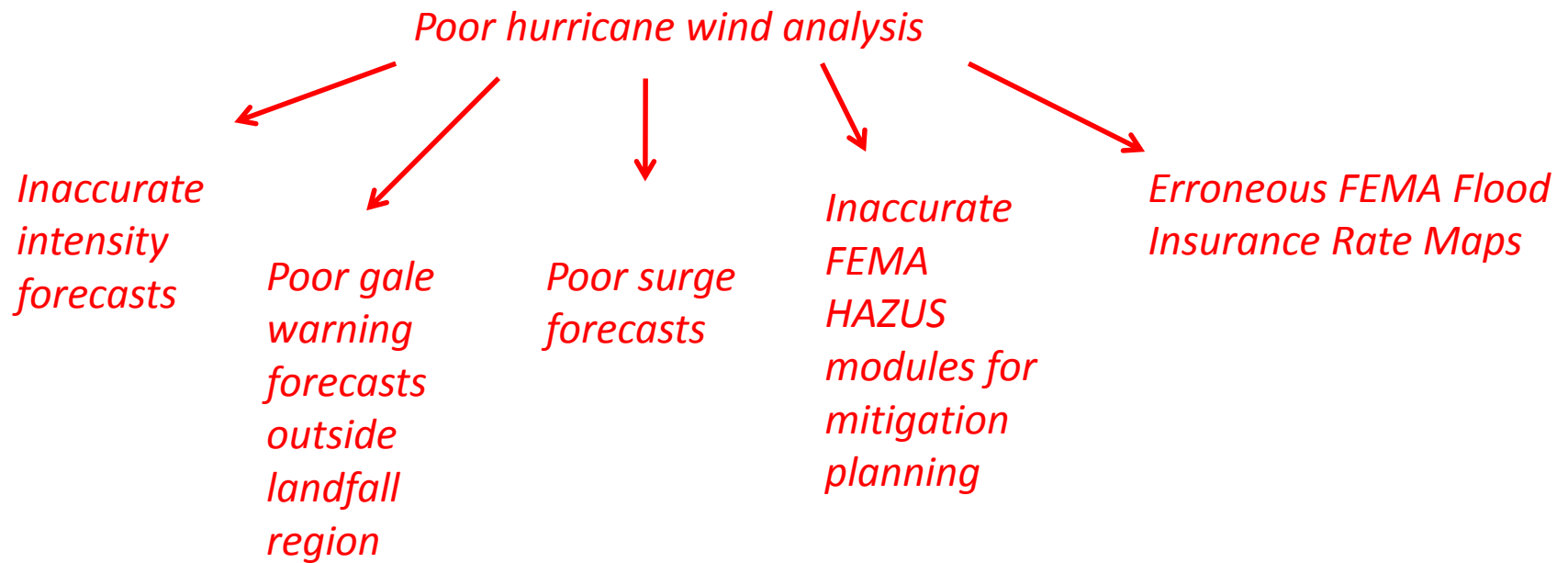


Current and recent hurricane structure research at MSU

*Pat Fitzpatrick, Yee Lau, Chris Hill, and Haldun Karan
Geosystems Research Institute
Mississippi State University*

Intrinsically linked to hurricane intensity

- Recent hurricane research*
- New results on relationship to environmental moisture*



Posters

The Influence of Cyclones on the Fate and Transport of the
Deepwater Horizon Oil Spill

Wetland Loss Associated with Hurricane Storm Surge near
the Caernarvon Freshwater Diversion

[paper submitted to *International Journal of Remote Sensing*]

Recent research

(detailed presentations available upon request)

Meteorological modeling – Fitzpatrick, MSU

Screen capture of wind accuracy scheme being used by operational hurricane centers in the Automated Tropical Cyclone Forecasting System (ATCF)

07 2012 Southern Hemisphere - ETHEL

Date-Time-Group: 2012011918 ▼

| | Lat | Lon | Max Wind (kt) | Dir (deg) | Spd (kt) |
|-------------|--|--|---------------|-----------|----------|
| Past 24 hr: | 13.7 S | 68.7 E | 30 | | |
| Past 12 hr: | 14.9 S | 67.2 E | 45 | 218 | 9 |
| Current: | 17.1 ▼ <input type="checkbox"/> N <input type="checkbox"/> S | 65.9 ▼ <input type="checkbox"/> E <input type="checkbox"/> W | 55 ▼ | 210 ▼ | 11 ▼ |

Eye Diameter: 0 ▼ nm

Max Wind Radius: 15 ▼ nm

Vertical Extent of Circulation: Medium 700 - 400 mb ▼

Central Pressure: 982 ▼ mb

Outermost Closed Isobar: 1005 ▼ mb

Radius Outermost Closed Isobar: 200 ▼ nm

Speed/Quadrant

| | NE (nm) | SE (nm) | SW (nm) | NW (nm) |
|--------|---------|---------|---------|---------|
| 34 kt: | 55 ▼ | 60 ▼ | 55 ▼ | 55 ▼ |
| 50 kt: | 15 ▼ | 15 ▼ | 15 ▼ | 15 ▼ |
| 64 kt: | 0 ▼ | 0 ▼ | 0 ▼ | 0 ▼ |

Buttons: Help, OK, Cancel

Guidance...

Central Pressure Trend

1000 mb is your -24 h central pressure.
996 mb is your -18 h central pressure.
989 mb is your -12 h central pressure.
989 mb is your -06 h central pressure.

982 mb is your current central pressure.

Central Pressure Guidance

992 mb,Courtney and Knaff (2009) - Accounts for size, lati:
993 mb,Courtney and Knaff (2009), NHC 2011 version - Acco:
982 mb,Knaff and Zehr (2007) Appendix A - Simple WP basin
994 mb,Dvorak (1984) - Suggested AL/EP central pressures.

Your central pressure of 982 mb is within +/-10 mb of Courtney :

Radius of Outermost Closed Isobar Trend

180 nm is your -24 h ROCI.
180 nm is your -18 h ROCI.
200 nm is your -12 h ROCI.
200 nm is your -06 h ROCI.

200 nm is your current ROCI.
Your ROCI hasn't changed for 12 hours!

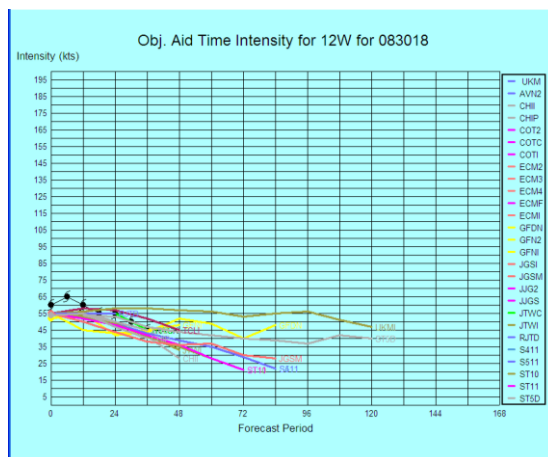
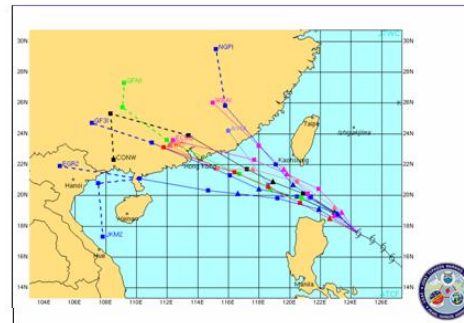
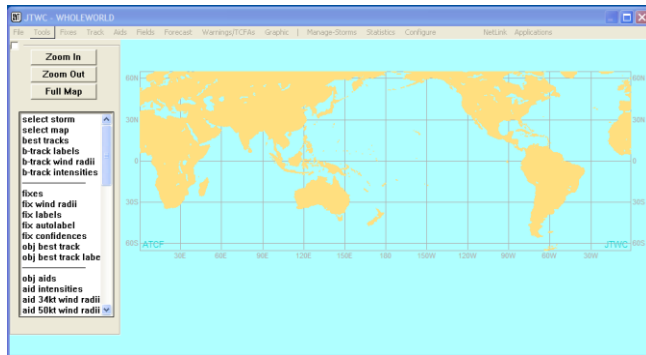
Holland B Guidance (Knaff et al. 2011)

This parameter checks consistency of several bogus parameters:
982 mb is your central pressure.
1005 mb is your outermost closed isobar.
55 kt is your intensity.
11 kt is your storm speed.
1.0 is your Holland B value.

The climatological range for Holland B is 0.6 to 1.8.
Your value is an average value.

Automated Tropical Cyclone Forecasting System (ATCF)

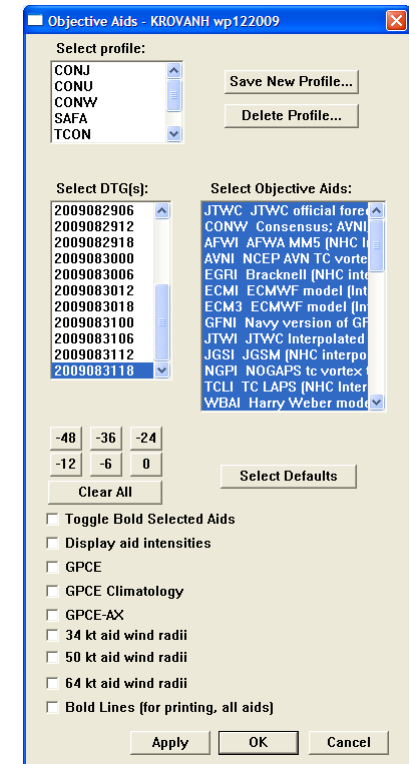
- Used by the National Hurricane Center
- Used by the Joint Typhoon Warning Center
- A GUI with many operational purposes, including objective aids
- Further information: http://www.nrlmry.navy.mil/atcf_web/



annexwp.2009

Statistics for JTWC on storm WP1209

| DTG | NO. | LAT | LONG | wind | POSITION ERRORS | | | | | | | | | | | | WIND ERRORS | | | | | | | | | | | | PLATFORM |
|----------|-----|-------|--------|------|-----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------------|----|----|-----|--|--|--|--|--|--|--|--|----------|
| | | | | | 00 | 12 | 24 | 36 | 48 | 72 | 96 | 120 | 00 | 12 | 24 | 36 | 48 | 72 | 96 | 120 | | | | | | | | | |
| 09082800 | 5 | 21.9N | 148.5E | 30 | 0 | 55 | 97 | 110 | 117 | 185 | 753 | 0 | -5 | -5 | -10 | -10 | 10 | | | | | | | | | | | | |
| 09082806 | 6 | 22.6N | 148.4E | 40 | 0 | 36 | 66 | 92 | 119 | 251 | 0 | 0 | 0 | 0 | 10 | 10 | | | | | | | | | | | | | |
| 09082812 | 7 | 23.7N | 148.2E | 45 | 0 | 50 | 48 | 88 | 70 | 126 | 0 | 5 | 5 | 15 | 10 | | | | | | | | | | | | | | |
| 09082818 | 8 | 24.8N | 148.0E | 50 | 0 | 24 | 63 | 83 | 45 | 209 | 0 | 0 | 0 | 10 | 10 | 0 | | | | | | | | | | | | | |
| 09082900 | 9 | 26.0N | 147.6E | 50 | 0 | 34 | 86 | 82 | 69 | 234 | 0 | 0 | 0 | 10 | 0 | 0 | | | | | | | | | | | | | |
| 09082906 | 10 | 27.4N | 146.8E | 55 | 0 | 39 | 114 | 165 | 219 | 0 | 0 | 10 | 10 | 5 | | | | | | | | | | | | | | | |
| 09082912 | 11 | 28.6N | 145.8E | 55 | 31 | 118 | 158 | 238 | 298 | 0 | 0 | 10 | 0 | 5 | | | | | | | | | | | | | | | |
| 09082918 | 12 | 29.6N | 144.2E | 60 | 23 | 82 | 103 | 158 | 188 | 0 | 10 | 5 | 0 | 0 | | | | | | | | | | | | | | | |
| 09083000 | 13 | 30.4N | 142.4E | 60 | 30 | 73 | 139 | 186 | 120 | 0 | 0 | 5 | -10 | -10 | | | | | | | | | | | | | | | |
| 09083006 | 14 | 31.1N | 141.0E | 55 | 6 | 24 | 44 | 35 | 0 | -5 | -5 | -10 | | | | | | | | | | | | | | | | | |
| 09083012 | 15 | 31.7N | 140.5E | 55 | 0 | 8 | 50 | 111 | 0 | -10 | 0 | 5 | | | | | | | | | | | | | | | | | |
| 09083018 | 16 | 32.6N | 140.0E | 60 | 0 | 25 | 71 | -5 | -5 | 0 | | | | | | | | | | | | | | | | | | | |
| 09083100 | 17 | 33.5N | 139.5E | 65 | 0 | 38 | 92 | -10 | 0 | -5 | | | | | | | | | | | | | | | | | | | |
| 09083106 | 18 | 34.7N | 140.6E | 60 | 0 | 43 | -5 | 0 | | | | | | | | | | | | | | | | | | | | | |
| 09083112 | 19 | 36.3N | 141.5E | 55 | 0 | 59 | -5 | -5 | | | | | | | | | | | | | | | | | | | | | |
| 09083118 | 20 | 38.4N | 142.9E | 55 | 0 | -5 | | | | | | | | | | | | | | | | | | | | | | | |
| AVERAGE | 6 | 45 | 87 | 121 | 139 | 201 | 753 | -2 | 3 | 4 | 6 | 7 | 6 | 10 | | | | | | | | | | | | | | | |
| BIAS | | | | | | | | -2 | -1 | 0 | 3 | 2 | 10 | | | | | | | | | | | | | | | | |
| # CASES | 16 | 15 | 13 | 11 | 9 | 5 | 1 | 16 | 15 | 13 | 11 | 9 | 5 | 1 | | | | | | | | | | | | | | | |



The Holland Wind Profile

- Holland, G.J., 1980: An analytic model of the wind and pressure profiles in hurricanes, MWR, 1212-1218

- $P(r) = P_c + (P_n - P_c) \exp(-A/r^B)$

- P_c = minimum P, P_n = ambient P
 - A, B = structure parameters

- Assume cyclostrophic balance with constant density ρ

- $V(r) = [AB(P_n - P_c) \exp(-A/r^B) / \rho r^B]^{1/2}$

- $A = (r_m)^B$
 - $B = \rho e V_m^2 / \Delta P$

- Holland profile used extensively in damage modeling applications

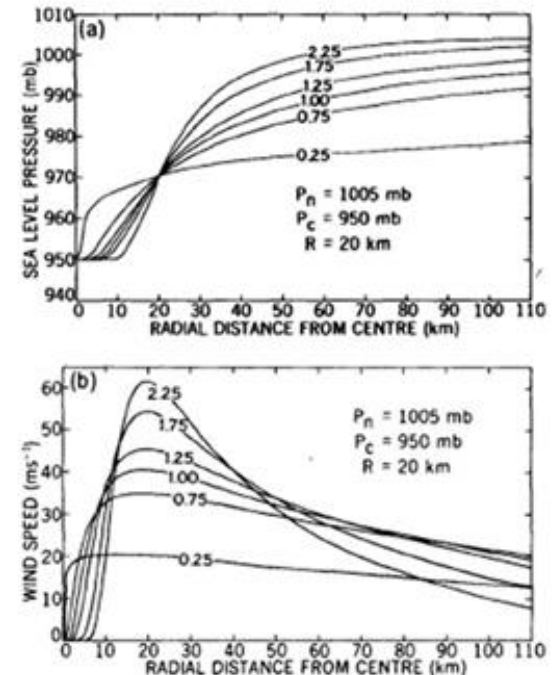


FIG. 2. The effect of varying the parameter B on (a) the sea level pressure profile and (b) the gradient wind profile.

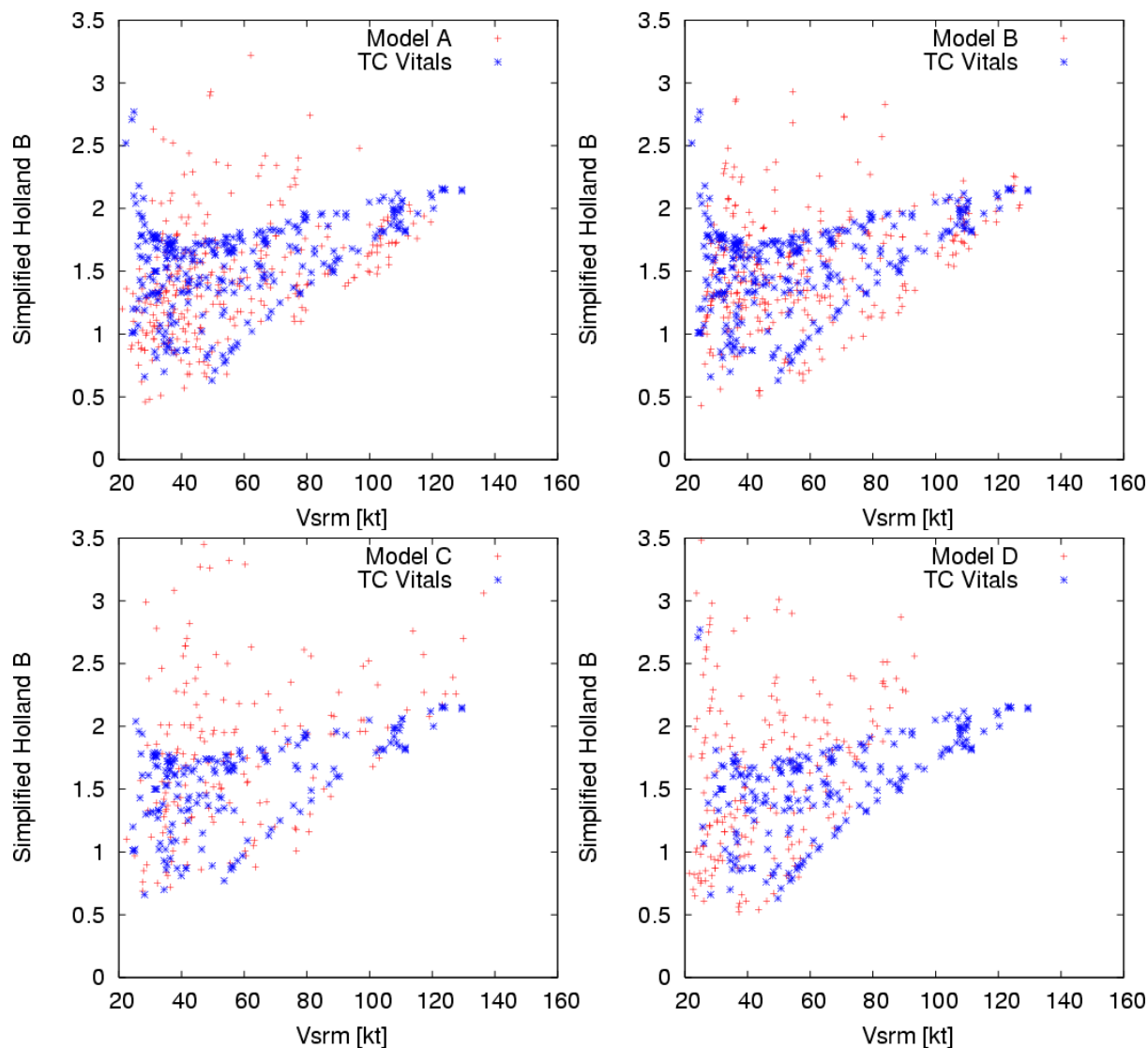
Collaboration
with NOAA CIRA
and NRL

Note large differences
in all 4 models. The
diagnostic tool alerts
forecasters that the
initial wind field may
be erroneous

