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

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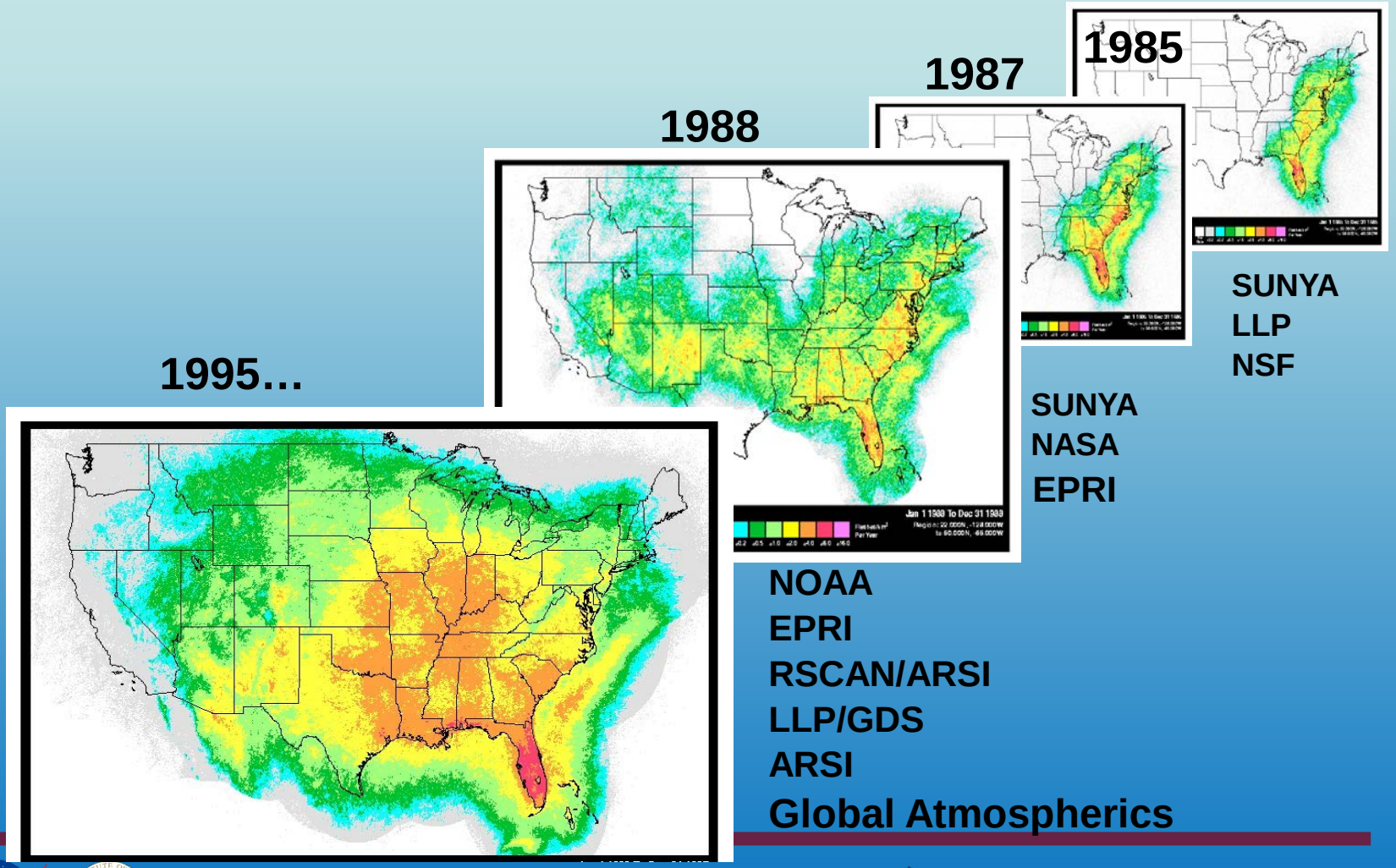
Why This Topic Now?

- 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

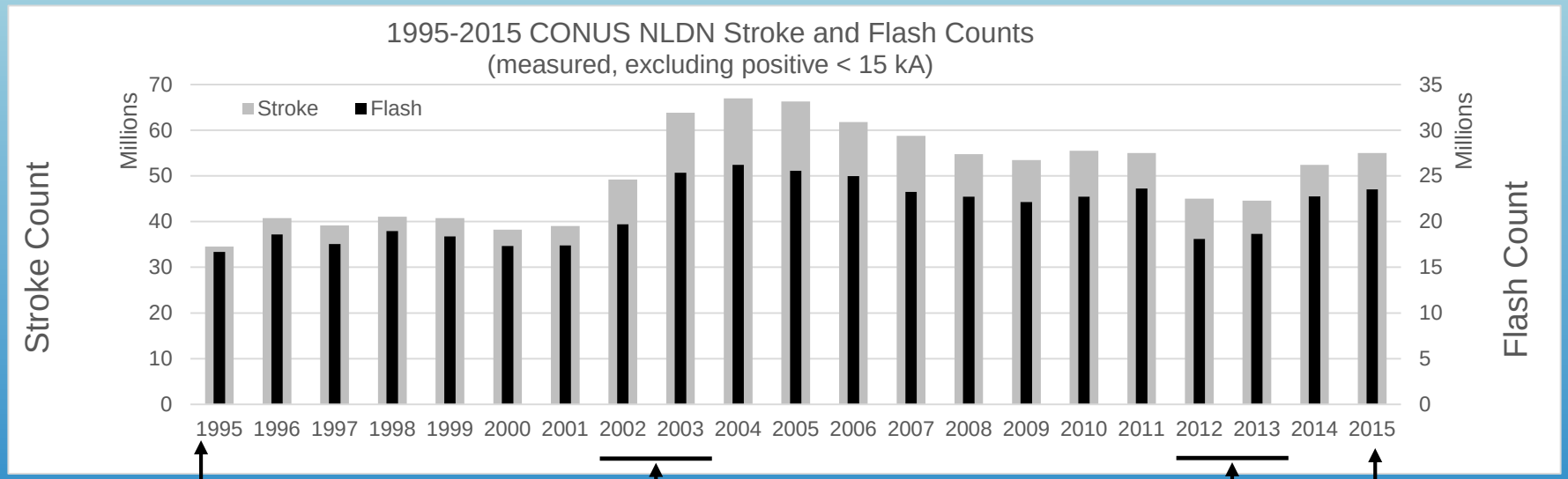
- Lots of changes to the NLDN over the last 23 years
  - We need to correct for network effects in order to tease-out underlying weather and climate variation

