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*

Poor hurricane wind analysis

- *Inaccurate intensity forecasts*
- *Poor gale warning forecasts outside landfall region*
- *Poor surge forecasts*
- *Inaccurate FEMA HAZUS modules for mitigation planning*
- *Erroneous FEMA Flood Insurance Rate Maps*

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

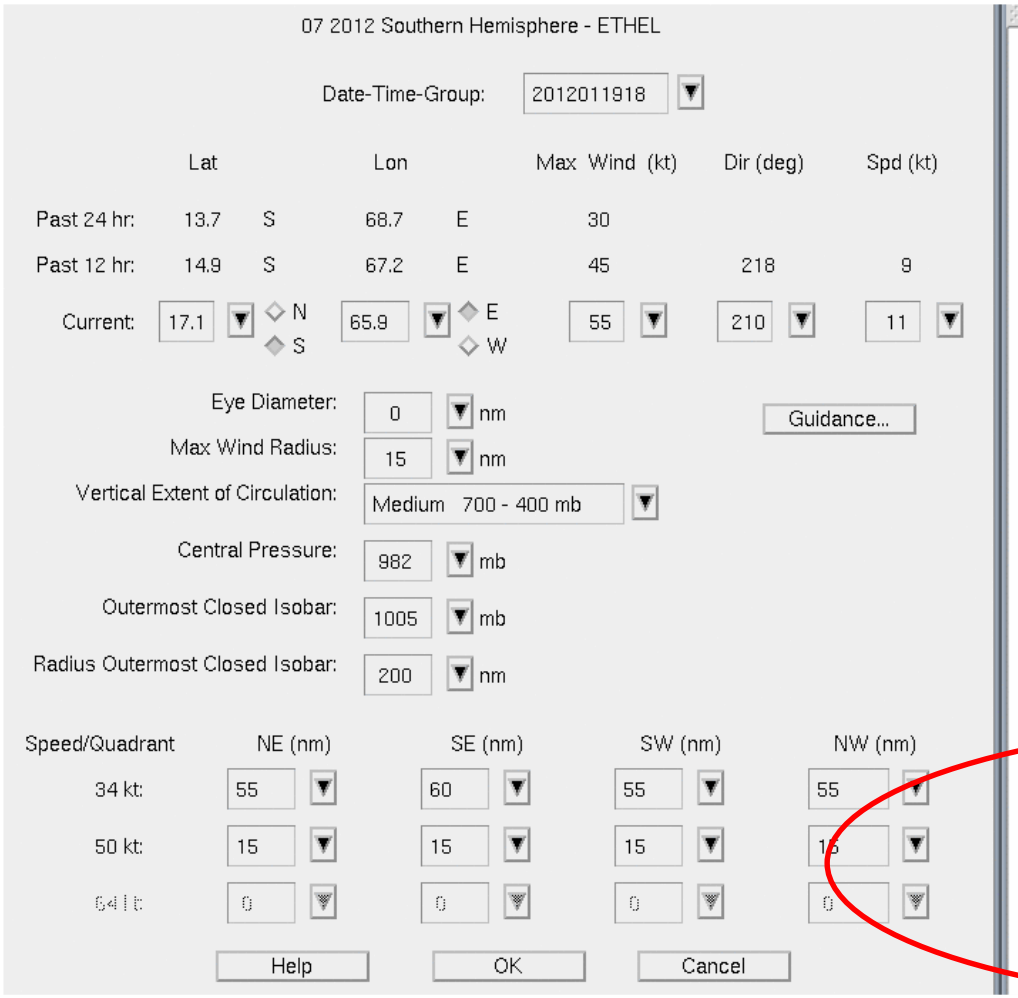
[paper submitted to *International Journal of Remote Sensing*]

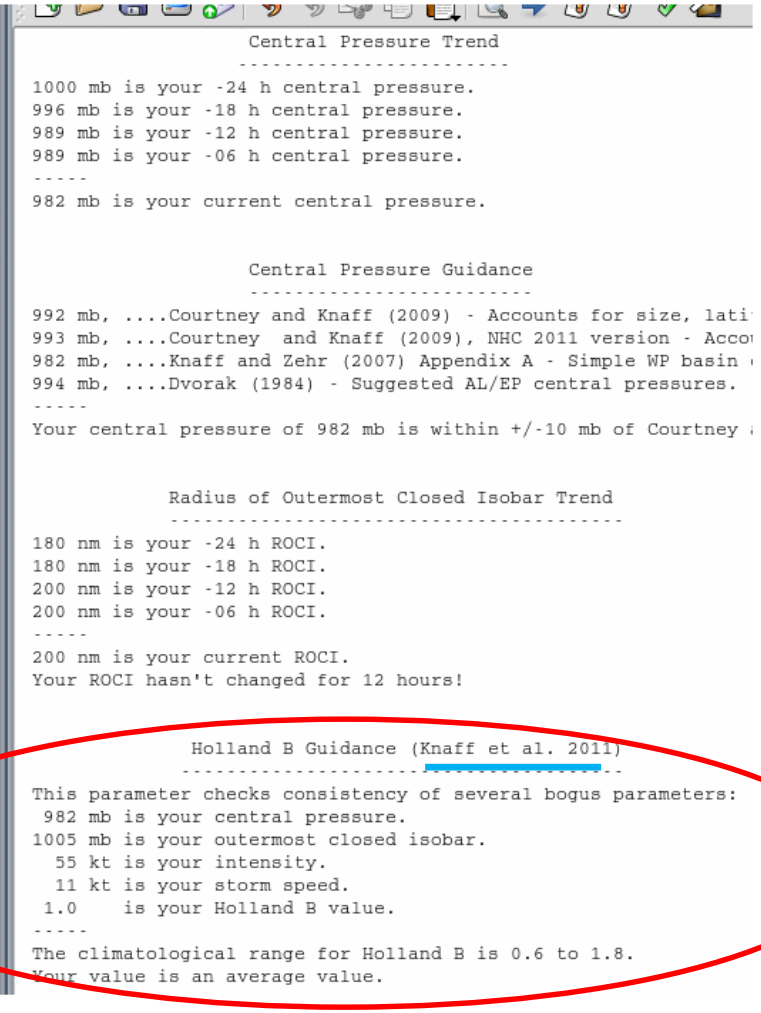
Recent research

(detailed presentations available upon request)

Meteorological modeling – Fitzpatrick, MSU

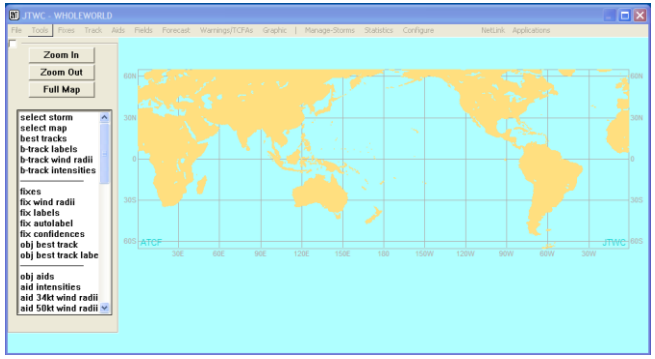
Screen capture of wind accuracy scheme being used by operational hurricane centers in the Automated Tropical Cyclone Forecasting System (ATCF)

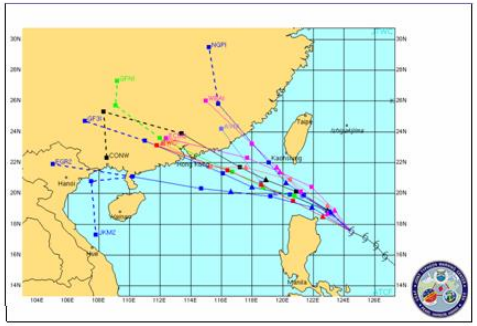


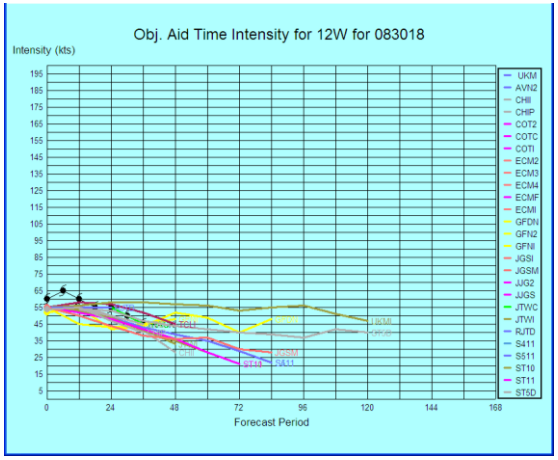


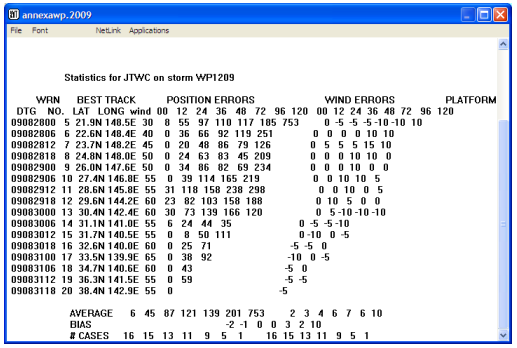
Automated Tropical Cyclone Forecasting System (ATCF)

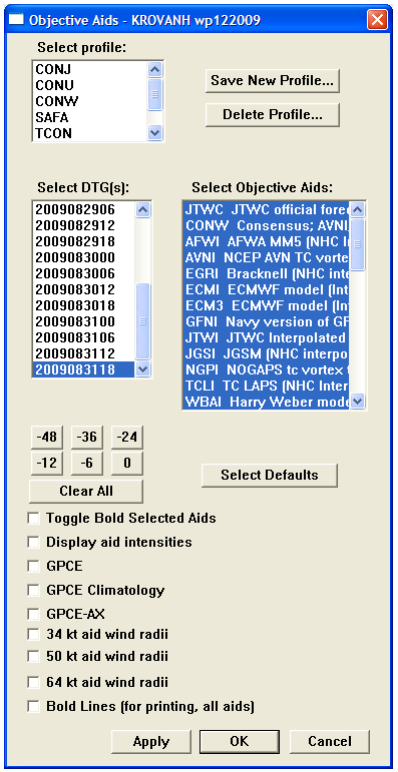
- Used by the National Hurricane Center
- Used by the Joint Typhoon Warning Center
- A GUI with many operational purposes, including objective aids
- Further information: http://www.nrlmry.navy.mil/atcf_web/











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

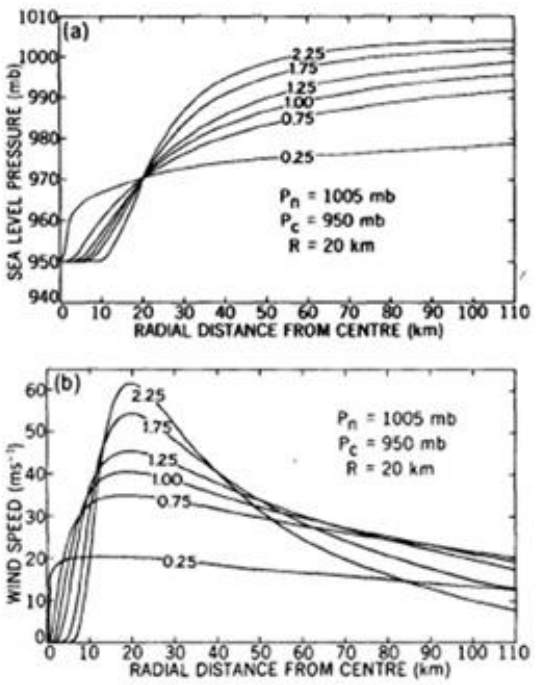


FIG. 2. The effect of varying the parameter B on (a) the sea level pressure profile and (b) the gradient wind profile.

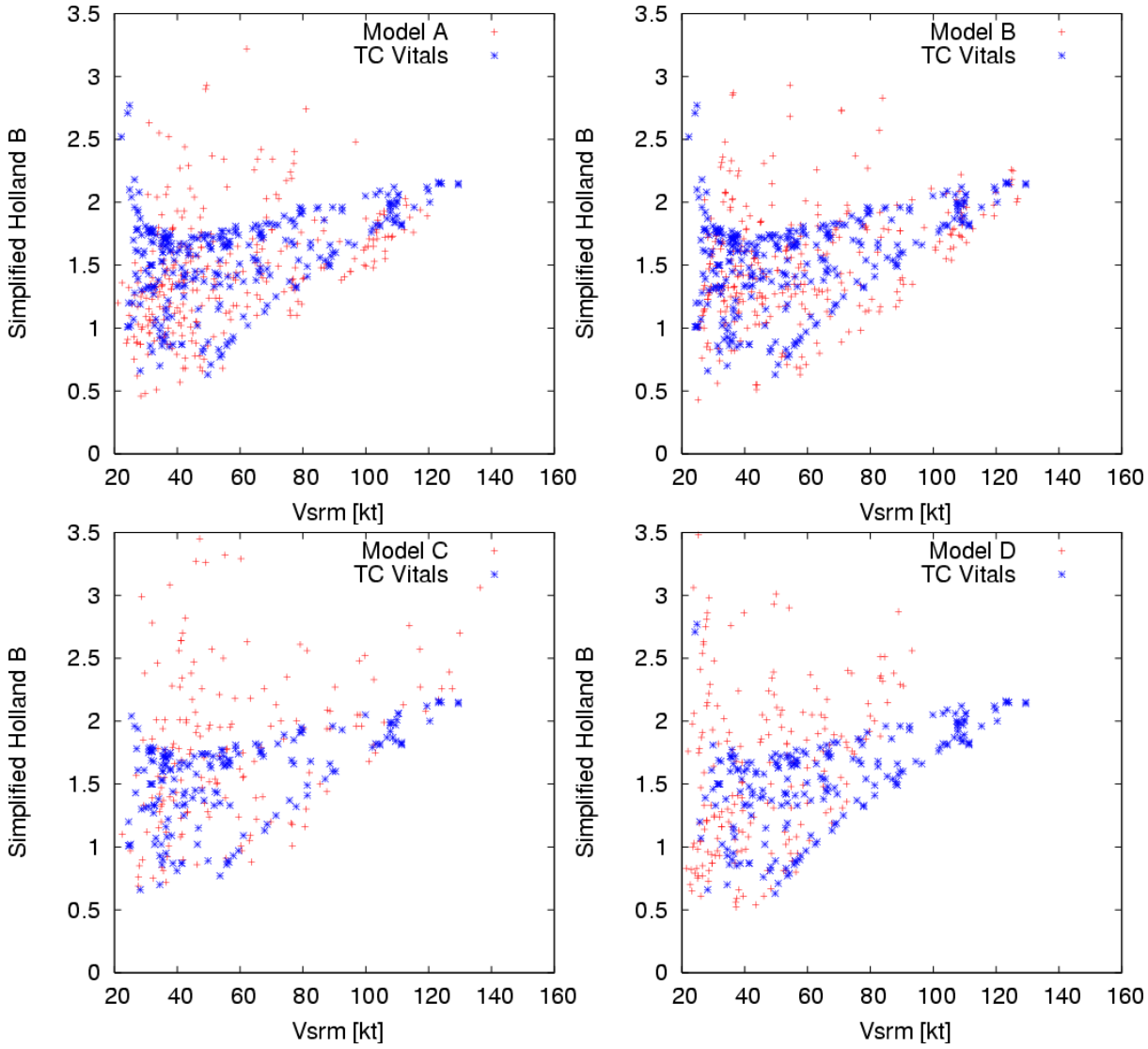
Collaboration with NOAA CIRA and NRL

Analysis of operational weather model wind profiles

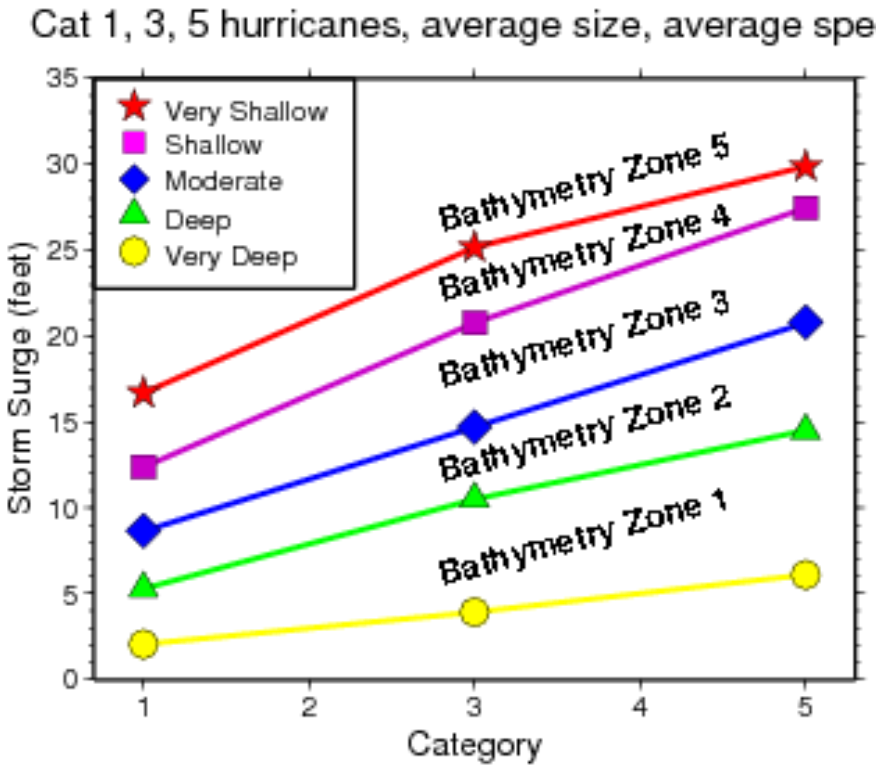
Note large differences in all 4 models. The diagnostic tool alerts forecasters that the initial wind field may be erroneous

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.



