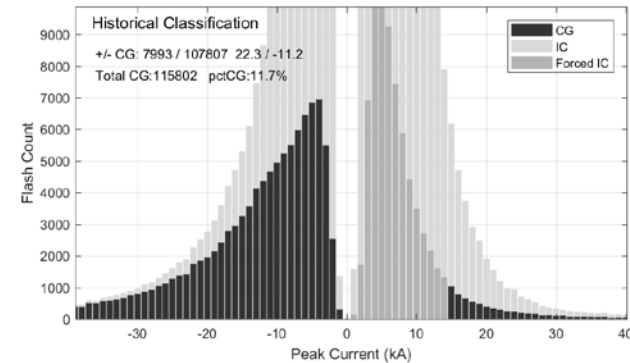
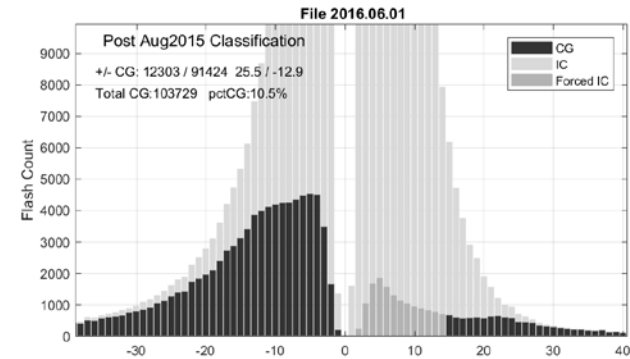
Eliminated restriction on $+I_p < 15$ kA

Impact on Peak Current Distributions

Full Distributions

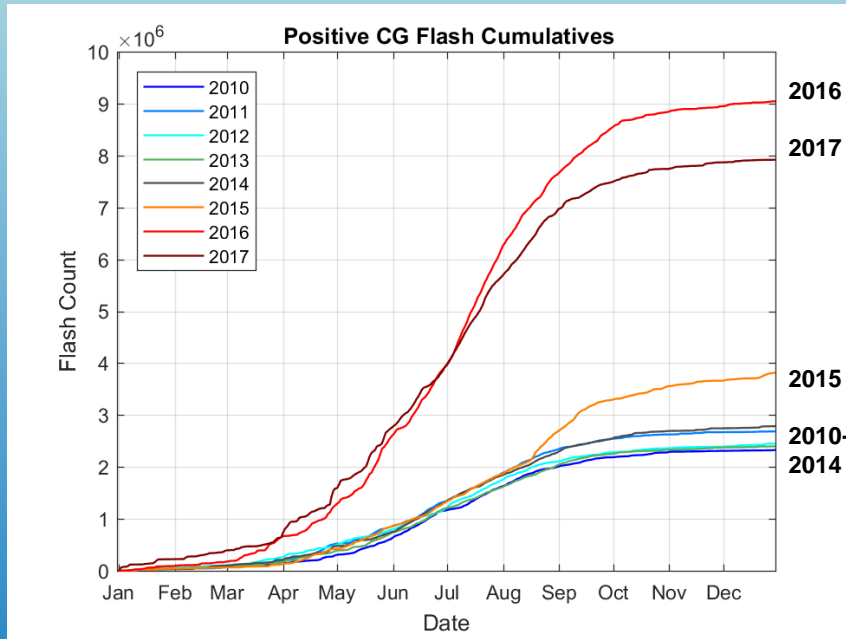


Zoom-in on CG Flashes



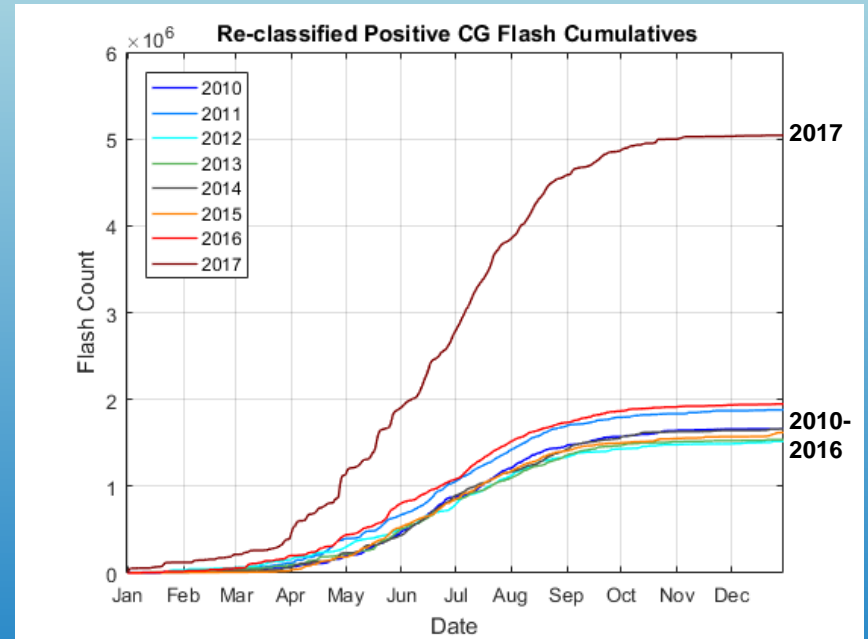
Day-of-year Cumulative CG Flashes

Cumulative Daily Positive Counts (Full NLDN)

