

# The National Hurricane Center GOES-R Proving Ground

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**GLM Science Meeting, Huntsville, AL**

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# Outline

- Overview of NHC Proving Ground
- Lightning and tropical cyclone rapid intensity change (RIC)
- Experimental RIC forecast algorithm
- Results from 2010 NHC GOES-R Proving Ground
- Preliminary results from the 2011 Proving Ground

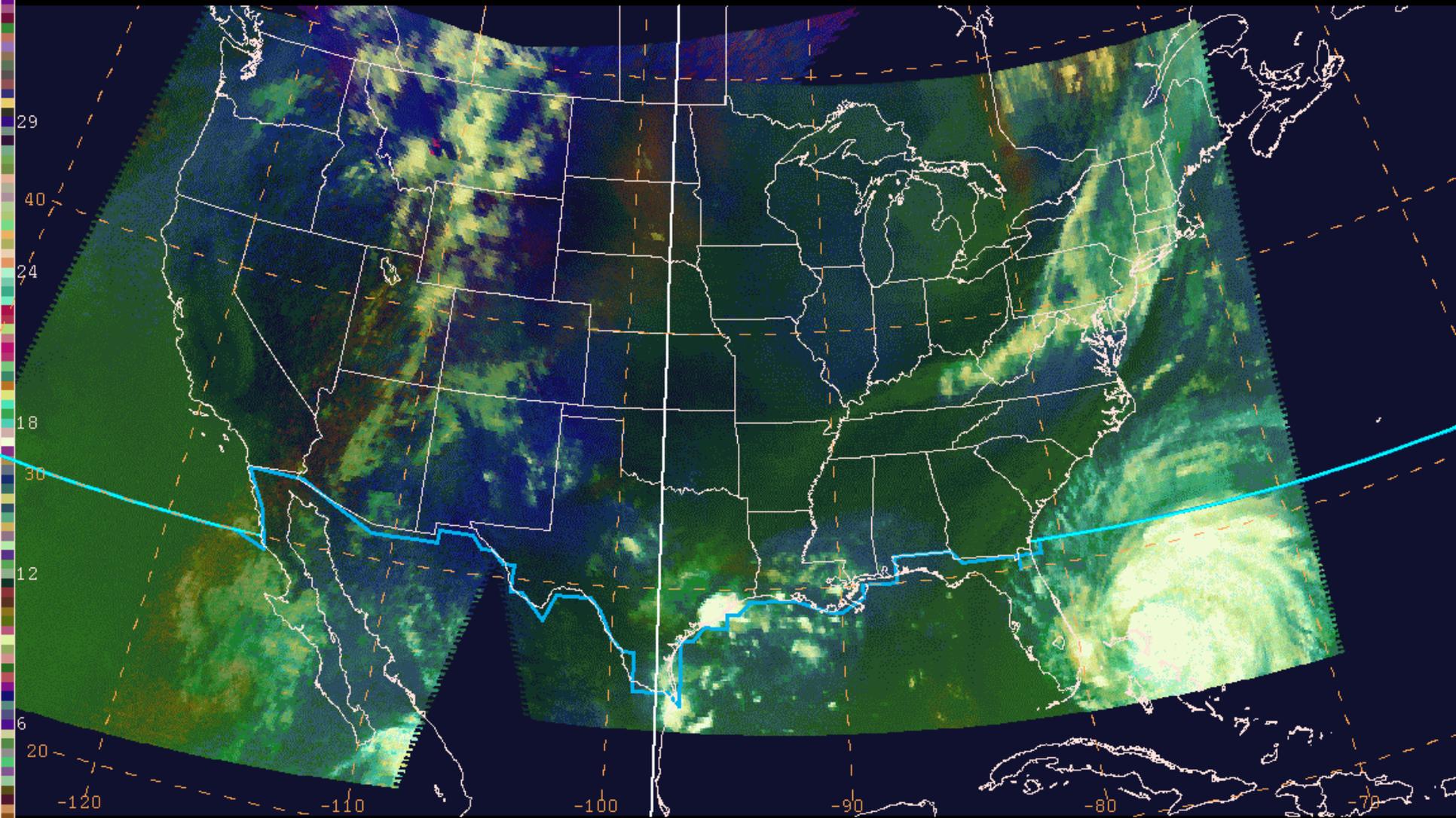
# The NHC Proving Ground

- Purpose
  - Provide NHC forecasters with an advance look at GOES-R tropical cyclone forecast products for evaluation and feedback
- Proxy data
  - ABI from SEVIRI, Current GOES, MODIS
  - GLM from WWLLN and GLD360
- 2010 Activities
  - 6 products tested Aug 1 to Nov 30
  - Final report available
  - Modifications suggested for 2011 proving ground
- 2011 Activities
  - 9 products being tested Aug 1 to Nov 30
  - Mid-project meeting at NHC Sept 13<sup>th</sup>
- Participants:
  - Users - NHC
  - Providers - NESDIS, CIRA, CIMSS, SPoRT, HRD/CIMAS

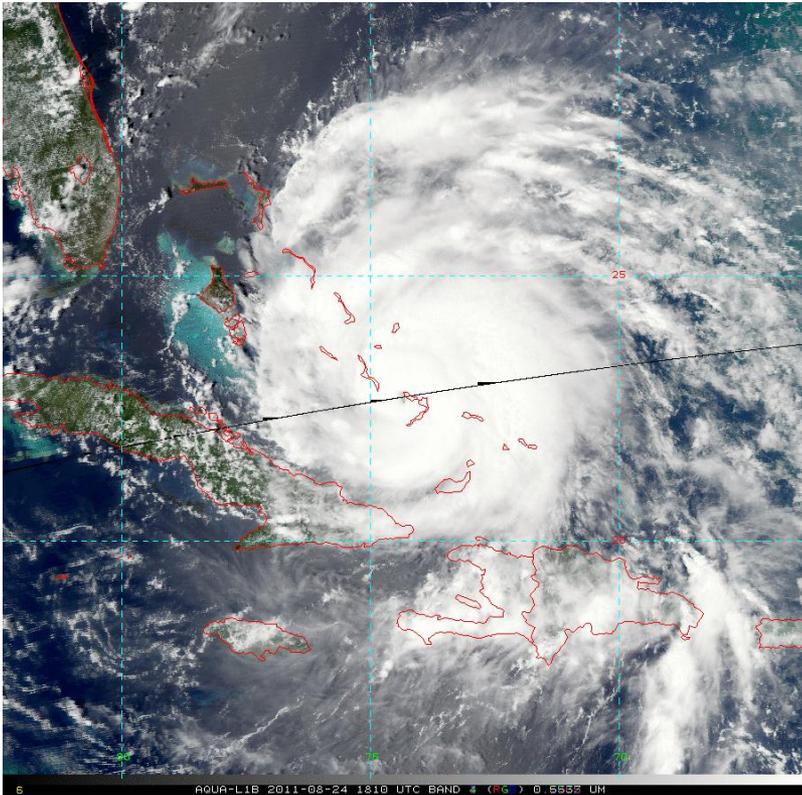
# 2011 NHC Proving Ground Products

- **Baseline**
  - Hurricane Intensity Estimate (HIE) from CIMSS
  - Super Rapid Scan Imagery coordinated by CIRA and NHC
- **Future Applications (formerly known as Option 2)**
  - Tropical Overshooting Top (TOT) Detection Algorithm from CIMSS **(new in 2011)**
- **Additional Future Applications from GOES-R Risk Reduction**
  - Red-Green-Blue (RGB) Air Mass Product from CIRA/SPoRT
  - RGB Dust Product from CIRA/SPoRT
  - Saharan Air Layer (SAL) Product from CIMSS
  - GOES-R Natural Color Imagery from CIRA **(new)**
  - Pseudo Natural Color Imagery from CIMSS **(new)**
  - Lightning based Rapid Intensification Index (RII) from CIRA

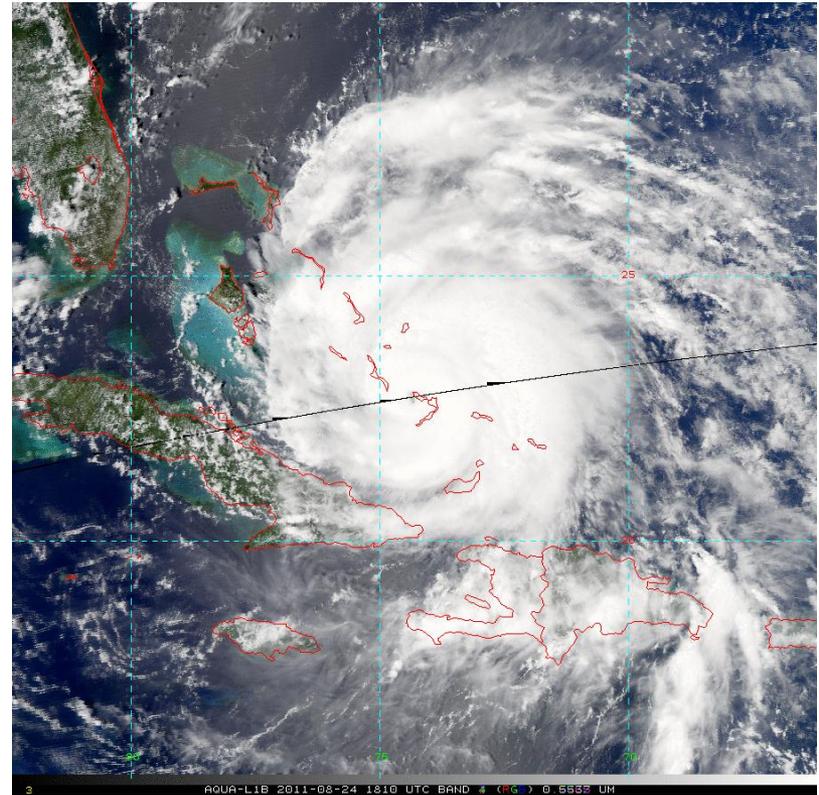
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# Natural Color Imagery from MODIS



