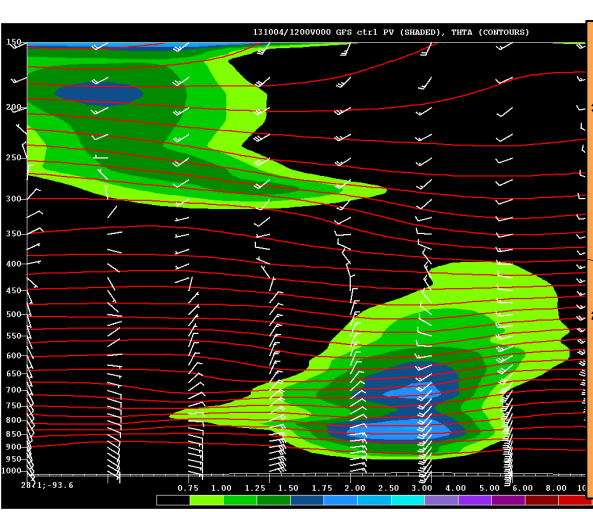
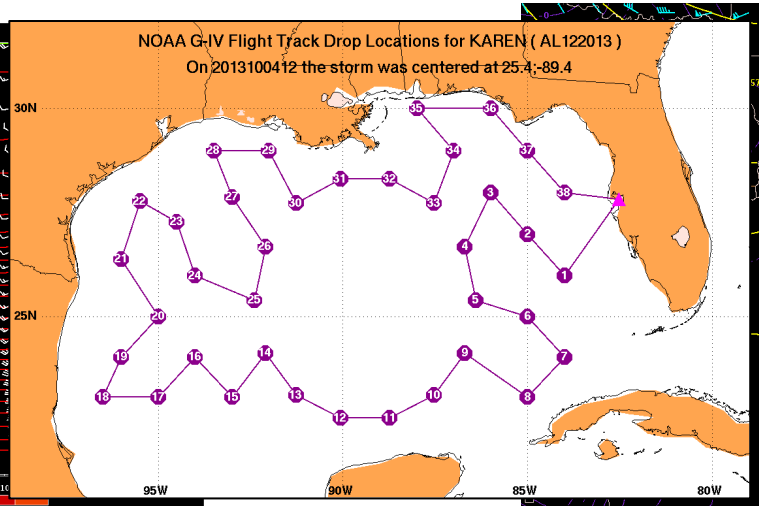
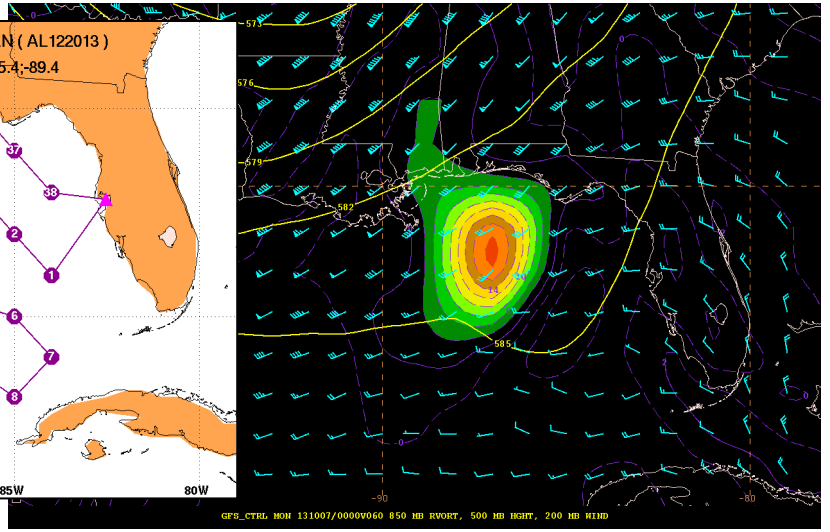
# Assimilation of Supplemental Observations during Tropical Cyclones in the NCEP Hybrid Gridpoint Statistical Interpolation (GSI) scheme

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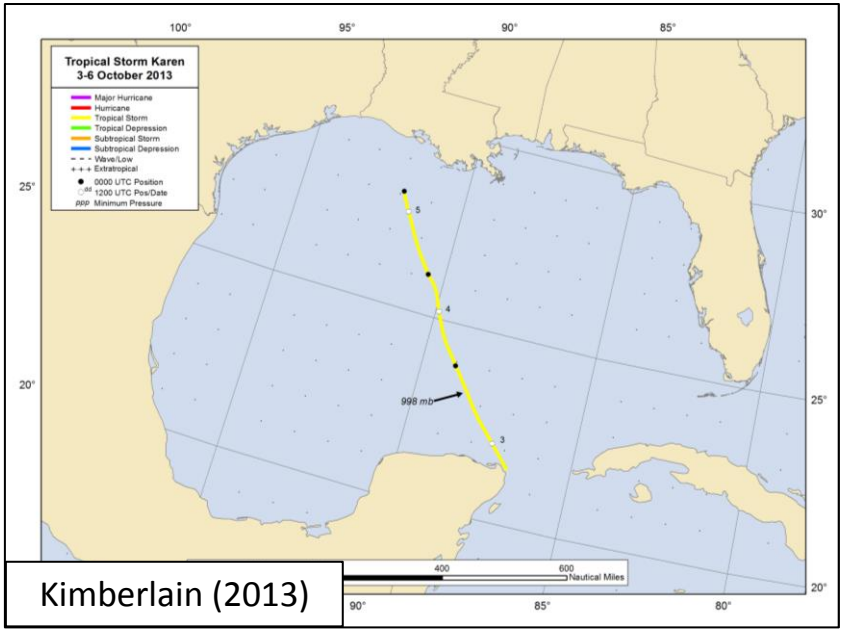
**31st Conference on Hurricanes and Tropical Meteorology**
**1 April 2014**

# Motivation

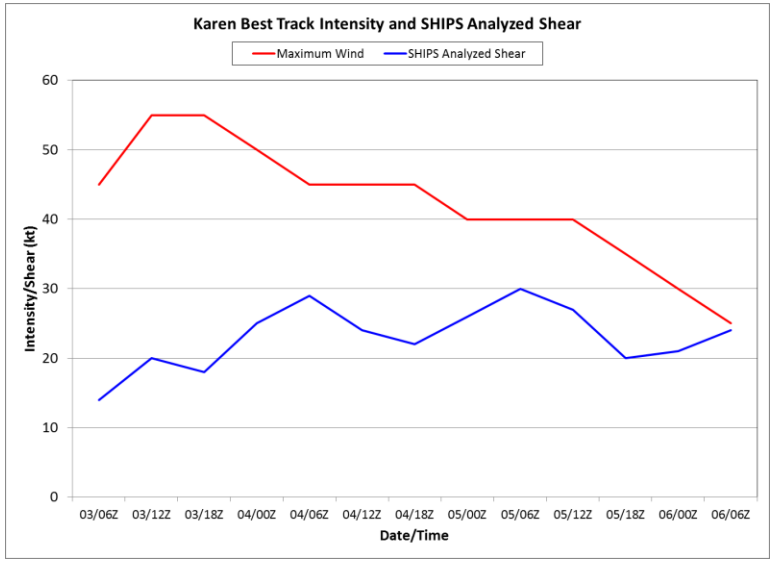
- Previous studies (e.g., Aberson 2010; Majumdar et al. 2013) have examined the impact of synoptic surveillance dropsonde data on GFS model forecasts of TC track
- In 2012 the NCEP Gridpoint Statistical Interpolation (GSI) data assimilation scheme was upgraded to use a hybrid ensemble-variational approach with characteristics of 3D-Var and an Ensemble Kalman Filter (Wang et al. 2013)
- What is the impact of these supplemental observations in the new hybrid GSI on TC intensity and structure?

# Karen (2013)

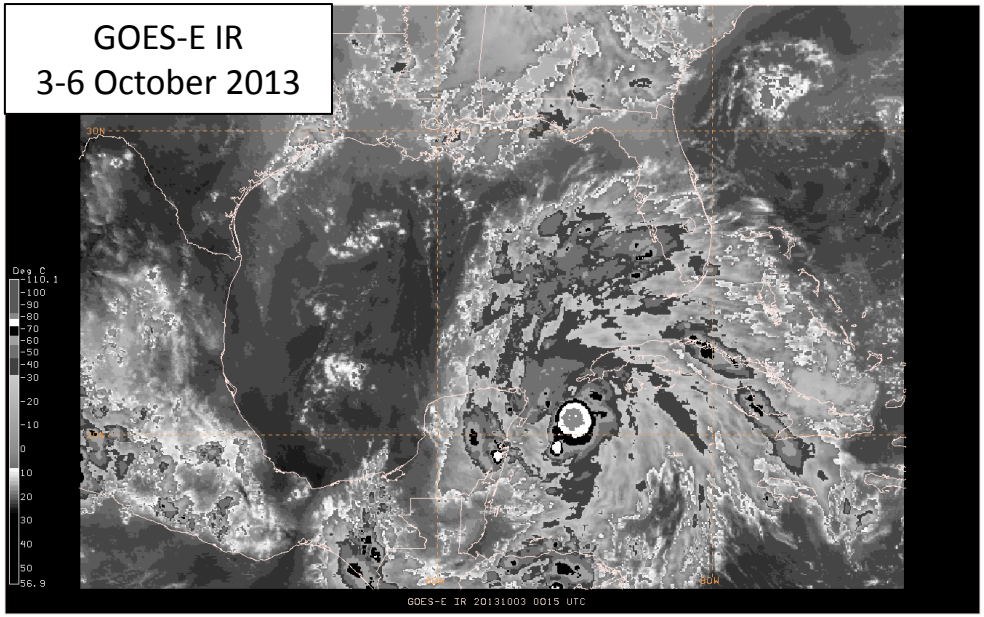
- Karen formed as a 45-kt tropical storm early on 3 October 2013 in the Gulf of Mexico and reached a peak intensity of 55 kt later that day despite moderate vertical shear
- As the shear increased Karen steadily weakened before dissipating on 6 October
- Operational TC intensity guidance and global models showed Karen strengthening before reaching the northern Gulf Coast
- Hurricane Watch was issued from Grand Isle, Louisiana, to Indian Pass, Florida




Kimberlain (2013)