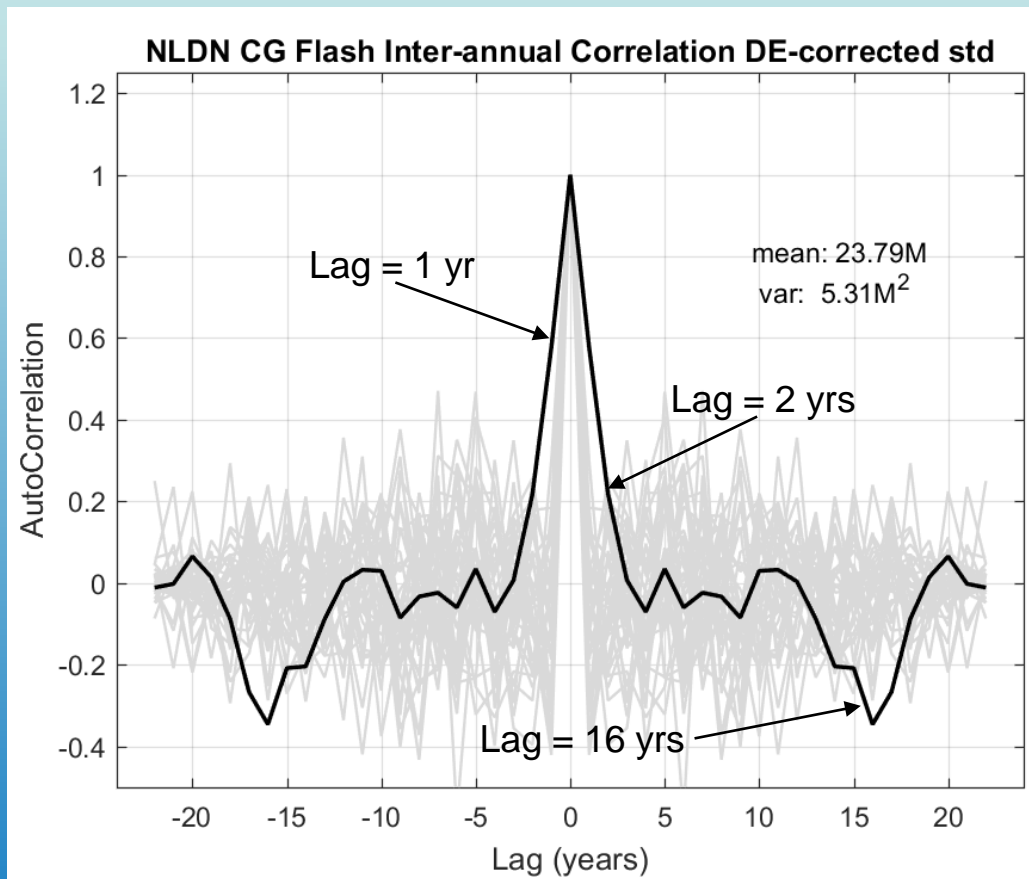


Cumulative Daily Positive Counts (CONUS)

(Pre-2015 Classification)



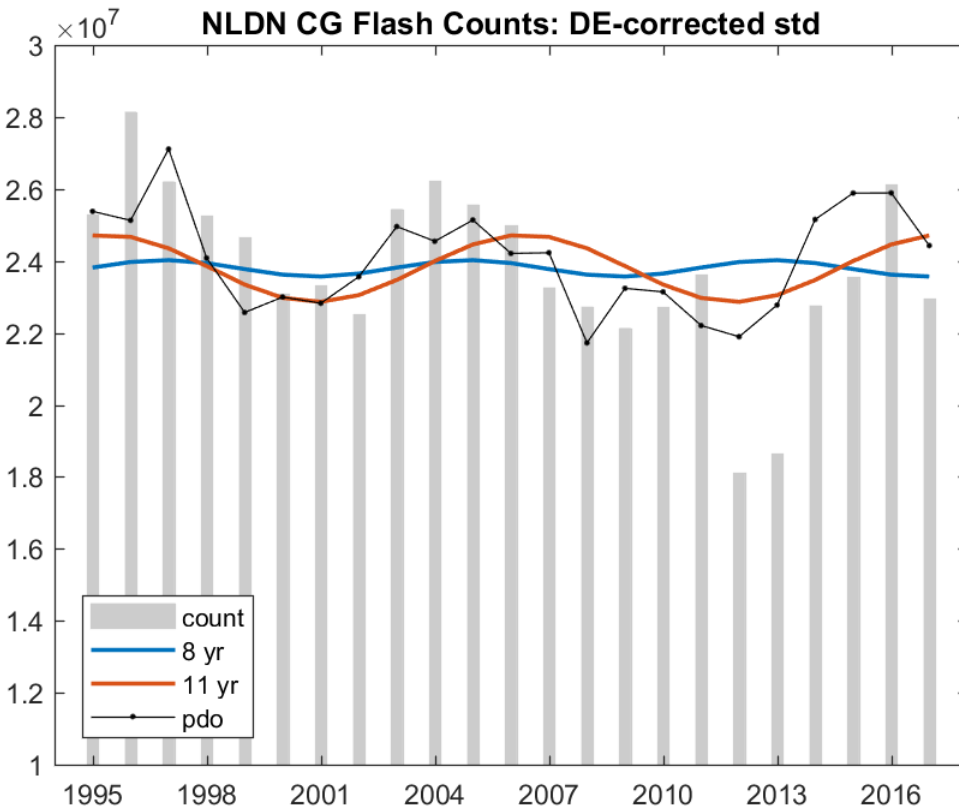
USING THE Data: Inter-annual Temporal Correlation



Findings (non-random):

- Sequential years are correlated ($\rho=0.6$)
- Lags between 3-13 years show no significant correlation
- Possible meaningful negative correlation at lags of 15-17 years
 - Need longer study period to be sure

USING the Data: Decadal Patterns in the Annual Data?