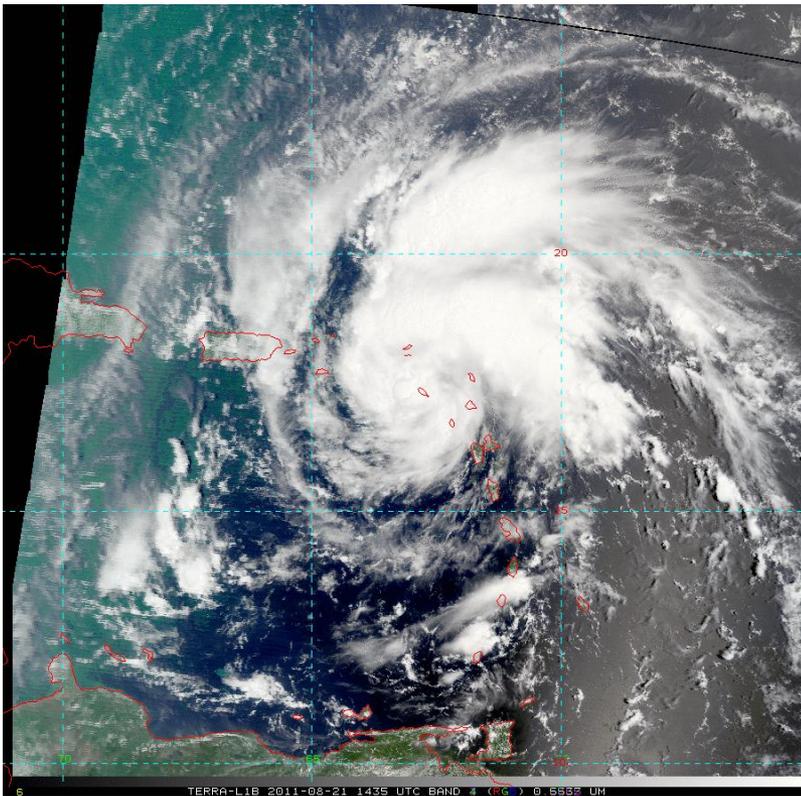
Simulated Green



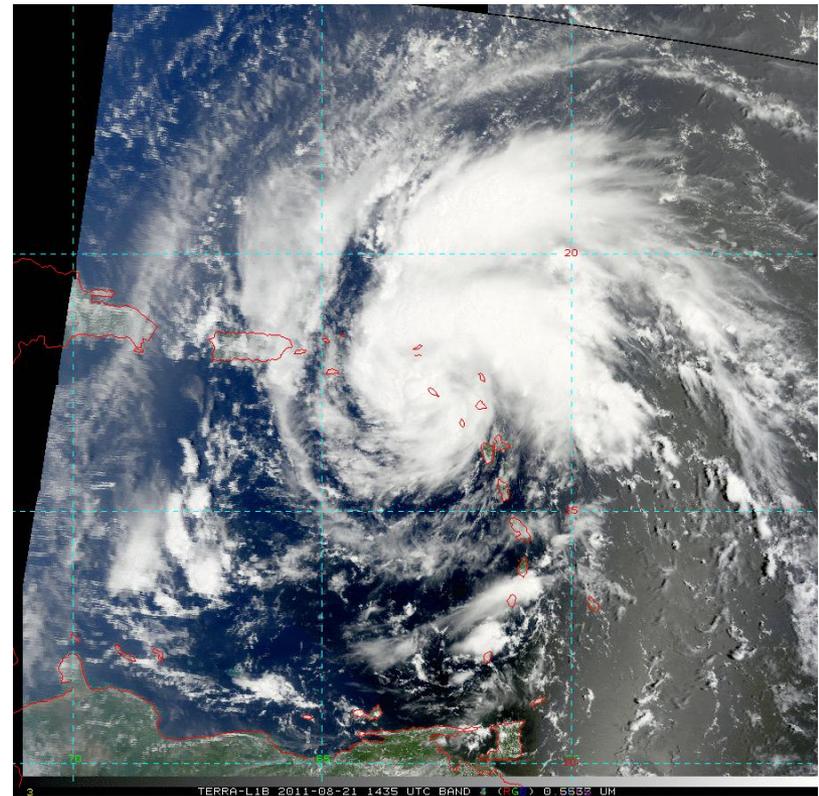
Observed Green

Caption: GOES-R natural color (left) and true color (right) from MODIS. Storm was close to center of MODIS pass, so limb effects less obvious. Shows shallow water regions in western Bahamas.

# Natural Color Imagery from MODIS



Simulated Green



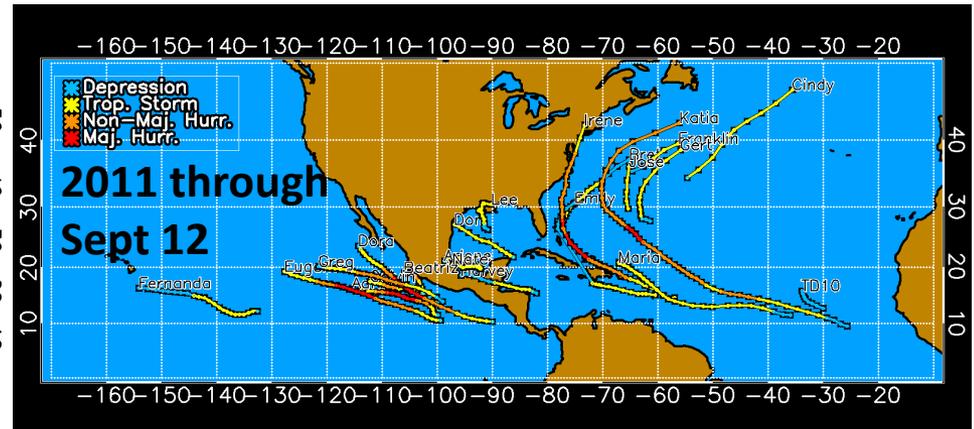
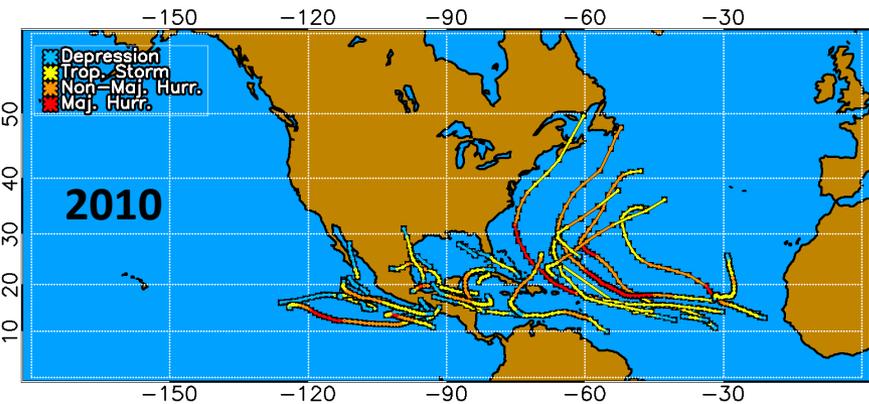
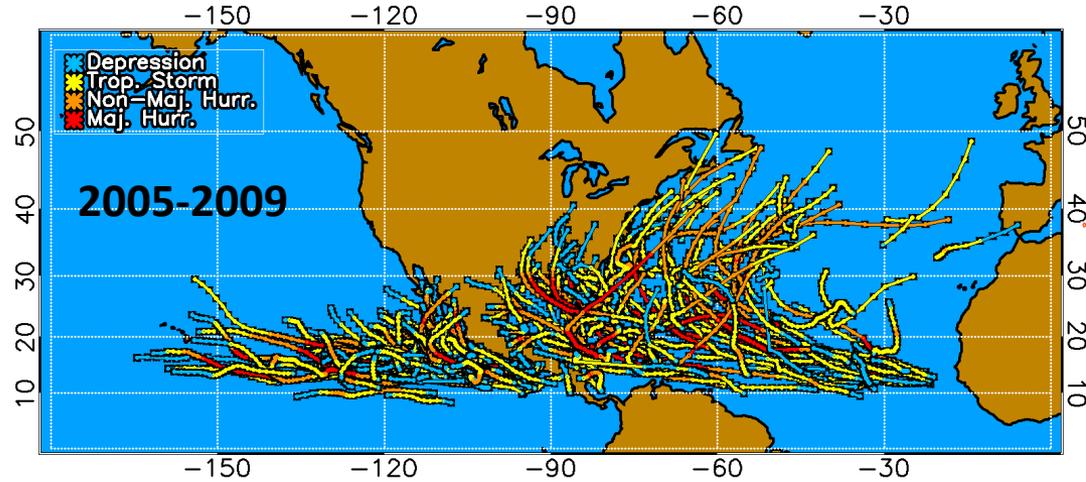
Observed Green

Caption: GOES-R natural color (left) and true color (right) from MODIS. Limb effects evident on left side of image. Algorithm correction developed by the imagery team

# Forecasting Rapid Intensity Changes with Lightning Data

- Use large sample of cases to develop statistical relationships with intensity change
- Combine with SHIPS model database
  - SST, shear, etc
- Full life cycle of Atlantic and east/central Pacific tropical cyclones 2005-2011
- WWLLN data proxy for GLM
- Annual basin wide correction for detection efficiency, conversion to total lightning
  - Normalize to OTD/LIS climatology

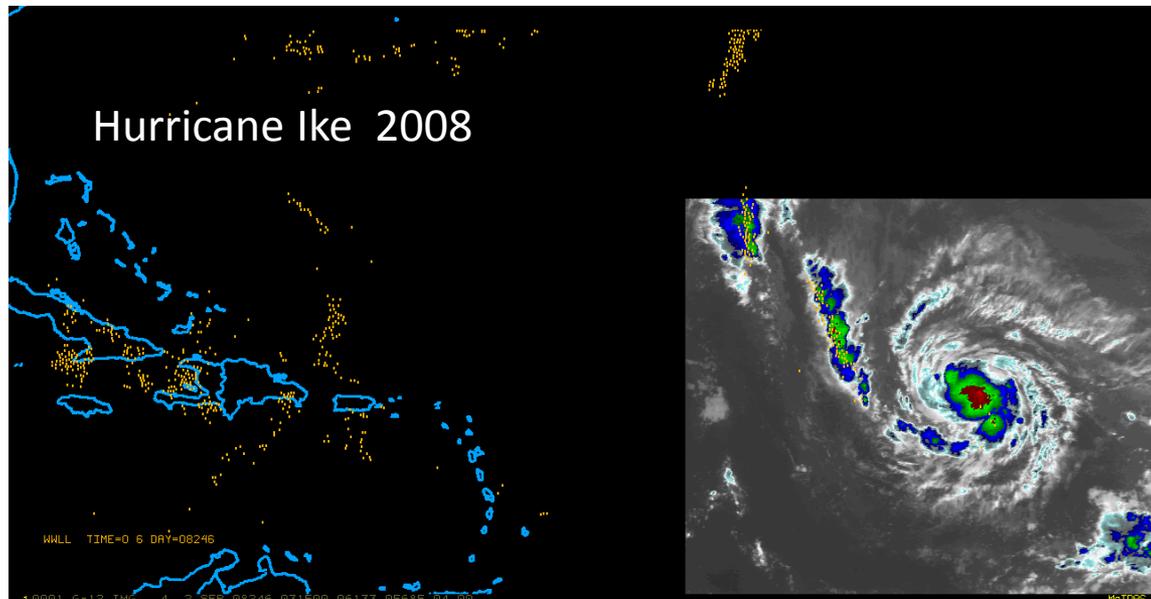
# Tropical Cyclone Sample



2005-2010 sample = 2542 cases from 172 tropical cyclones

# Lightning Analysis

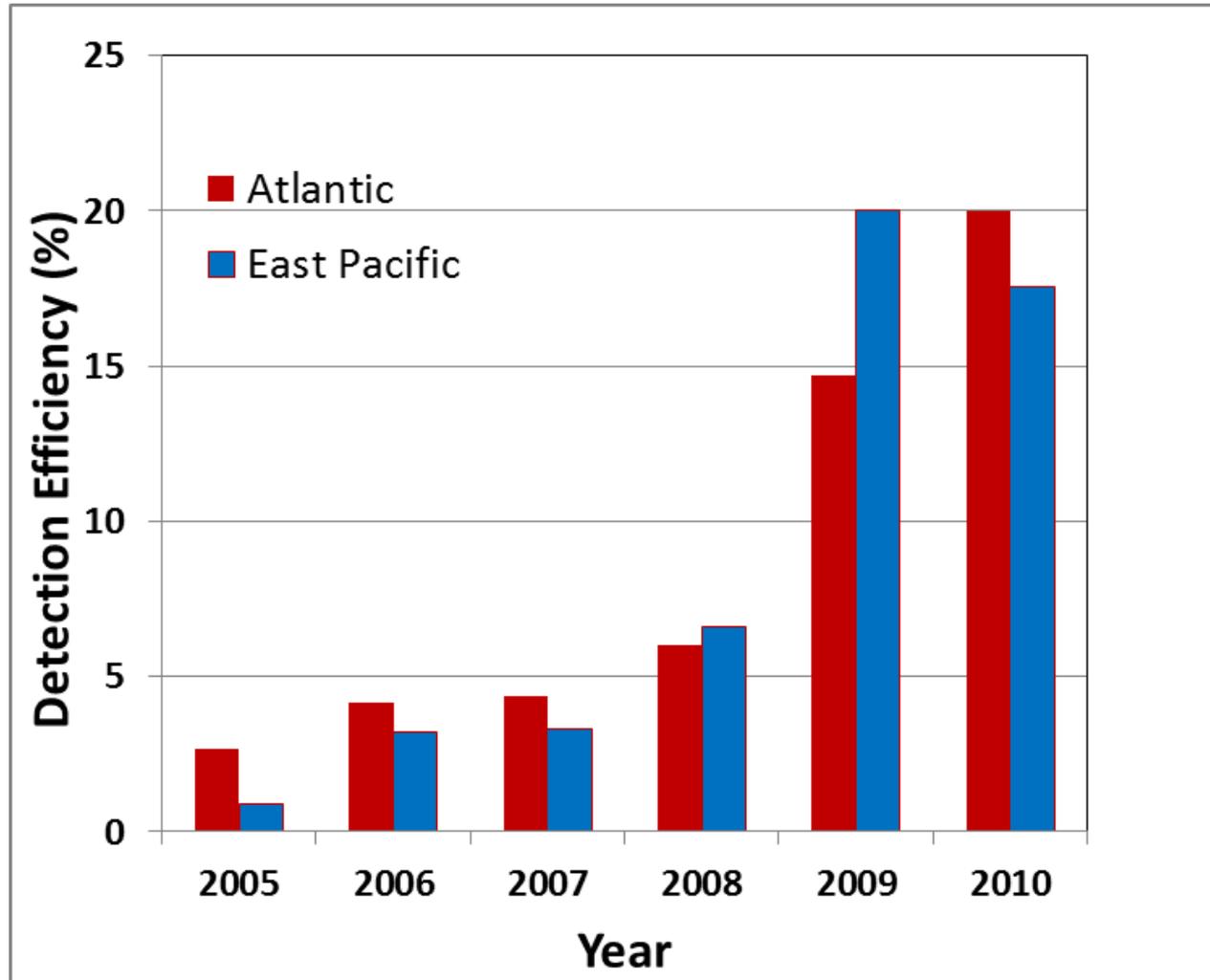
- Transform strike locations to storm-centered cylindrical grid
- Composite data over 6 hour intervals
- Compute lightning density in radial intervals
  - 0-50, 50-100, 100-200 km, ...
- Adjust density using annual conversion factors



