The Impact of Lightning Density Input on Tropical Cyclone Rapid Intensity Change Forecasts

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Outline

- Lightning activity and tropical cyclone intensity change
- Lightning density from WWLLN and rapid intensification (RI)
- Experimental RI forecast algorithm
- Results from 2010 NHC GOES-R Proving Ground
- Plans for 2011 NHC Proving Ground
  - Include rapid weakening and rapid intensification

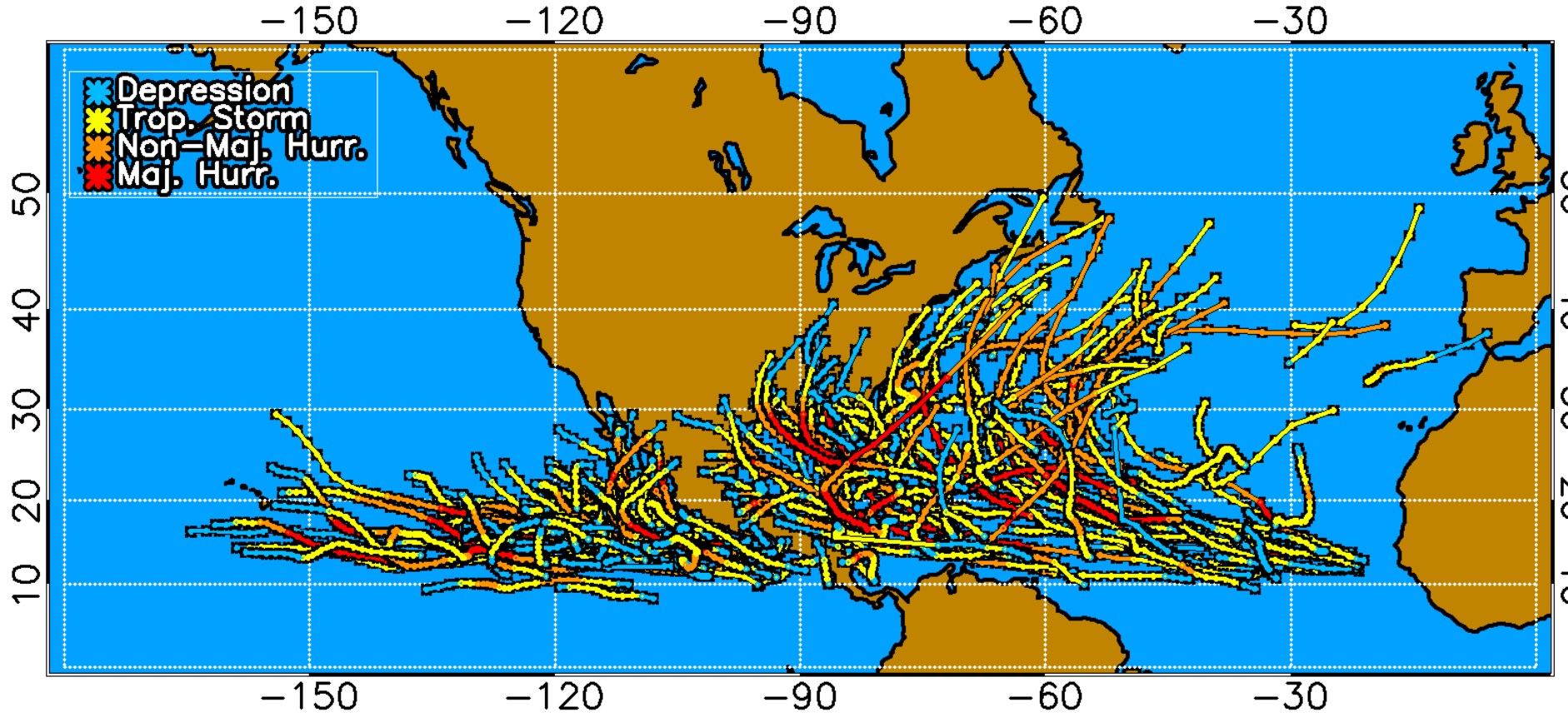
Lightning and TC Intensity Change

- Cecil and Zipser (1999)
  - More lightning in weaker storms
  - Little relationship with TC intensity change
  - Small OTD sample
- Squires and Businger (2008)
  - Eyewall lightning outbreaks during rapid intensification of Rita and Katrina
- Price et al. (2009)
  - Lightning increases related to rapid intensification
  - Time lag highly variable
- DeMaria and DeMaria (2009)
  - Rainband lightning most correlated with rapid intensification
  - Largest inner core lightning density with sheared systems
- Abarca et al. (2011)
  - Flash density smaller for hurricanes than non-hurricanes
  - More lightning for intensifying systems
  - Lightning distribution more symmetric for intensifying systems

Data Sample for 2010 Experimental Forecast Algorithm

- Full lifecycle of all Atlantic and east Pacific tropical cyclones 2005-2009
  - Over water only
- Storm environmental variables from SHIPS intensity model database
  - SST, vertical shear, etc.
- Storm centered lighting density
  - WWLLN data w/ annual normalization to OTD/LIS
  - 6-hour composites
  - 100-km radial intervals 0 to 600 km

2005-2009 Storm Tracks

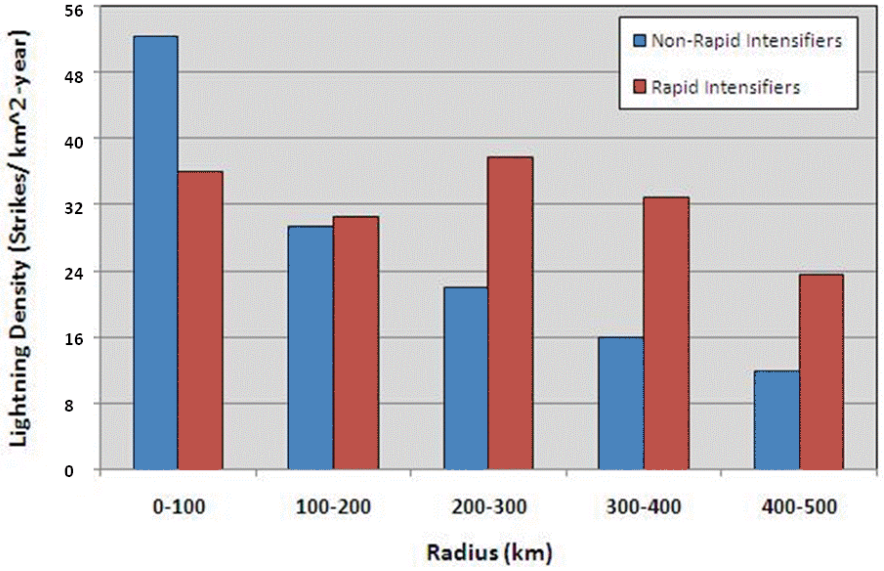


East Pacific: 1327 cases from 90 tropical cyclones
Atlantic: 1154 cases from 86 tropical cyclones

