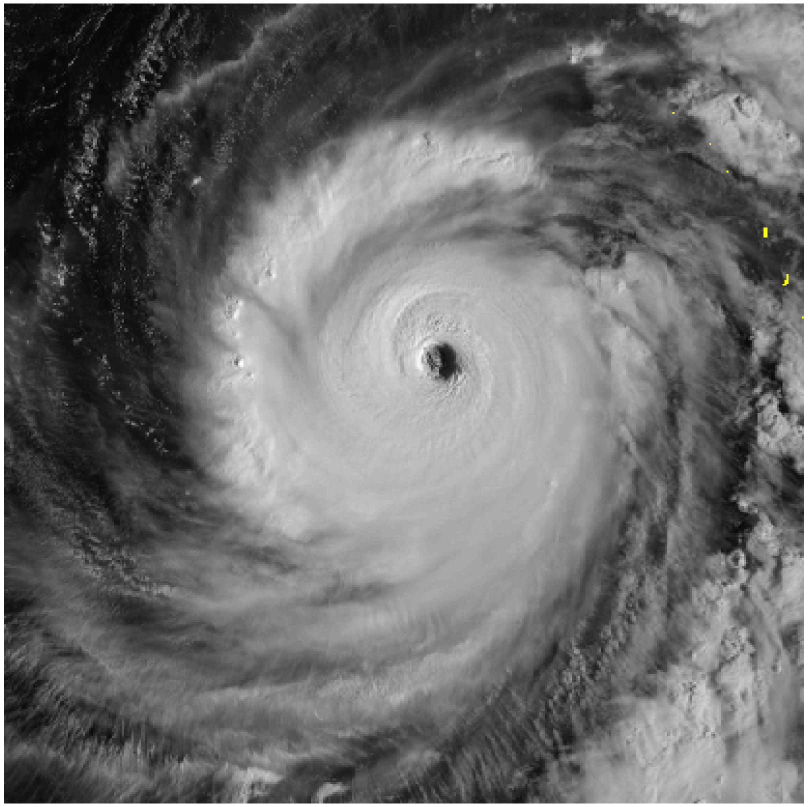
Aspects of Global Tropical Cyclone Climatology Metrics



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August 18, 2009

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Robert E. Hart

Motivation for Global TC Energy Long-Period Dataset

Tropical Cyclone's role in climate Robert Hart (FSU)

Motivation for a homogeneous, high-resolution long-period surface winds database appropriate for Tropical Cyclone global energy climate research.

Notion of **independence** (not relying on National Hurricane Center advisory information or subjective criteria).

Importance for operational/climatological and *climate change* applications.

Results from work emanating from a series of papers on TC climatology related issues.   Emanuel (2005, 2007), Maue and Hart (GRL 2007), Maue (GRL 2009), dissertation

And website http://www.coaps.fsu.edu/~maue/tropical **or Google: Ryan FSU**

Tropical Cyclone Metrics

Days

Weeks

Months

Years

Decades

Eons

Time Scales: Operational vs. Climatological

Storm by storm cases: cyclogenesis, eye-wall cycles, size changes, extratropical transition, tropical waves, surge

SST wakes, downstream development, Rossby-wave dispersion

Madden-Julian Oscillation modulation

Seasonal / individual basin

El Nino Southern Oscillation

Solar Cycles

Multidecadal Oscillations   Atlantic Mult. O   Pacific Decadal O

Orbital and celestial mechanics, ice ages, paleotempestology

Tropical Cyclone Metrics

FREQUENCY **DURATION** **INTENSITY** **SIZE**

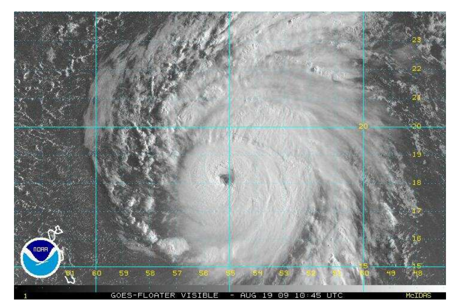
Counts by Category
Saffir-Simpson Scale

Hours / days / etc

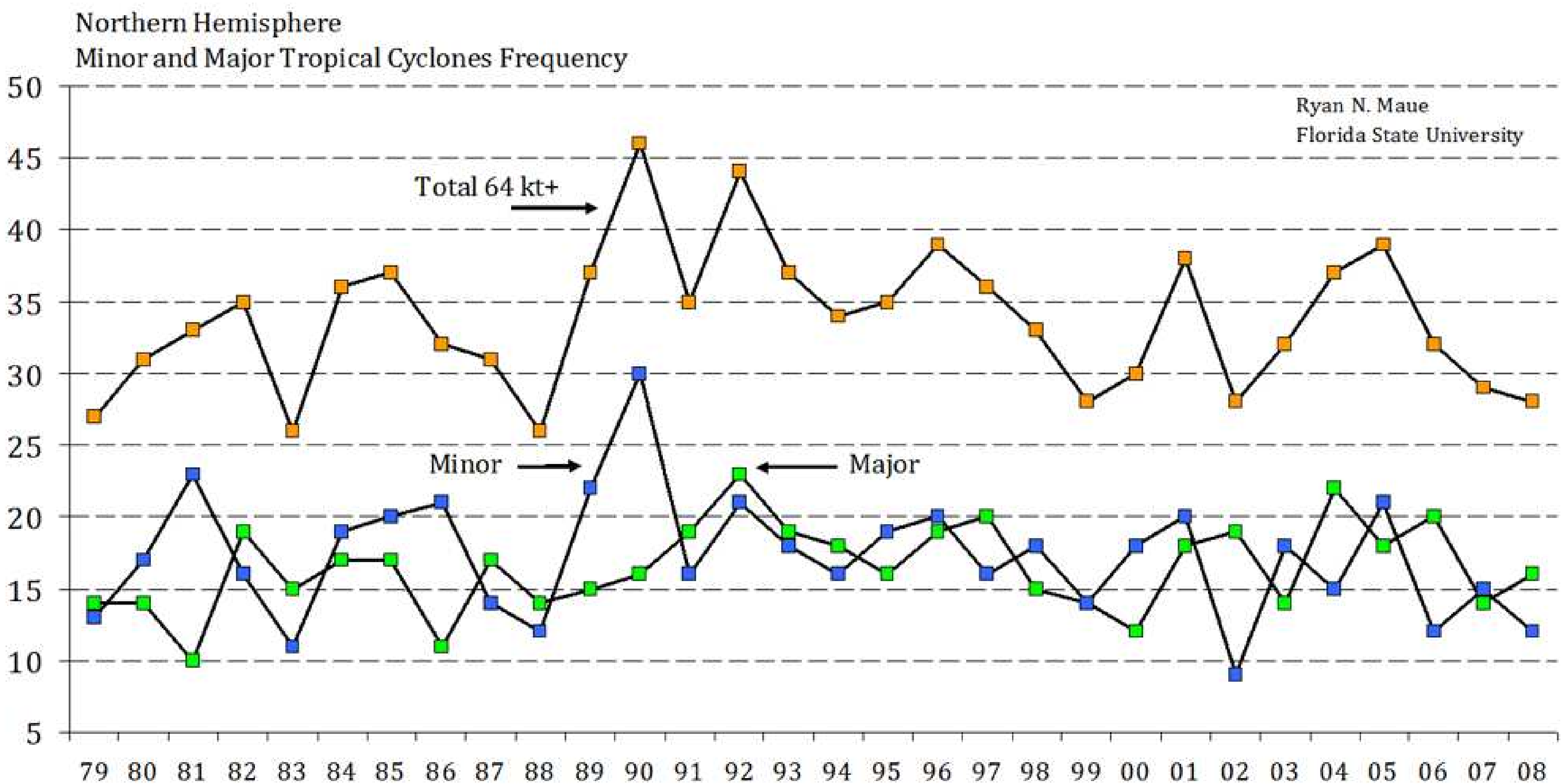
Maximum Sustained Winds
Minimum Central Pressure