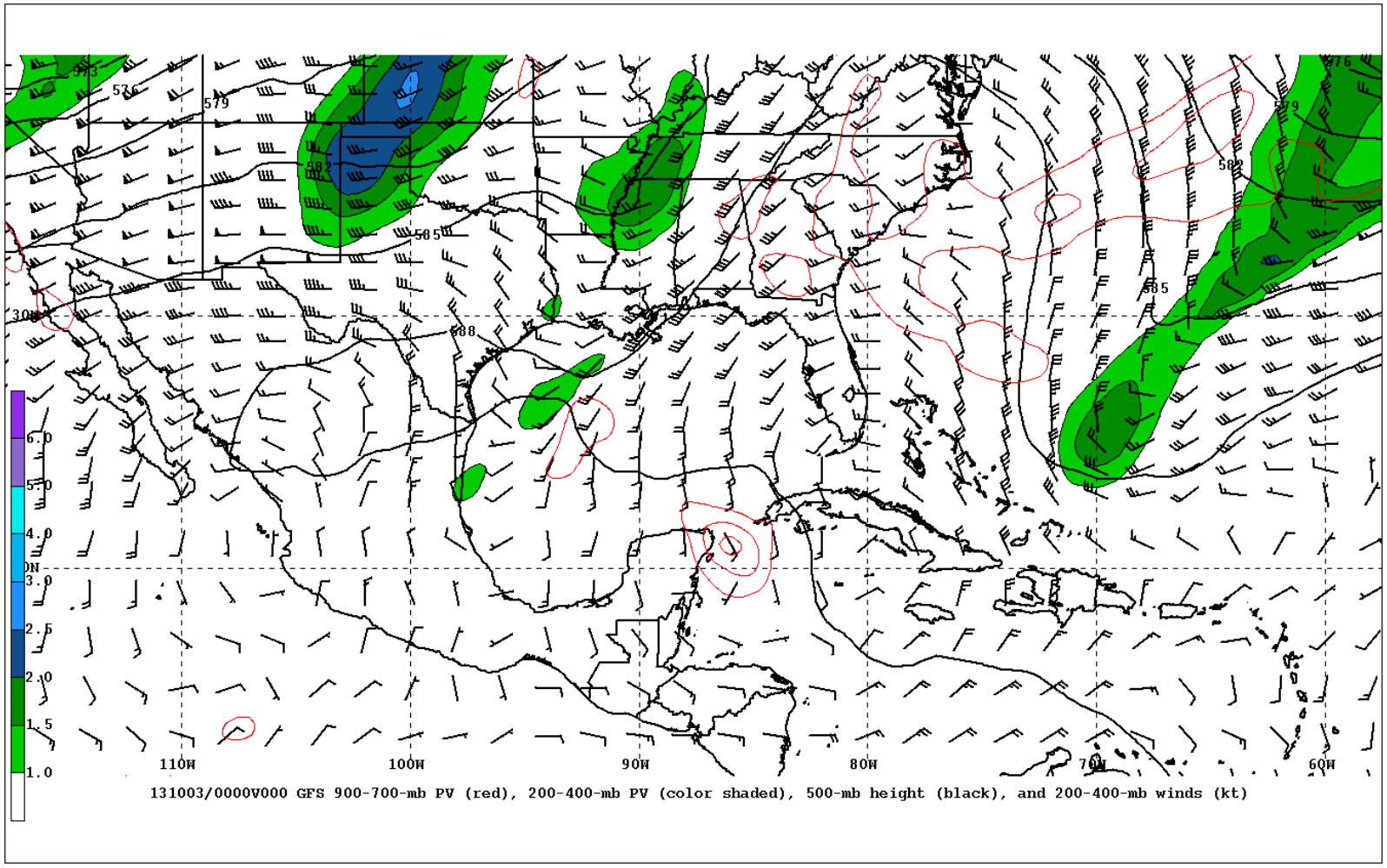



GOES-E IR
3-6 October 2013



# Karen Synoptic Evolution

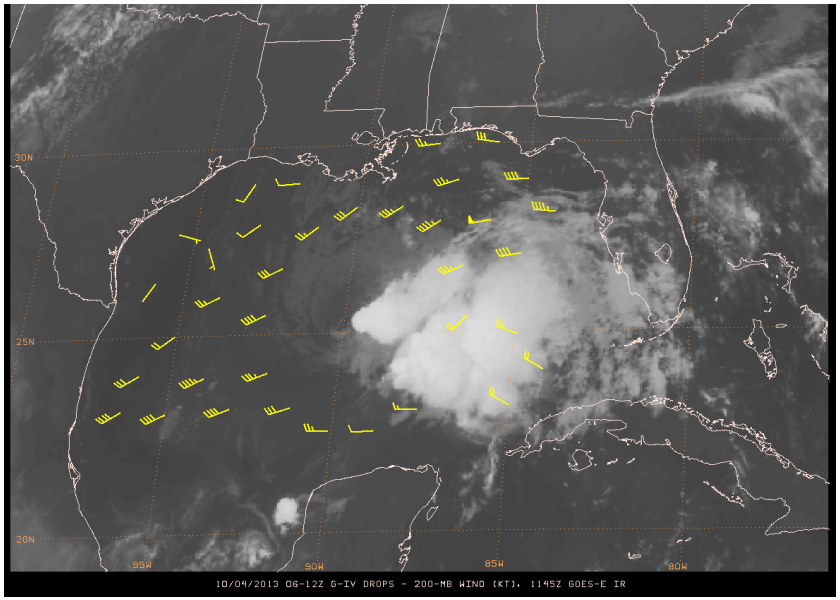
## GFS Analysis




200-400 mb PV, 900-700 mb PV, 500-mb heights, and 200-400 mb layer average winds (kt)

# Karen G-IV Mission

- After the completion of the G-IV mission, it was recognized operationally that the 12Z GFS run trended much weaker with the cyclone




G-IV dropsonde 200-mb winds (kt) and 1145 UTC GOES-E IR image

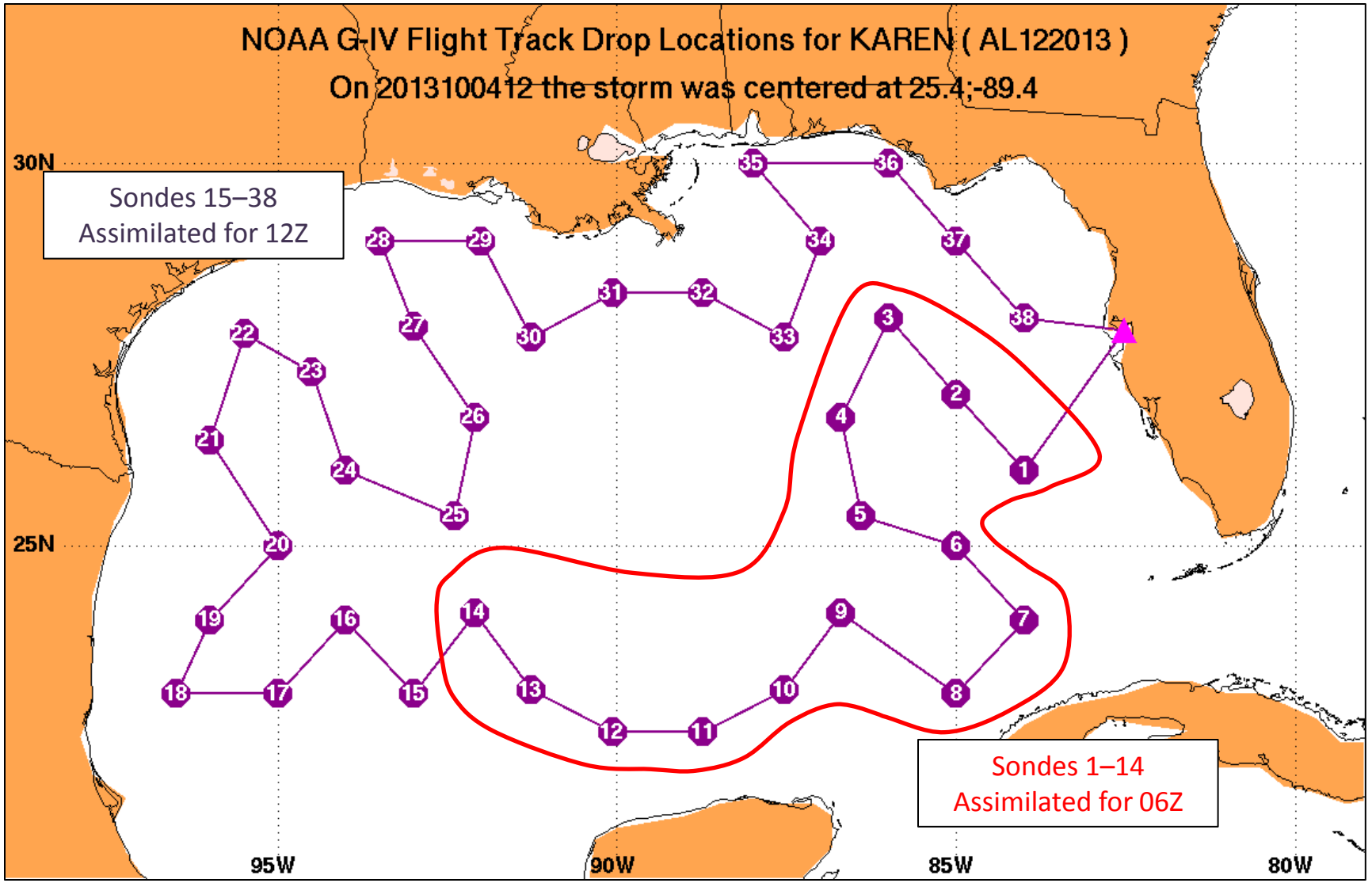
TROPICAL STORM KAREN DISCUSSION NUMBER 7
NWS NATIONAL HURRICANE CENTER MIAMI FL AL122013
400 PM CDT FRI OCT 04 2013

THE GLOBAL MODELS ARE NOW IN BETTER AGREEMENT ON THIS EVOLUTION...AND SHOW THE MID-LEVEL CIRCULATION WEAKENING OR DISSIPATING ENTIRELY IN THE NEXT DAY OR TWO. IN PARTICULAR THE GFS IS WEAKER WITH ITS FORECAST OF KAREN AFTER DATA FROM THE NOAA GULFSTREAM-IV JET...WHICH SHOWED 200-MB WINDS WEST OF KAREN STRONGER THAN PREVIOUSLY ANALYZED...WERE INCORPORATED INTO THE 12Z ANALYSIS. AFTER 24 HOURS... KAREN COULD STRENGTHEN A LITTLE DUE TO AN INCREASE IN UPPER-LEVEL DIVERGENCE AHEAD OF A MID-LATITUDE TROUGH...BUT SIGNIFICANT STRENGTHENING IS NOT EXPECTED. AN ALTERNATIVE SCENARIO IS THAT KAREN COULD BECOME COMPLETELY DECOUPLED FROM THE DEEP CONVECTION AND WEAKEN.

**Can we quantify this impact?**

# Karen NOAA G-IV Synoptic Surveillance Mission

## 0530-1300 UTC 4 October 2013



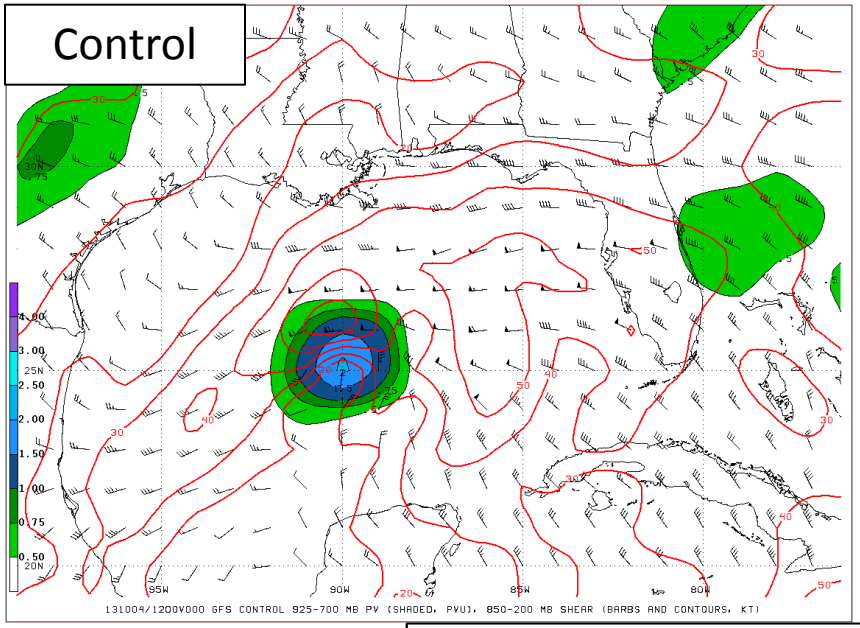
# Experiment Methodology

- Quantify the impact of these observations using data denial experiments
- Experiments run cycling GFS with the GSI hybrid EnKF data assimilation
  - Include all data (Control)
  - Exclude G-IV dropsonde data (No Drop)
- Compare evolution of the TC and environment
- Run SHIPS statistical-dynamical TC intensity model (DeMaria et al. 2005) on output from Control and No Drop experiments
- All results shown here are from the 12Z cycle on 4 October to account for the impact of all dropsondes

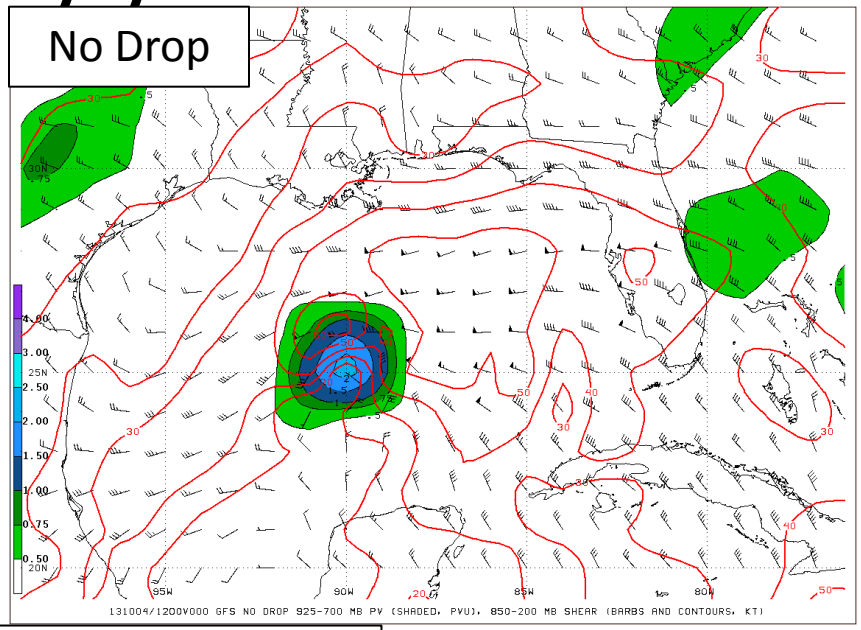
# Low-Level Vortex and Shear

## F00 – 12Z 10/4/2013

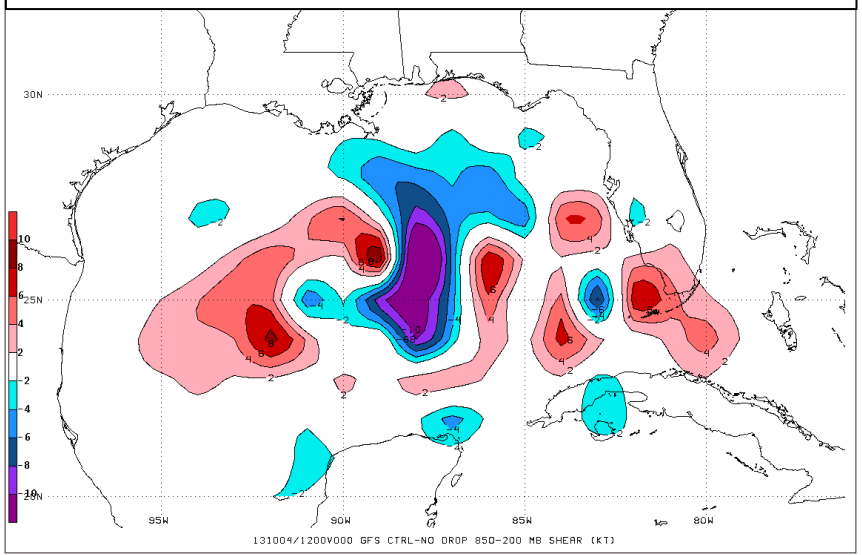
Control




No Drop




Shear Difference (Control – No Drop)