Paper published
in American
Meteorological
Society journal:

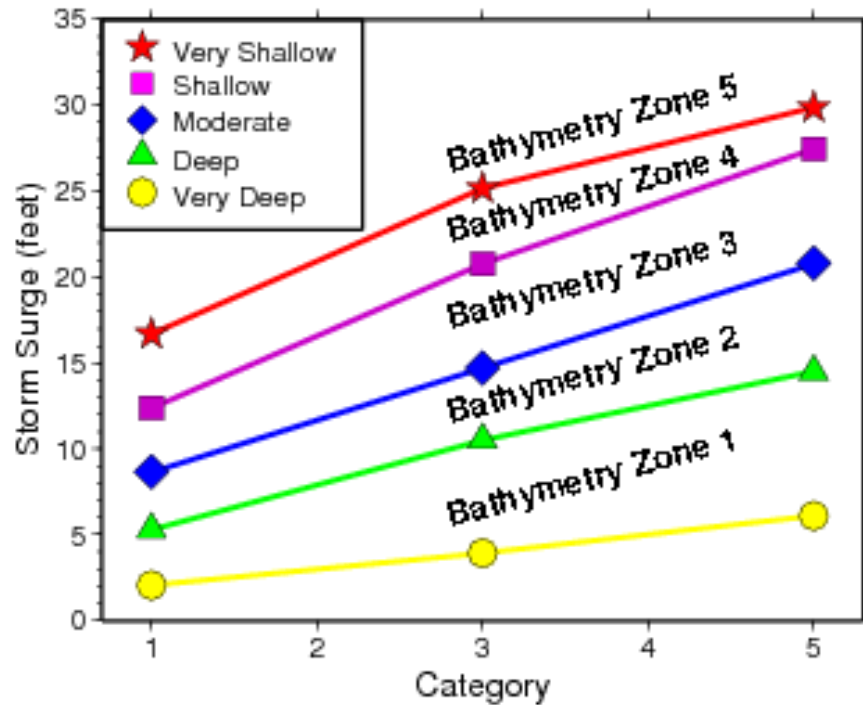
Knaff, J. A., P. J.
Fitzpatrick, C. R.
Sampson, Y. Jin, and C.
Hill, 2011: Simple
diagnosis of tropical
cyclone structure via
pressure gradients.
Wea. Forecasting, **26**,
1020-1031.

Analysis of operational weather model wind profiles



Effect of hurricane intensity, size, and speed on storm surge

Cat 1, 3, 5 hurricanes, average size, average speed



Correction factors for speed and size

Size

Zone 2: ± 1.5 (Cat 3–5)

Zone 3: ± 1.0 (Cat 1–2), ± 1.8 (Cat 3), ± 2.5 (Cat 4–5)

Zone 4: ± 1.6 (Cat 1–2), ± 2.5 (Cat 3), ± 3.6 (Cat 4–5)

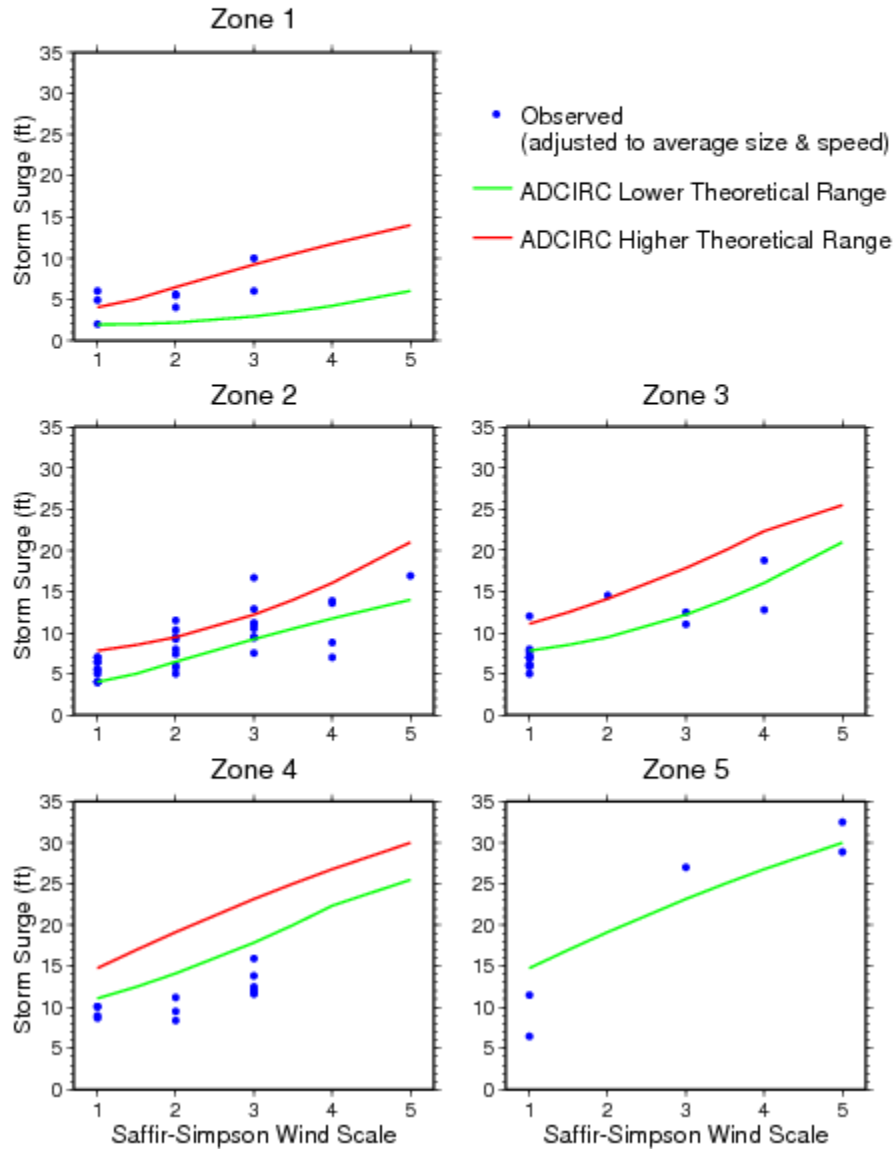
Zone 5: ± 2.3 (Cat 1–2), ± 3.3 (Cat 3), ± 4.3 (Cat 4–5)

Speed

Zone 4: ± 1.5 (Cat 1–2), ± 2.0 (Cat 3), ± 2.6 (Cat 4–5)

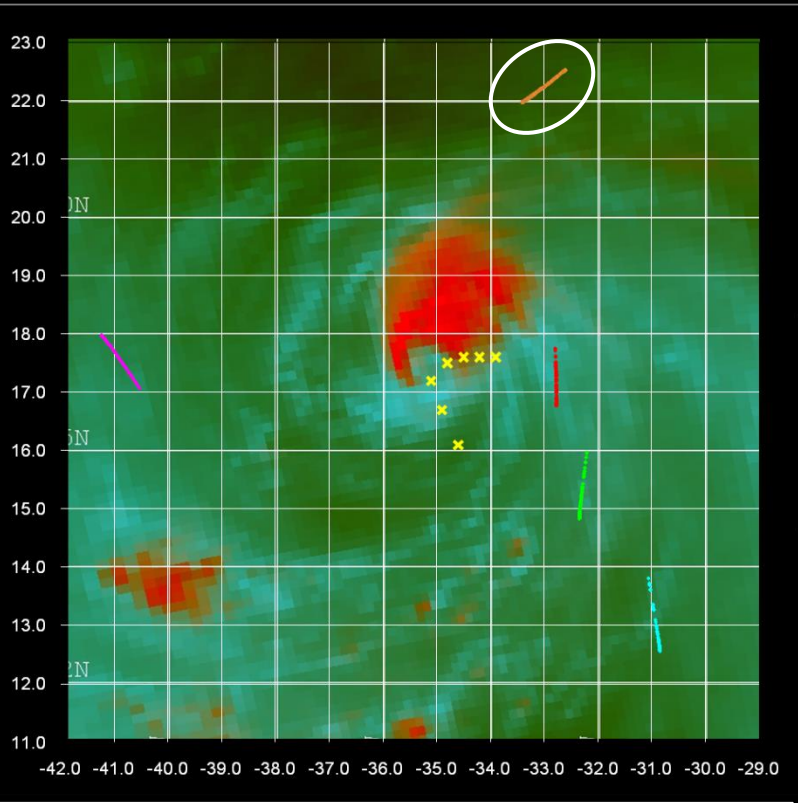
Zone 5: ± 3.0 (Cat 1–2), ± 3.9 (Cat 3), ± 5.2 (Cat 4–5)

Observed Open Coast Peak Eyewall Surge for Different Zones

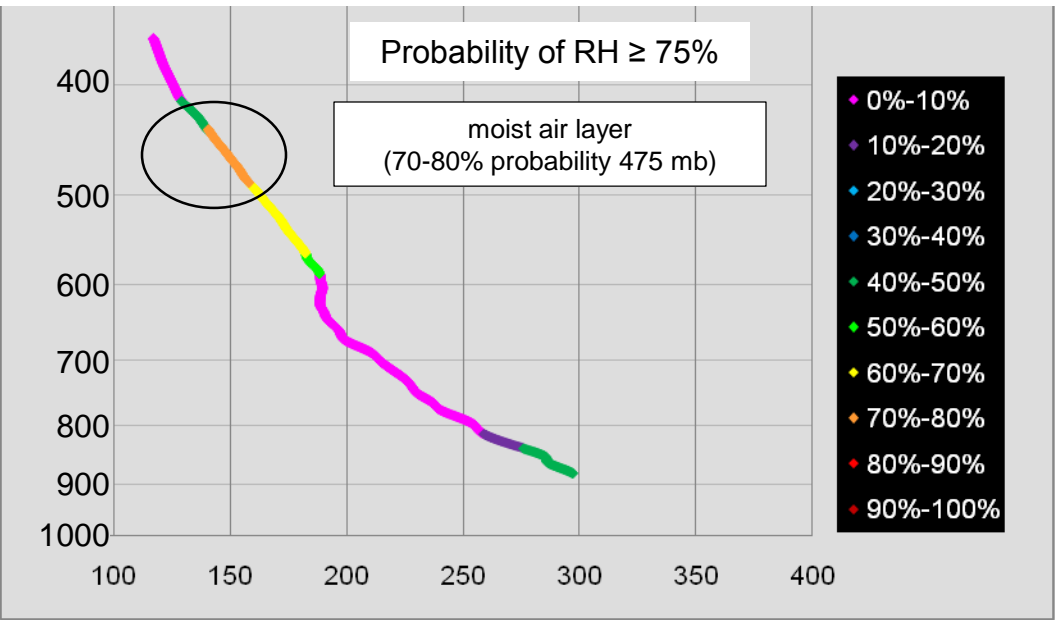
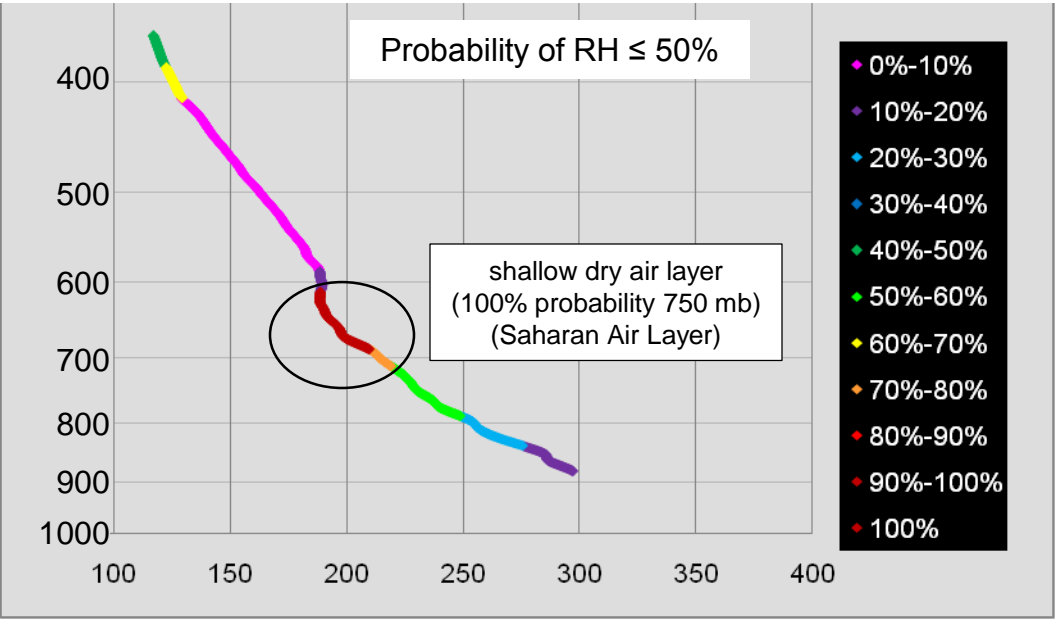


Paper in revision
for *Nat. Hazards Earth
Syst. Sci.*

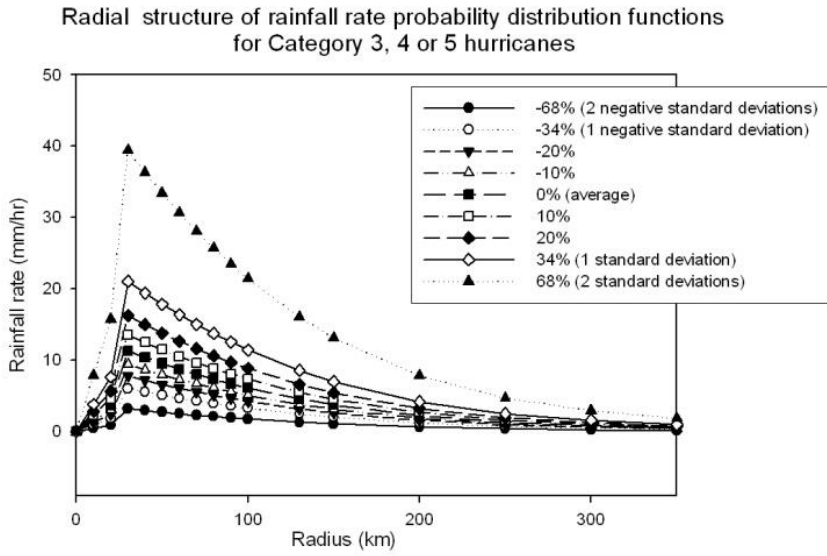
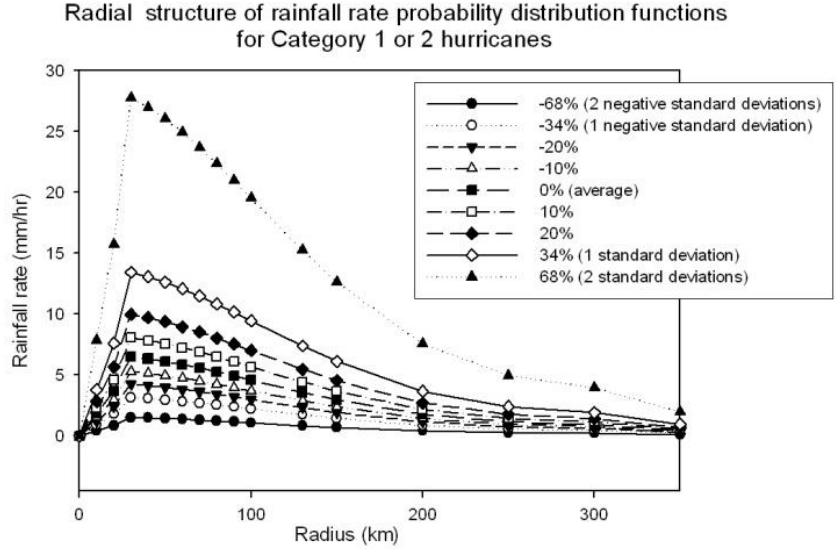
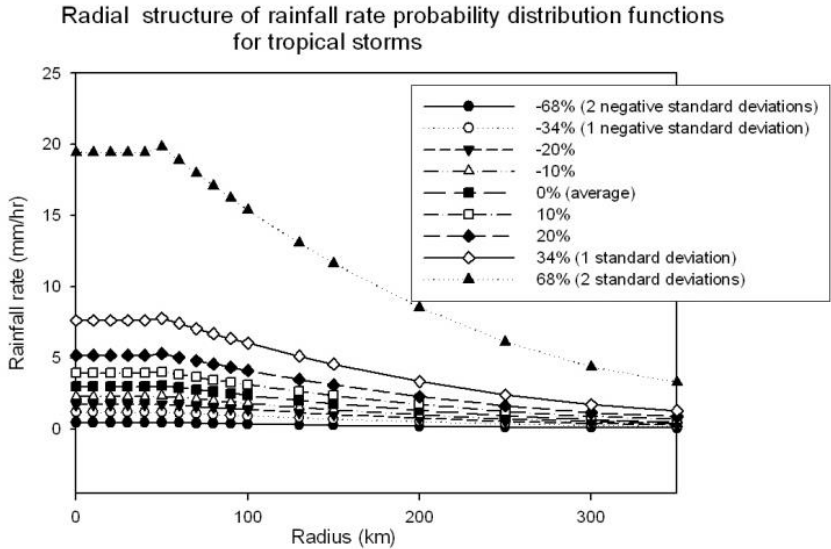
Hurricane Fred 2009



23:41 UTC 10 September 2009
AMSU-B image from METOP-A satellite
(image provided by NRL-Monterey)



Average rainfall is 3, 6, and 11 mm/hr for TS, Min Hurr, and Major Hurr – but large spread!