Evolution Towards a National Network

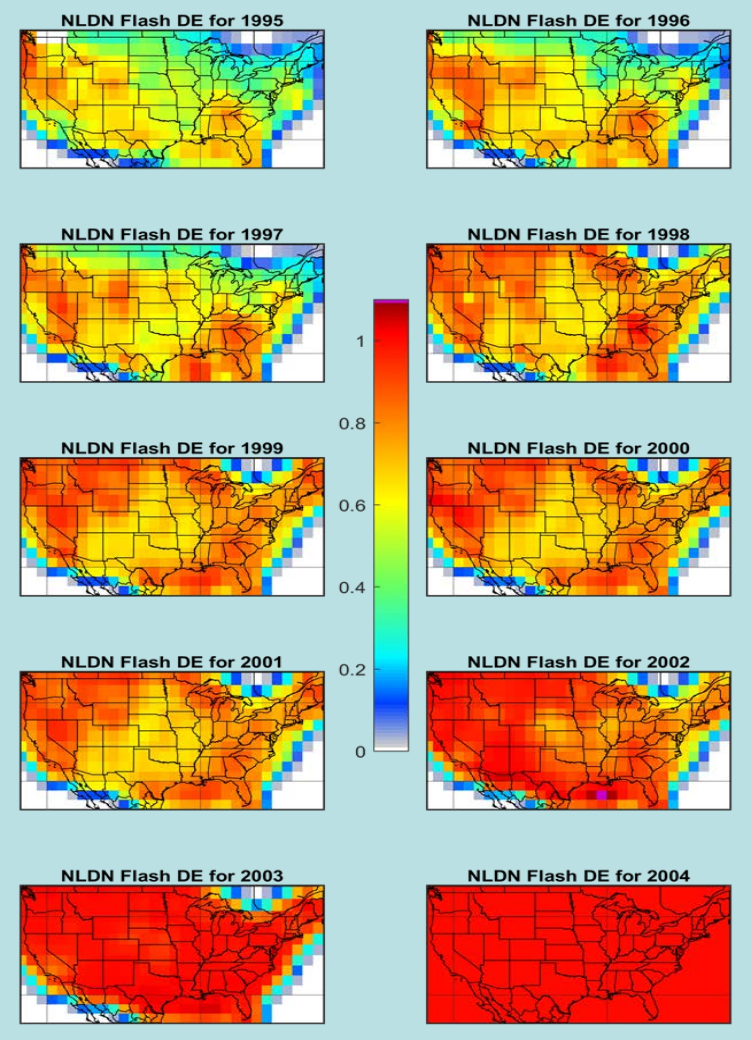


Background/Motivation

- 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



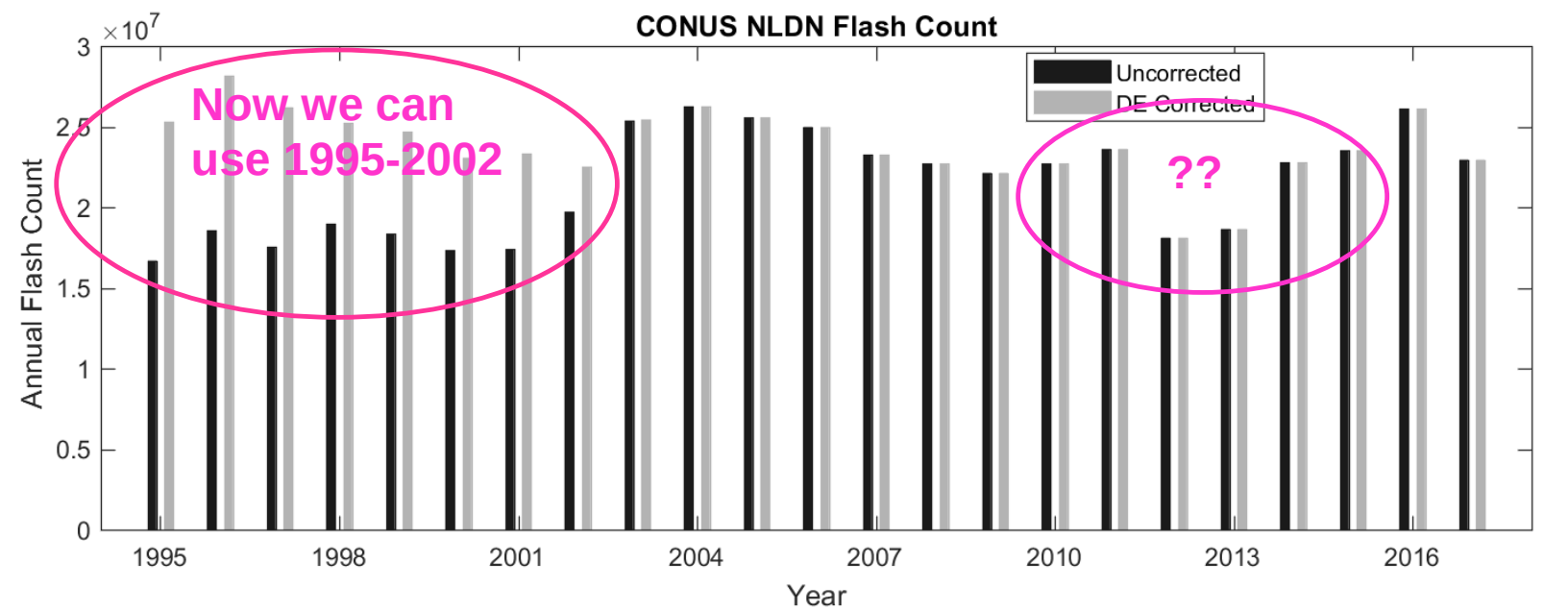
- 2x2 degree analysis grid
- 2004 Reference Year
- Method:

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



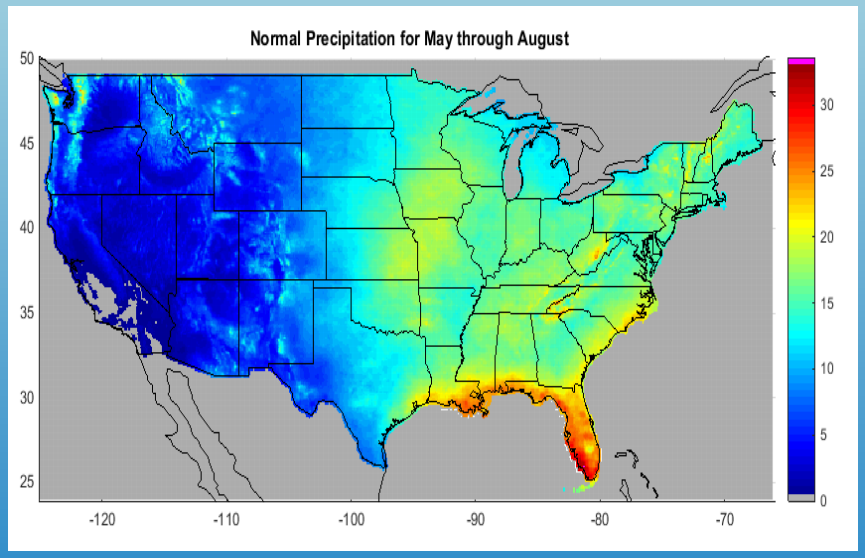
Was there an underlying weather issue?

- 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

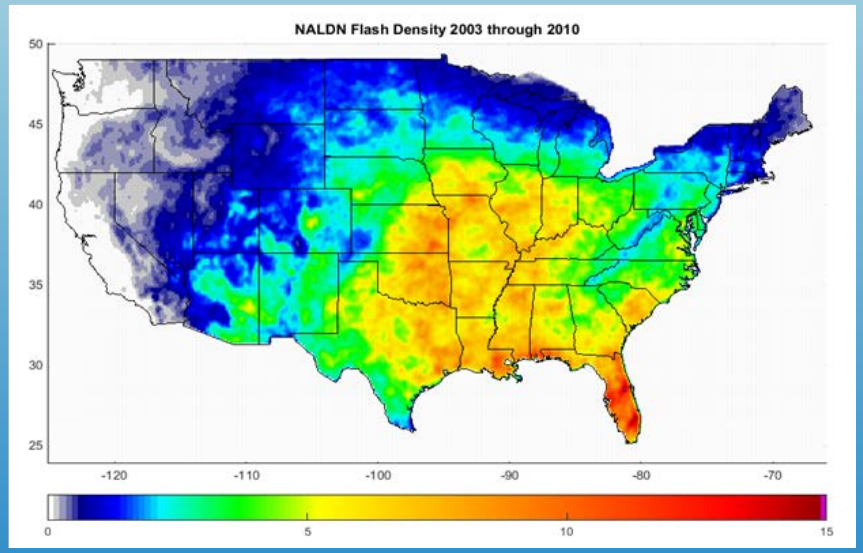
Climatology

30-year PRISM Precipitation
(May through August)



