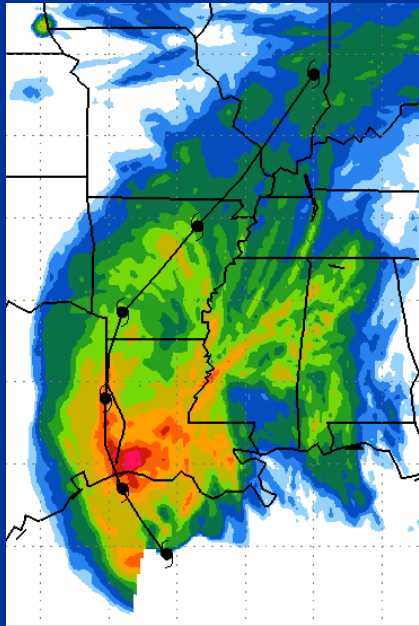
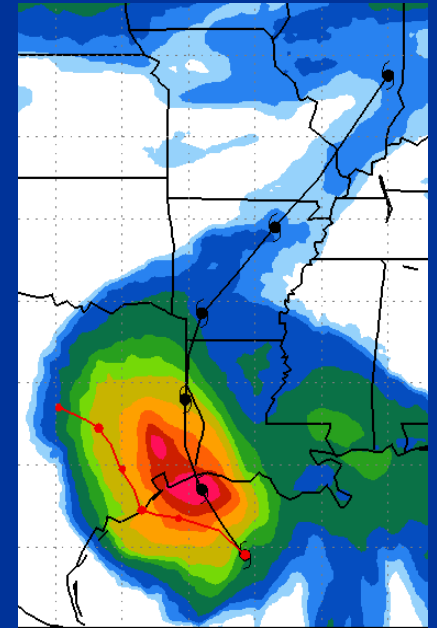


Verification of model wind structure and rainfall forecasts for 2008 Atlantic storms



Tim Marchok
NOAA / GFDL

*HFIP Hurricane Diagnostics and
Verification Workshop
NHC, Miami, FL
04 May 2009*



Collaborators: Rob Rogers (NOAA / AOML / HRD)

Bob Tuleya (NCEP/EMC & Old Dominion Univ.)

Mark Powell (NOAA / AOML / HRD)

Motivation

- Inland flooding from TC rainfall accounts for a significant percentage of deaths from U.S. landfalling TCs.
- Storm size / structure has a major impact on the amount of damage at landfall.

...both aspects have only recently begun to receive attention in terms of model evaluation

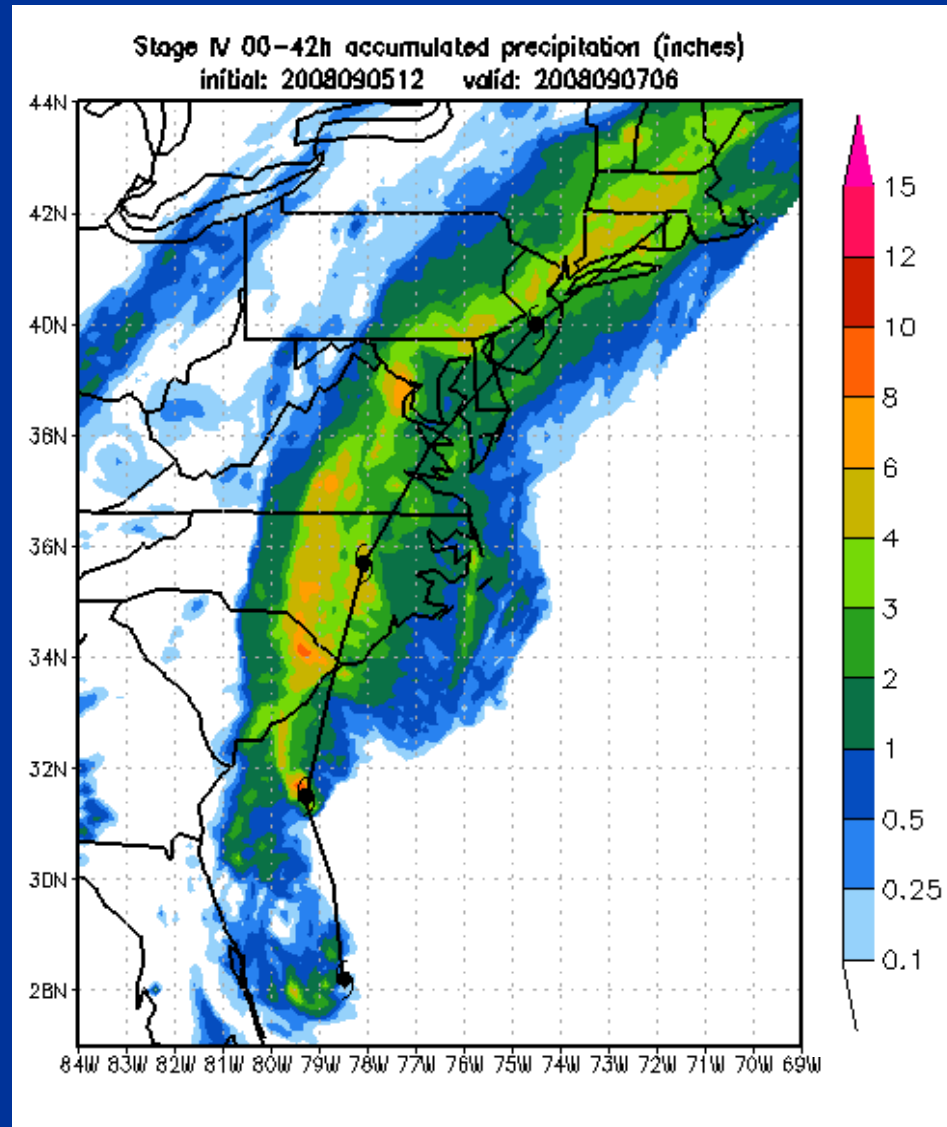
Outline

- Rainfall validation & techniques
- Application of TC QPF validation techniques to 2008 U.S. landfalling storms
- Development of model wind structure validation techniques
- Application of wind structure validation techniques to 2008 Atlantic TCs

Rainfall validation: What to focus on?

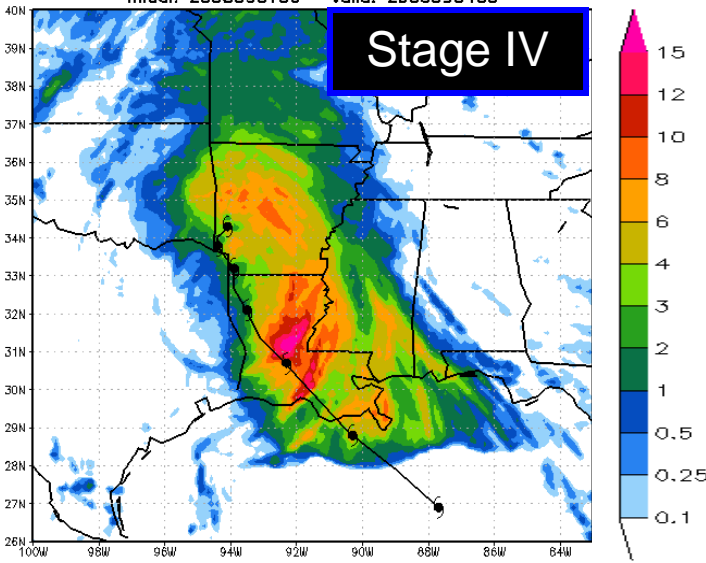
- Rainfall patterns
- Rainfall mean & volume
- Extreme amounts

The TC track: An anchor for QPF validation

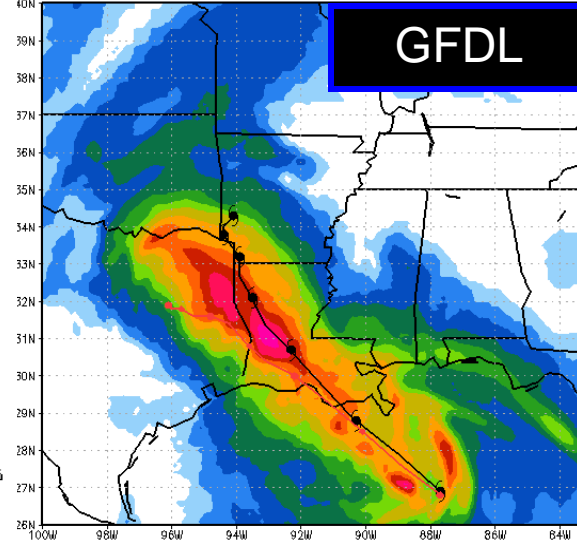


Example: Hurricane Gustav 72-h total rainfall

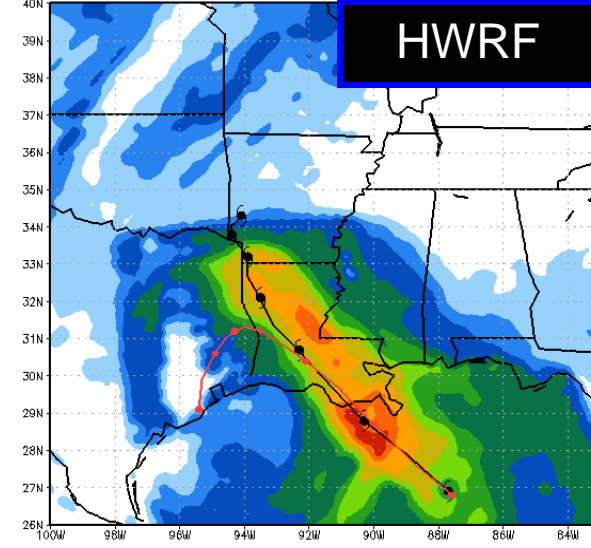
Stage IV 00-72h accumulated precipitation (inches)
initial: 2008090100 valid: 2008090400



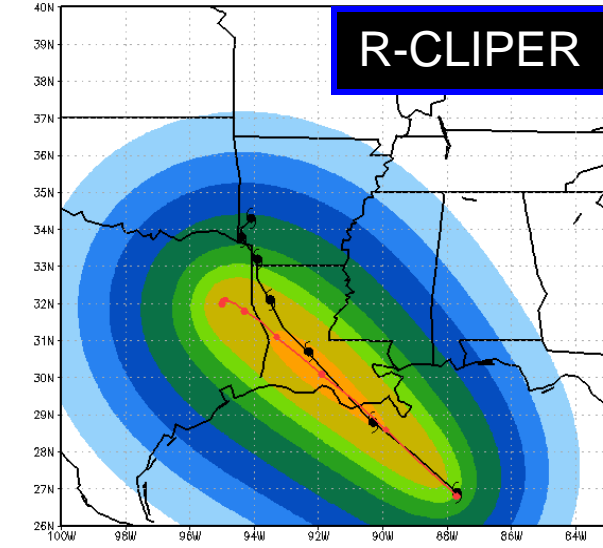
GFDL model 00-72h accumulated precipitation (inches)
initial: 2008090100 valid: 2008090400



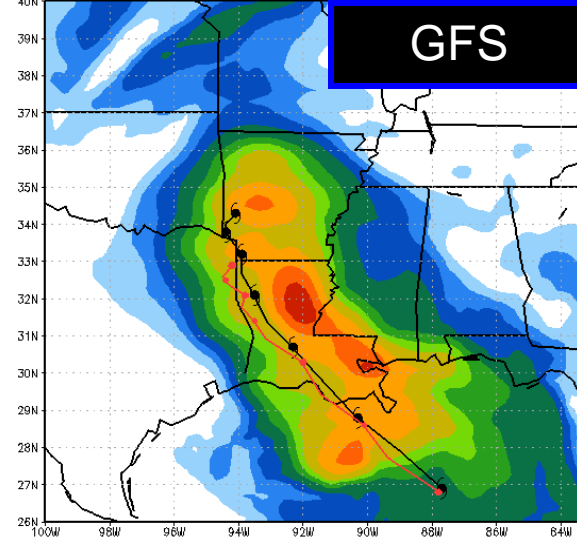
HWRF model 00-72h accumulated precipitation (inches)
initial: 2008090100 valid: 2008090400