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



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)

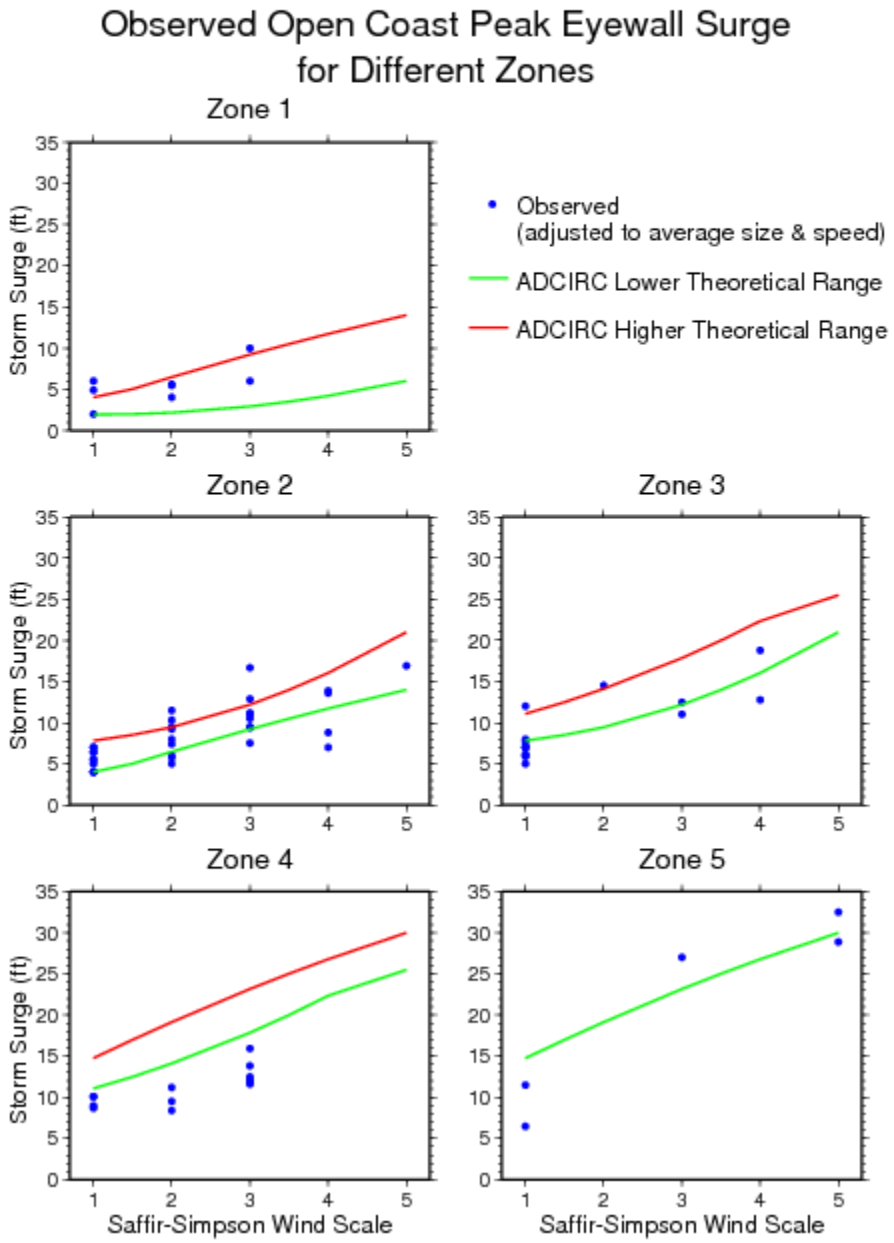
Zone 5: ± 2.3 (Cat 1–2), ± 3.3 (Cat 3), ± 4.3 (Cat 4–5)

Speed

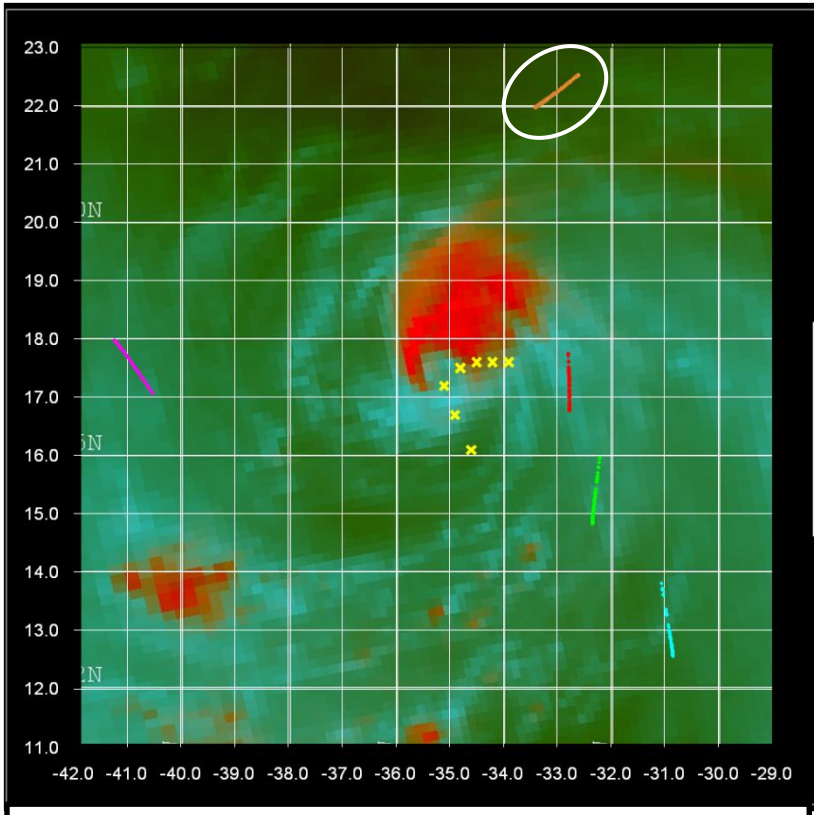
Zone 4: ± 1.5 (Cat 1–2), ± 2.0 (Cat 3), ± 2.6 (Cat 4–5)

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

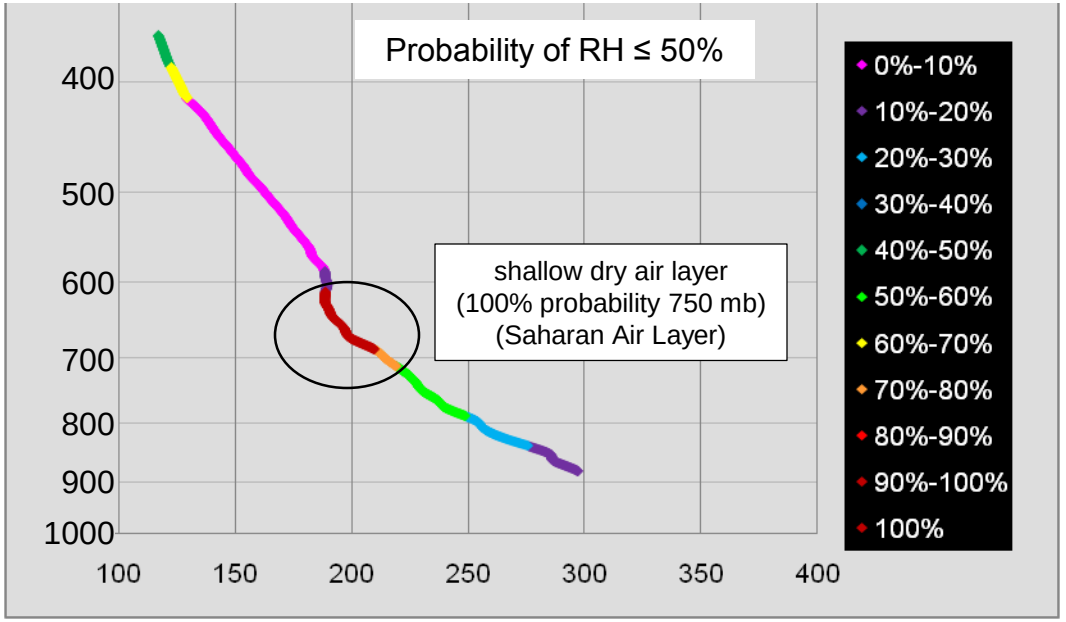
Paper in revision
for *Nat. Hazards Earth Syst. Sci.*

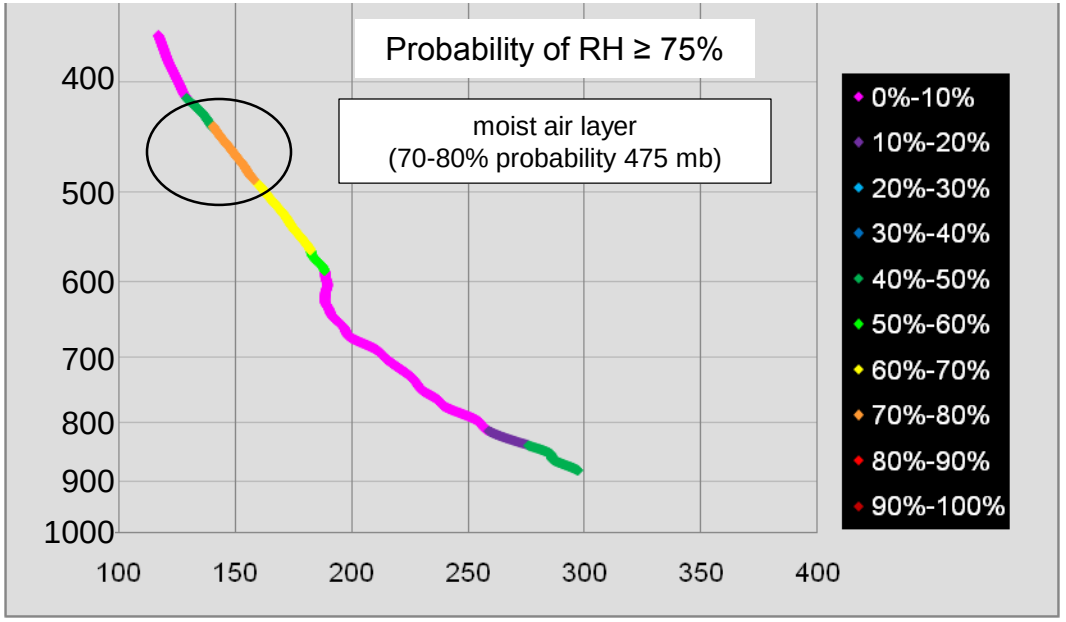


Hurricane Fred 2009

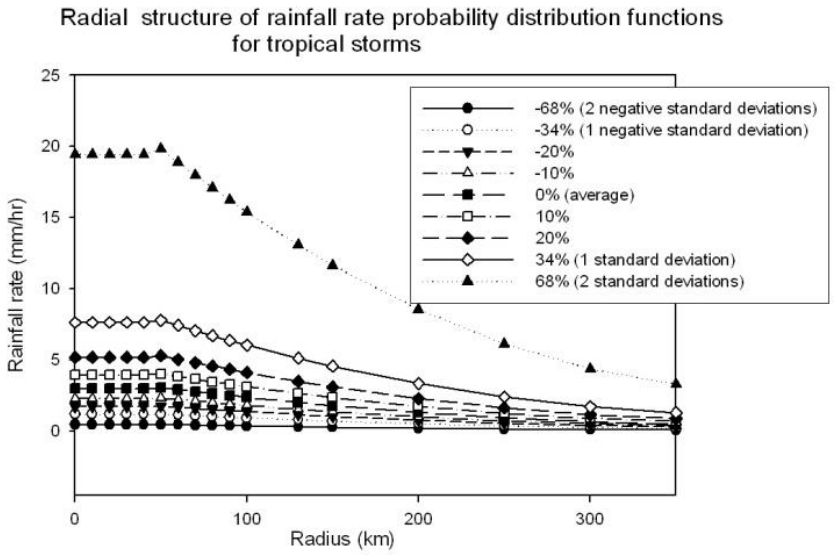


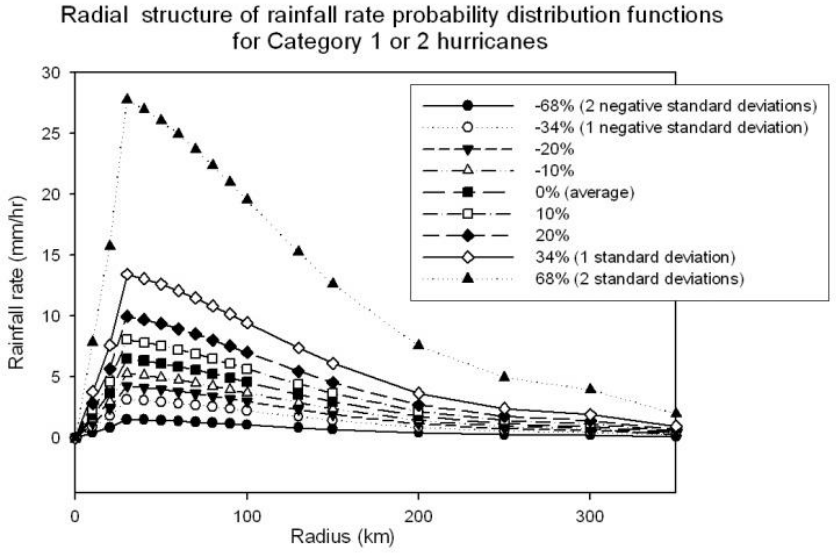
23:41 UTC 10 September 2009
AMSU-B image from METOP-A satellite
(image provided by NRL-Monterey)

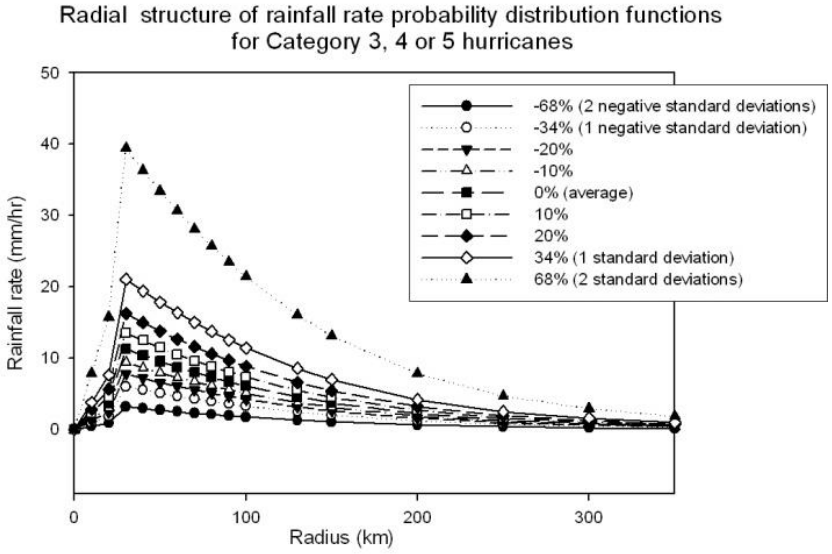




Average rainfall is 3, 6, and 11 mm/hr for TS, Min Hurr, and Major Hurr – but large spread!



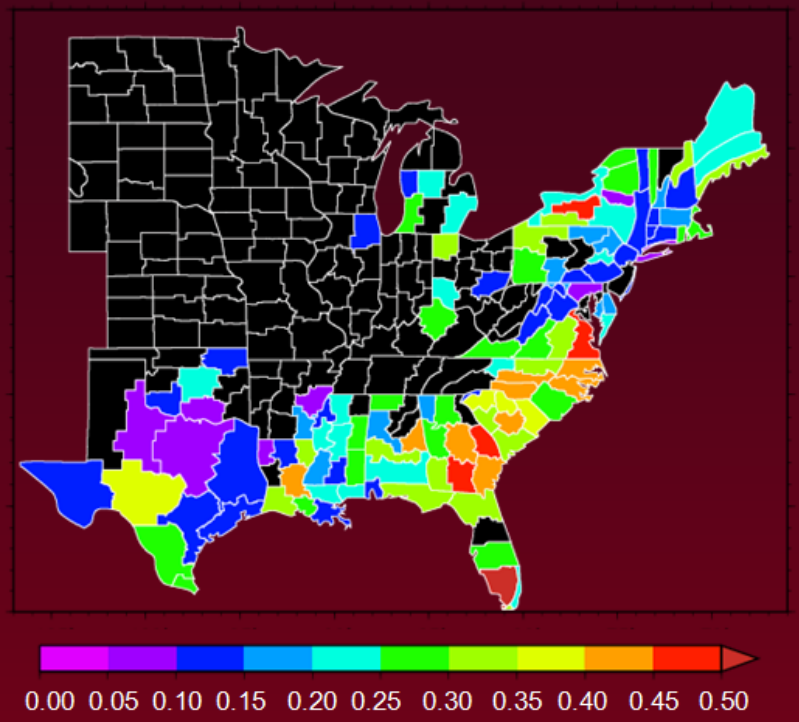




From Fitzpatrick and Lau (2011) Based on Lonfat et al. (2007)

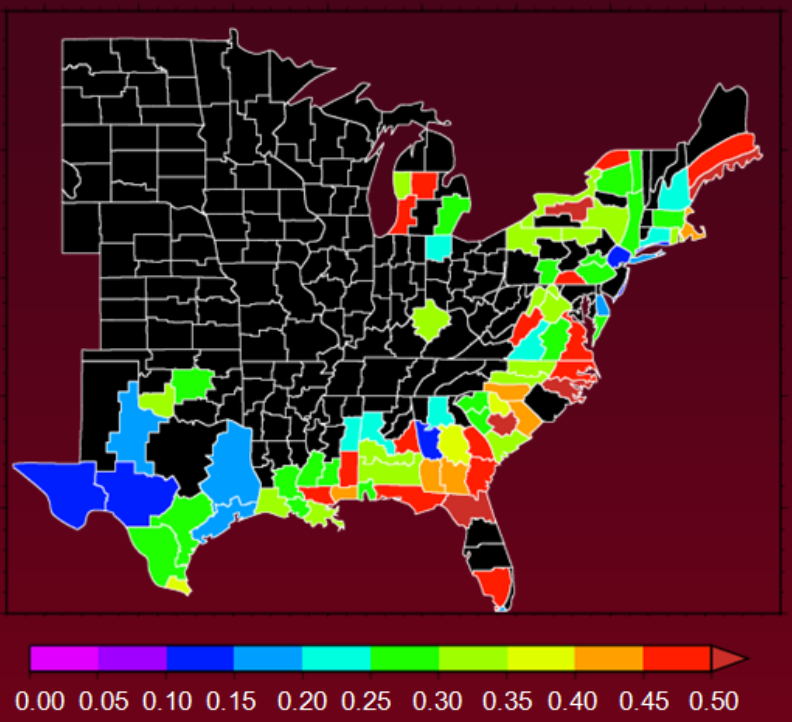
Percentage of droughts ended by tropical storms or hurricanes

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



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

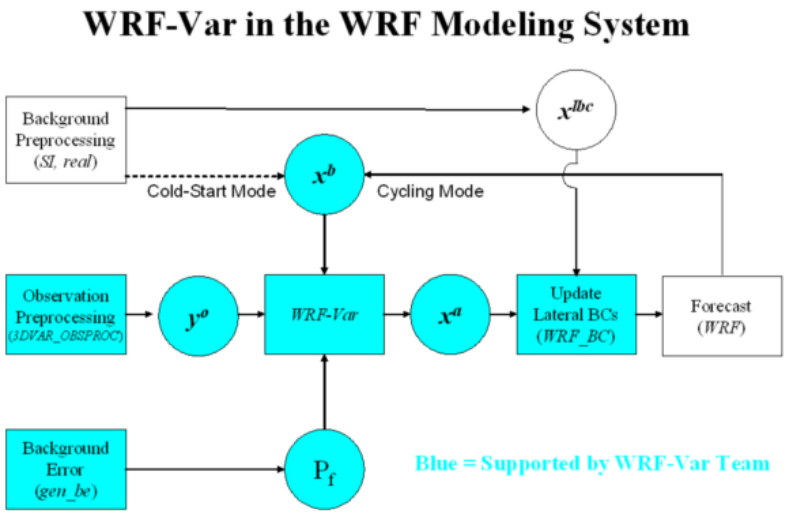
TC-affected ADE frequency (R34 range) 1988 - 2010



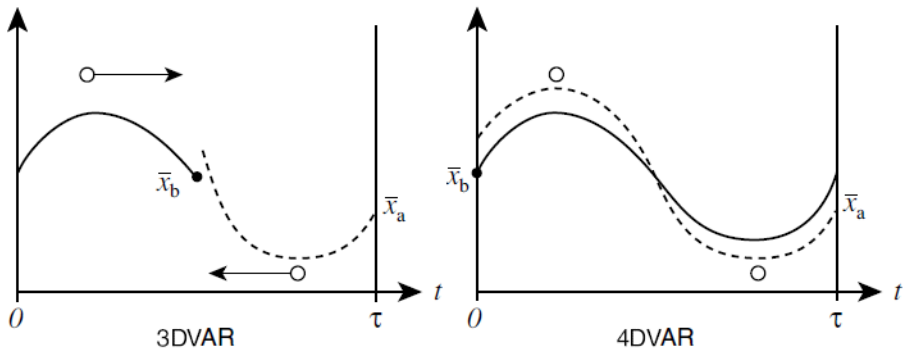
The frequency of ADEs contained within the R34 circulation area of TCs.