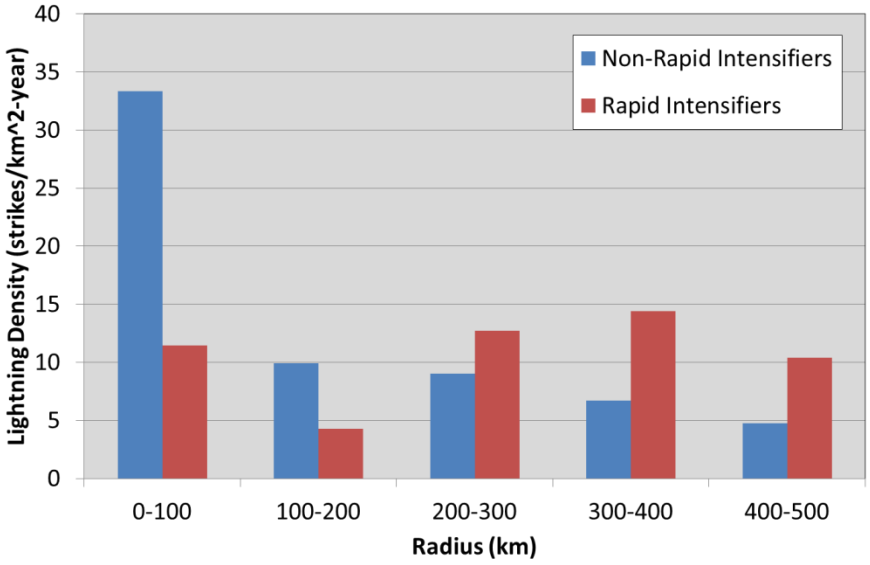
Rapid Intensification (RI)

- Increase in maximum winds of 30 kt or more in 24 hr
  - Difficult but important forecast problem
- ~10th percentile of long-term climatology
- Environmental factors associated with RI
  - Low shear, large upper-level divergence
  - High oceanic heat content, warm SST,
  - high low-level RH
  - Cold and symmetric cloud tops (from GOES IR)
  - Some intensification in previous 12 hr

Lightning Density vs. Radius for RI and non-RI Cases



Atlantic



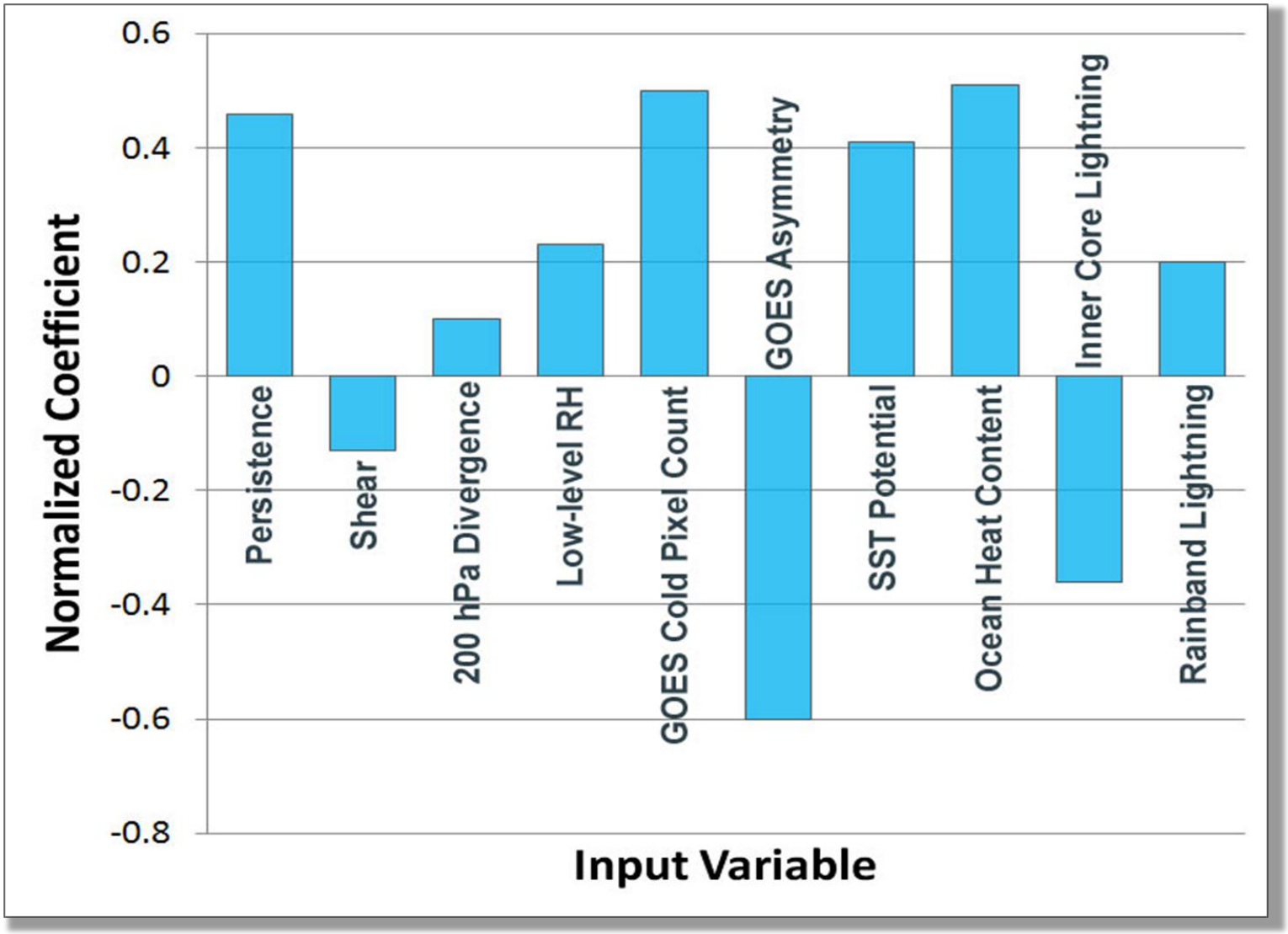
East Pacific

Lightning density also function of vertical shear, SST, initial intensity, etc.

