UNIVERSITY OF MIAMI
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ATMOSPHERIC SCIENCE

Influence of assimilating supplemental observations on tropical cyclone analyses and predictions

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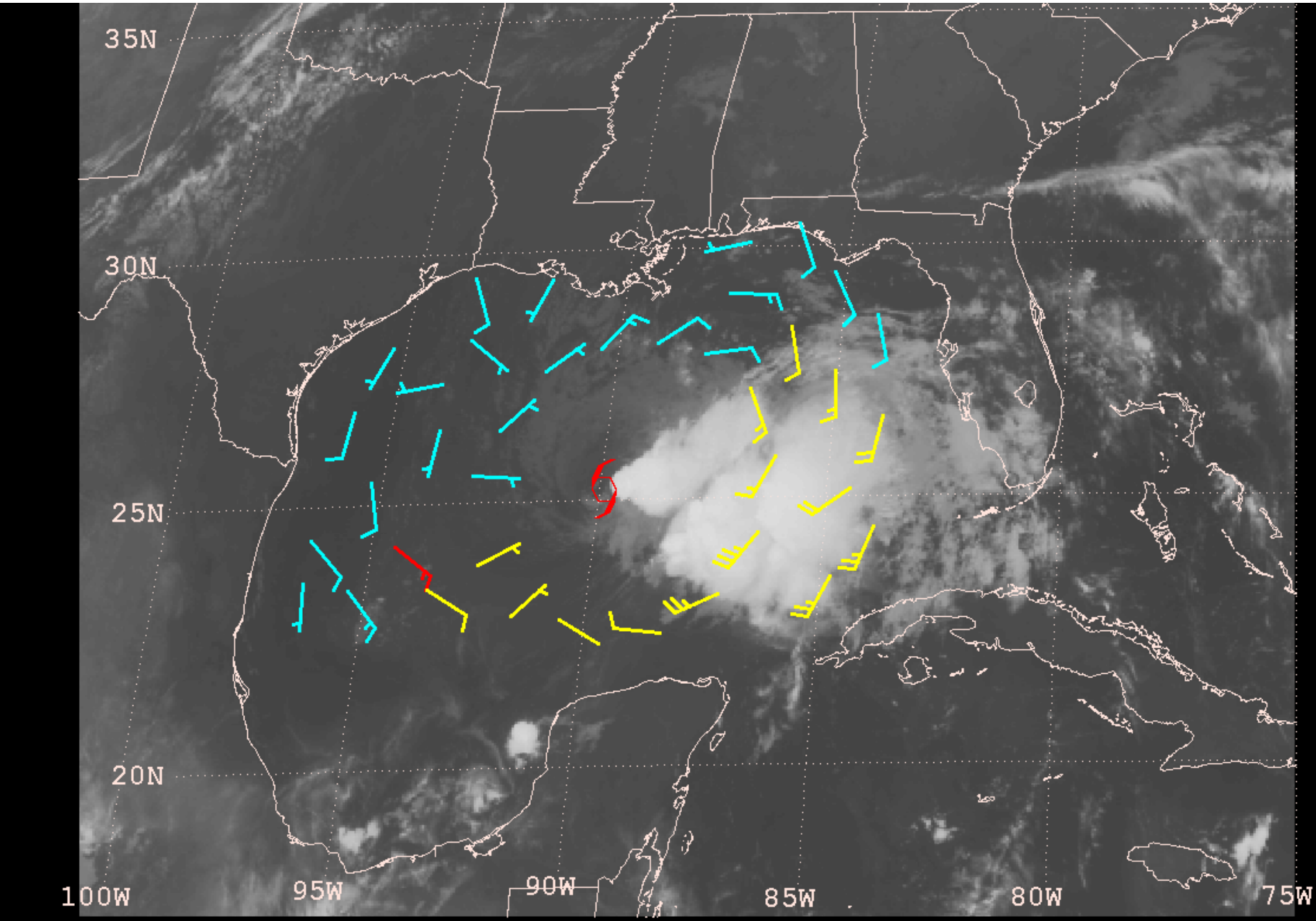


(b) 1215 UTC 4 OCTOBER 2013 GOES-E IR AND G-IV DROPSONDE LOCATIONS

Available supplemental resources

Dropwindsondes released from NOAA Gulfstream IV (G-IV) aircraft

06 and 18 UTC rawinsondes

Pre-2010 Data Denial Experiments

- 1982-1996: NOAA Synoptic Flow Experiments
  - 16-30% improvement in 12-60 h track forecasts
- 1997-2006: NOAA Synoptic Surveillance
  - 10-15% improvement in 12-60h track forecasts
- 2003-2008: DOTSTAR and T-PARC in NW Pacific
  - 10-20% improvement in 1-5 day track forecasts
- **Results vary substantially with model/DA**
- **Programs ongoing in 2010s, few evaluations**