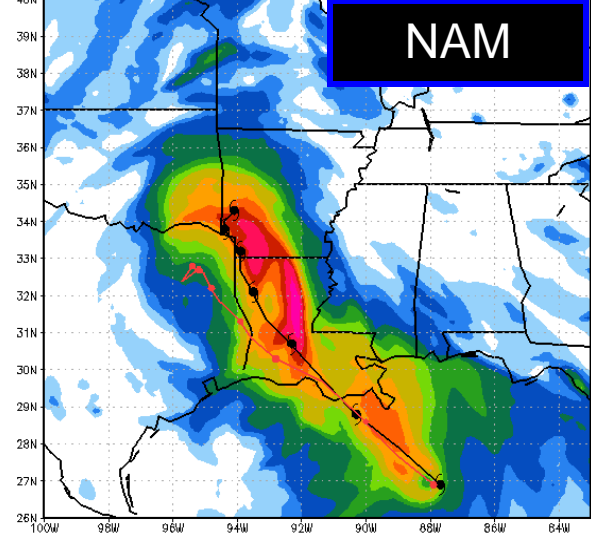
R-CLIPER (OFCL) model 00-72h accumulated precipitation (inches)
initial: 2008090100 valid: 2008090400



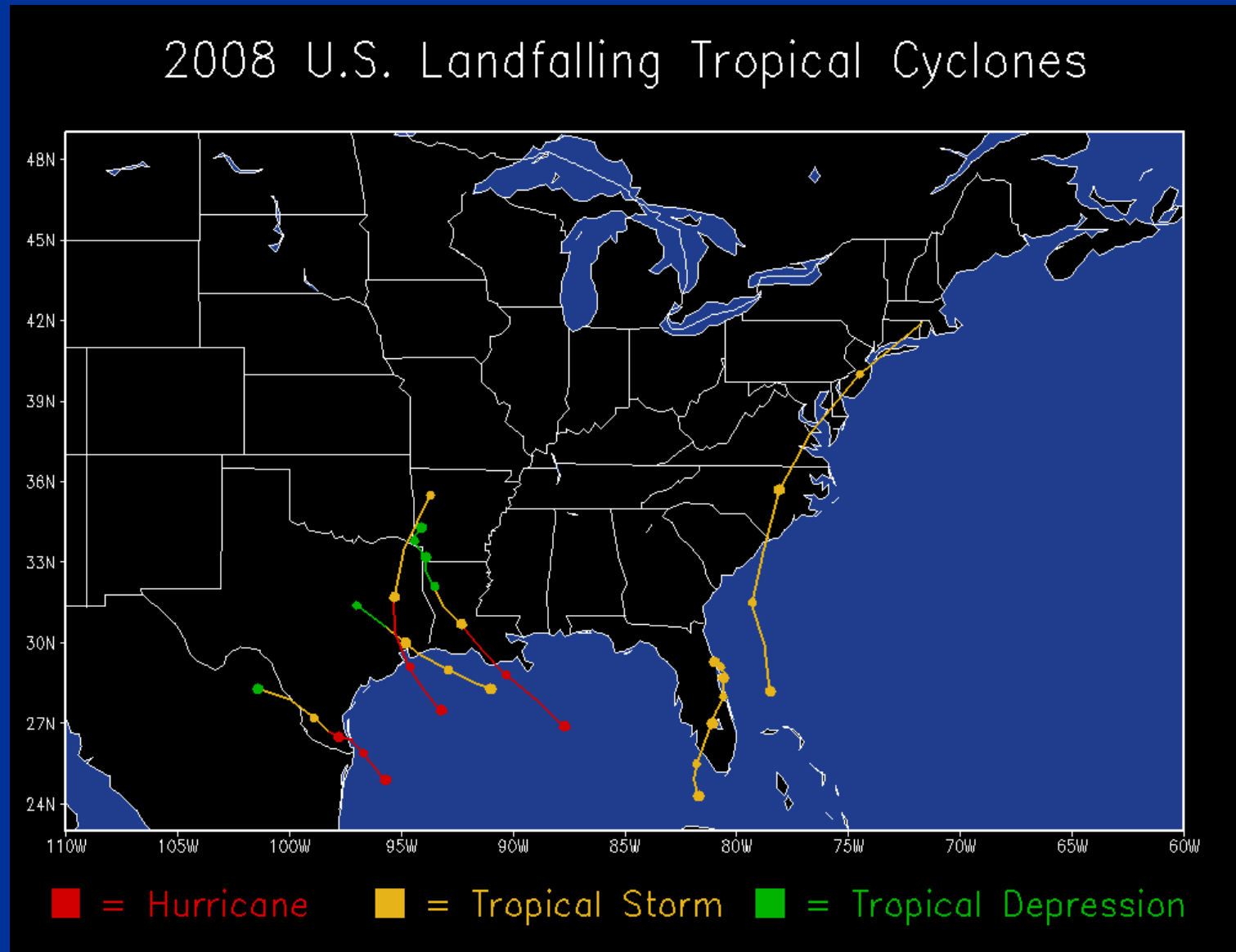
GFS model 00-72h accumulated precipitation (inches)
initial: 2008090100 valid: 2008090400



NAM model 00-72h accumulated precipitation (inches)
initial: 2008090100 valid: 2008090400



2008 Landfalling Storms



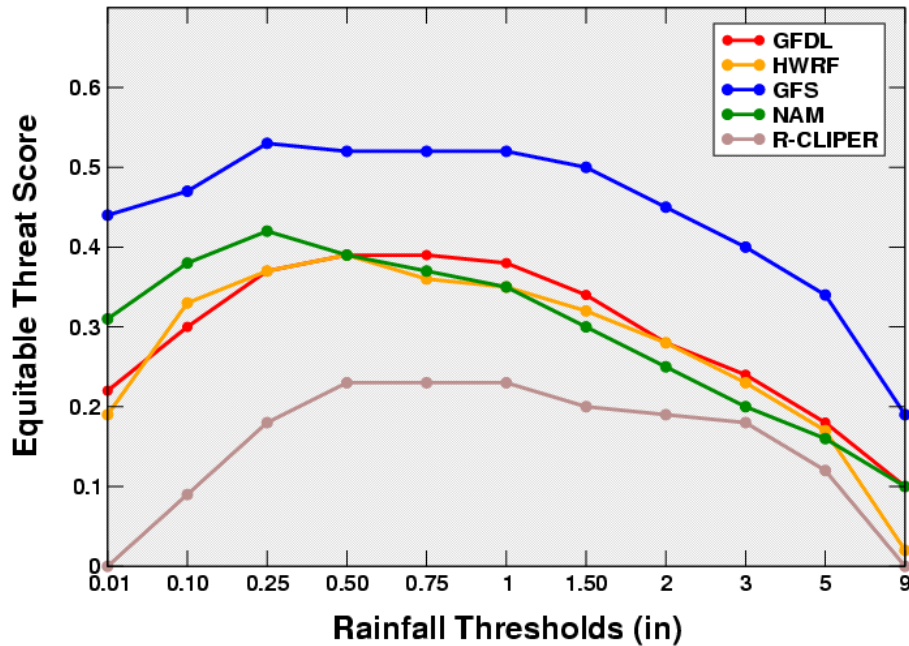
Rainfall Patterns

Equitable Threat Scores

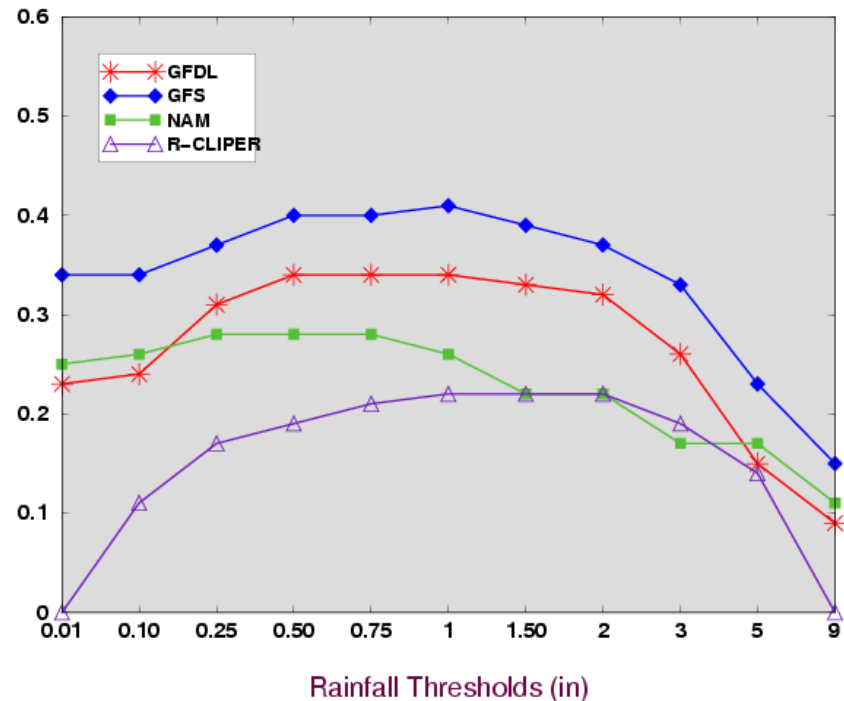
2008

2005

Equitable Threat Score Comparison for Landfalling Atlantic Storms, 2008



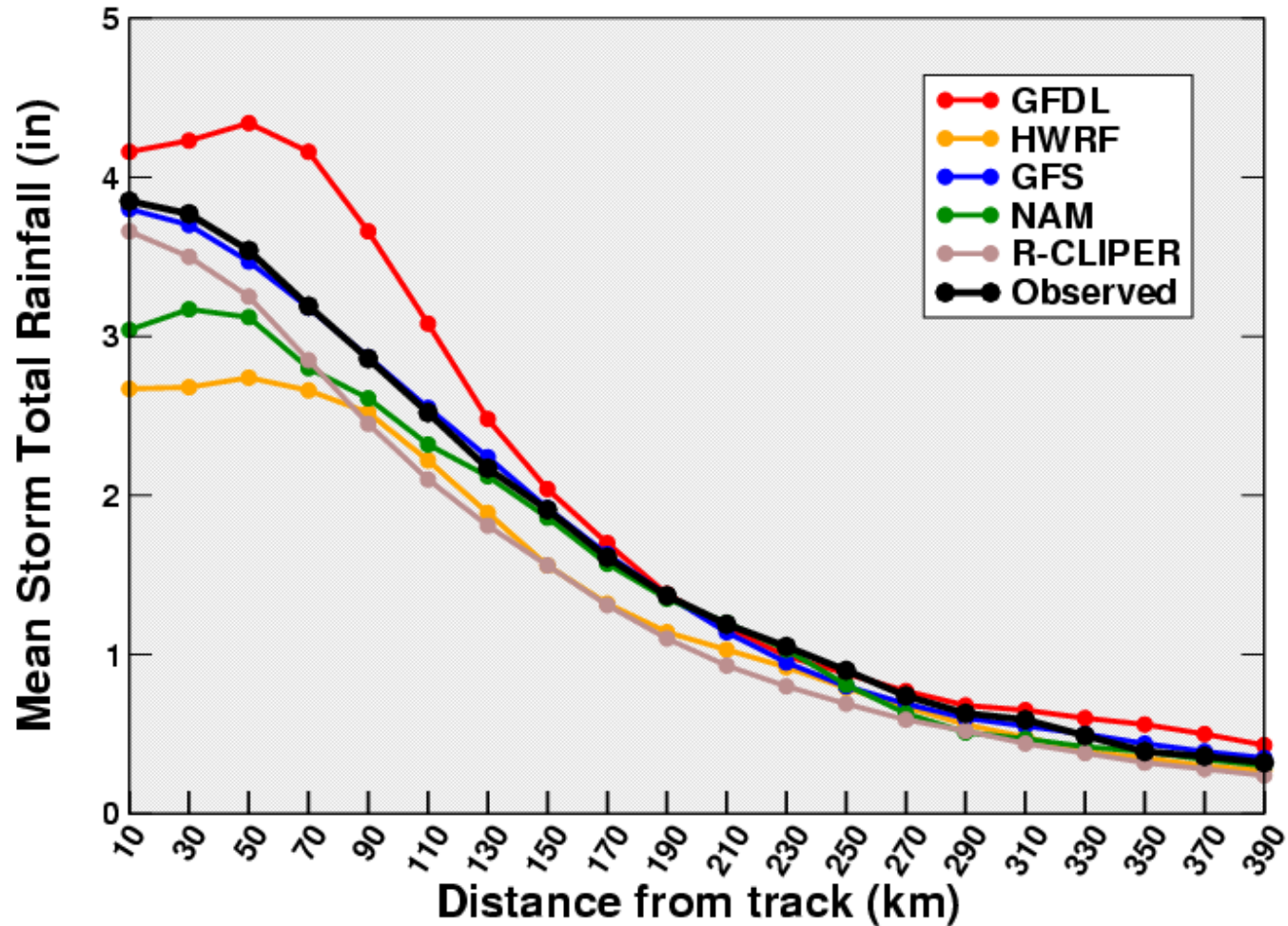
Equitable Threat Score Comparison for Landfalling Atlantic Storms, 2005