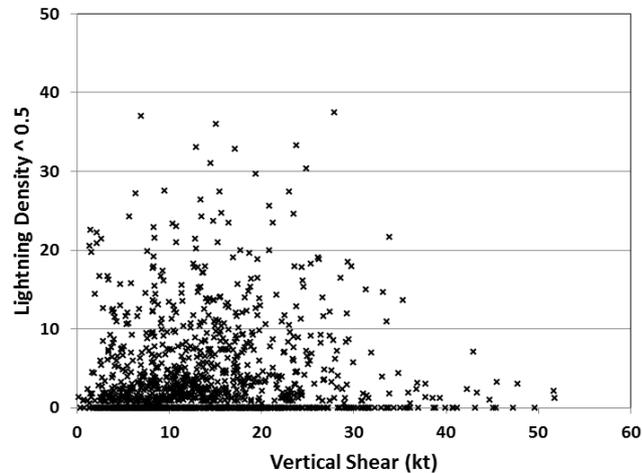
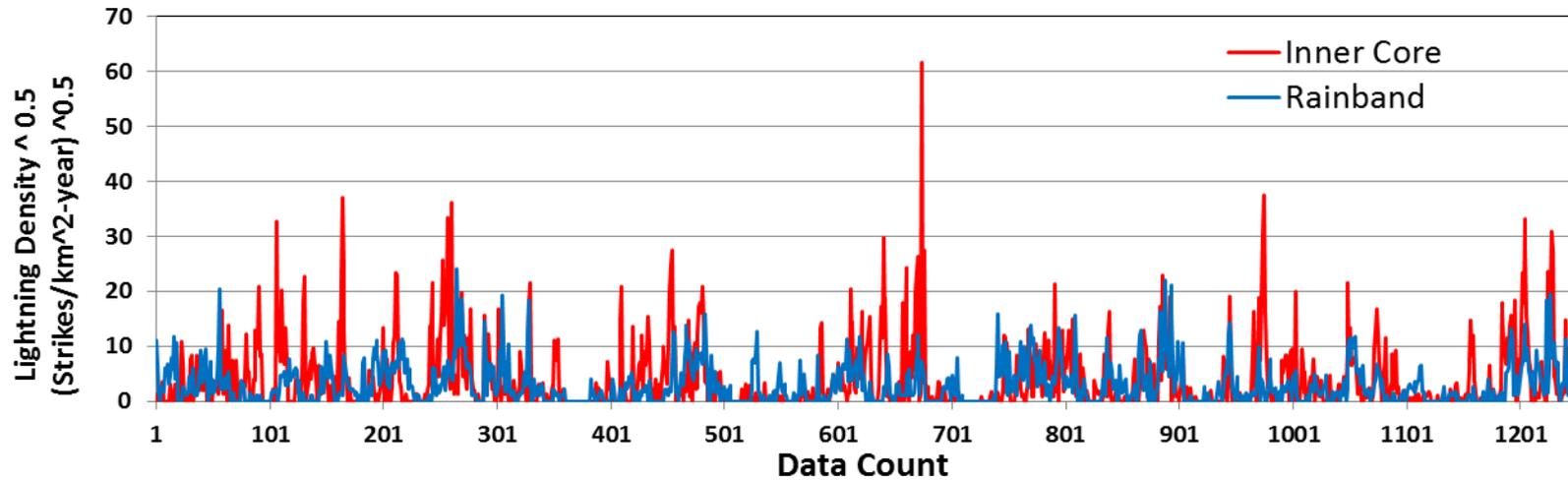
# Lightning Density Normalization

- Calculate annual average lightning density from WWLLN
  - Atlantic domain: 0-40°N, 100 to 10°W
  - East Pacific domain: 0-40°N, 180 to 100°W
- Compare with 1998-2005 OTD/LIS climatology
- Apply adjustment factor to WWLLN to make the values equal to OTD/LIS
- Inverse of adjustment factor is estimate of WWLLN detection efficiency for total lightning

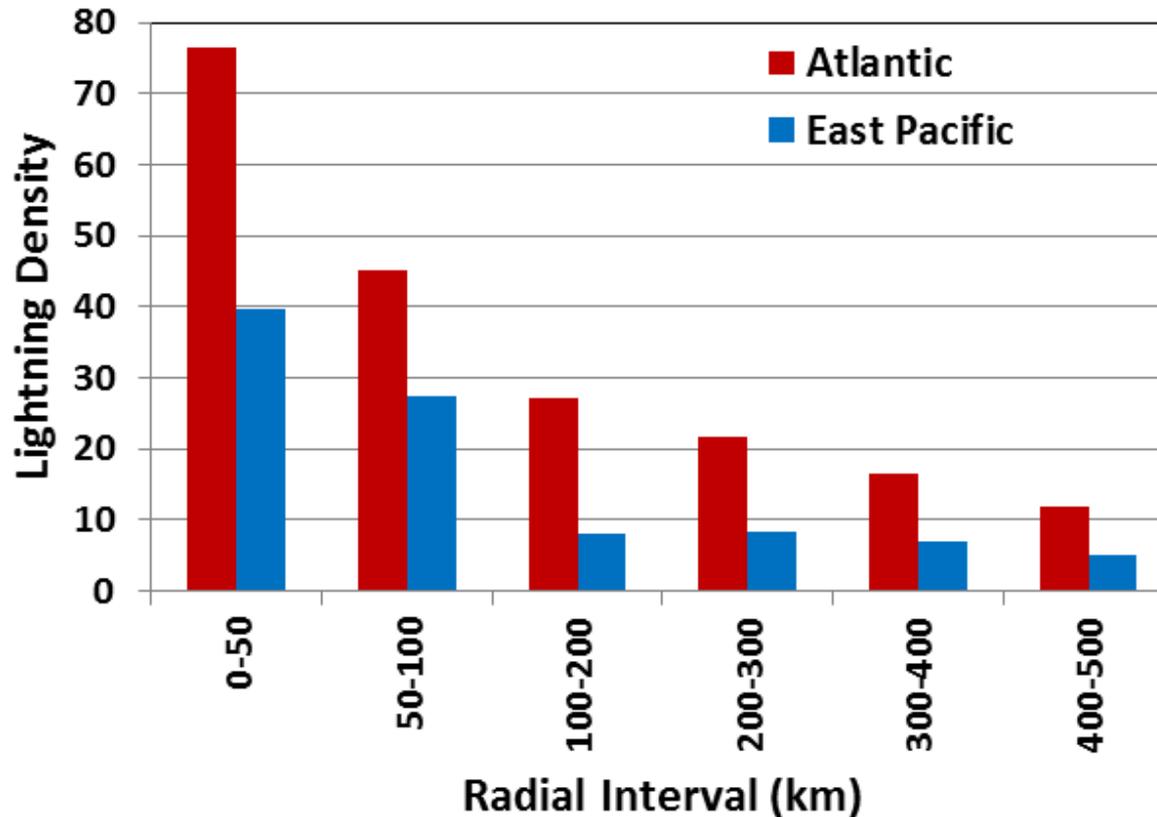
# Detection Efficiency



# 2005-2010 Atlantic Normalized Lightning Density Time Series



# Radial Structure



Eye wall 0-50 km

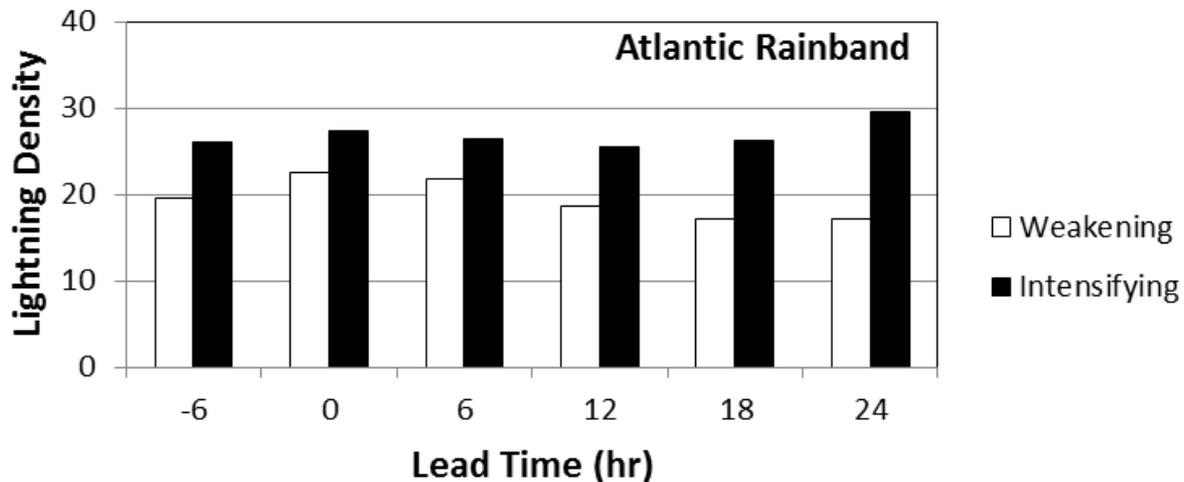
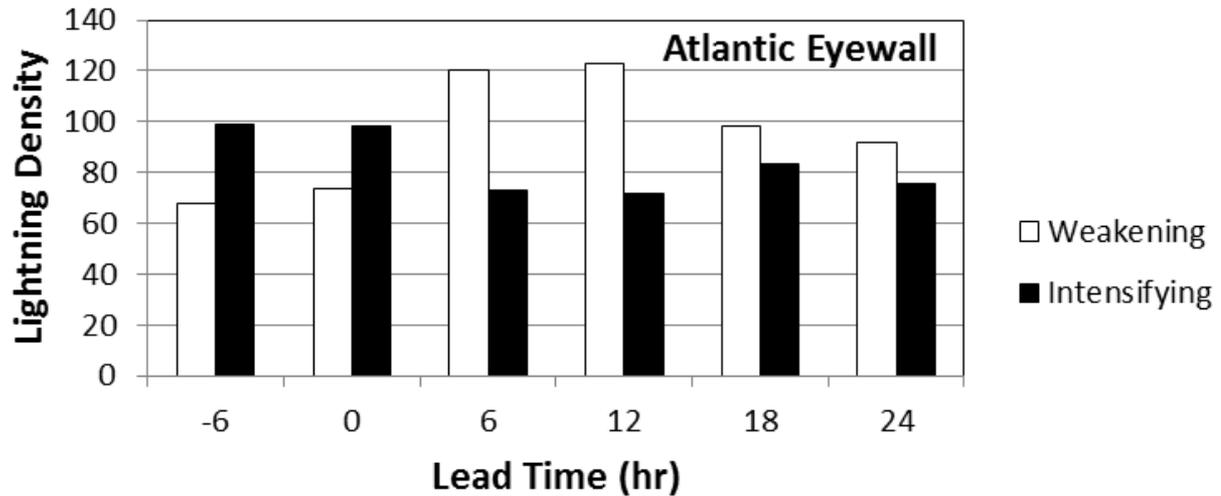
Inner Core 0-100 km