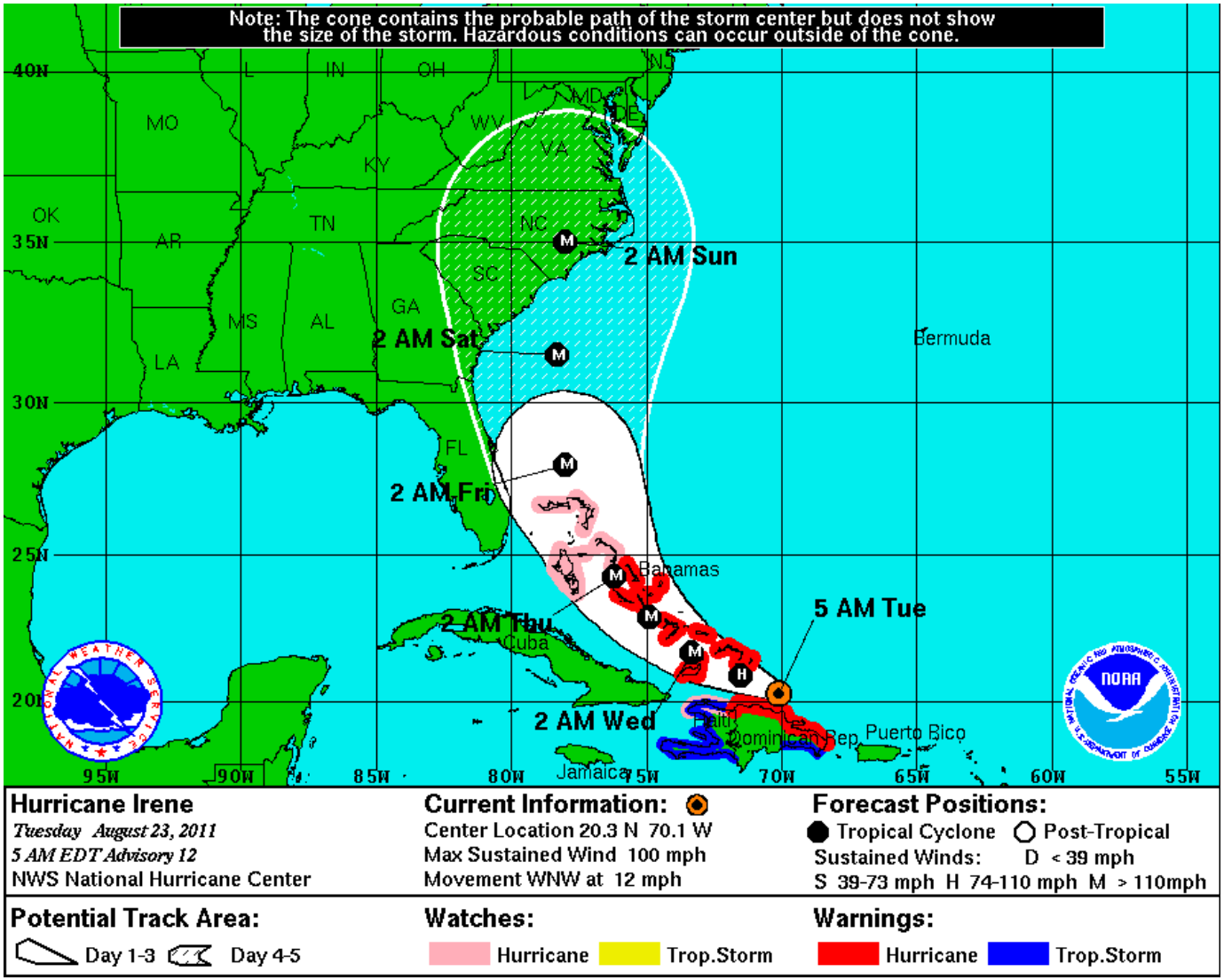
Post-2010 Data Denial Experiments

- **Irene (2011). 3d-Var. Majumdar et al. (WAF, 2013)**

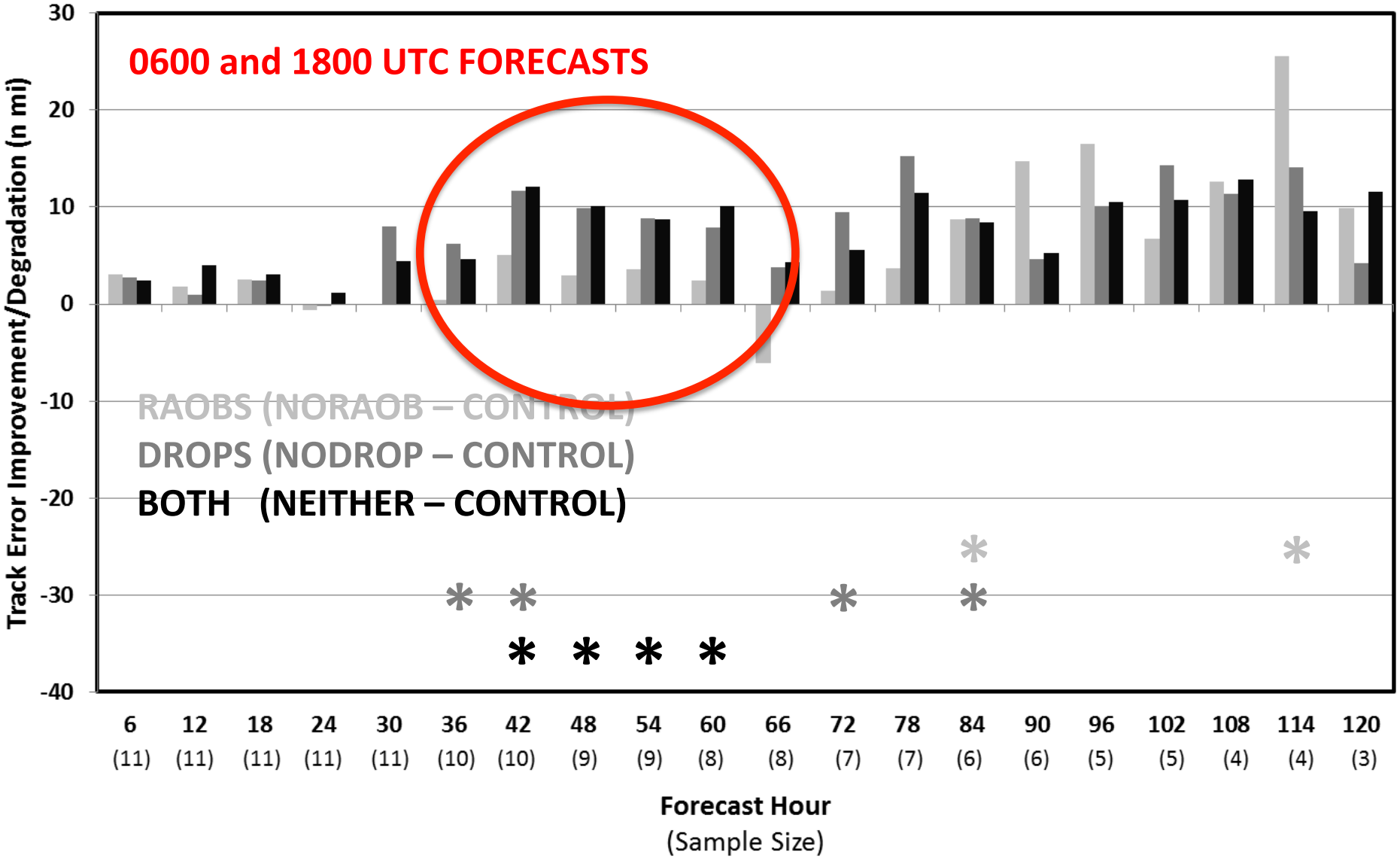
- **Isaac (2012). Hybrid 3d-Var/EnKF.**
- **Sandy (2012). Same DA. Small impact.**
- **Karen (2013). Same DA. Brennan et al. (WAF, 2015)**
- **Joaquin (2015). Same DA. Small impact.**