Radius of Max Wind
Gale (R34 Radius)
Outer Closed Isobar

The above parameters only partially describe the evolution or lifecycle of a tropical cyclone.



Tropical Cyclone Frequency 1979-2008



Minor 64 kts – 95 kts (Cat 1-2)   Major 96 kts+ (Cat 3+)

Tropical Cyclone Metrics

Overarching questions

FREQUENCY DURATION INTENSITY SIZE

- **What data are available that include any/all of these parameters?**

  "Best track" hurricane databases   Reanalysis/operational numerical models

  Remote Sensing: i.e. QuikSCAT   Objective Satellite Algorithms   H*WIND

- **What are the relationships between convolutions of these metrics?**

  Hurricane Power Dissipation / Integrated Kinetic Energy

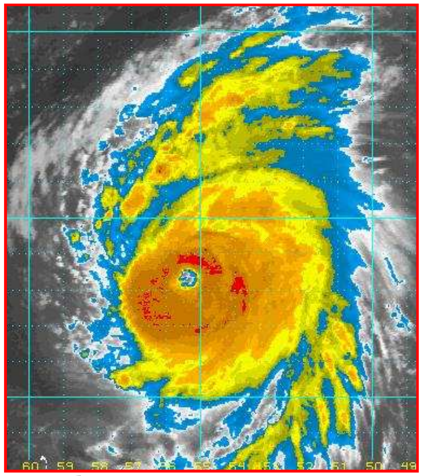
- **How are these parameters observed?**

  Often indirectly; observations vs. data assimilation or model generated

  Inputs include remote sensing (GOES Dvorak; Microwave Remote Sensing)

  Analyst diagnostics based upon available information

Accumulated Cyclone Energy (ACE)

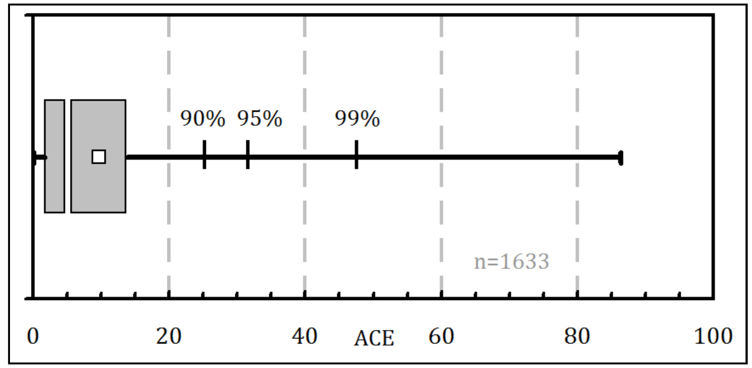


- Bell and Chelliah (2006 J. Climate)
- **ACE = $\Sigma V^2 dt$ UNITS 10^4 kts^2**
- Summation of wind speed squared
- Over the lifecycle of the storm, TS (34 knots+)
- Combination of Lifecycle/Duration, Intensity, and Frequency
- Uses Maximum Sustained 1-minute **surface** wind speed calculations provided by operational center advisories – best-track datasets
- 6-hourly intensity estimates – duration component dominates
- Long-lived, intense hurricanes contribute disproportionately to the ACE metric -- no SIZE information

Accumulated Cyclone Energy (ACE)

$ACE = \Sigma V^2 \, dt \quad x10^4 \, kts^2$

Northern Hemisphere ACE per storm 1979-2008



1-day at 65 kts = 1.69 ACE UNITS
1-day at 100 kts = 4.00 ACE UNITS
1-day at 150 kts = 9.00 ACE UNITS
1-day at 35 kts = 0.49 ACE UNITS

2009: Claudette: 0.405, Felicia: 19.6
Bill: 8.71, Ana: 0.98
Ivan (2004): 71.1 Ioke (2006): 86.4