Rain band 200-300 km

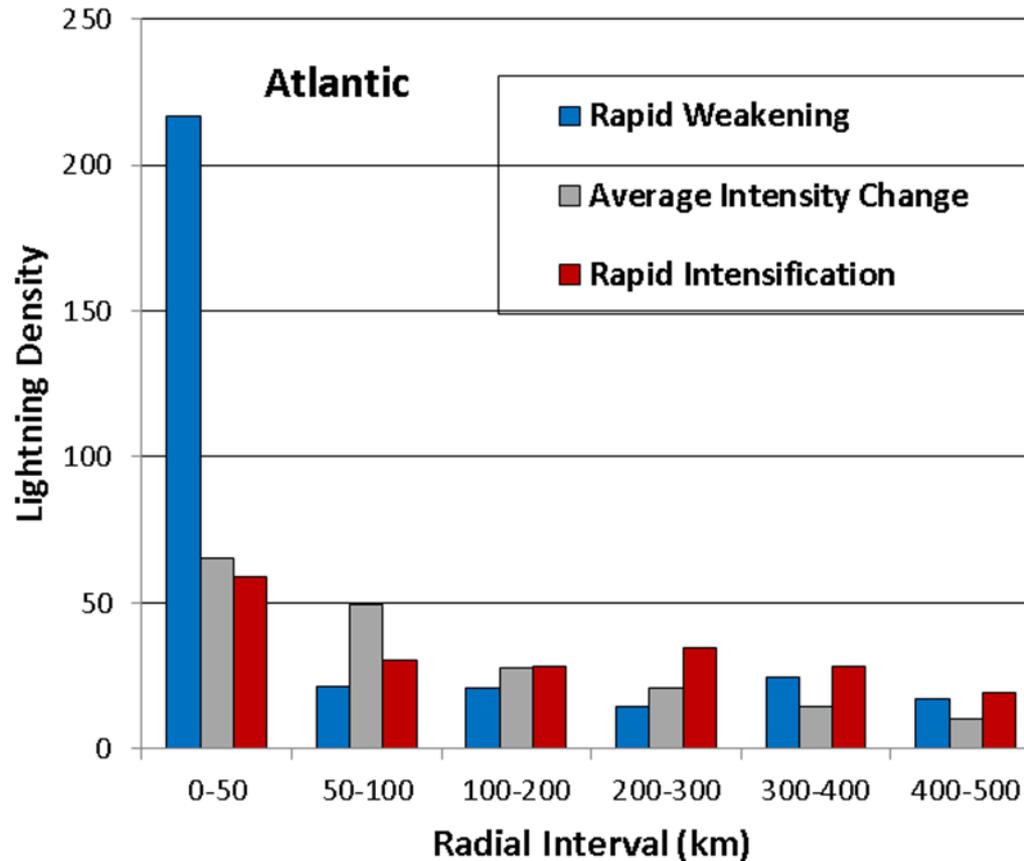
# Rapid Intensity Change

- Rapid Intensification (RI)
  - Increase in maximum wind of 30 kt or more in 24 hr
  - ~95<sup>th</sup> percentile of Atlantic sample
- Rapid Weakening (RW)
  - Decrease of maximum wind of 20 kt or more in 24hr
  - ~5<sup>th</sup> percentile of Atlantic sample (over water)
- Stratify lightning density by intensity change, RW and RI

# Stratification by Intensity Change at Various Time Lags



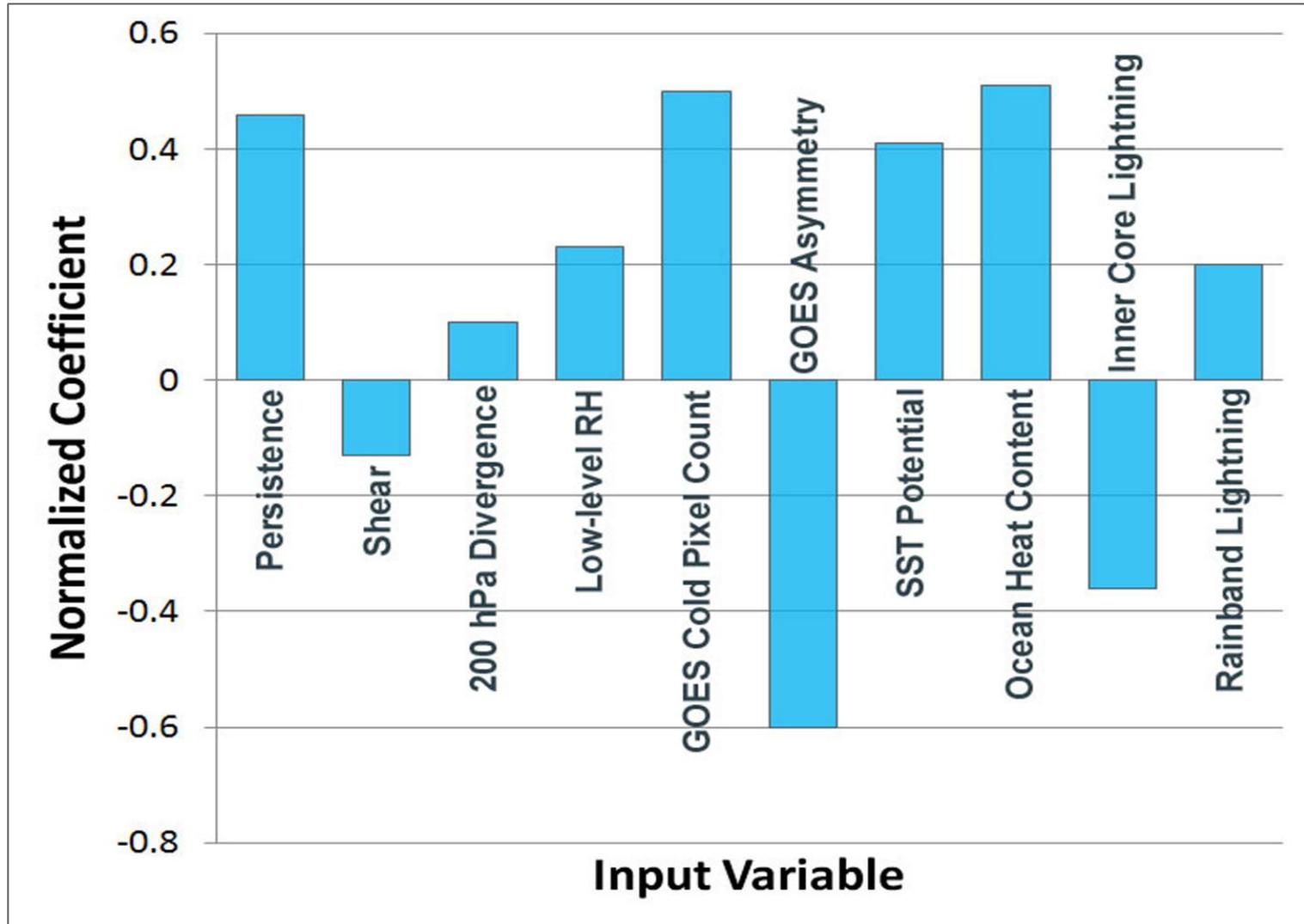
# Stratification by Rapid Intensity Change in the following 24 hr



# Experimental Algorithm in 2010 NHC Proving Ground

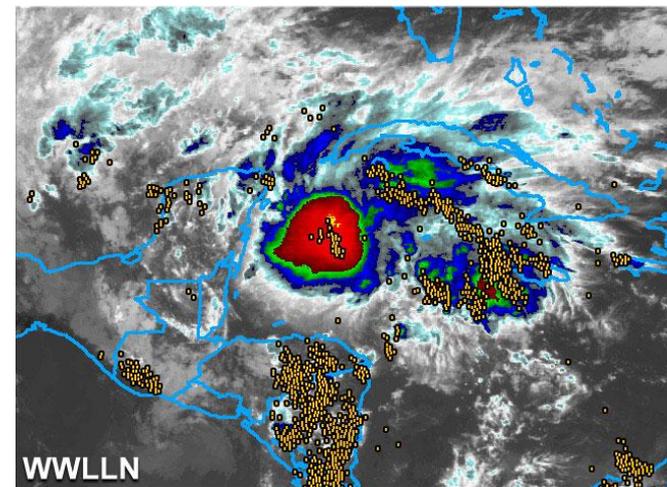
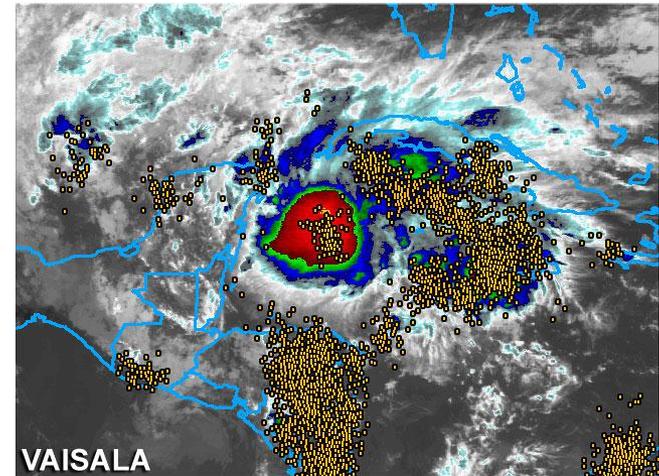
- Operational Rapid Intensification Index modified to include lightning input
  - Inner core and rain band lightning density
- Linear Discriminant Analysis technique used to estimate probability of RI
- Developed from 2005-2009 WWLLN sample
- Lightning density from GLD360 data in real time
- 2010 Cases run with WWLLN input in post season for comparison

# Normalized Discriminant Weights (Atlantic RII Algorithm)



# Normalization of GLD360 data

- Spatially dependent adjustments to GLD360
- Based on 3 month overlap of WWLLN, GLD-360
  - Oct-Dec 2009