Pattern Correlations: GFS ($r = 0.78$) GFDL ($r = 0.53$) R-CLIPER ($r = 0.51$)
 (2008) HWRF ($r = 0.60$) NAM ($r = 0.52$)

Mean Rainfall

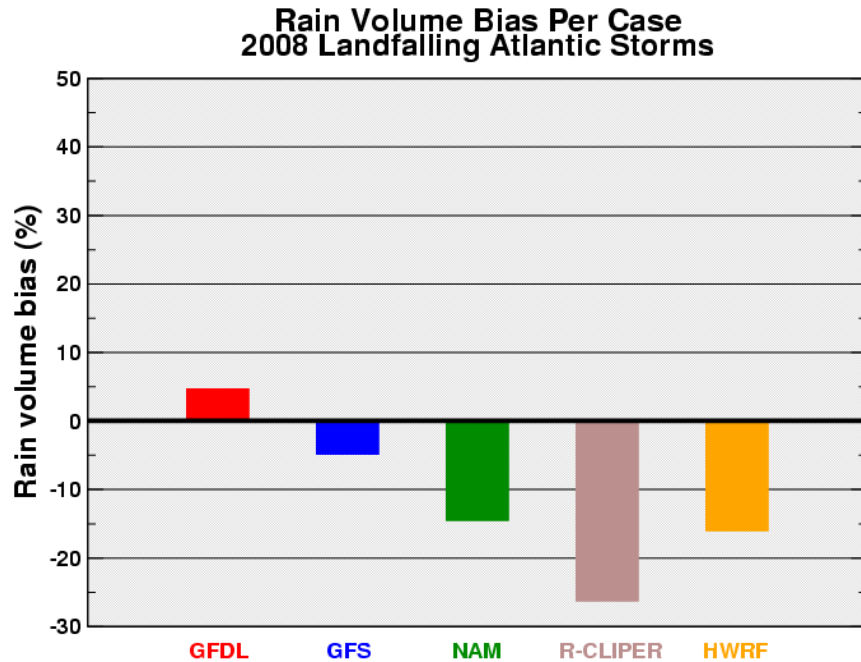
Mean Storm Total Rainfall Comparison
Landfalling Atlantic Storms, 2008