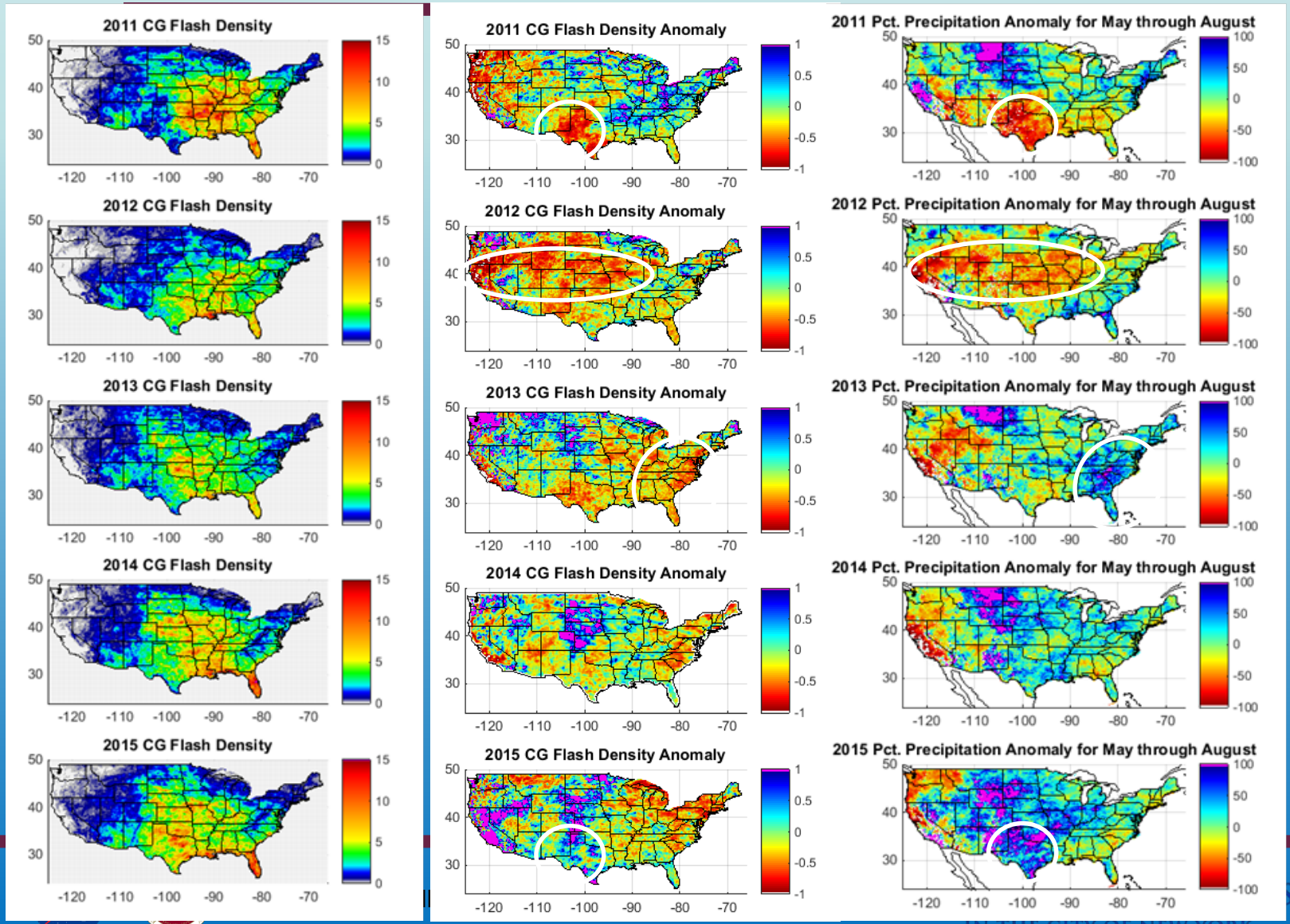
Note: All mapped data are accumulated into 0.5°x0.5° grids and trimmed to CONUS

2003-2010 NLDN CG Flash Density



Good coherence with the interesting exception in the Appalachians

Annual CG Lightning and Related Anomalies



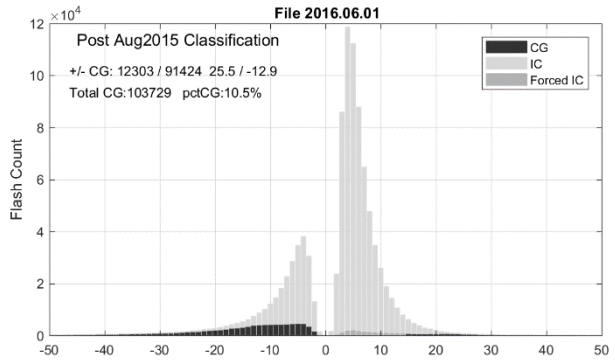
How About Lightning Type Classification?

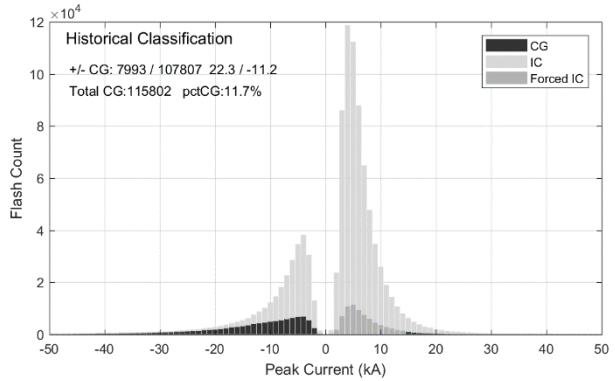
- Sequence of Classification Changes

Change Date	***** NLDN Change *****
Before April, 2006	Waveform Width only
April 2006	Waveform Width; +Ip<15 kA set to CG
May-Aug 2012	Increase sensor sensitivity
Aug 18, 2015	New multi-parameters classification
March 23, 2016	Eliminated restriction on +Ip<15 kA