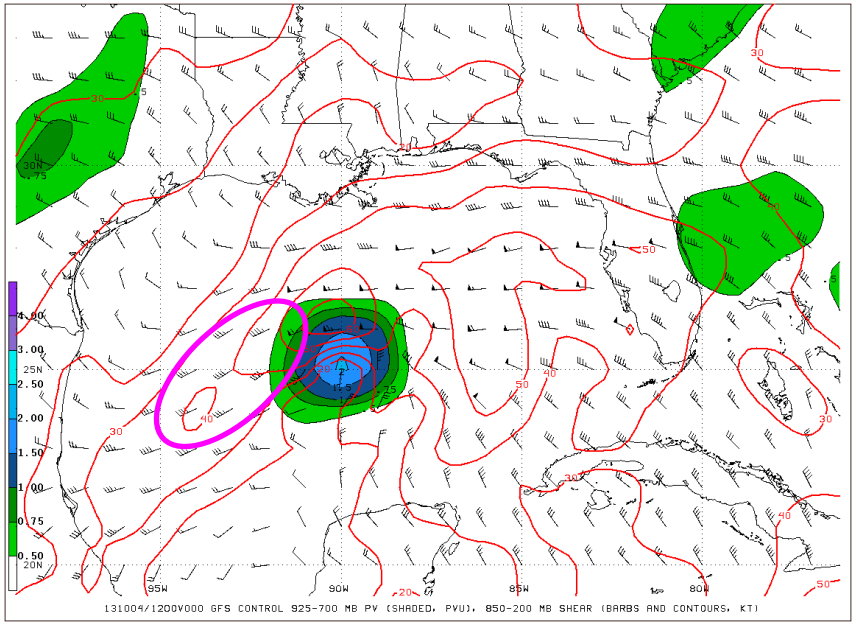


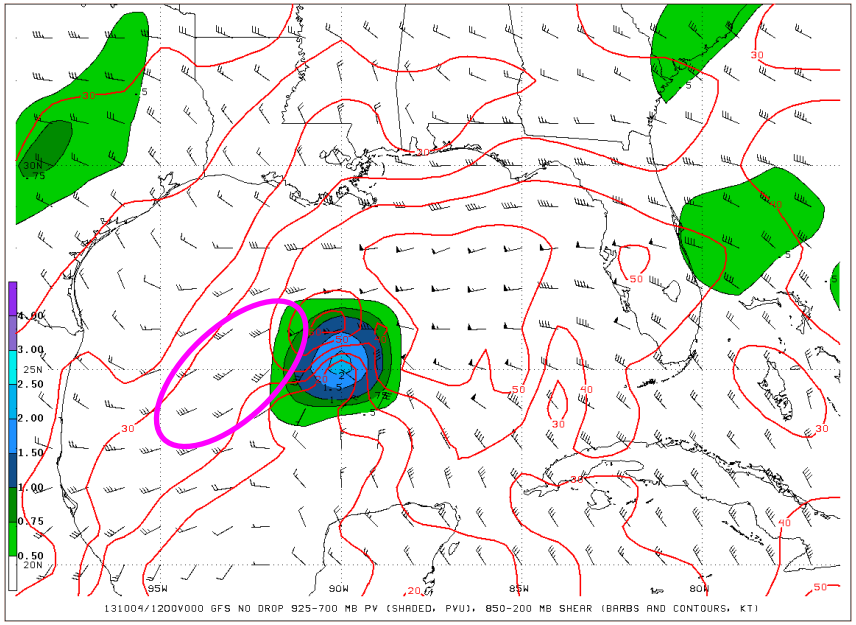

- 925-700 mb PV
- 850-200 mb wind shear magnitude
- 850-200 mb wind shear (kt)

# Low-Level Vortex and Shear

## F00 – 12Z 10/4/2013

| Control<br>Central Pressure: 1009 mb | No Drop<br>Central Pressure: 1009 mb |
|---|---|

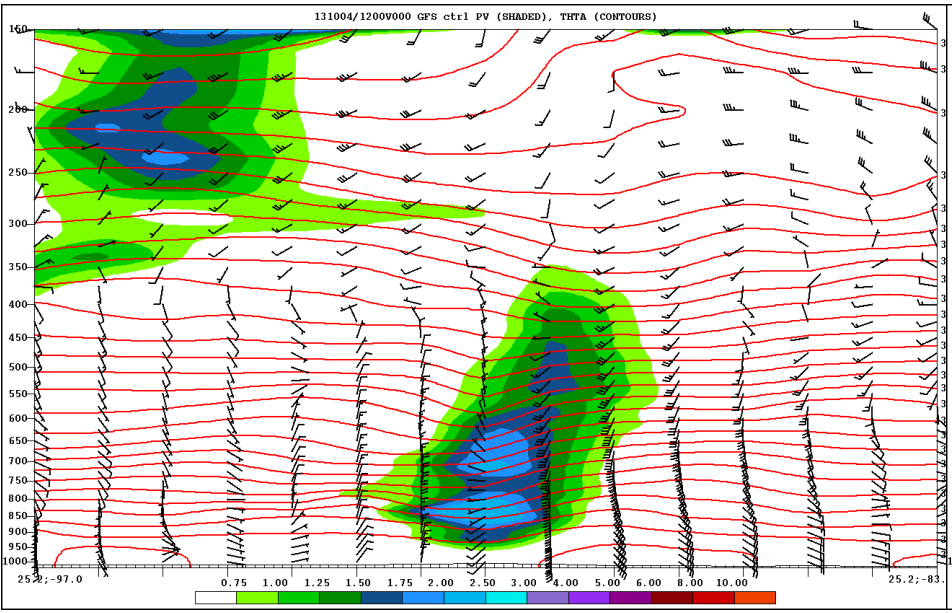


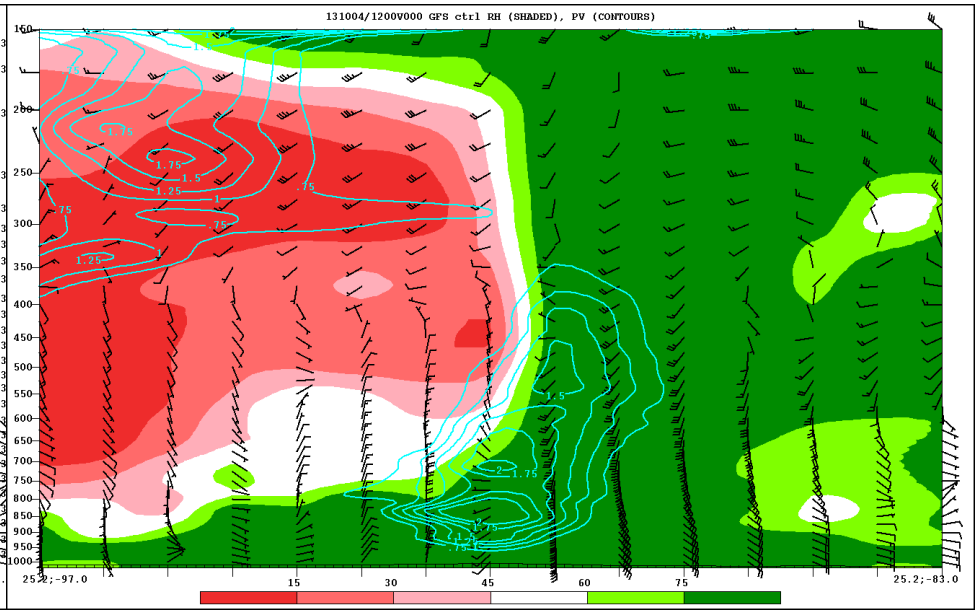

925-700 mb PV (shaded), 850-200-mb vertical shear magnitude (kt),
850-200-mb vertical wind shear (kt)

# Vortex Structure (Analysis – 12Z 4 October)

## Control




PV (shaded), Potential Temperature, Wind (kt)

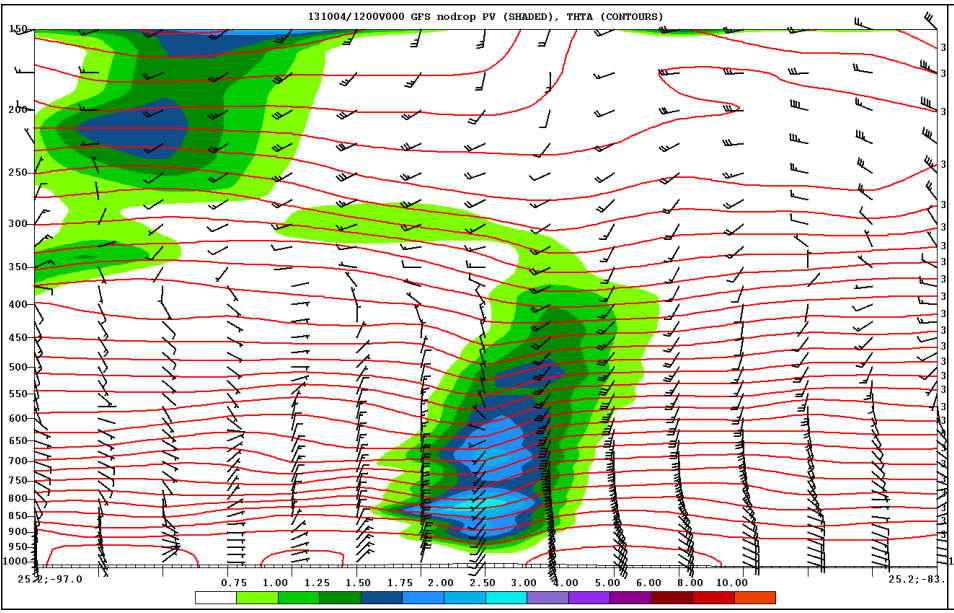



Relative Humidity (shaded), PV, Wind (kt)

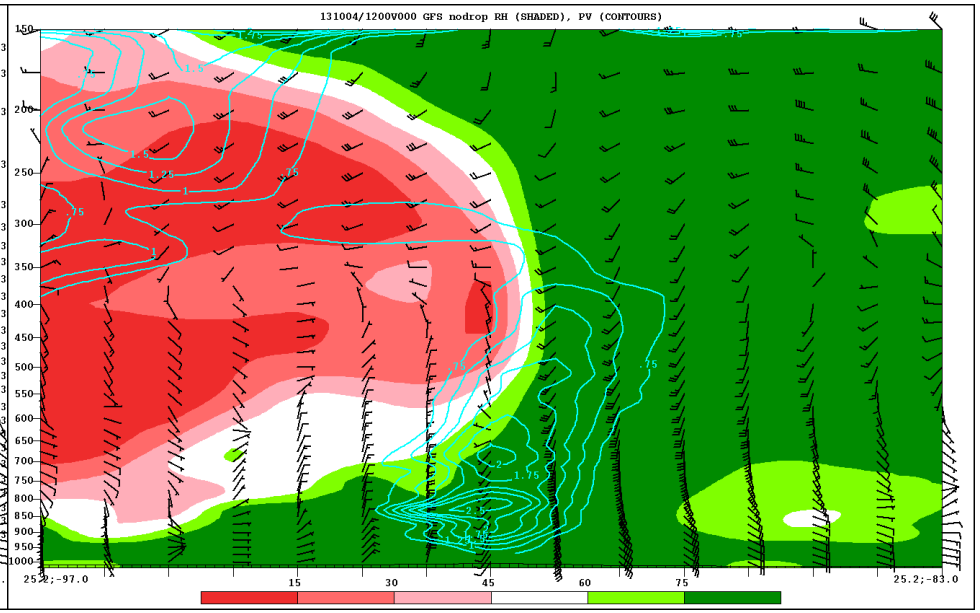
- W-E cross section along 25.2°N from 97°W to 83°W
- Control shows more tilt in Karen's PV tower in the 12Z analysis
- Control also shows stronger upper-level winds west of Karen and more dry air over the western part of Karen's circulation relative to No Drop