Experimental Forecast Algorithm: The Lightning-based Rapid Intensification Index (L-RII)

- Linear discriminant analysis
  - Optimally weights multiple inputs to separate data sample into 2 classes
    - RI and non-RI cases
- NHC operational RII algorithm includes 8 inputs
- Add 2 lightning parameters for L-RII
  - Inner core density (0-100 km)
  - Rainband density (300-400 km)
- Versions with and without lightning from same developmental sample
- Provides probability of RI in the next 24 hr

Normalized Discriminant Weights (Atlantic L-RII Algorithm)

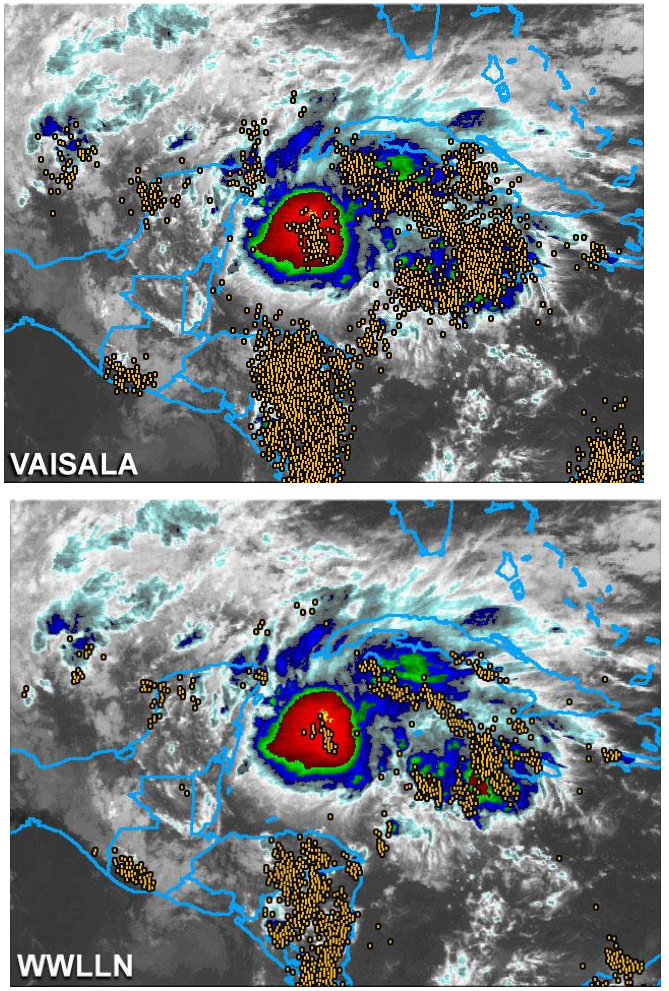


The GOES-R Proving Ground

- GOES-R will include 16 channel advanced baseline imager and geostationary lightning mapper (GLM)
  - Scheduled for late 2015
- Proving ground provides real-time demonstrations of GOES-R data and products to NWS forecasters
  - Run with proxy data
- 6 products demonstrated at NHC
  - Including experimental rapid intensity algorithm
  - GLM proxy from Vaisala GLD360 lightning locations