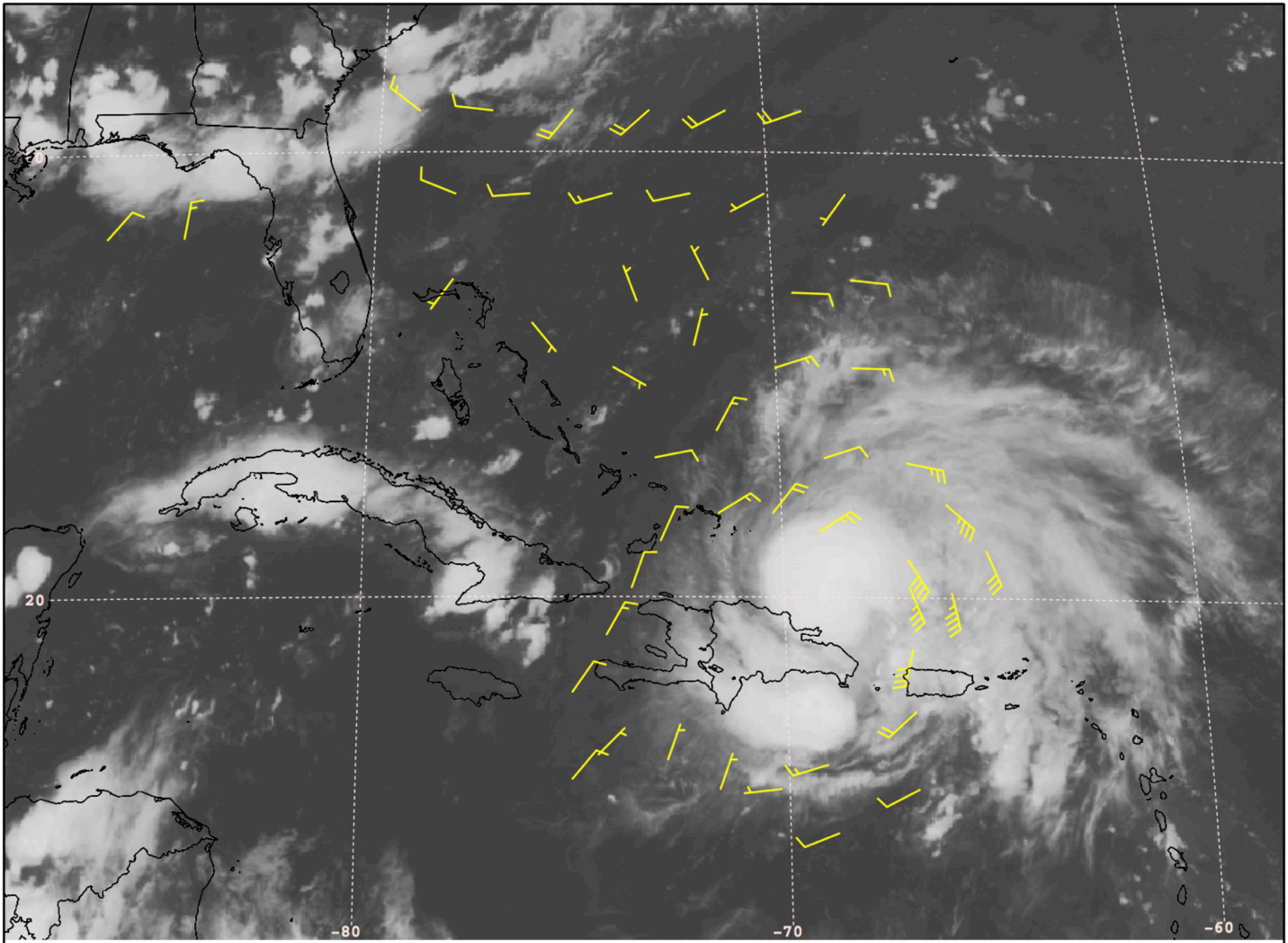
- ***Future storms: Hybrid 4d-EnVar***

1. Hurricane Irene (2011)



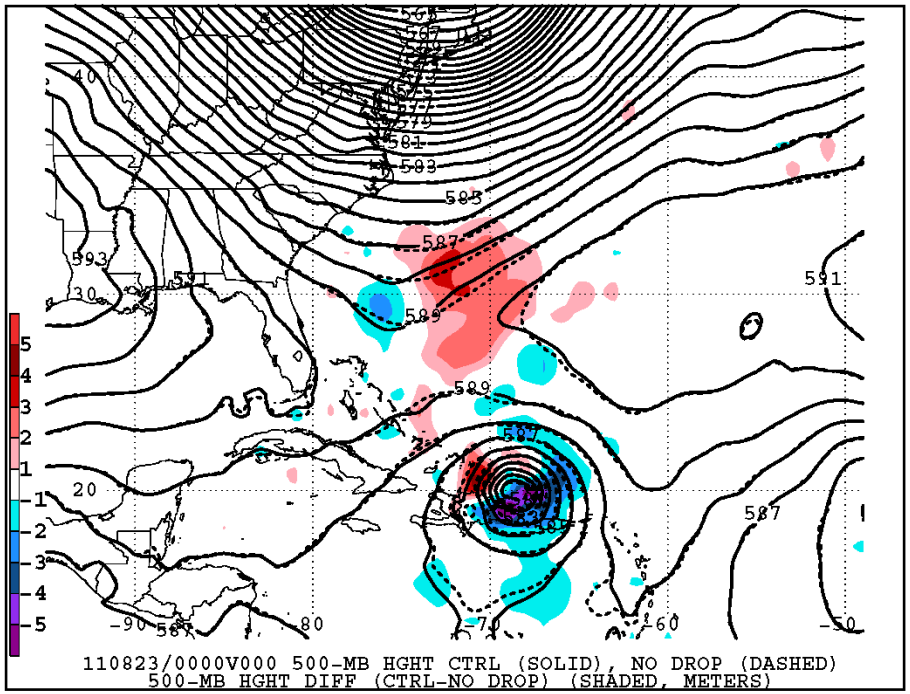
Net Track Forecast Improvement





GOES-E IR 0015Z 23 AUG, DROPS 1800Z 22 AUG-0300Z 23 AUG 2011


NO DROP
CONTROL
BEST TRACK
120
108
96
84
72
60
48
36
24
12
00
35N
30N
25N
20N
85W
80W
75W
70W
65W
Irene Best Track (black), GFS CTRL (green), GFS NO DROP (red)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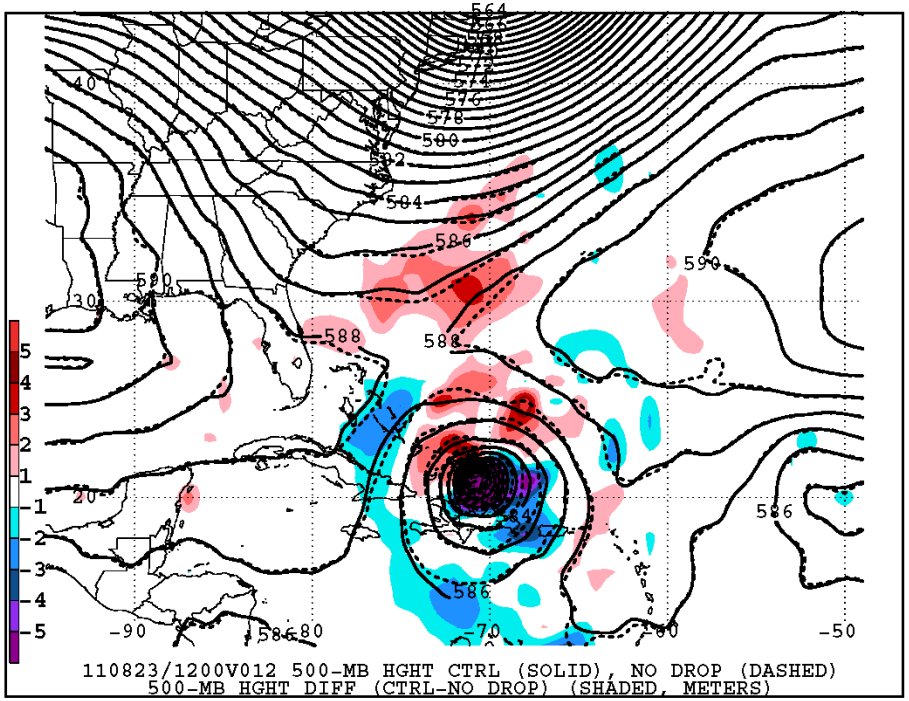
500-MB HGHT DIFF (CTRL-NO DROP) (SHADED, METERS)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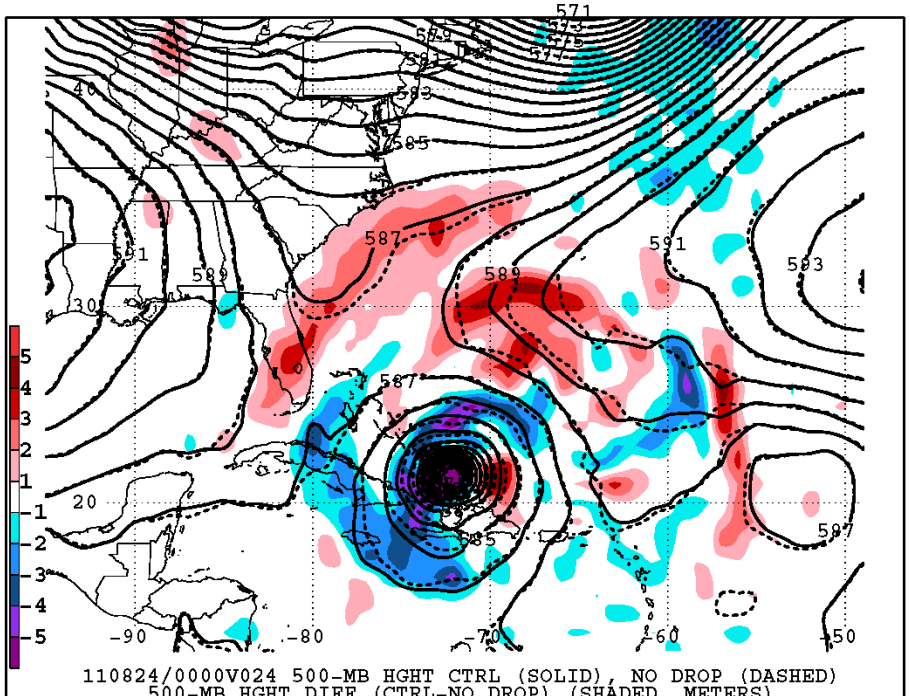
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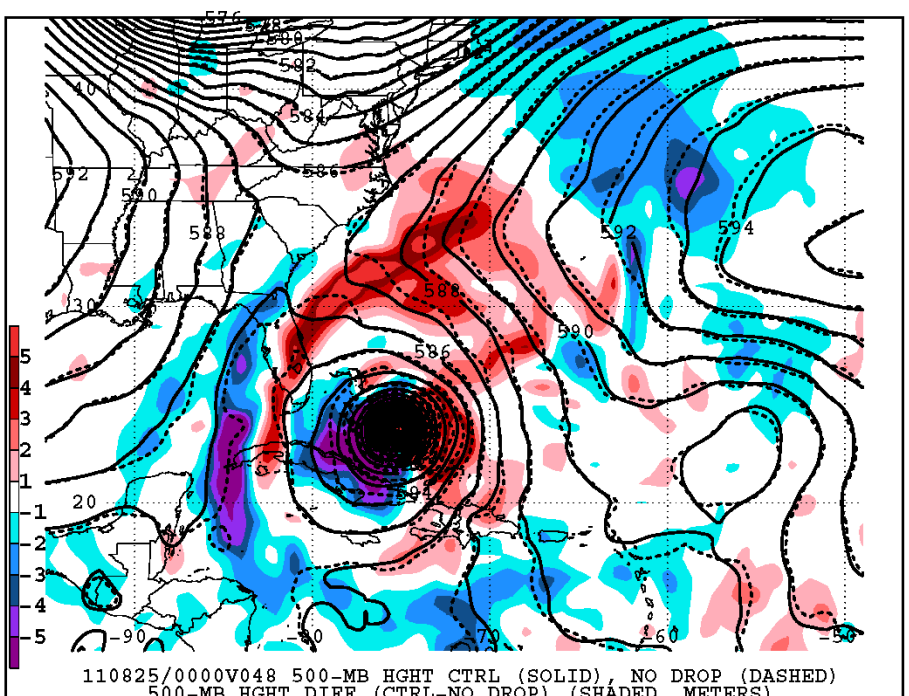
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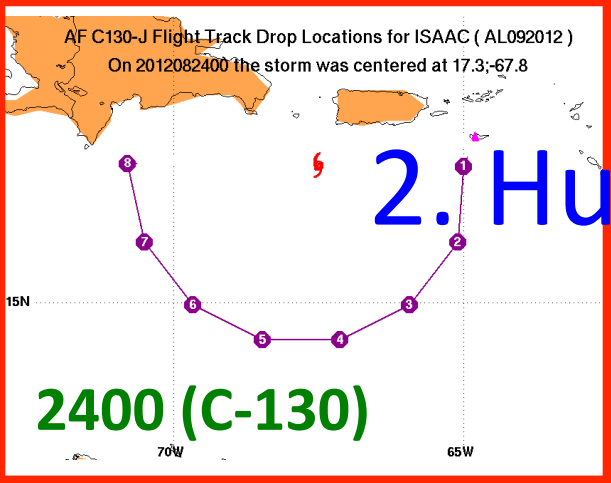
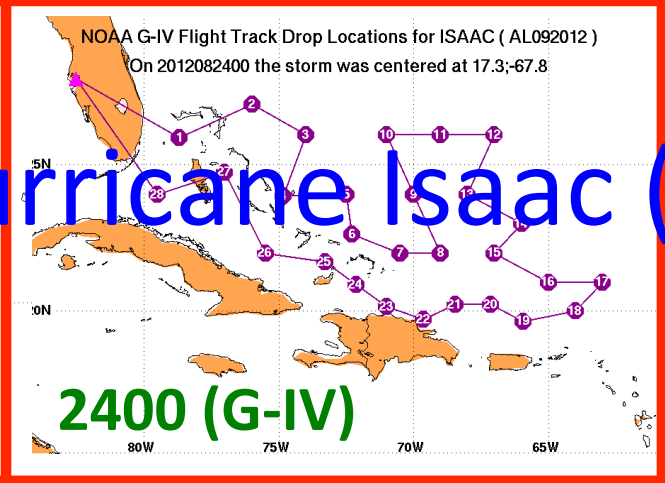
500-MB HGHT DIFF (CTRL-NO DROP) (SHADED, METERS)

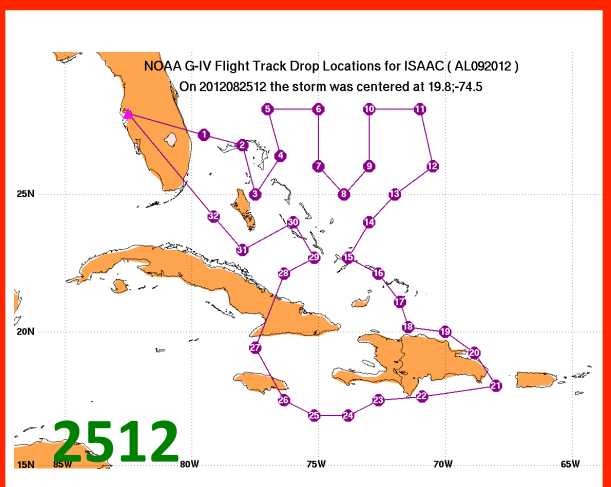
Conclusions 1: Irene (2011)

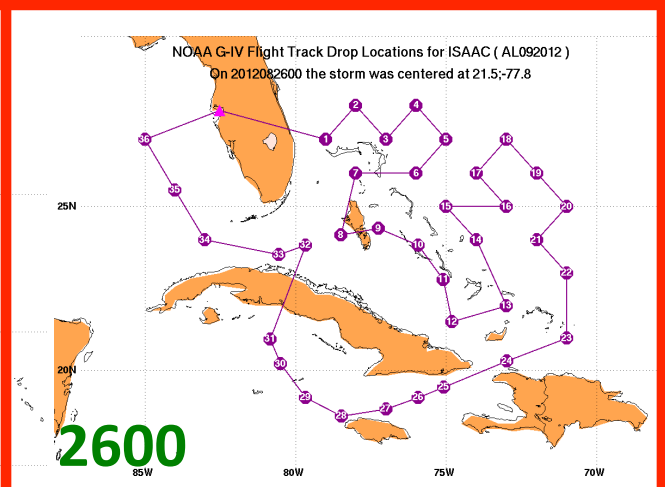
- Very little room for improvement
  - Dropwindsondes: 2-3 day forecasts improved
  - Rawinsondes: 4-5 day forecasts improved
  - Combination: Small net improvement
- Improvements particularly for 0600 and 1800 UTC forecasts
- Small corrections to right-of-track bias