# Vortex Structure (Analysis – 12Z 4 October)

## No Drop



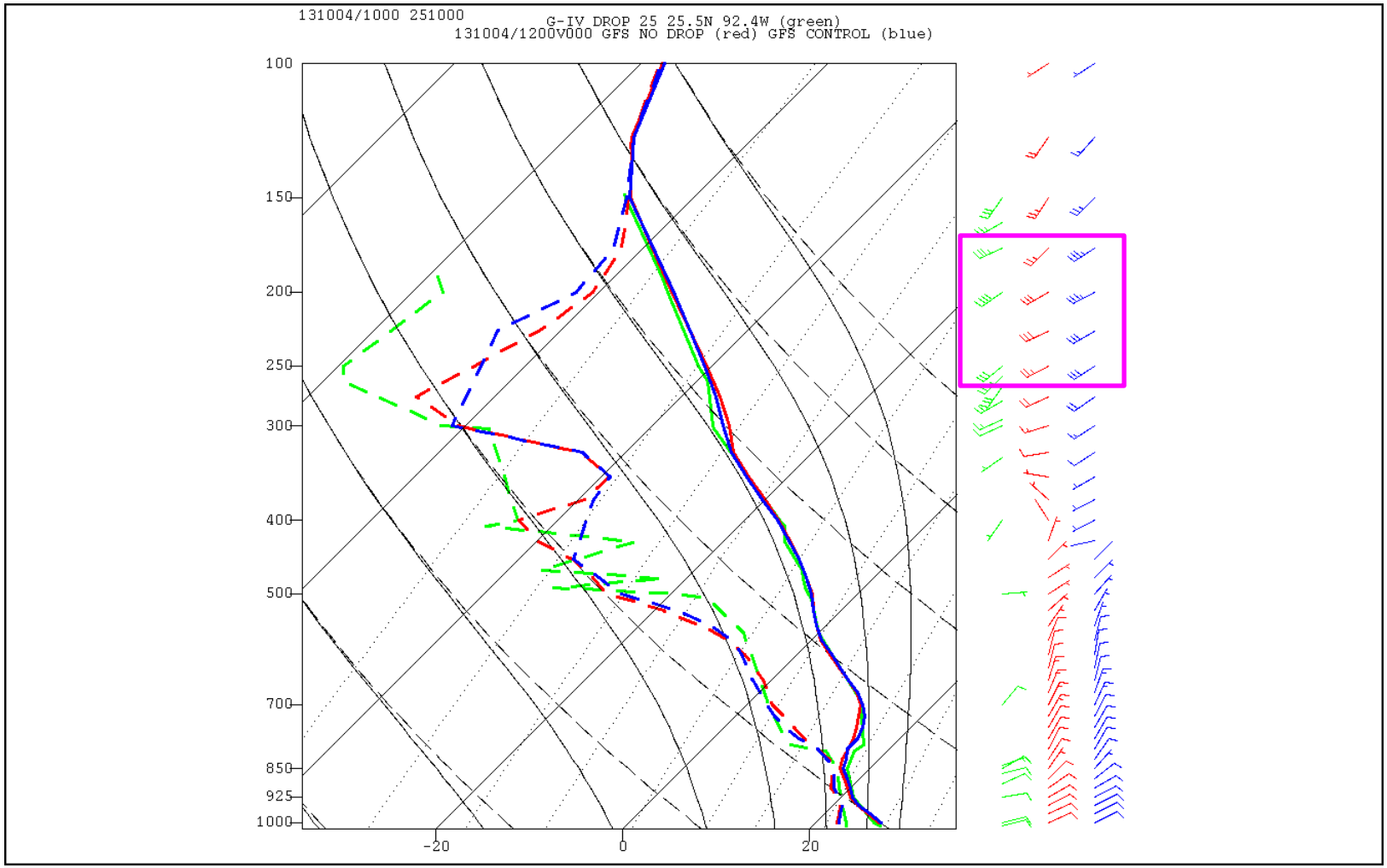

PV (shaded), Potential Temperature, Wind (kt)




Relative Humidity (shaded), PV, Wind (kt)

- W-E cross section along 25.2°N from 97°W to 83°W
- Control shows more tilt in Karen's PV tower in the 12Z analysis
- Control also shows stronger upper-level winds west of Karen and more dry air over the western part of Karen's circulation relative to No Drop

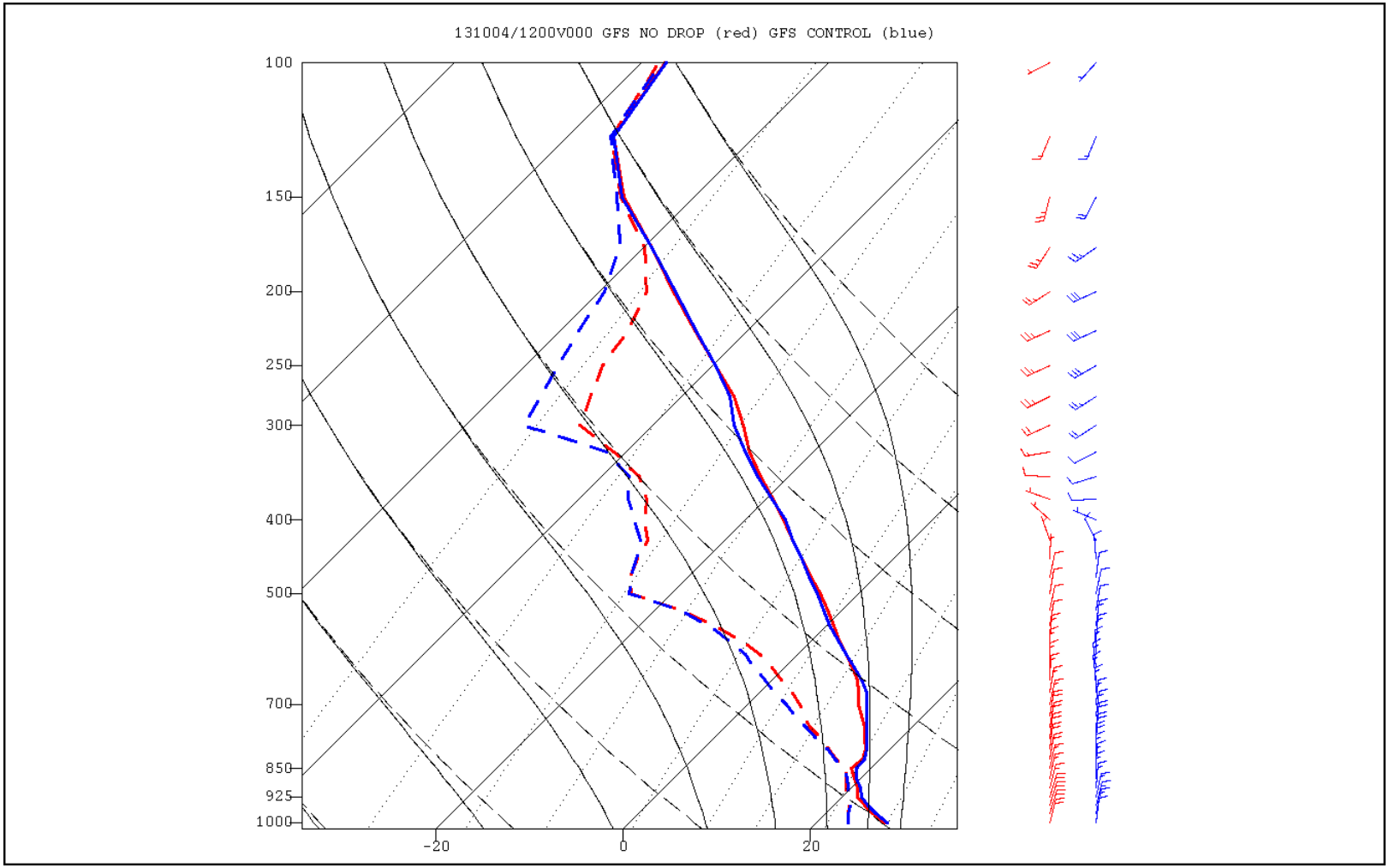
# Drop 25 – 25.5°N 92.4°W
# 10Z 4 October