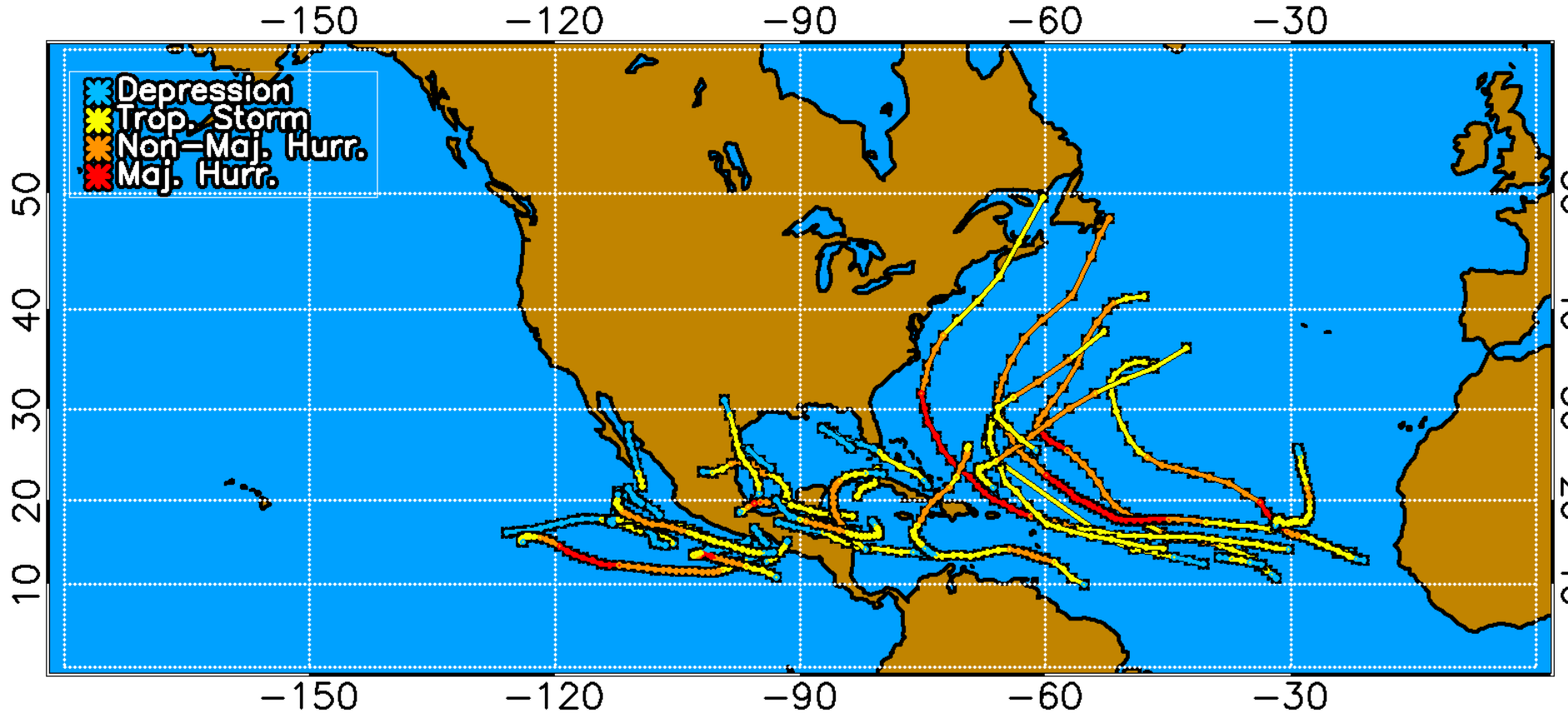
Normalization of GLD360 data

- Spatially dependent adjustments to GLD360
- Based on 3 month overlap of WWLLN, GLD360
  - Oct-Dec 2009



Hurricane Ida Nov., 2009

2010 Storm Tracks

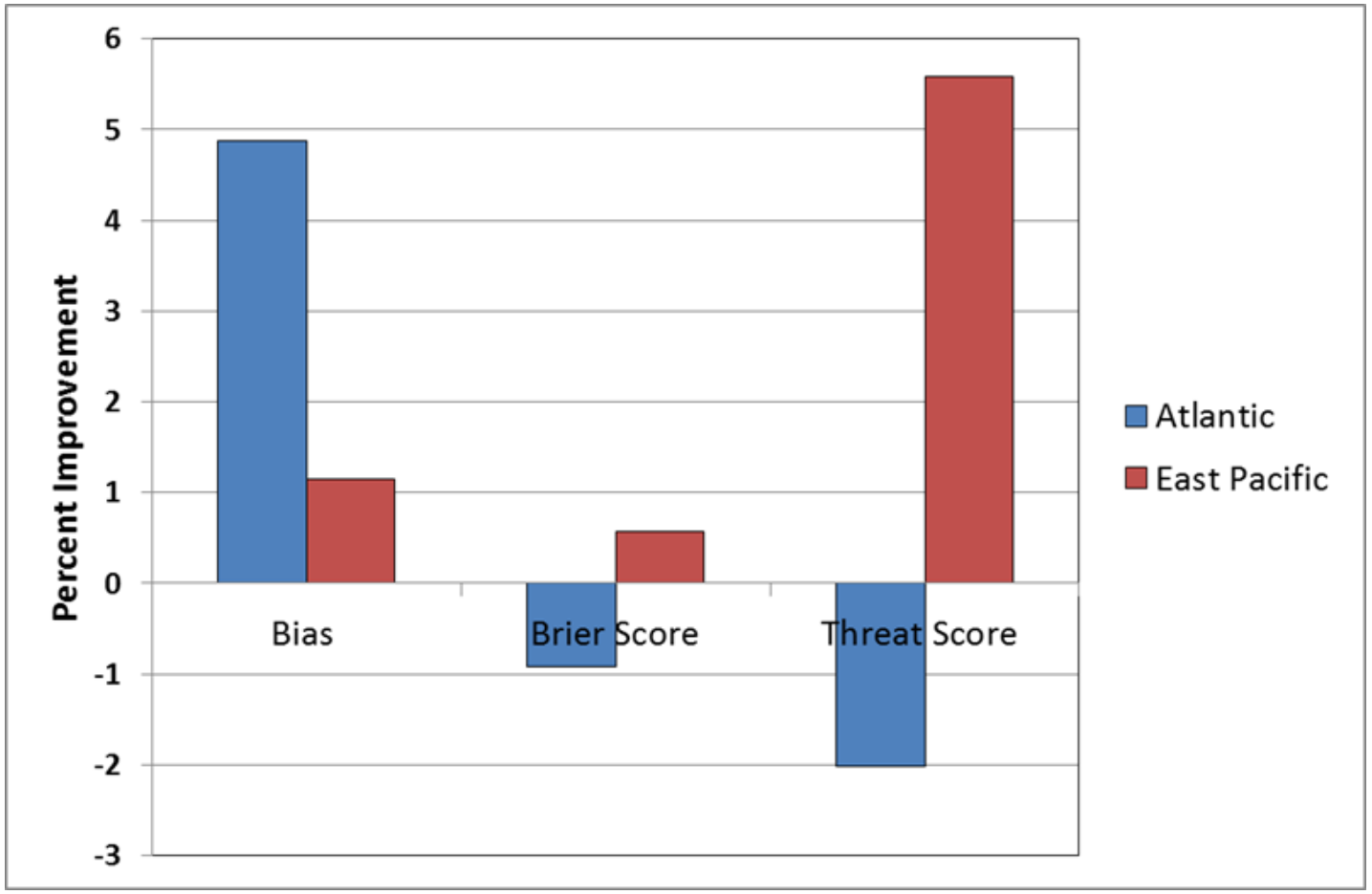


East Pacific: 121 cases from 12 tropical cyclones
Atlantic: 291 cases from 21 tropical cyclones

RII Verification Metrics

- Bias = ($\Sigma P_f / N_{obs}$) - 1
- Brier Score = $(1/N_f)\Sigma[P_f - P_{obs}]^2$
- Threat Score = a/(a+b+c) from 2 by 2 contingency table
  - Area of overlap between forecast and observations
  - Find max TS for range of probability thresholds