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)

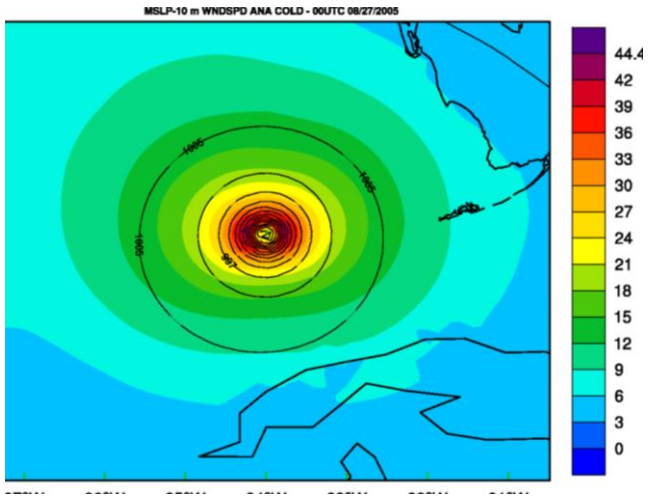


$$J(\mathrm{x}) = J_b(\mathrm{x}) + J_o(\mathrm{x}) = \frac{1}{2}(\mathrm{x}-\mathrm{x}^b)^T\mathbf{B}^{-1}(\mathrm{x}-\mathrm{x}^b) + \frac{1}{2}(\mathrm{y}-\mathrm{y}^o)^T(\mathbf{E}+\mathbf{F})^{-1}(\mathrm{y}-\mathrm{y}^o)$$

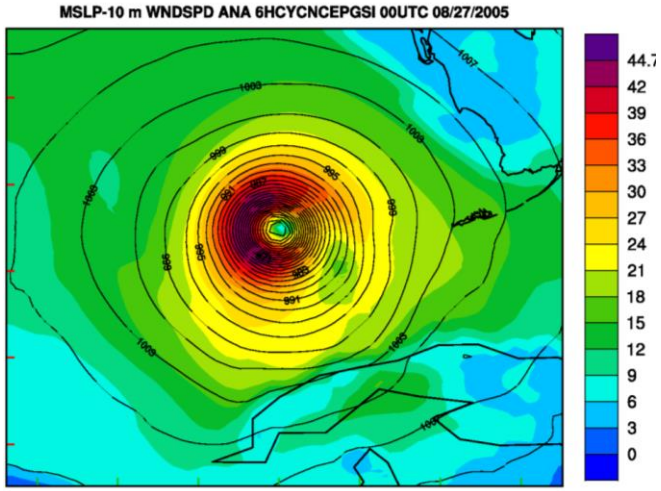


Data assimilation example

Katrina no data



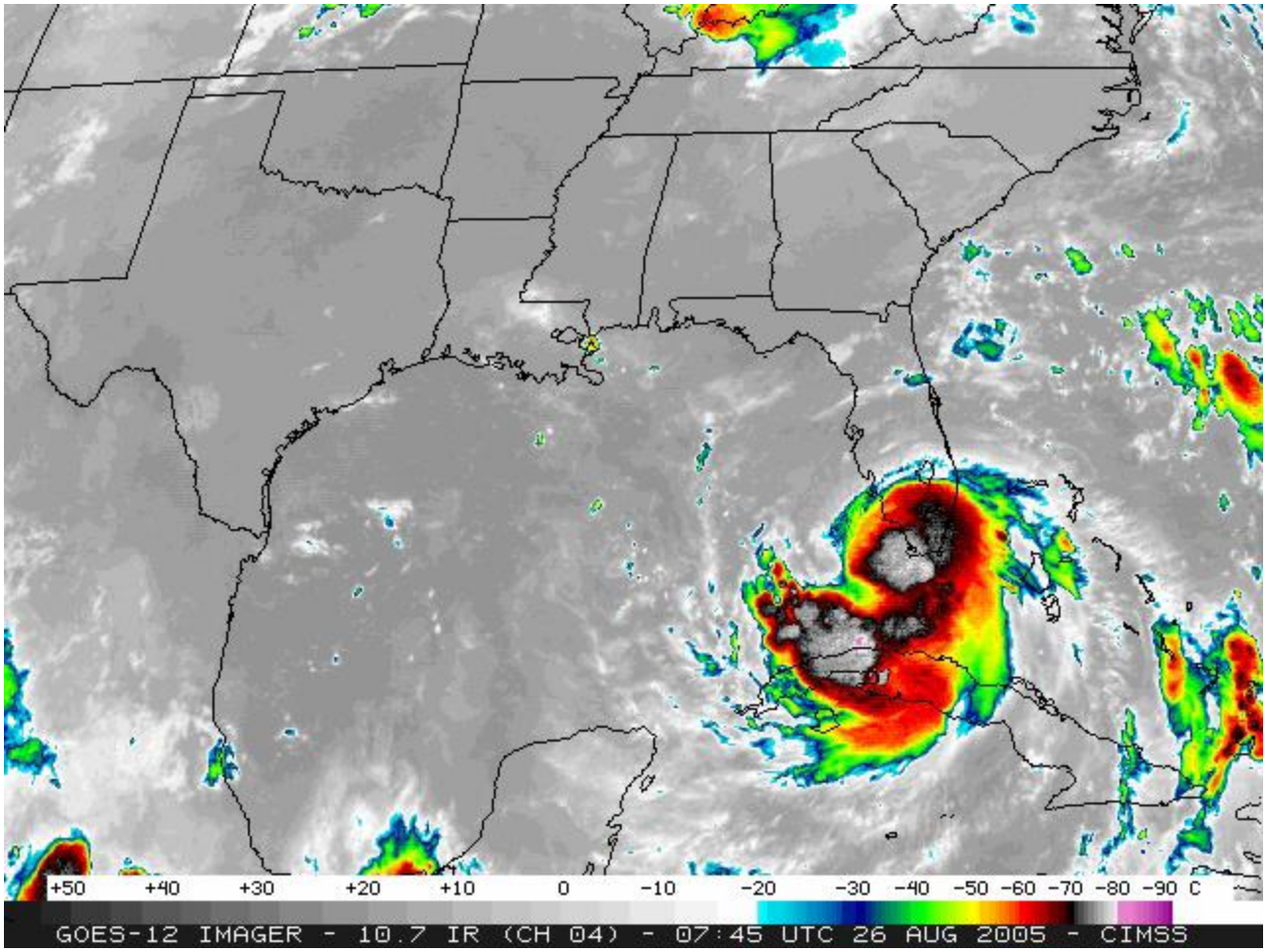
Katrina with aircraft data



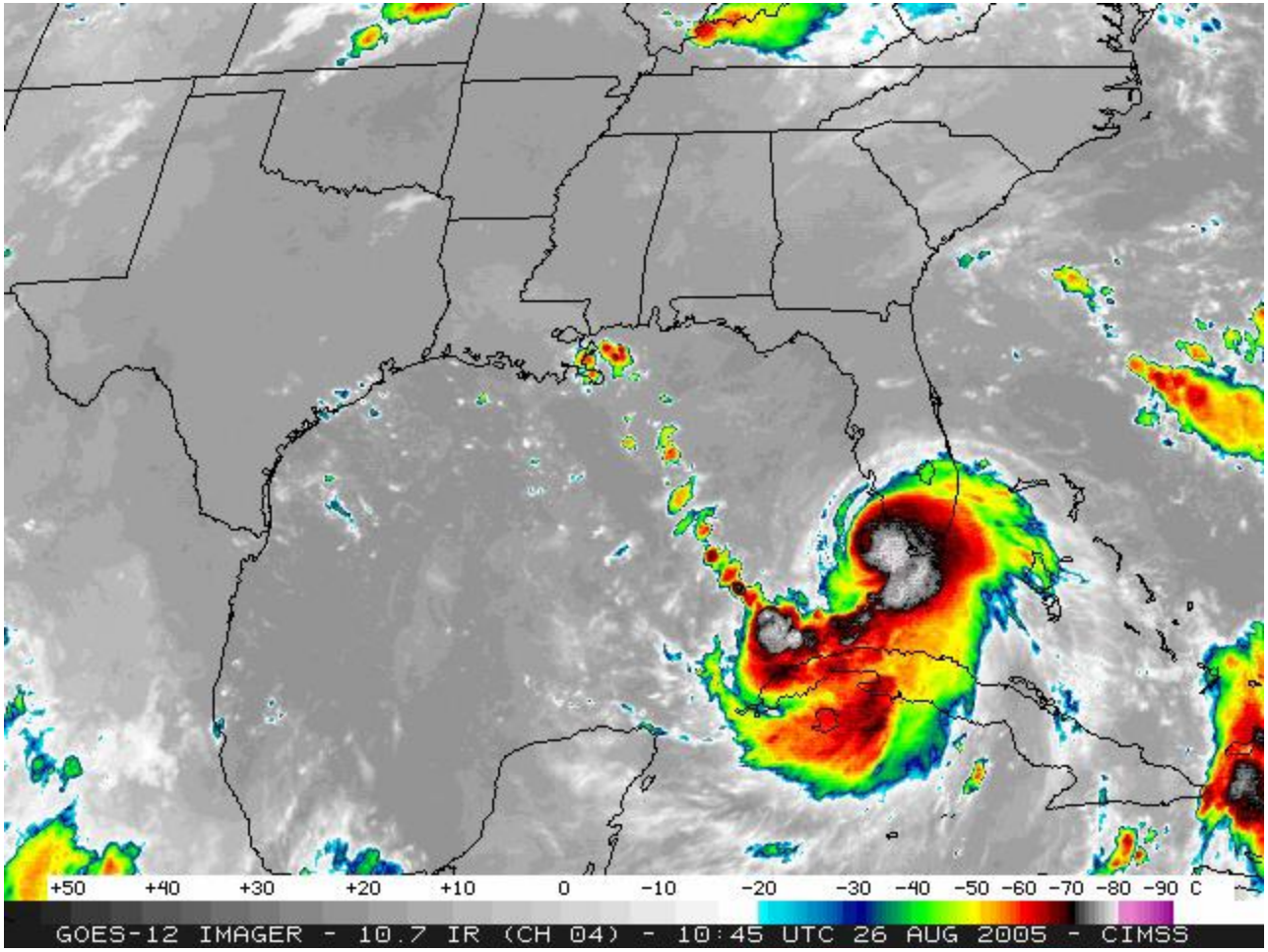
New research
Tropical cyclone size changes