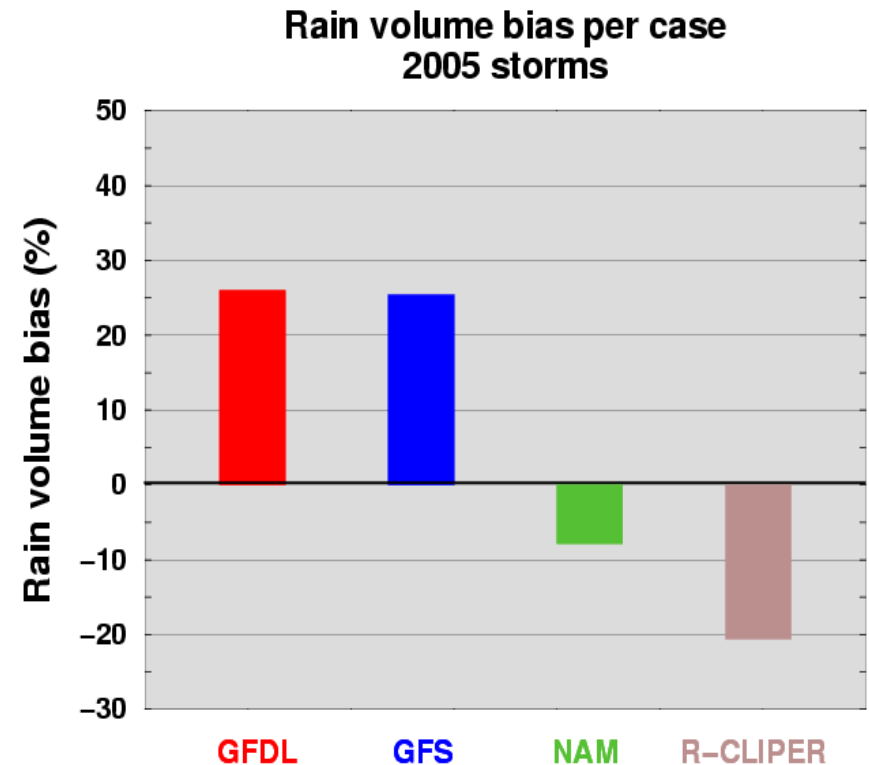
Rainfall volume

Comparison of rain volume bias by model

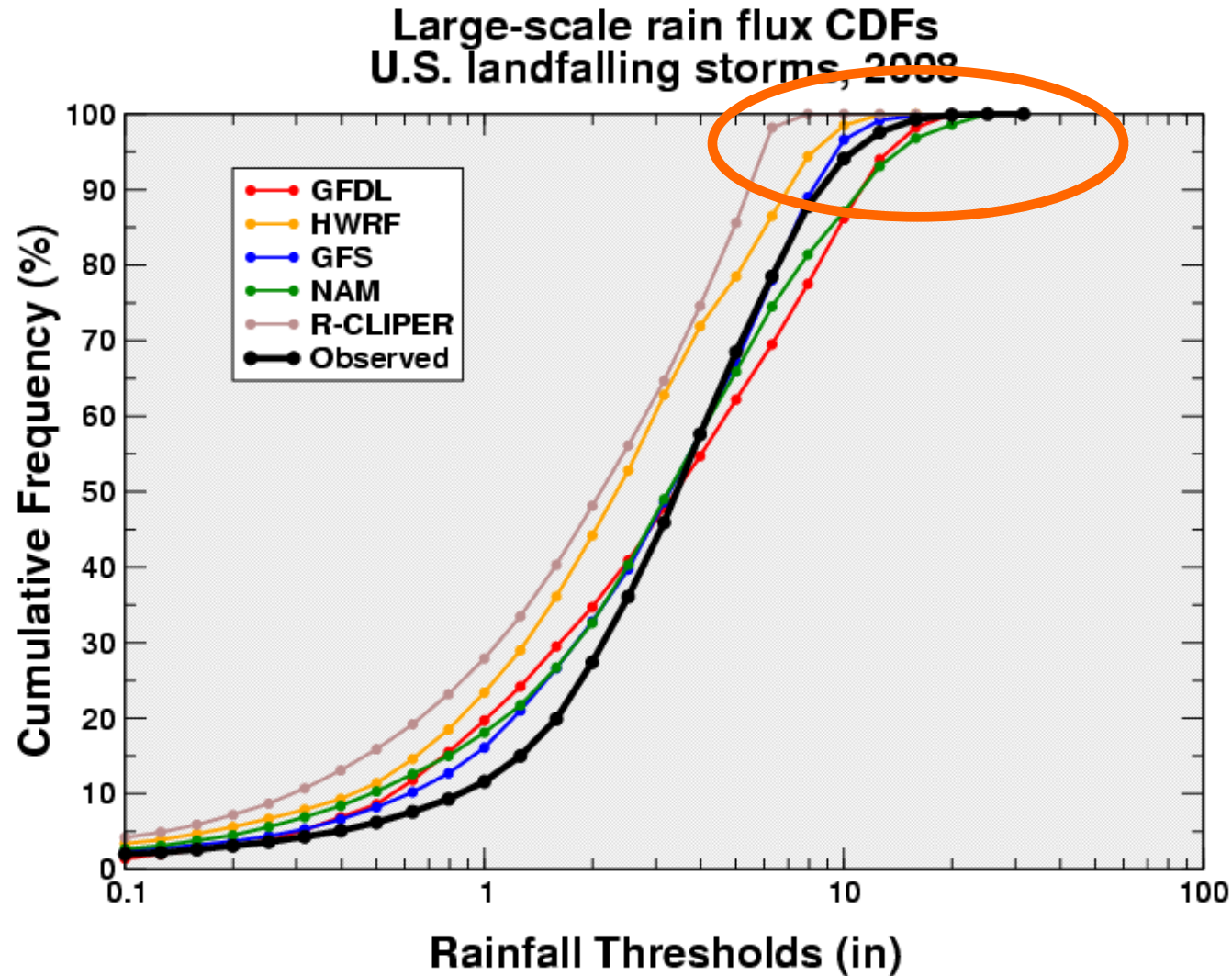
2008



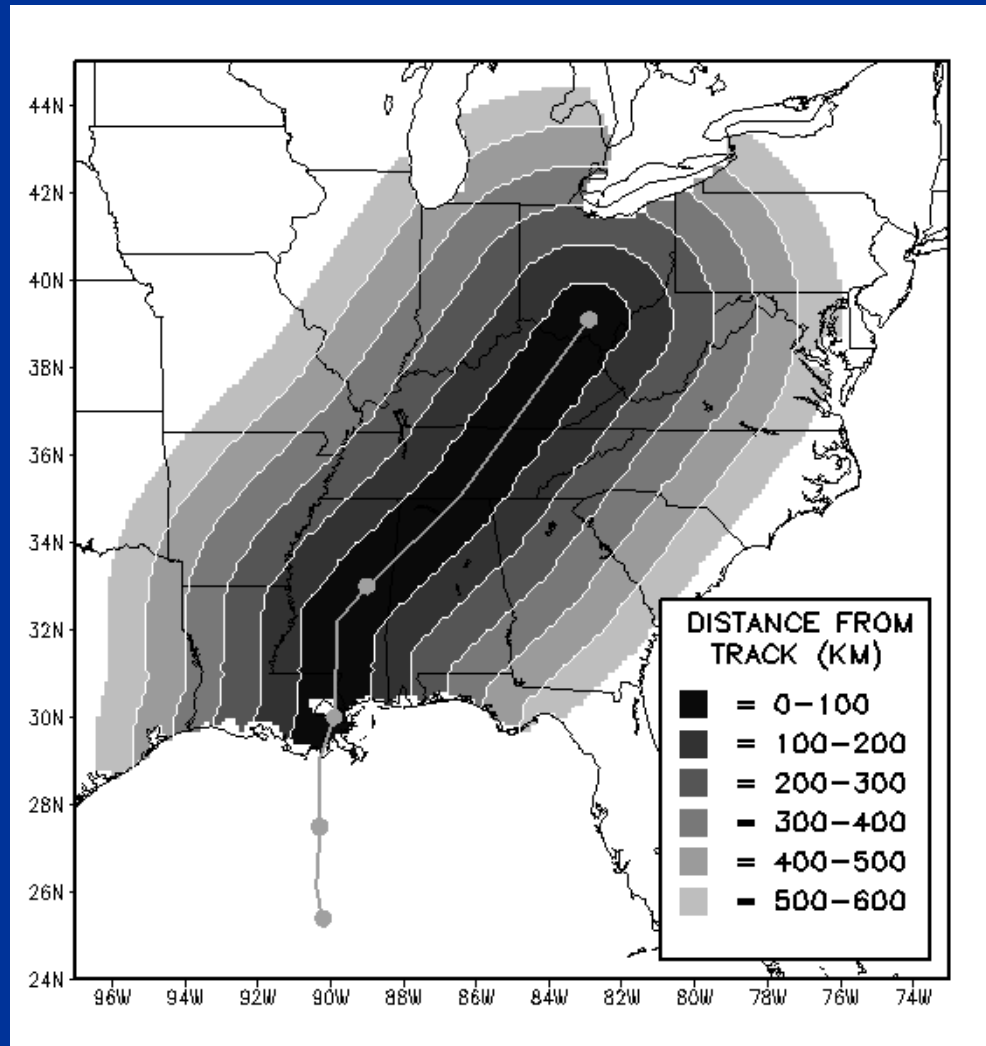
2005



2008 Landfalling Storms



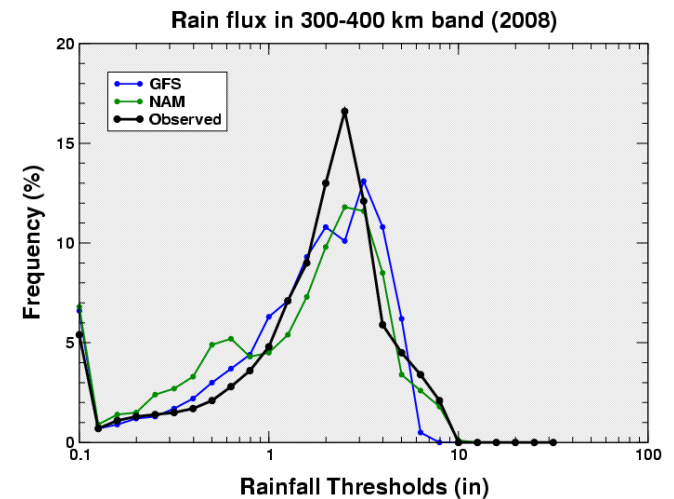
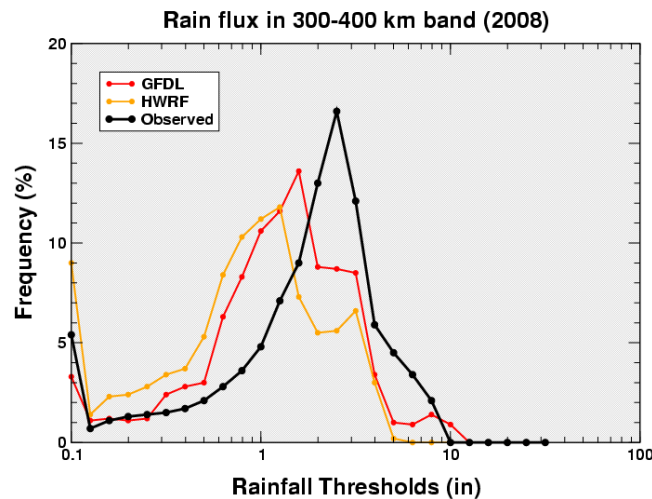
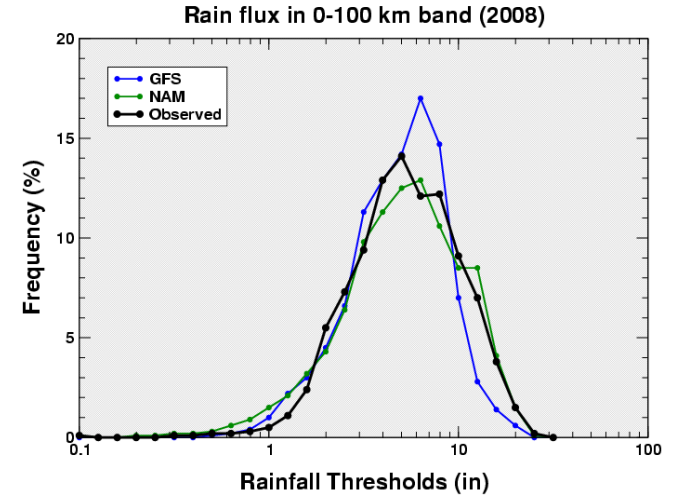
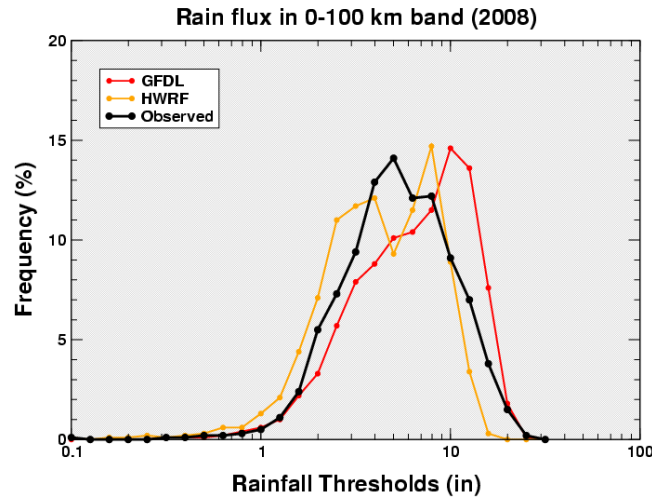
Track-relative rain flux analyses



Rain volume: Rain flux in select bands

GFDL, HWRF

GFS, NAM



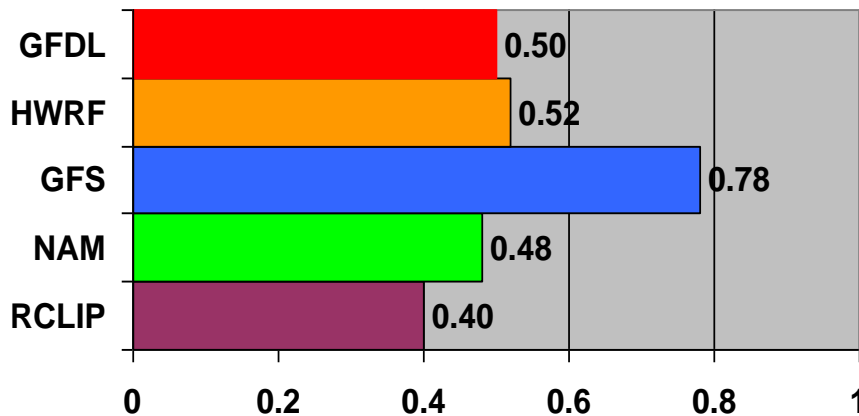
0-100 km

300-400 km

Skill Indices: Pattern Matching

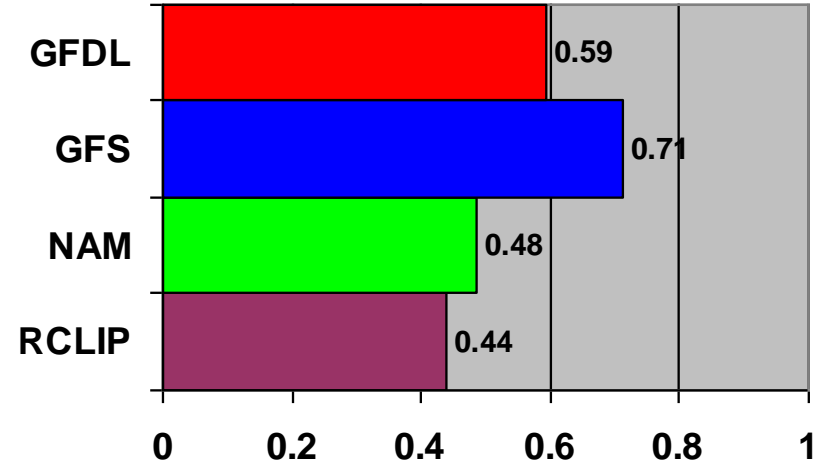
2008

Pattern Matching (2008)



2005

Pattern Matching (2005)

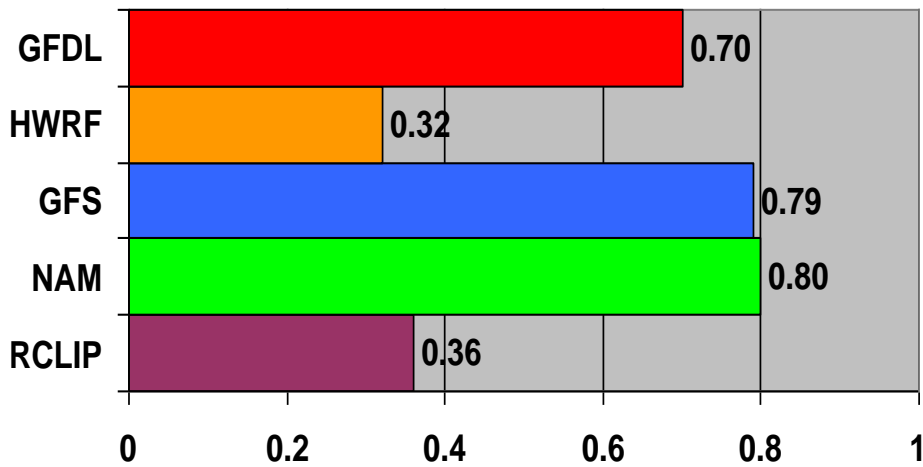


- GFS performs the best in both samples
- All models have skill relative to R-CLIPER

Skill Indices: Mean / Volume

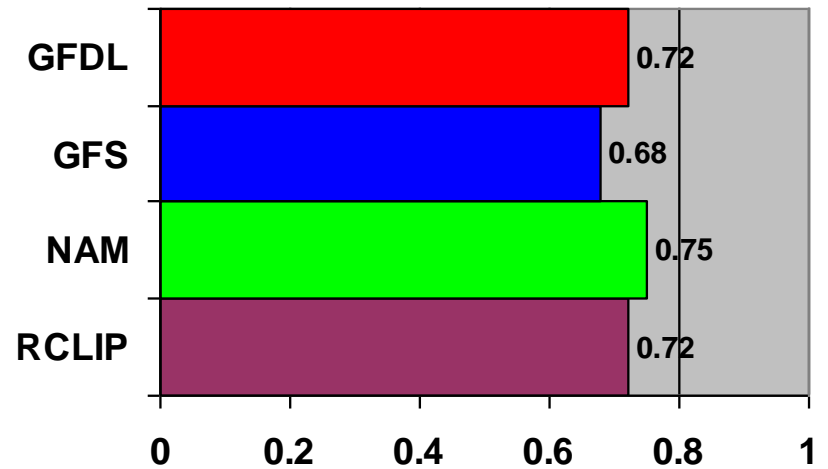
2008

Mean / Volume (2008)



2005

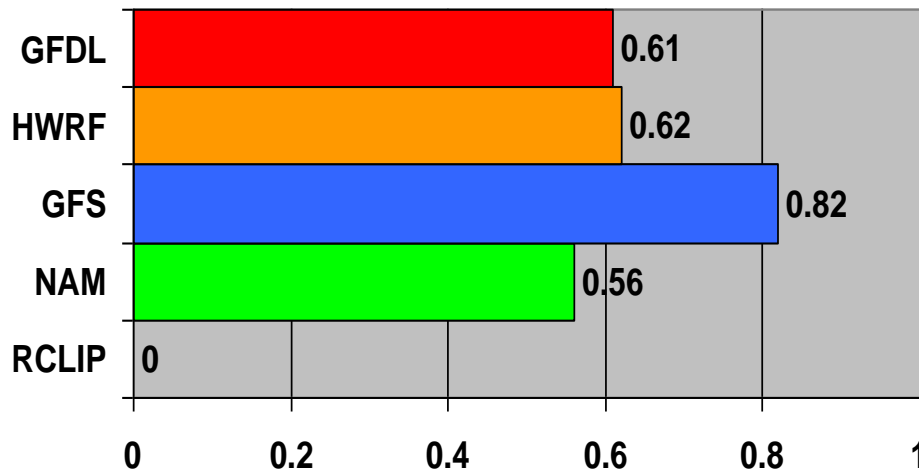
Volume (2005)



Skill Indices: Extreme Amounts

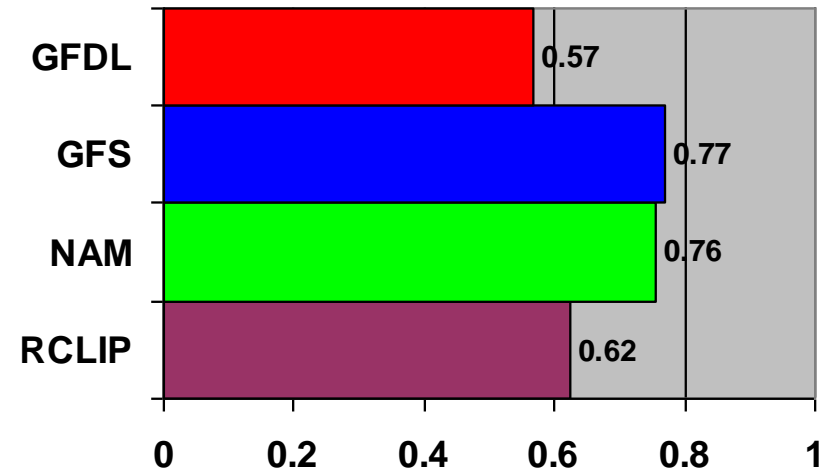
2008

Extreme Amounts (2008)



2005

Extreme Amounts (2005)



- GFDL overforecasts the large amounts, HWRF underforecasts them, resulting in comparable indices
- GFS performs best despite lowest resolution