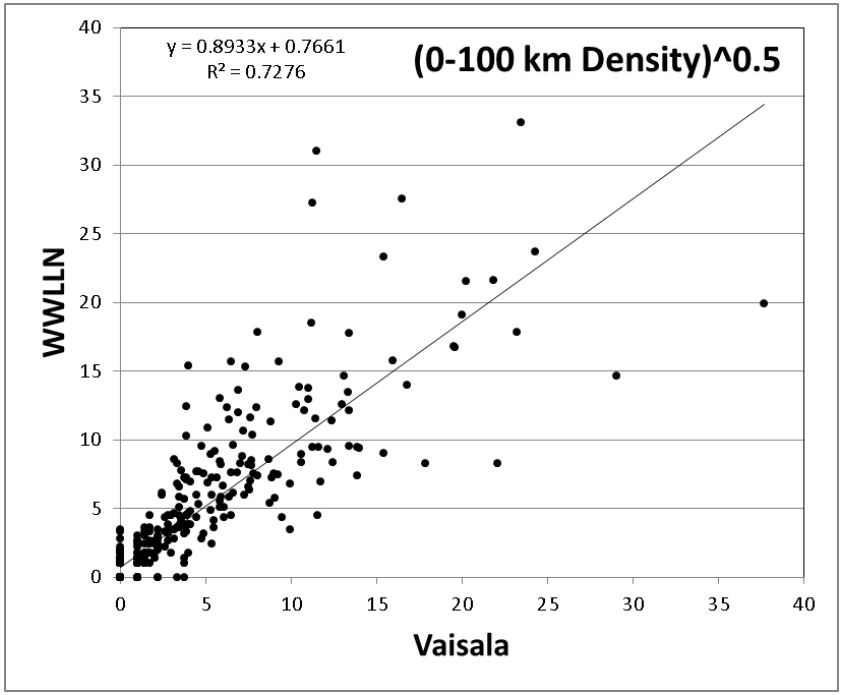
2010 Verification Results: Impact of Lightning Input (GLD-360)

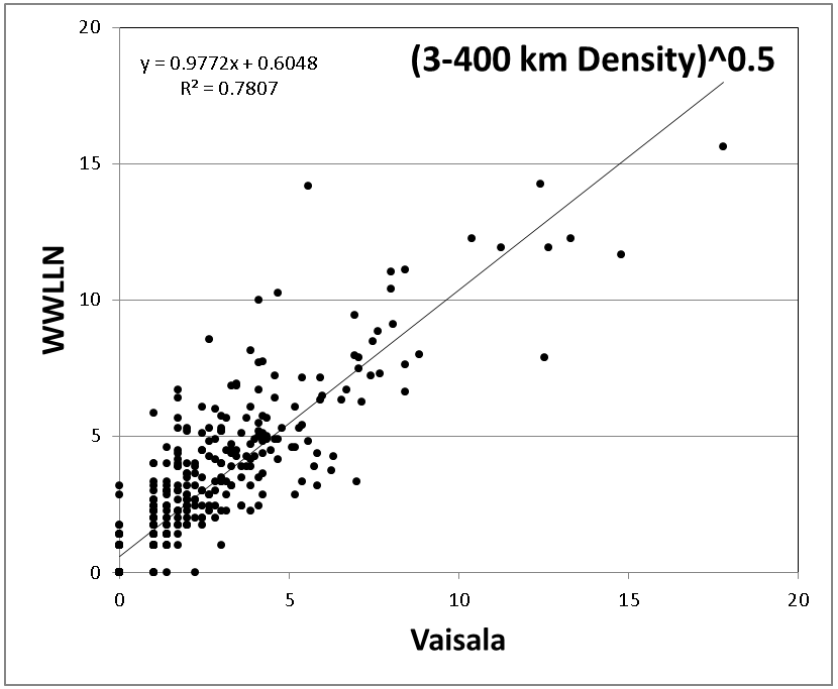


Evaluation of GLD360 to WWLLN Adjustment

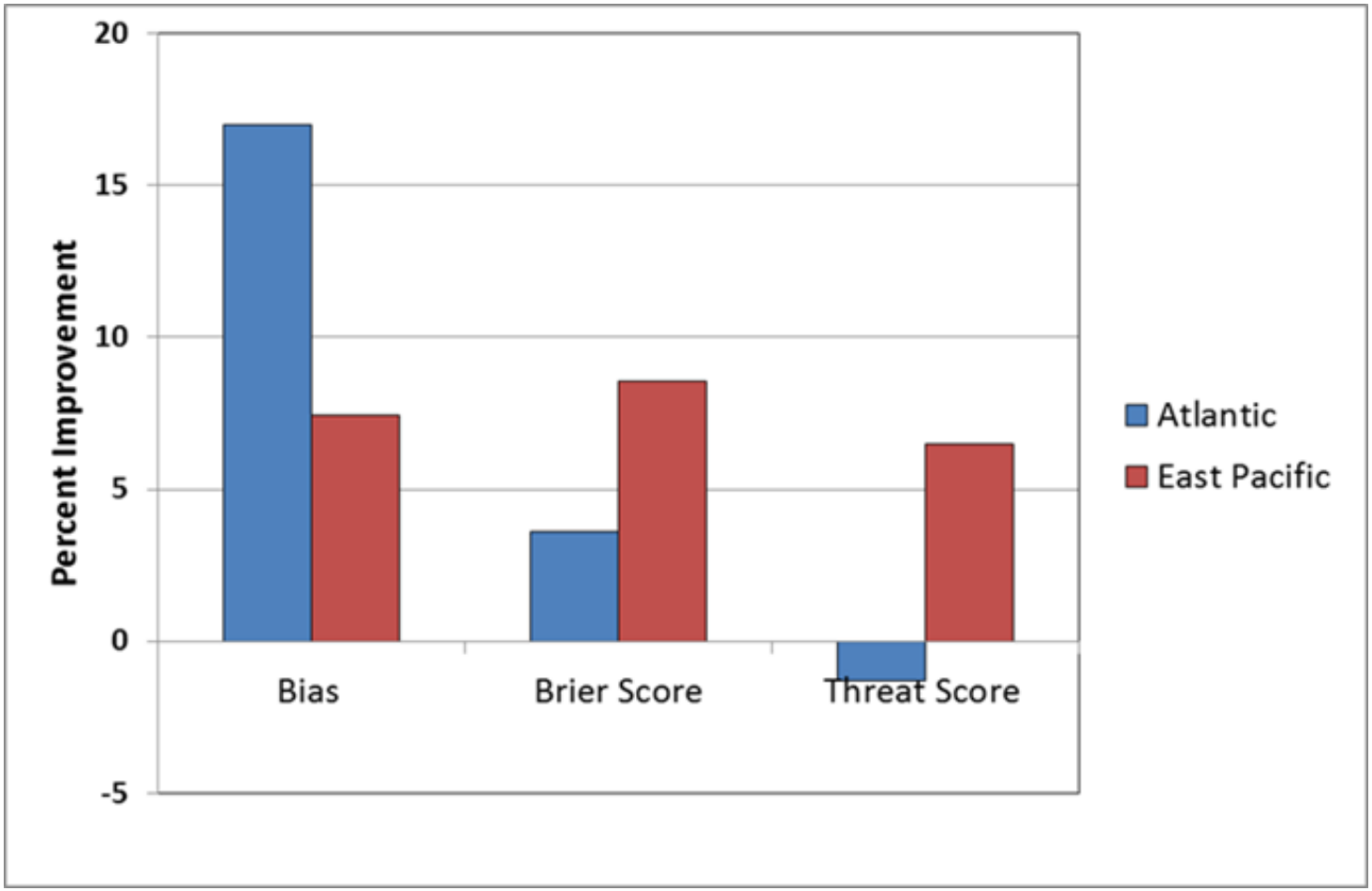
- 2010 WWLLN data obtained in post season
- Compare RII lightning parameters with GLD360 and WWLLN input
- Rerun 2010 RII forecasts with WWLLN-based parameters