First Steps:

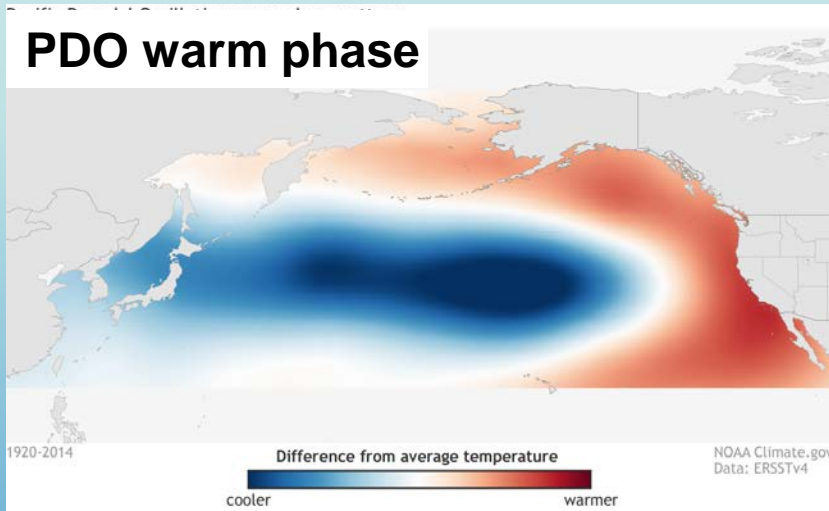
Conus annualized correlations

- 8 and 11 year periodicity
- ENSO
- Atlantic Multi-decadal Osc.
- Pacific Decadal Osc.
- Pacific North American Pattern

Findings:

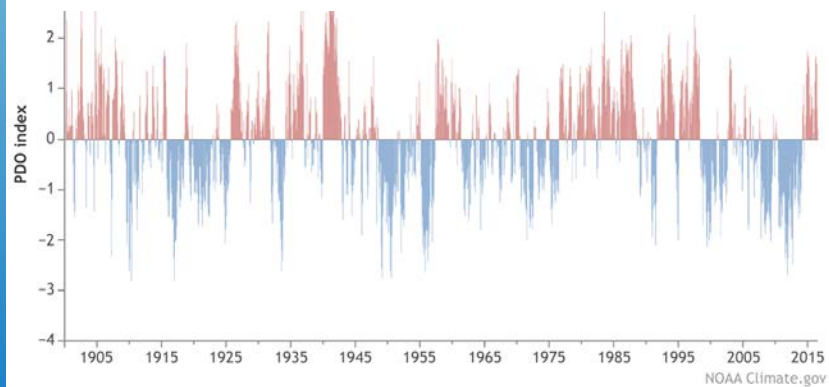
- Solar Cycle (11 years) is not the strongest correlation
- Possible meaningful correlation with PDO
 - $\rho = 0.63$
 - (Really?)

The Pacific Decadal Oscillation (PDO)

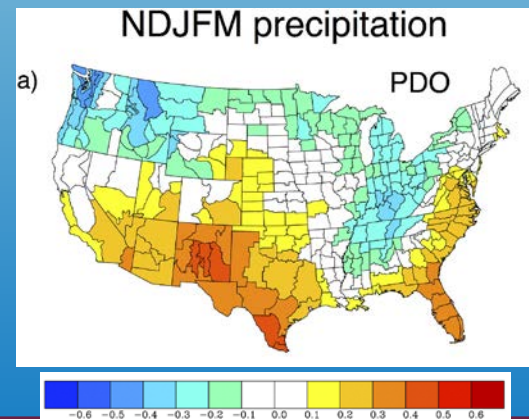


Pacific Decadal Oscillation (PDO) status from 1900 to 2016

PDO time series 1900-2016



- ▶ Dominant Pattern of North Pacific SST variability (anomaly 1st EOF)
 - Decadal time scale
- ▶ PDO = tropical forcing + local ocean-atmosphere processes + weather
- ▶ Climate impacts similar to El Niño
 - Wet in S. CA, South and Southeast