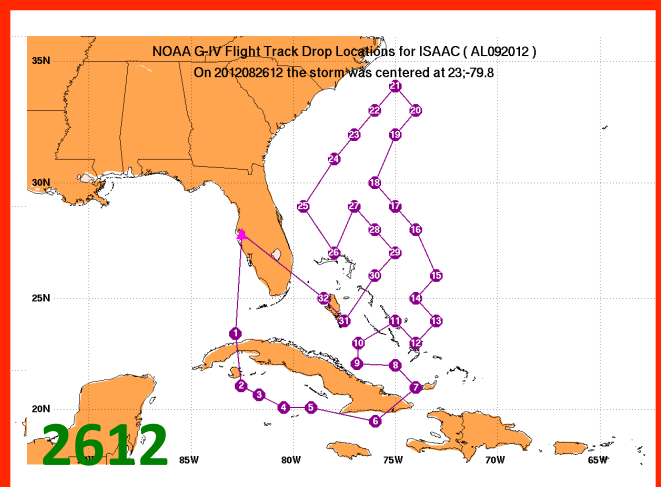
2. Hurricane Isaac (2012)





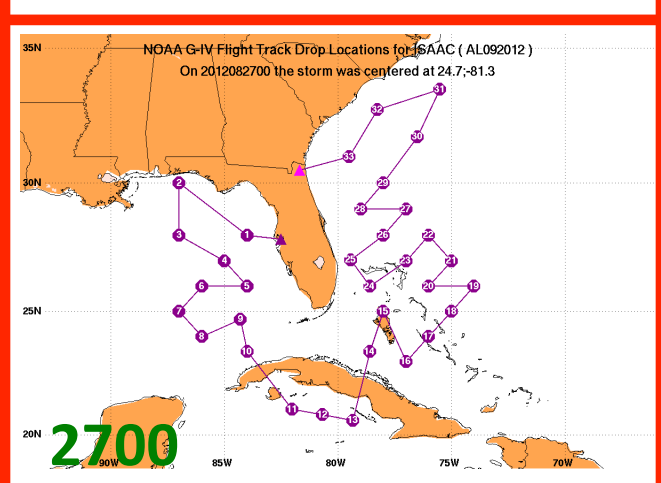


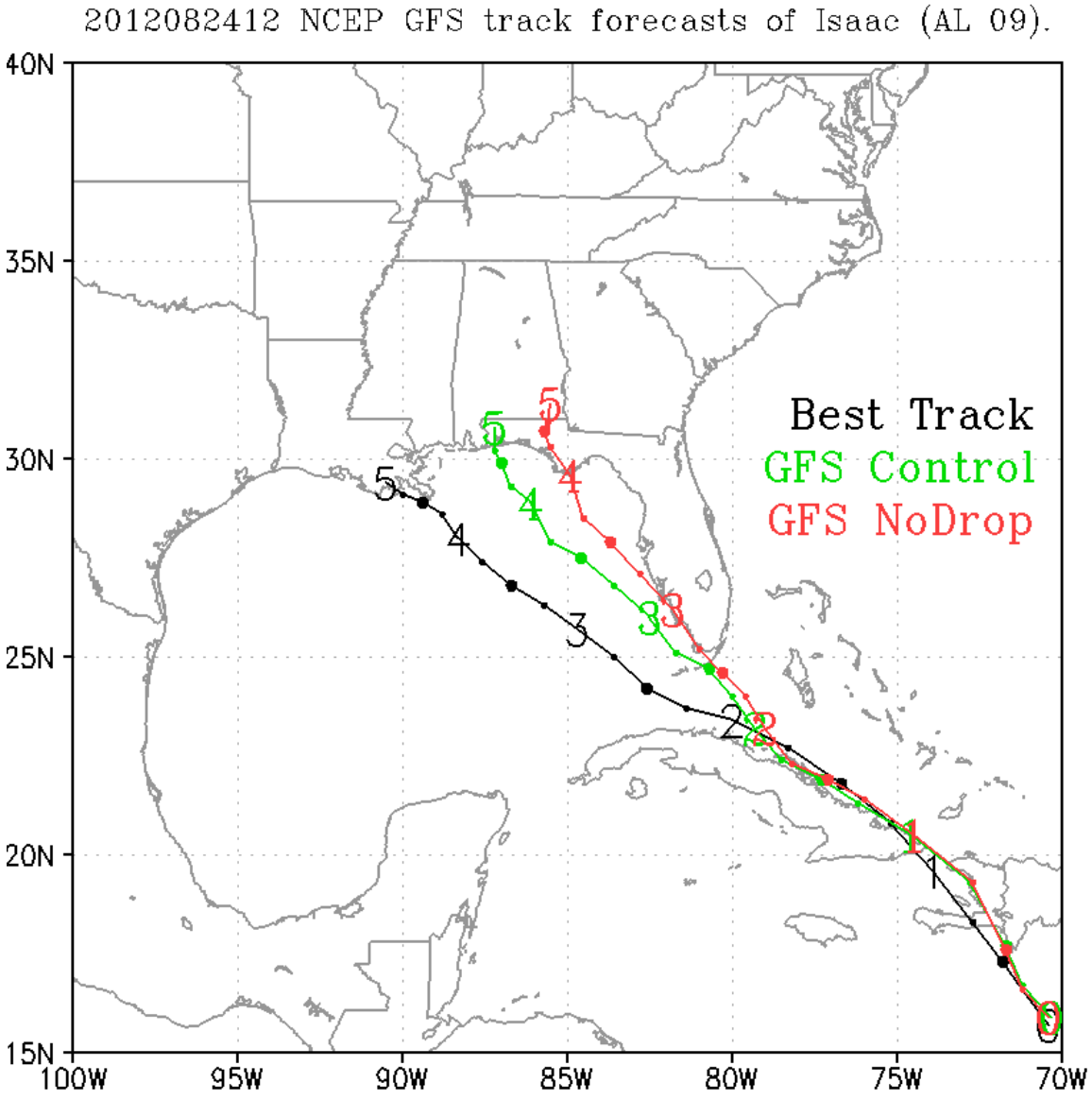




7 Synoptic Surveillance Missions
24-27 August

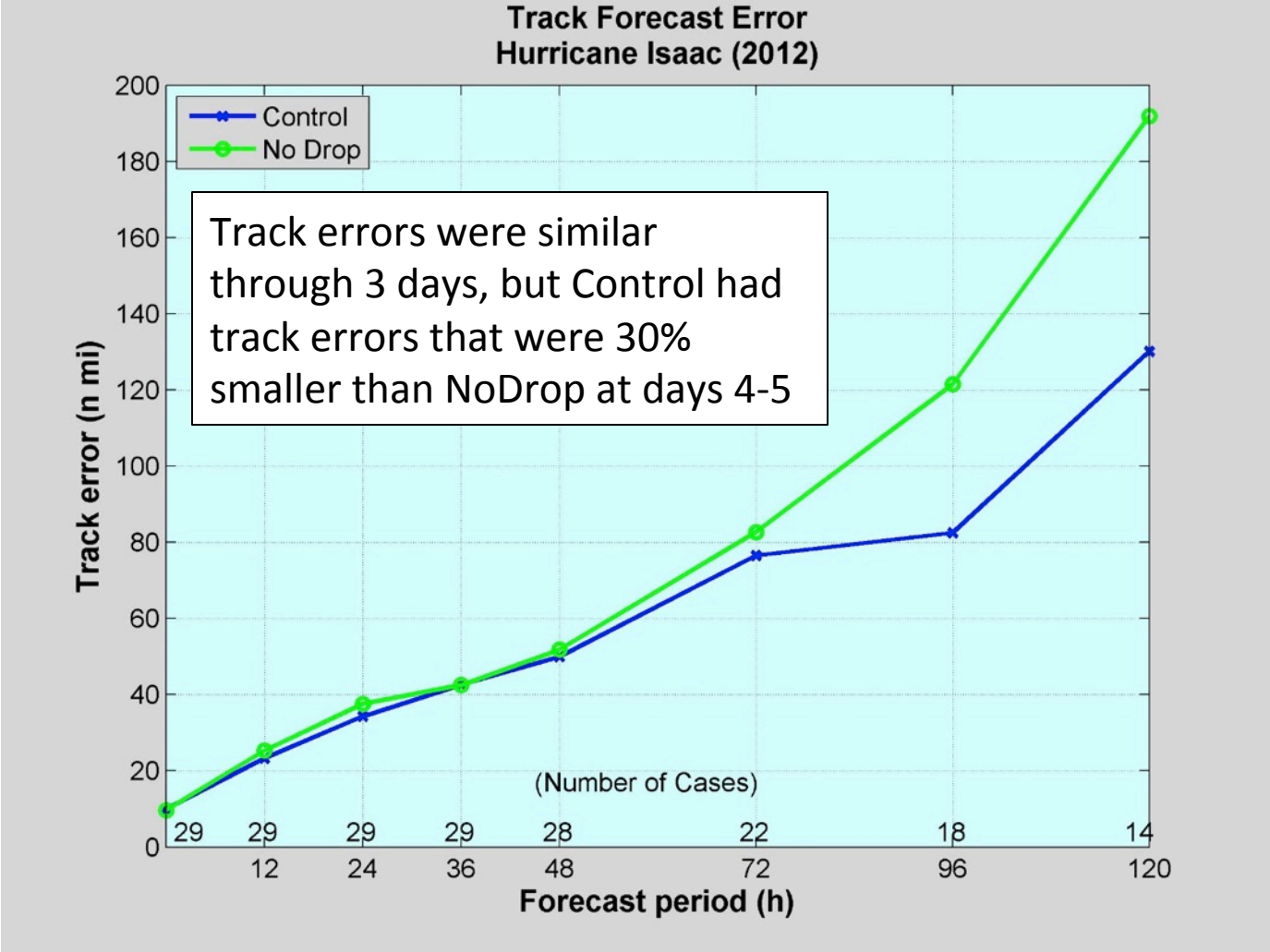
Targets: Isaac; subtropical ridge north of Isaac; mid-upper trough along U.S. southeast coast.