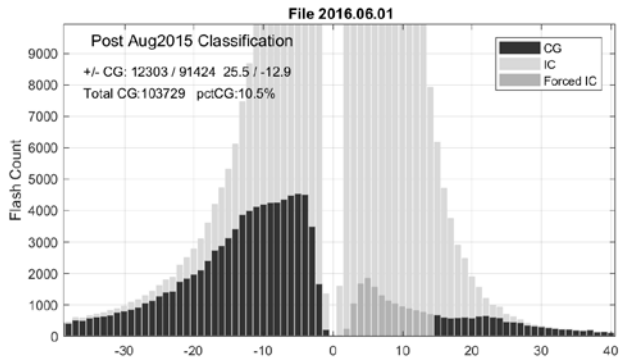
Impact on Peak Current Distributions

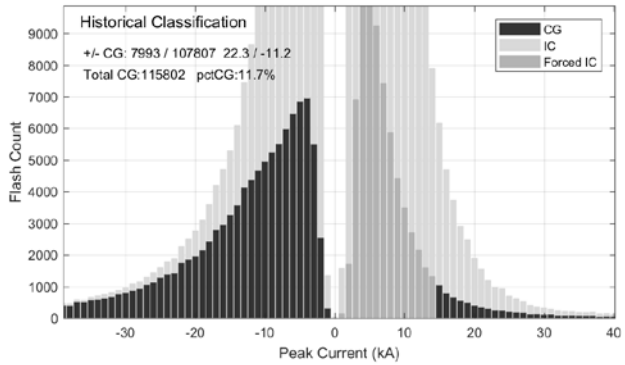
Full Distributions





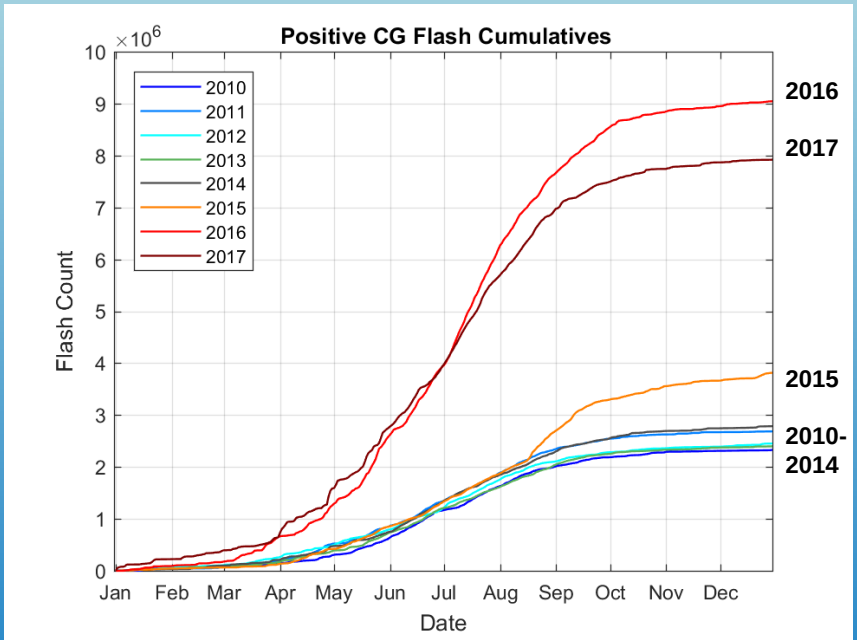
Zoom-in on CG Flashes





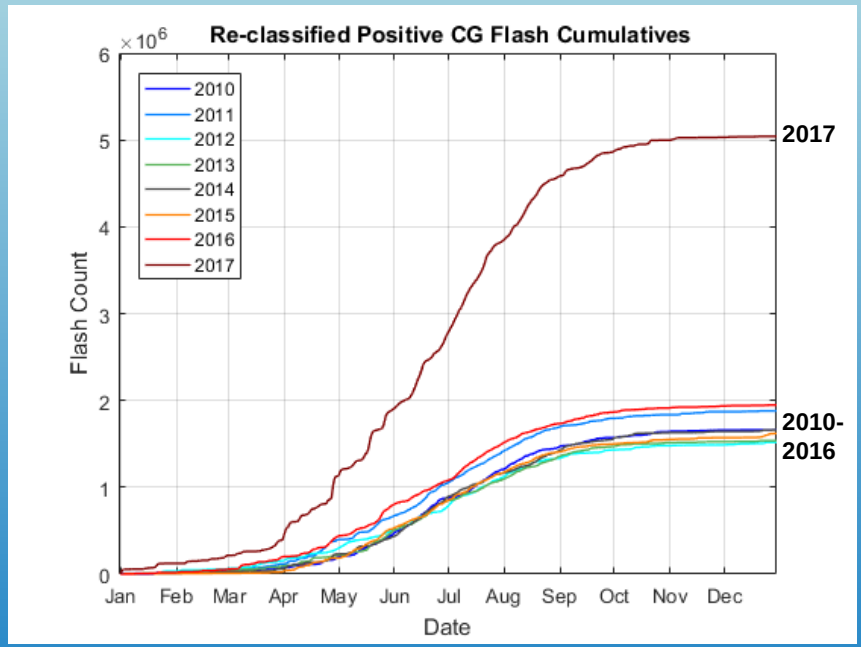
Day-of-year Cumulative CG Flashes

Cumulative Daily Positive Counts (Full NLDN)

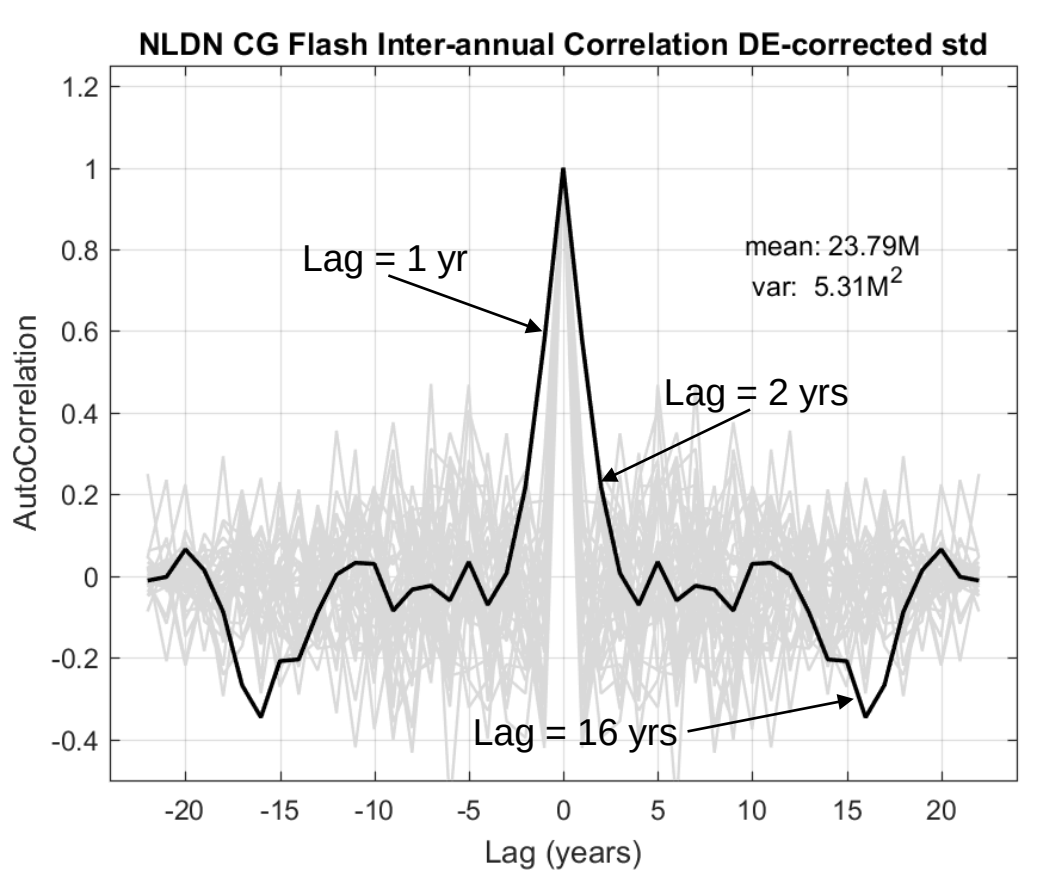


Cumulative Daily Positive Counts (CONUS)

(Pre-2015 Classification)



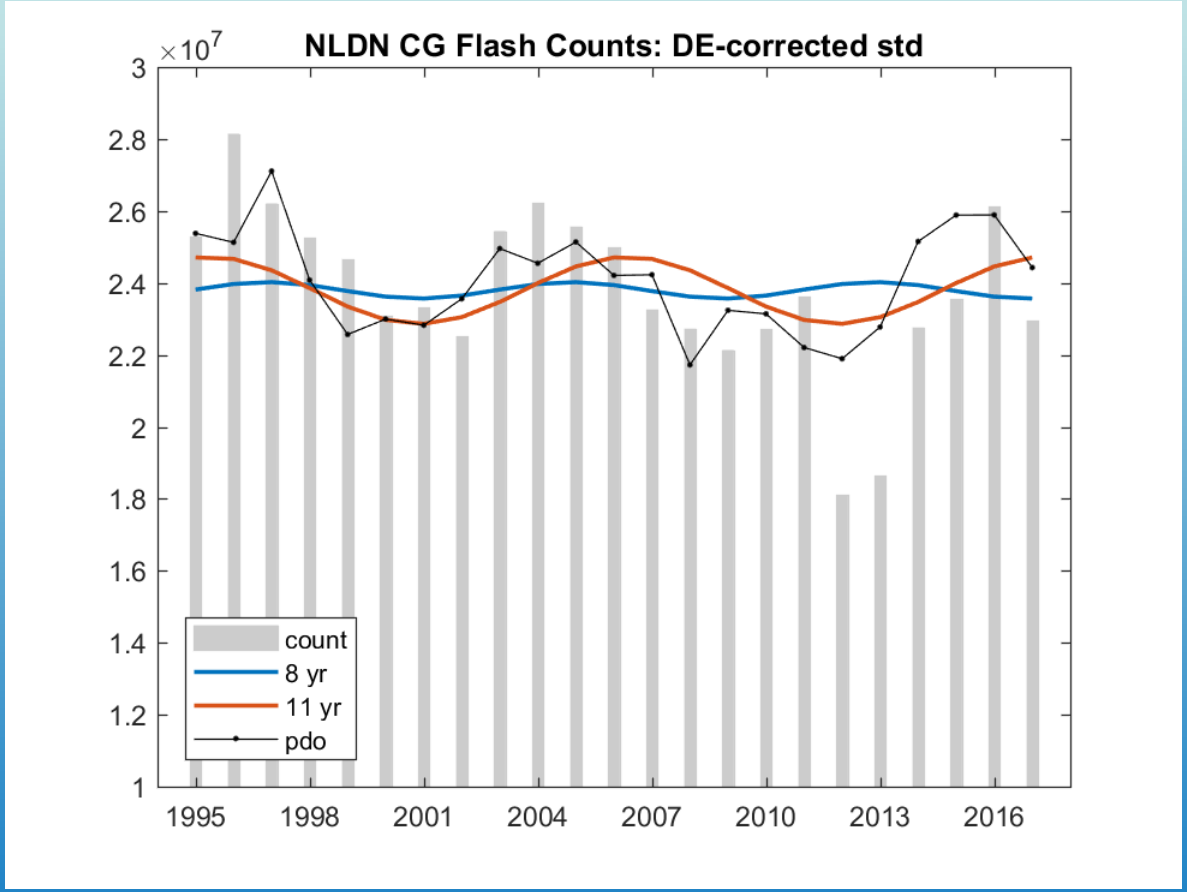
USING THE Data: Inter-annual Temporal Correlation