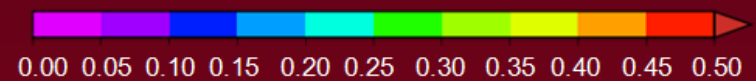
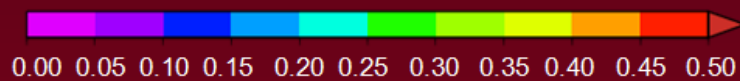
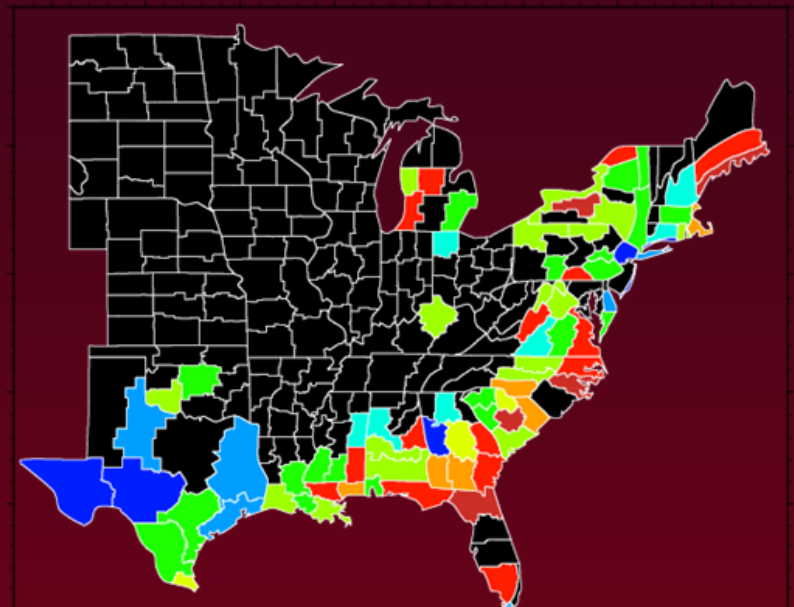
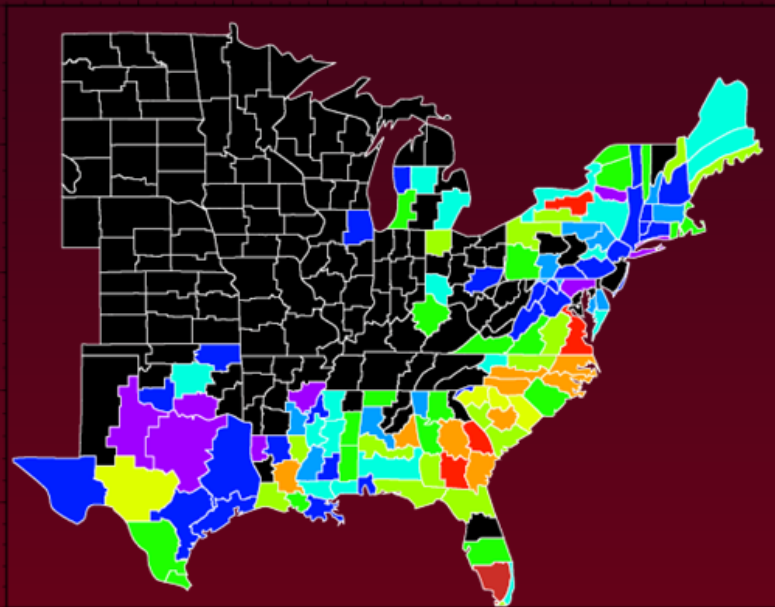


From Fitzpatrick and Lau (2011)
Based on Lonfat et al. (2007)

Percentage of droughts ended by tropical storms or hurricanes

TC-affected ADE frequency
(150 km range)
1960 - 2010

TC-affected ADE frequency
(R34 range)
1988 - 2010



The frequency of ADEs contained within the {R = 150 km} circulation area of TC.

The frequency of ADEs contained within the R34 circulation area of TCs.

Data assimilation and numerical modeling

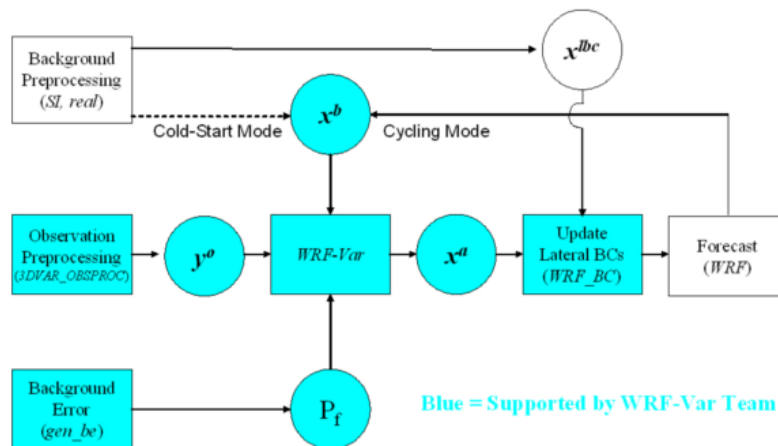
- Numerical models:

- Weather Research and Forecast model (WRF)
- Hurricane WRF (HWRF)
- Advanced Hurricane WRF (AHW)
- MM5 and COAMPS
- All require supercomputers

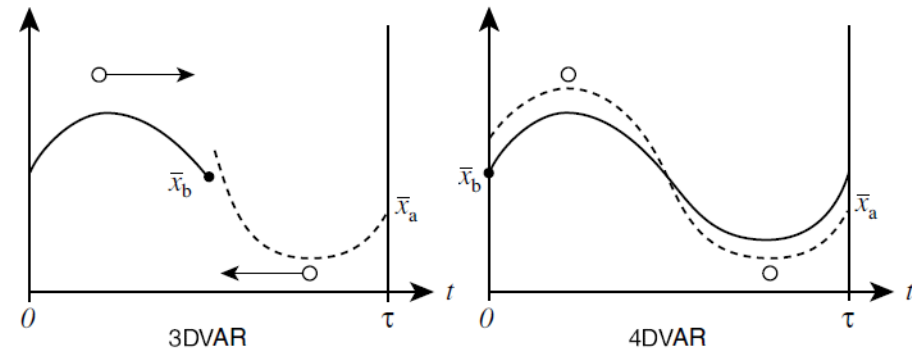
- Model data assimilation schemes:

- 3D Variational analysis (3DVAR). NCAR-3DVAR is used in WRF and HWRF, and NCEP-3DVAR is used by NCEP (called the Gridpoint Statistical Interpolation, or GSI) in all models, including AHW
- 4D Variational analysis (4DVAR; used in WRF and HWRF)

WRF-Var in the WRF Modeling System

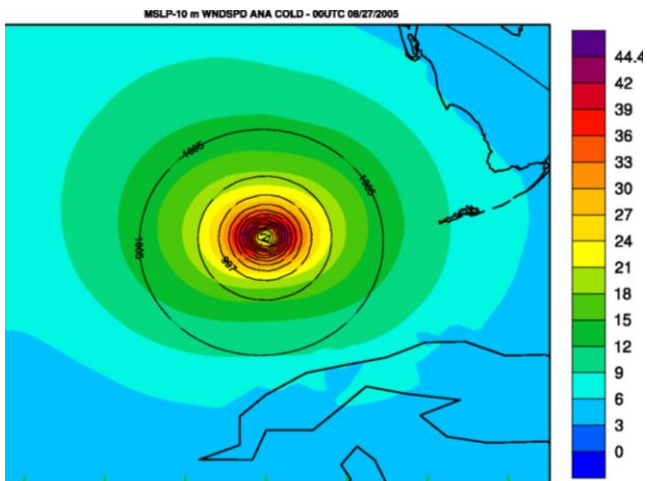


$$J(x) = J_b(x) + J_o(x) = \frac{1}{2}(x - x^b)^T B^{-1}(x - x^b) + \frac{1}{2}(y - y^o)^T (E + F)^{-1}(y - y^o)$$

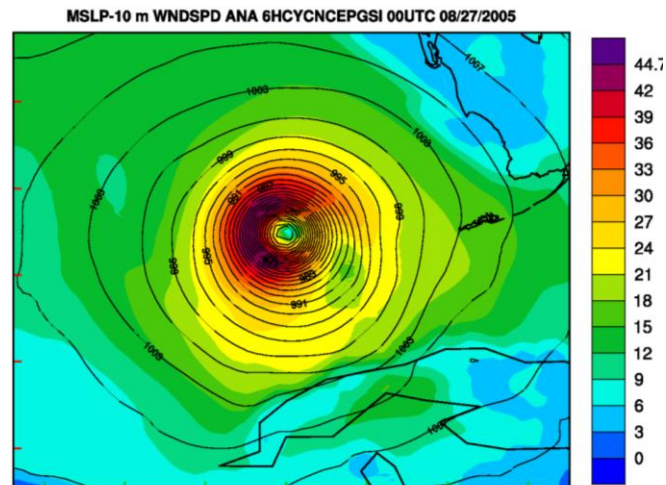


Data assimilation example

Katrina no data



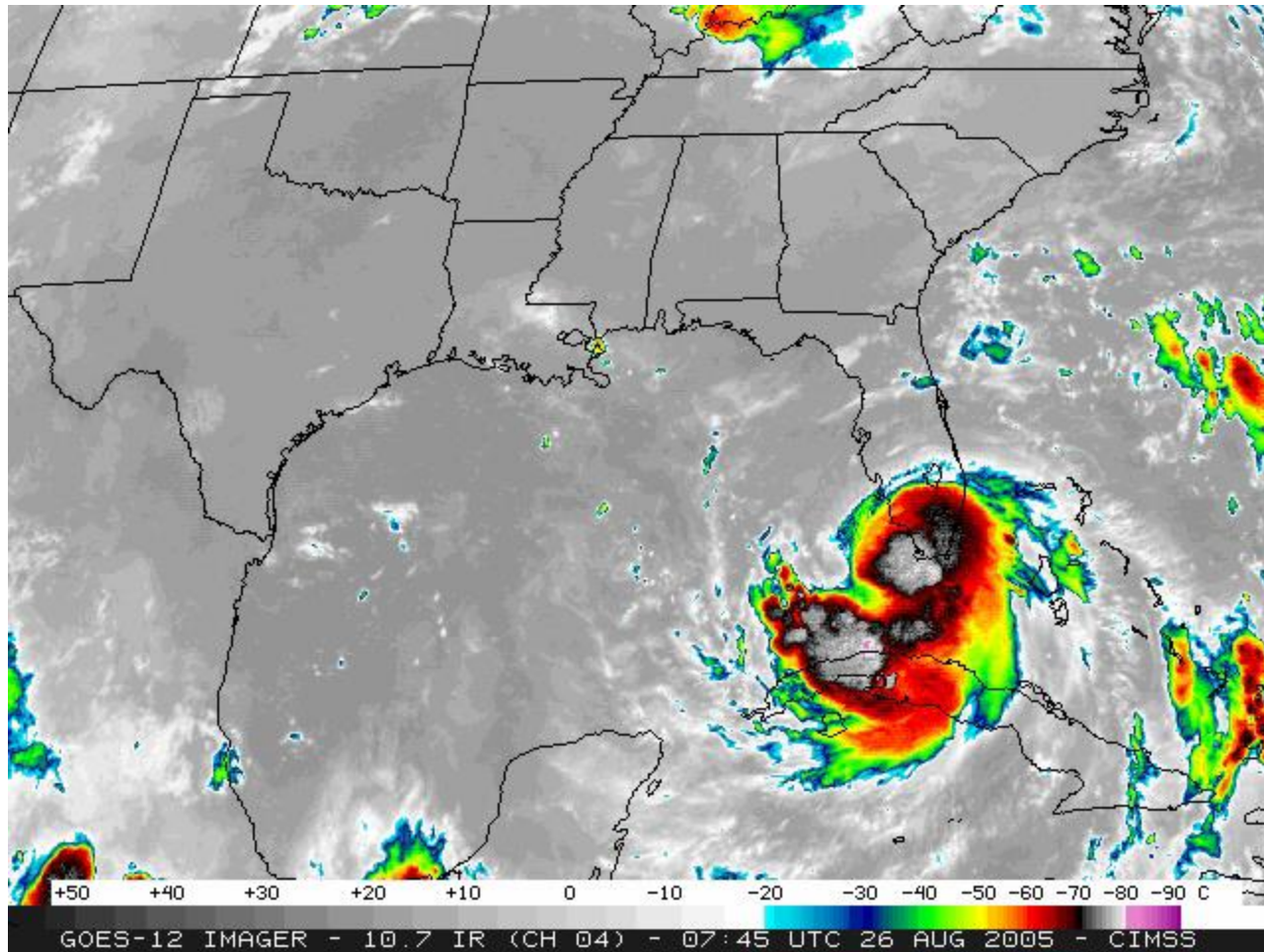
Katrina with aircraft data



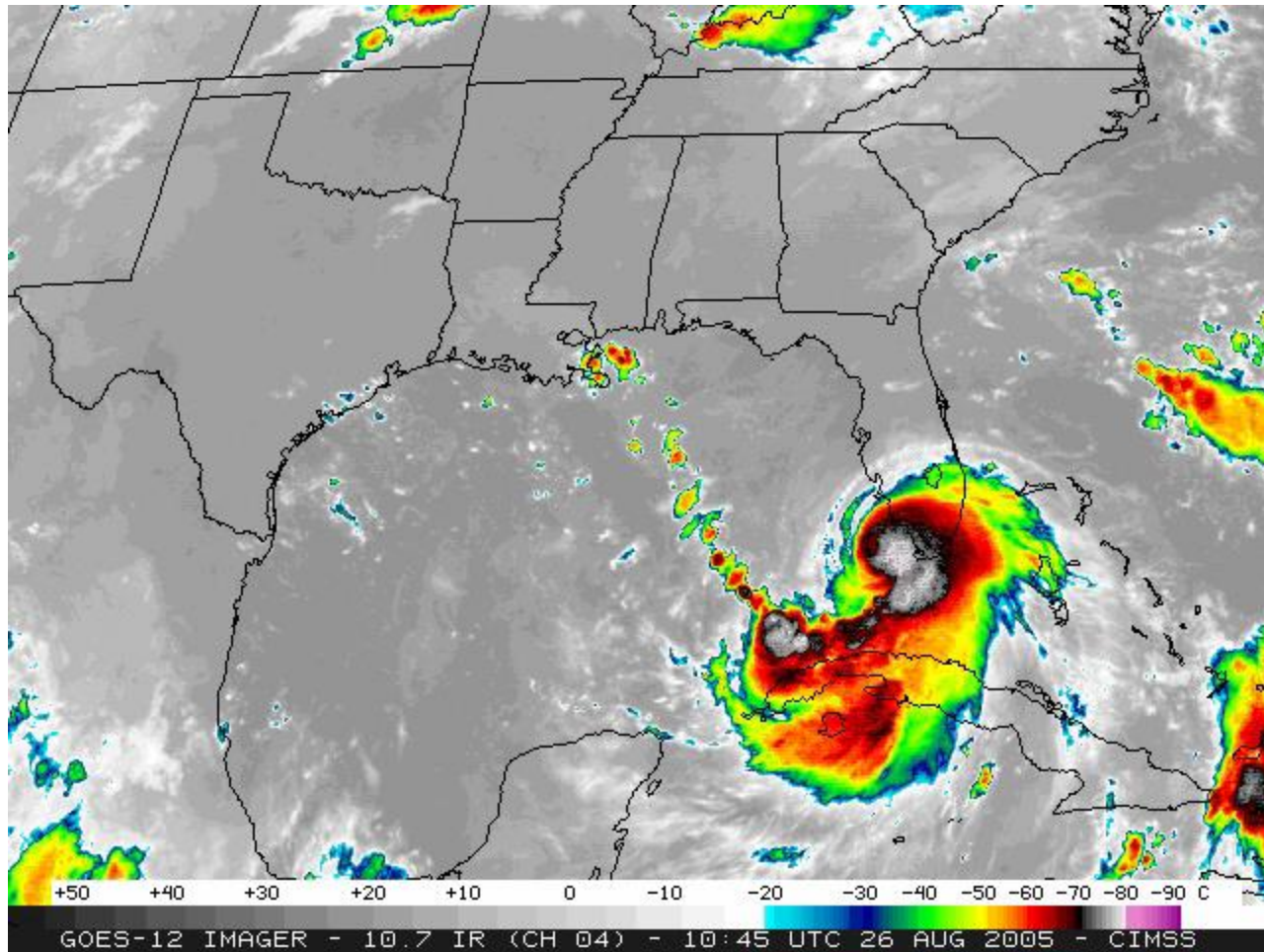
New research
Tropical cyclone size changes