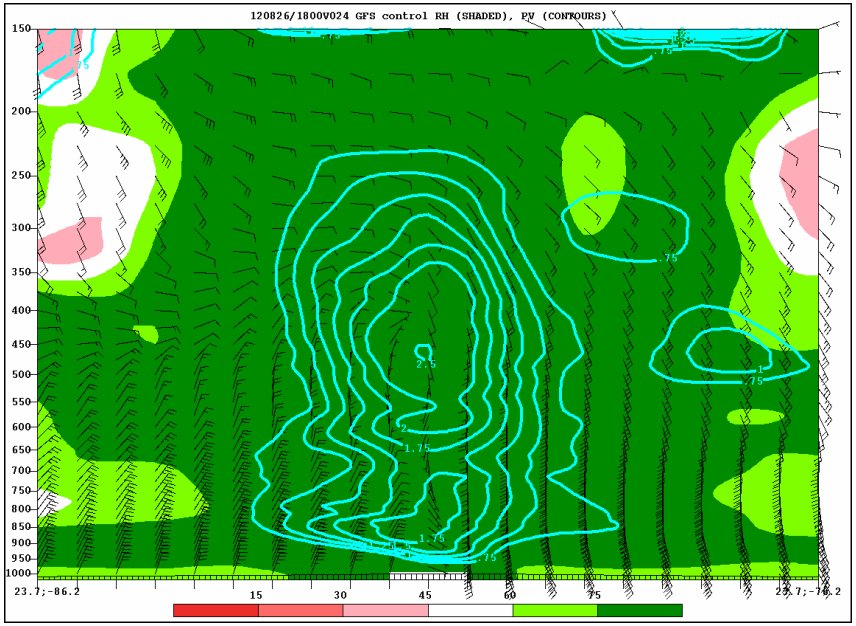
24-25 August cycles: GFS forecast tracks generally to the right of the best track. Drops usually shift forecast closer to best track.

Average Track Errors

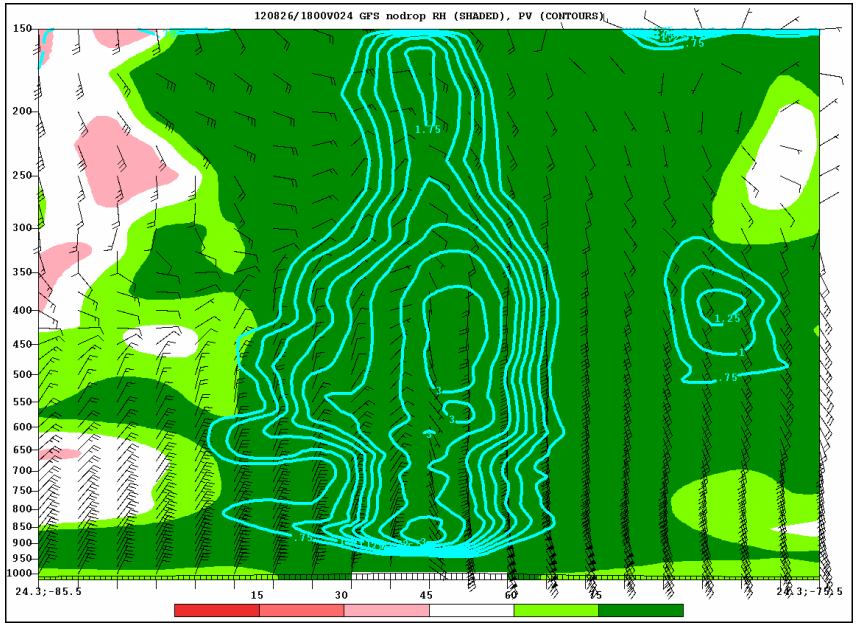


Vortex Structure (24-h Forecast Valid 18Z 26 August)

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



Control

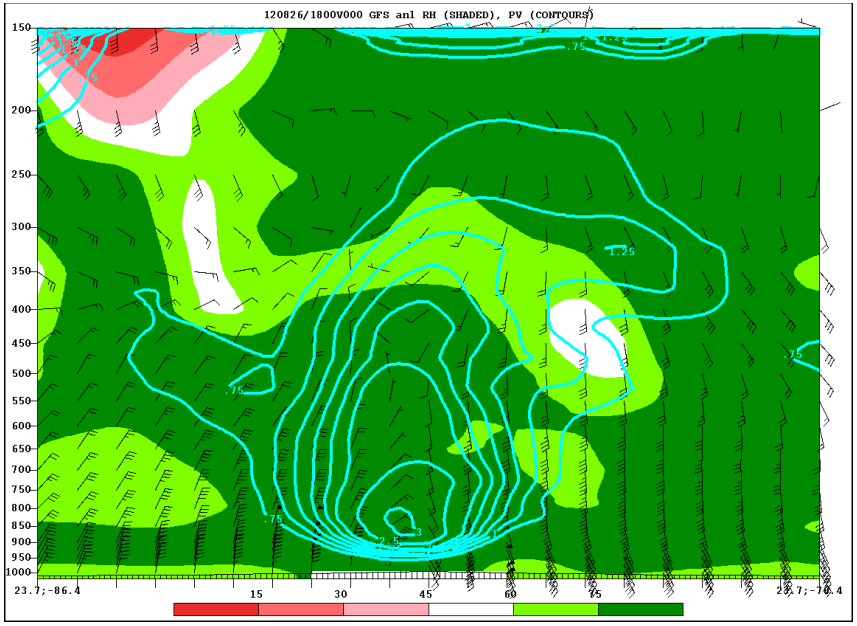


No Drop

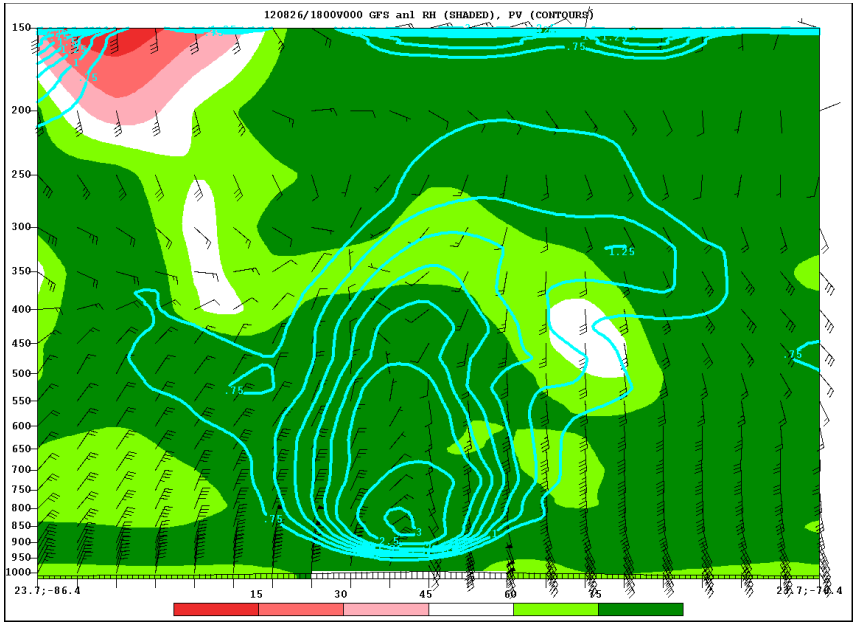
- W-E cross section through center
- Control shows shallower, weaker vortex relative to No Drop

Vortex Structure (Analysis Valid 18Z 26 August)

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



Analysis



Analysis

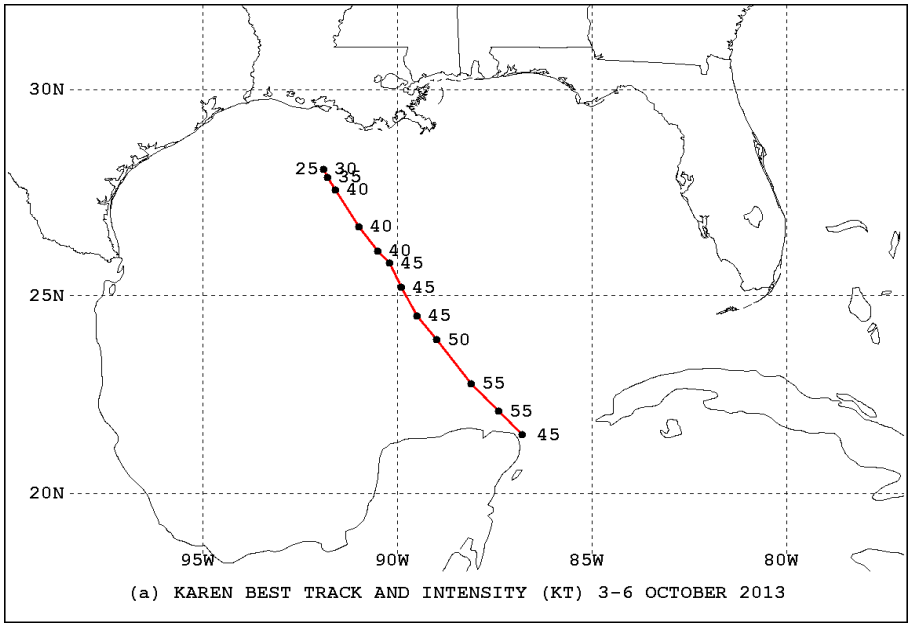
- Analysis shallow and weak, more similar to Control than No Drop