Findings (non-random):

- Sequential years are correlated (ρ=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:

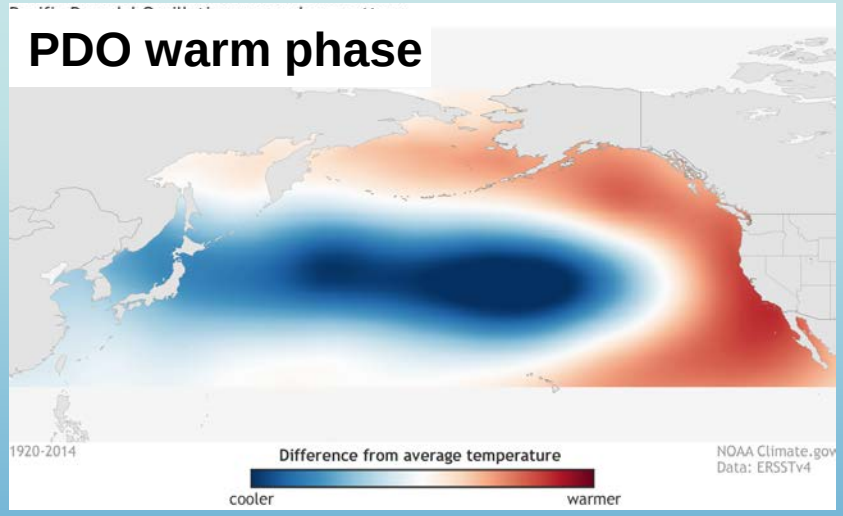
Conus annualized correlations

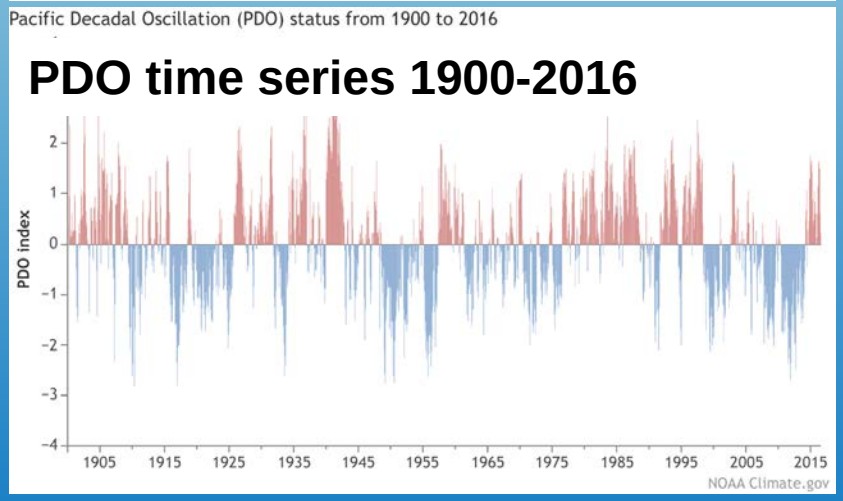
- 8 and 11 year periodicity
- ENSO
- Atlantic Multi-decadal Osc.
- Pacific Decadal Osc.
- Pacific North American Pattern

Findings:

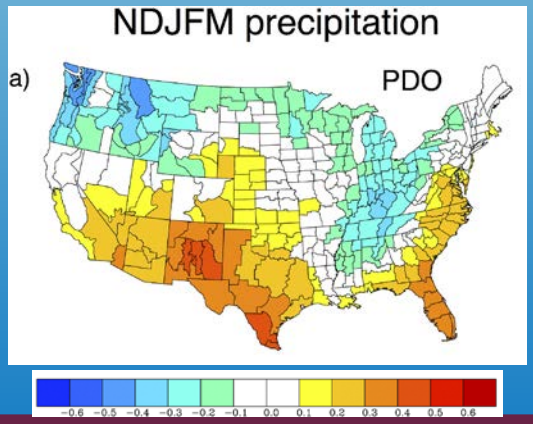
- Solar Cycle (11 years) is not the strongest correlation
- Possible meaningful correlation with PDO
  - ρ = 0.63
  - (Really?)

The Pacific Decadal Oscillation (PDO)

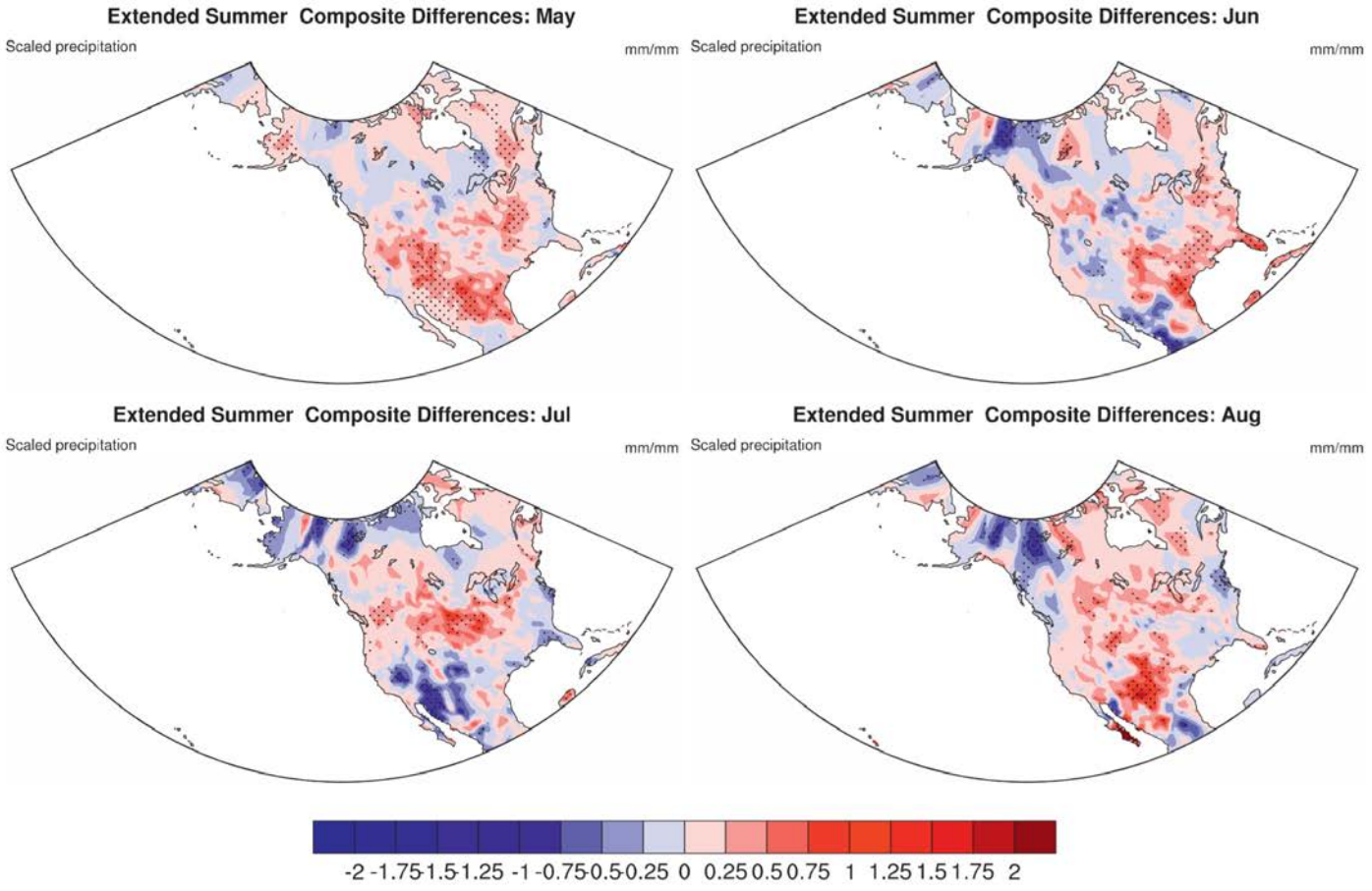




- Dominant Pattern of North Pacific SST variability (anomaly 1st EOF)
  - Decadal time scale
- PDO = tropical forcing + local ocean-atmosphere processes + weather
- Climate impacts similar to El Nino
  - Wet in S. CA, South and Southeast