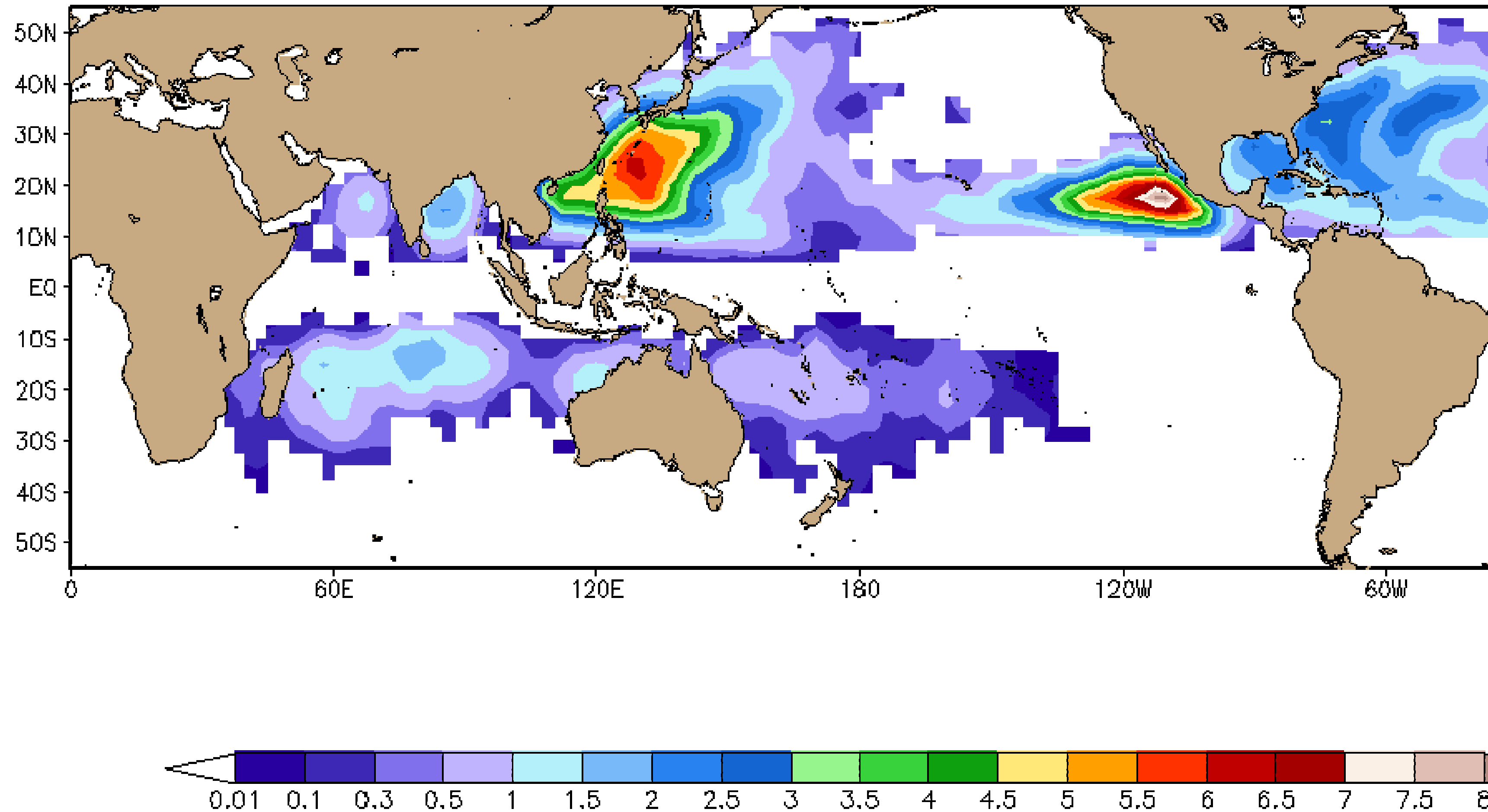
- **Highly correlated with number of Hurricane Days and similarly # of Hurricanes**
- **Highly correlated with Power Dissipation Index (Emanuel 2005) which is the wind speed cubed, due to domination of the duration component**

$$PD = 2\pi \int_0^{\tau} \int_0^{r_0} C_D \rho |V|^3 r\,dr\,dt \longrightarrow PDI = \int_0^{\tau} V_{max}^3 \, dt$$

