

Future Directions for Hurricane Research

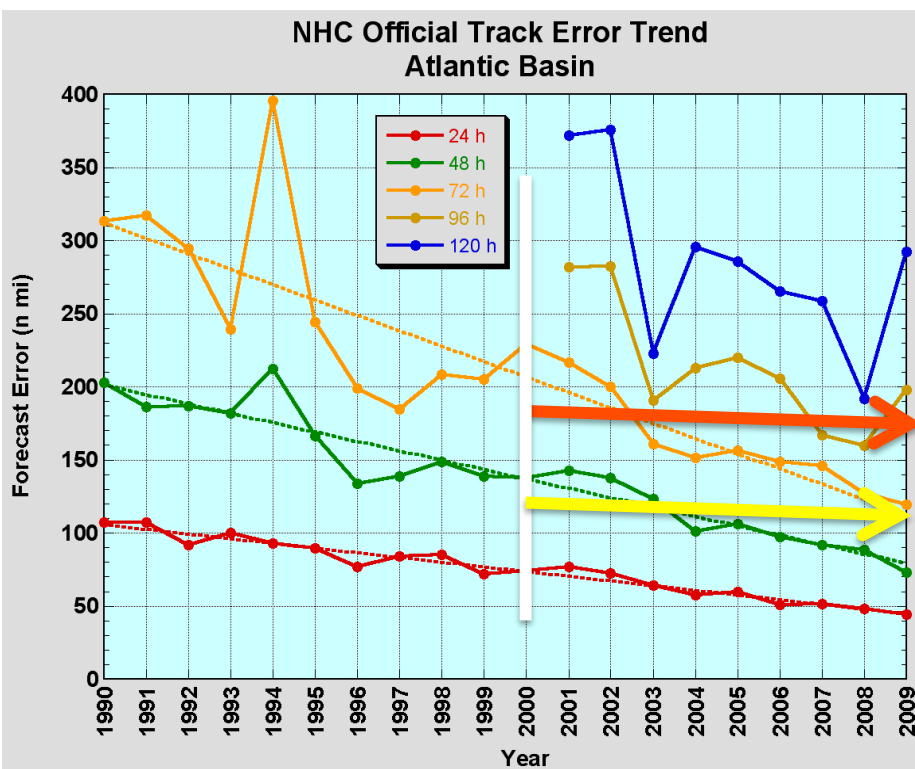


Frank Marks
NOAA/AOML Hurricane Research Division
7 November 2011

Current Capabilities

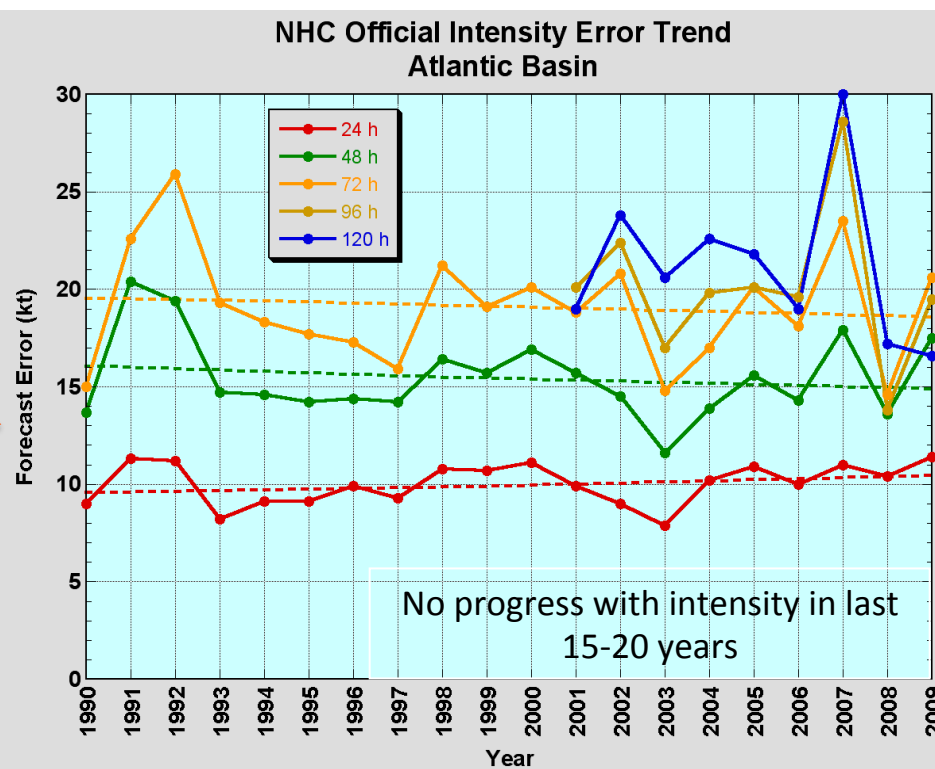


The Good – track forecast improvements



- Errors cut in half over past 15
- 10-year improvement - As accurate at 48 hours as we were at 24 hours in 1999

The Bad - Intensity no real gains



- 24-48h intensity forecast off by 1 category
- Off by 2 categories perhaps 5-10% of time



National Hurricane Forecast Improvement Project

Meeting the Nation's Needs

Improvements still needed!



- NWS Strategic Plan emphasizes Decision Support Services (DSS)
- More accurate forecasts are needed of all the impacts of hurricanes
 - Wind
 - Surge
 - Fresh water flooding
 - Severe weather
- Irene 2011
 - 42 deaths (primarily flood)