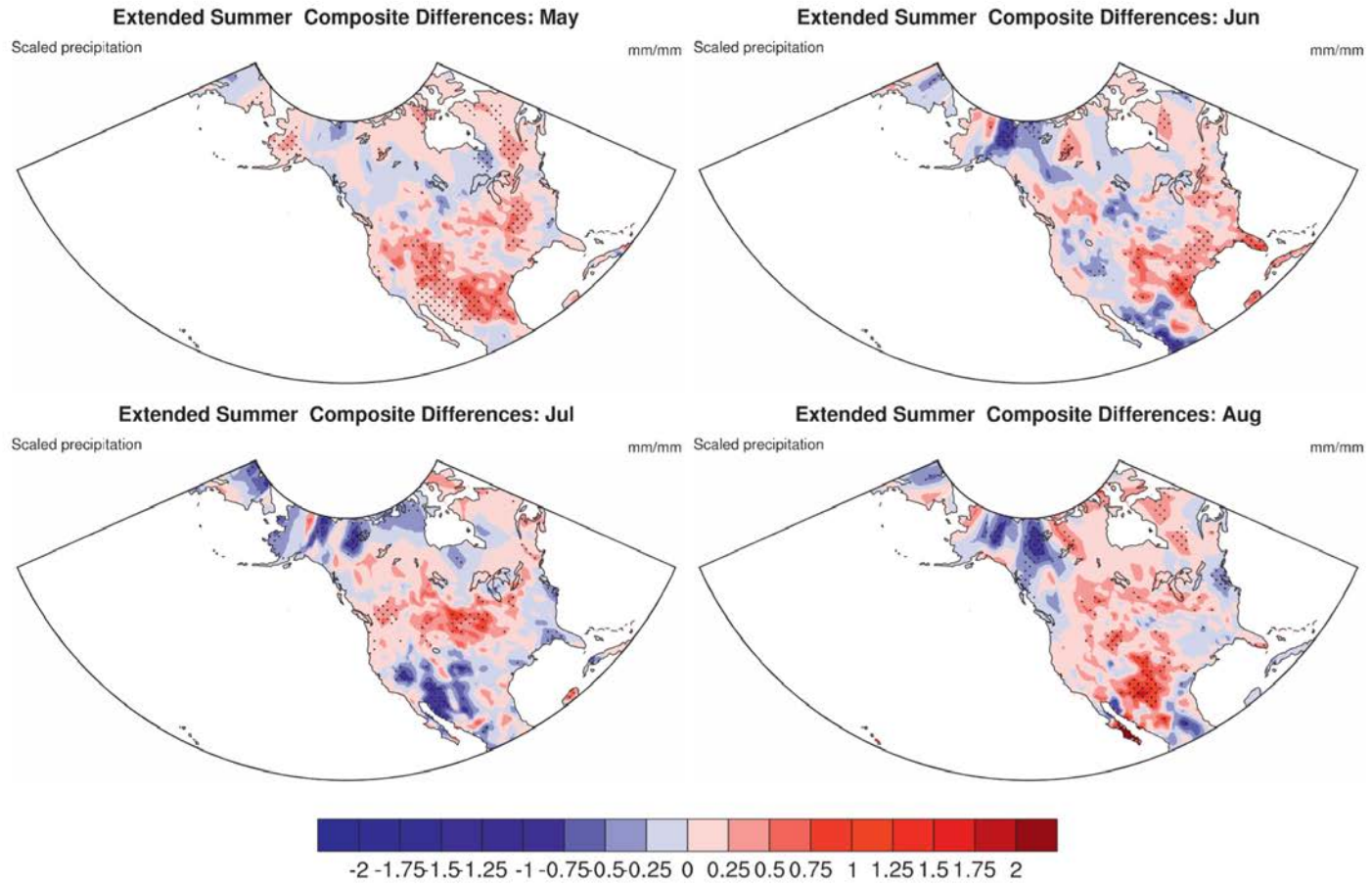


Mills and Walsh, 2013

1588

JOURNAL OF CLIMATE

VOLUME 26



Conclusions

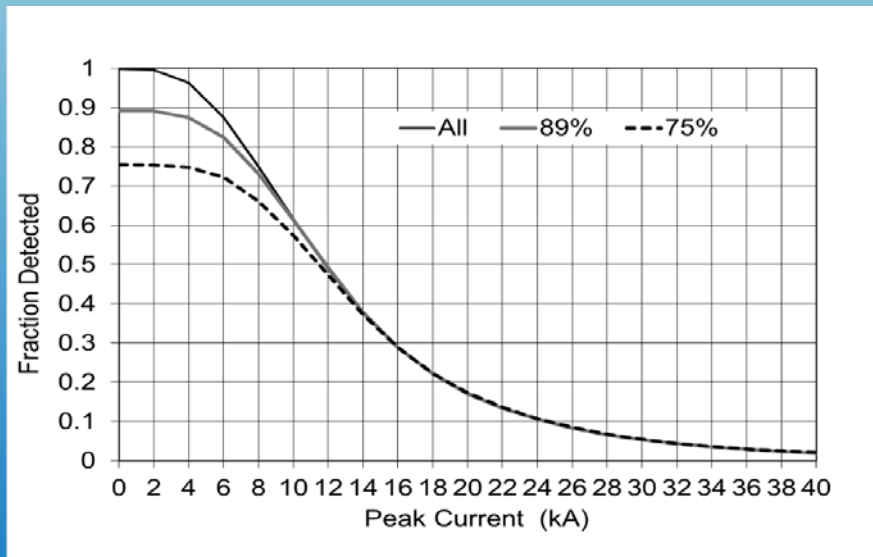
- ▶ Reasonable NLDN DE corrections that are available to the public
- ▶ Low lightning incidence in 2012 is well-correlated with drought
- ▶ New lightning-type classification must be “managed” for studies aimed at climate-related analyses
- ▶ PDO has intriguing correlation with annual CONUS flash counts, accounting for ~40% of the variability
 - Future work will dissect-out underlying factors
 - ▶ CAPE
 - ▶ CAPE*Precip
 - ▶ Dew Point temperature
 - ▶ ??