G-IV Drop 10 UTC

12 UTC Analysis: GFS Control, GFS No Drop

# Analyzed Profiles 1°W of Karen's Center (25.2°N 90.9°W)

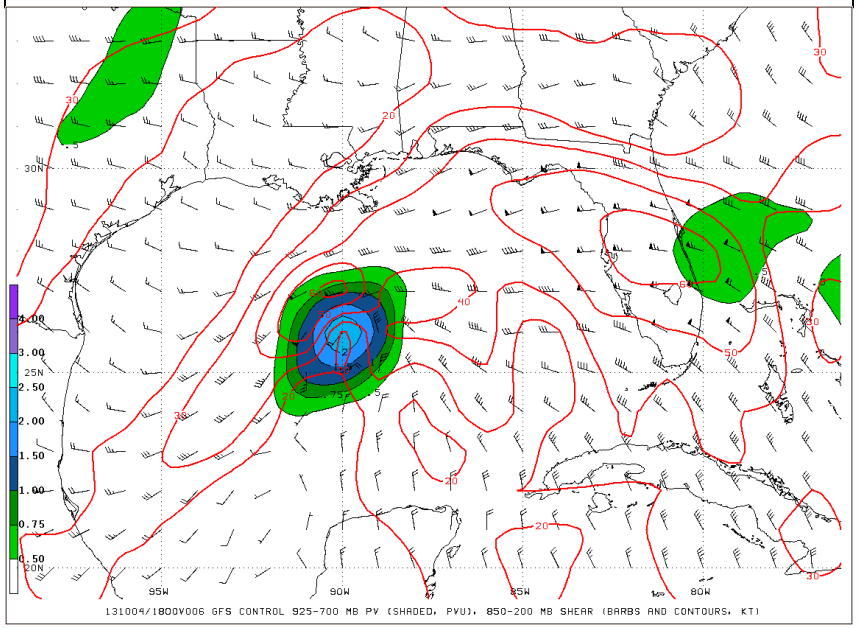



12 UTC Analysis: GFS Control, GFS No Drop

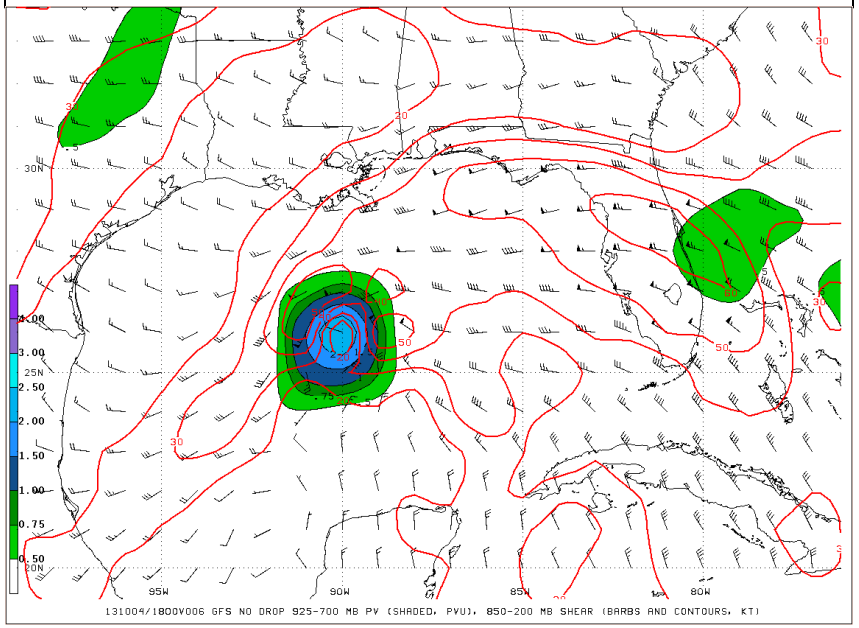
# Low-Level Vortex and Shear

## F06 – 18Z 10/4/2013

Control
Central Pressure: 1009 mb
GFS Intensity: 39 kt



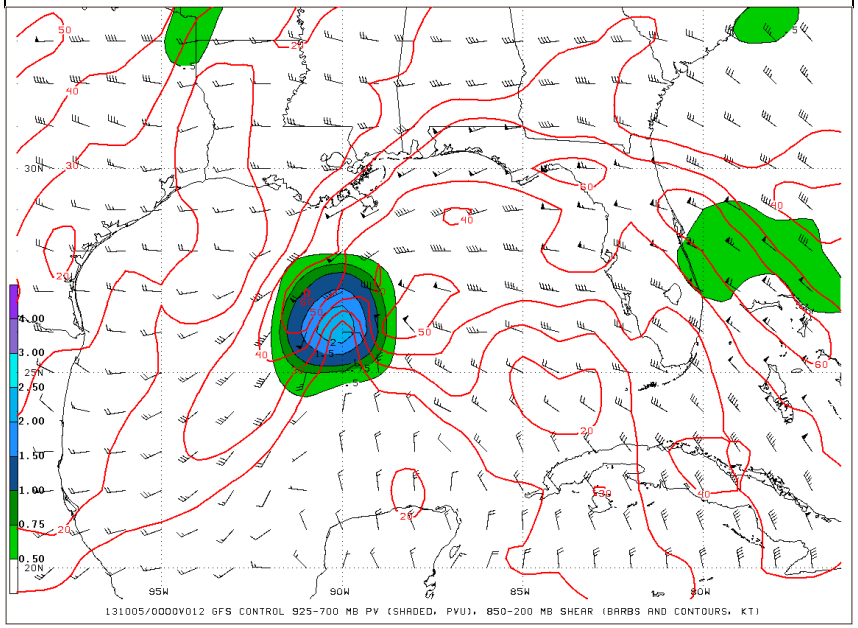

No Drop
Central Pressure: 1008 mb
GFS Intensity: 43 kt

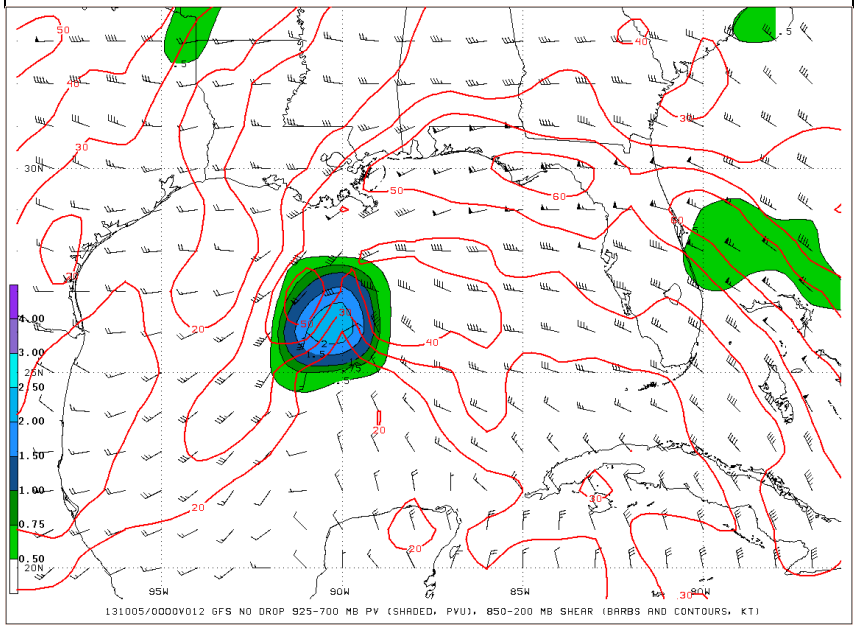


# Low-Level Vortex and Shear

## F12 – 00Z 10/5/2013

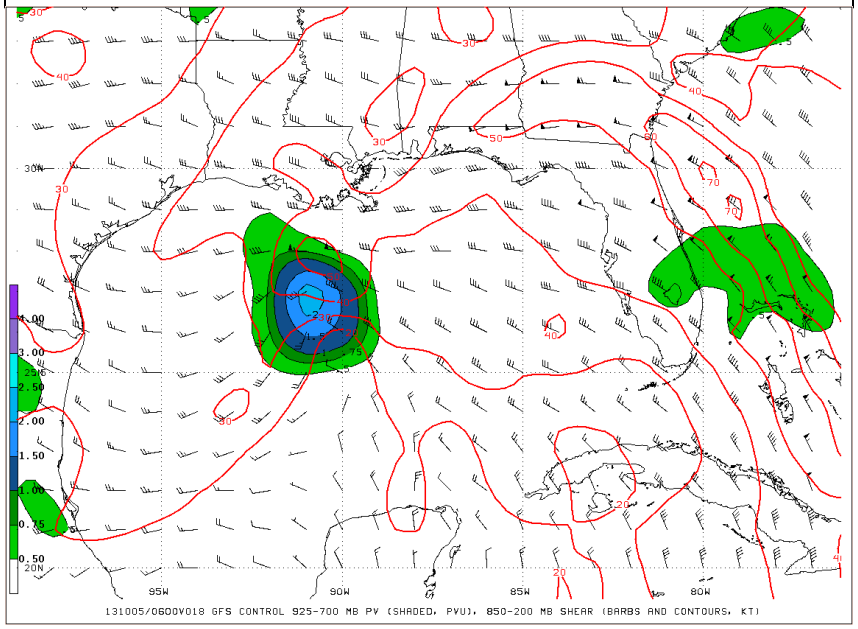
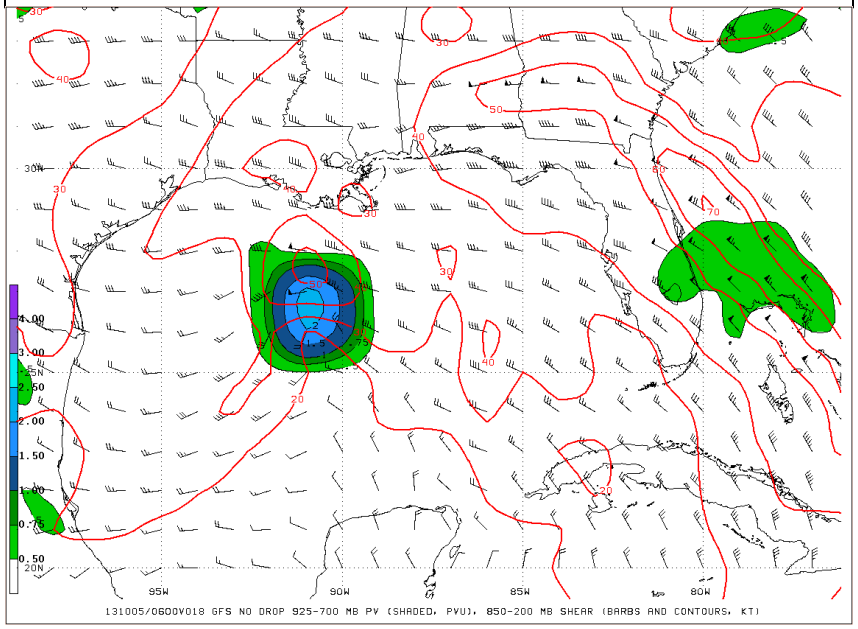
| Control | No Drop |
|---|---|
| Central Pressure: 1008 mb<br>GFS Intensity: 41 kt | Central Pressure: 1007 mb<br>GFS Intensity: 42 kt |



# Low-Level Vortex and Shear

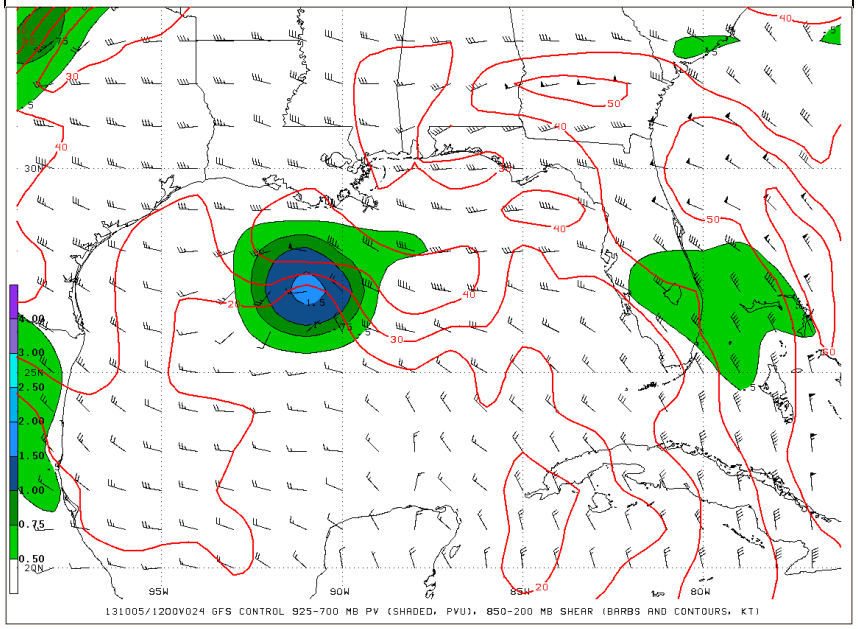
## F18 – 06Z 10/5/2013

| Control<br>Central Pressure: 1009 mb<br>GFS Intensity: 38 kt | No Drop<br>Central Pressure: 1009 mb<br>GFS Intensity: 36 kt |
|---|---|
|  |  |