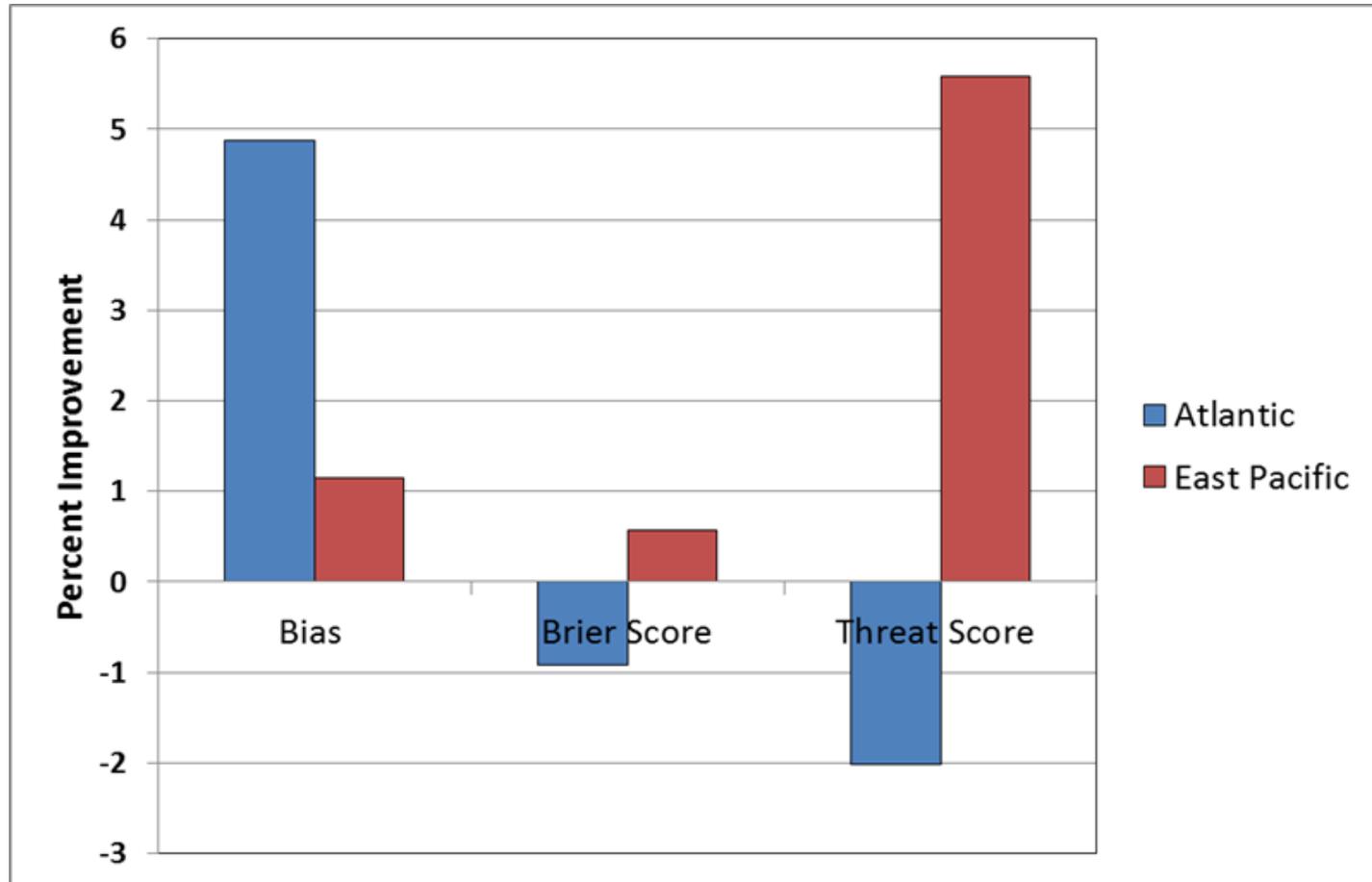


Hurricane Ida Nov., 2009

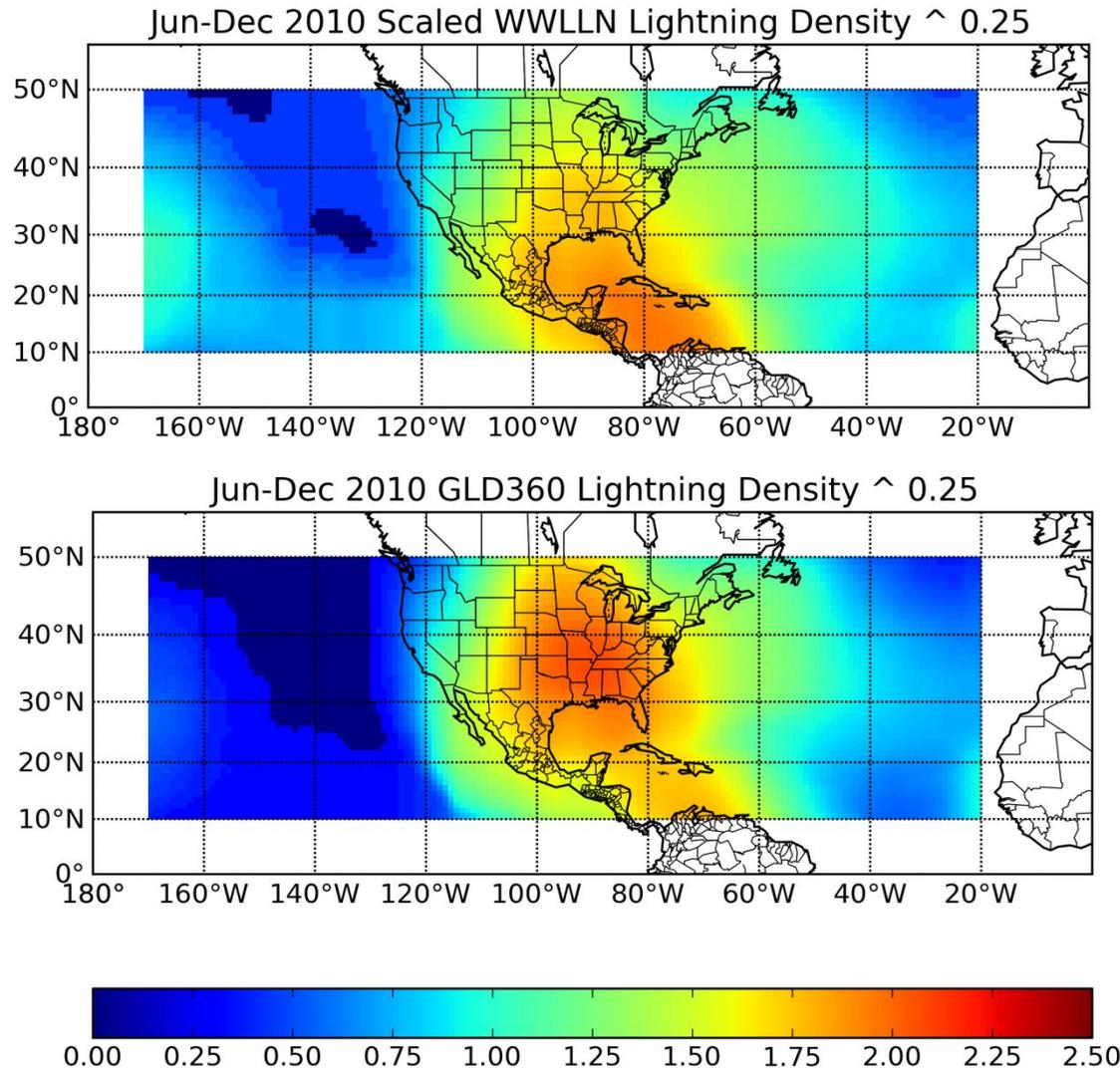
# RII Verification Metrics

- Bias =  $(\sum P_f / N_{obs}) - 1$
- Brier Score =  $(1/N_f)\sum[P_f - P_{obs}]^2$
- 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

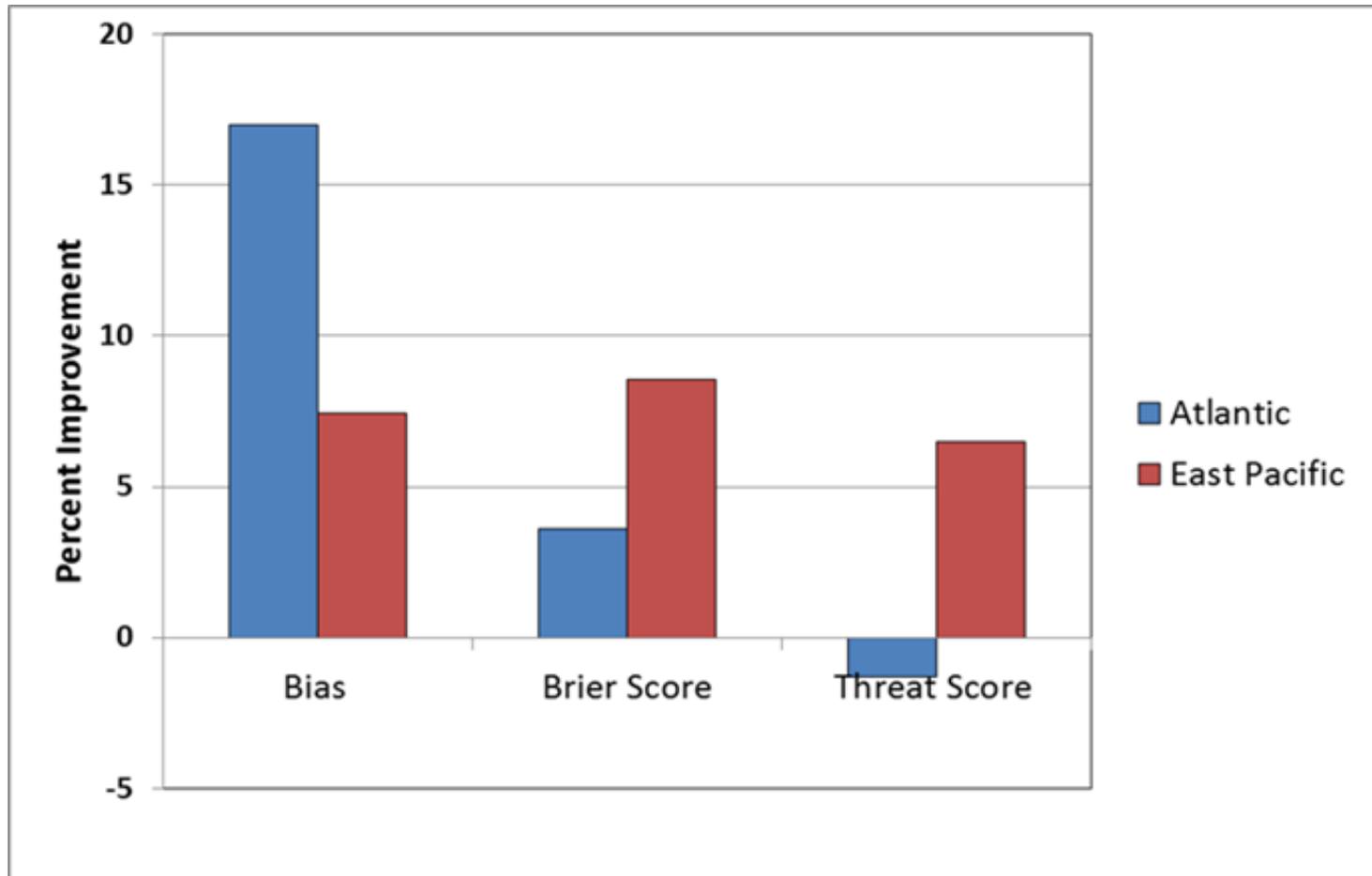
# 2010 Verification Results: Impact of Lightning Input (GLD360)