Mills and Walsh, 2013



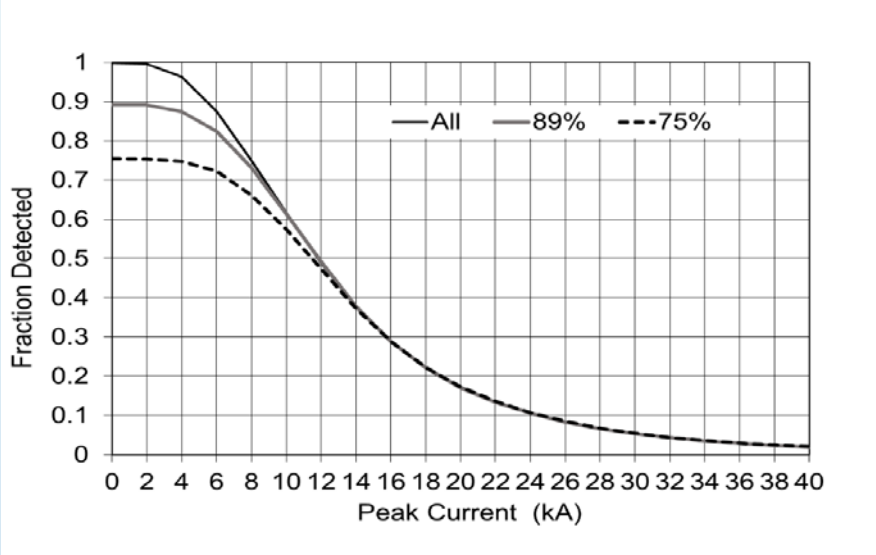
Conclusions

- 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

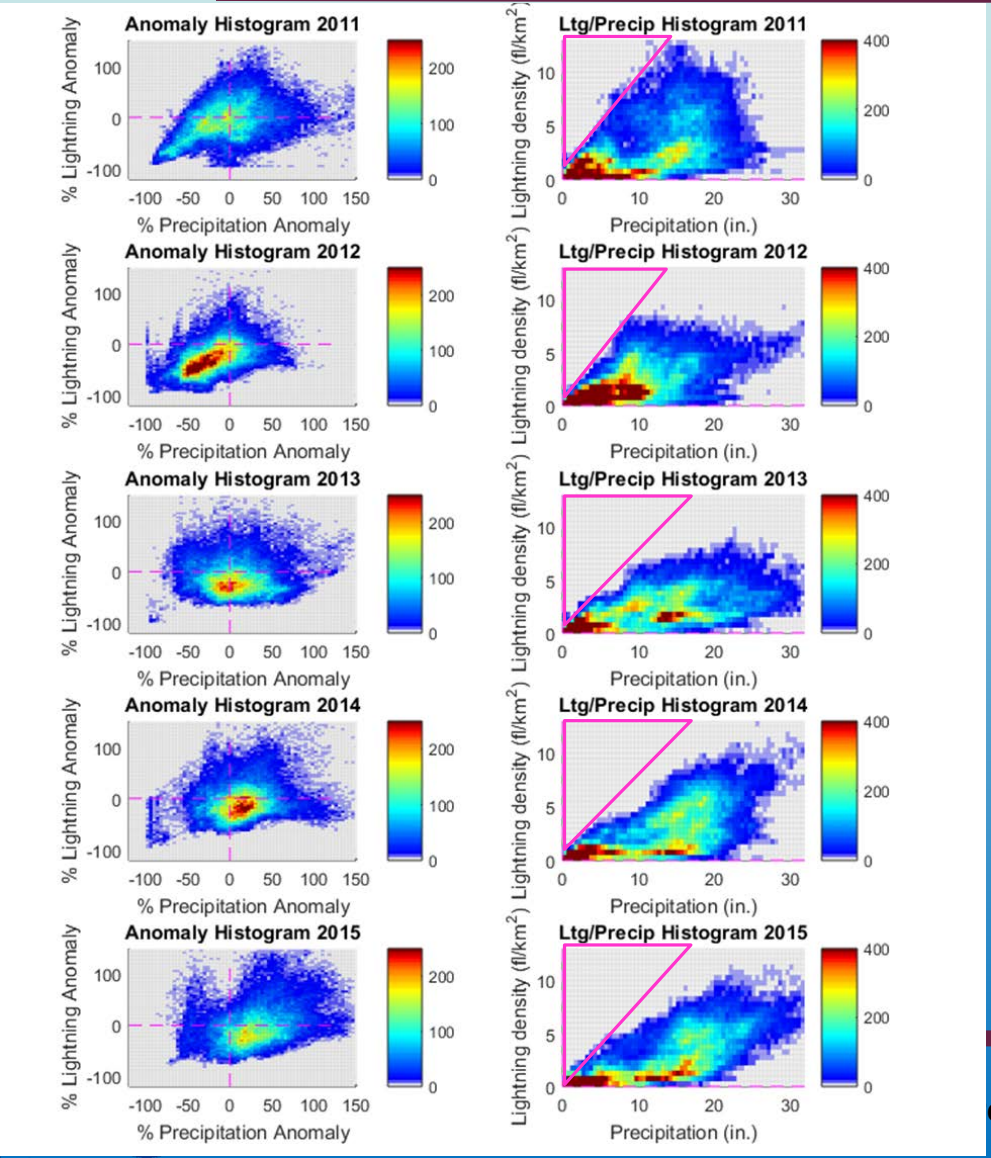
- Use DE Modeling?
  - Modeling is nice, but DATA speaks louder!
- What is the basic reason for imperfect DE?
  - Inability to detect low-amplitude discharges
    - Lightning is far from the sensors
    - Low-current discharges within sensor baseline distances



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

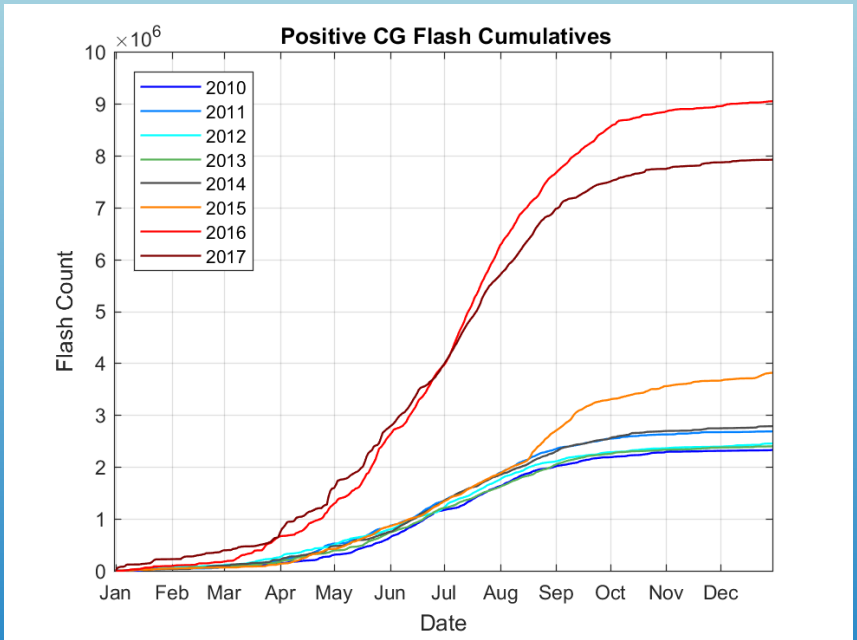


- 2D Ltg/Precip histograms show positive correlation, and the "Fleetwood Mac Effect" *(thunder only happens when it's raaanin'…)*