Comparison of RII Input Parameters with WWLLN and Vaisala GLD360





2010 Verification Results: Impact of Lightning Input (WWLLN)

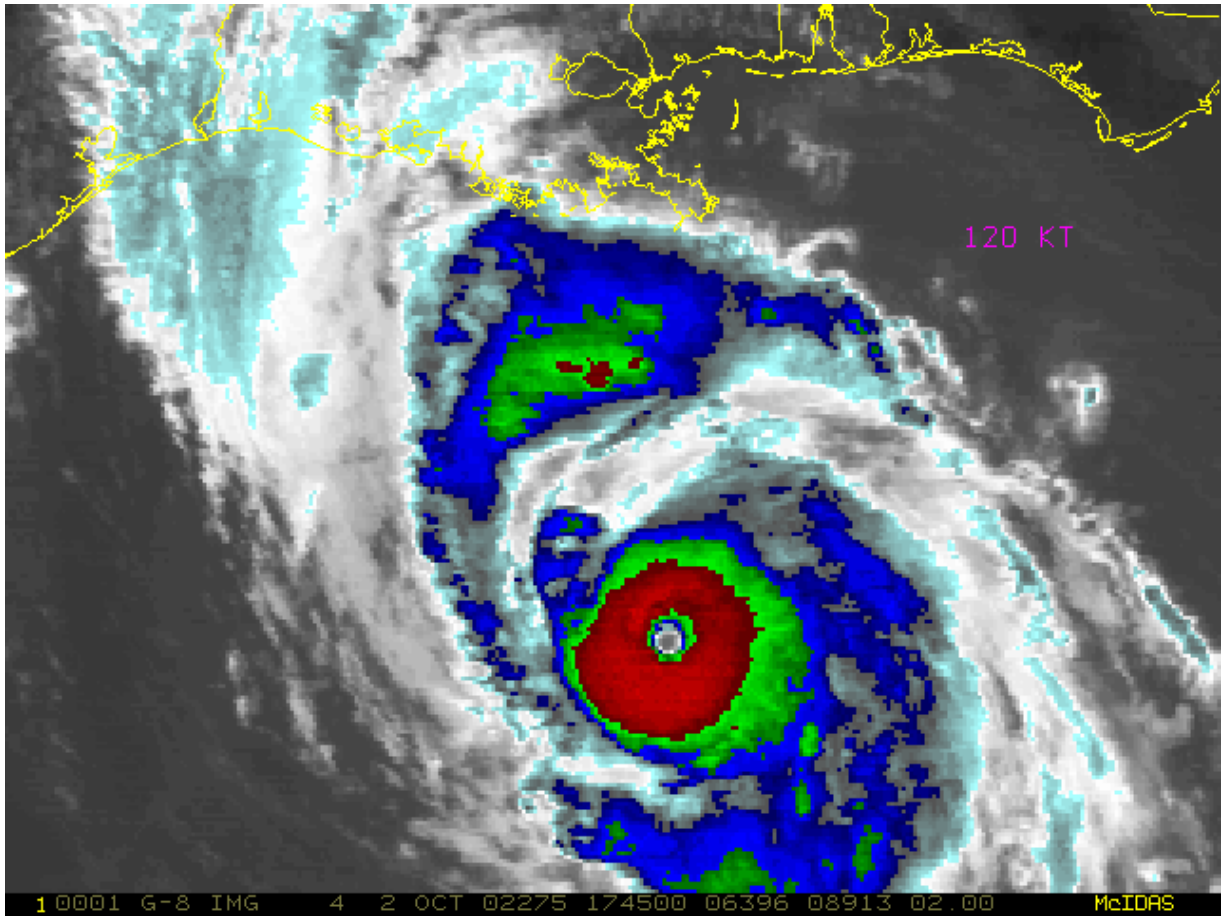


Plans for 2011

- Add 2010 storm cases to developmental sample
- Run lightning and no lightning version in 2011 NHC Proving Ground
  - starts Aug. 1st
- Use real time WWLLN data feed
  - Consistent with developmental sample
- Generalize RII algorithm to also include over-water rapid weakening cases