Motivation - Katrina

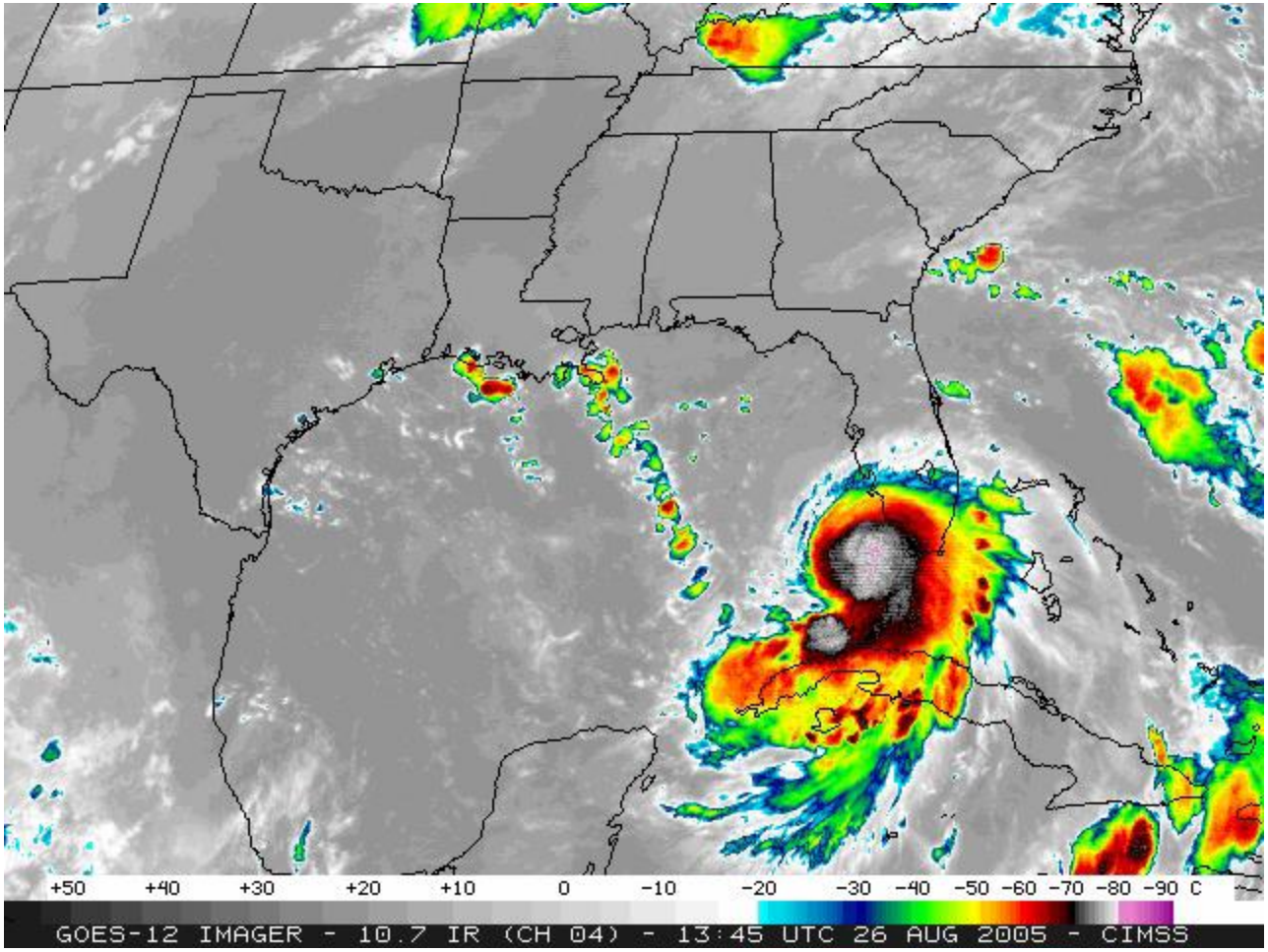
August 26, 08Z



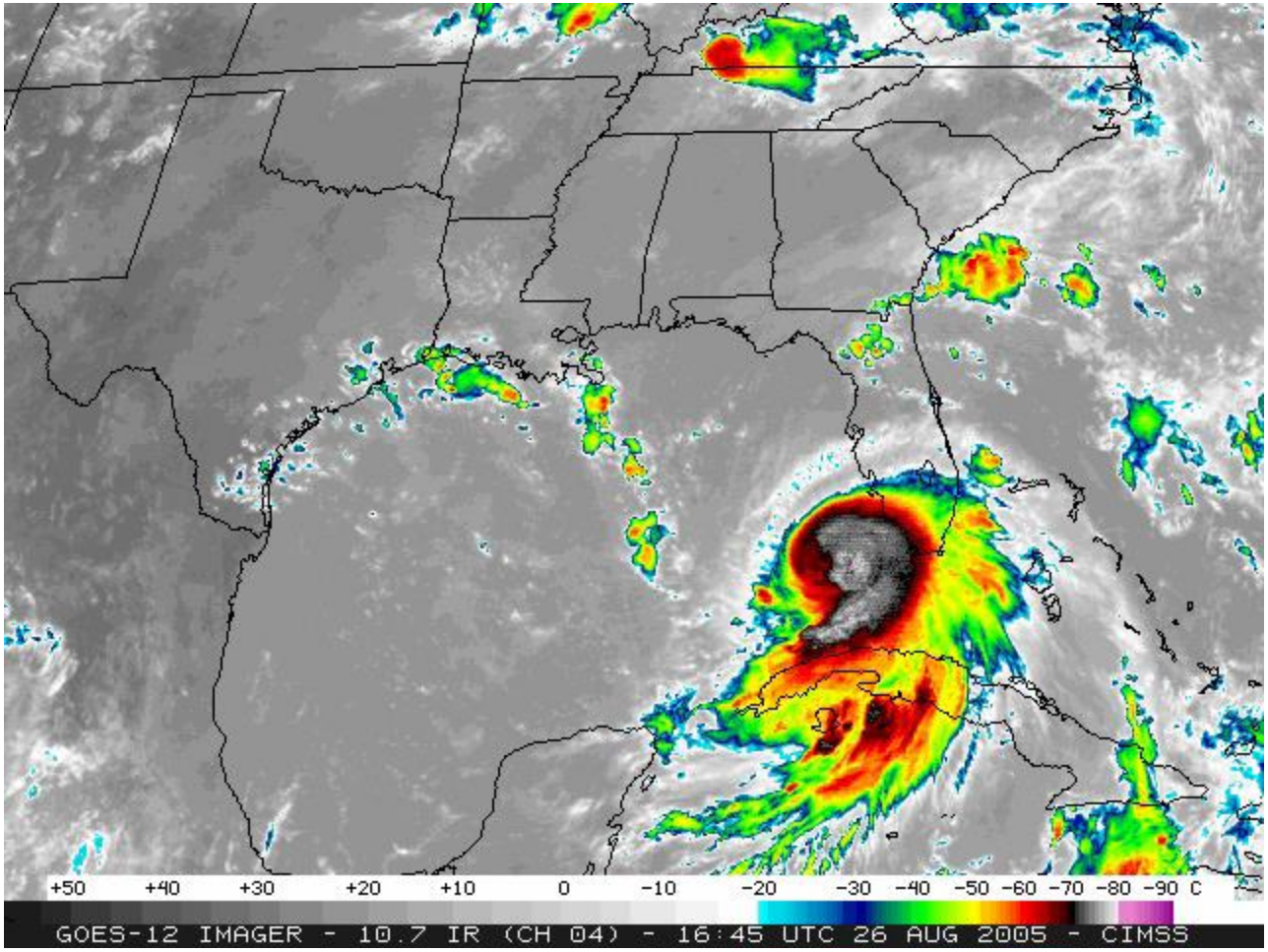
August 26, 11Z



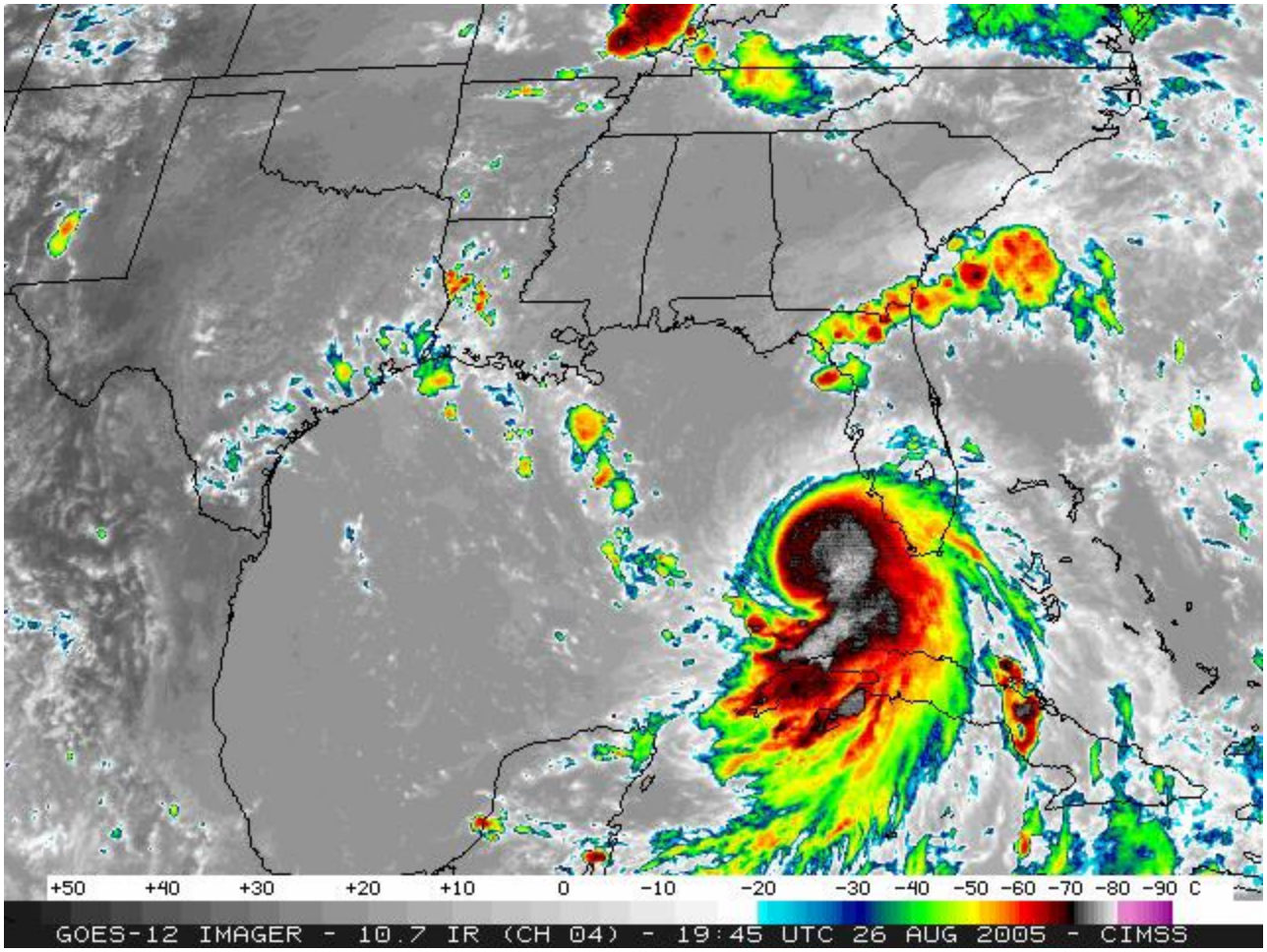
August 26, 14Z



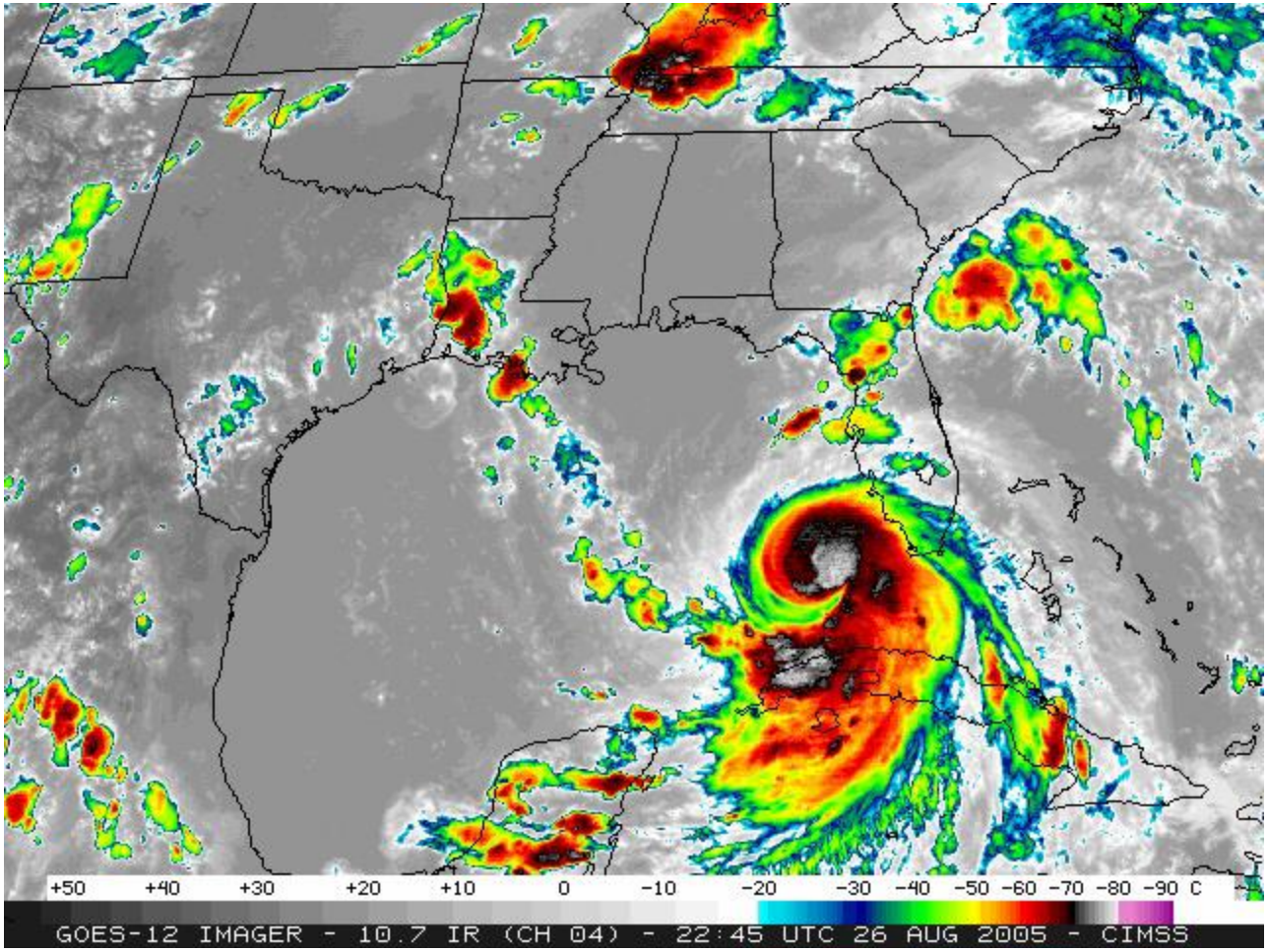
August 26, 17Z



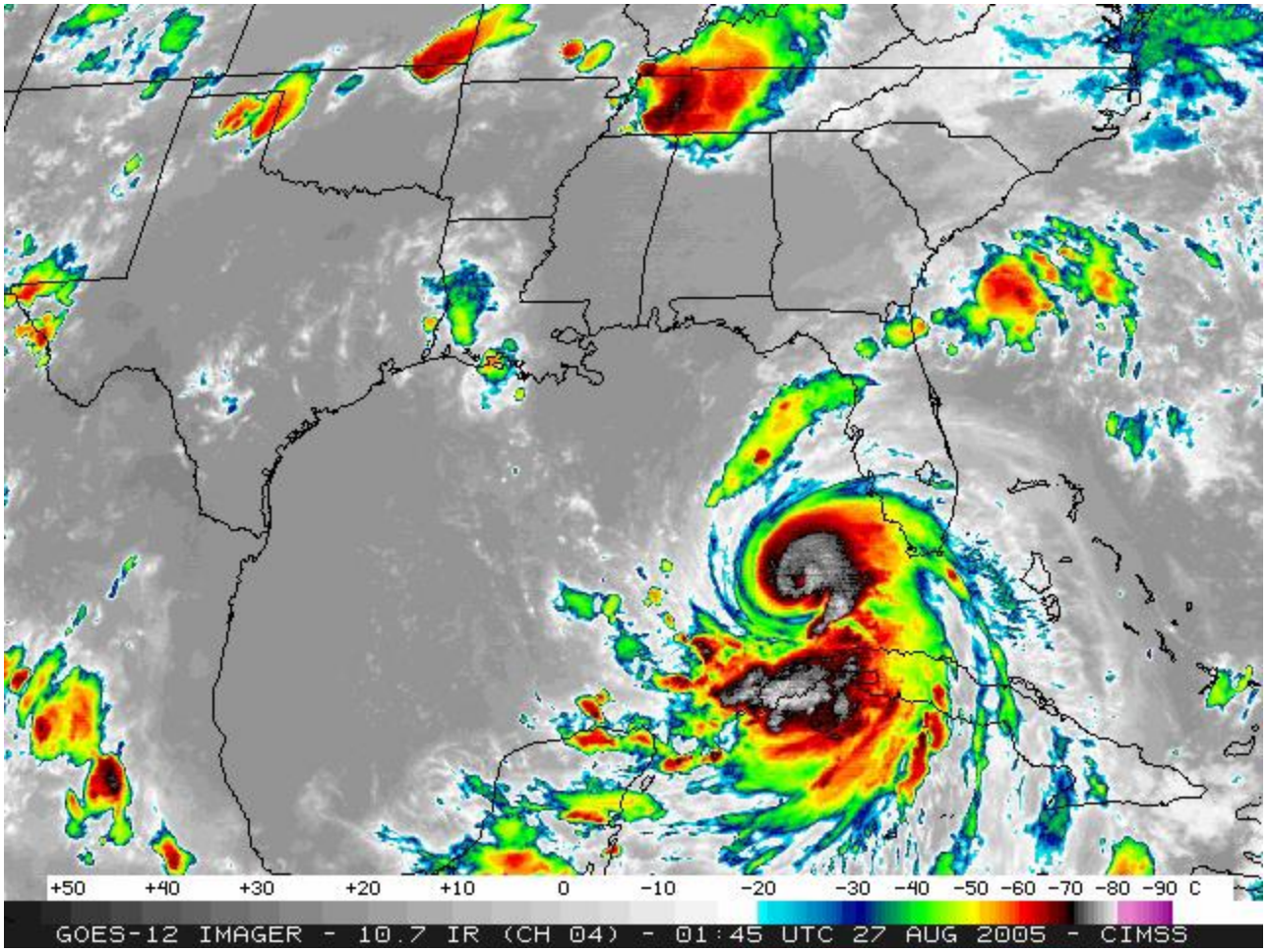
August 26, 20Z



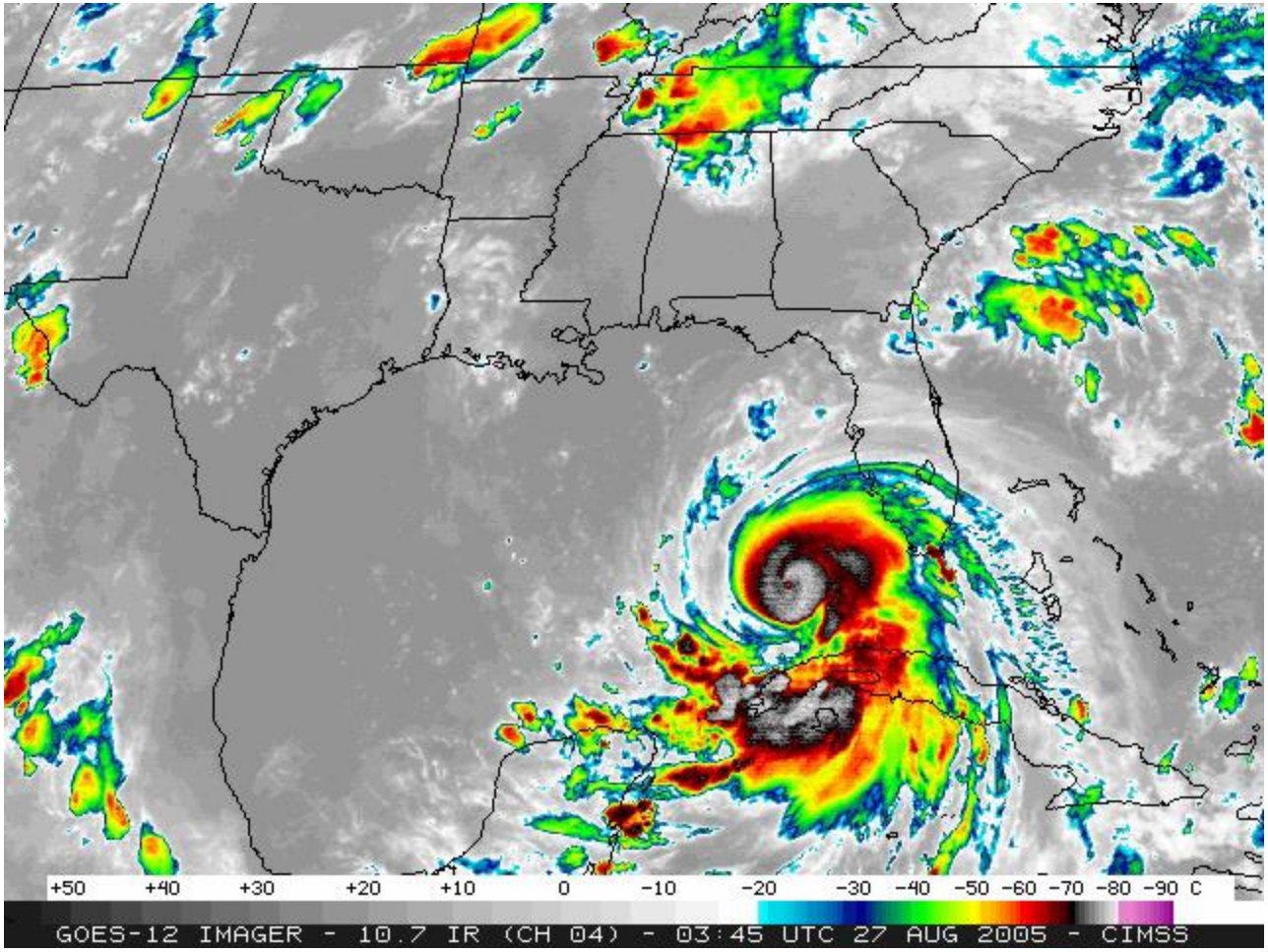
August 26, 23Z