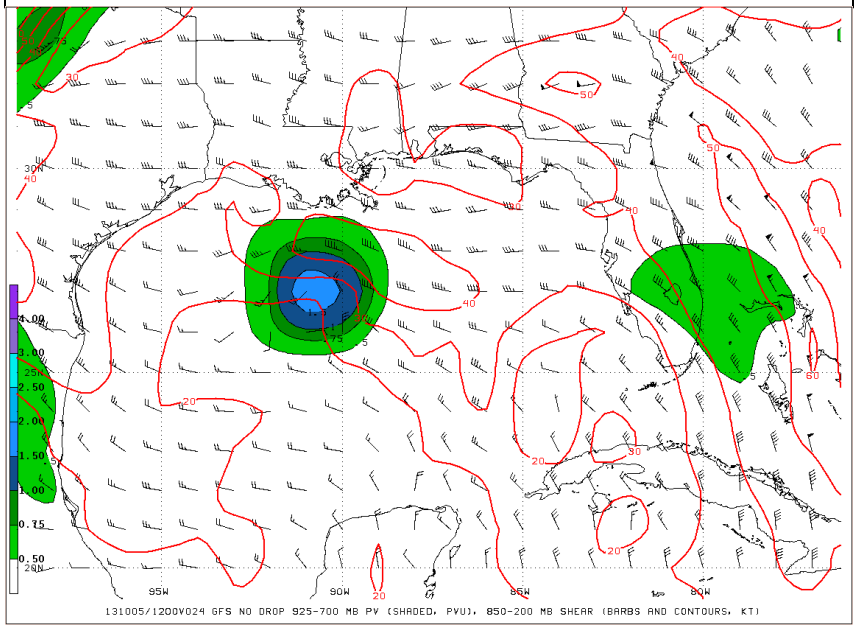
# Low-Level Vortex and Shear

## F24 – 12Z 10/5/2013

Control
Central Pressure: 1009 mb
GFS Intensity: 32 kt



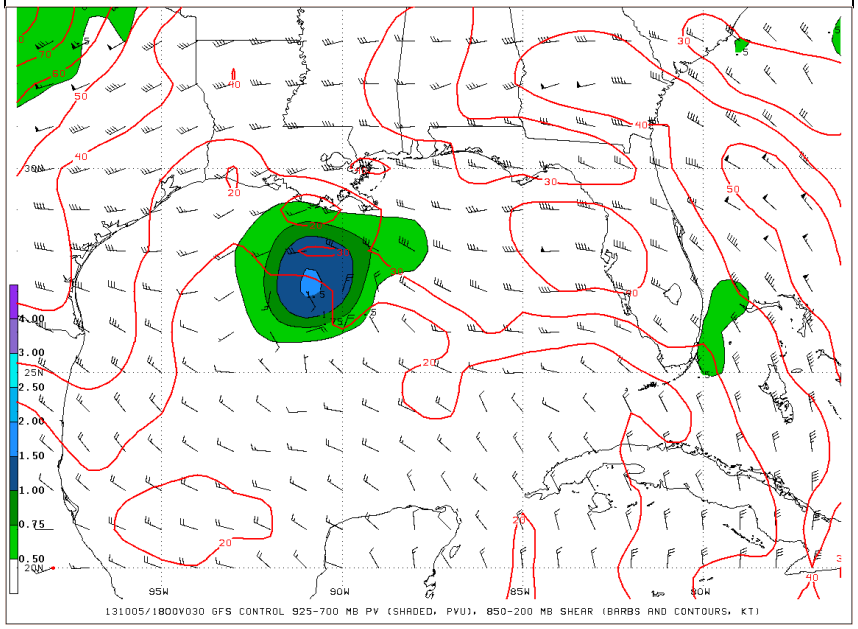

No Drop
Central Pressure: 1008 mb
GFS Intensity: 32 kt



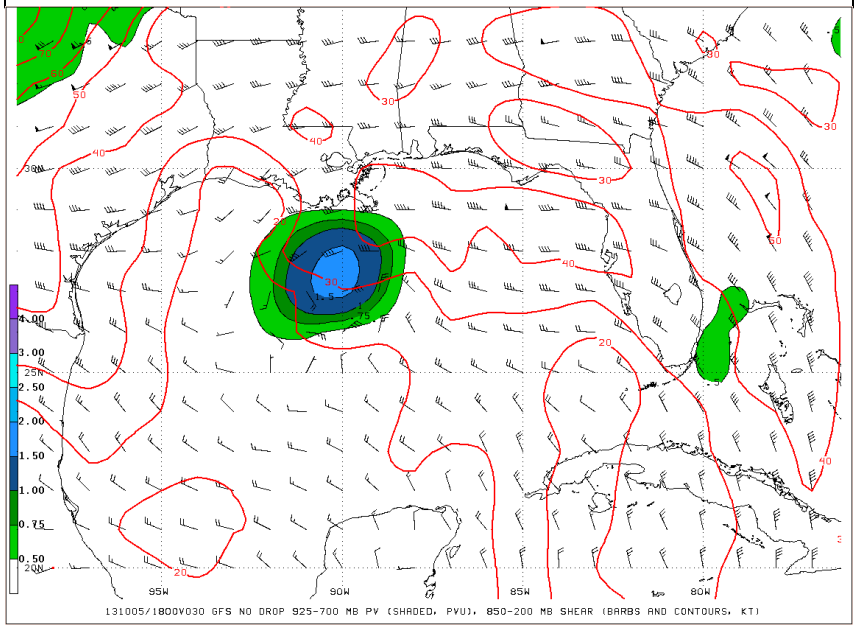
# Low-Level Vortex and Shear

## F30 – 18Z 10/5/2013

Control
Central Pressure: 1009 mb
GFS Intensity: 28 kt



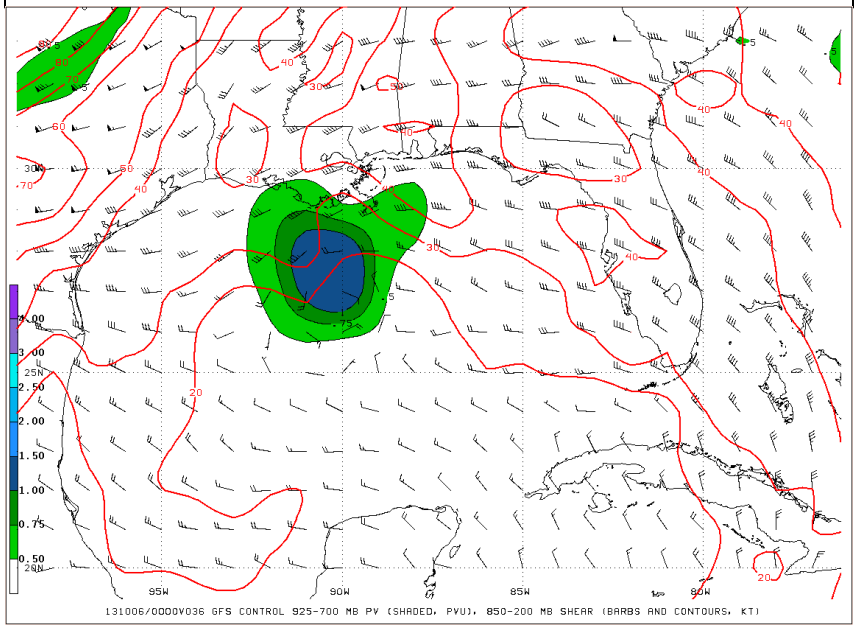

No Drop
Central Pressure: 1009 mb
GFS Intensity: 35 kt



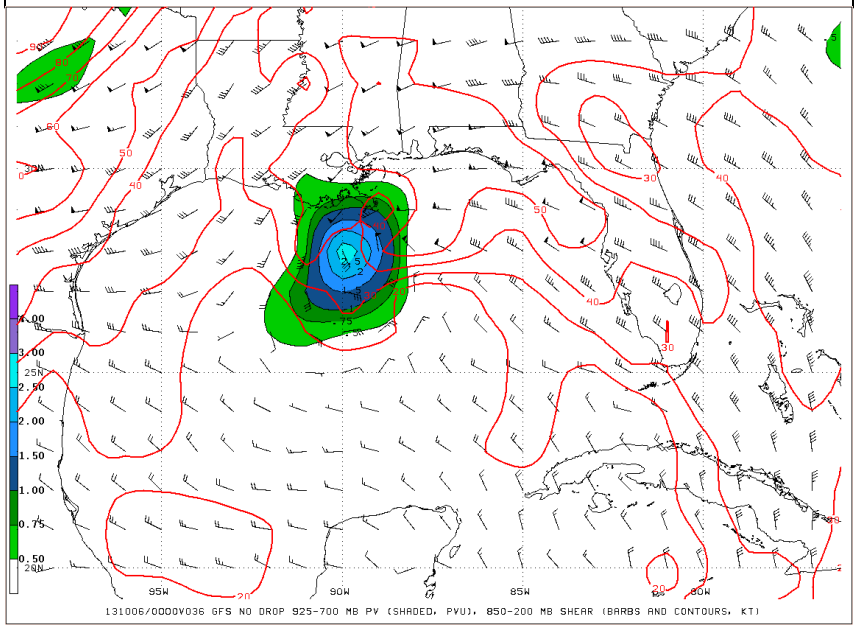
# Low-Level Vortex and Shear

## F36 – 00Z 10/6/2013

Control
Central Pressure: 1007 mb
GFS Intensity: 27 kt



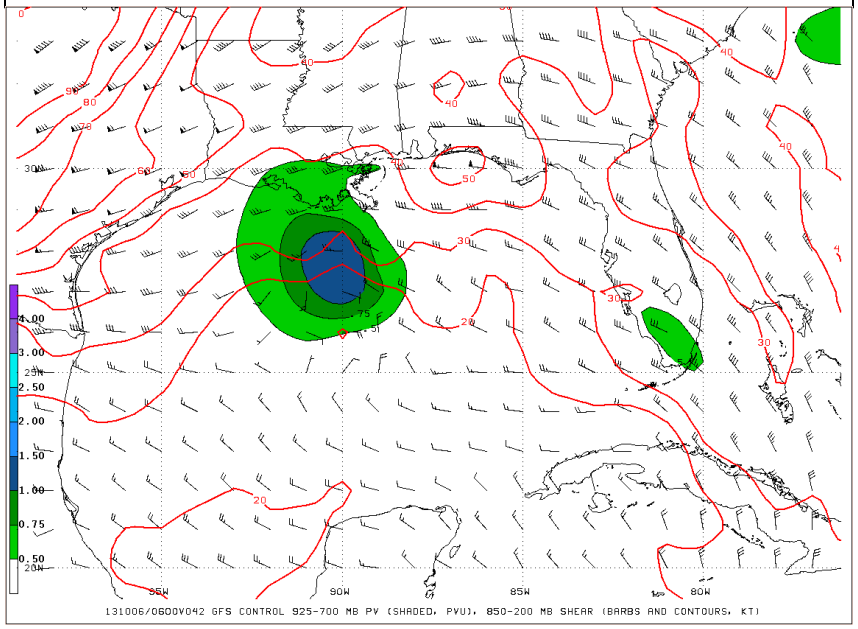

No Drop
Central Pressure: 1006 mb
GFS Intensity: 41 kt



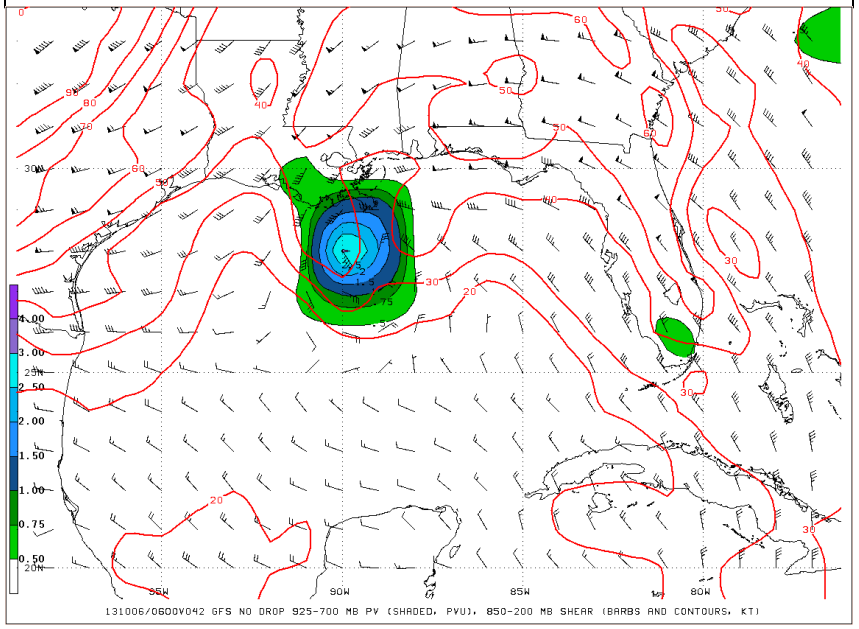
# Low-Level Vortex and Shear

## F42 – 06Z 10/6/2013

Control
Central Pressure: 1008 mb
GFS Intensity: 28 kt



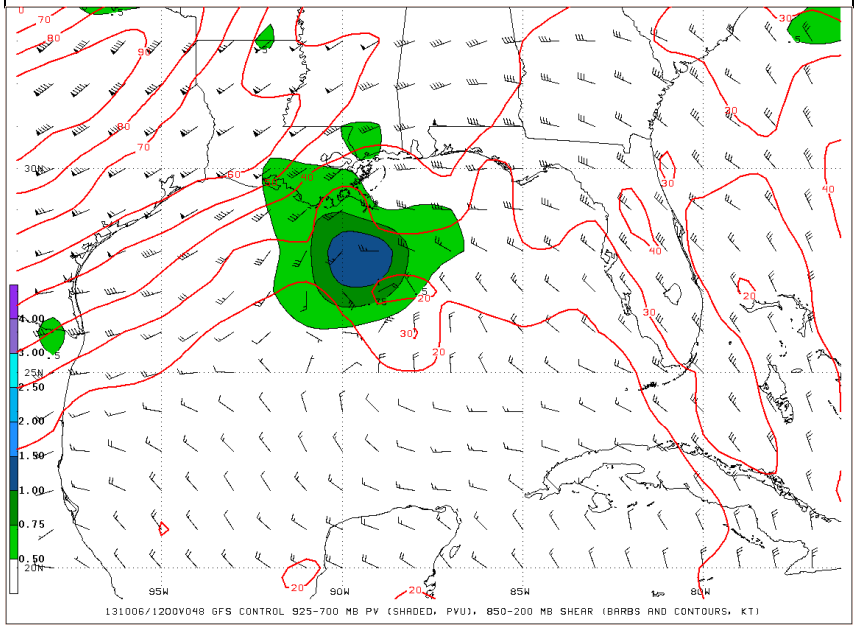

No Drop
Central Pressure: 1005 mb
GFS Intensity: 40 kt



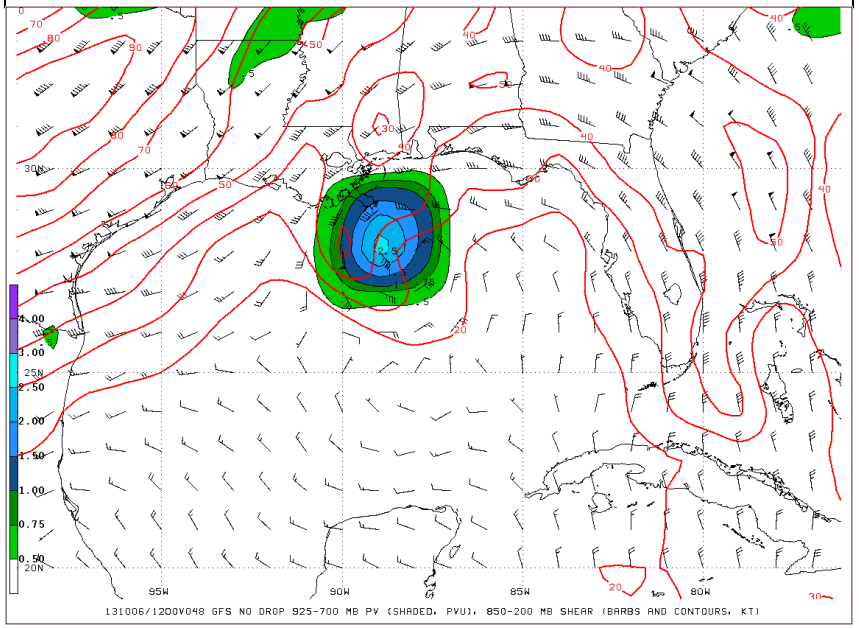
# Low-Level Vortex and Shear

## F48 – 12Z 10/6/2013

Control
Central Pressure: 1007 mb
GFS Intensity: 26 kt