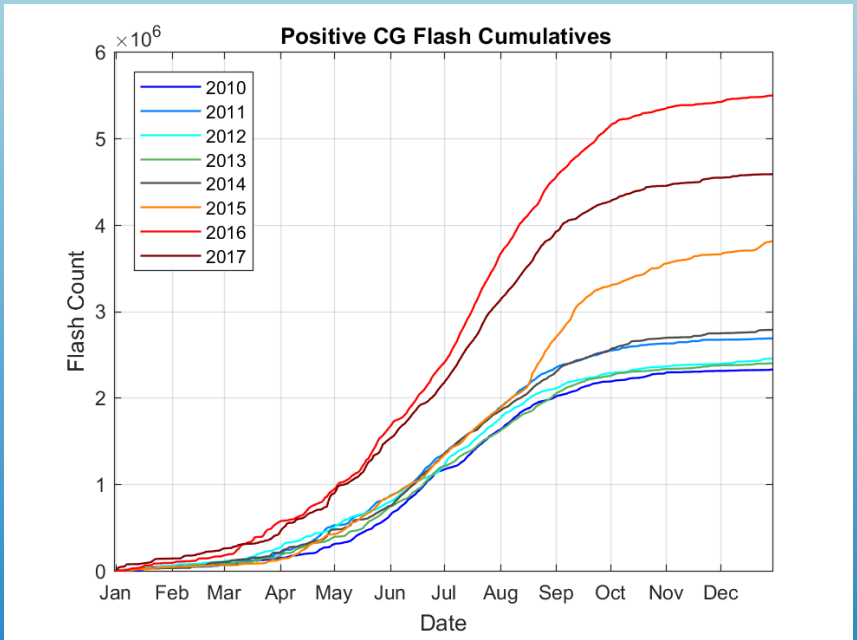
- Anomaly histograms show:
  - Widespread and correlated negative bias in 2012
  - Negative lightning bias in many regions in 2013

Day-of-year Cumulative CG Flashes

Cumulative Daily Positive Counts (Full NLDN)

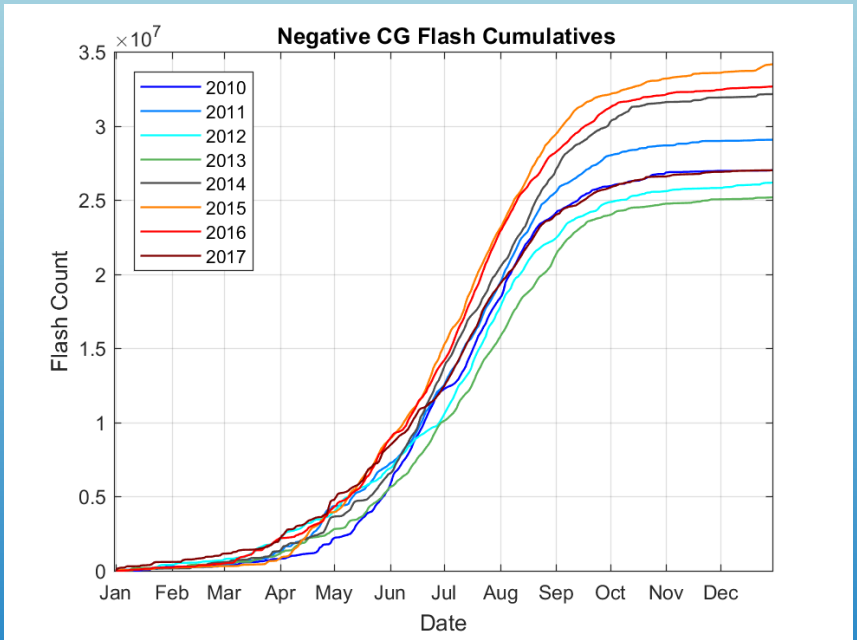


Cumulative Daily Positive Counts > +15 kA (Full NLDN)