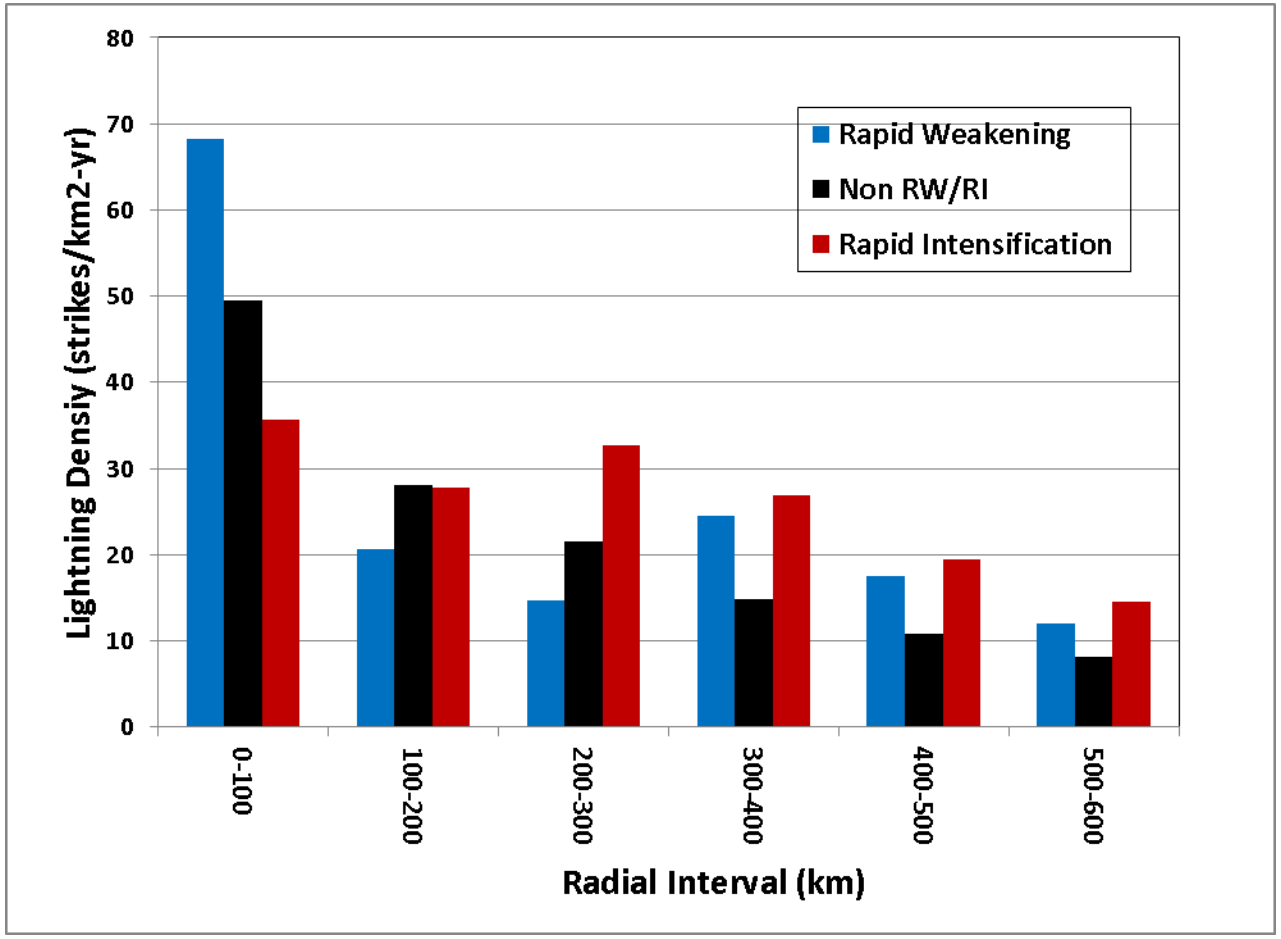
  Decrease in maximum winds of at least 20 kt in 24 hr (~7th percentile)