Rainfall Summary

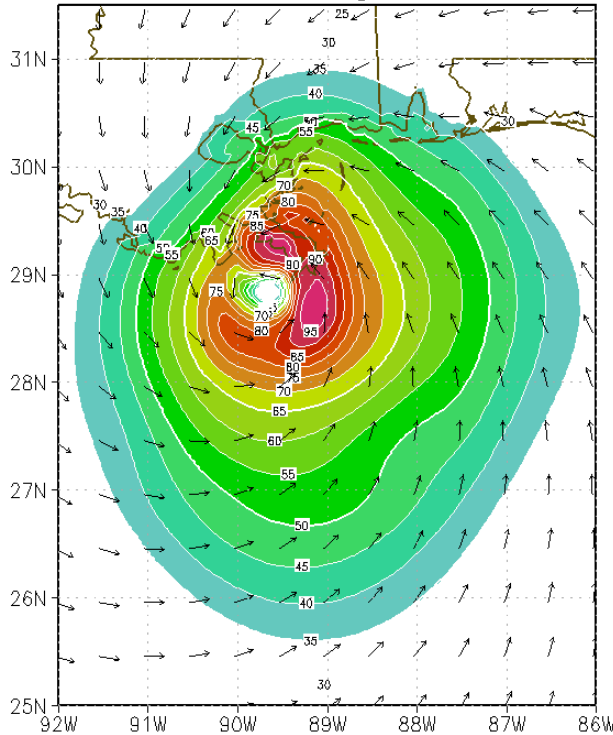
- Validation techniques address unique TC rainfall attributes:
 - Pattern matching
 - Rainfall volume
 - Extreme amounts
- TC QPF skill indices for operational forecast evaluation
- GFS most skillful in 2008 (similar to 2005)

Outline

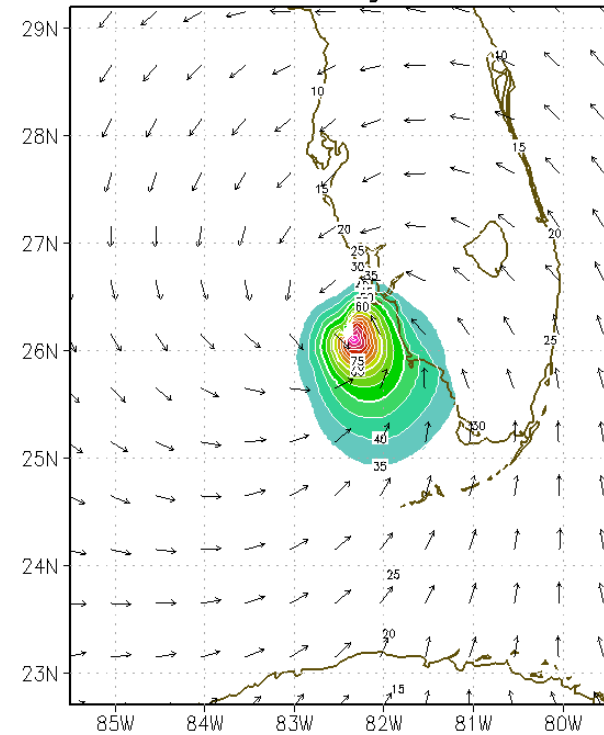
- Rainfall validation & techniques
- Application of TC QPF validation techniques to 2008 U.S. landfalling storms
- **Development of model wind structure validation techniques**
- Application of wind structure validation techniques to 2008 Atlantic TCs

The importance of near-surface wind structure

Hurricane Katrina H*Wind Analyzed 10-m Winds
09 UTC 29 August 2005



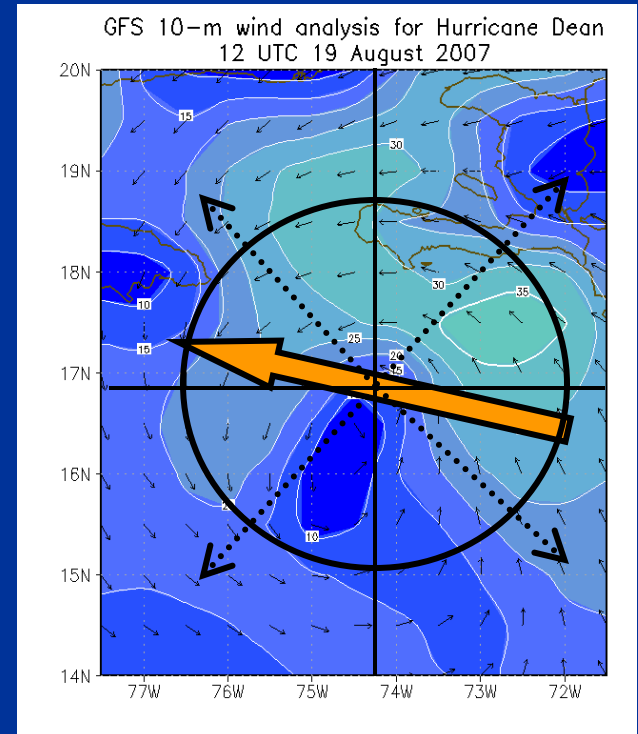
Hurricane Charley H*Wind Analyzed 10-m Winds
18 UTC 13 August 2004



$$\frac{\text{Area}_{\text{TS}_{\text{Katrina}}}}{\text{Area}_{\text{TS}_{\text{Charley}}}} = \text{Factor of 9}$$

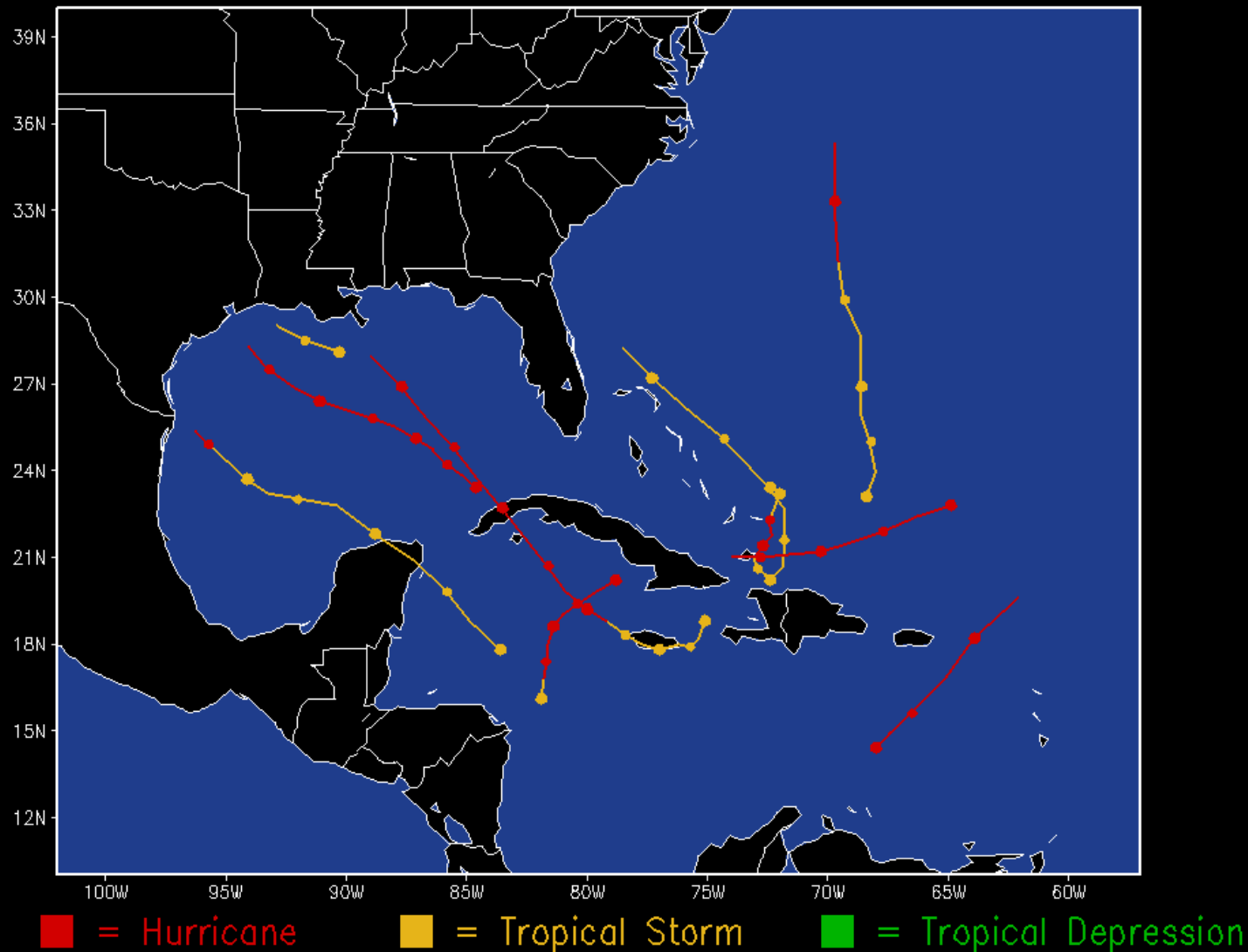
Focus is on continuous / homogeneous methods

- Distribution of Winds
 - Fractional areal coverage
 - PDFs of the winds
- Radial Structure
 - Earth-relative profiles
 - Storm motion-relative profiles
 - Radius of max winds
- Storm Destructive Potential
 - IKE, SDP, WDP (Powell and Reinhold 2007)
- Others?



Cases included in study...

2008 cases included in wind structure validation



Distribution: Fractional Areal Coverage (34-kt winds)

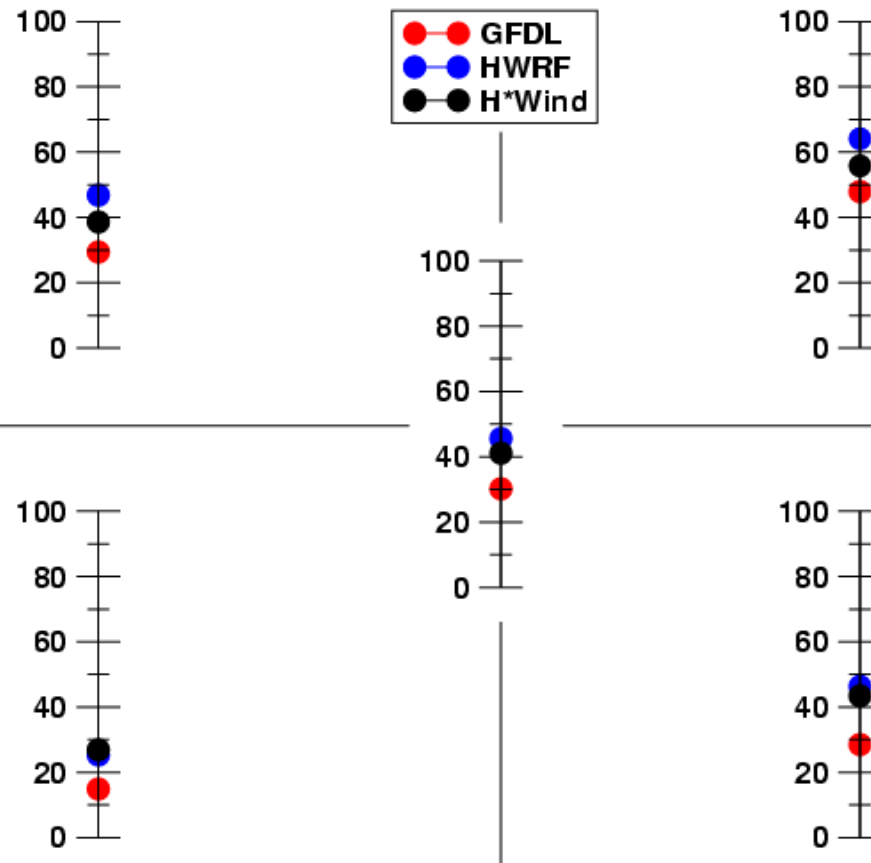
Fractional Area (%) Covered by 34-knot Winds

R < 300 km, tau = 00h

Subset of 2008 Atlantic Storms (ncase = 97)

NW

NE



Storm-sample average at tau=00h

SW

SE

Distribution: Fractional Areal Coverage (34-kt winds)