 - \$7–\$10 Billion damage (wind, surge, flood)
 - Major infrastructure losses (wind, surge, flood)
 - Power lost to 8 million (primarily wind)



Hurricane Research Priorities



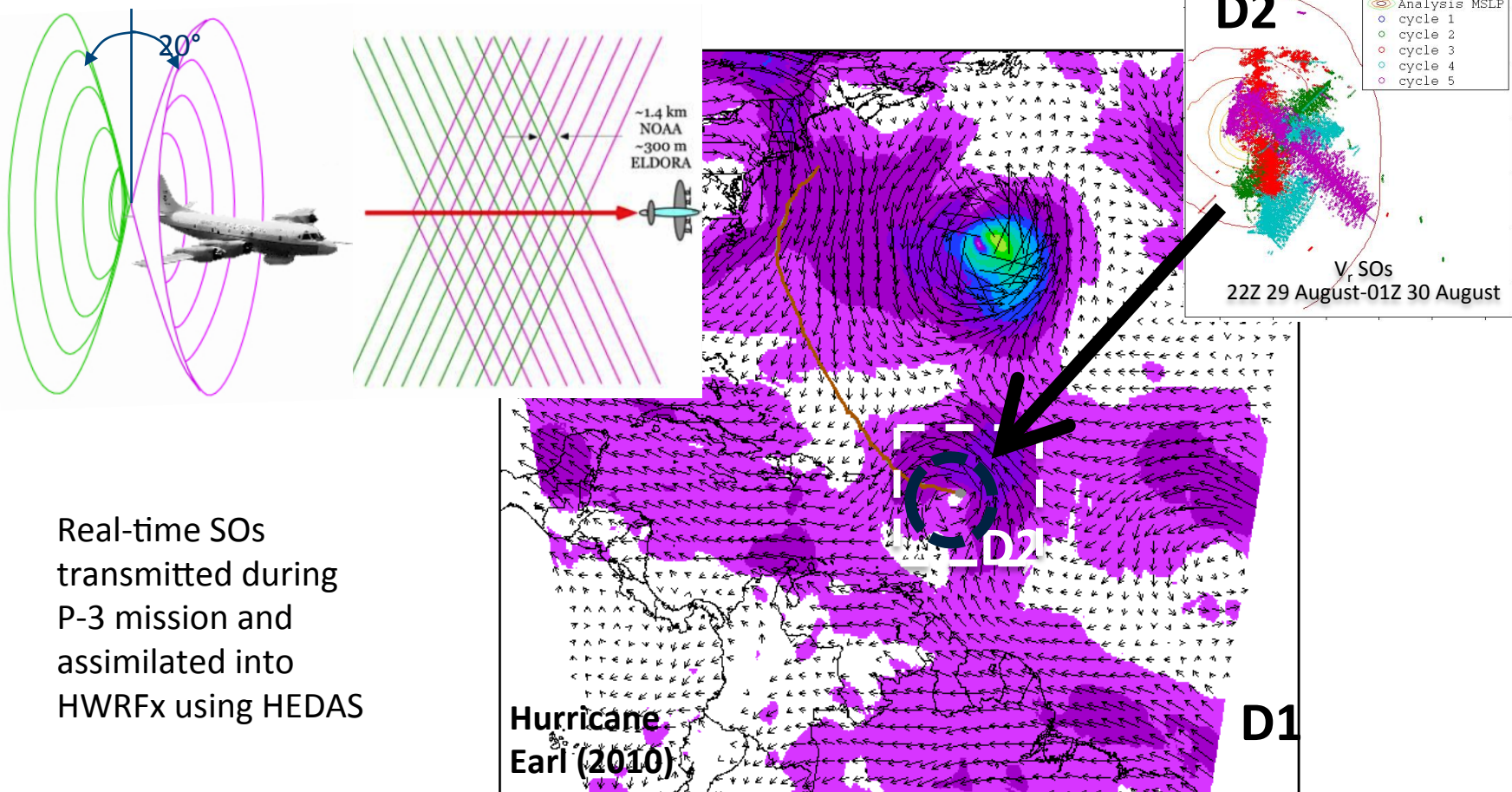
1. Advancement in DA techniques
 - **Techniques to maximize the usefulness of observations**
 - **Identification and analyses of sources of model errors**
2. Physics Advancements
 - **Air-sea and BL processes**
 - **Microphysical/aerosol/radiation processes**
3. Advanced model diagnostic techniques
 - **Analyses and forecast of vortex low-order wavenumber evolution**
 - **Analyses and forecast of large-scale and hurricane environment evolution (e.g. shear/track)**
4. Development of high resolution ensembles (little progress to date)
 - **Identify techniques to utilize ensemble members for improved intensity guidance**