Backup Slides on the remaining pages



Compensating for Varying Detection Efficiency

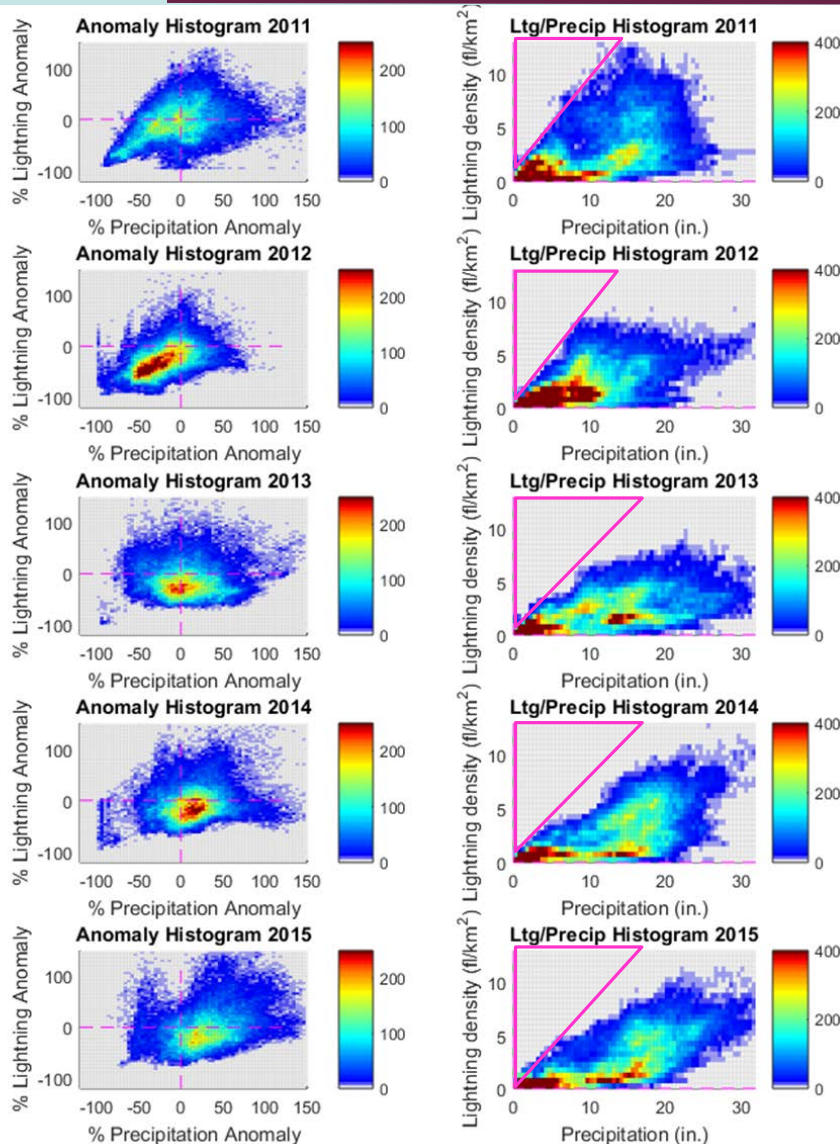
- ▶ Use DE Modeling?
 - Modeling is nice, but DATA speaks louder!
- ▶ What is the basic reason for imperfect DE?
 - Inability to detect low-amplitude discharges
 - ▶ Lightning is far from the sensors
 - ▶ Low-current discharges within sensor baseline distances



Approaches:

- Eliminate all low-current strokes
 - Assures common behavior
 - Might lose important information
- Scale the curves in a manner that results in a DE estimate...

Annual Ltg:Precip Relationships: CONUS

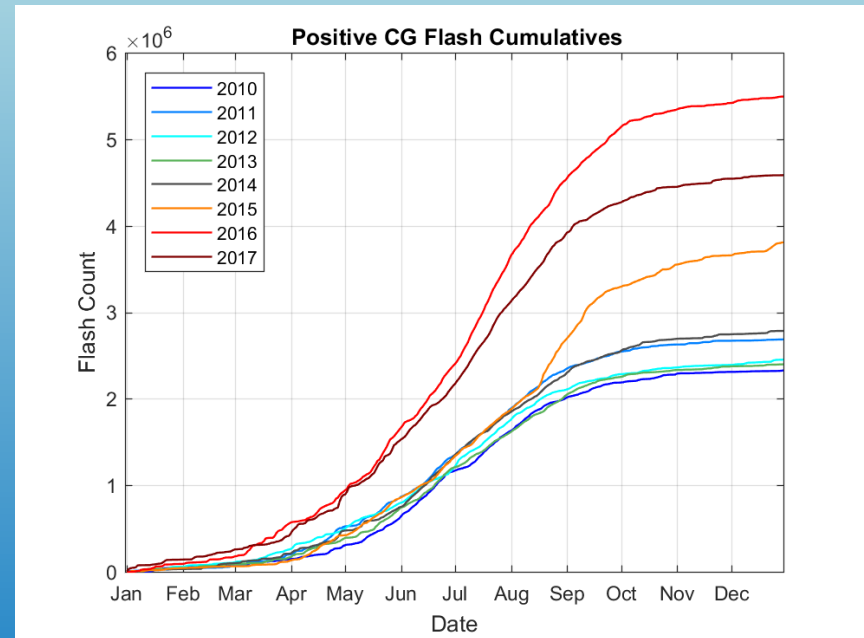
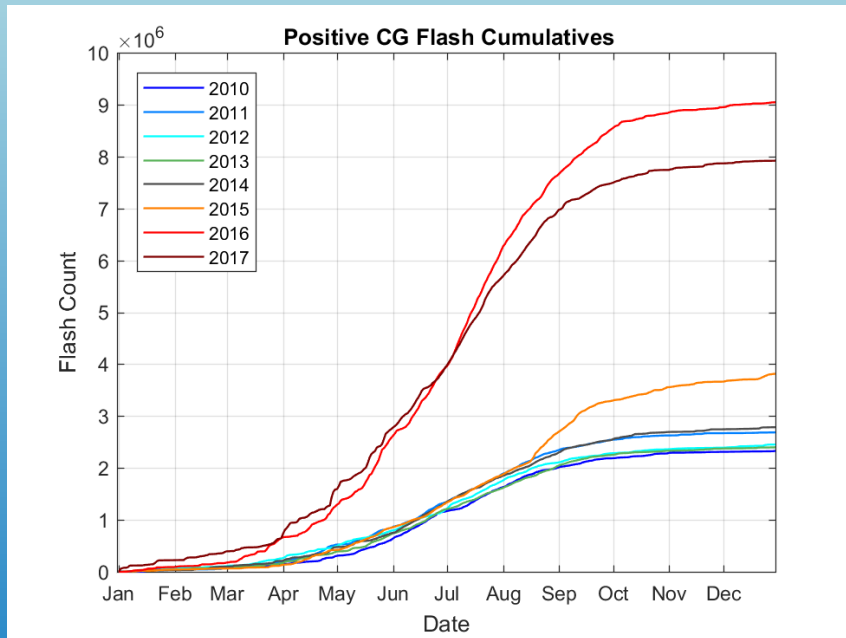