Global Tropical Cyclone ACE

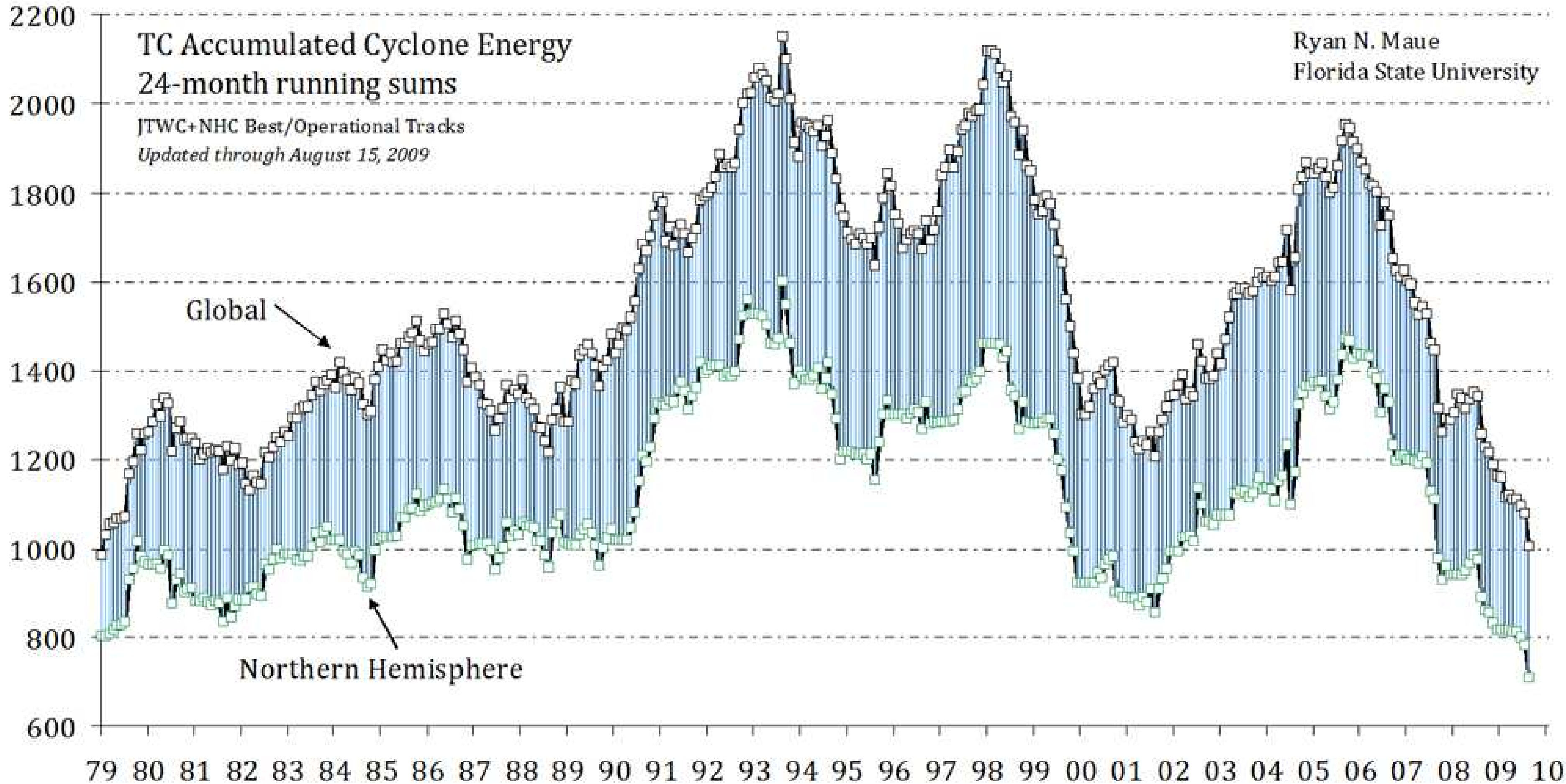
Best-Track ACE Density 1970-2008

normalized for comparison 2.5ºx2.5º



Great Depression: Historically Low Global TC Activity

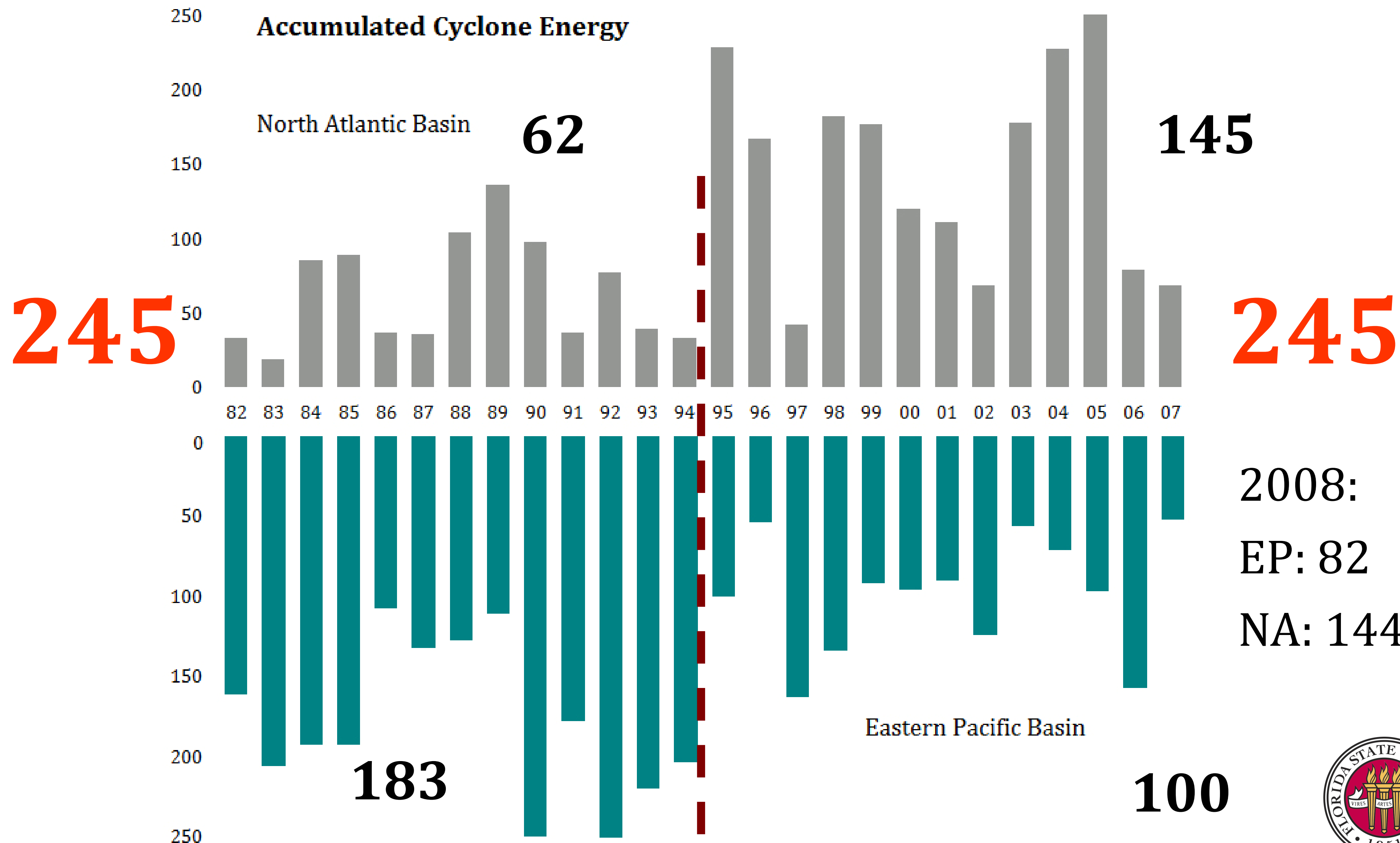
24-month running sums for global/NH TC ACE