Motivation - Katrina

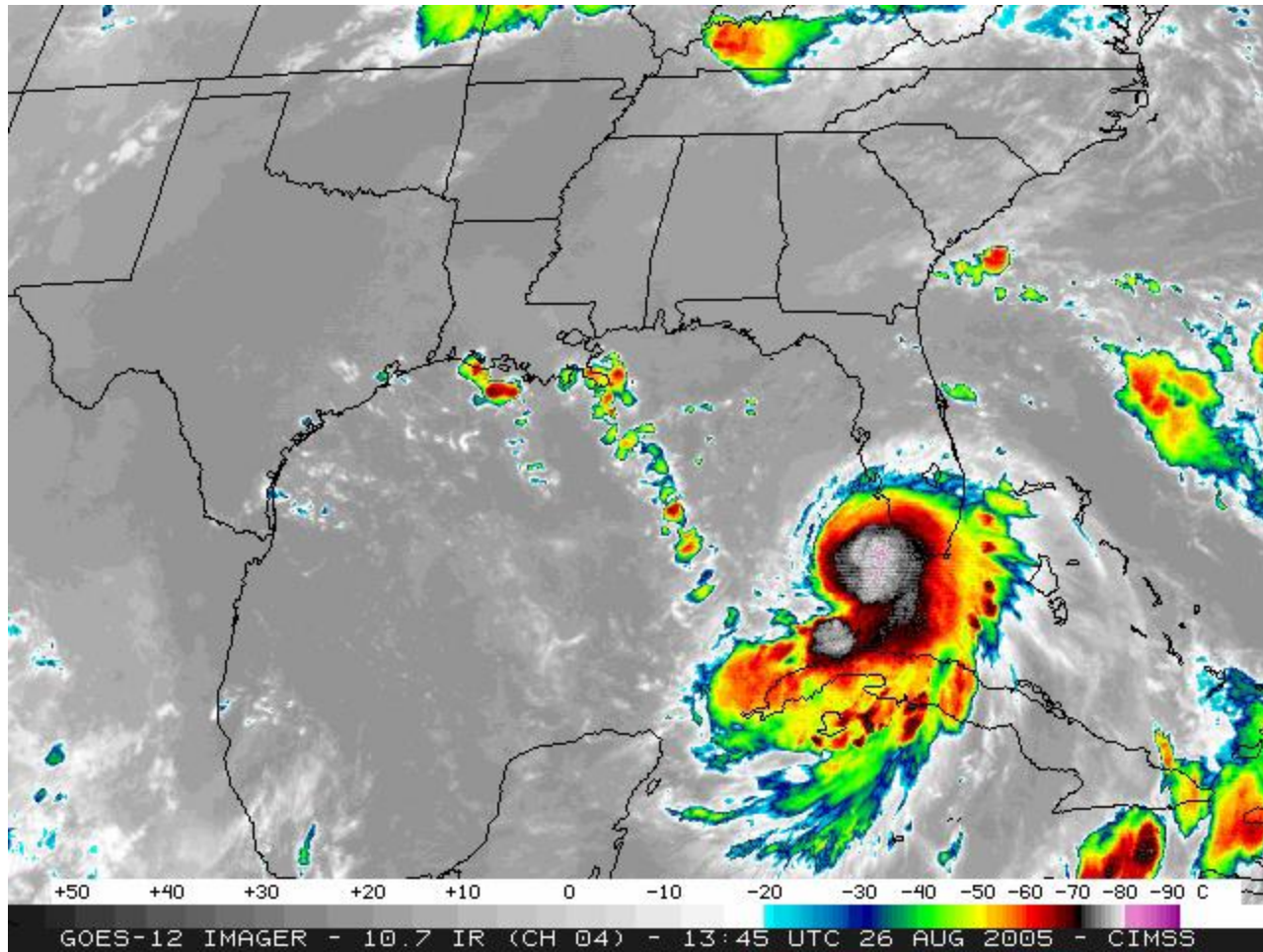
August 26, 08Z



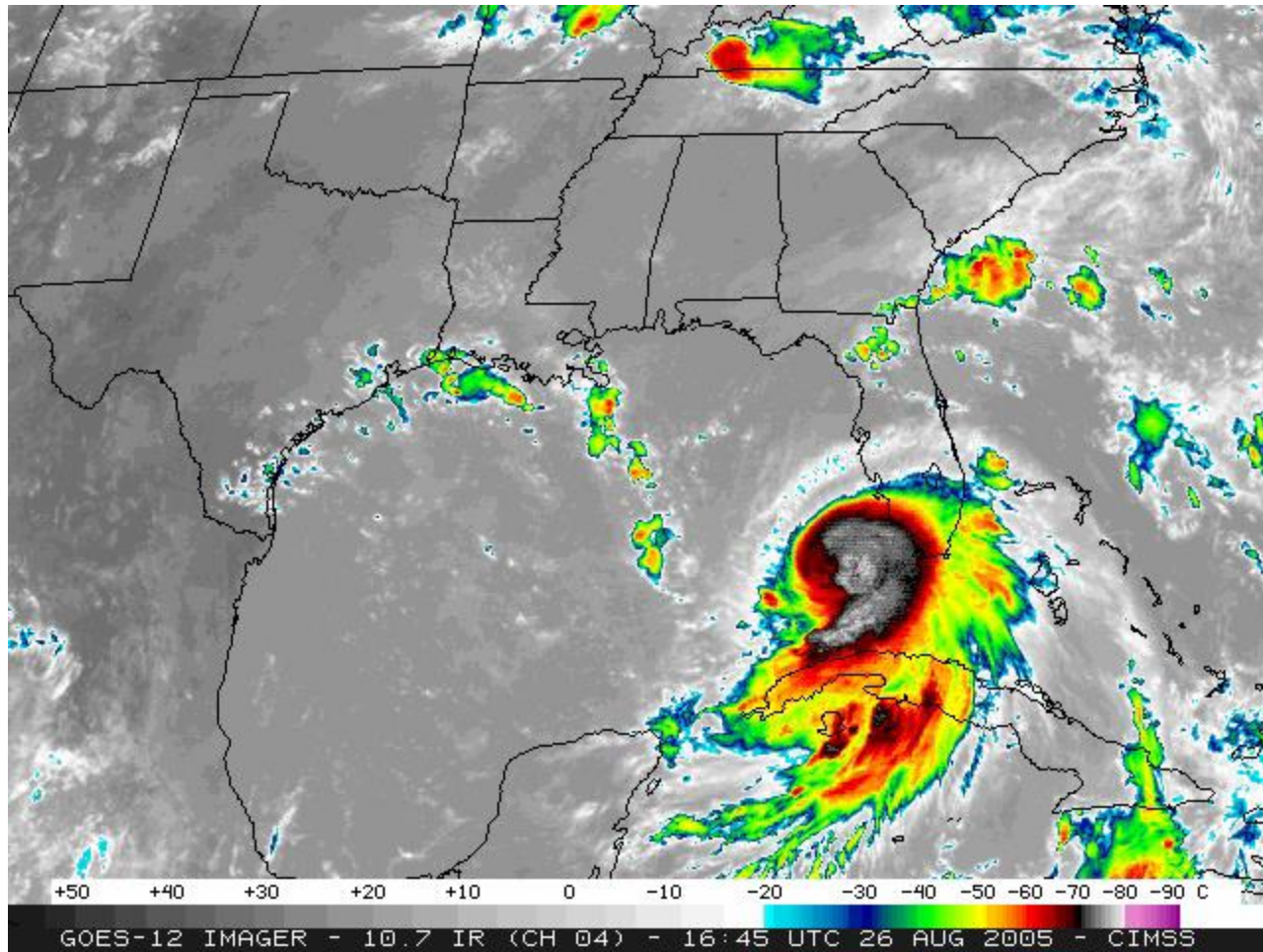
August 26, 11Z



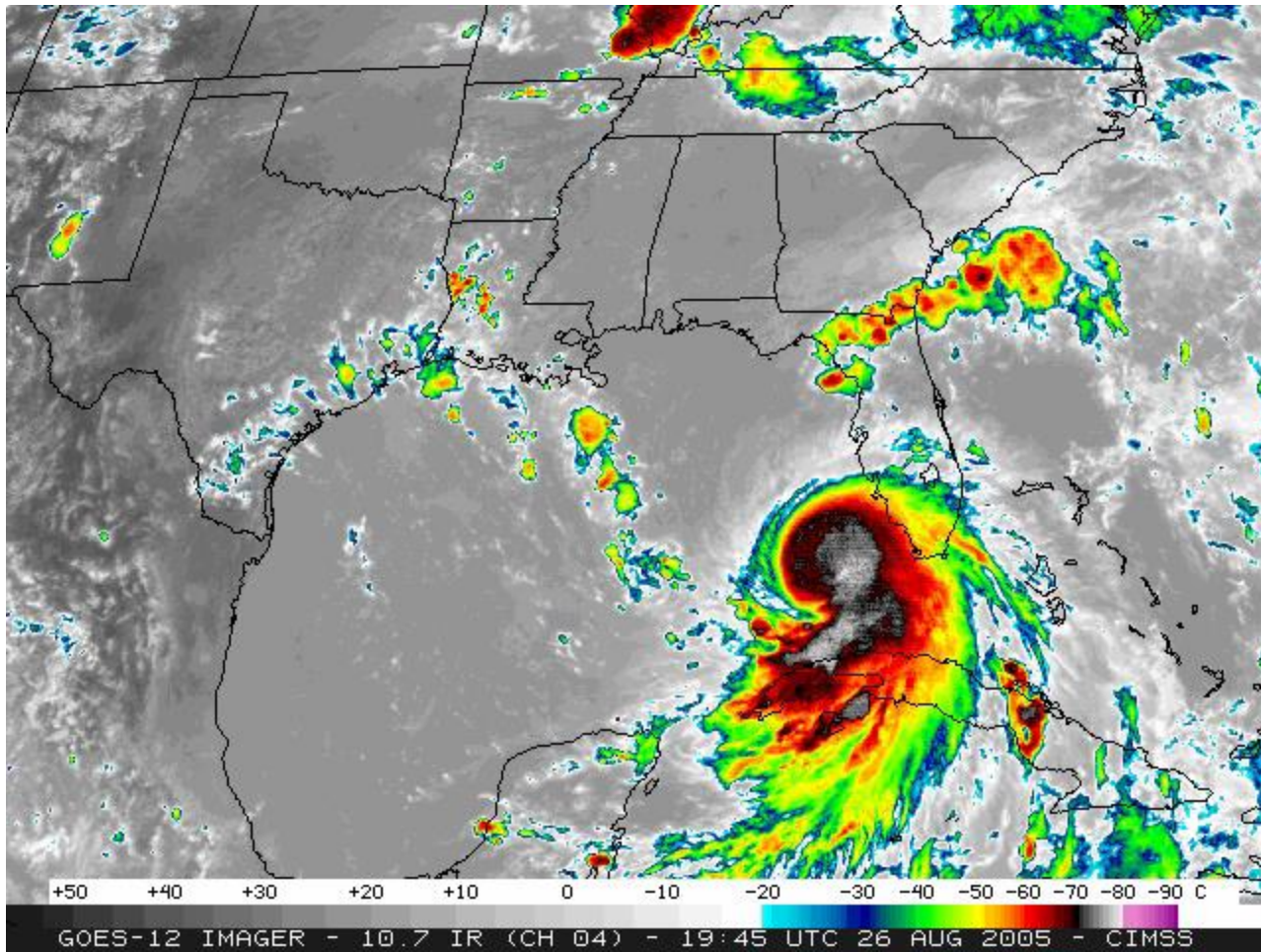
August 26, 14Z



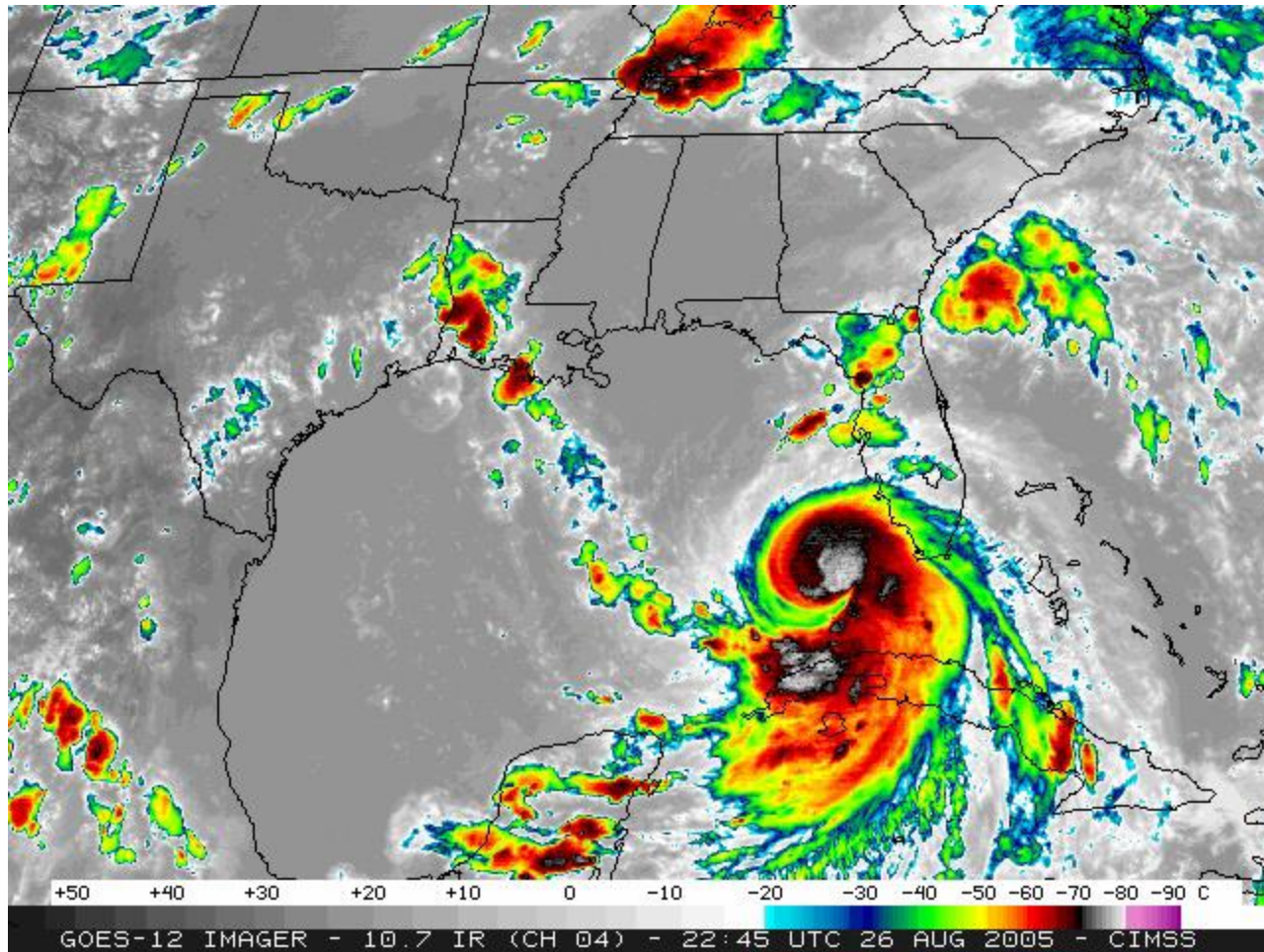
August 26, 17Z



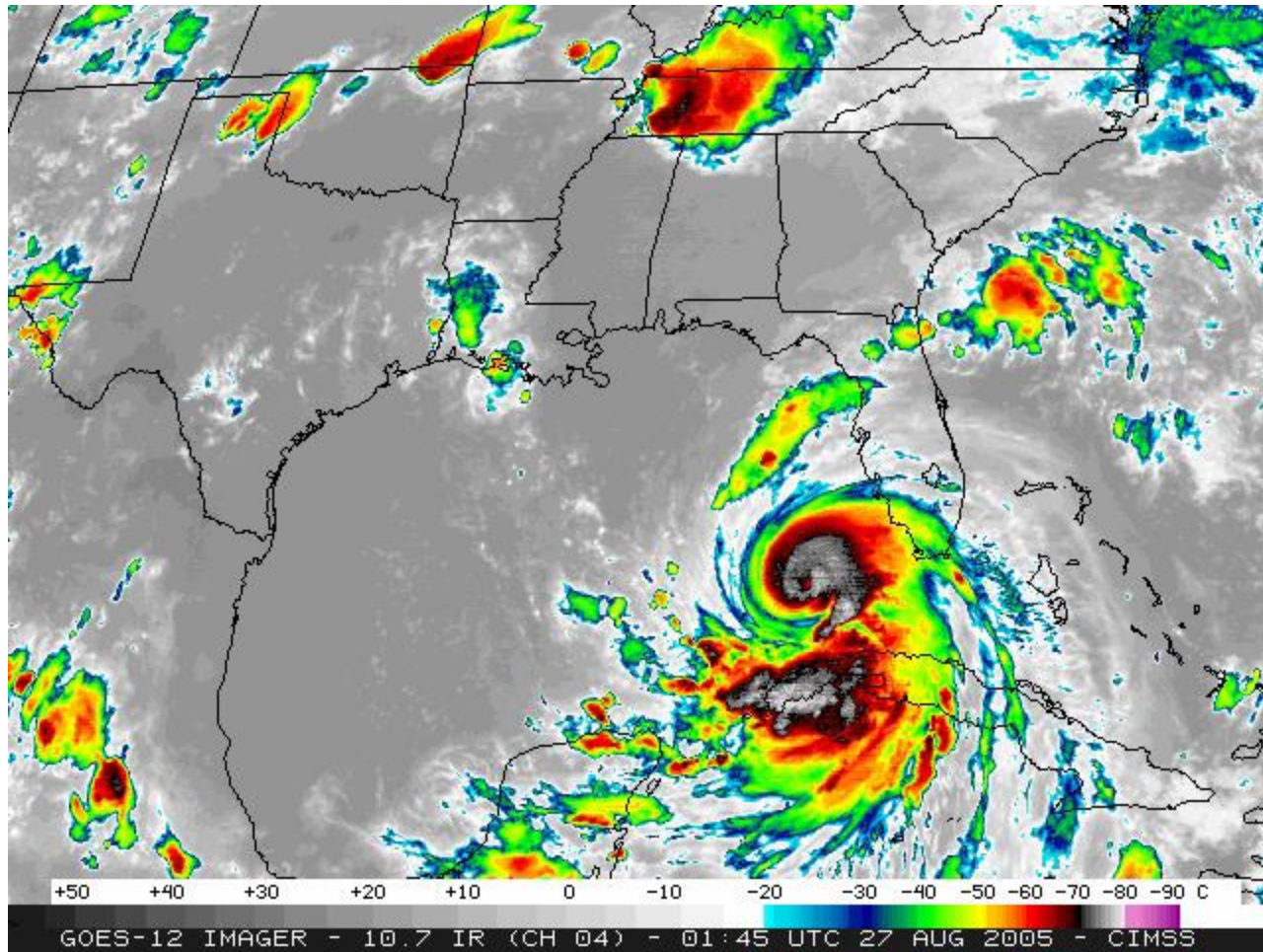
August 26, 20Z



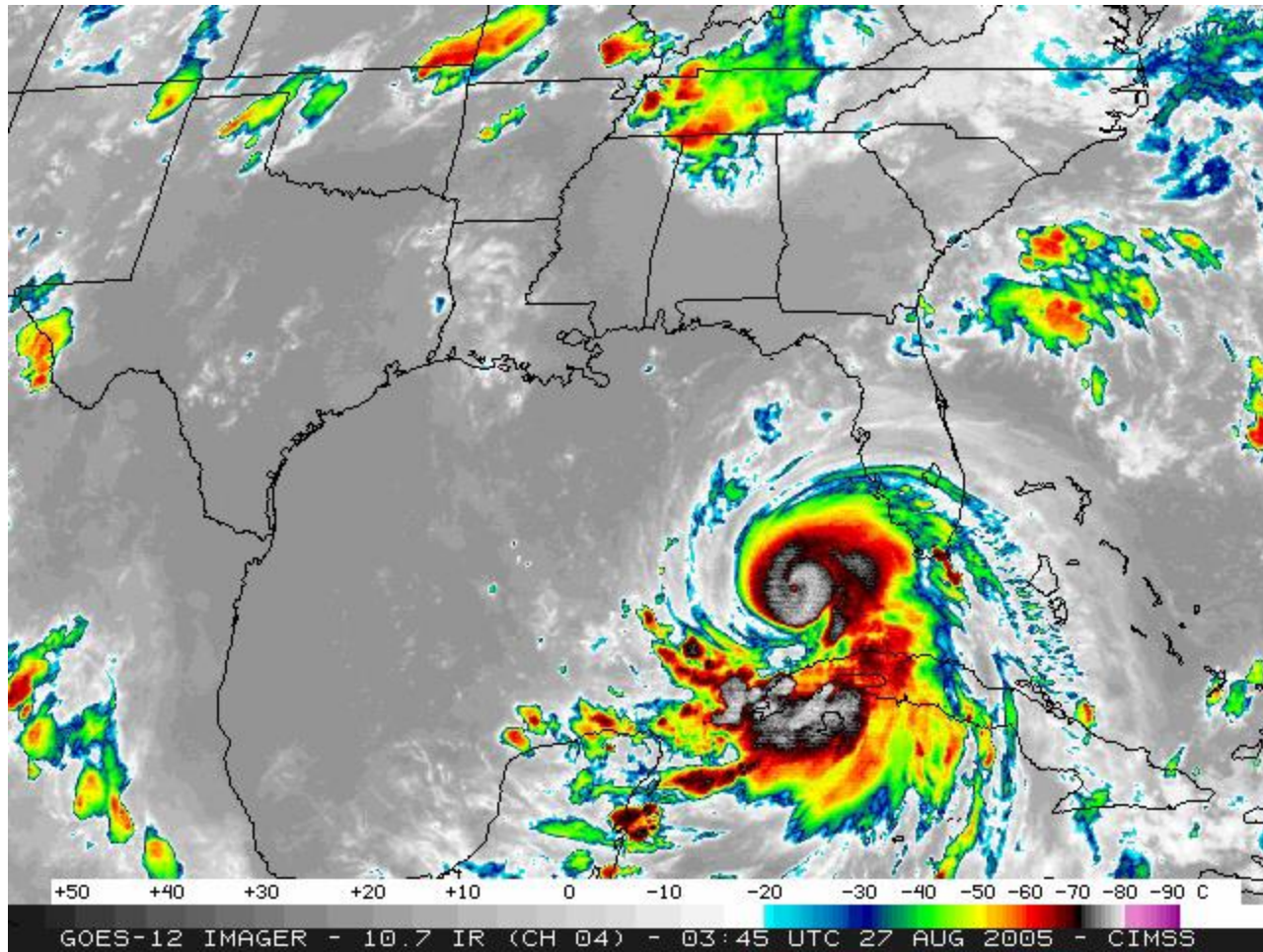
August 26, 23Z



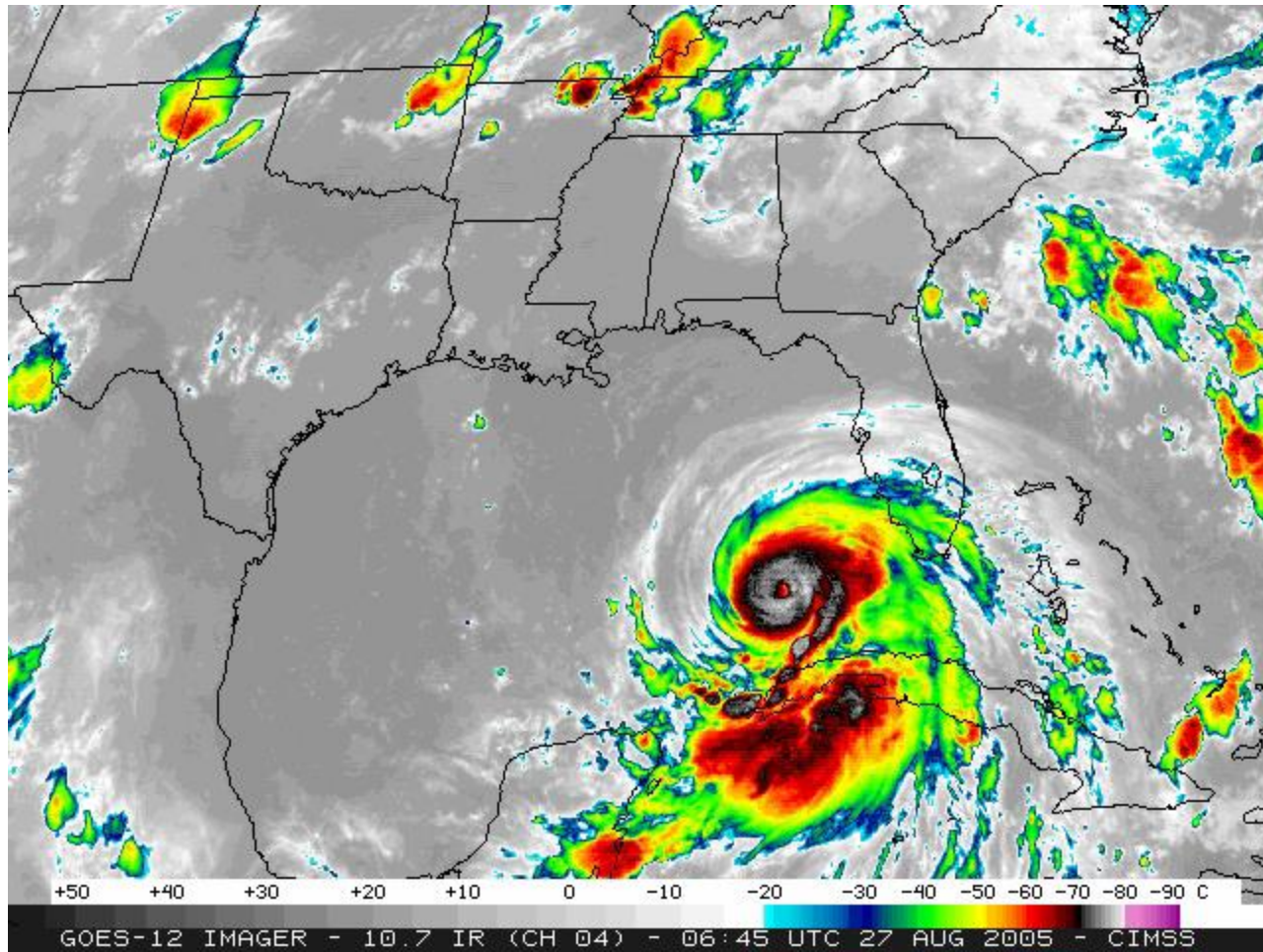
August 27, 02Z



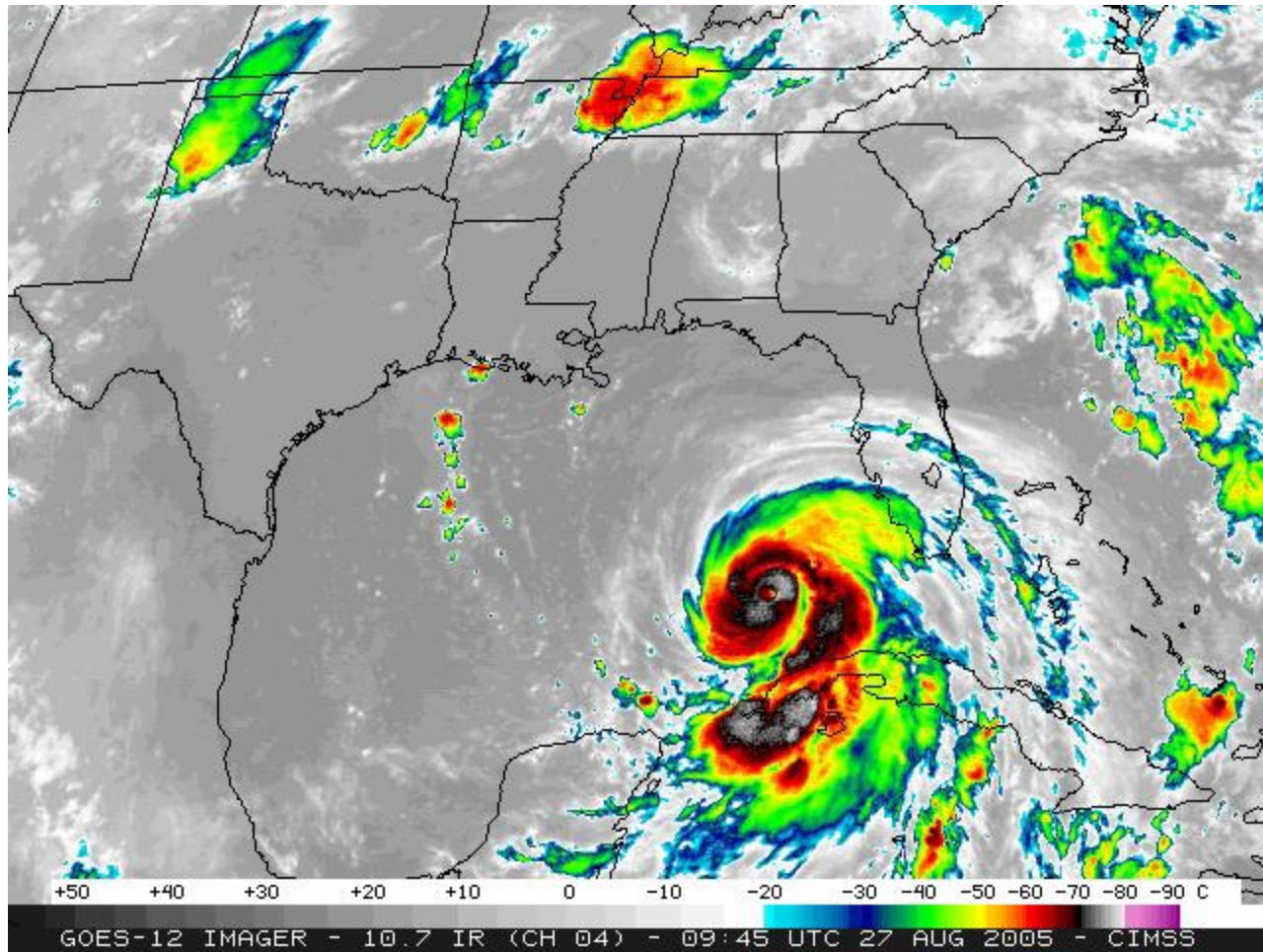
August 27, 04Z



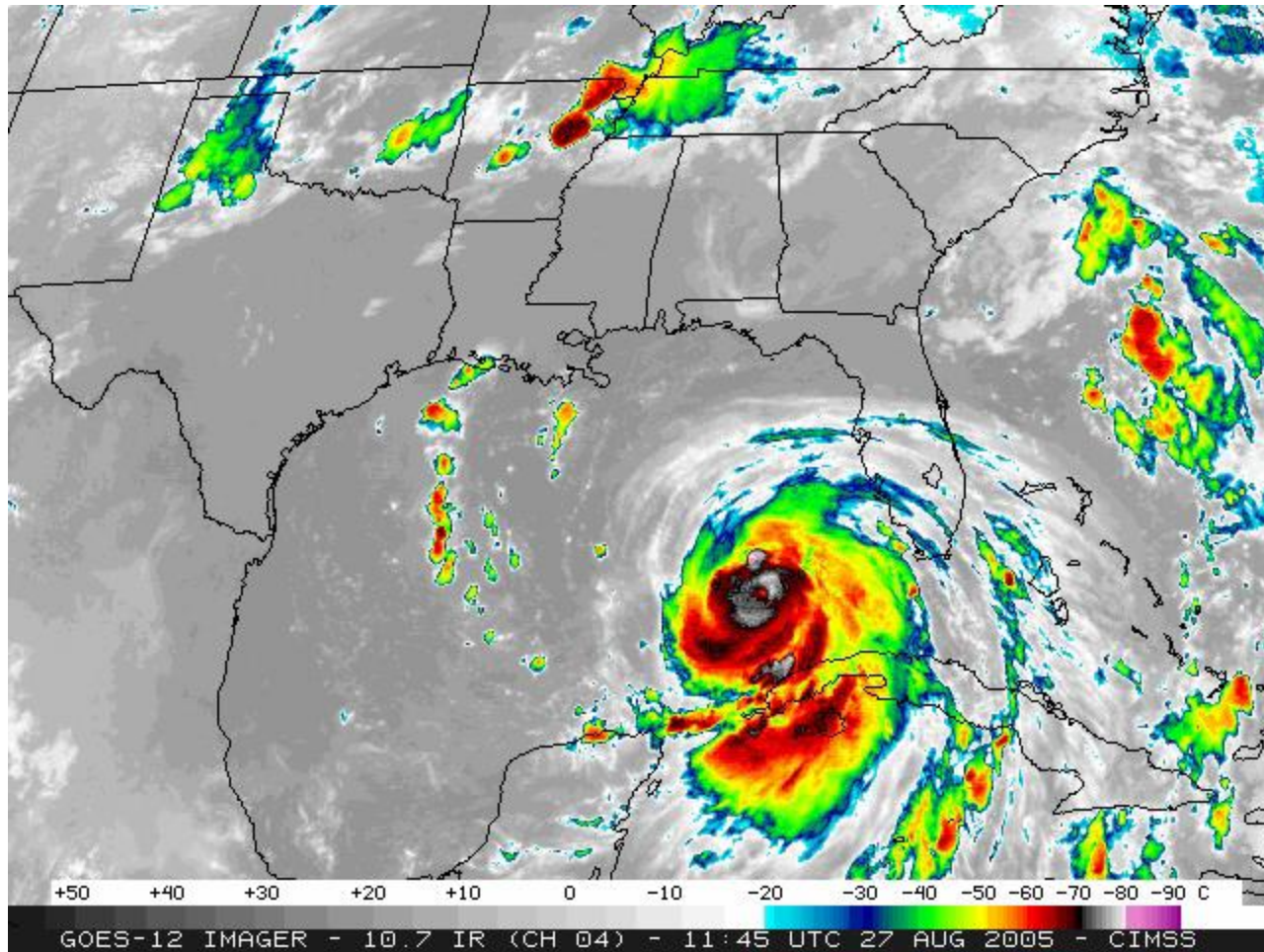
August 27, 07Z