Conclusions 2: Isaac (2012)

- Dropwindsondes **reduced 4-5 day average track forecast errors by about 30%**
  - When differences were seen due to the drops, they were improvements
  - For some cycles, little change was seen
- Drops appear to **reduce the cycle-to-cycle variability** in the GFS track
- Track forecast uncertainty **increased** during the period of the 7 missions
- Little change in GFS intensity forecast errors due to the drops

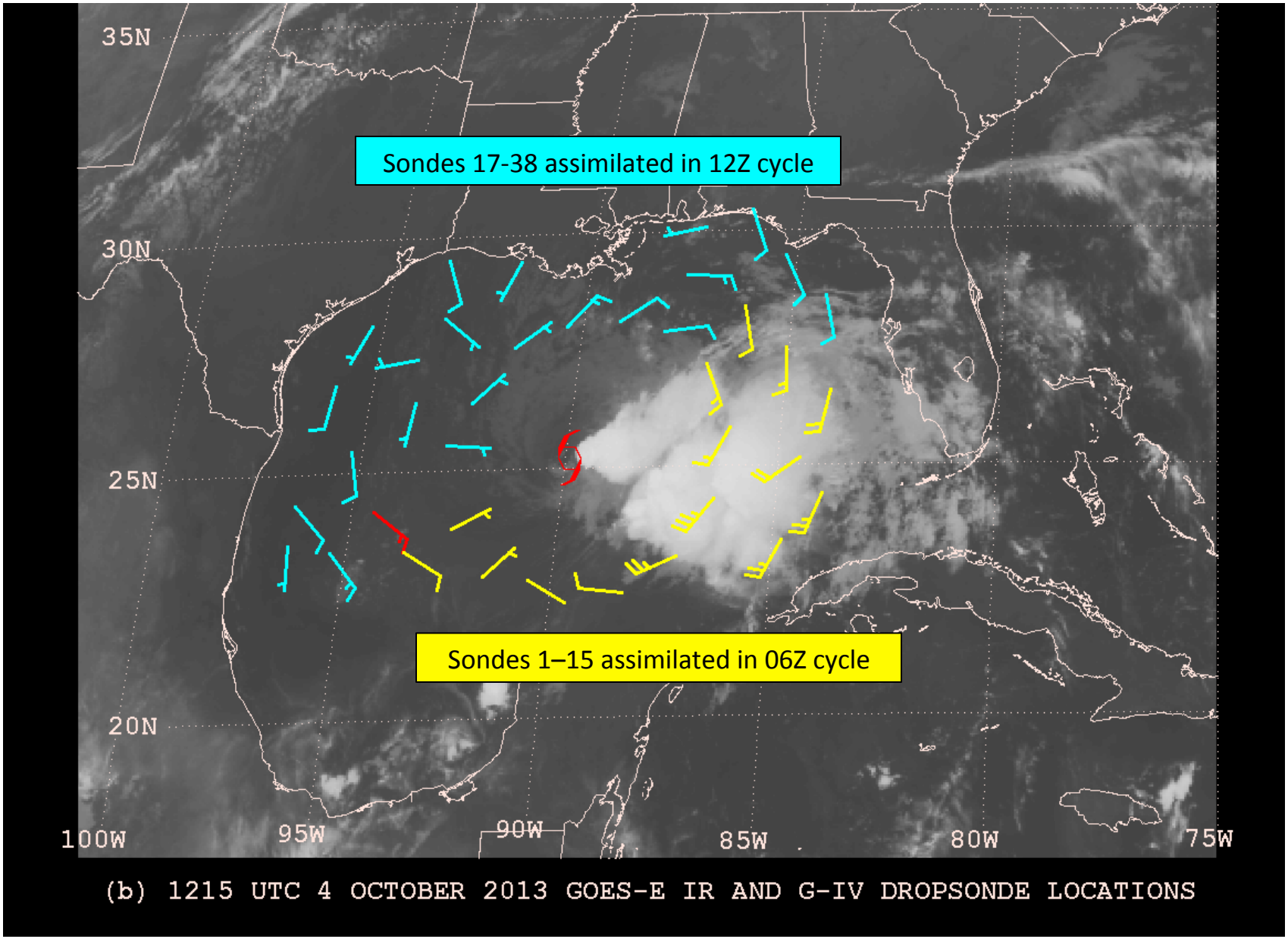
3. Tropical Storm Karen (2013)

- Karen formed as a 45-kt tropical storm early on 3 October 2013 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
- Intensity guidance and global models showed Karen strengthening before reaching northern Gulf Coast



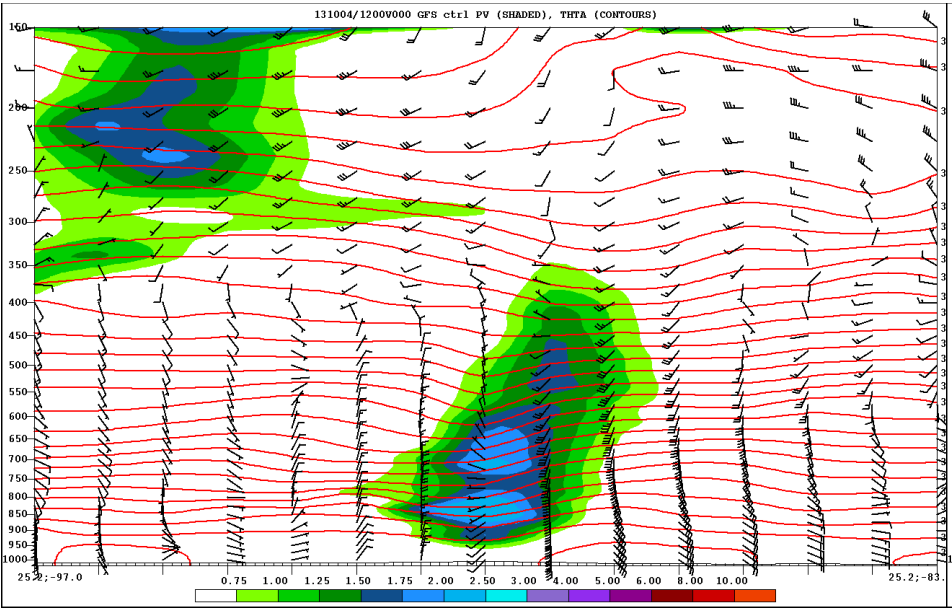
Karen NOAA G-IV Synoptic Surveillance Mission

0530-1300 UTC 4 October 2013

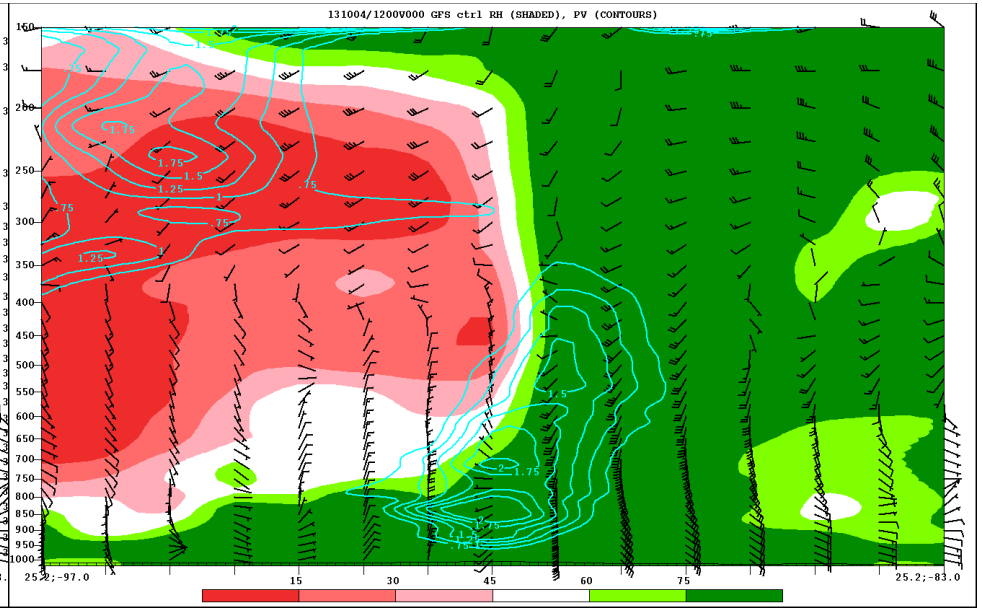


Vortex Structure (Analysis – 12Z 4 October)