- 2D Ltg/Precip histograms show positive correlation, and the *“Fleetwood Mac Effect”* (*thunder only happens when it's raaanin'...*)
- Anomaly histograms show:
 - Widespread and correlated negative bias in 2012
 - Negative lightning bias in many regions in 2013

Day-of-year Cumulative CG Flashes

Cumulative Daily Positive Counts (Full NLDN)

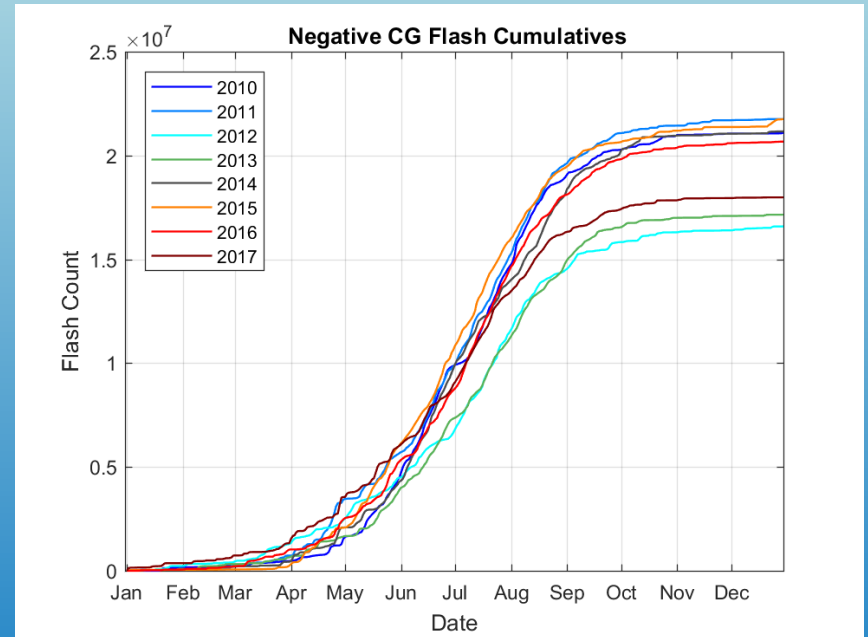
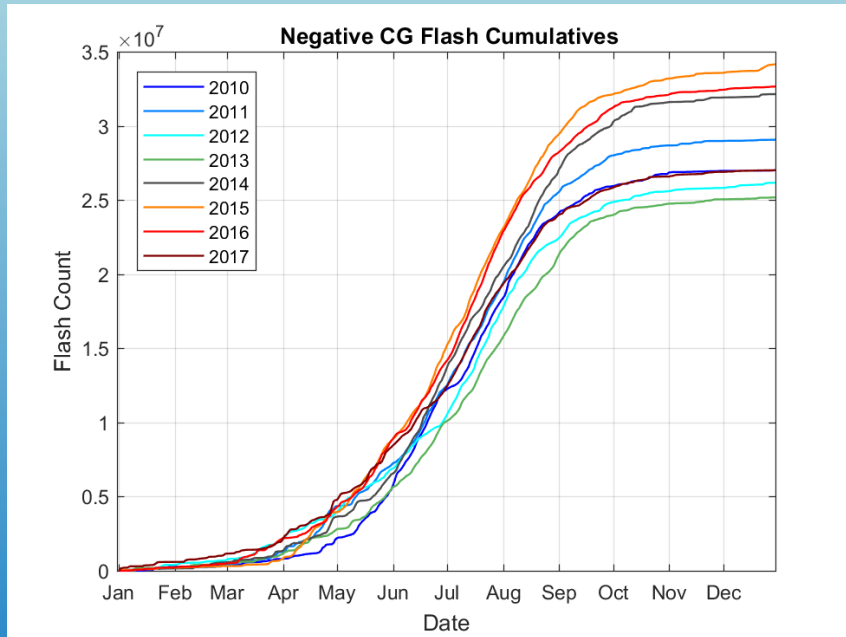
Cumulative Daily Positive Counts > +15 kA (Full NLDN)