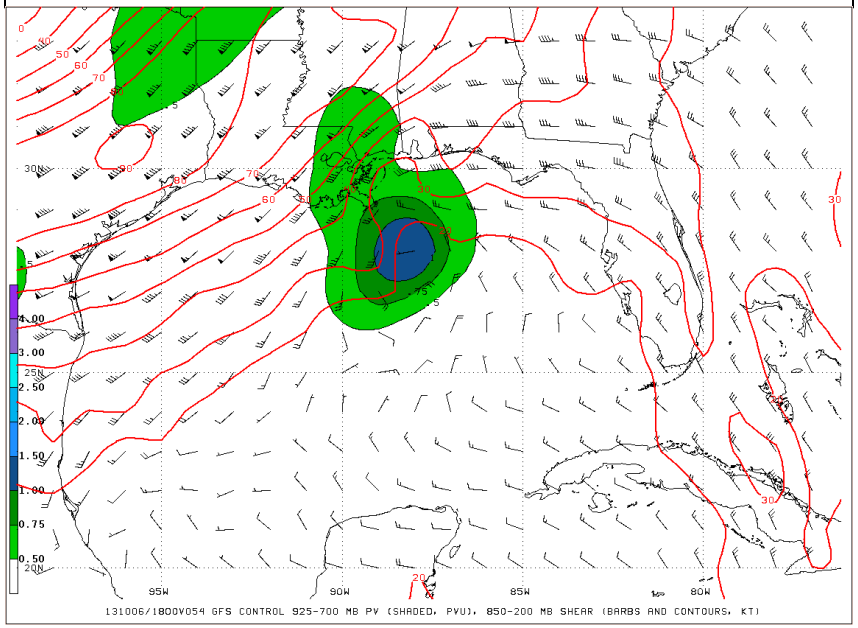

No Drop
Central Pressure: 1004 mb
GFS Intensity: 38 kt



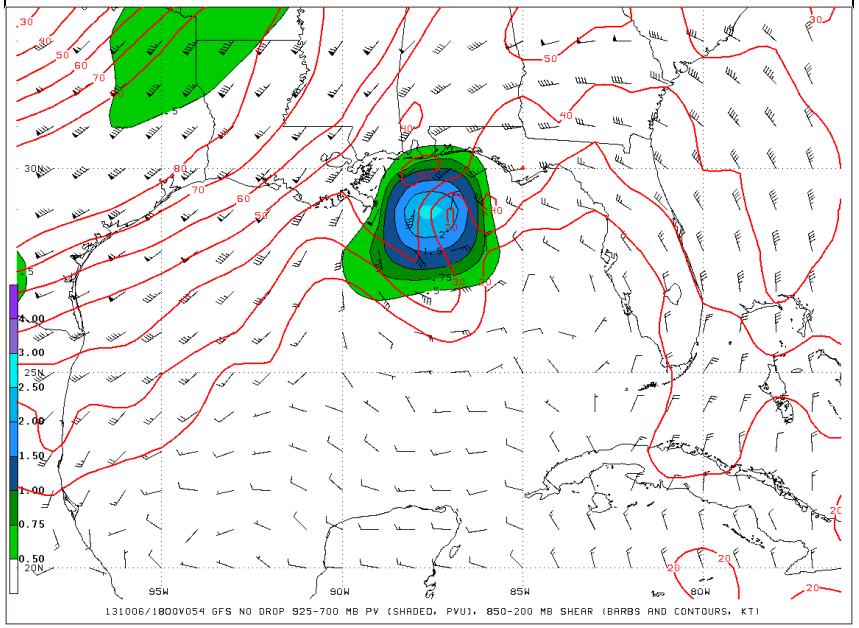
# Low-Level Vortex and Shear

## F54 – 18Z 10/6/2013

Control
Central Pressure: 1007 mb
GFS Intensity: 28 kt



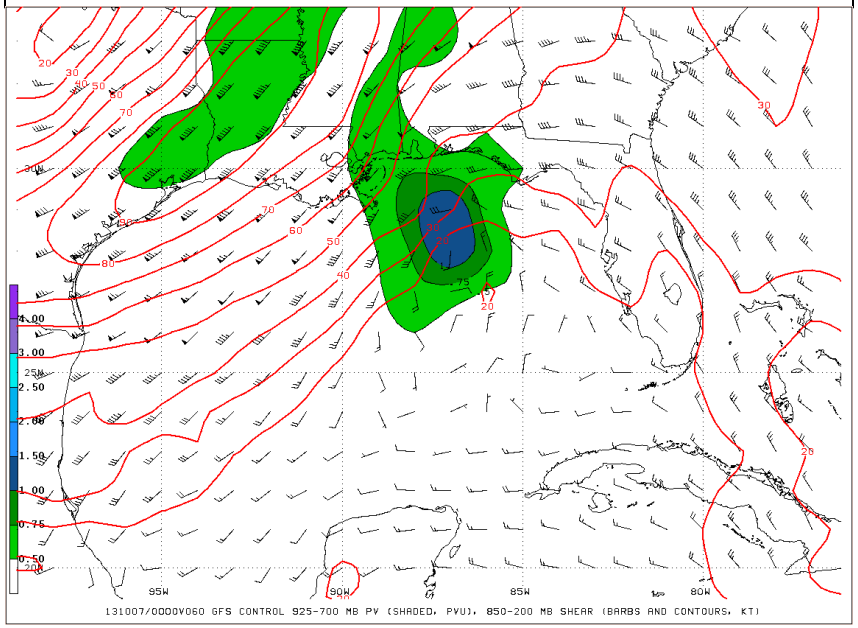

No Drop
Central Pressure: 1003 mb
GFS Intensity: 42 kt



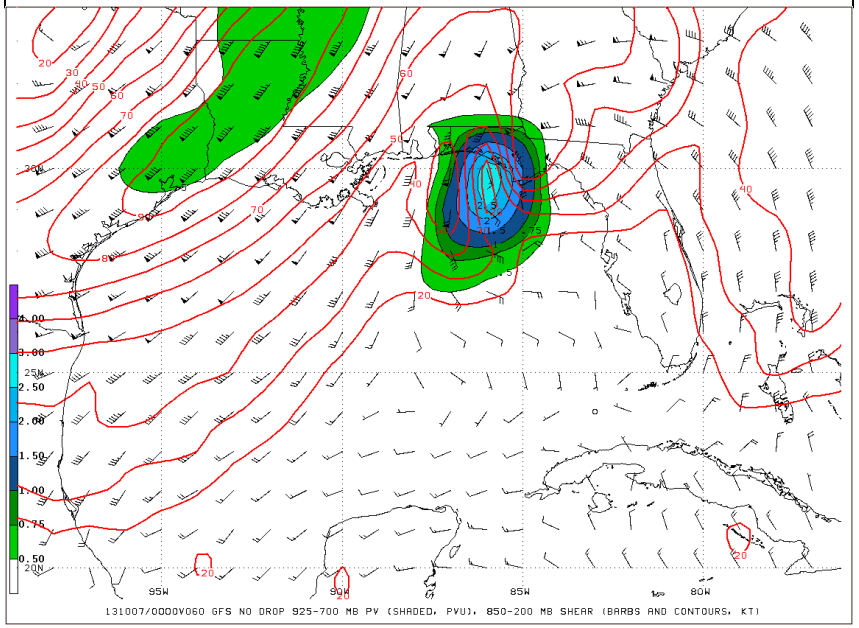
# Low-Level Vortex and Shear

## F60 – 00Z 10/7/2013

Control
Central Pressure: 1006 mb
GFS Intensity: 27 kt

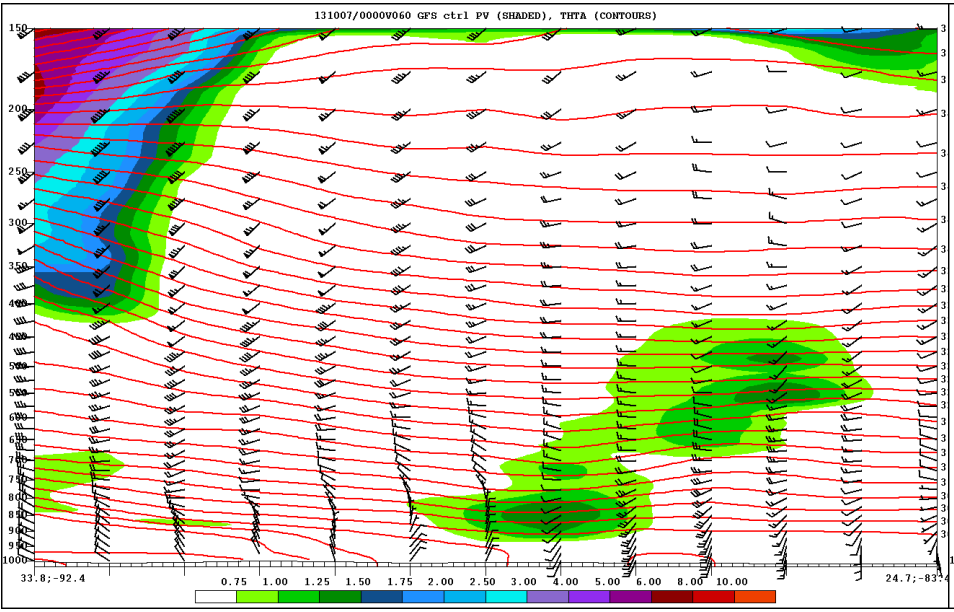



No Drop
Central Pressure: 1003 mb
GFS Intensity: 48 kt

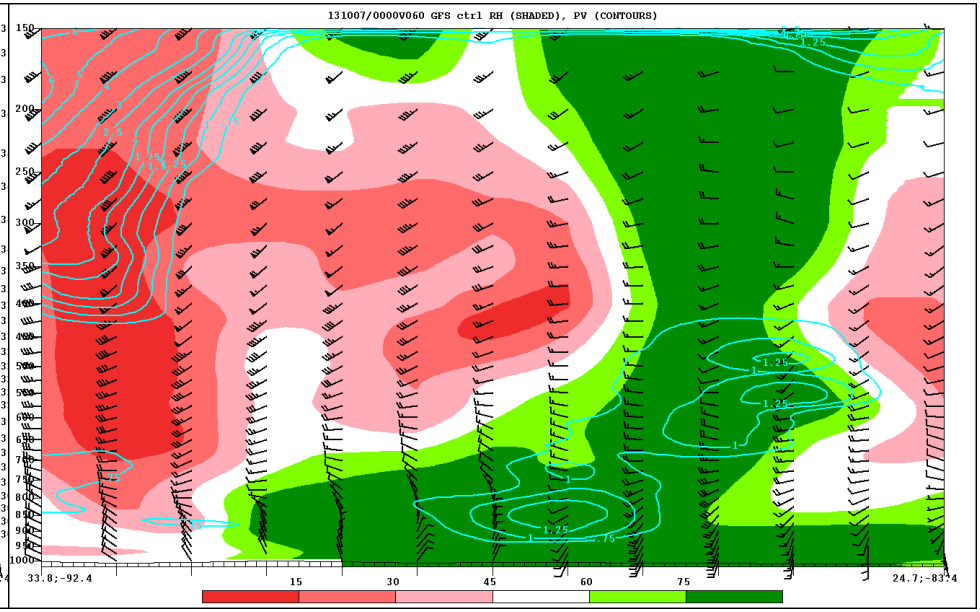


# Vortex Structure (F60)

## Control




PV (shaded), Potential Temperature, Wind (kt)

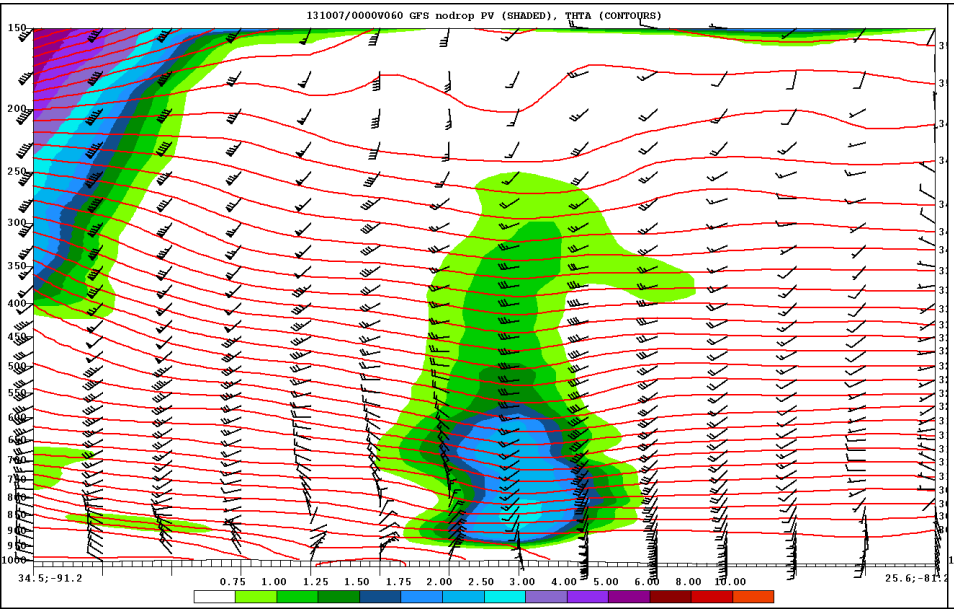



Relative Humidity (shaded), PV, Wind (kt)

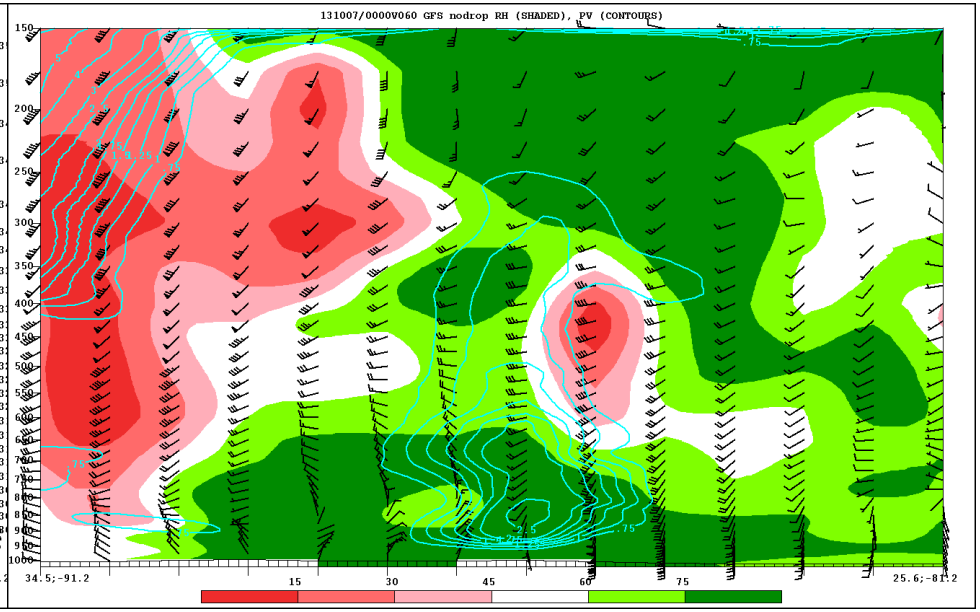
- NW-SE cross section along from 33.8°N 92.4°W to 24.7°N 83.4°W
- By F60, Control has weak vortex with dry air above that does not intensify ahead of approaching upper-level trough
- Cyclone in No Drop is much deeper and appears to intensify in region of upper-level divergence