Control



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

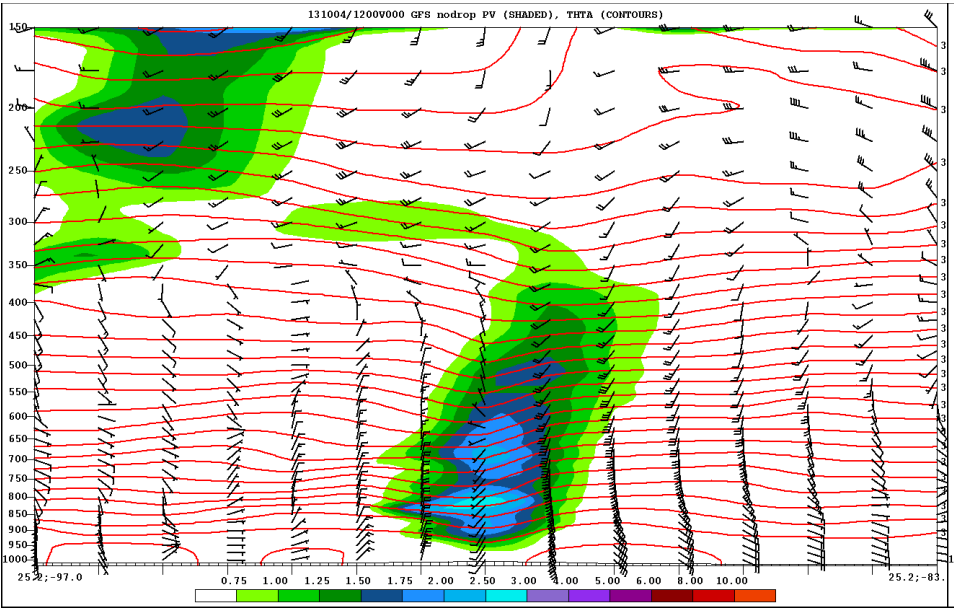


Relative Humidity (shaded), PV, Wind (kt)

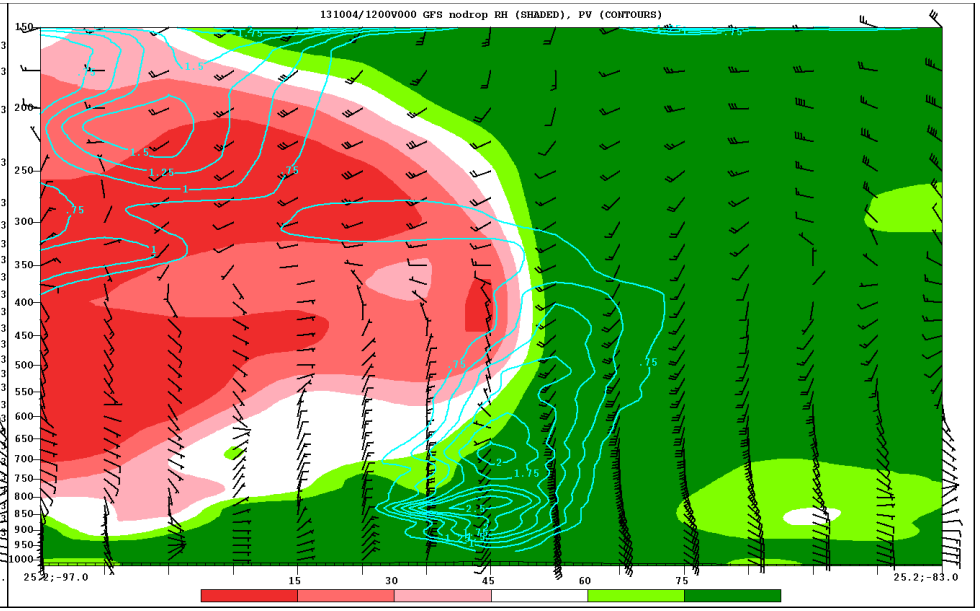
- Control shows more tilt in Karen's PV tower in the 12Z analysis
- Control also shows stronger upper-level winds west of Karen and more dry air over the western part of Karen's circulation relative to No Drop

Vortex Structure (Analysis – 12Z 4 October)

No Drop



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



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

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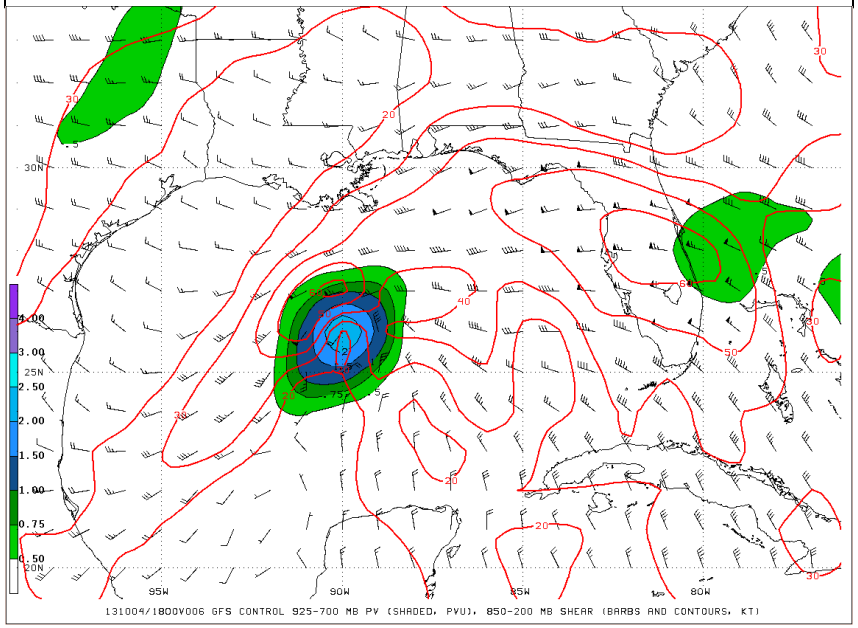
- Control also shows stronger upper-level winds west of Karen and more dry air over the western part of Karen's circulation relative to No Drop

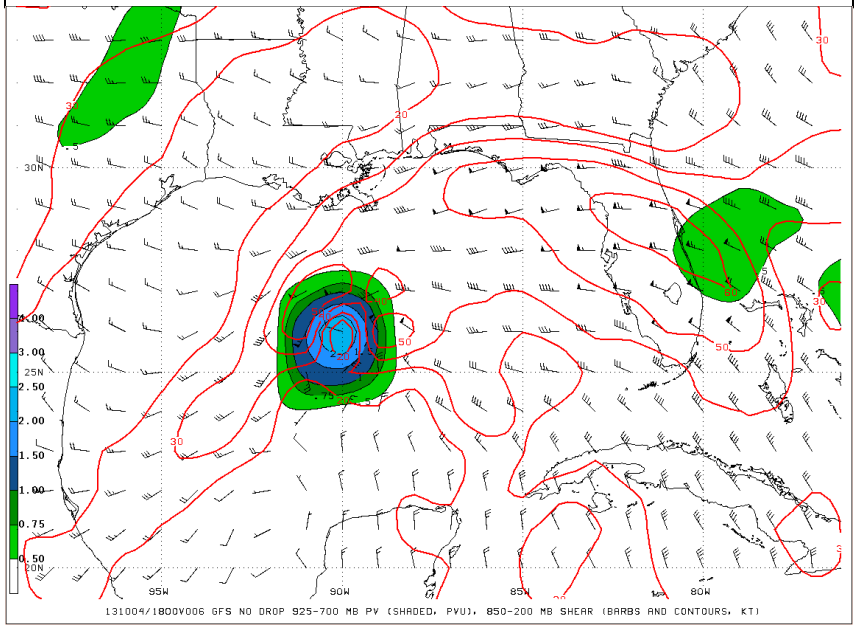
Low-Level Vortex and Shear

F06: 18Z 10/4/2013

Control
Central Pressure: 1009 mb
GFS Intensity: 39 kt



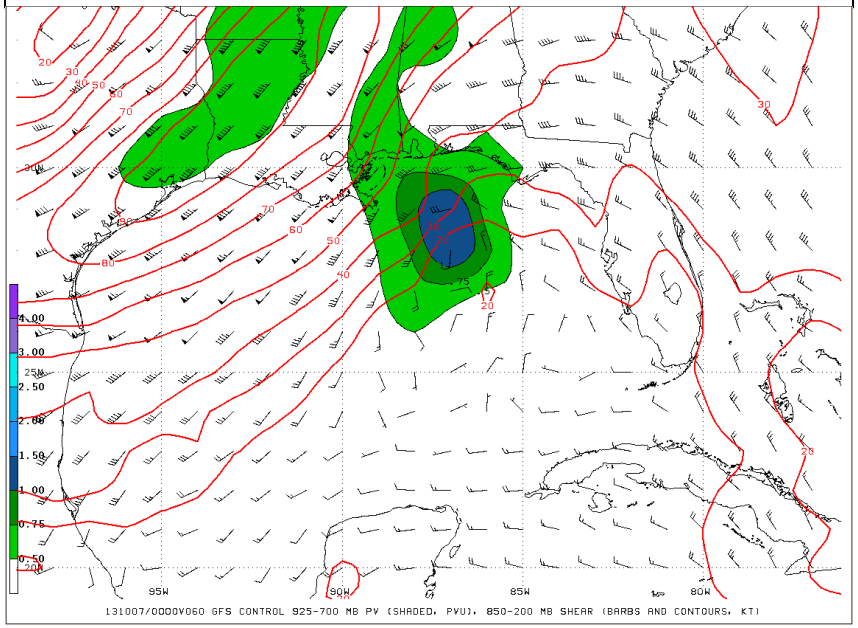
No Drop
Central Pressure: 1008 mb
GFS Intensity: 43 kt