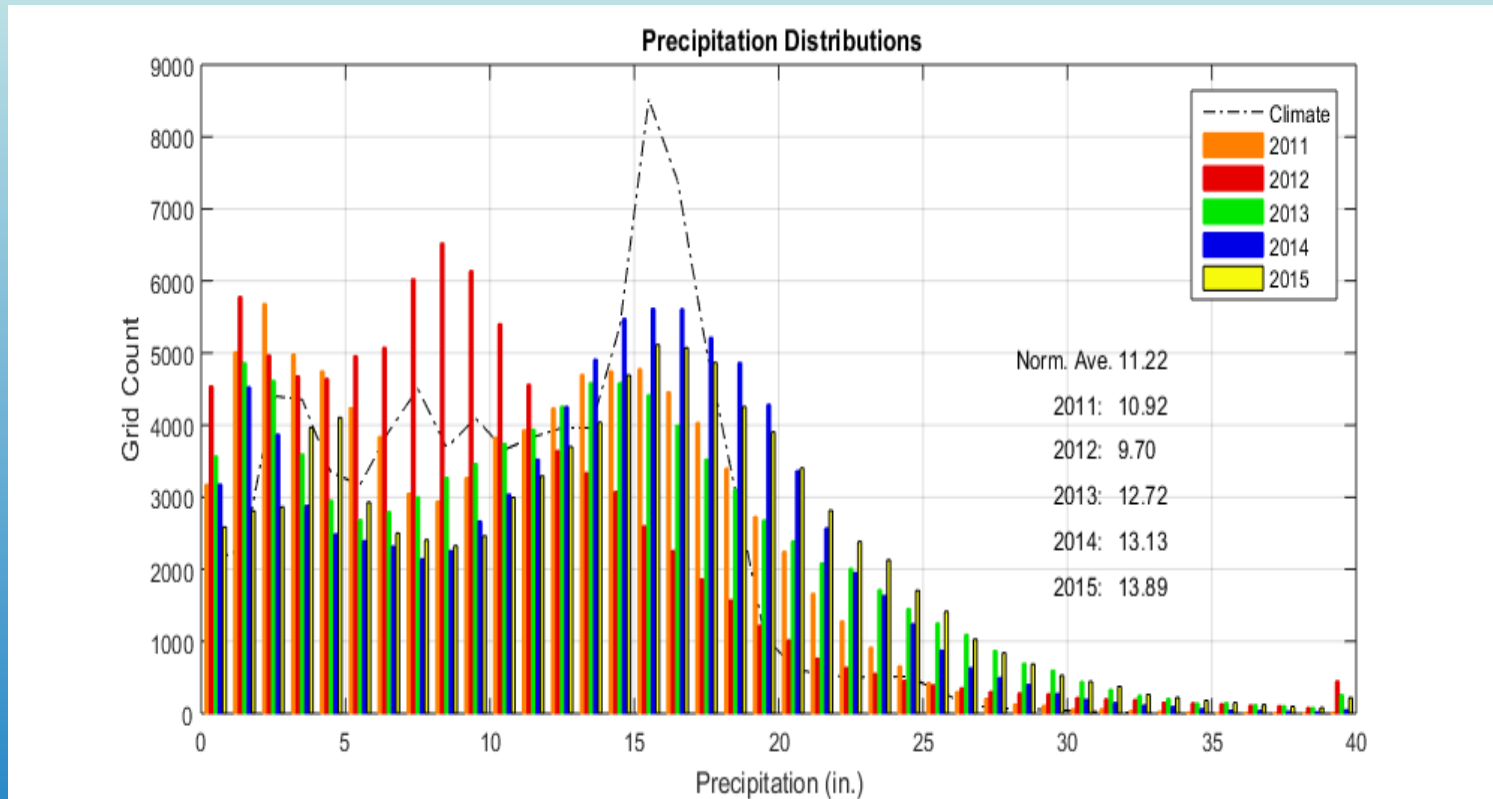
Day-of-year Cumulative CG Flashes

Cumulative Daily Negative Counts (Full NLDN)