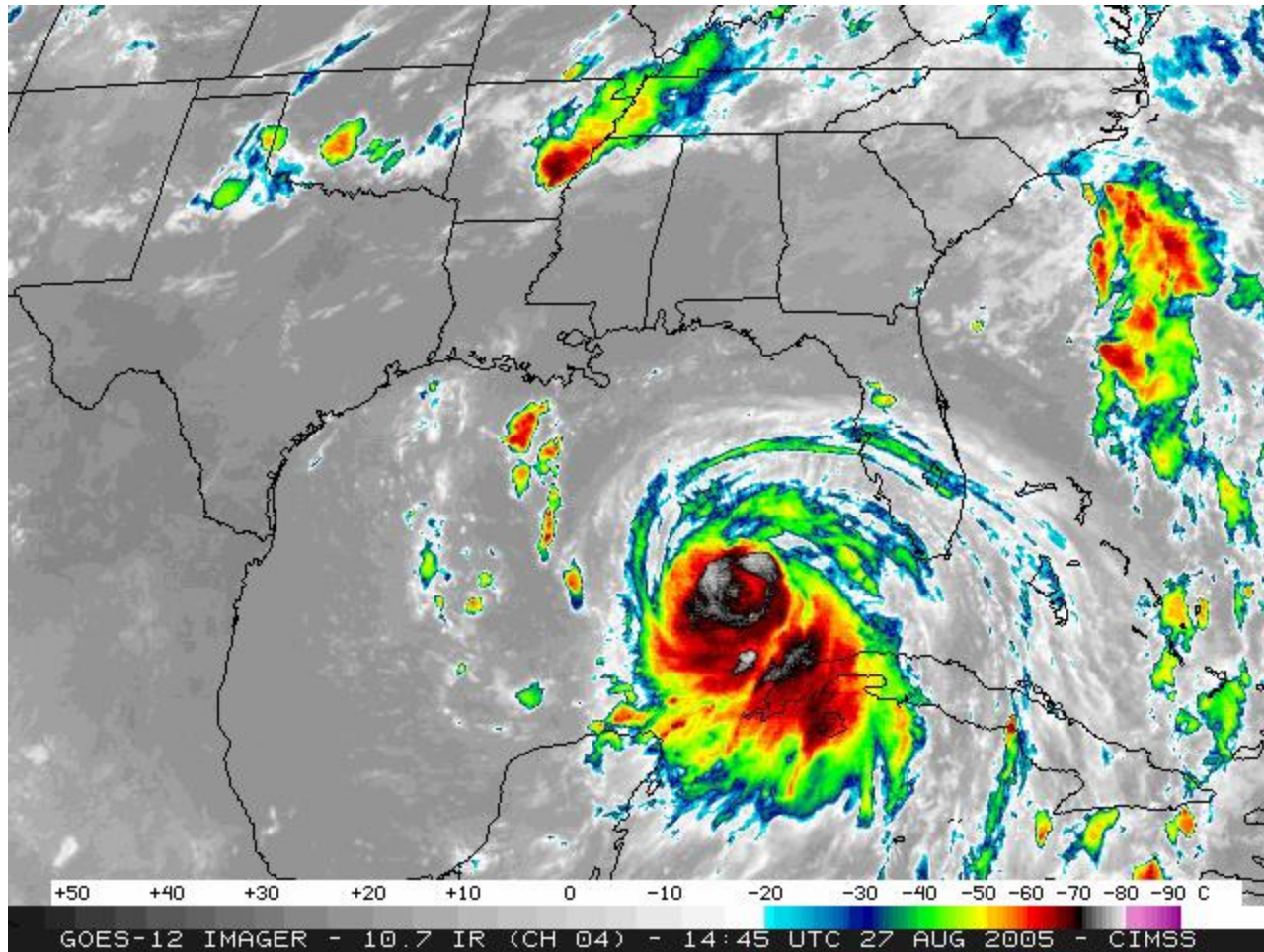
August 27, 10Z



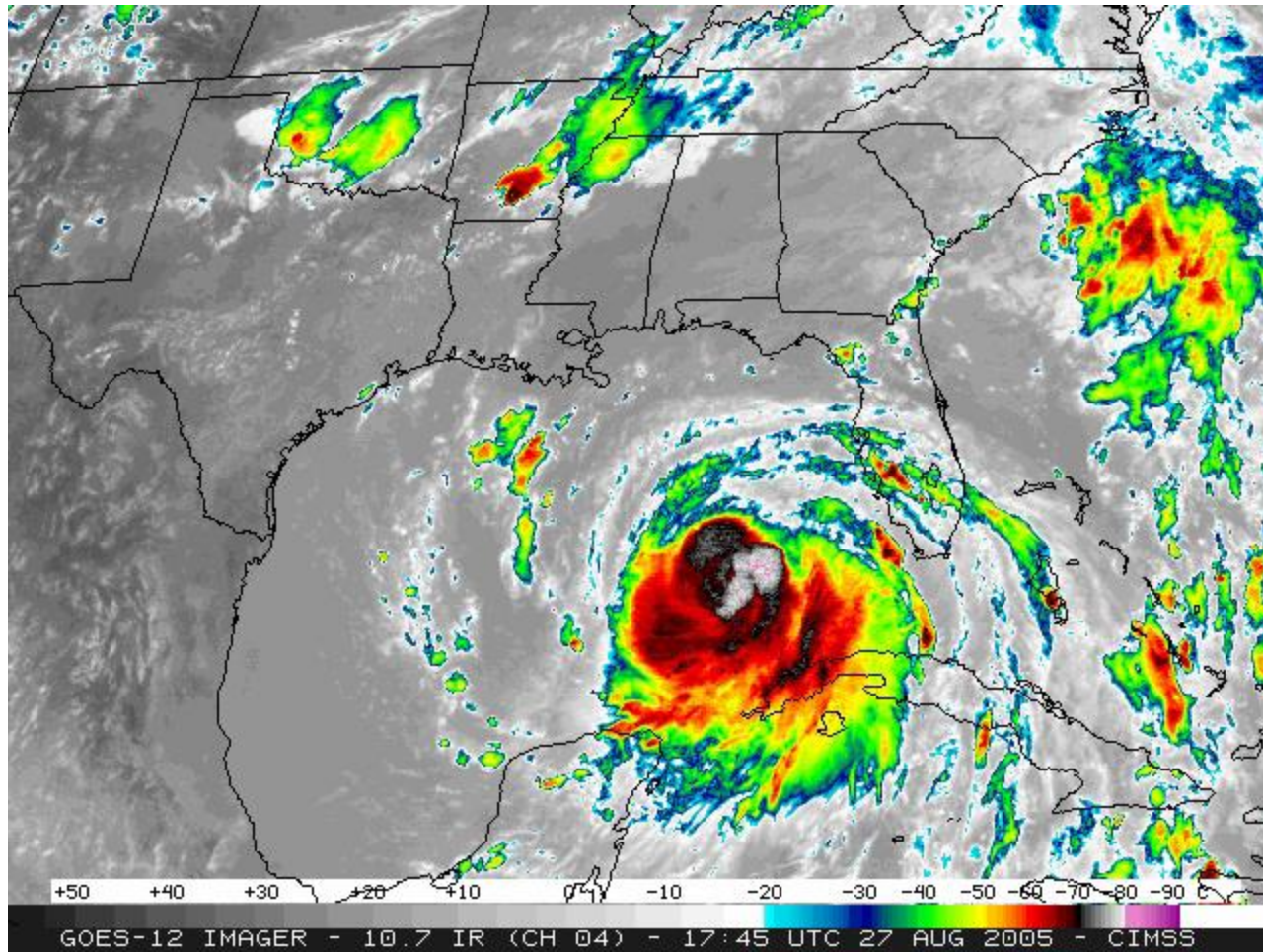
August 27, 12Z



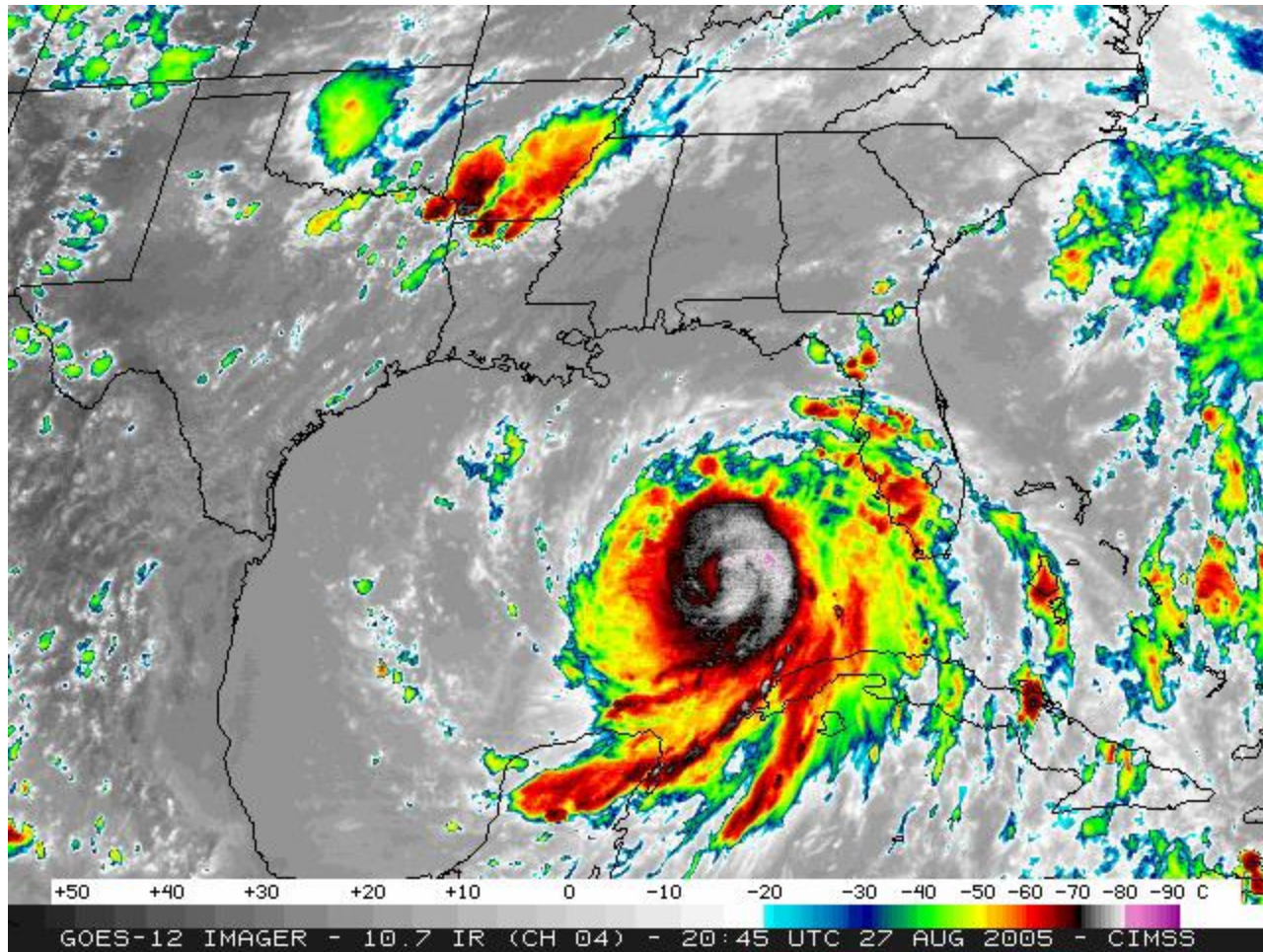
August 27, 15Z



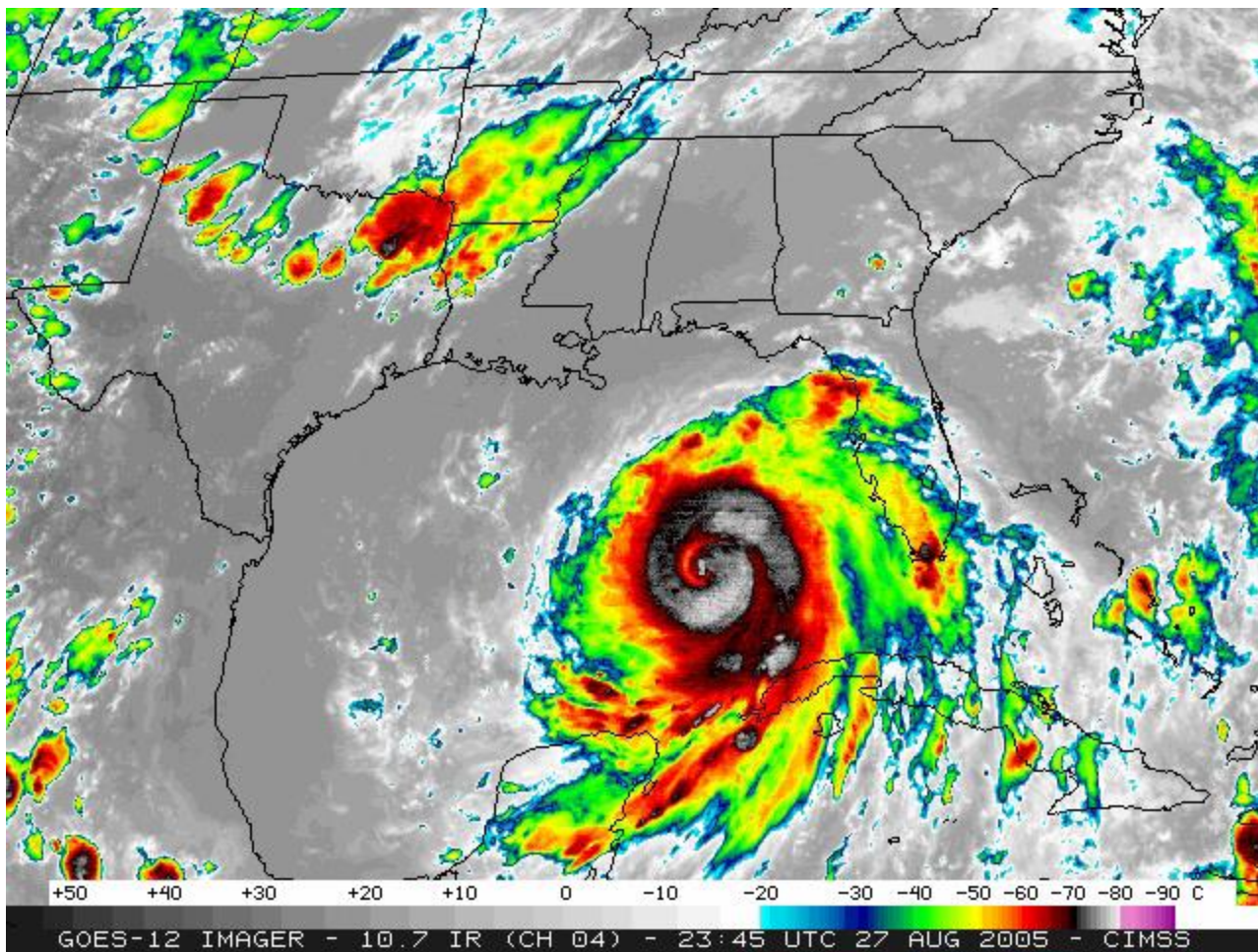
August 27, 18Z



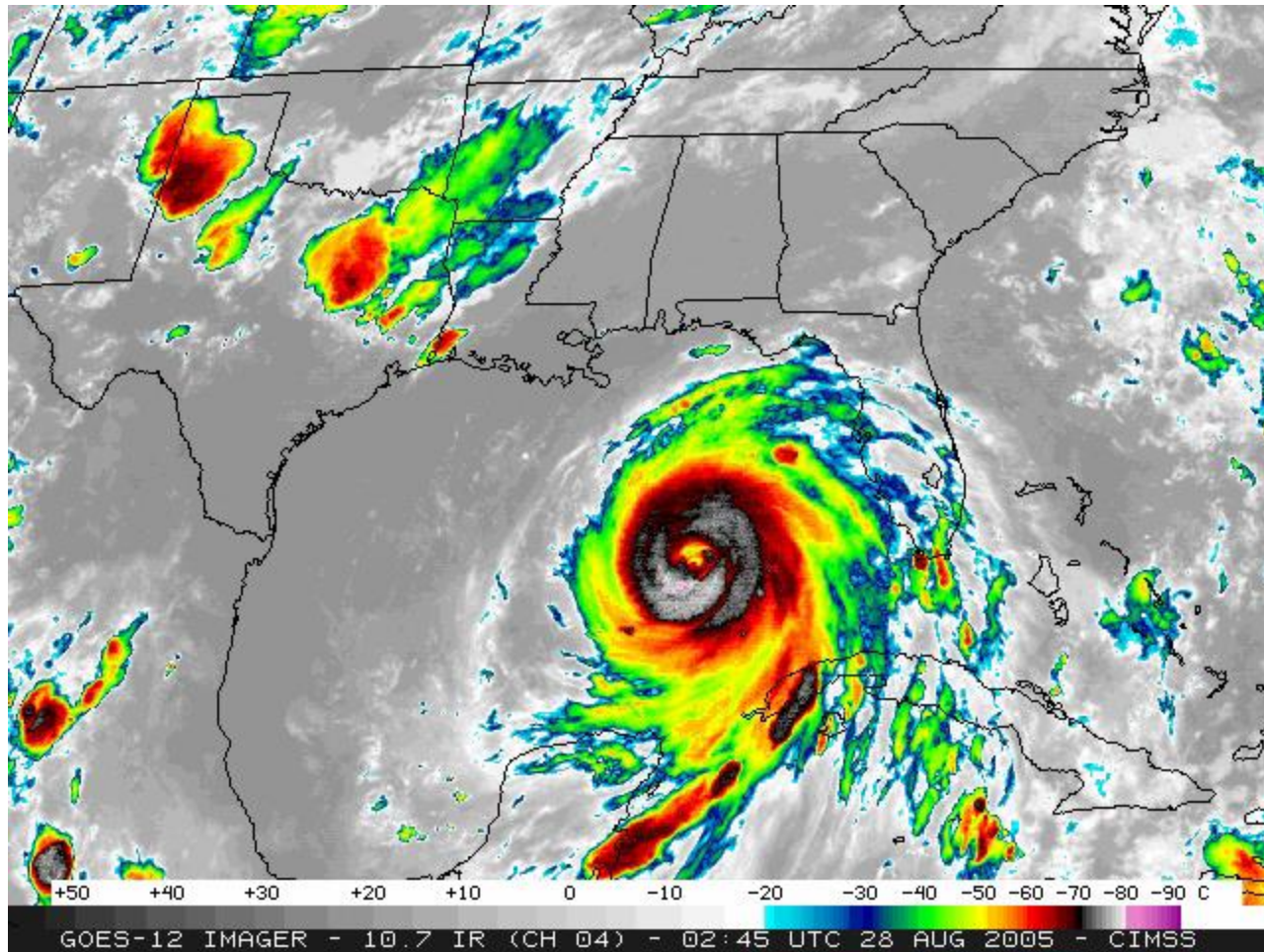
August 27, 21Z



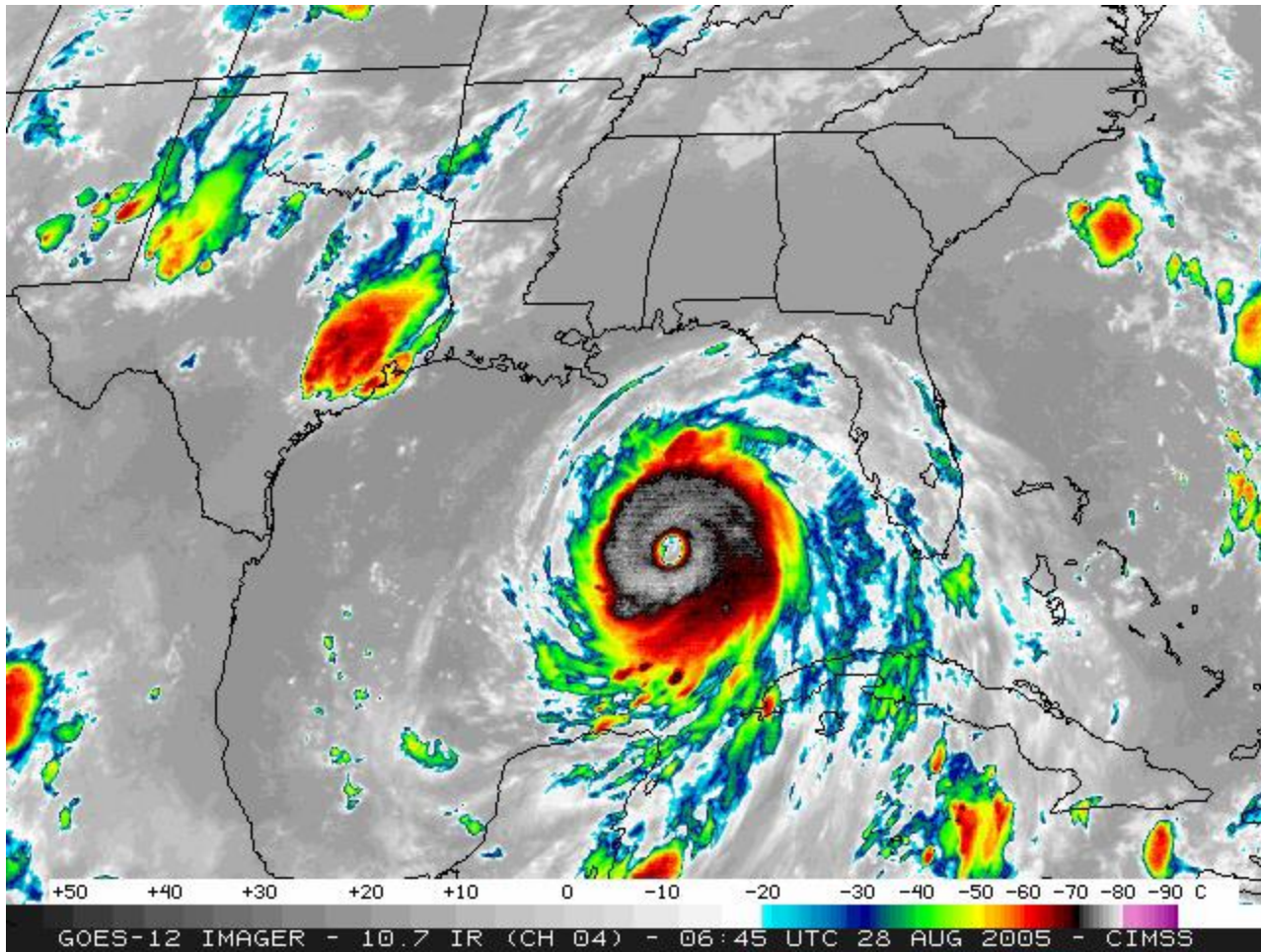
August 28, 00Z



August 28, 03Z

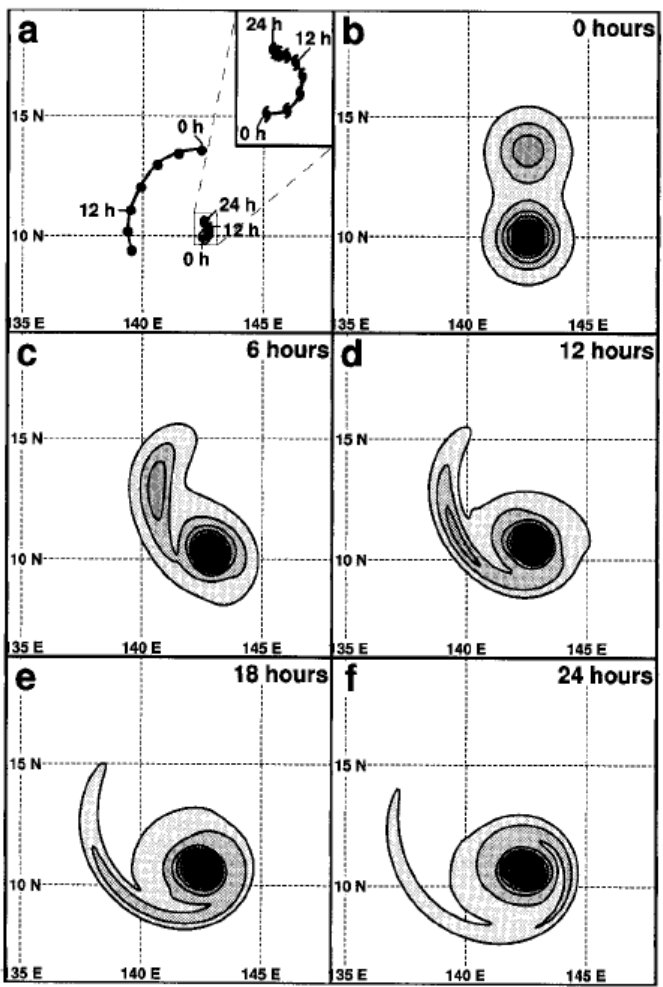


August 28, 07Z

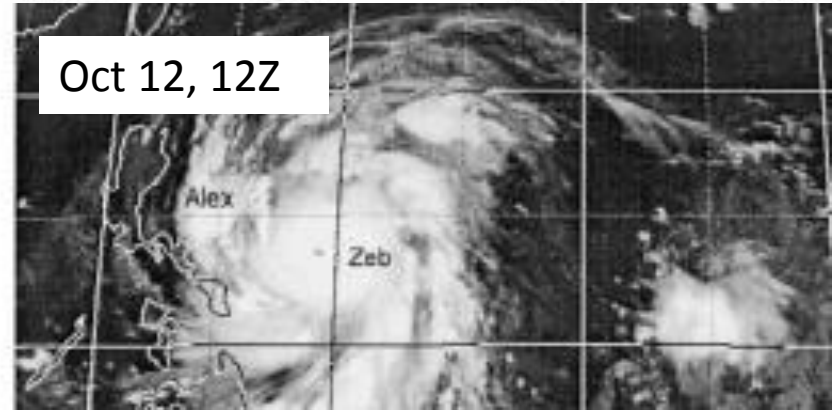
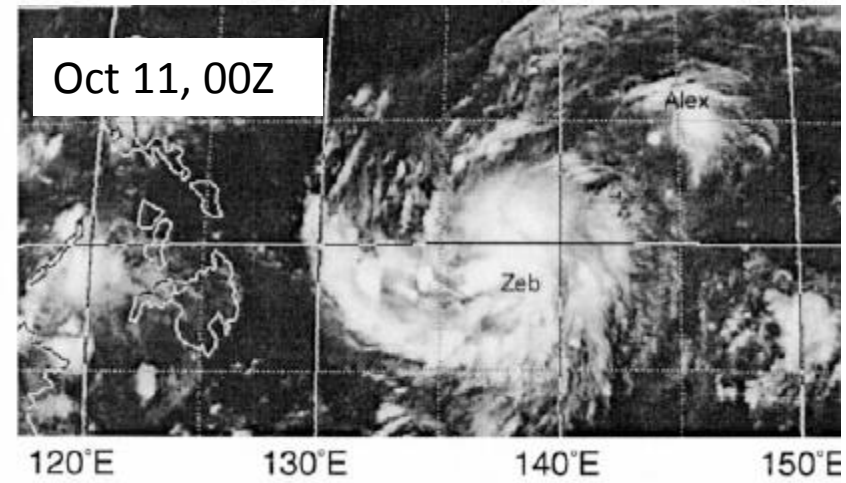
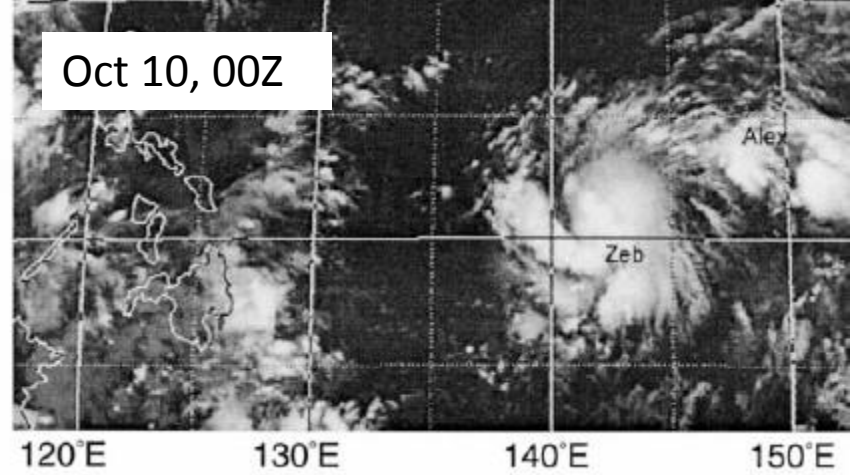


Vortex merger ideas