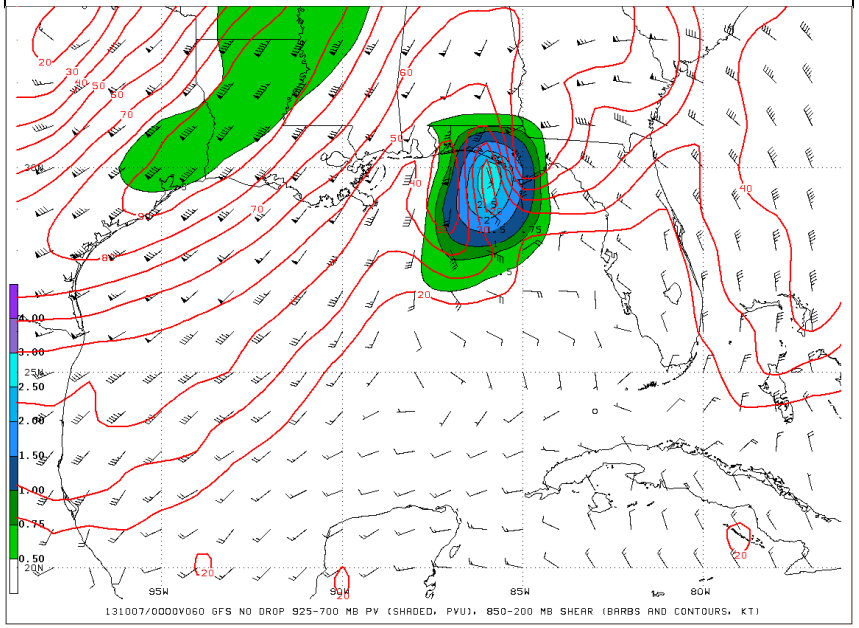
Low-Level Vortex and Shear

F60: 00Z 10/7/2013

Control
Central Pressure: 1006 mb
GFS Intensity: 27 kt

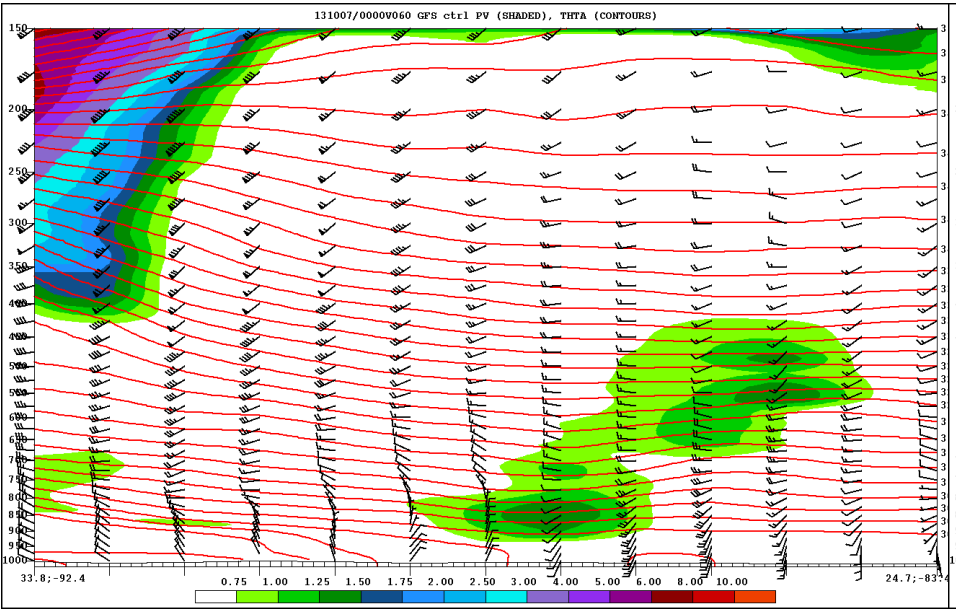


No Drop
Central Pressure: 1003 mb
GFS Intensity: 48 kt

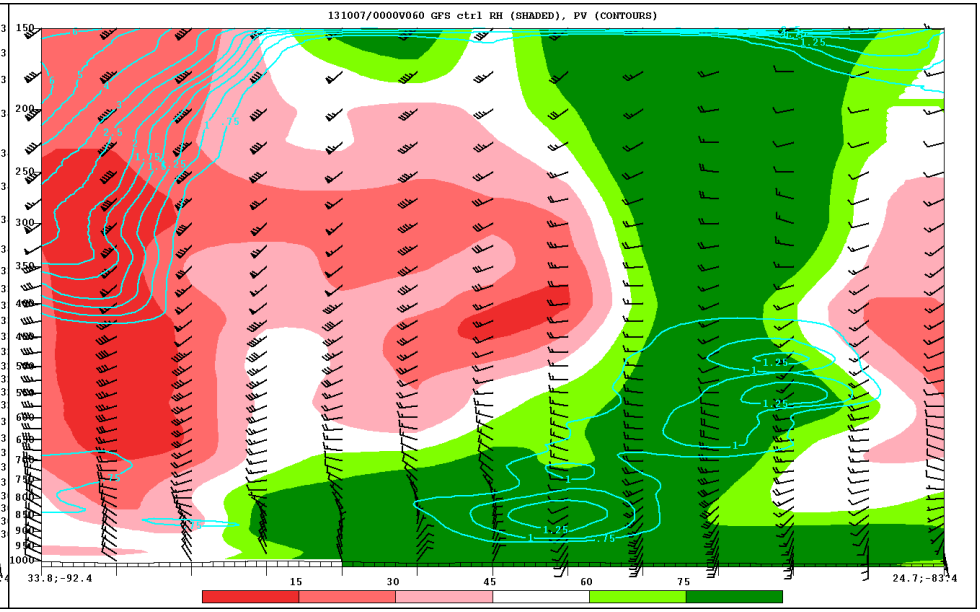


Vortex Structure (F60)

Control



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

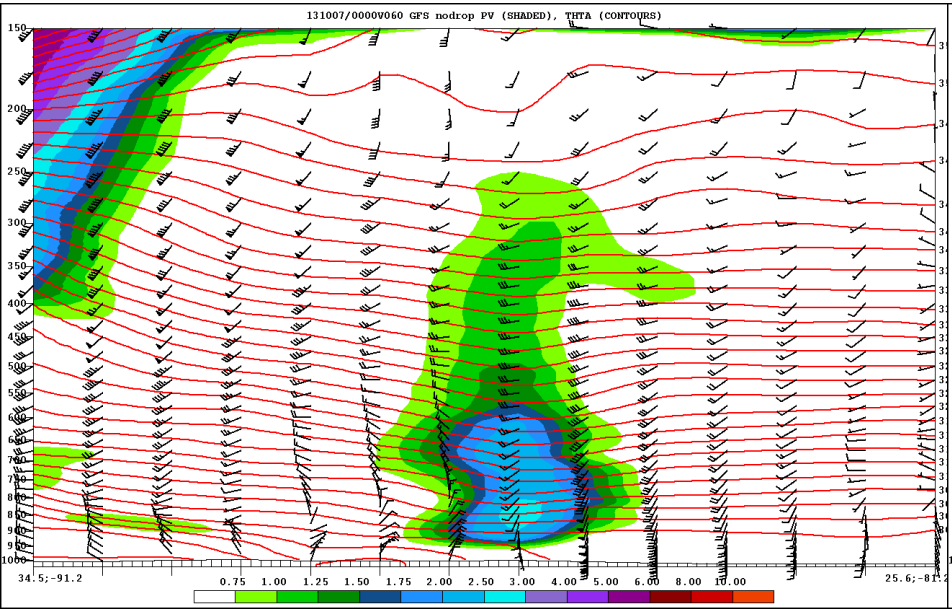


Relative Humidity (shaded), PV, Wind (kt)

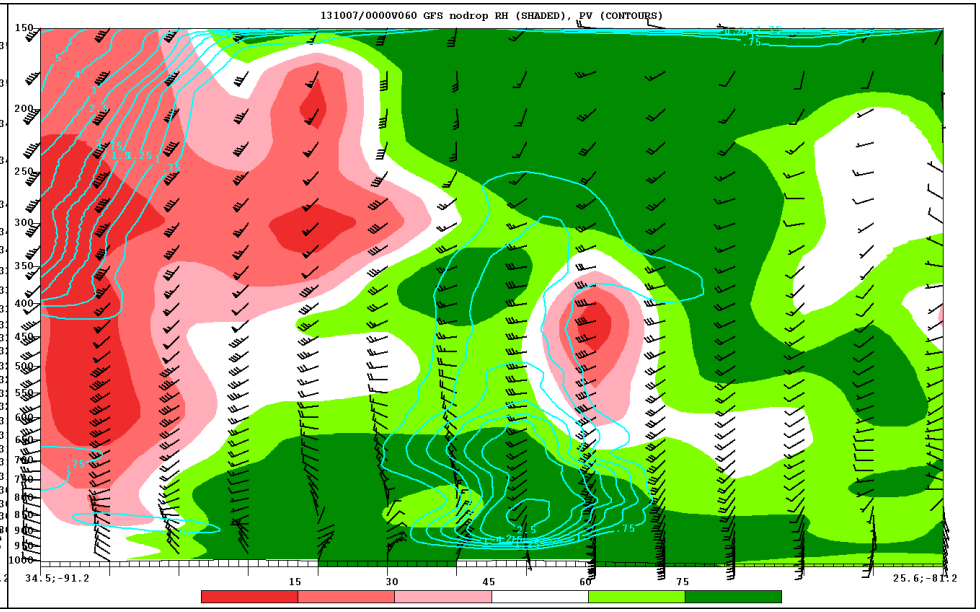
- By F60, Control shows weak vortex with dry air above that does not intensify ahead of approaching upper-level trough

Vortex Structure (F60)

No Drop



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



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

- By F60, cyclone in No Drop is much deeper and appears to intensify in region of upper-level divergence

Conclusions 3: Karen (2013)

- G-IV data appear to result in a **slightly more tilted vortex, stronger vertical wind shear** and **drier air aloft** impinging on the circulation of Karen

- **Control** shows gradual weakening and tilting after 12 h, qualitatively similar to observations

- **No Drop** shows 10-15 kt strengthening in 24-48 h, contrary to observations

Future Work

- Examine additional cases, especially those in which **intrinsic predictability is low** (forecast variance is high)
- Diagnose how the changes due to supplemental obs are based on the **Hybrid GSI covariances**
  - Information in routine observations is being spread out more intelligently than before, leaving less room for improvement from surveillance missions?
- Develop more sophisticated methodologies for **planning the spatial and temporal deployment of supplemental data**, e.g. ensemble sensitivity