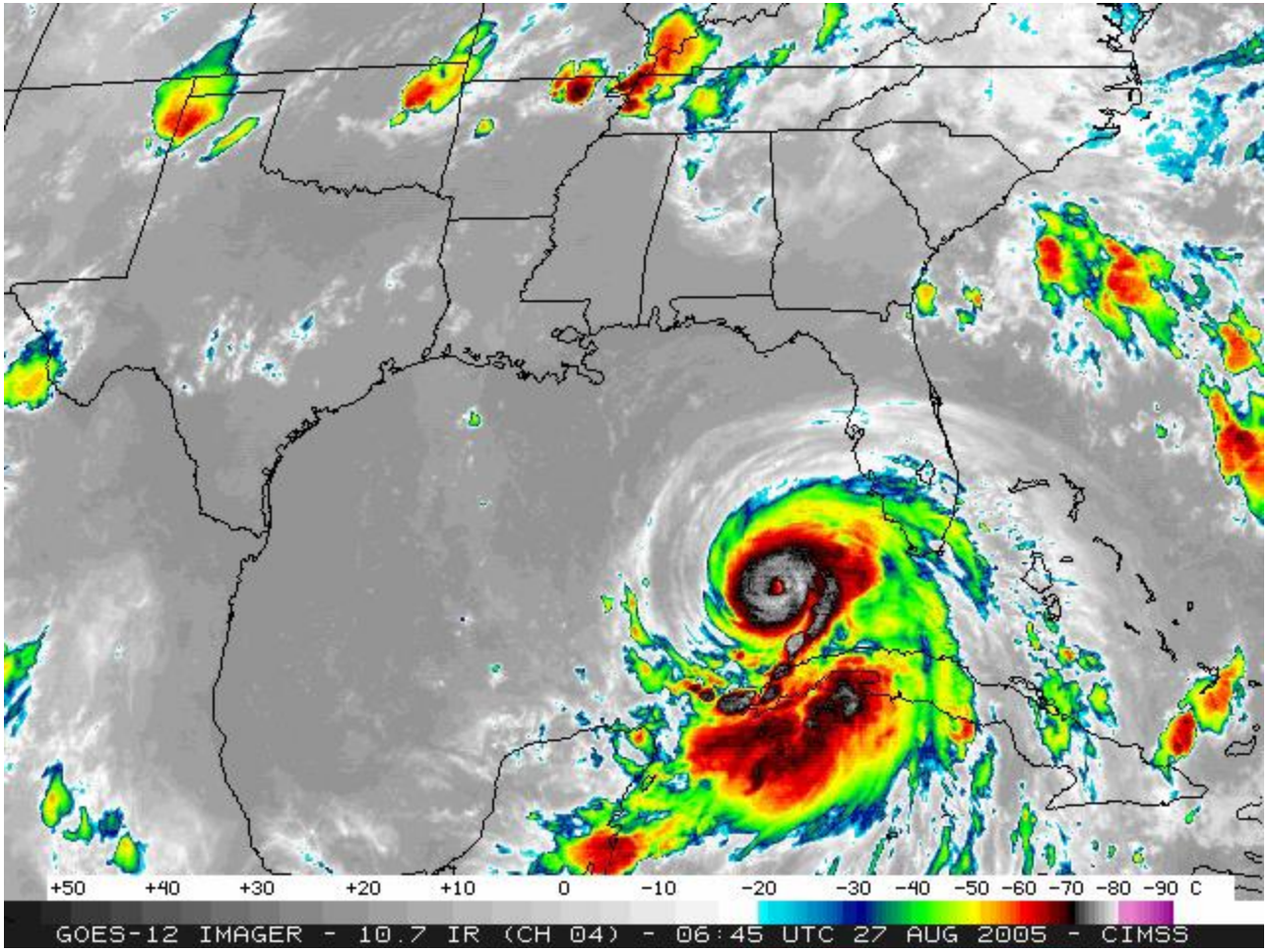
August 27, 02Z



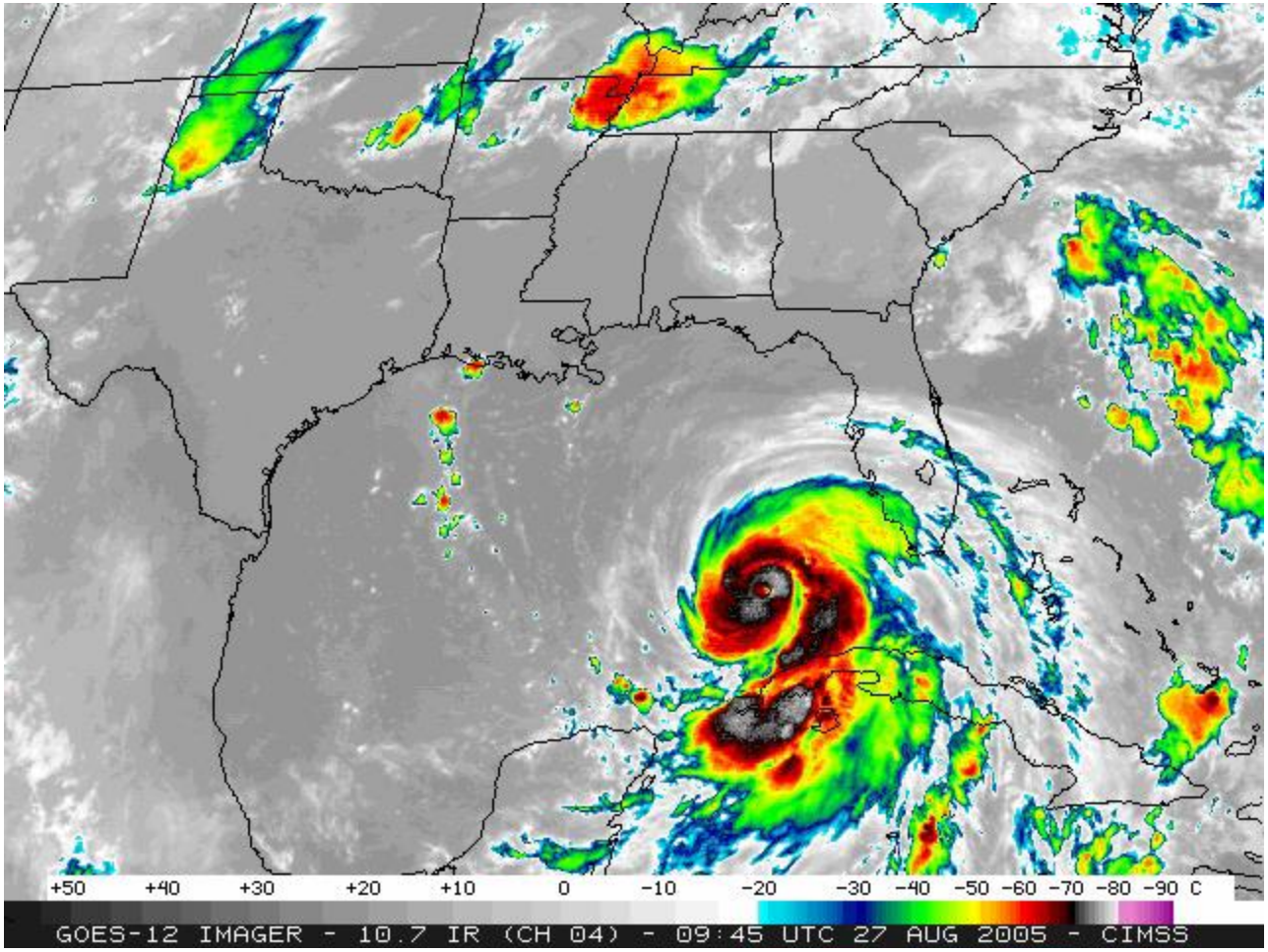
August 27, 04Z



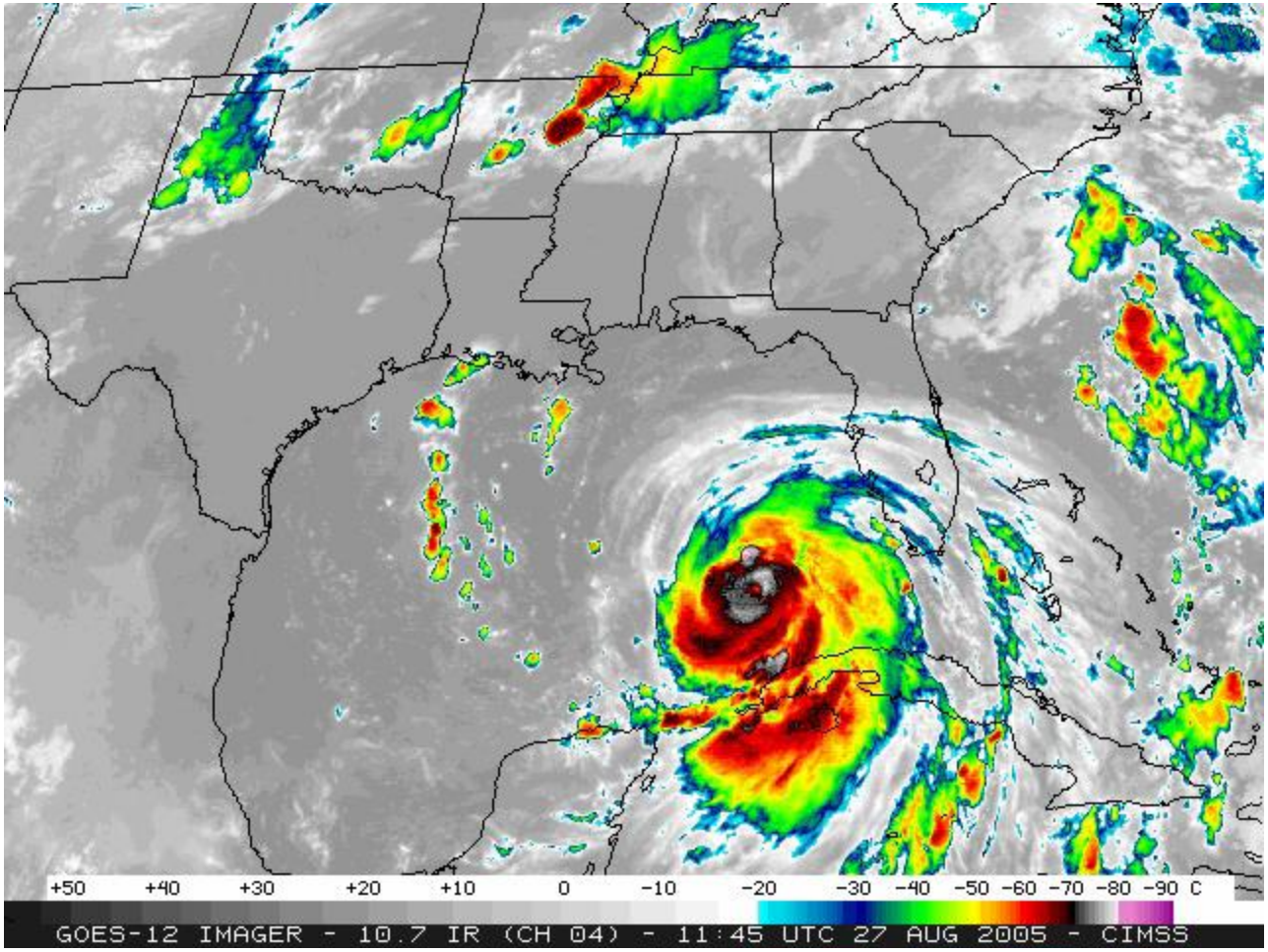
August 27, 07Z



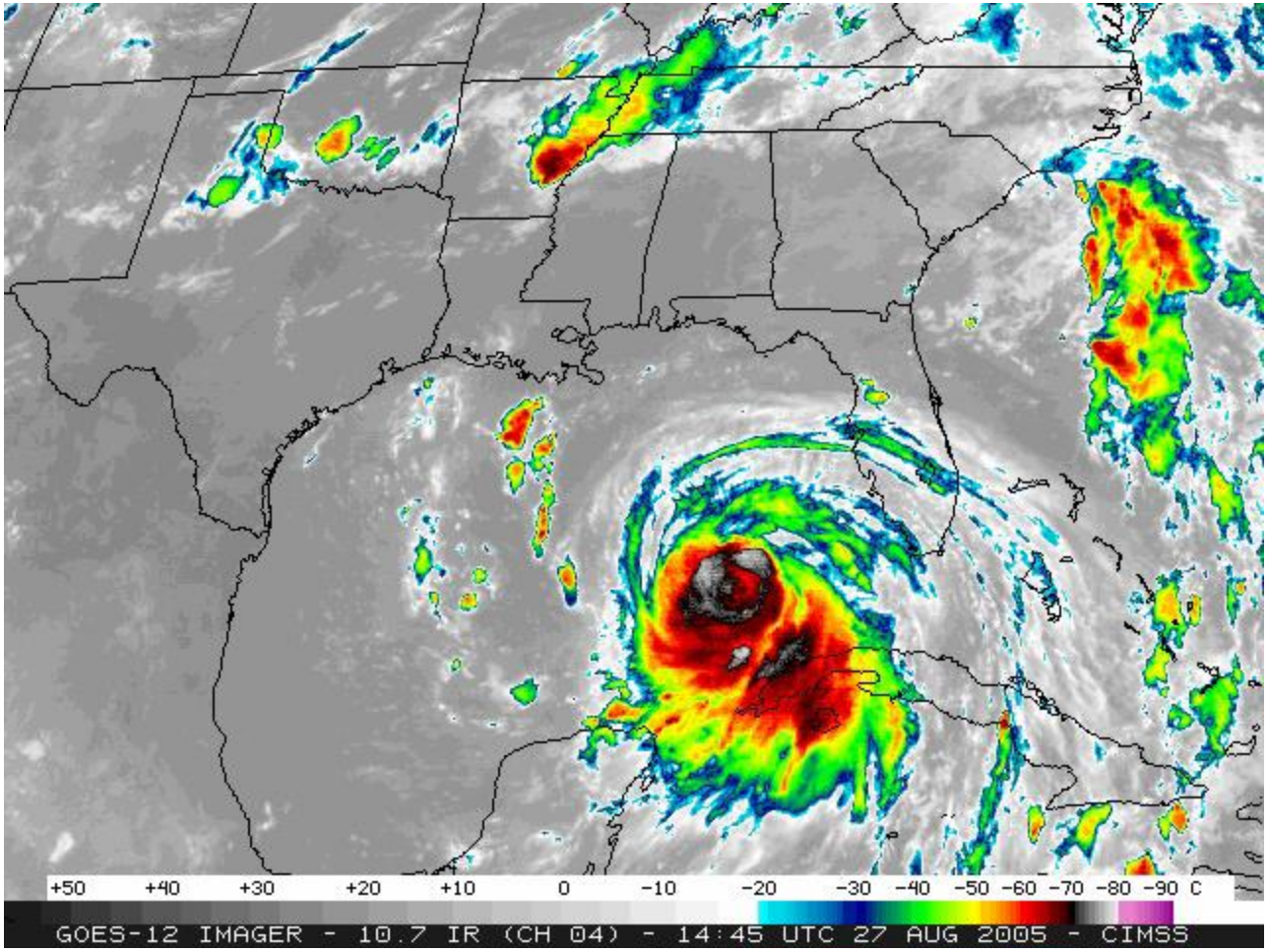
August 27, 10Z



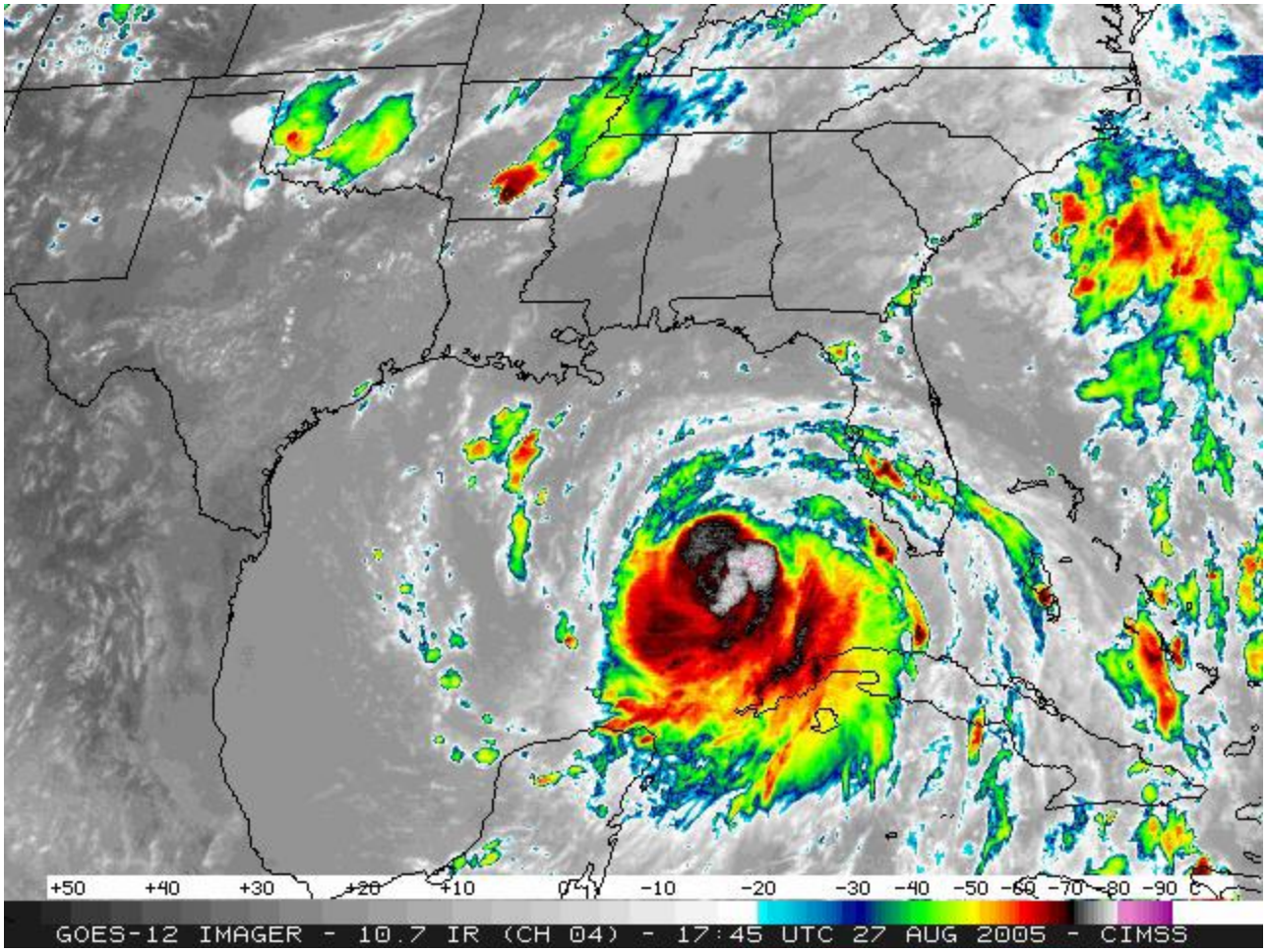
August 27, 12Z



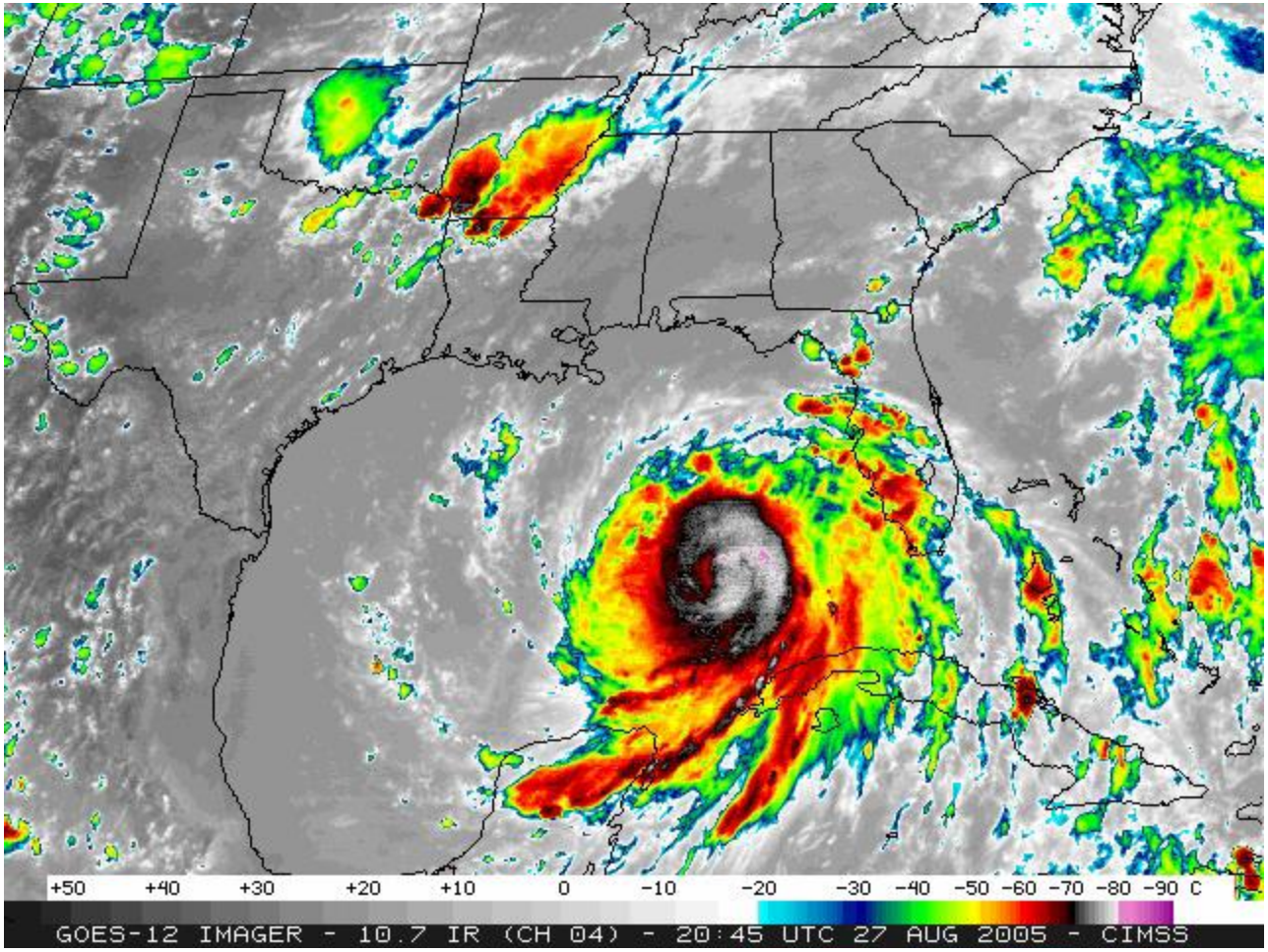
August 27, 15Z



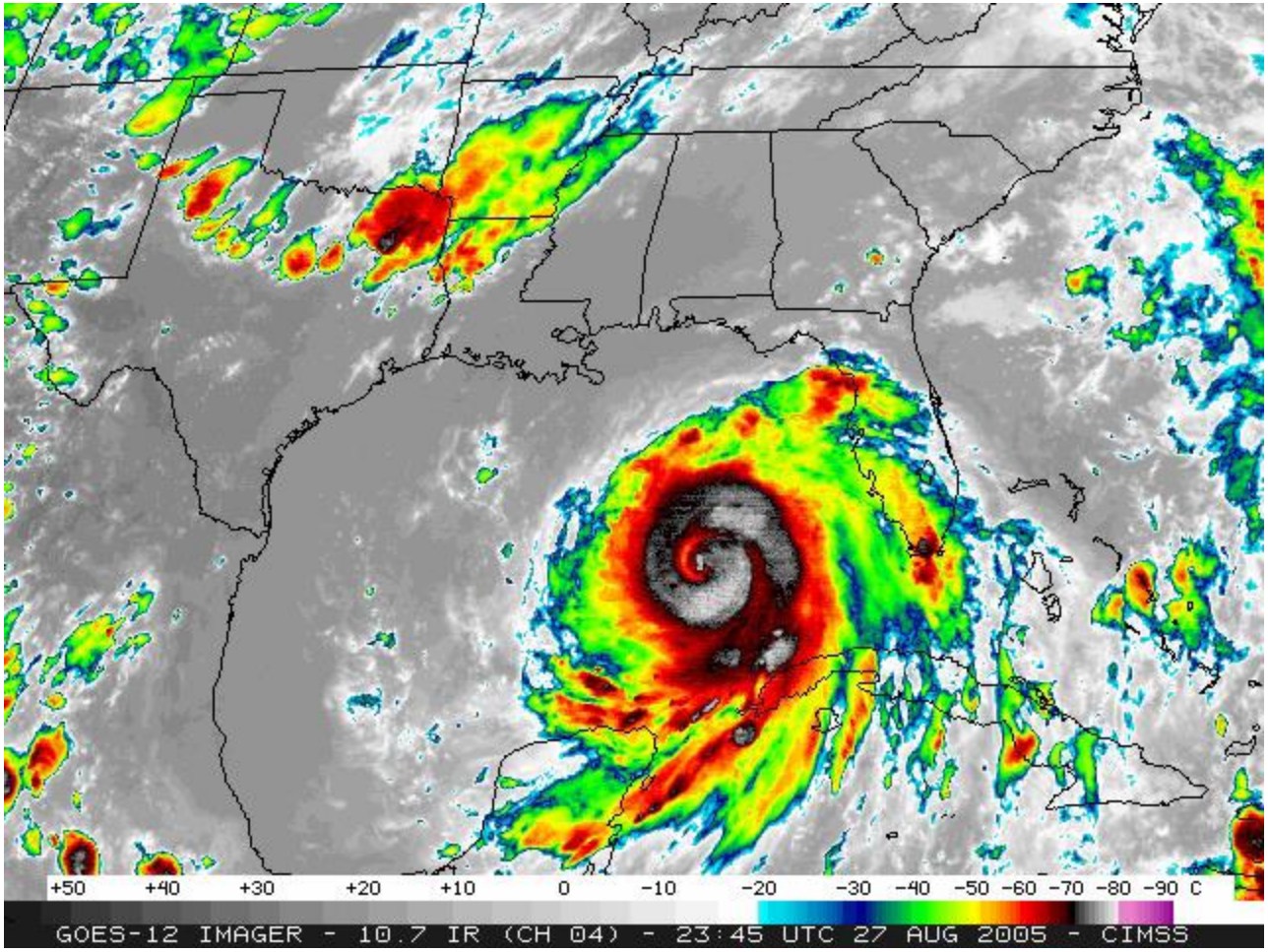
August 27, 18Z