(Lander, Holland, Dietachmayer 1993, 1994)

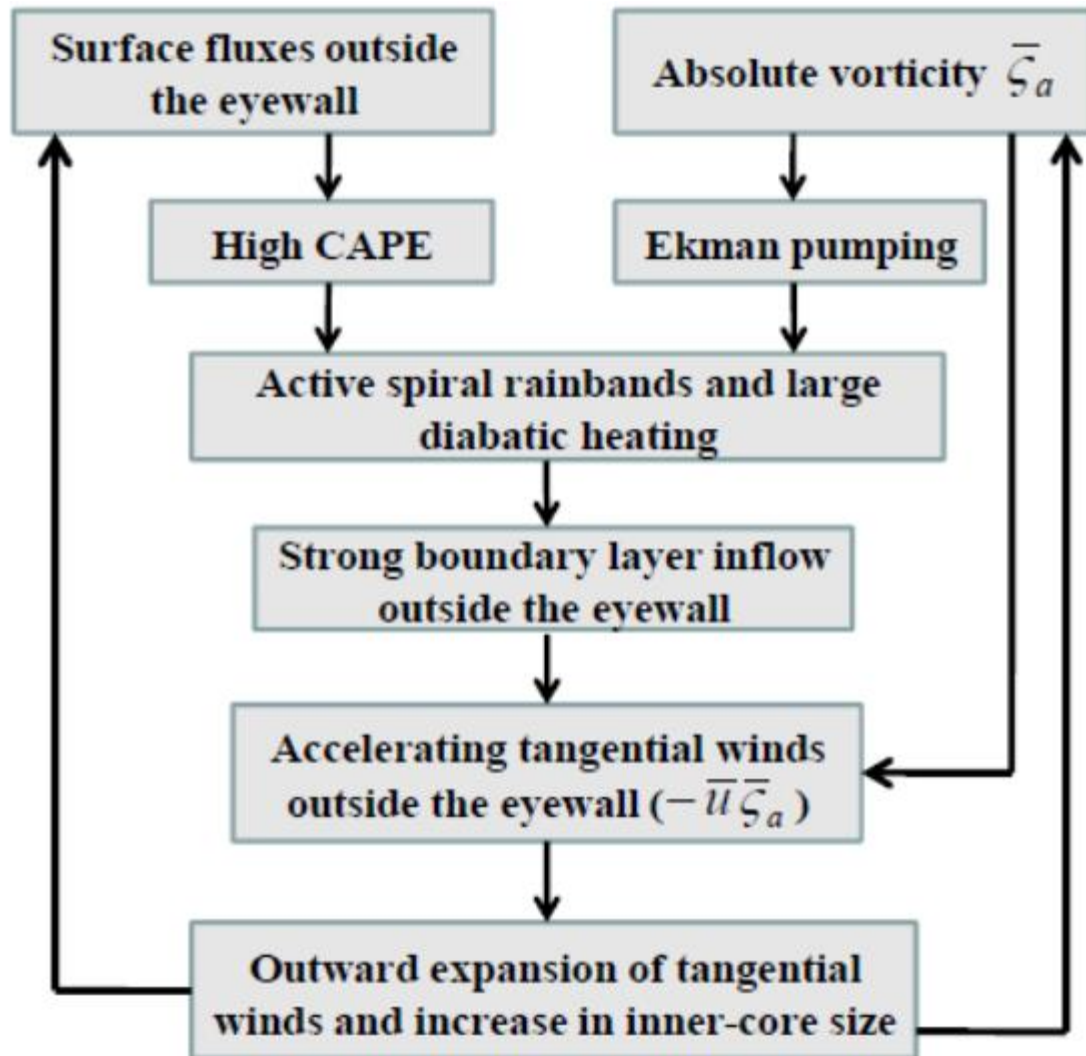


Ritchie and Elsberry 2000



Kuo, Chen, and Lin 2000

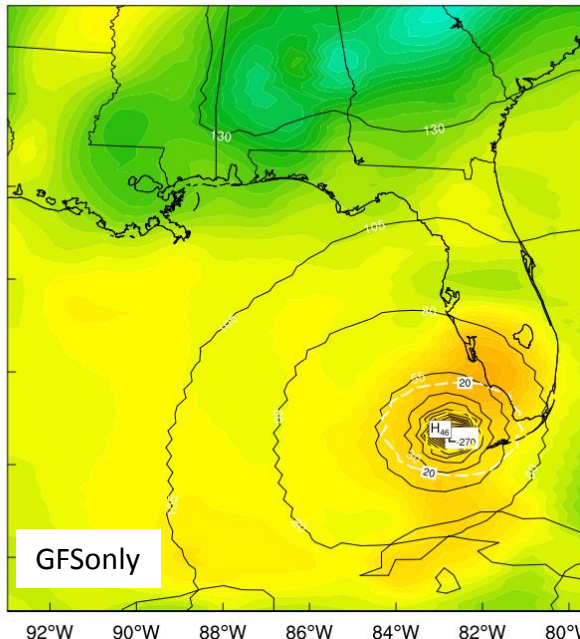
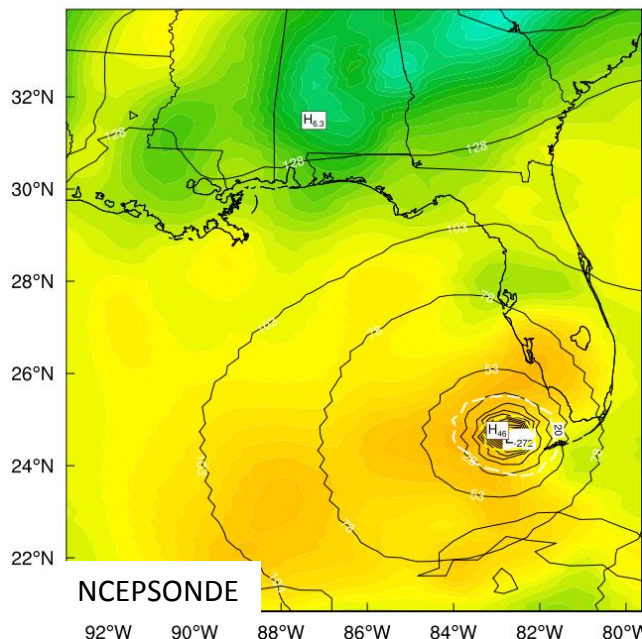
Feedback to environmental moisture (Xu and Wang 2010)



Color contour = specific humidity g/kg Solid contour=heights of 1000 mb isobaric level

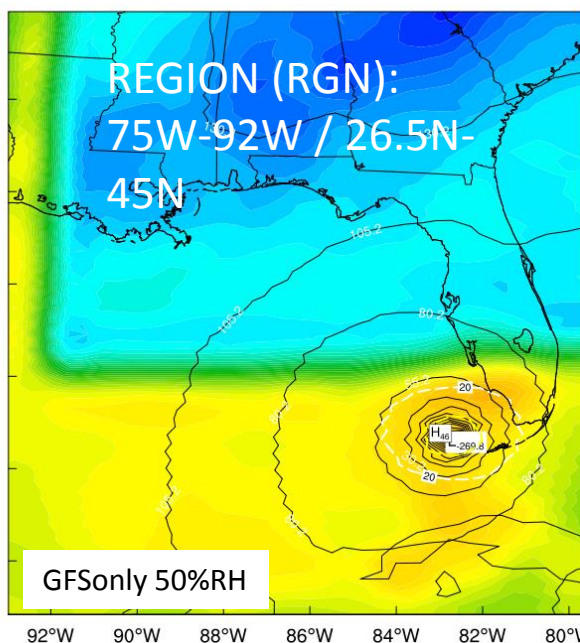
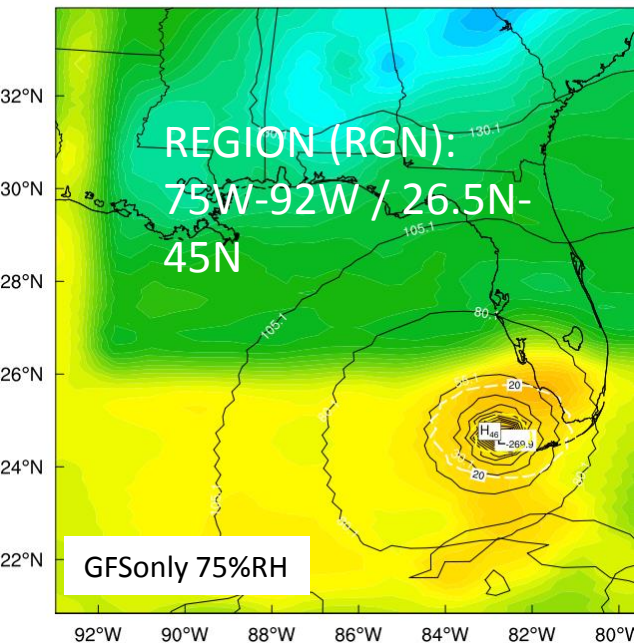
NCEPSONDE_FORCST SPF-HEIGHTS @1000mb 18Z00FH 08/26/2005

COLD_FORCST SPF-HEIGHTS @1000mb 18Z00FH 08/26/2005