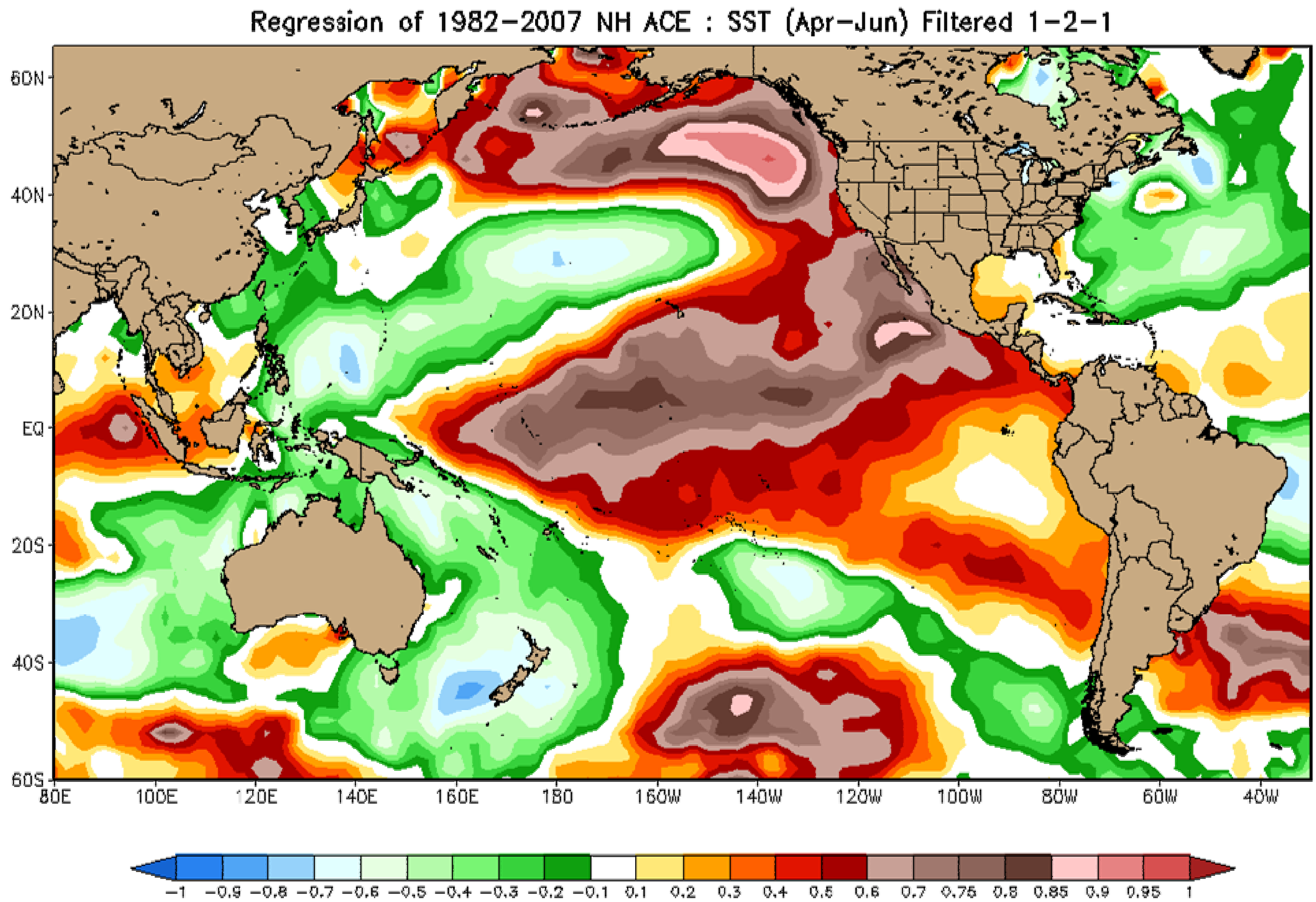
Difference between lines is Southern Hemisphere

The Climate Shift of 1995 to North Atlantic "above-average" activity

Many have suggested AGW SST Increase



Northern Hemi ACE / Hadley SST Regression



Interbasin TC Activity Hypothesis

- **ENSO is the main driver of NH (& global) TC activity**
- **R**(NH ACE:NPAC SST) = 0.95 [1981-2008]
- **R**(WPAC ACE:NPAC SST) = 0.88
- **R**(EPAC ACE:NPAC SST) = 0.18
- **R**(NATL ACE:NPAC SST) = 0.23

- If you know ENSO 3-6 months in advance, you know the overall NH ACE. Since WPAC ACE has been a nearly constant 55% of NH activity over the past 30 years, that leaves 45% to fought over by the NATL+EPAC+IO. The IO is (2-4%). So, that leaves ~40-45% to the NATL and EPAC, which has been a relatively constant sum since 1980. (previous figure) Maue (2009, GRL)

- So, if you can get EPAC+WPAC correct, then will you know the ATL based upon North Pacific Sea Surface Temperature by subtraction?
- SST is a tracer? The large-scale prevailing climate **DOMINATES** the climate statistics of Tropical Cyclone activity on longer scales

Need for SIZE component?

- Many studies have consistently shown that there is little correlation or relationship between storm intensity and storm size (Emanuel 2005)

- Dean et al. (2009) GRL show that the distribution of North Atlantic hurricane size, as measured by the 34 knot wind radii – is a function NOT of the environment but the individual aspects of each storm.

- Leads to important issue: Can one simply use the maximum sustained wind speed (ACE/PDI) instead of the full 2-Dimensional surface storm footprint for CLIMATE applications? In other words, are the metrics consistent? What are the inner- vs. outer-core contributions?

Sources of 2-Dimensional TC "Footprints"

Reanalysis datasets: ERA-interim, ERA-40, ERA-15, NASA-MERRA, NCEP/NCAR Reanalysis, CFSRR, JRA-25   [1948, 1957, 1979 – 2009]
NCEP 20th Century Reanalysis