Improved Use of Observations: Assimilate Doppler Radar



EnKF data assimilation of inner core observations



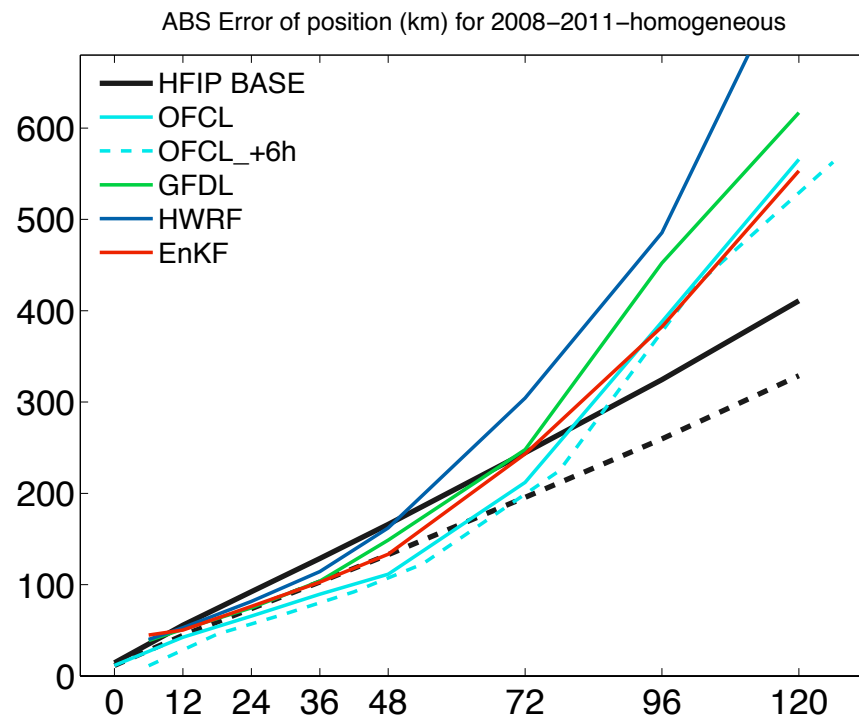
Improved Use of Observations:

Assessing Doppler radar – EnKF results

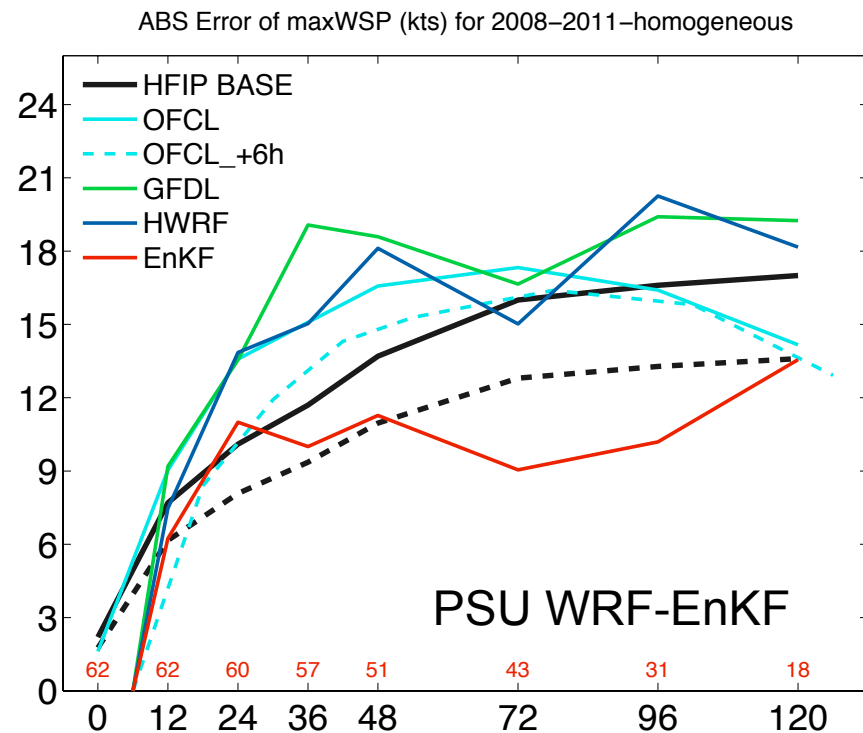


Performance of 2008-2011 Forecasts with assimilation of P-3 airborne radar

Track Error (km)



Intensity Error (kt)