COLD_25percent_reductionRH_75W92W_265N45N_FORCST SPF-HEIGHTS @1000mb 18Z00FH 08/26/2005

COLD_50percent_reductionRH_75W92W_265N45N_FORCST SPF-HEIGHTS @1000mb 18Z00FH 08/26/2005



HWRf GFSoonly versus

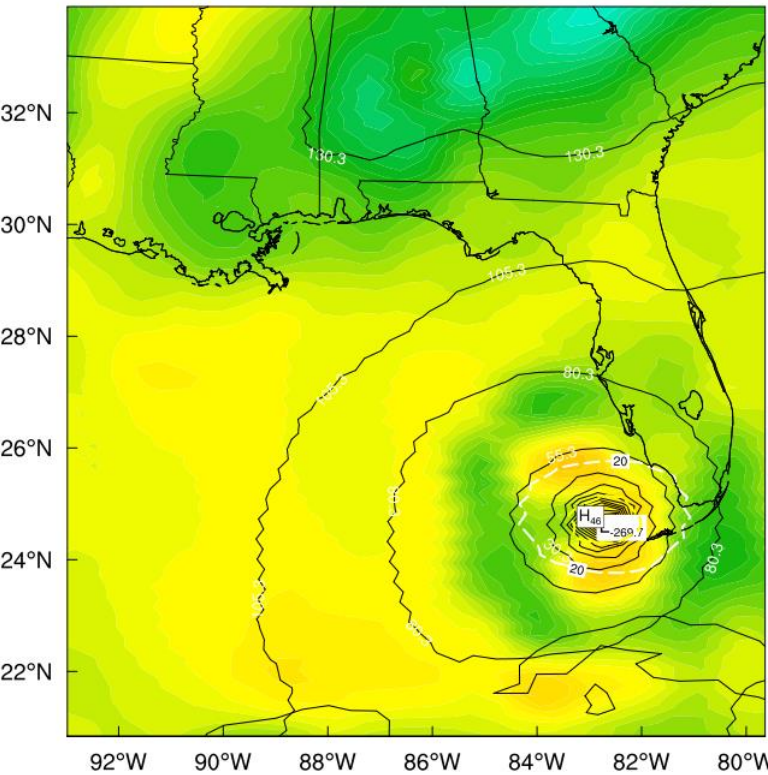
GFSoonly modified trough,

and GFS only with 25% and 50% reduced RH within the RGN,

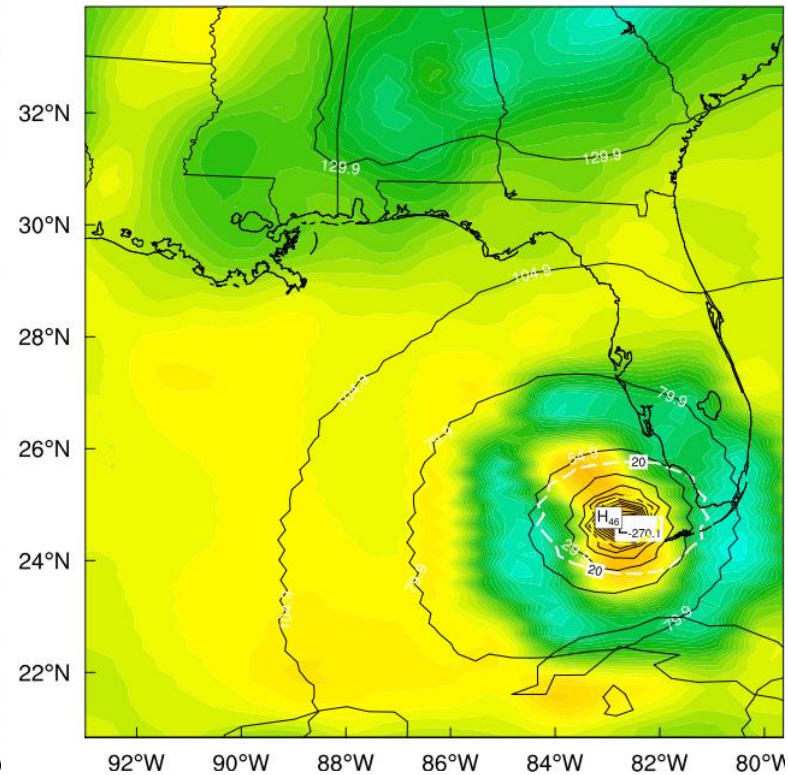
NEXT SLIDE:

and 25%RH reduction where wspd <17 and distance <300km and >50 km,

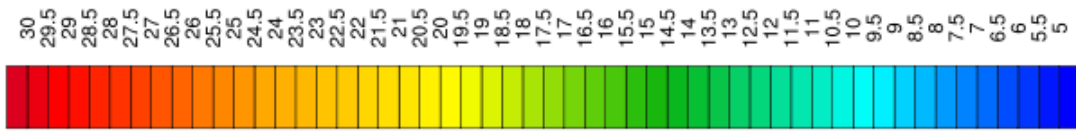
and 50%RH reduction where wspd <17 and distance <300 km, >50km.