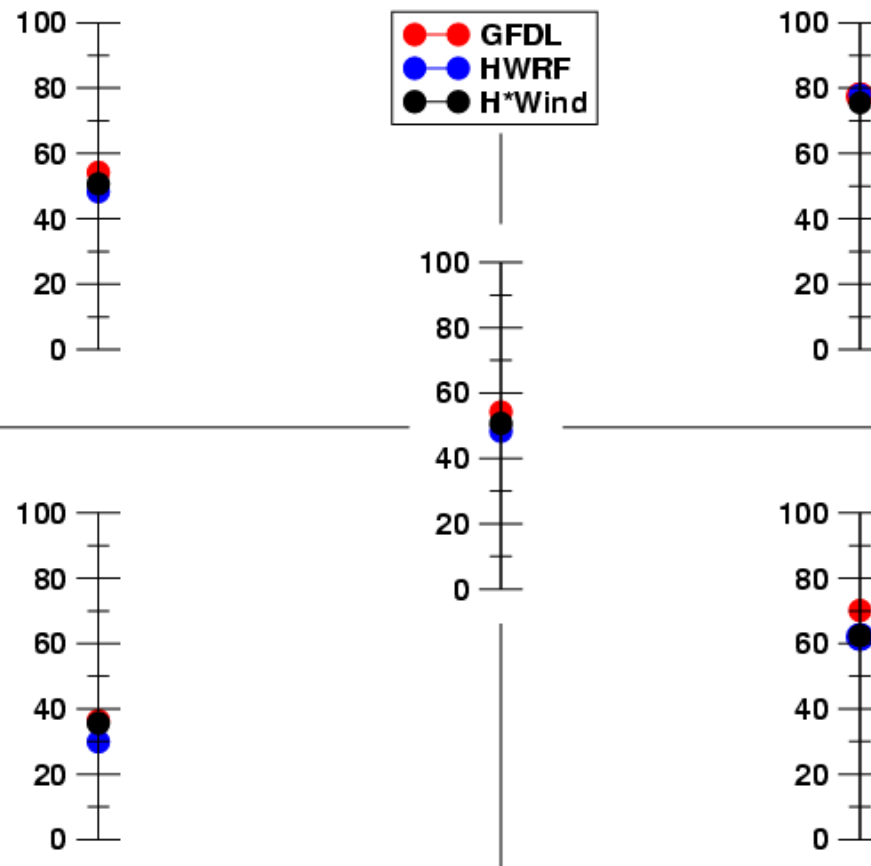
Fractional Area (%) Covered by 34-knot Winds

R < 300 km, tau = 48h

Subset of 2008 Atlantic Storms (ncase = 31)

NW

NE



Storm-sample average at tau=48h

SW

SE

Distribution: Fractional Areal Coverage (64-kt winds)

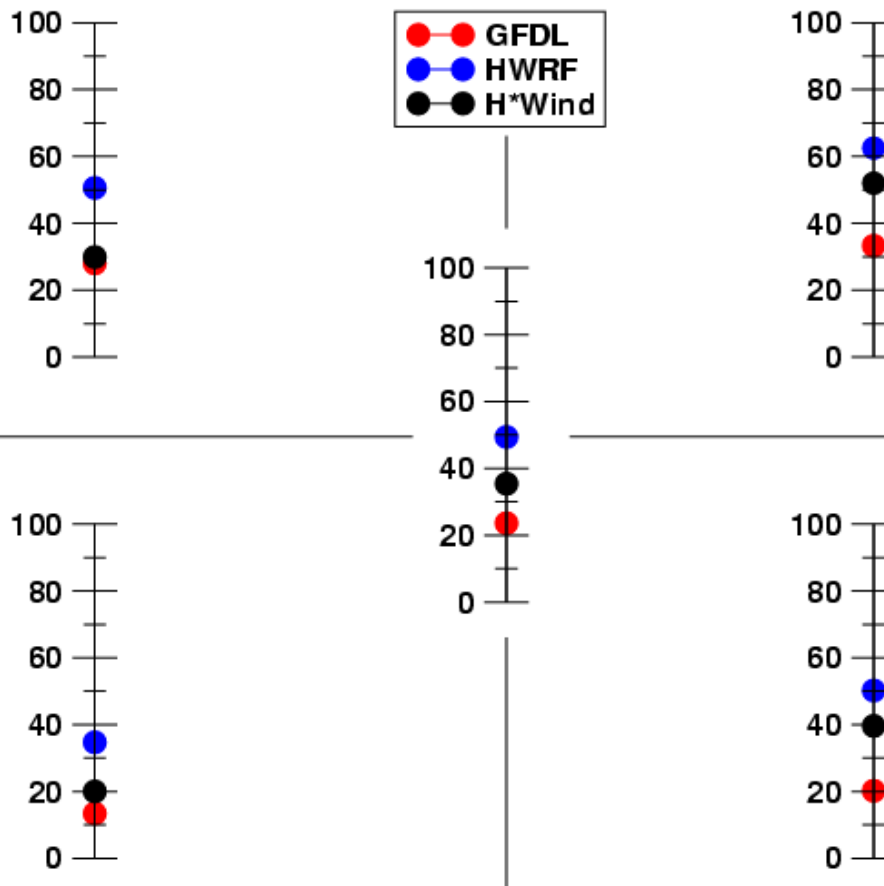
NW

NE

Fractional Area (%) Covered by 64-knot Winds

R < 100 km, tau = 00h

Subset of 2008 Atlantic Storms (Vmax Init > 64 kts; ncase= 47)



Storm-sample average at tau=00h

SW

SE

Distribution: Fractional Areal Coverage (64-kt winds)

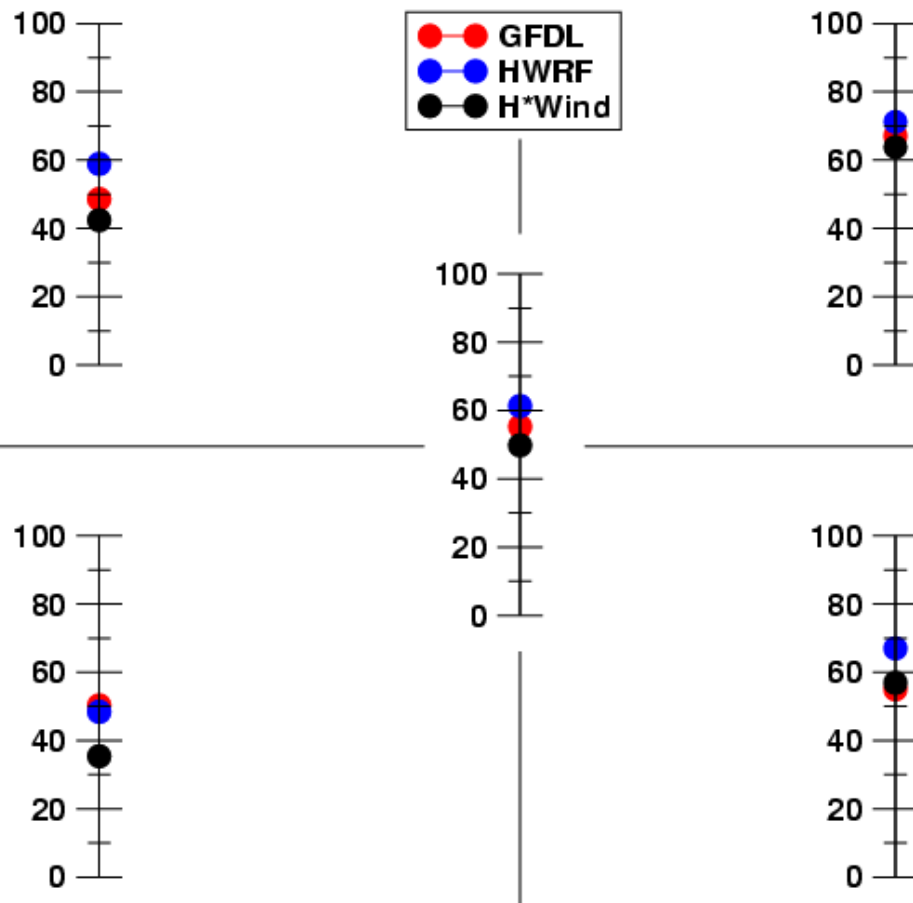
NW

Fractional Area (%) Covered by 64-knot Winds

$R < 100$ km, $\tau = 48$ h

NE

Subset of 2008 Atlantic Storms (V_{max} Init > 64 kts; $n_{case} = 7$)



Storm-sample average at $\tau = 48$ h

SW

SE

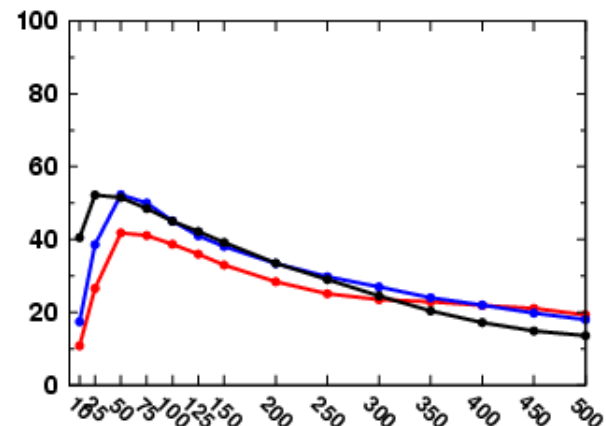
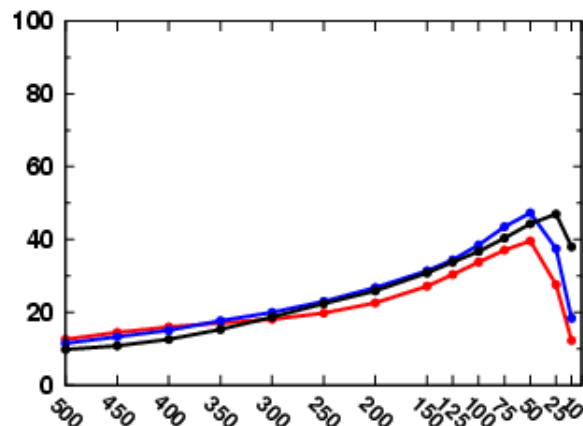
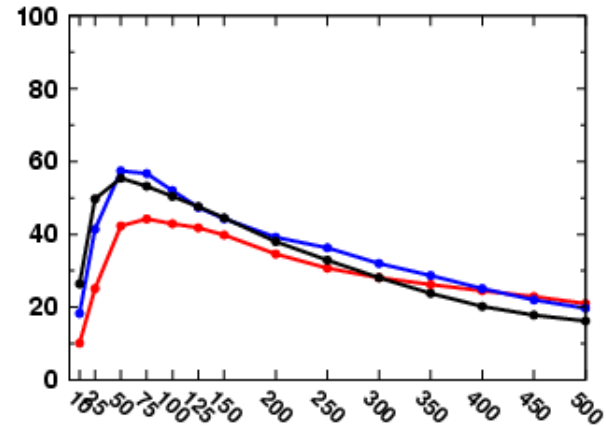
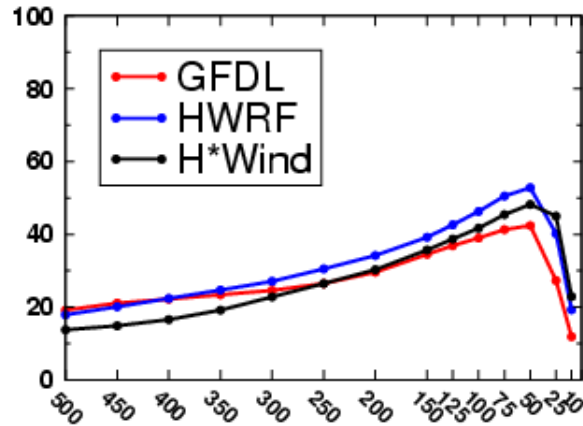
Radial profiles of the wind (all cases)

NW

Profiles of 10-m Wind Speed (kts) by Quadrant
2008 Atlantic TCs (all intensities), tau=00h