# WWLLN and GLD360 Jun-Dec 2010



# 2010 Verification Results: Impact of Lightning Input (WWLLN)

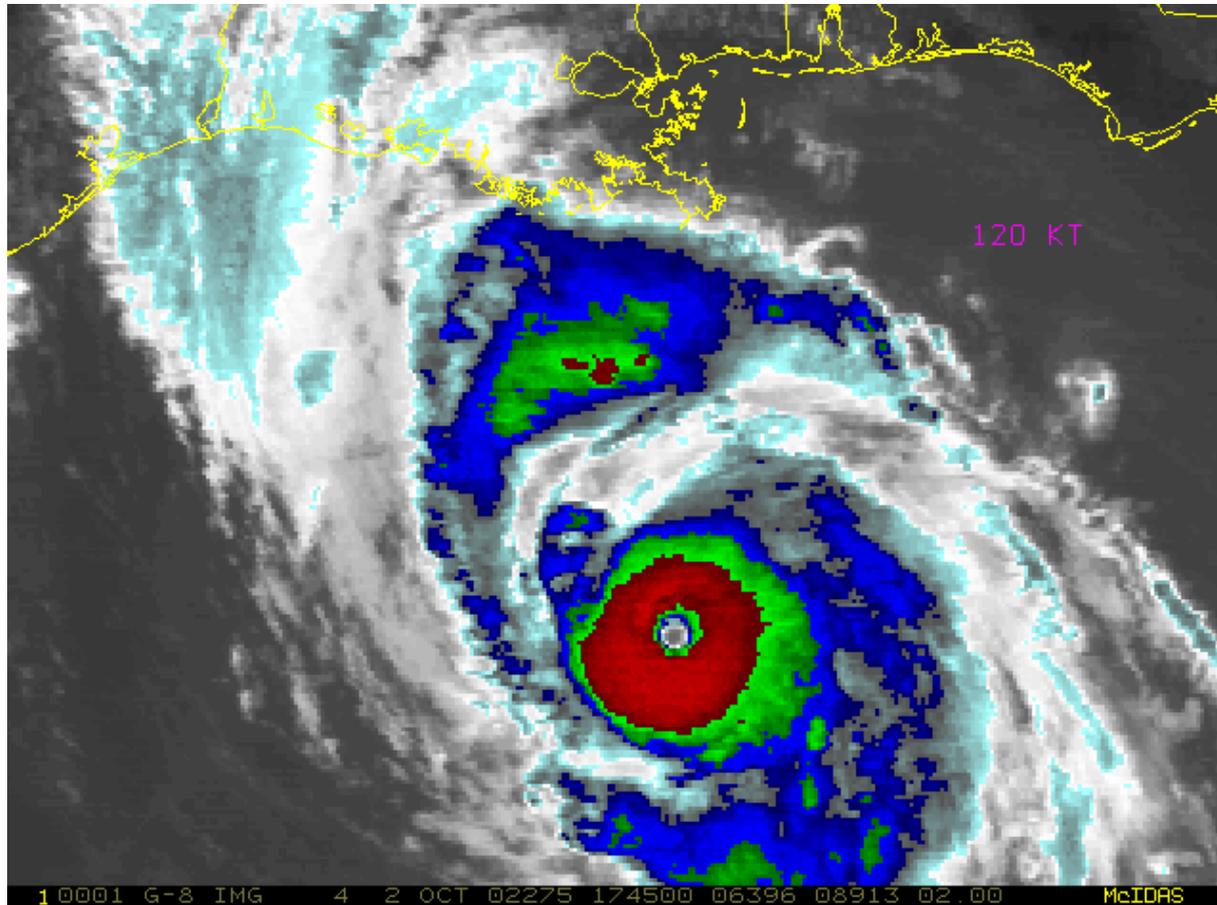


# Experimental Algorithm in 2011 NHC Proving Ground

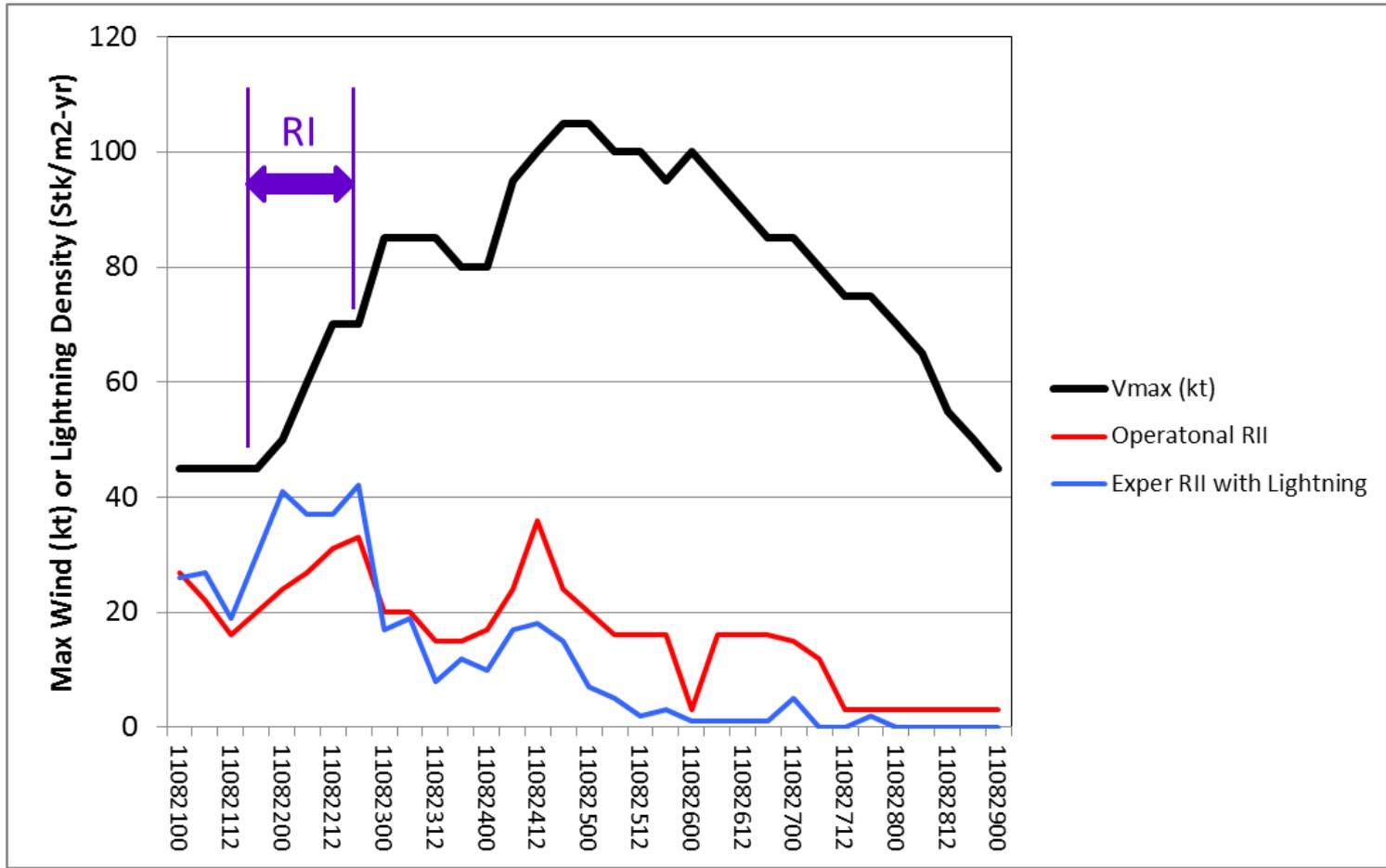
- 2010 cases added to sample
- 2 class LDA generalized to 3 class LDA
  - Rapid weakening, average intensification, rapid intensification
- WWLLN data obtained in real time
- Not many RI cases in Atlantic so far
- Several RW cases in east Pacific

# Hurricane Lili 2002

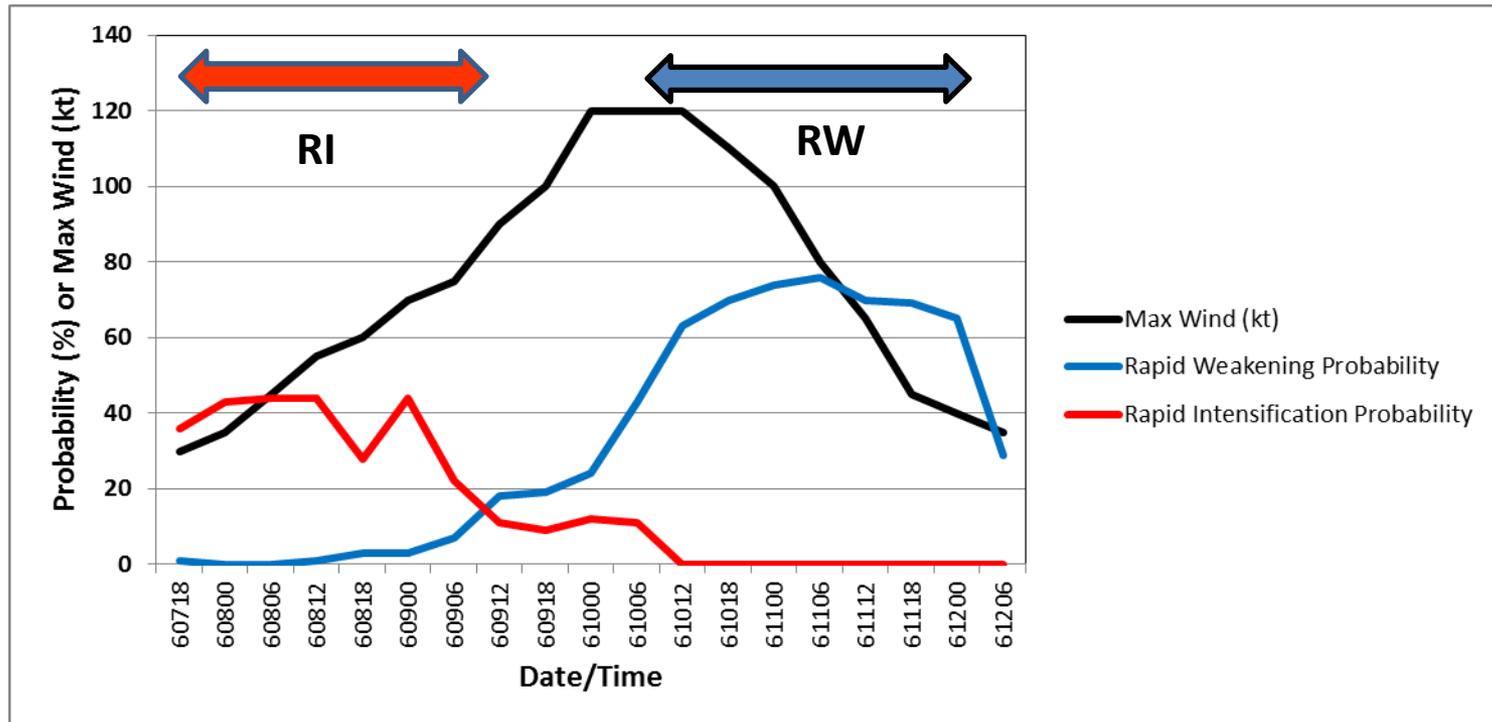
120 to 80 kt in 18 hr *before* landfall



# RI Probabilities For Irene (Operational and Experimental)



# RW and RI Probabilities for East Pacific Hurricane Adrian (2011)



# Conclusions

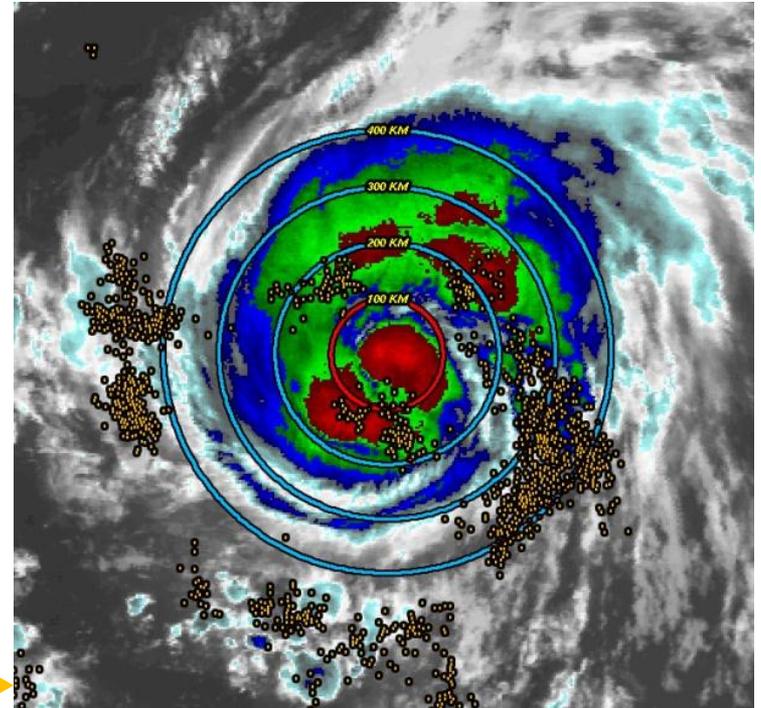
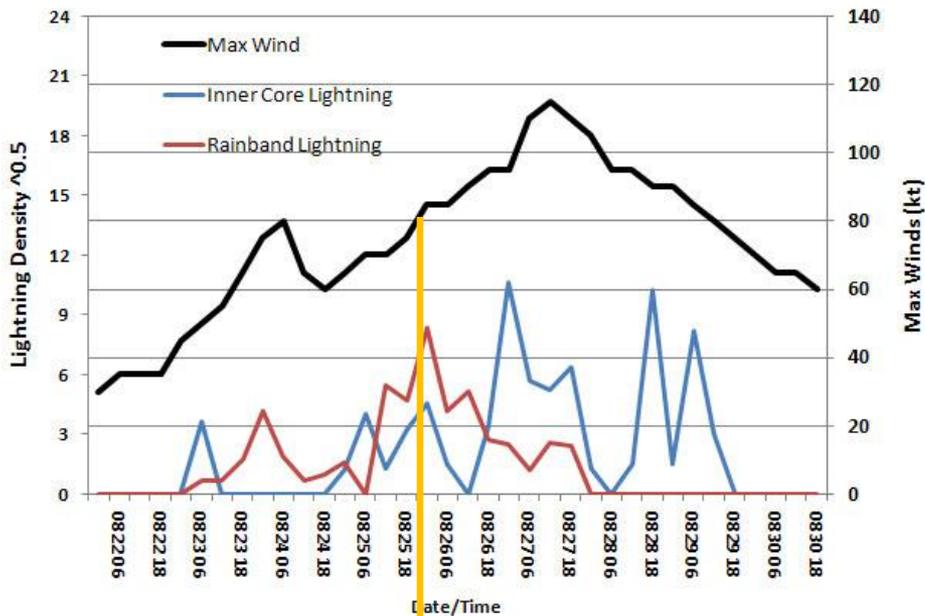
- Large sample of lightning and large-scale data created for Atlantic and east Pacific tropical cyclones
- Experimental rapid intensification forecast algorithm developed
  - Inner core and rain band lightning discriminators
  - *Inner core lightning positively correlated with current intensification, but negatively correlated with future intensification*
- Independent cases from 2010 showed reduced bias, improved Brier Score in Atlantic and east Pacific
- 2011 algorithm also include rapid weakening probability
- Quantitative evaluation following 2011 season