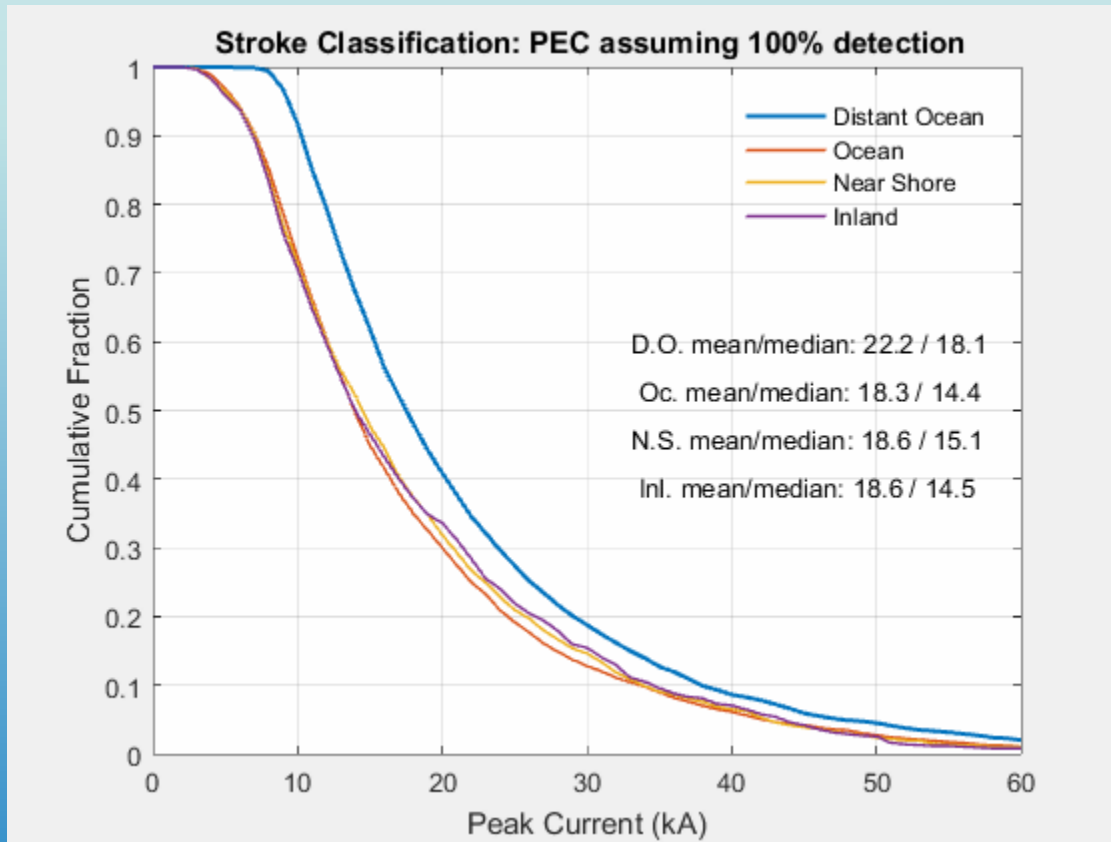
Cumulative Daily Negative Counts (CONUS)



Further Evidence of 2012 Drought



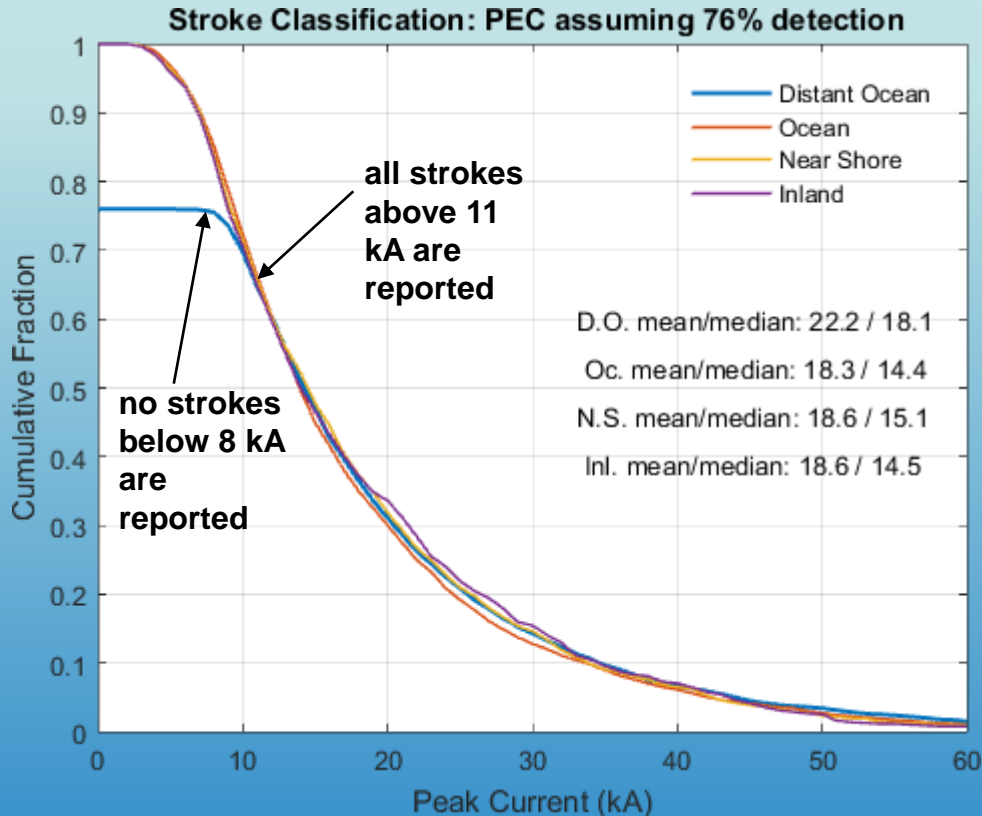
Peak Current Comparisons



- For each (small) region:
- Pick best year as a “reference”
 - Produce “normalized” Peak current curves for each “test” period (year)

Cumulative distributions of negative CG strokes in pre-existing channels, for four different locations

Peak Current Comparisons



For each (small) region:

- Pick best year as a “reference”
- Produce “normalized” Peak current curves for each “test” period (year)
- Determine the lowest current at which the curves can be matched by scaling the “test” curve
- Read-off DE at 0 current

Distant Ocean distribution scaled by its effective detection efficiency.

Pacific Decadal Oscillation (PDO) Scattergram