NE

Tau= 00h



SW

SE

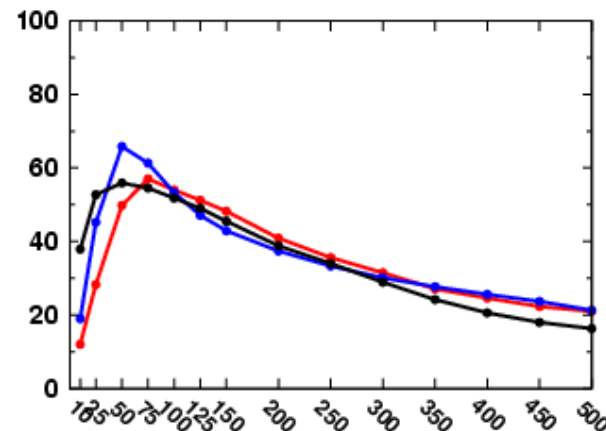
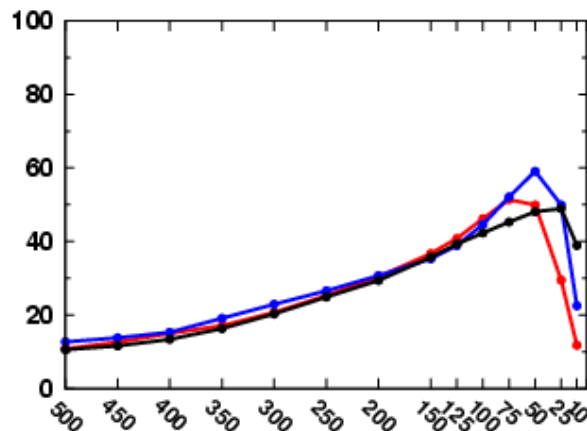
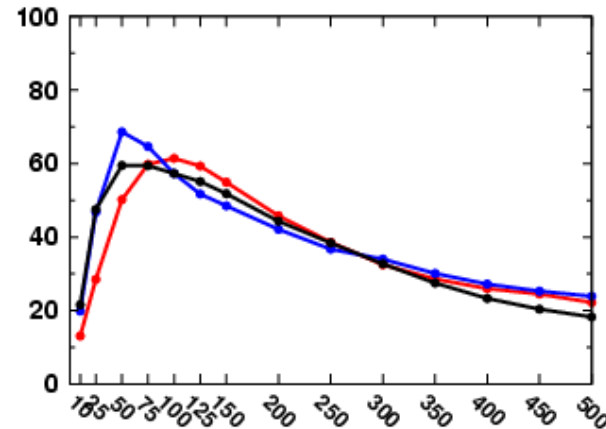
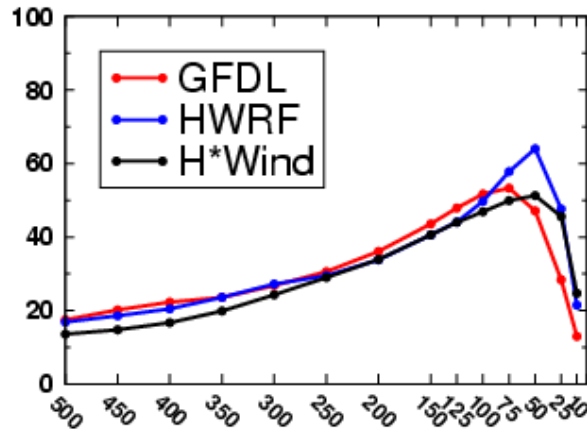
Radial profiles of the wind (all cases)

NW

Profiles of 10-m Wind Speed (kts) by Quadrant
2008 Atlantic TCs (all intensities), $\tau=48h$

NE

$\tau=48h$



SW

SE

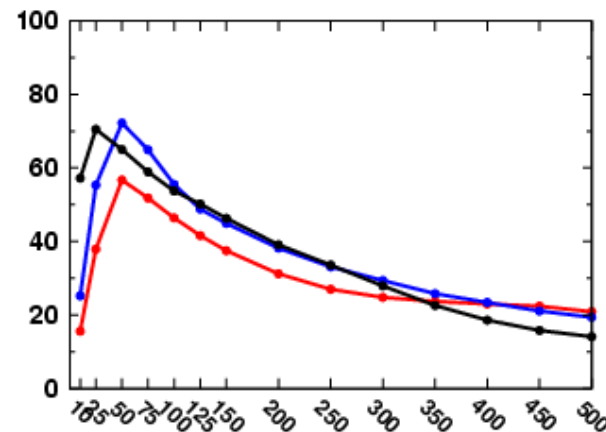
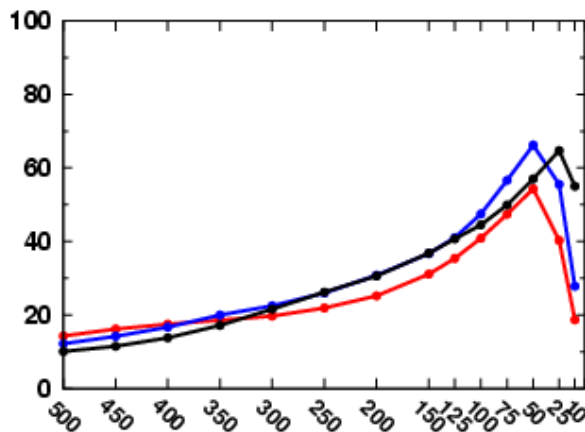
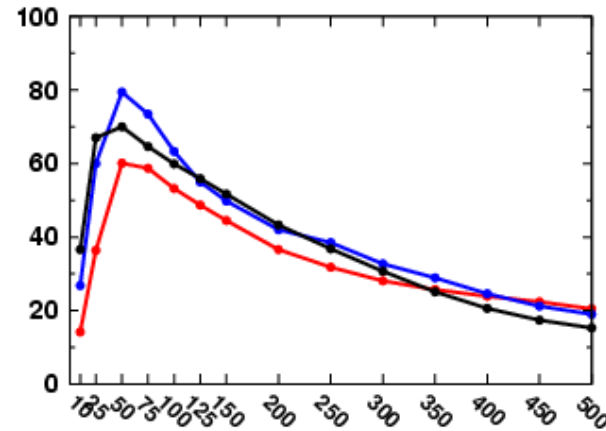
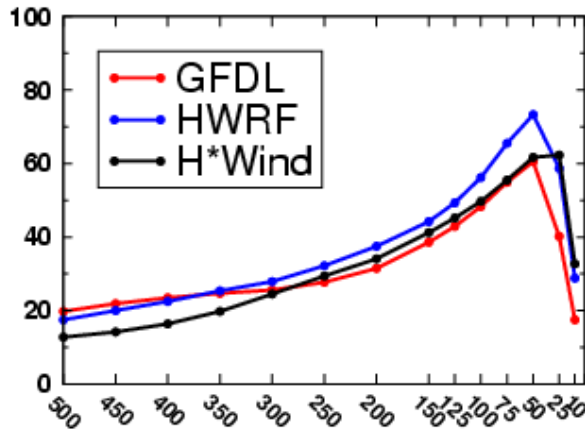
Radial profiles of the wind (Hurricanes only)

NW

Profiles of 10-m Wind Speed (kts) by Quadrant
2008 Atlantic TCs (Init Vmax > 64 kts), tau=00h

NE

Tau= 00h



SW

SE

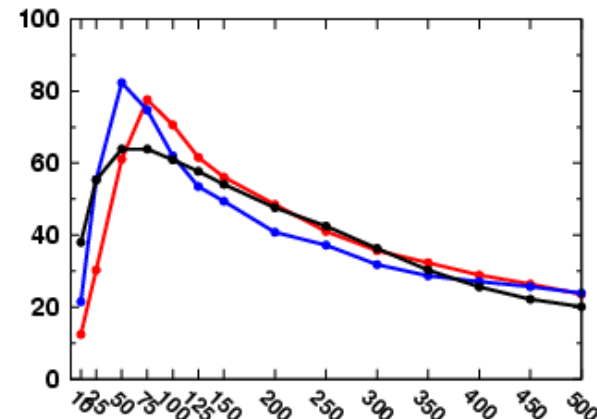
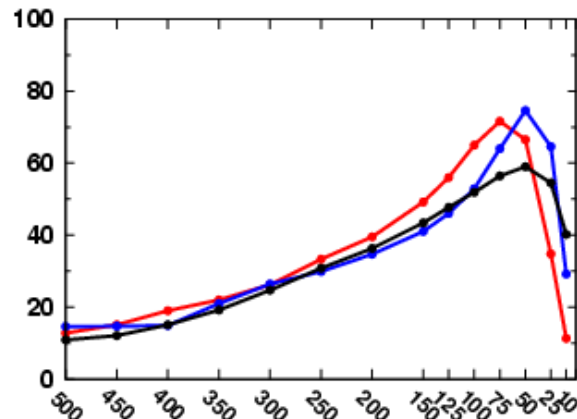
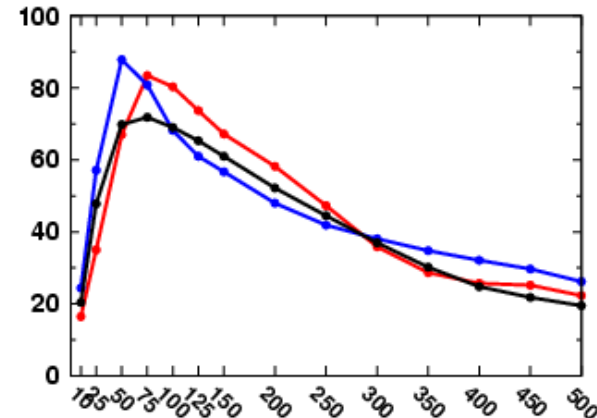
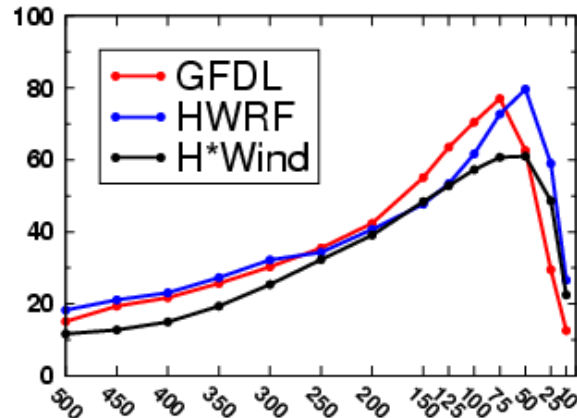
Radial profiles of the wind (Hurricanes only)

NW

Profiles of 10-m Wind Speed (kts) by Quadrant
2008 Atlantic TCs (Init Vmax > 64 kts), tau=48h

NE

Tau= 48h

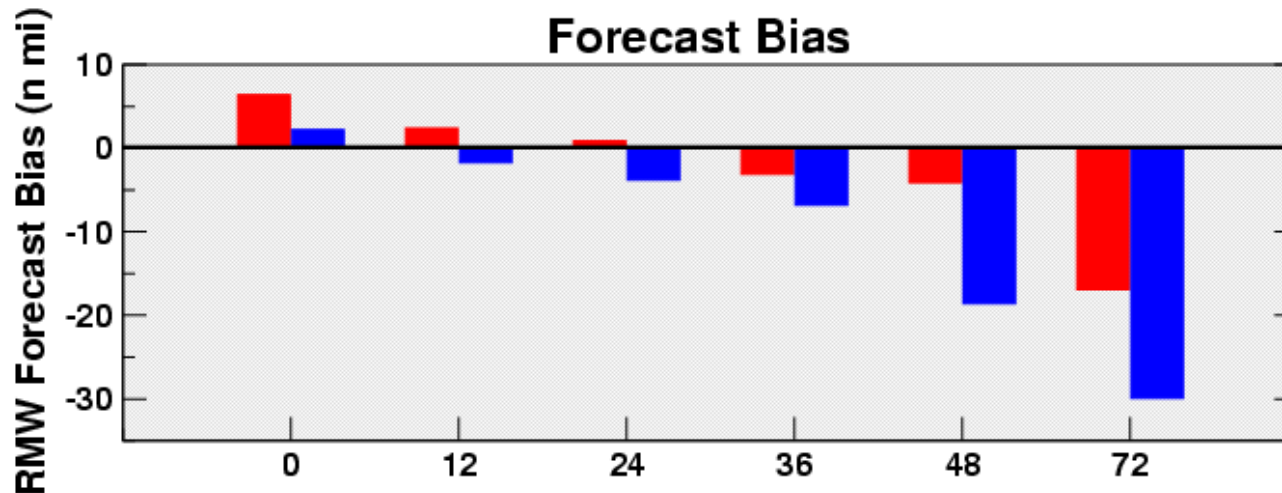
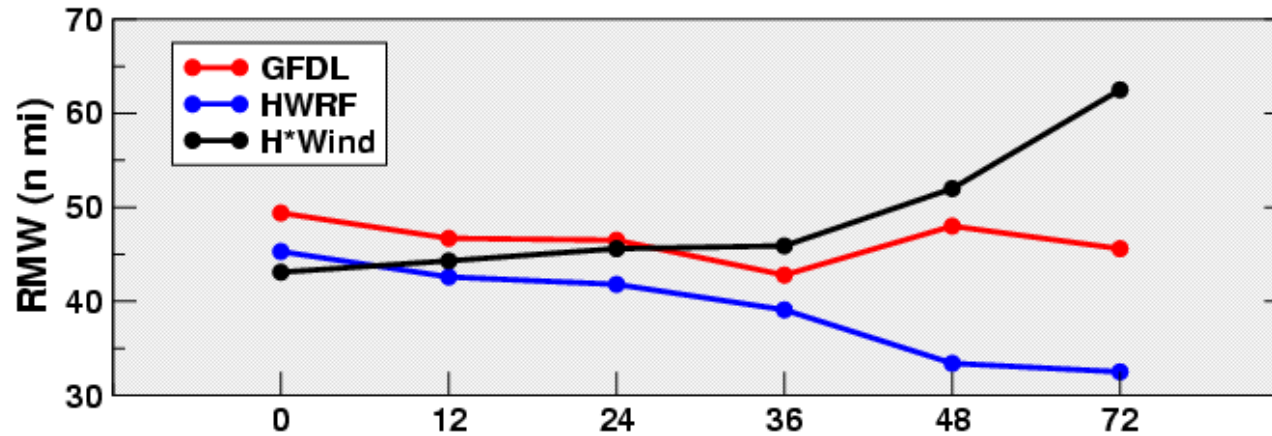