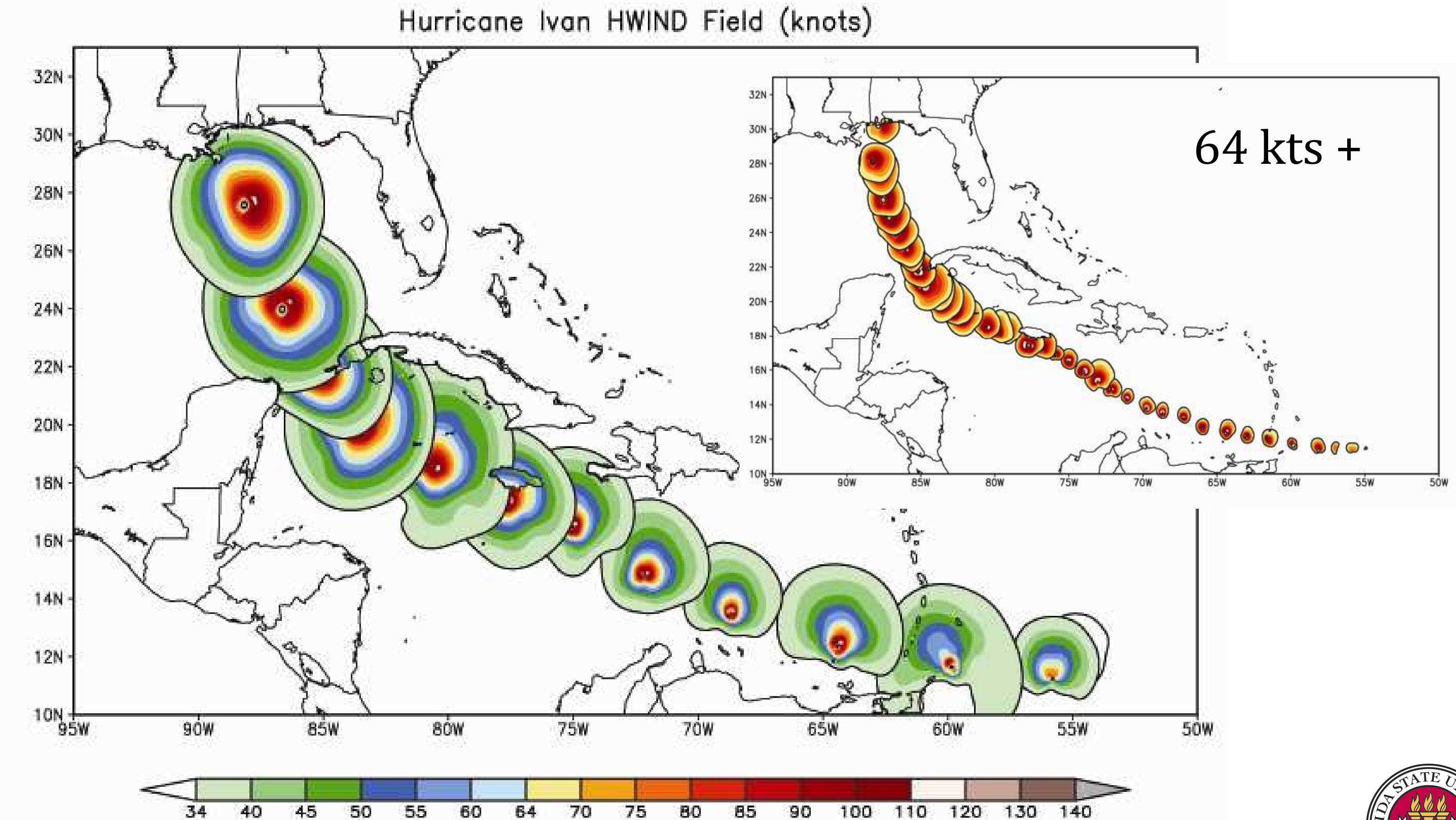
Only very coarse representations of tropical cyclones exist in reanalysis products. Maue and Hart (2007), Hart and Manning (2007), Swanson (2008)

- **Extended Best-Track** (DeMuth, DeMaria, Knaff, 2006)
- **Objective Satellite** (GOES IR) TC Reanalysis (Kossin et al. 2006)
  [utilize Rankine Vortex / wind-pressure relationship]   Quadrants/profiles
- **H*WIND** (Powell et al. 1998)
- **QuikSCAT**, other remote sensing platforms & products

Limited utility for examining storm energy evolution?

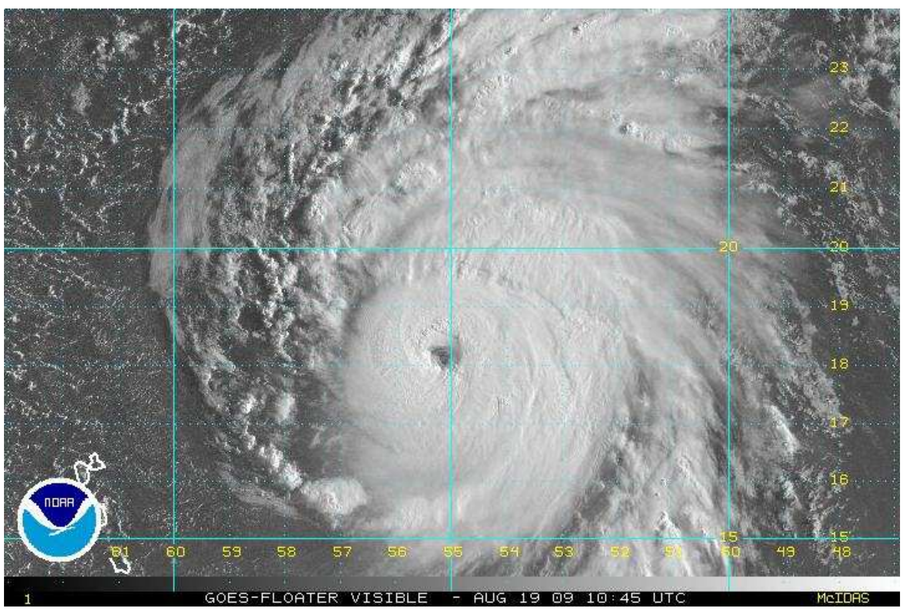
Sources of 2-Dimensional TC "Footprints"

Inner vs. outer core Powell et al. 1998



Hurricane Bill Guidance

- Coupled-Mesoscale model forecasts: use Global Forecast System (GFS) boundary conditions
- Initial conditions may be provided by bogus or synthetic observations of the storm structure including the inner-core
- Surface wind is not a model variable – lowest model level is ~ 35 meters