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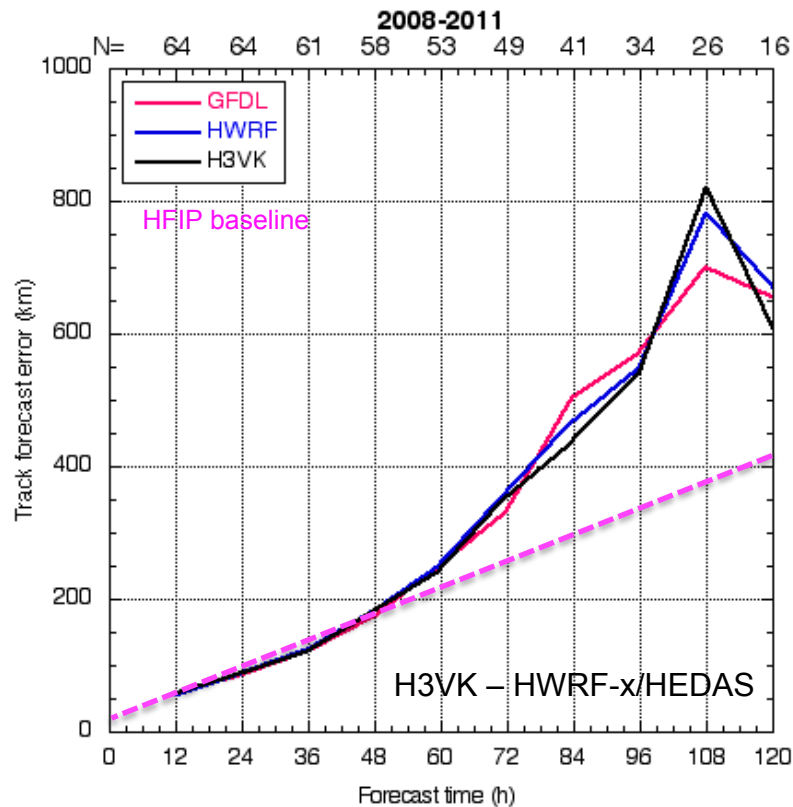
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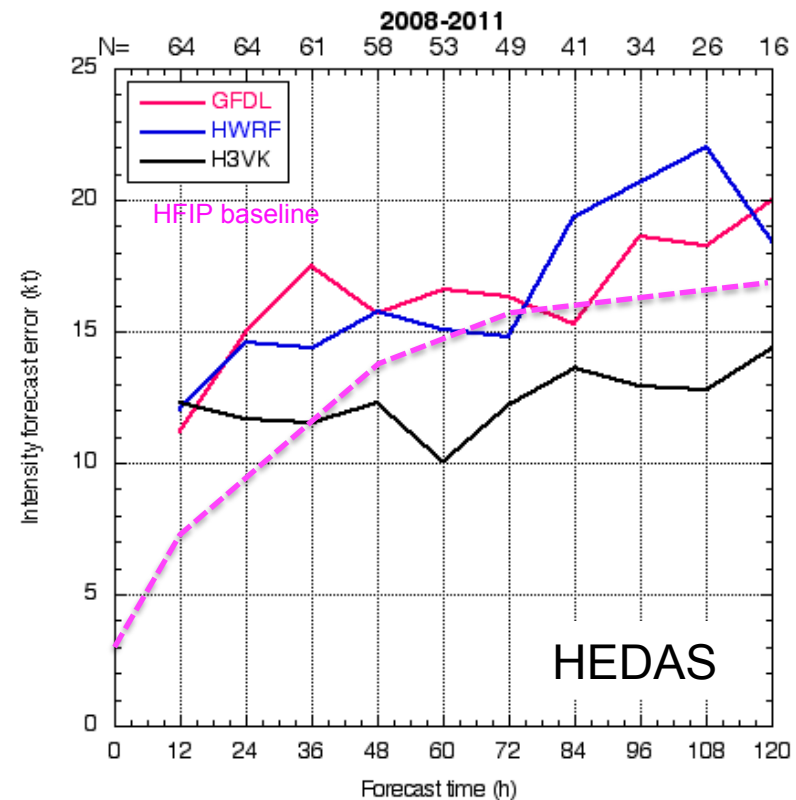


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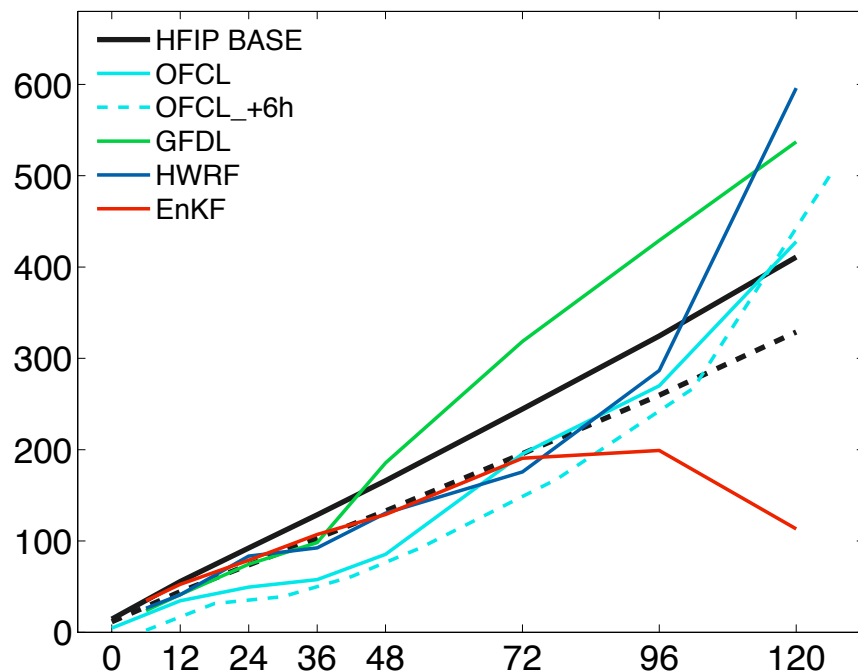
Assessing Doppler radar – EnKF results