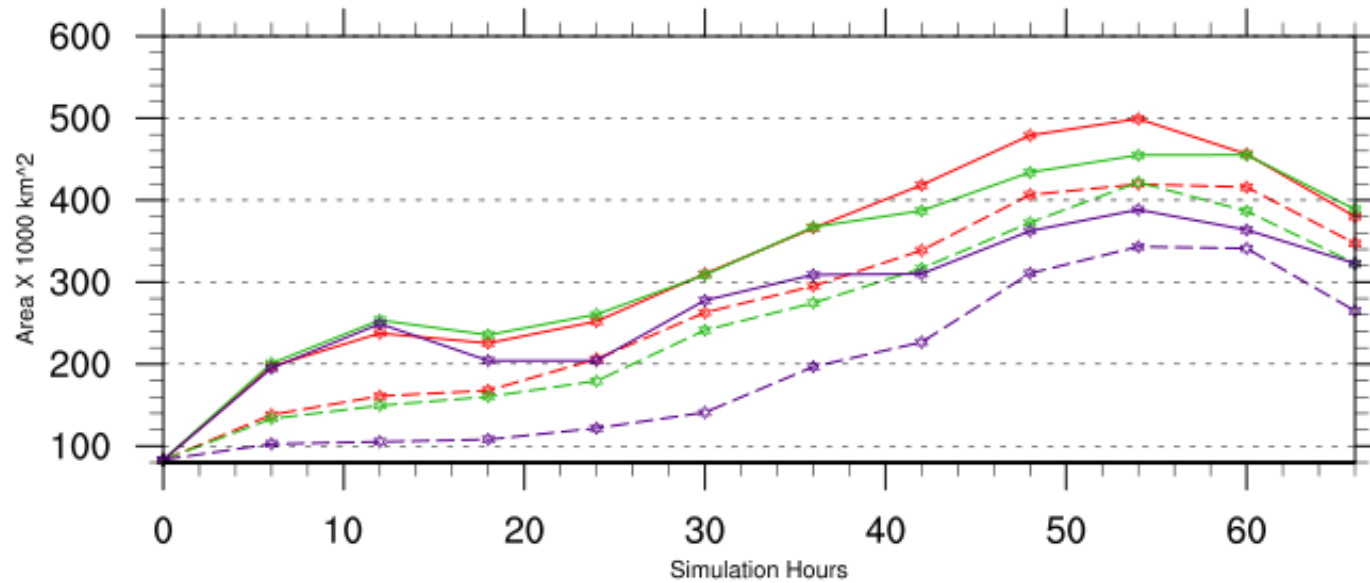
GFSOnly 75%RH-WTHNEST



GFSOnly 50%RH-WTHNEST

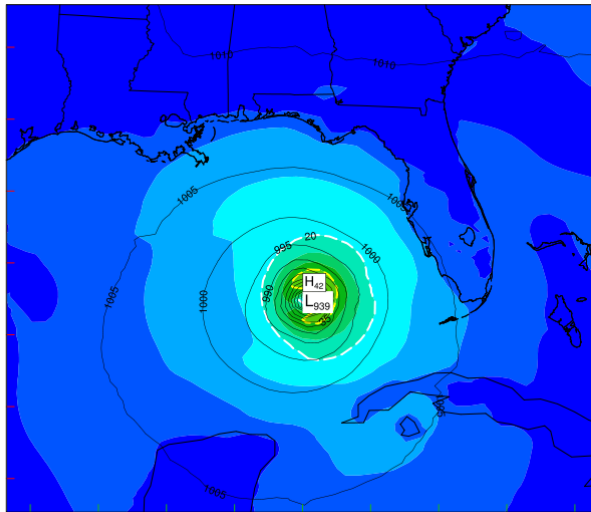


Size of the Areal Coverage of Wind speed > 17 m/s @ 10 m



- COLD_MODTROUGH_80W84W_30N33N_FORCST
- - - COLD_25percent_reductionRH_WIND16_DIST300_MODTROUGH_FORCST **NEST**
- COLD_25percent_reductionRH_75W92W_265N45N_FORCST **RGN**
- - - COLD_25percent_reductionRH_WIND16_DIST300_FORCST **NEST**
- COLD_50percent_reductionRH_75W92W_265N45N_FORCST **RGN**
- - - COLD_50percent_reductionRH_WIND16_DIST300_FORCST **NEST**

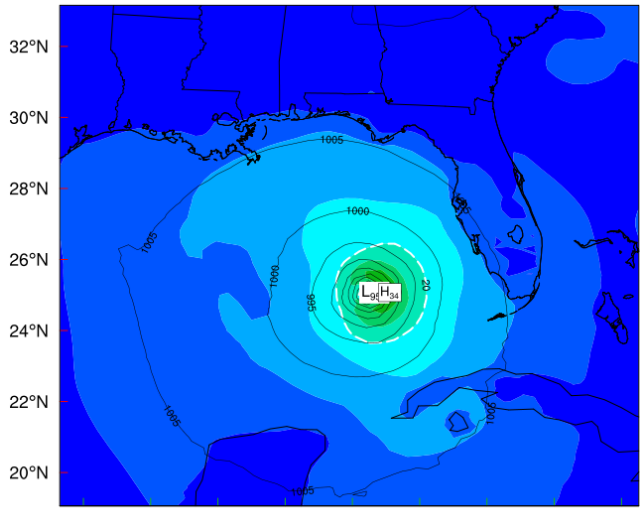
MSLP - WNDSPD@10m COLD_25percent_reductionRH_75W92W_265N45N_FORCST 08/26/2005 18UTC 24 FH



GFOnly 75%RH-RGN

24FH

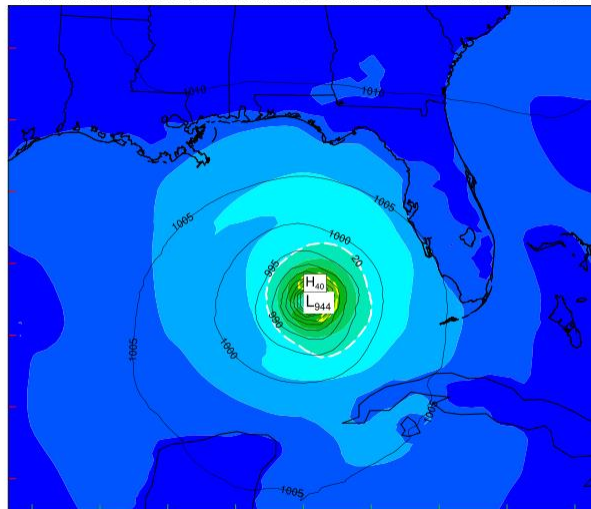
MSLP - WNDSPD@10m COLD_25percent_reductionRH_WIND16_DIST300_FORCST 08/26/2005 18UTC 24 FH



GFOnly 75%RH-NEST

24FH

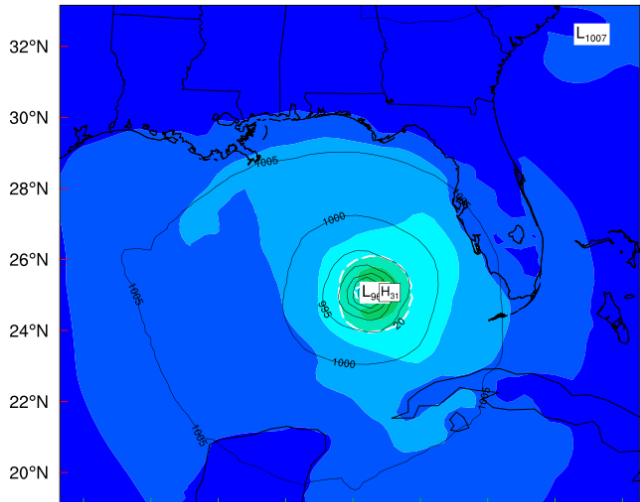
MSLP - WNDSPD@10m COLD_50percent_reductionRH_75W92W_265N45N_FORCST 08/26/2005 18UTC 24 FH



GFOnly 50%RH-RGN

24FH

MSLP - WNDSPD@10m COLD_50percent_reductionRH_WIND16_DIST300_FORCST 08/26/2005 18UTC 24 FH



GFOnly 50%RH-NEST

24FH



Is there a predictive moisture signal?

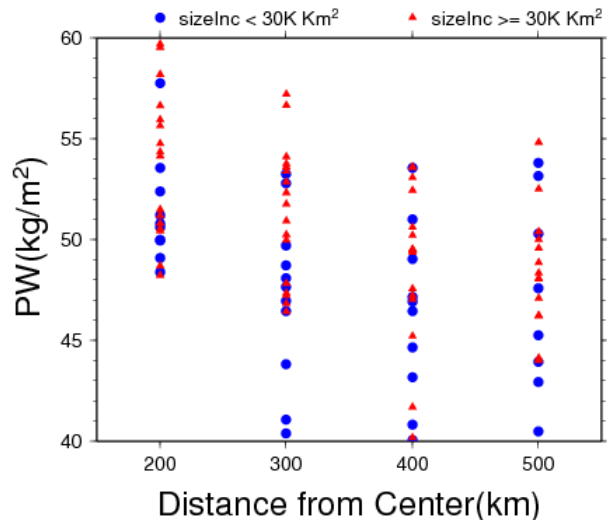
We examined historical storms vs precipitable water

Definition of Precipitable Water: total water vapor contained in a column of the atmosphere.

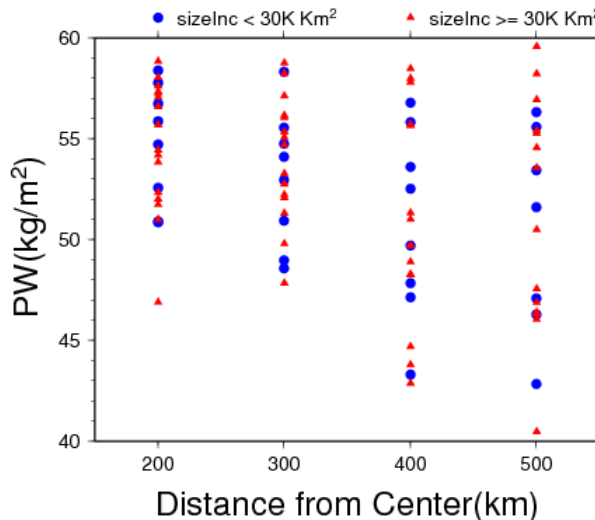
Extended Best Track 2000-2010 Central Atlantic To Florida storms intensified more than 10 Kts in 24 Hrs

60 Kts \leq MaxWind < 80Kts 30K Sq. Km cutoff PW scale 40 to 60

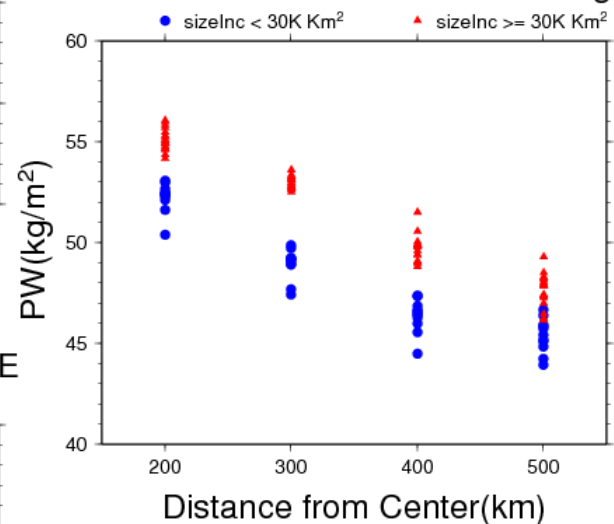
NARR PW - maxWind60to80Kts- NW



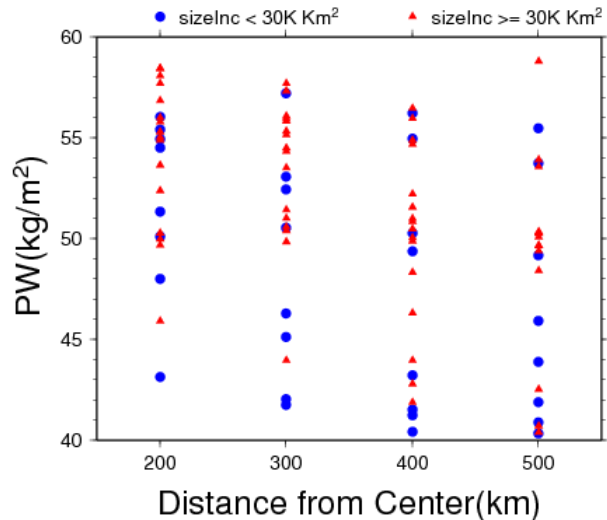
NARR PW - maxWind60to80Kts- NE



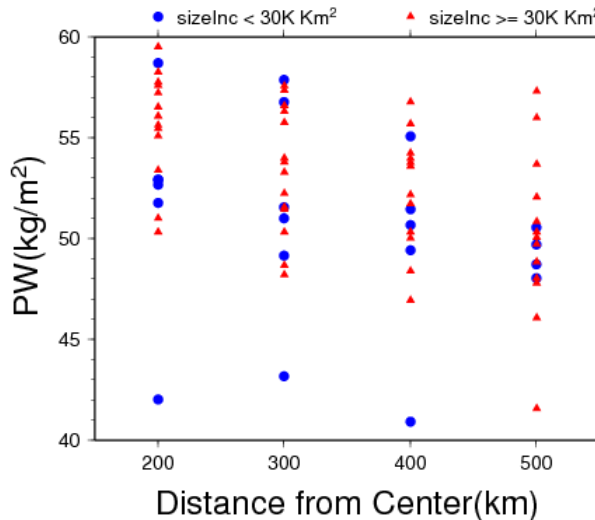
NARR PW - maxWind60to80Kts- Avg4Q



NARR PW - maxWind60to80Kts- SW



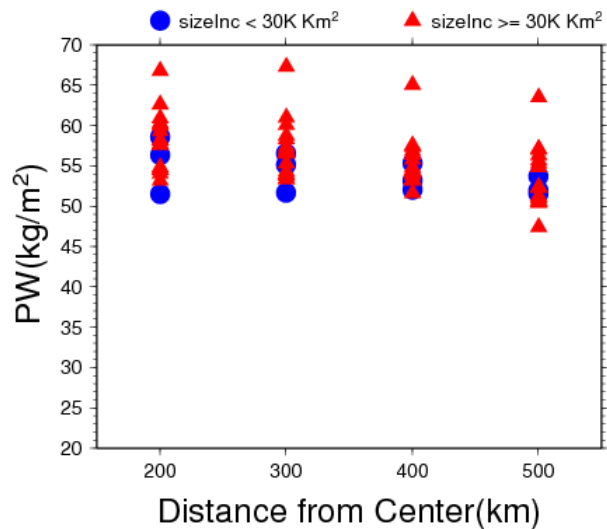
NARR PW - maxWind60to80Kts- SE



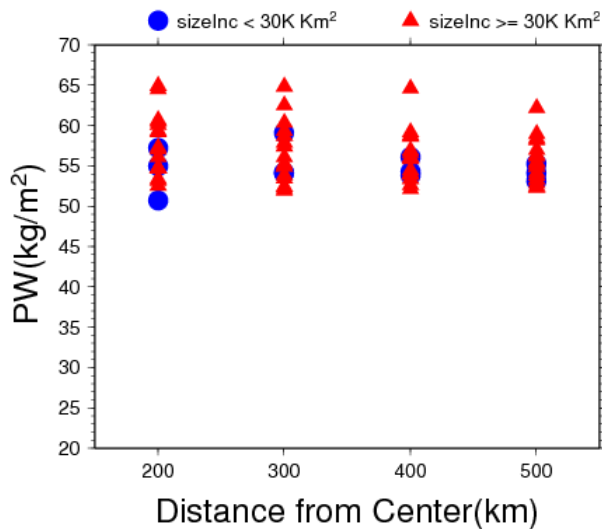
Extended Best Track 1988-2010 Gulf of Mexico storms intensified more than 10 Kts in 24 Hrs

60 Kts \leq MaxWind < 80Kts 30K Sq. Km cutoff PW scale 20 to 70

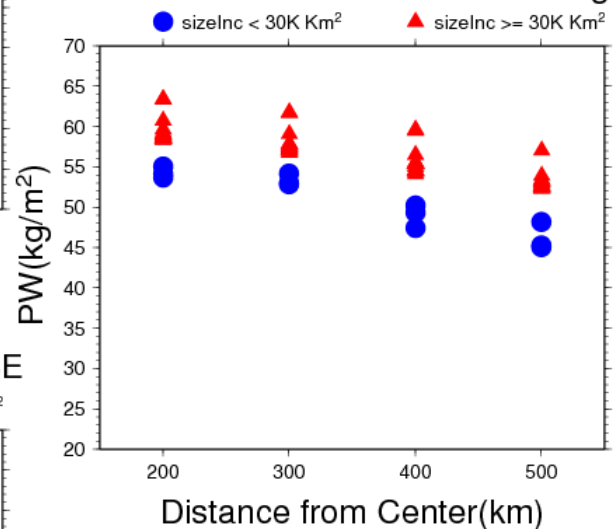
NARR PW - maxWind60to80Kts- NW



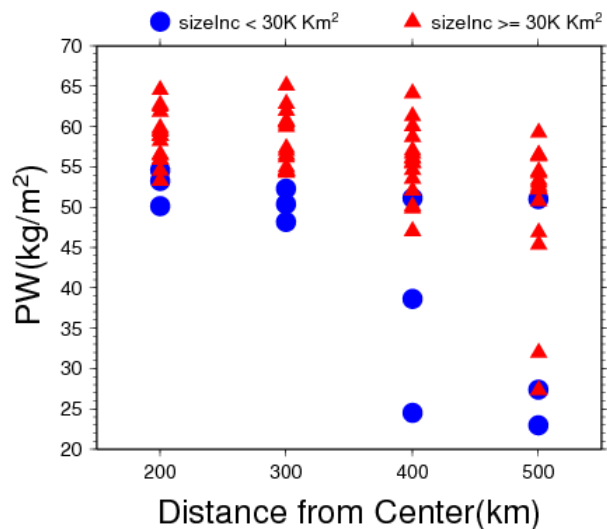
NARR PW - maxWind60to80Kts- NE



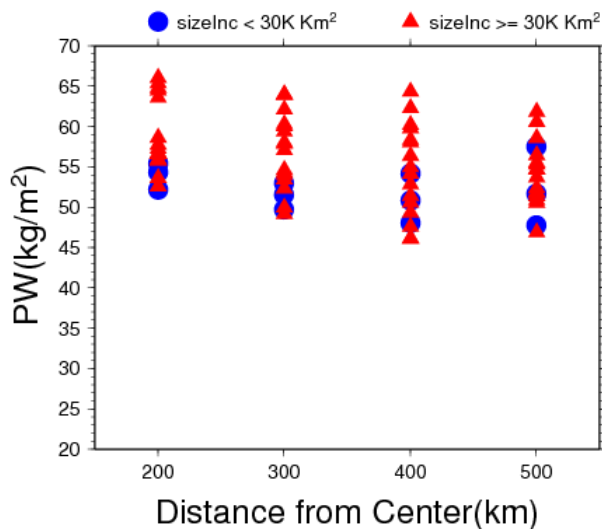
NARR PW - maxWind60to80Kts- Avg4Q



NARR PW - maxWind60to80Kts- SW



NARR PW - maxWind60to80Kts- SE



Tentative Conclusions

- No support for vortex merger hypothesis
- But modeling and tentative dataset analysis supports environmental moisture sensitivity
- Work ongoing to examine storm size by intensity and initial size
- Predictability of tropical cyclone change may be possible using precipitable water fields