10:45Z Aug 19

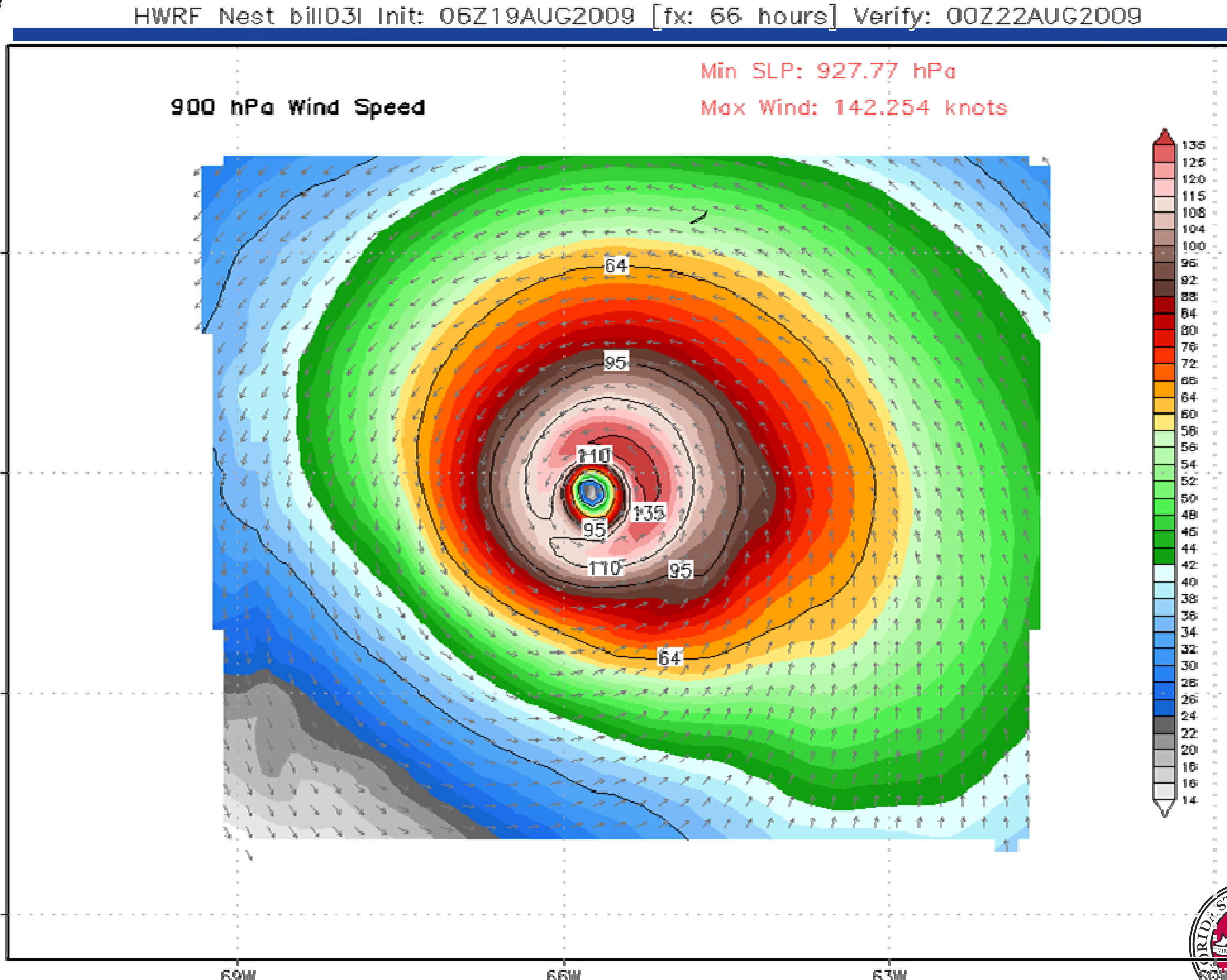
115 knots – Category 4

948 mb

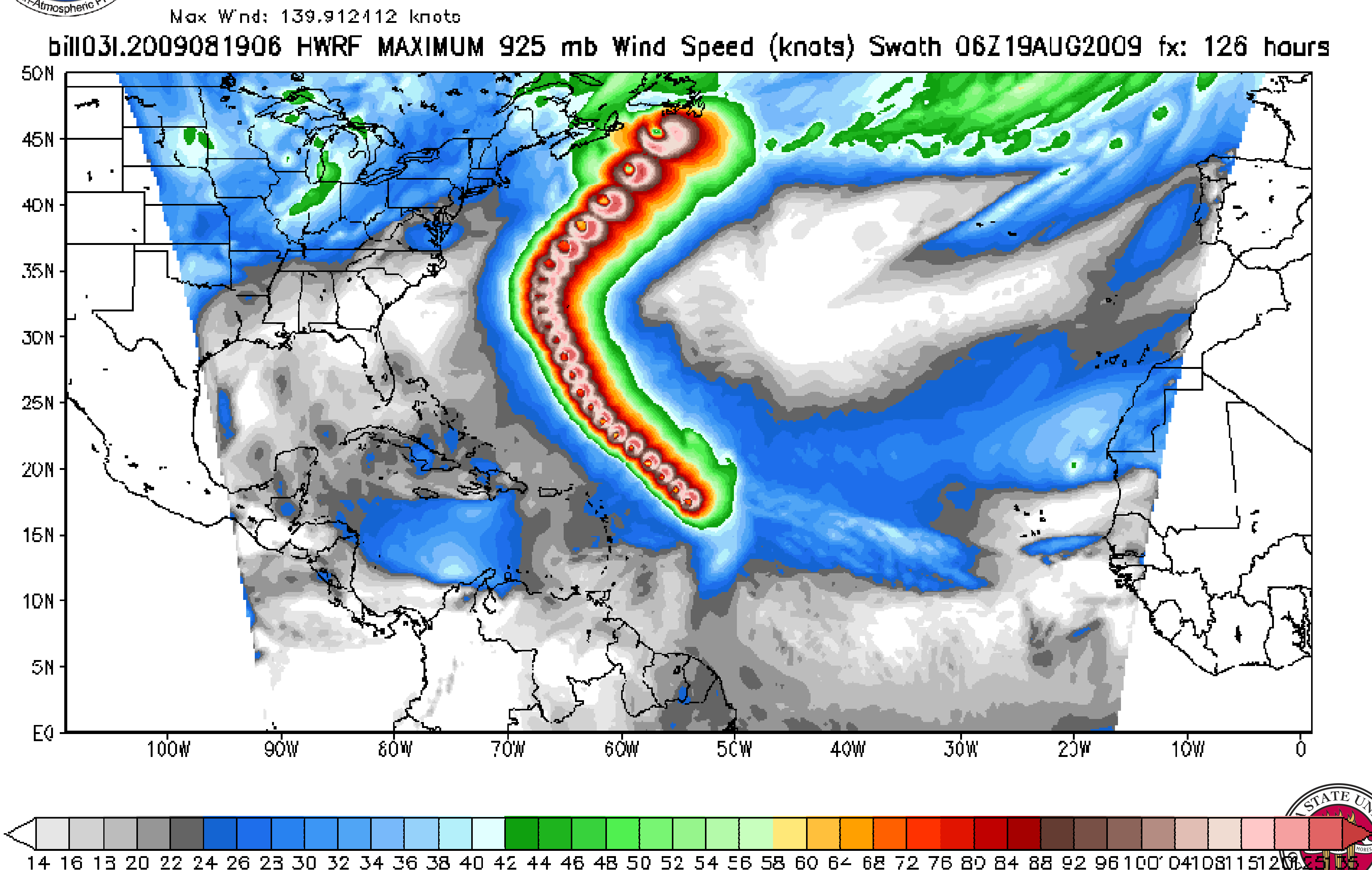
NHC Advisory

HWRF, GFS Forecasts for Bill

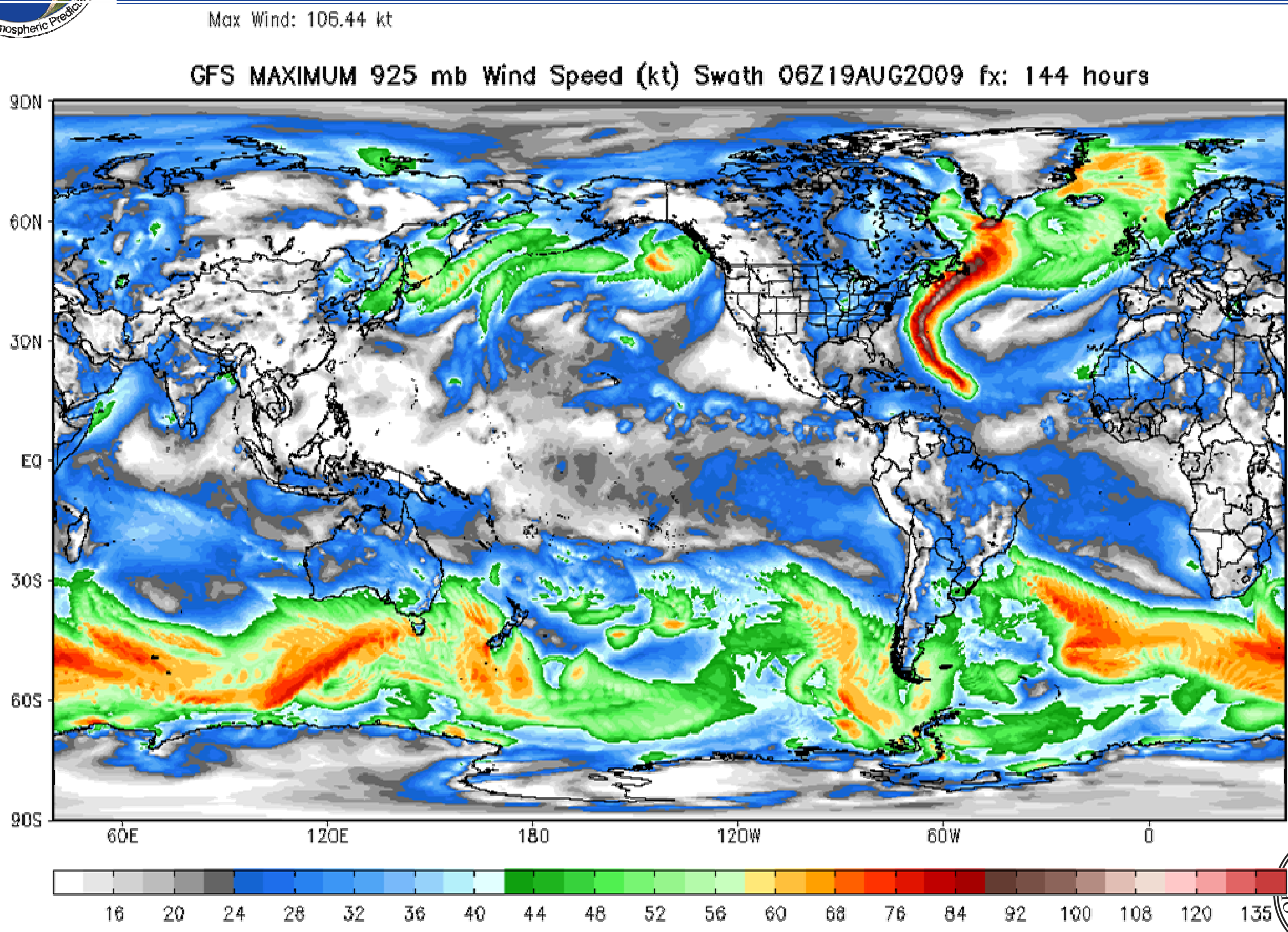
.10°



HWRF, GFDL, GFS Forecasts for Bill



HWRF, GFS Forecasts for Bill



Application of high-resolution scatterometer

- High-resolution, accurate high-speeds, surface-wind retrievals would greatly benefit the development of two-dimensional storm footprints for Tropical Cyclone energy calculations

- Beneficial for a multitude of applications associated with the lifecycle of tropical cyclones on all time-scales.

- Assist in data assimilation procedures in operational to reanalysis applications (QuikSCAT obs are net positive to forecast skill i.e. NOGAPS)

Forecasts of 2-Dimensional TC “Footprints”

Hurricane Ike “worm” forecast swath map