SW

SE

Radius of Maximum Winds

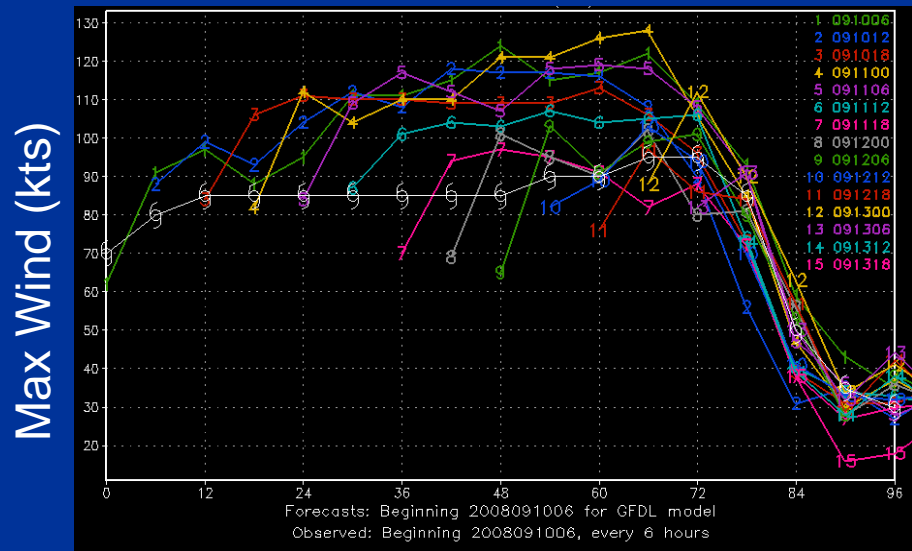
Forecast and Observed Radius of Maximum Winds Subset of Atlantic Storms, 2008



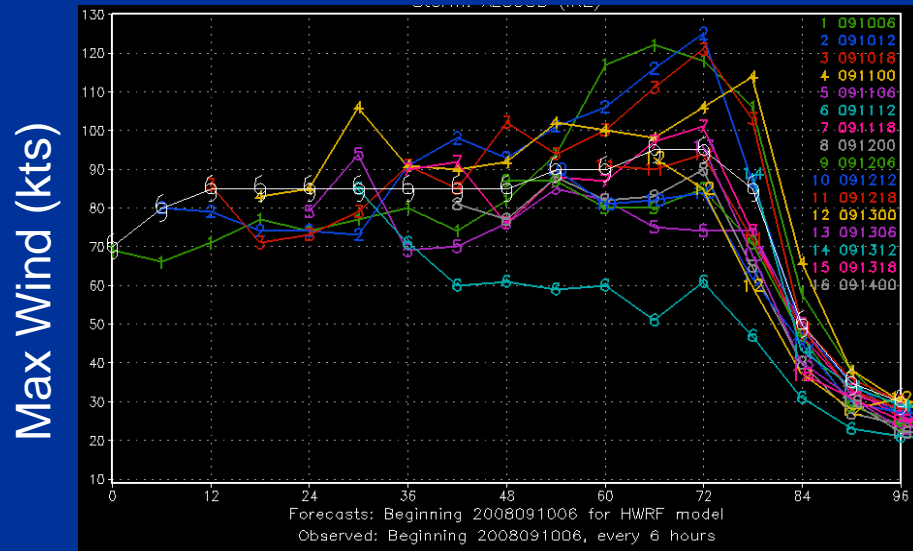
#CASES: 97 79 61 45 31 15

Forecasts of Integrated Kinetic Energy

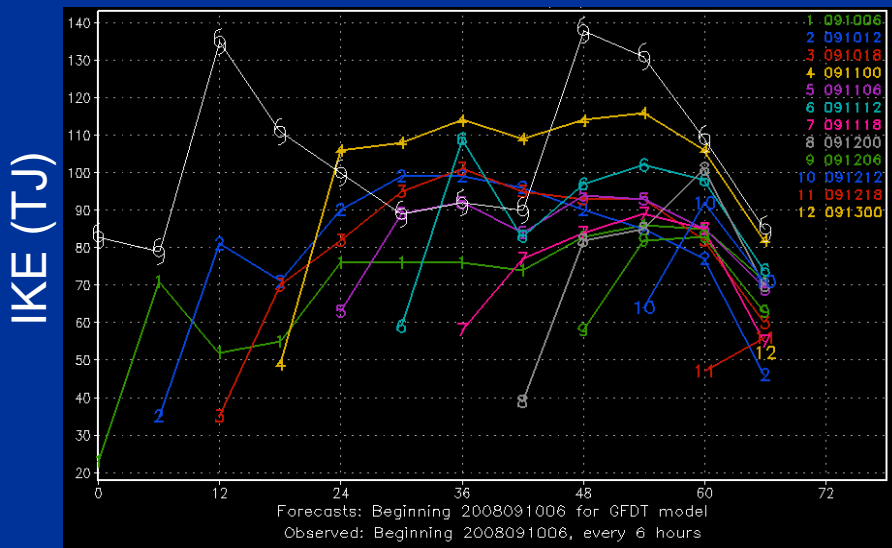
GFDL Ike Intensity Forecasts



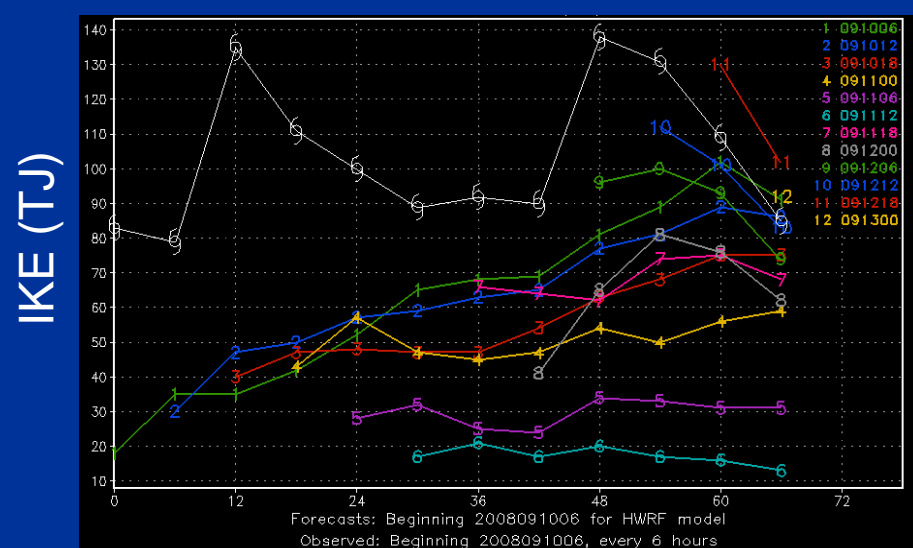
HWRF Ike Intensity Forecasts



GFDL Ike IKE (V>18 m/s) Forecasts

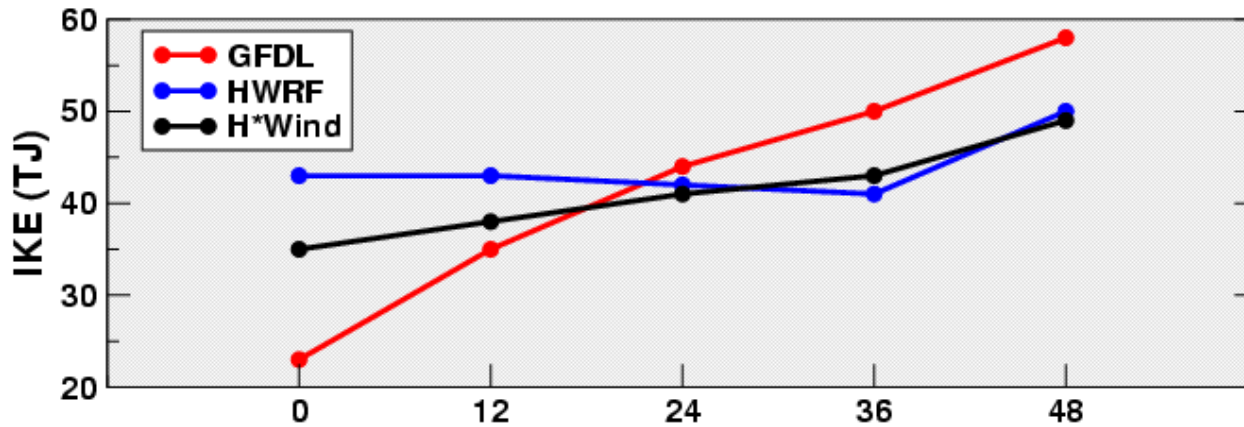


HWRF Ike IKE (V>18 m/s) Forecasts

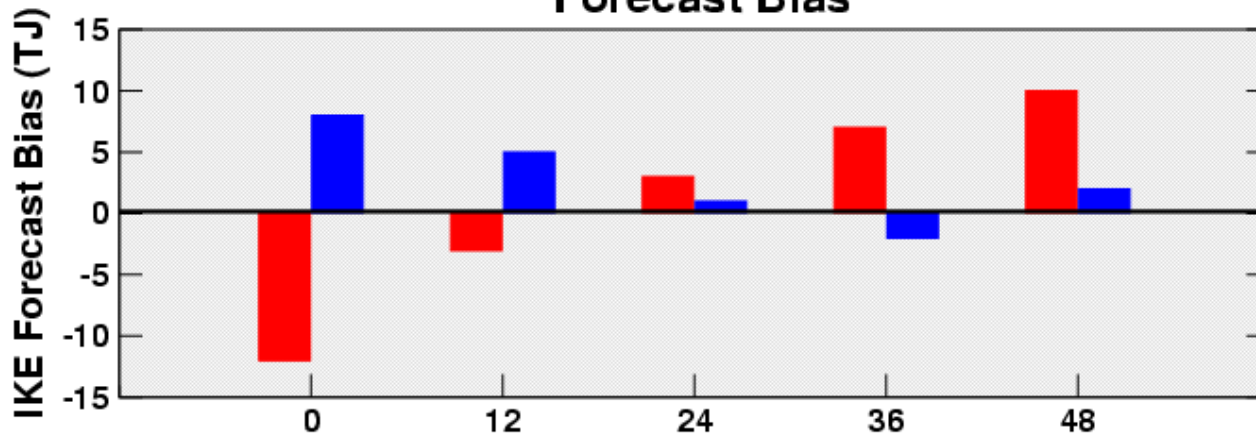


Forecasts of Integrated Kinetic Energy

Forecast and Observed IKE (for winds >18 m/s)
Subset of Atlantic Storms, 2008



Forecast Bias



#CASES: 97 79 61 45 31

Wind Structure Summary

- Methods complementary to wind radii validation
- Focus on various aspects of wind field
 - Distribution
 - Radial structure
 - IKE / Storm destructive potential
 - Others...?
- Some biases already evident