# Back-Up Slides

# Qualitative Use of Lightning Time Series

## Hurricane Danielle (2010) example

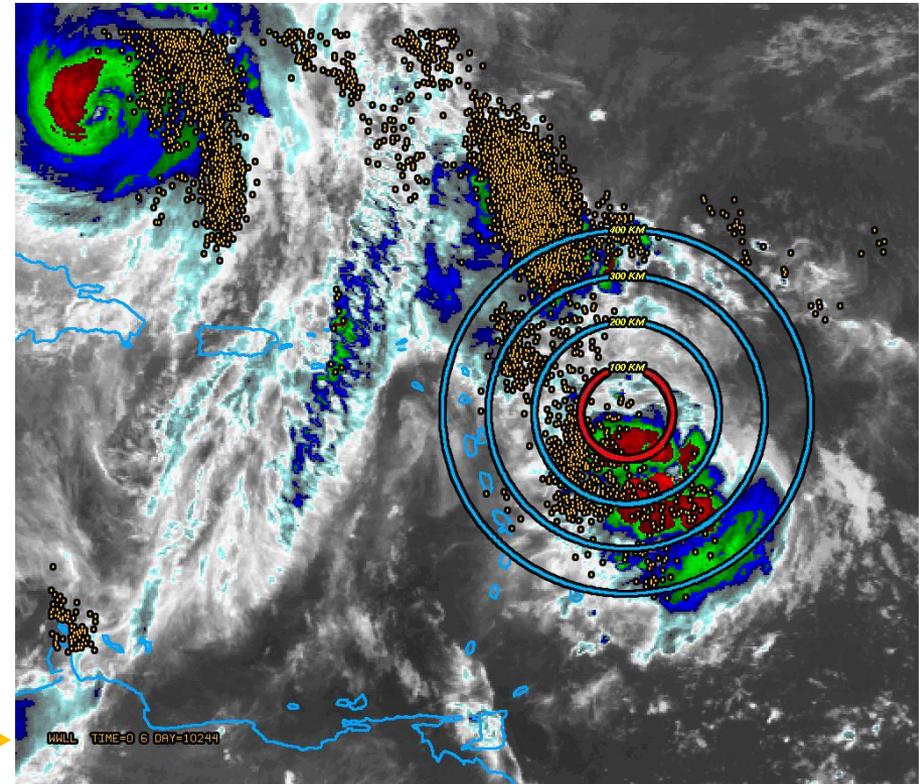
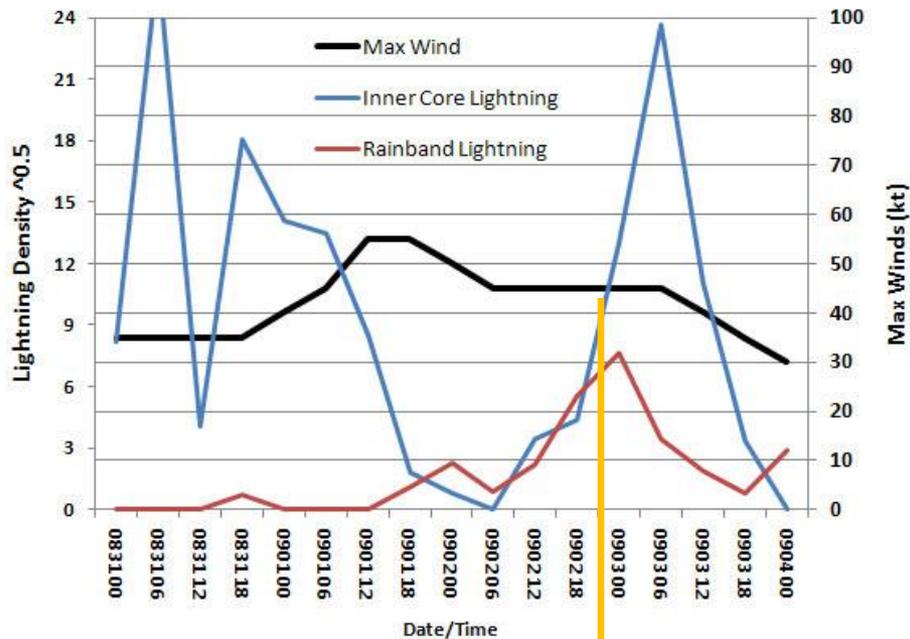
Hurricane Danielle 2010



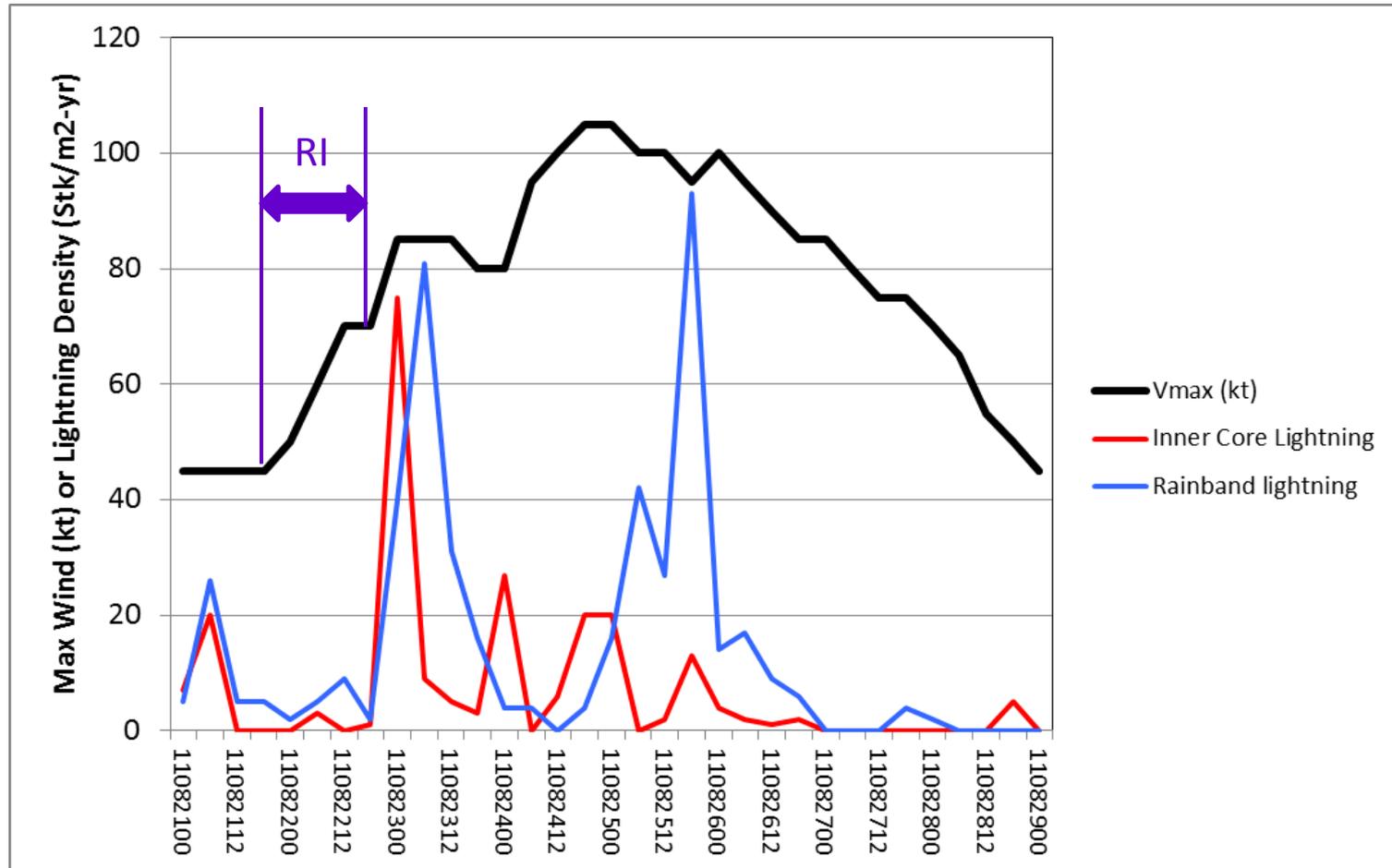
# Qualitative Use of Lightning Time Series

## Tropical Storm Fiona (2010) example

Tropical Storm Fiona 2010

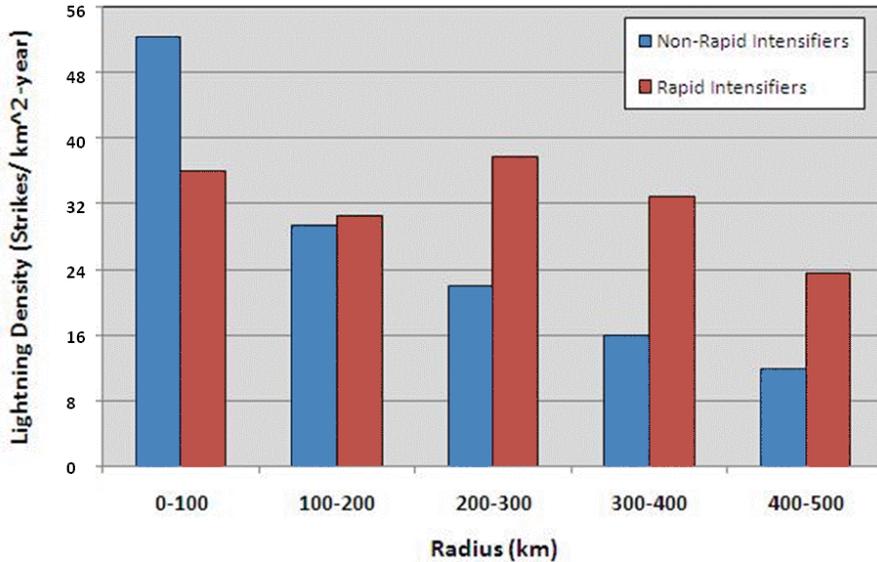


# Irene Max Wind and Lightning Density

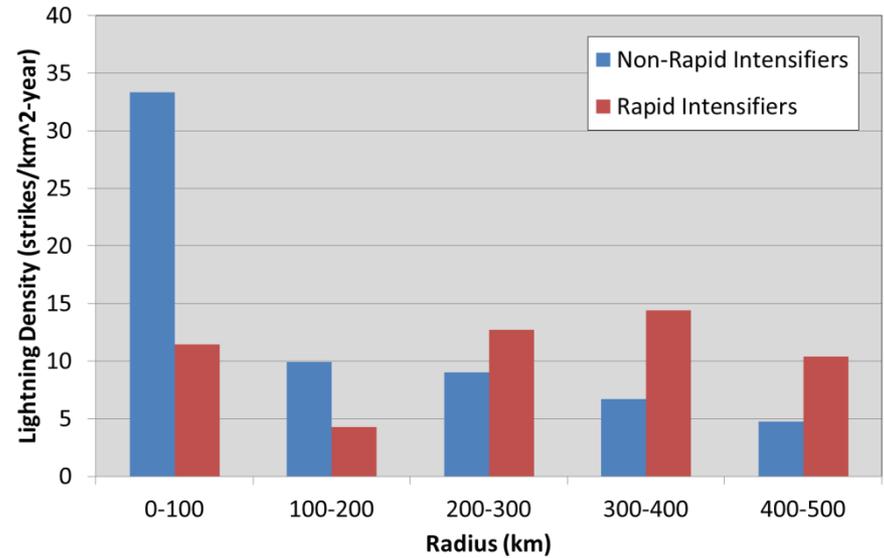


Caption. Working best track shows just one 24 hr period with RI (30 kt increase). Lightning data showed two time periods (around 082306 and 082600) with best configuration for intensification (large rainband, less inner core lightning). In first period intensification may have been hindered by interaction with Hispaniola. In second period (north of the Bahamas) large pressure falls occurred, but wind increase was small.