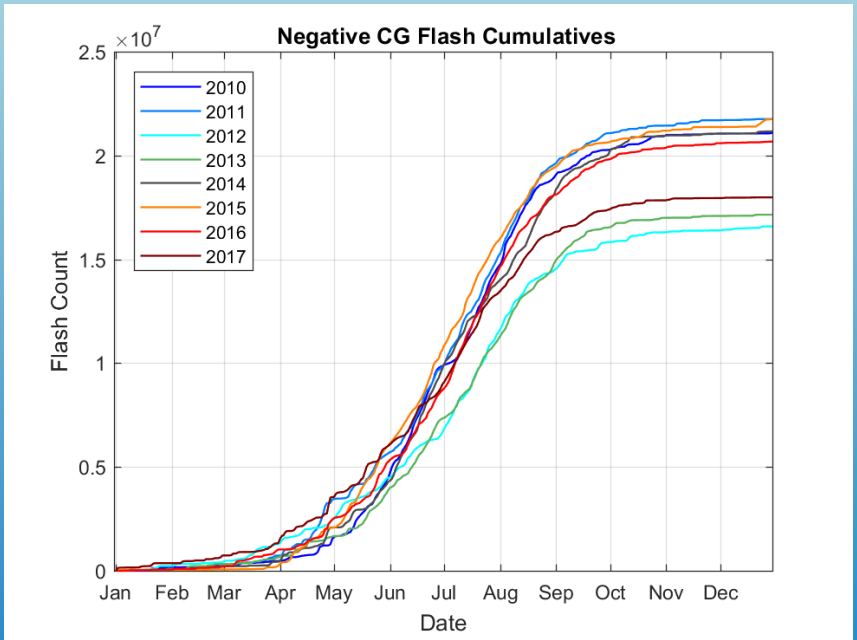


Day-of-year Cumulative CG Flashes

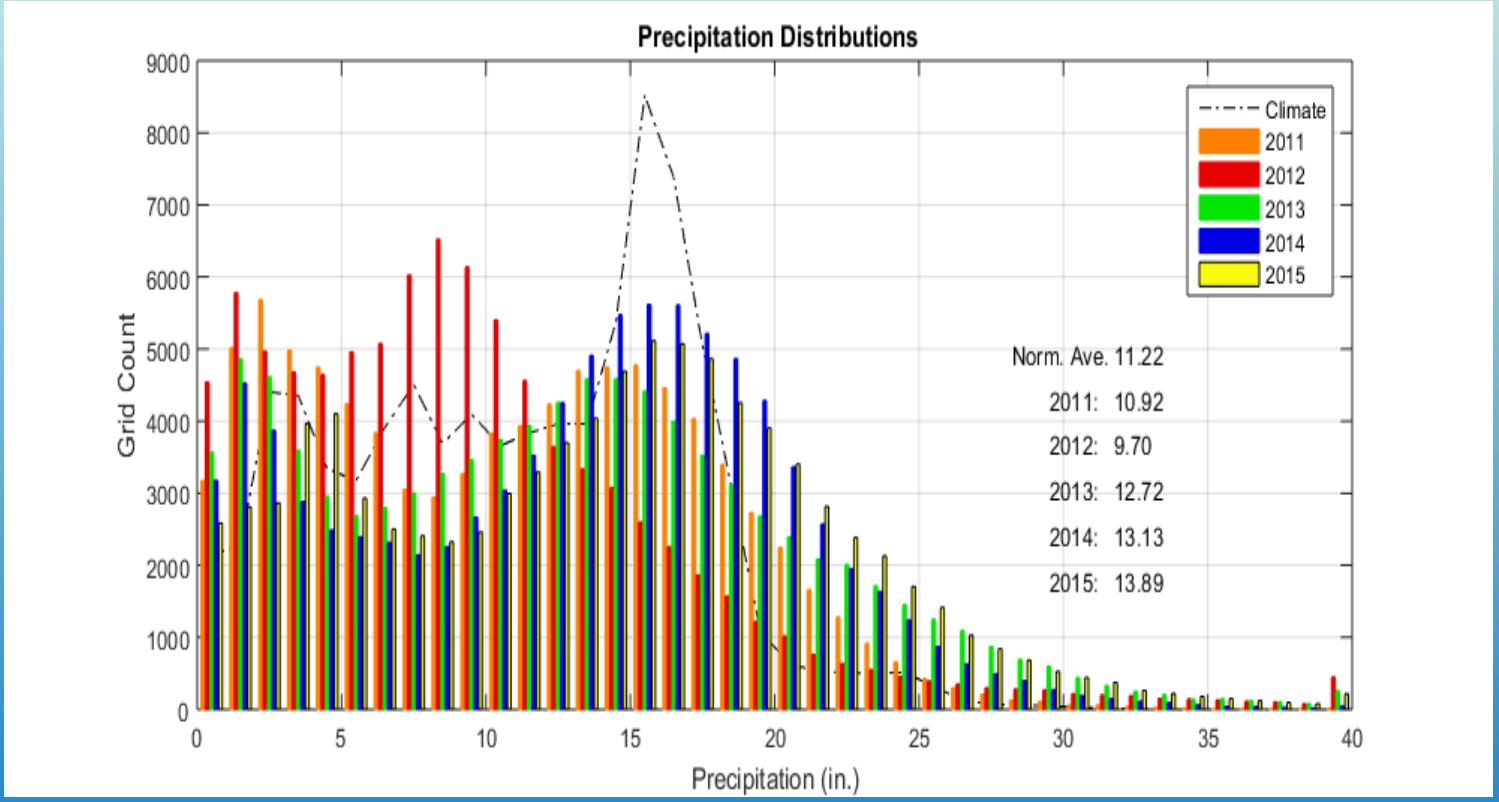
Cumulative Daily Negative Counts (Full NLDN)



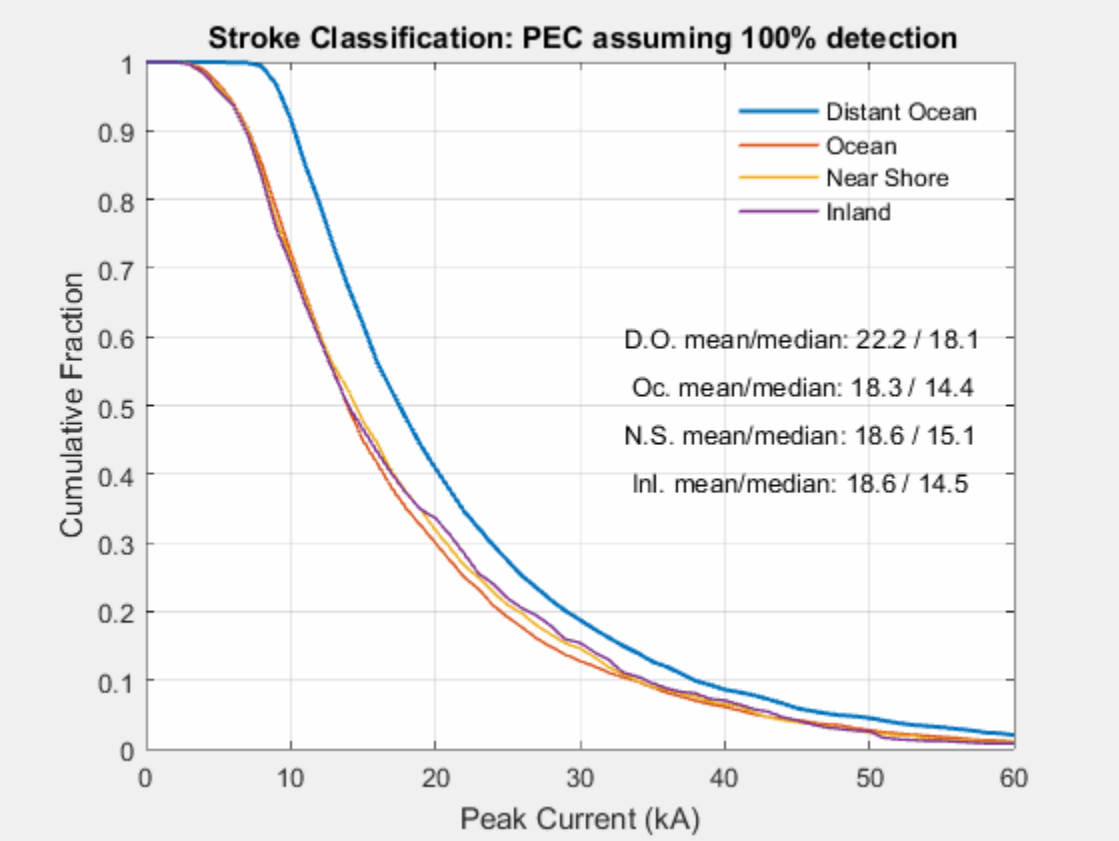
Cumulative Daily Negative Counts (CONUS)



Further Evidence of 2012 Drought



Peak Current Comparisons

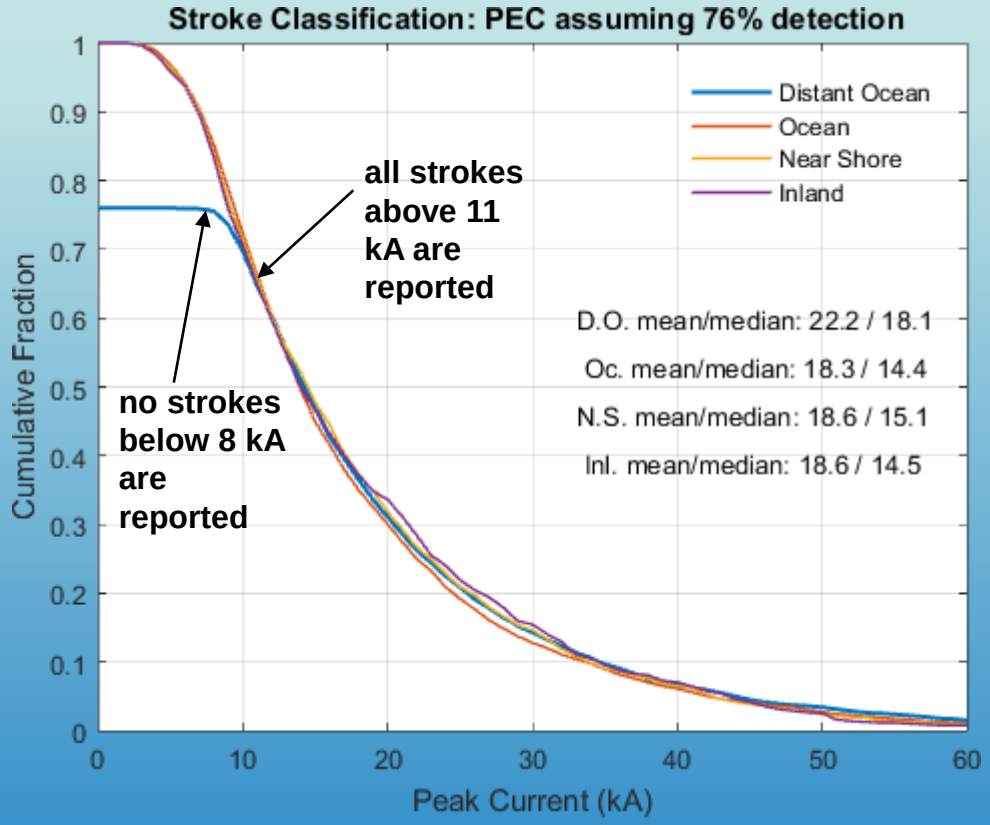


For each (small) region:

- 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