# Vortex Structure (F60)

## No Drop



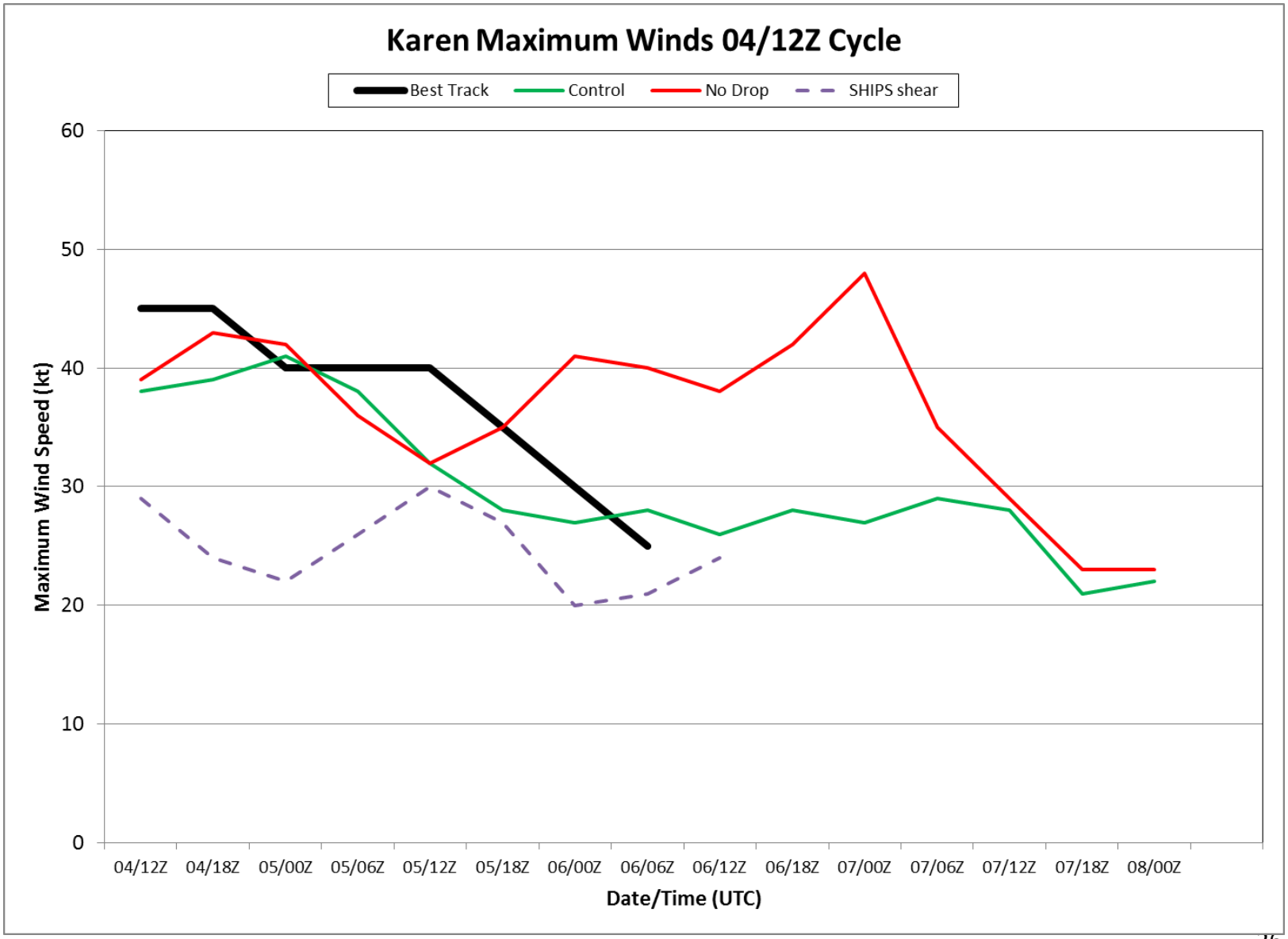

PV (shaded), Potential Temperature, Wind (kt)



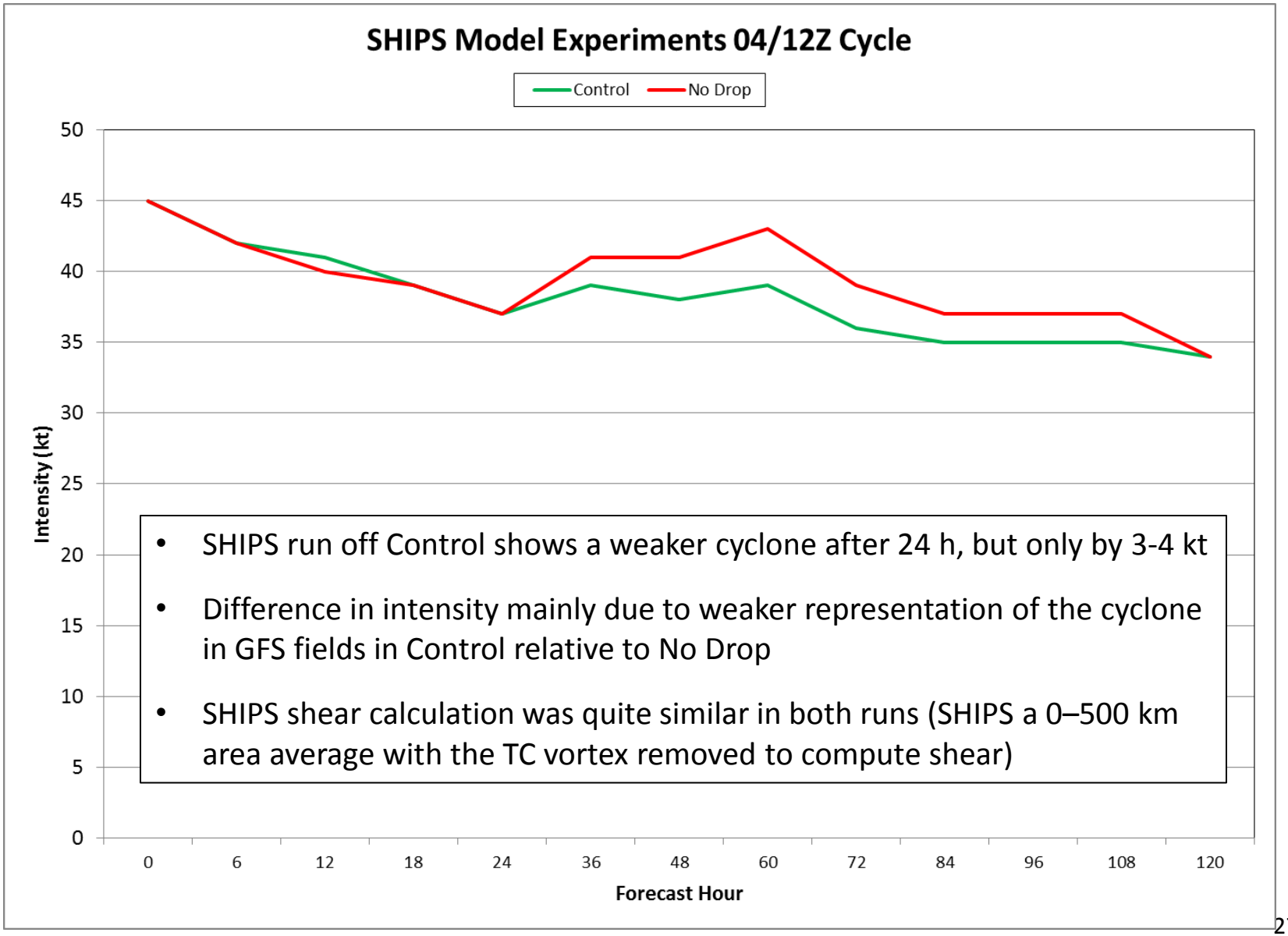

Relative Humidity (shaded), PV, Wind (kt)

- NW-SE cross section along from 34.5°N 91.2°W to 25.6°N 81.2°W
- By F60, Control shows weak vortex with dry air above that does not intensify ahead of approaching upper-level trough
- Cyclone in No Drop is much deeper and appears to intensify in region of upper-level divergence

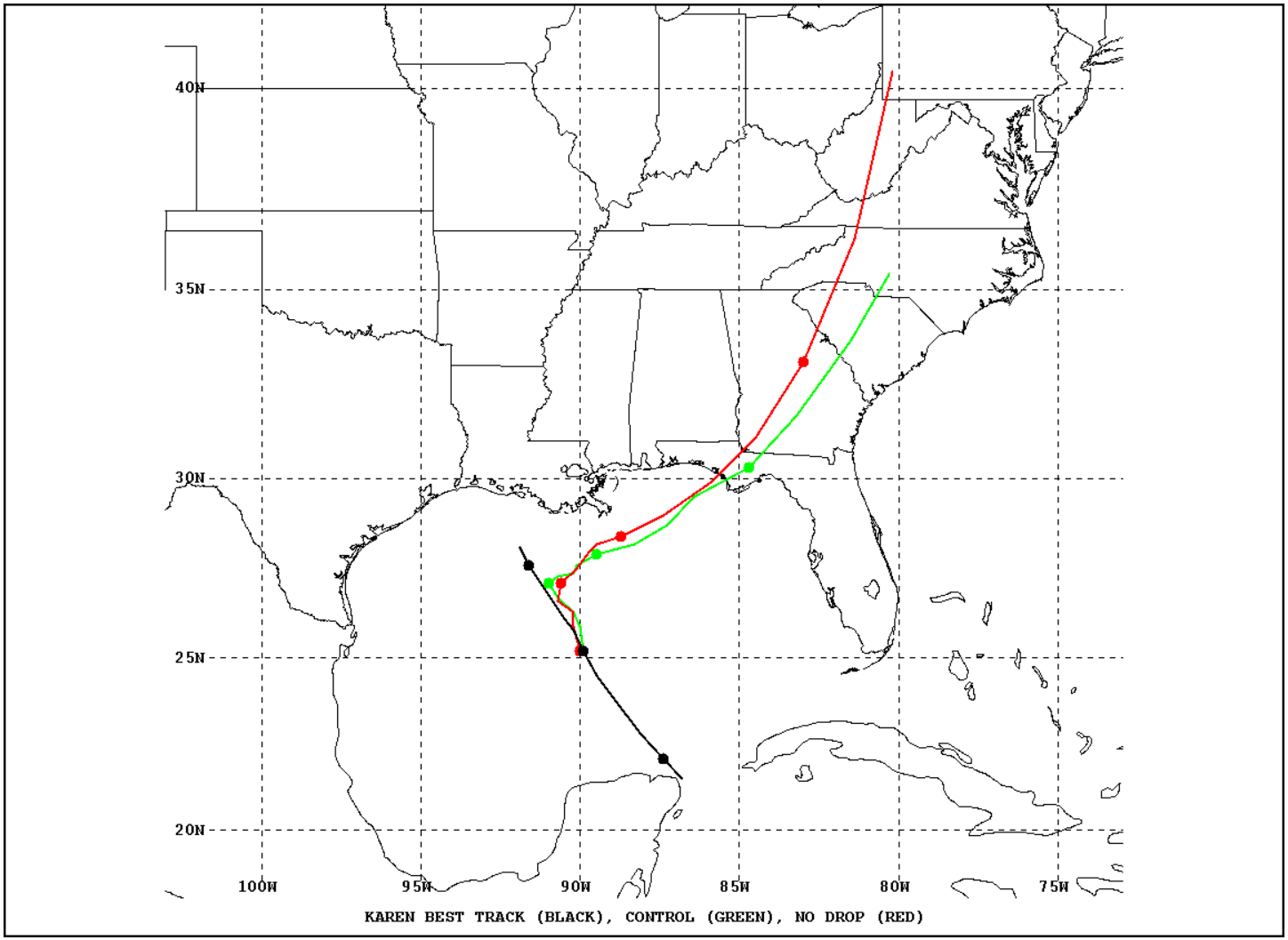
# Karen Intensity – GFS Experiments



# SHIPS Model Experiments



# Karen Track – GFS Experiments




12Z 10/4/2013 – Control, No Drop, Best Track

# Summary

- G-IV data appear to result in slightly stronger shear and more dry air aloft impinging on the circulation of Karen in the initial conditions at 12Z 4 October
- No Drop experiment shows 10-15 kt strengthening in 24-48 hours vortex as it approaches the northern Gulf Coast, perhaps through trough interaction
- Control experiment shows gradual decay after 12 hours, qualitatively similar to observations
- SHIPS experiments only show small differences, with SHIPS run from No Drop only 3-4 kt stronger than Control from 48-72 hours
- These results suggest that G-IV dropsonde data may be useful in improving forecasts of structure and intensity in some cases

# Future Work

- Examine additional cases (Isaac 2012, 2014?)
- See if any of the changes correlate with information in the EnKF-based ensemble
- Examine impacts of individual observations or groups of observations to see if symmetrical flight track of G-IV could be modified

# Acknowledgements


- Thanks for Andrea Schumacher (CSU/CIRA) and Mark DeMaria (NHC) for running the SHIPS model experiments