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



Atlantic

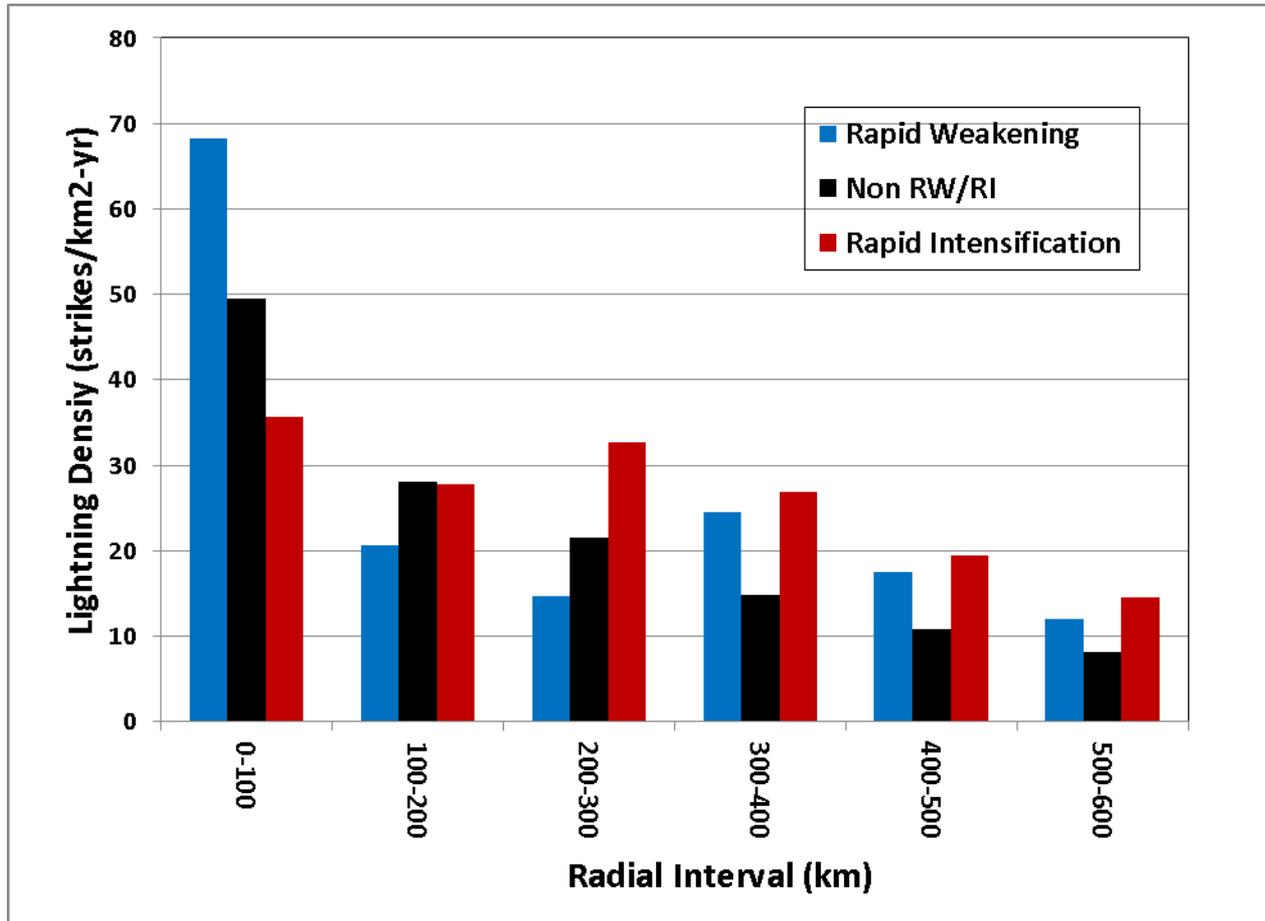


East Pacific

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

# 2005-2010 Atlantic Sample

## Lightning Density for RW, Avg, RI Cases

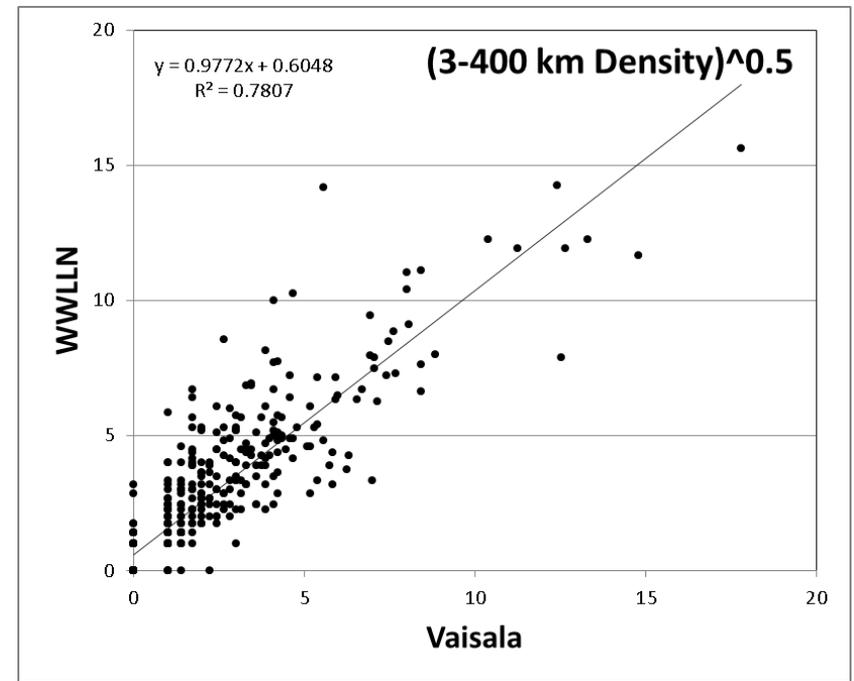
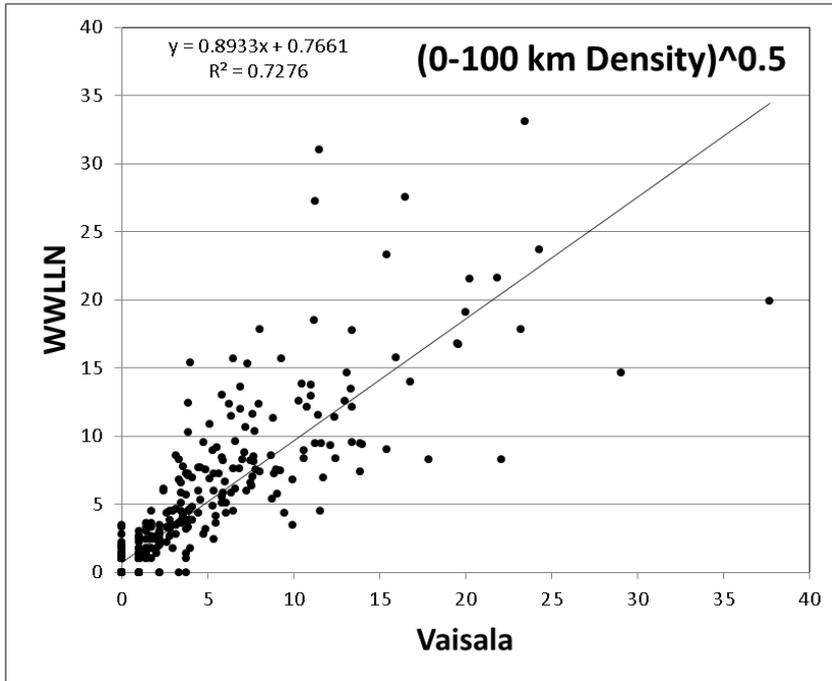


# Evaluation of GLD360 to WWLLN Adjustment

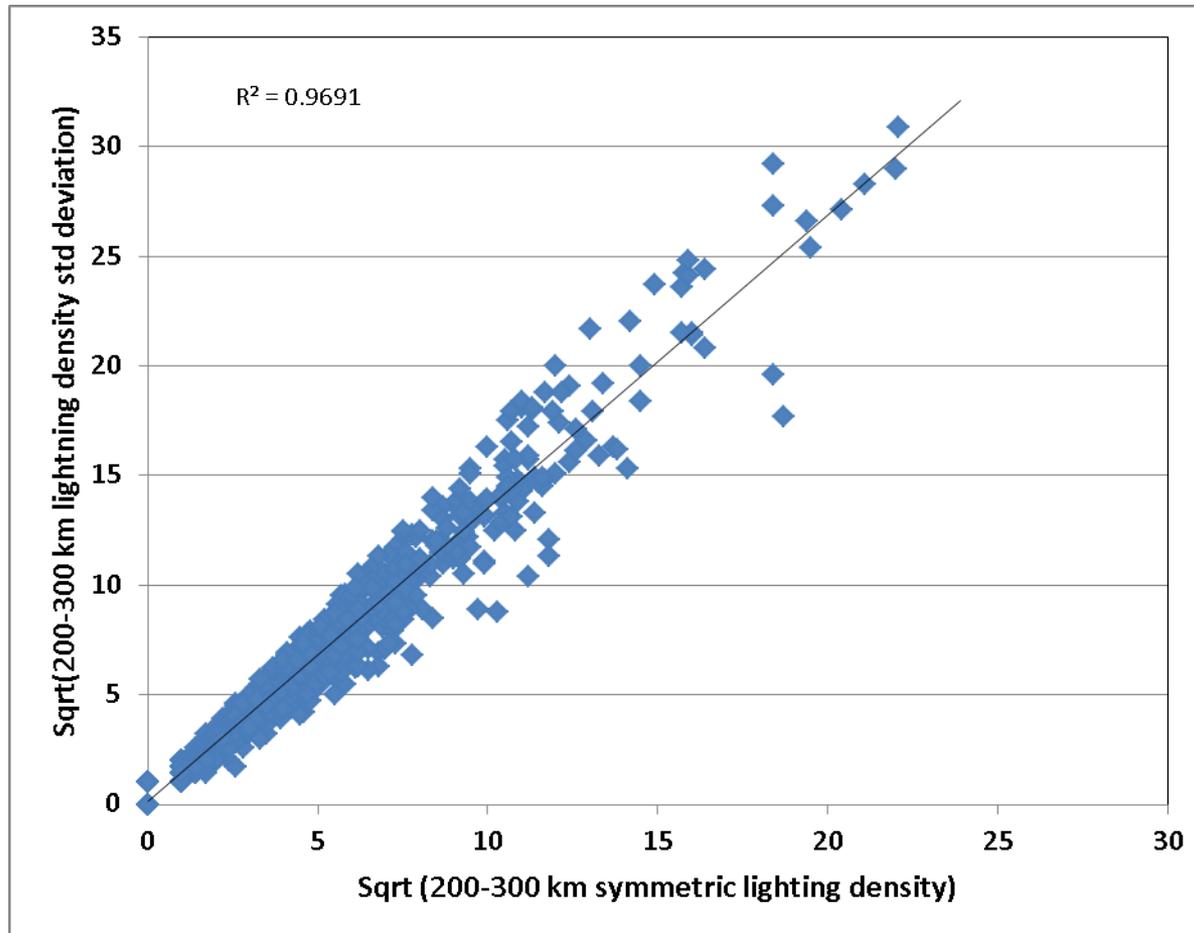
- 2010 WWLLN data obtained in post season
- Compare RII lightning parameters with GLD306 and WWLLN input
- Rerun 2010 RII forecasts with WWLLN-based parameters

# Comparison of RII Input Parameters with WWLLN and Vaisala

## with WWLLN and Vaisala



# Use of Lightning Asymmetry



**Mean and Standard Deviation are Highly Correlated**