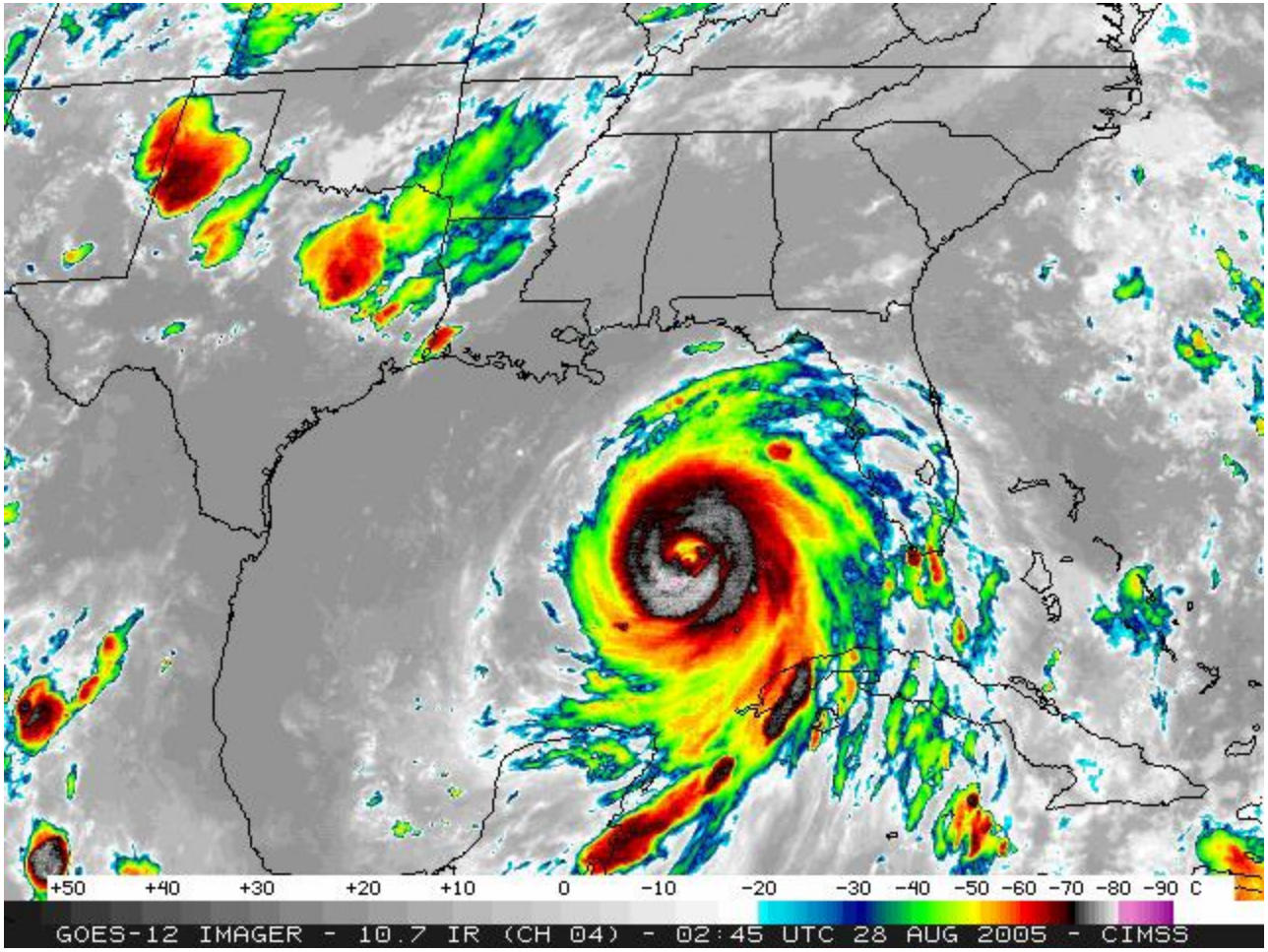
August 27, 21Z



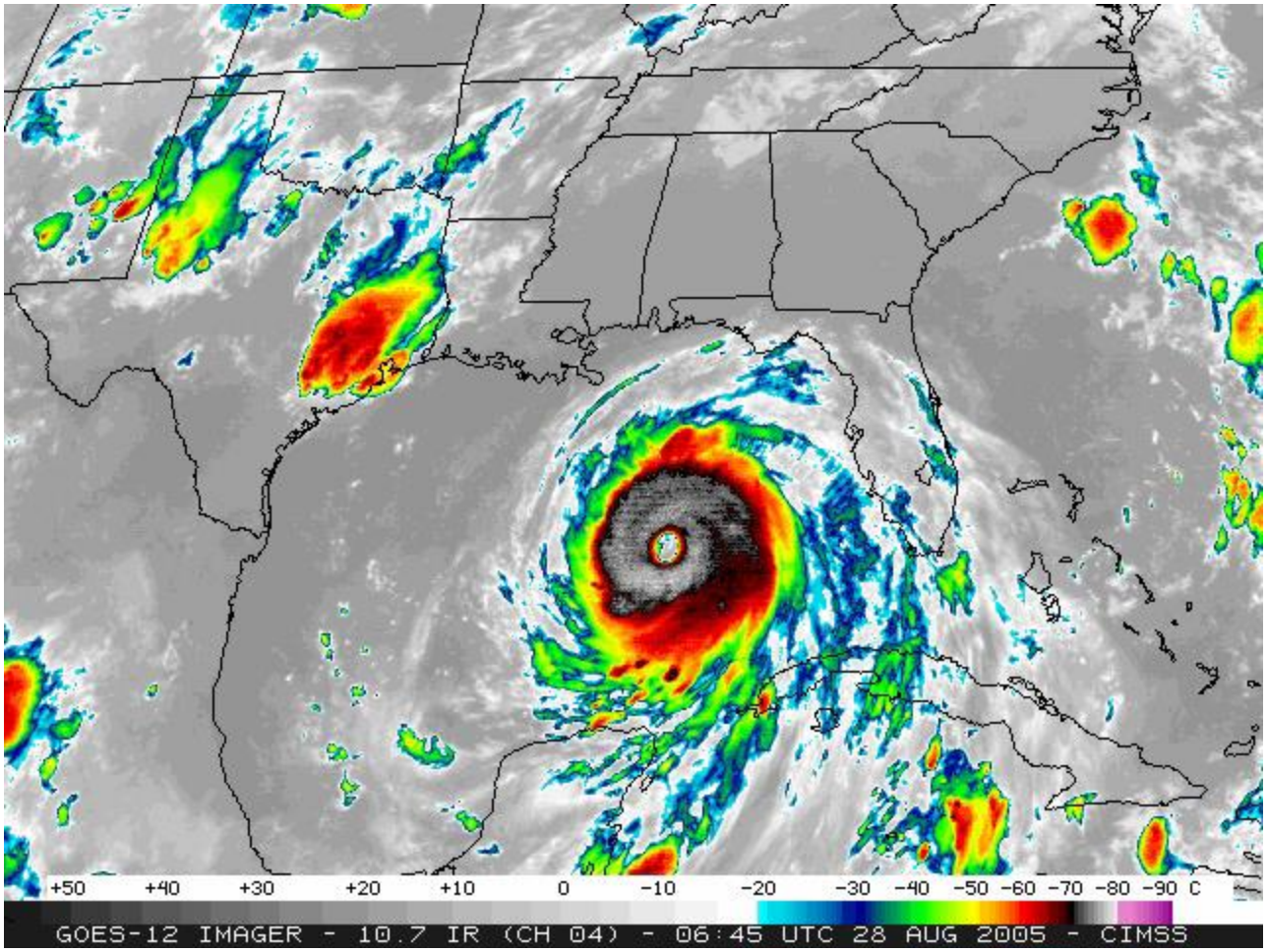
August 28, 00Z



August 28, 03Z

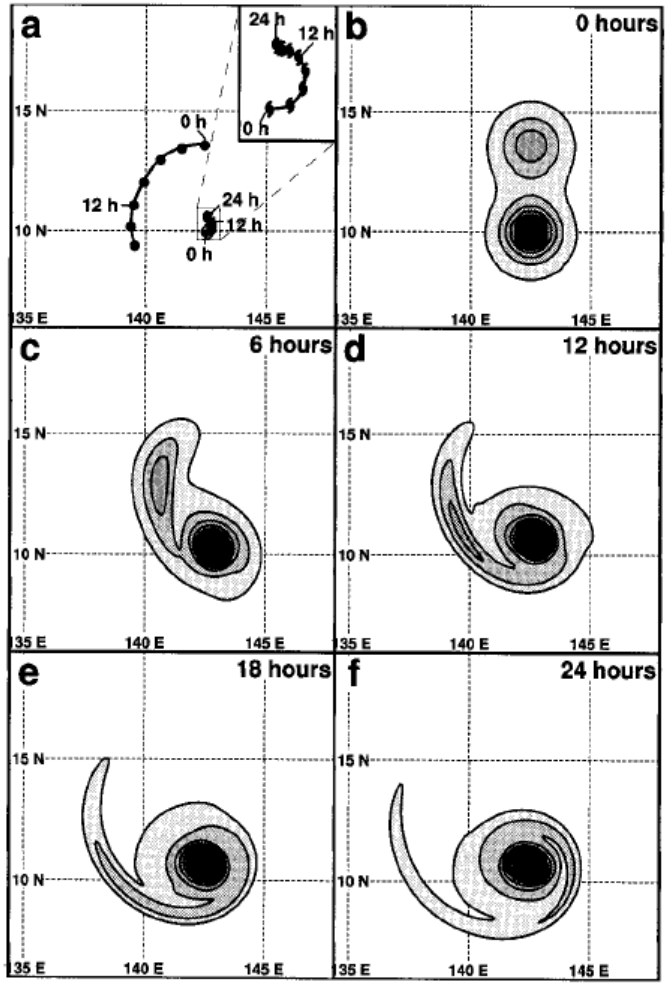


August 28, 07Z

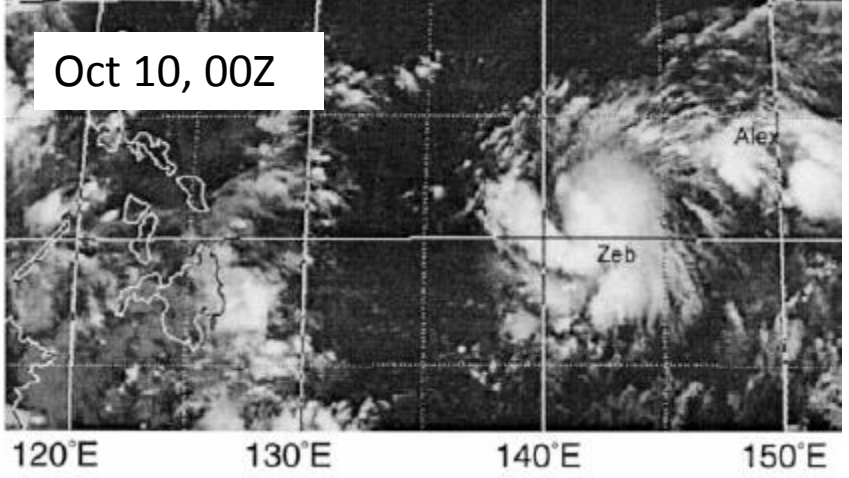


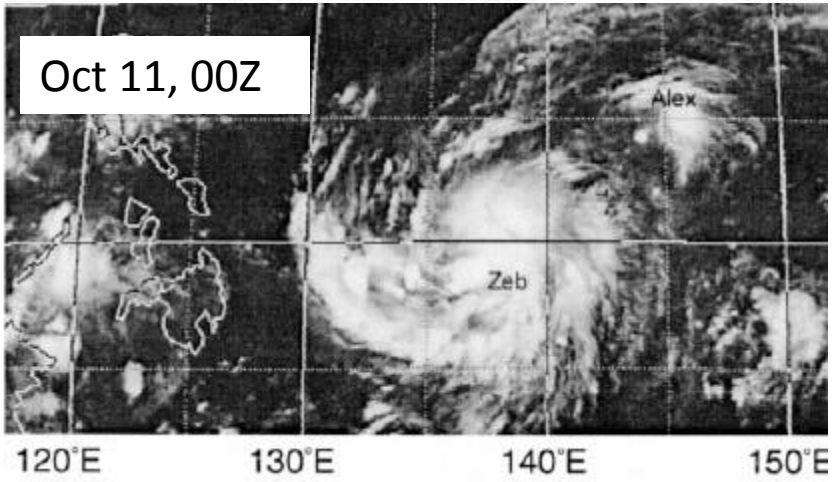
Vortex merger ideas

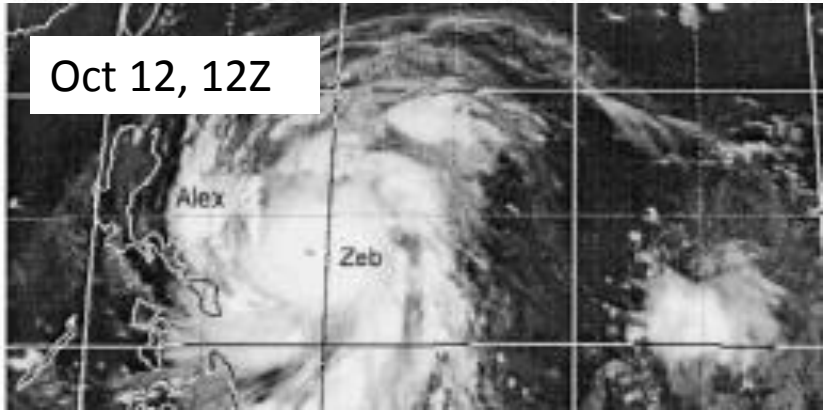
(Lander, Holland, Dietachmayer 1993, 1994)