Hurricane Lili 2002
120 to 80 kt in 18 hr *before* landfall

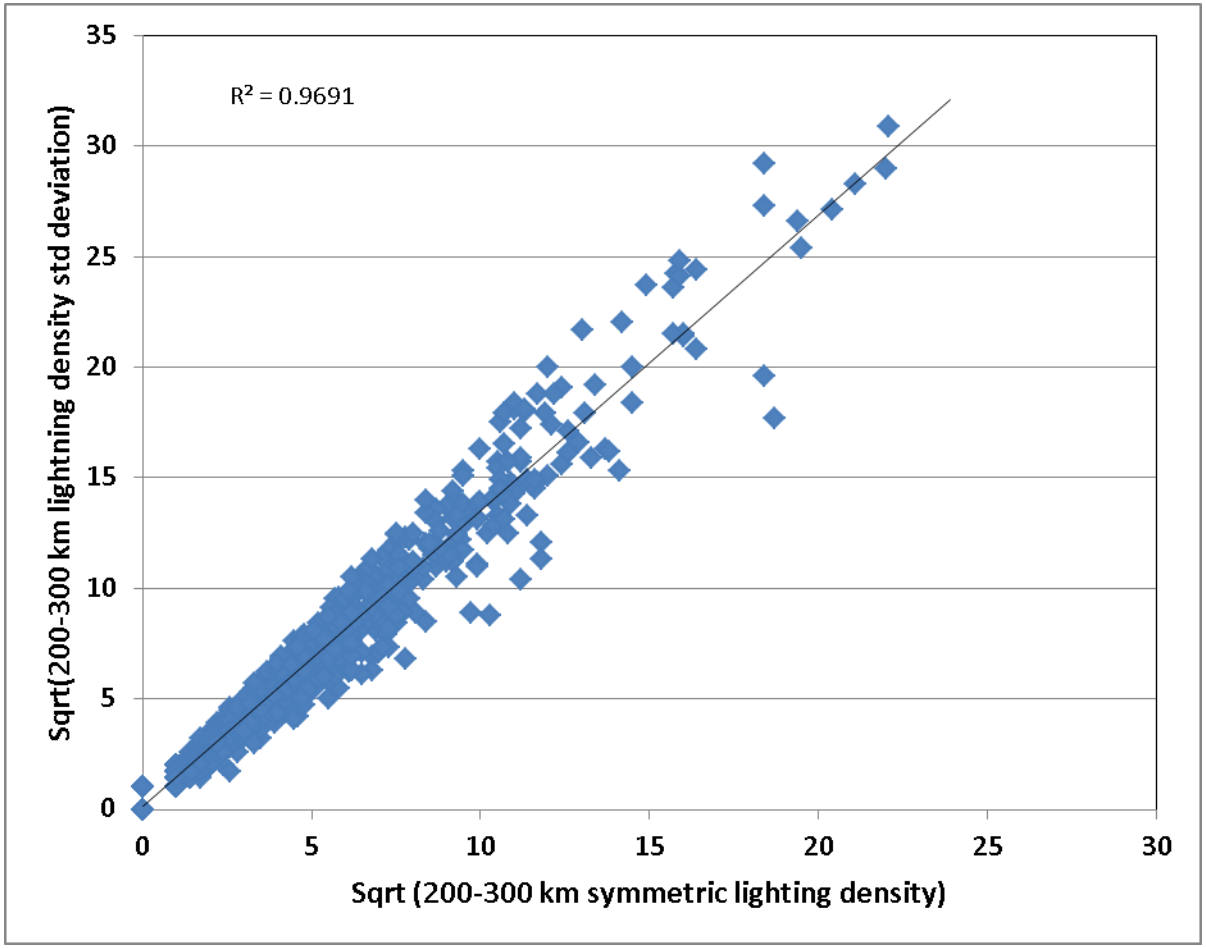


2005-2010 Atlantic Sample

Lightning Density for RW, Avg, RI Cases



Use of Lightning Asymmetry



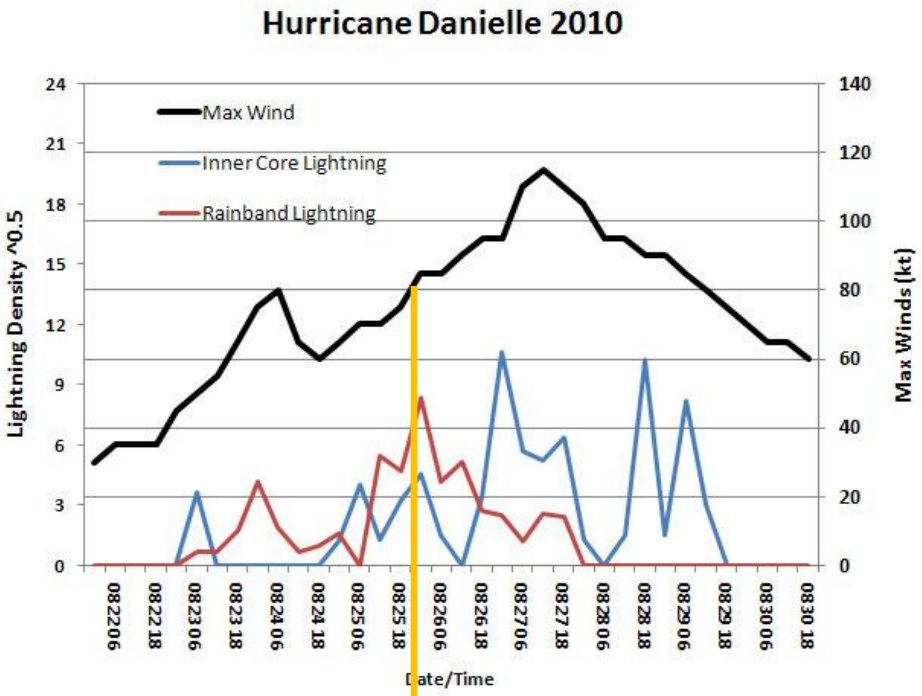
Mean and Standard Deviation are Highly Correlated

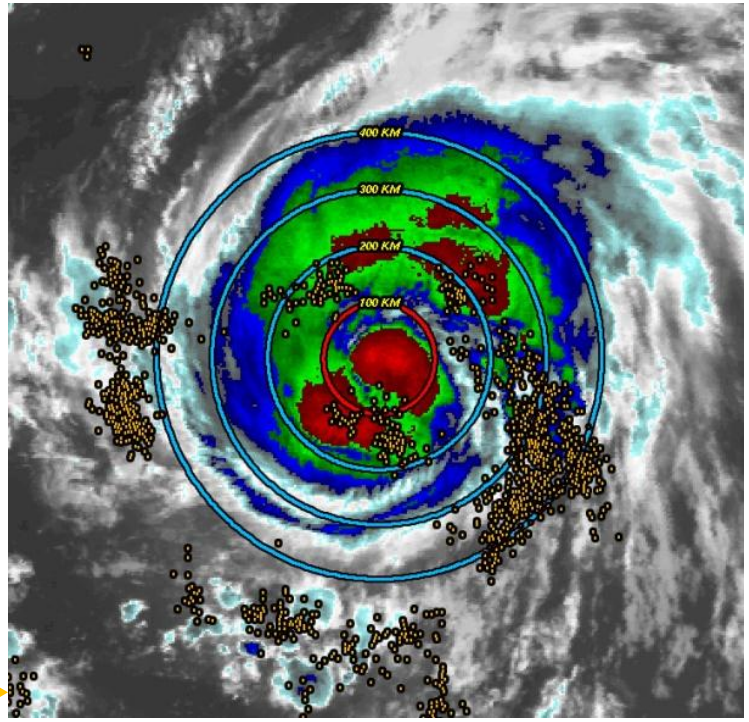
Conclusions

- Large sample of lightning and large-scale data created for Atlantic and east Pacific tropical cyclones
- Experimental rapid intensification forecast algorithm developed
  - Inner core and rainband lightning discriminators
- Independent cases from 2010 showed reduced bias, improved Brier Score in Atlantic and east Pacific
- 2011 algorithm will also include rapid weakening probability
- Real time runs begin Aug. 1st

Back-Up Slides

Qualitative Use of Lightning Time Series
Hurricane Danielle (2010) example





Qualitative Use of Lightning Time Series
Tropical Storm Fiona (2010) example