Ritchie and Elsberry 2000

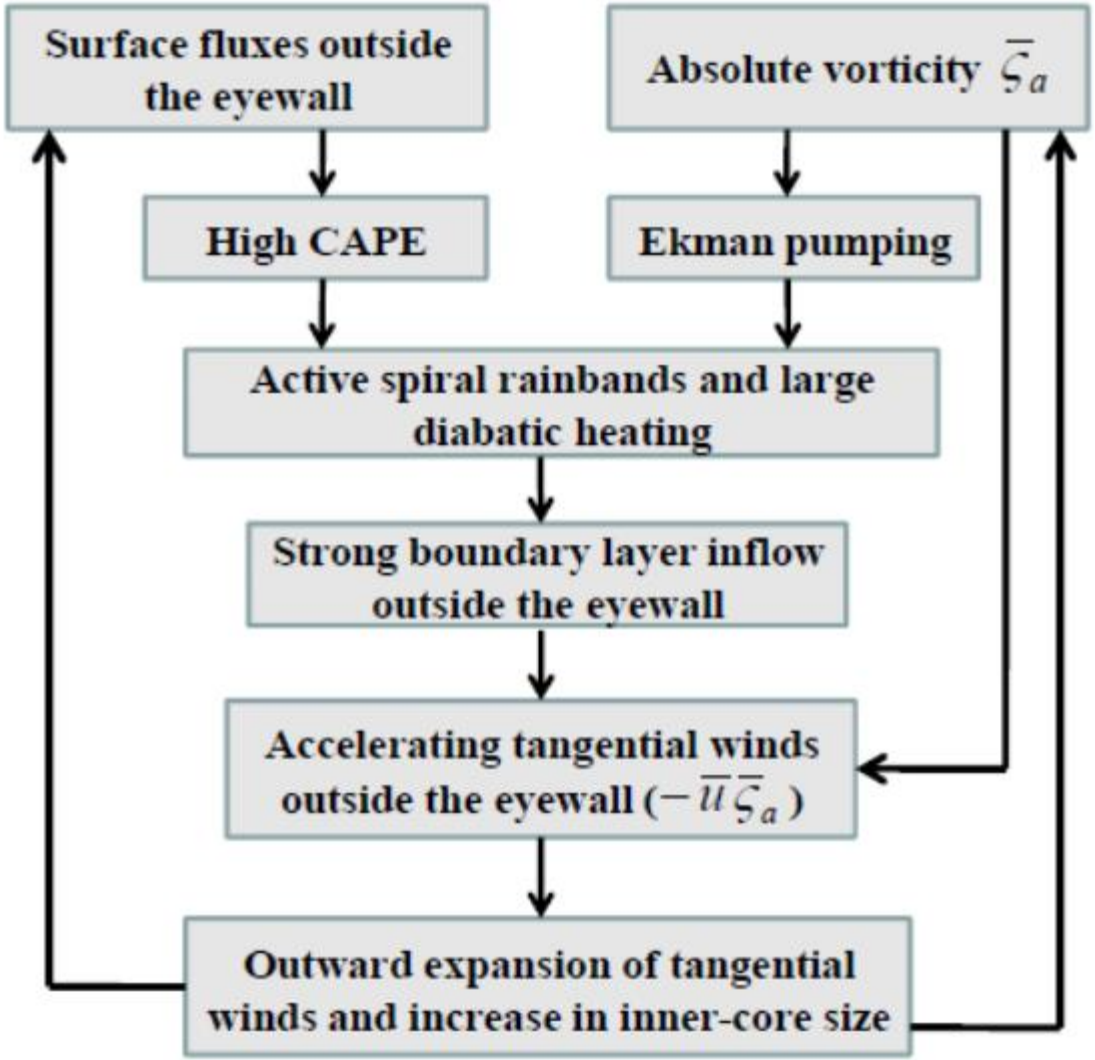




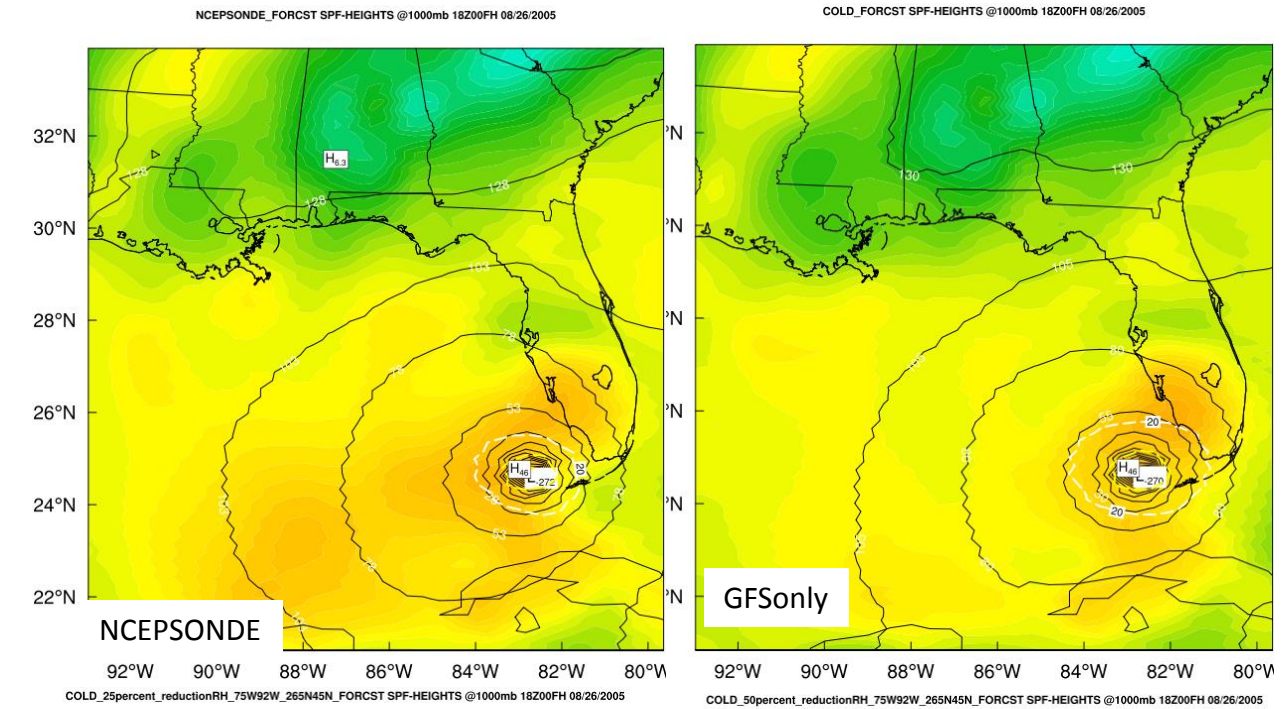


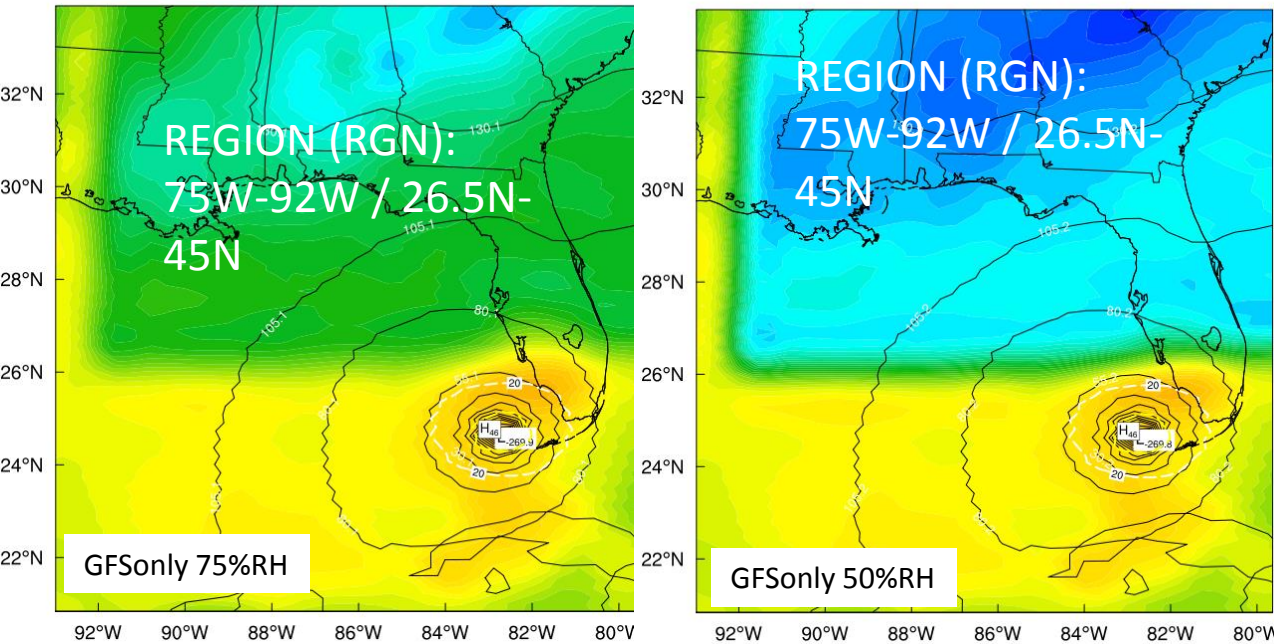
Kuo, Chen, and Lin 2000

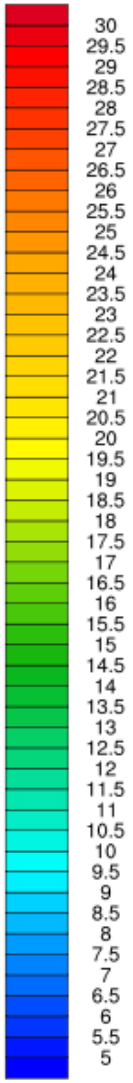
Feedback to environmental moisture (Xu and Wang 2010)



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







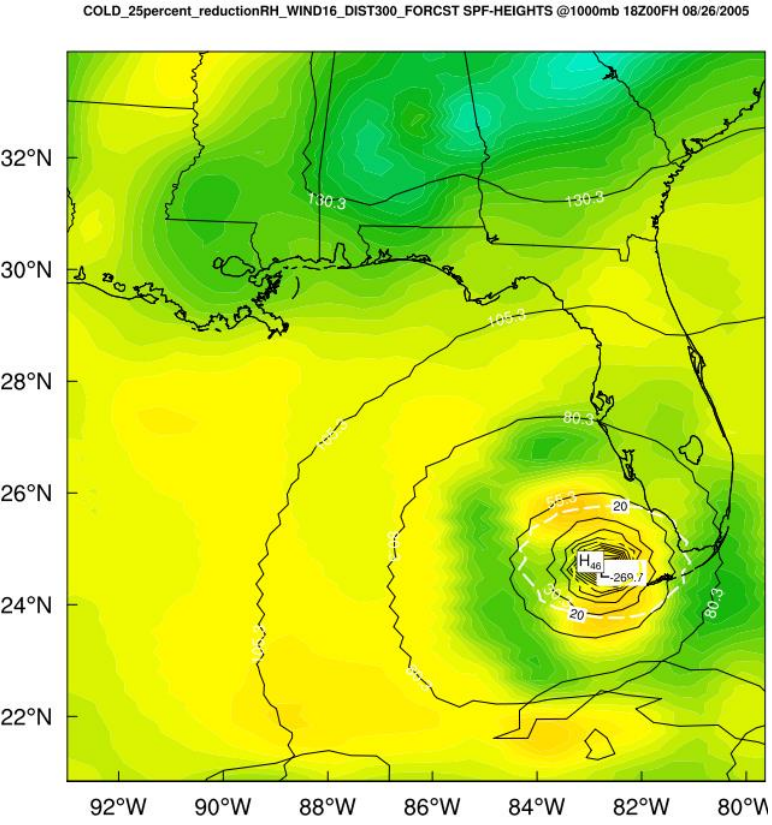
HWRF GFSonly versus

GFSonly modified trough,

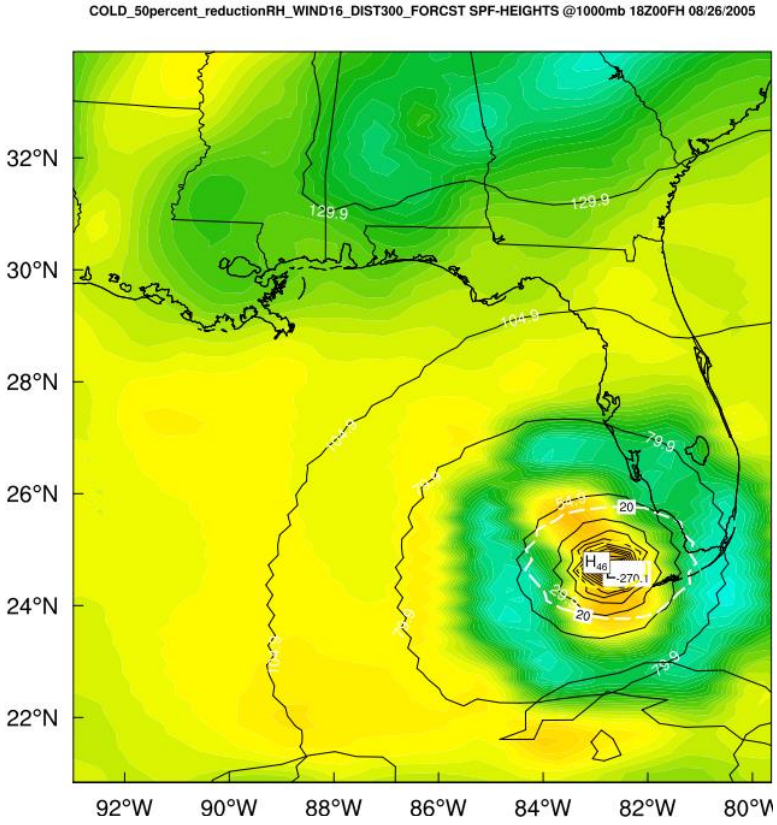
and GFS only with 25% and 50% reduced RH within the RGN,

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

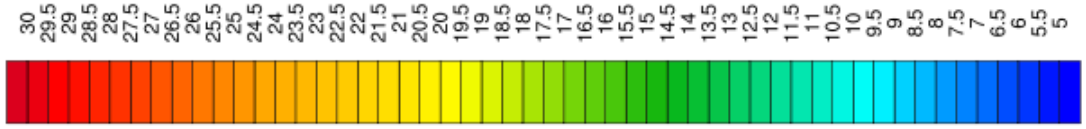
and 50%RH reduction where wspd <17 and distance <300 km, >50km.

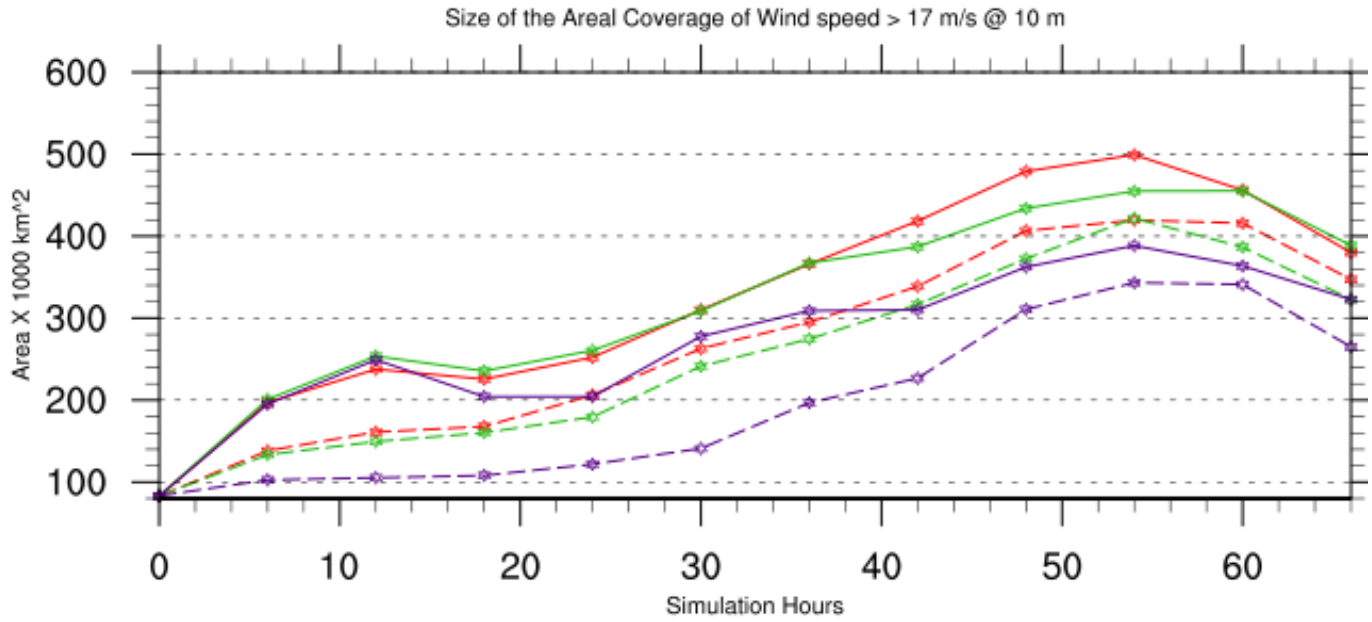


GFSonly 75%RH-WTHNEST



GFSonly 50%RH-WTHNEST





COLD_MODTROUGH_80W84W_30N33N_FORCST

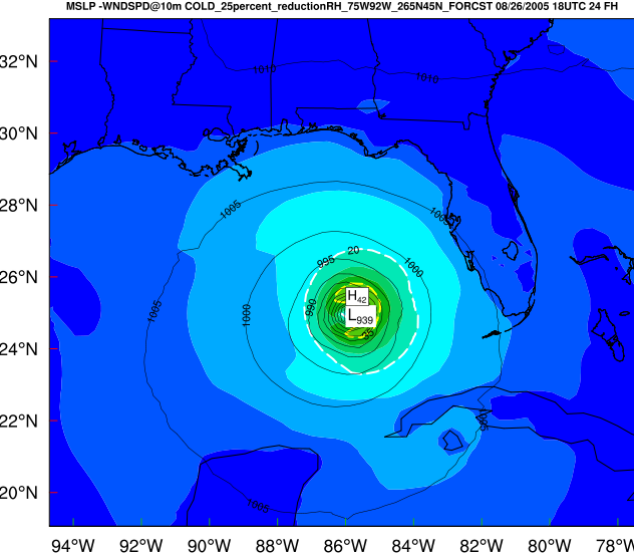
COLD_25percent_reductionRH_WIND16_DIST300_MODTROUGH_FORCST **NEST**

COLD_25percent_reductionRH_75W92W_265N45N_FORCST **RGN**

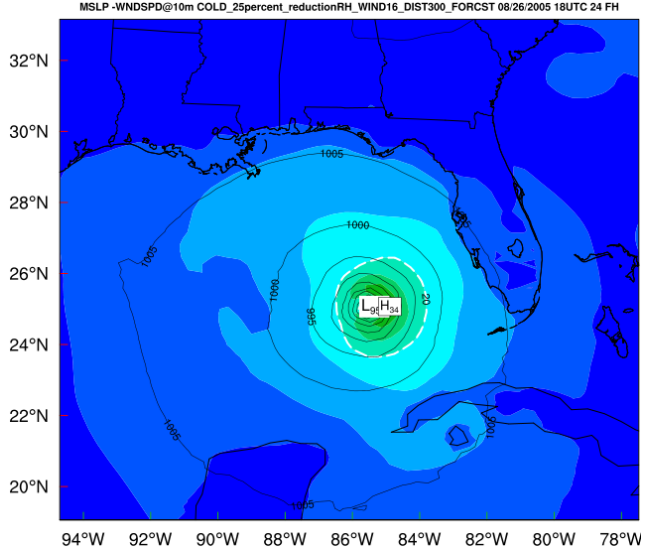
COLD_25percent_reductionRH_WIND16_DIST300_FORCST **NEST**

COLD_50percent_reductionRH_75W92W_265N45N_FORCST **RGN**

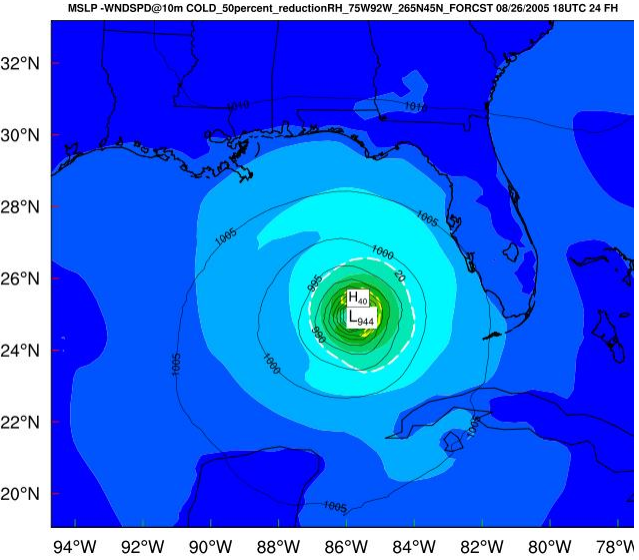
COLD_50percent_reductionRH_WIND16_DIST300_FORCST **NEST**



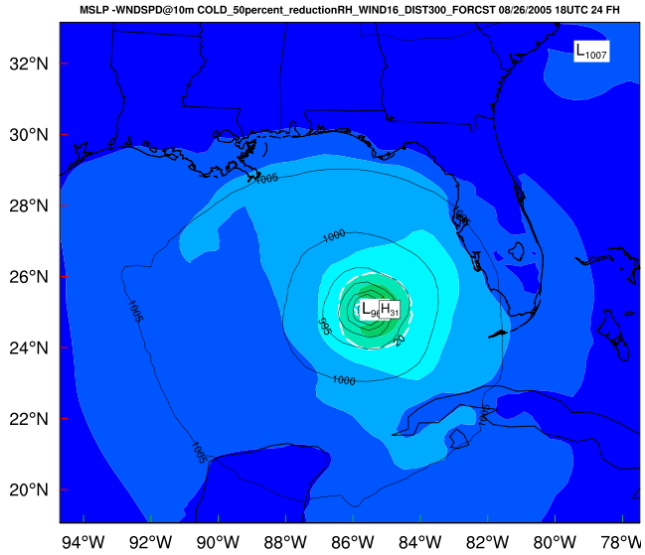
GFSonly 75%RH-RGN 24FH



GFSonly 75%RH-NEST 24FH



GFSonly 50%RH-RGN 24FH



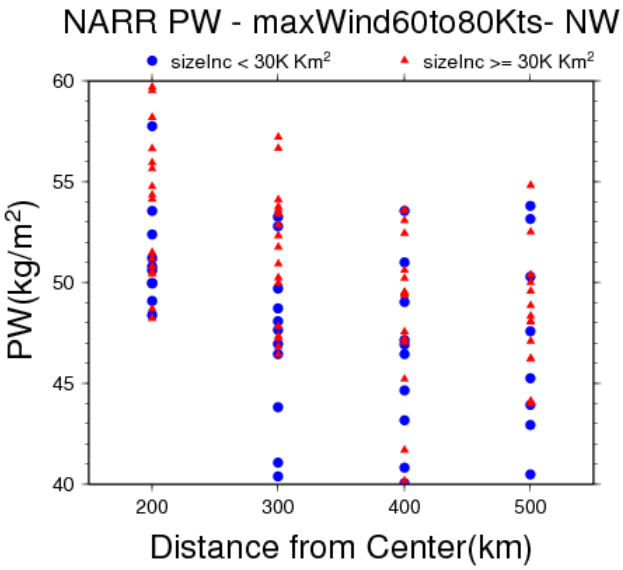
GFSonly 50%RH-NEST 24FH

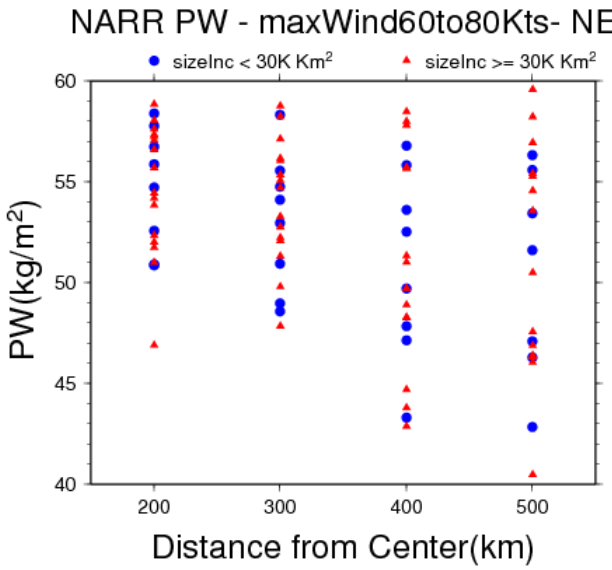
Is there a predictive moisture signal?

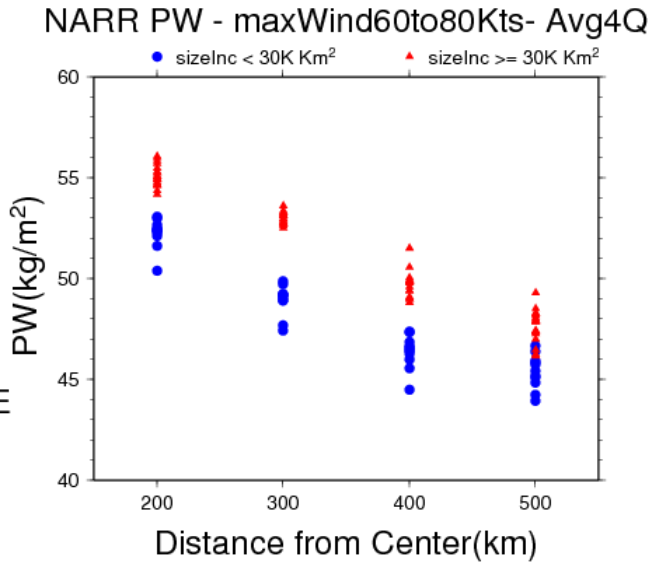
We examined historical storms vs precipitable water

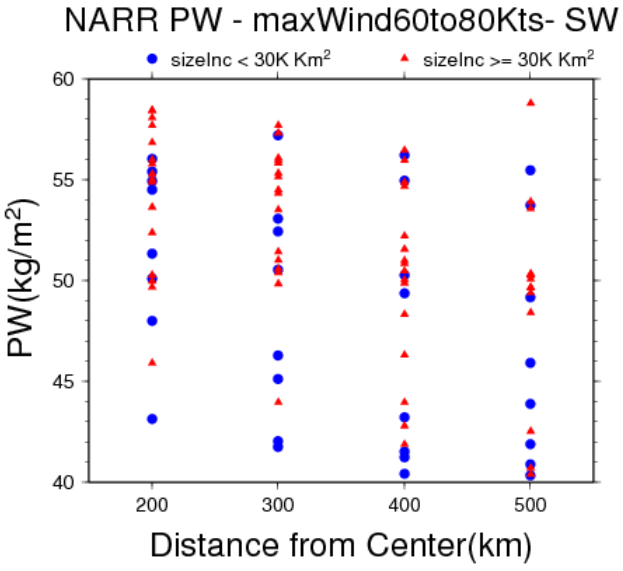
Definition of Precipitable Water: total water vapor contained in a column of the atmosphere.

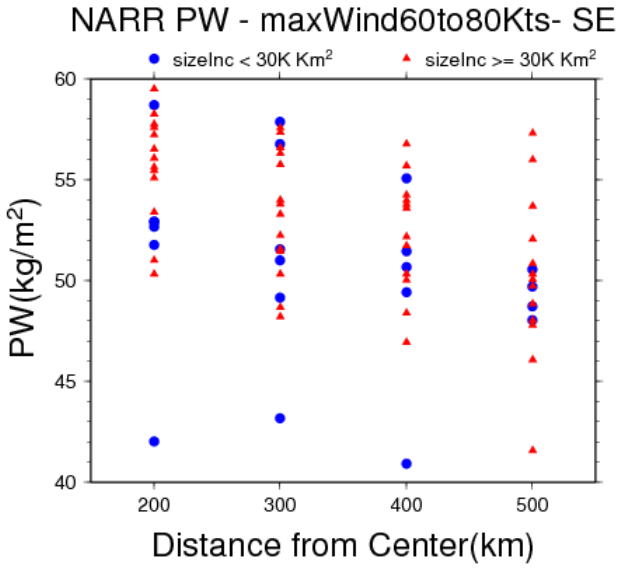
Extended Best Track 2000-2010 Central Atlantic To Florida storms intensified more than 10 Kts in 24 Hrs
60 Kts <= MaxWind < 80Kts 30K Sq. Km cutoff PW scale 40 to 60



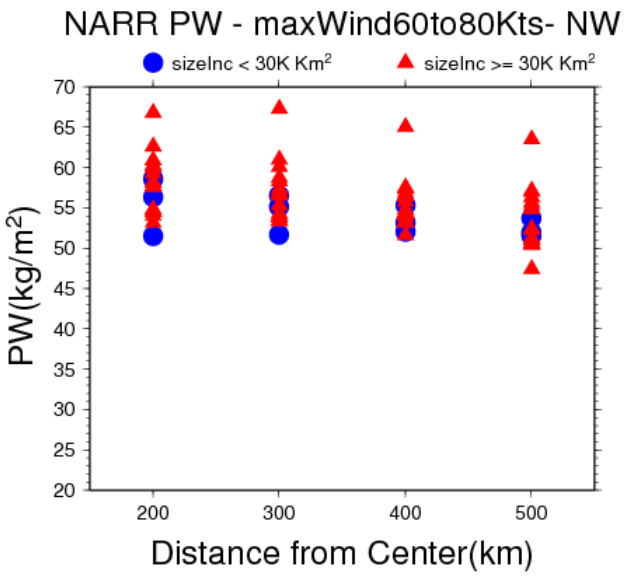


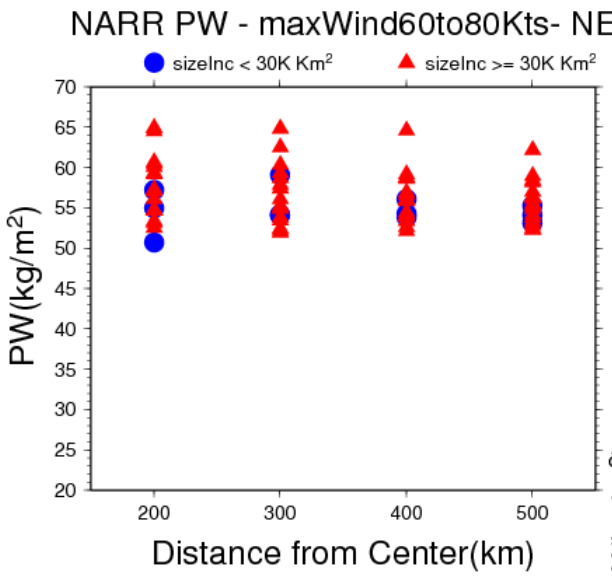


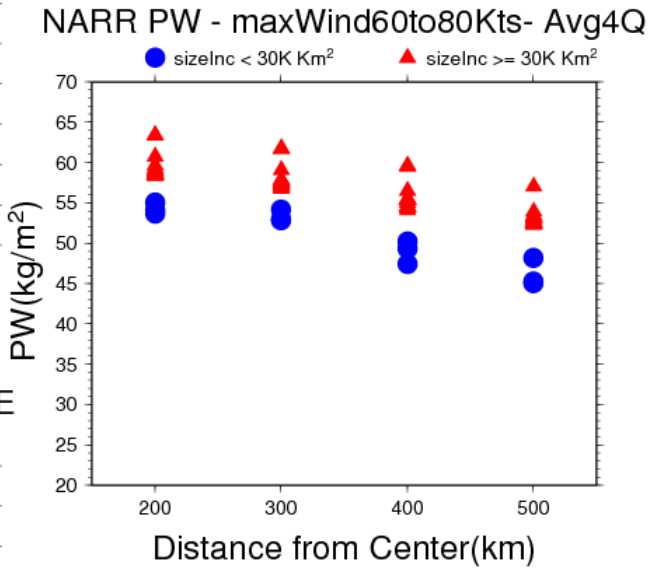


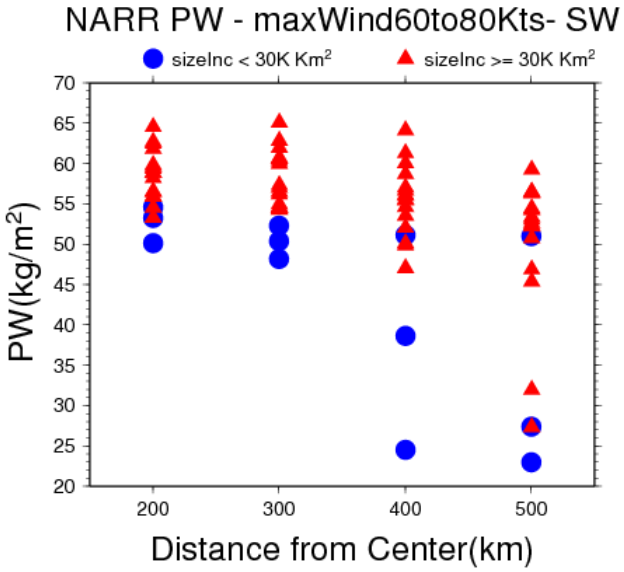


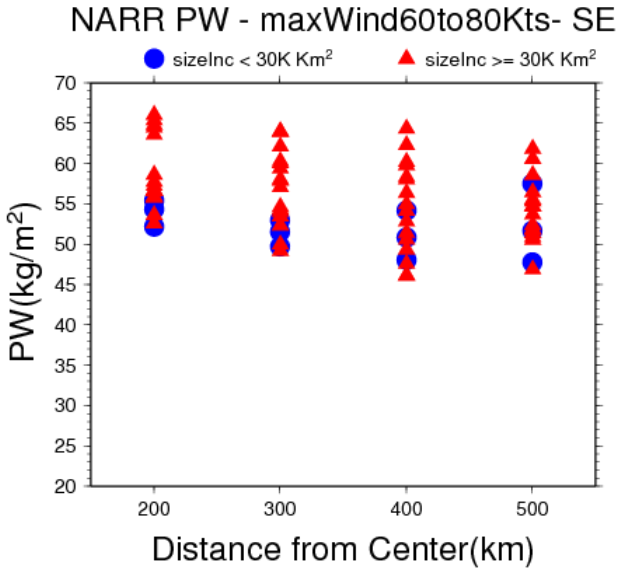
Extended Best Track 1988-2010 Gulf of Mexico storms intensified more than 10 Kts in 24 Hrs
60 Kts <= MaxWind < 80Kts 30K Sq. Km cutoff PW scale 20 to 70











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