Performance of the 2011 Real-time Forecasts with assimilation of P-3 airborne radar (Irene & Rina)

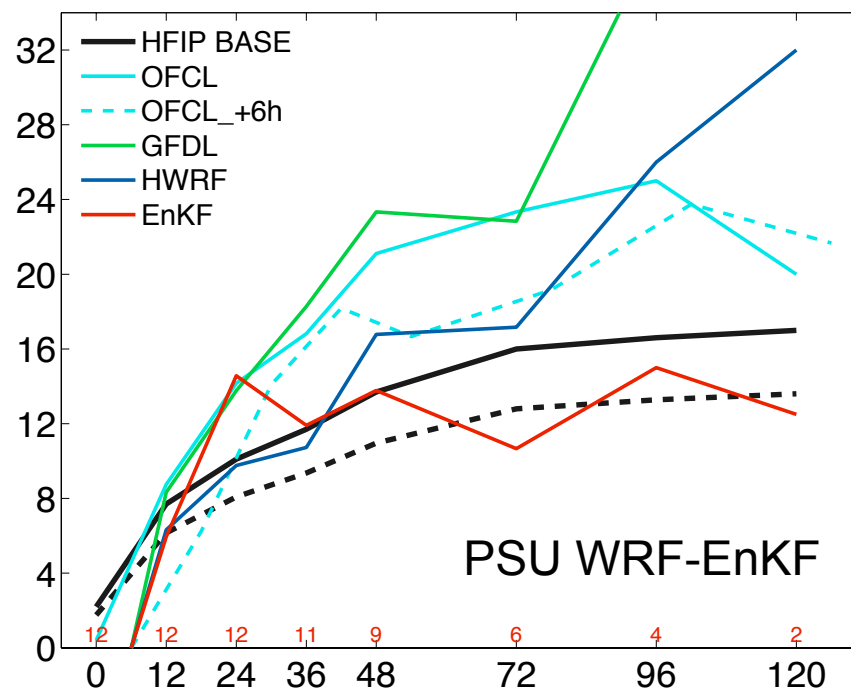
Track Error (km)

ABS Error of position (km) for 2011–2011–homogeneous



Intensity Error (kt)

ABS Error of maxWSP (kts) for 2011–2011–homogeneous



PSU WRF-EnKF



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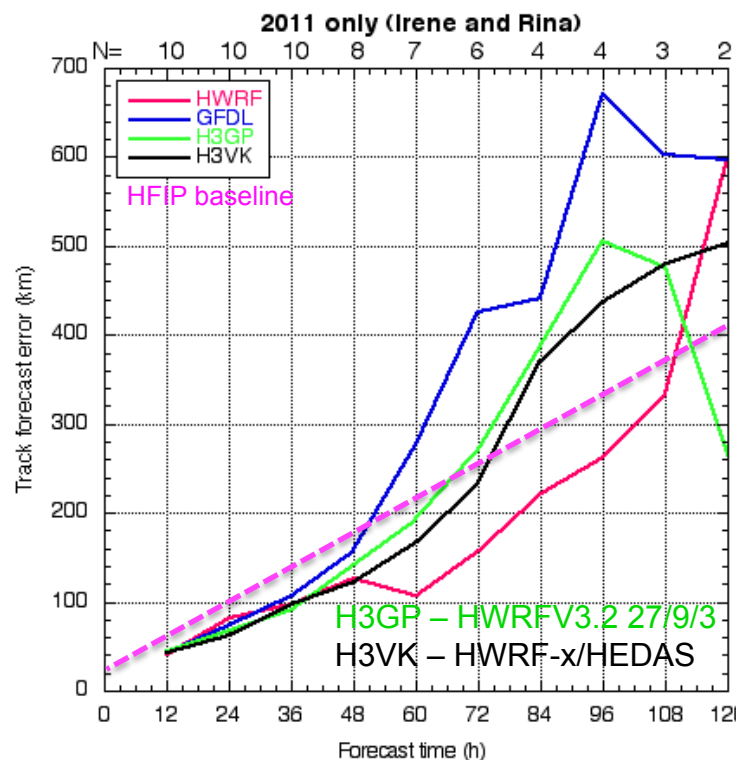
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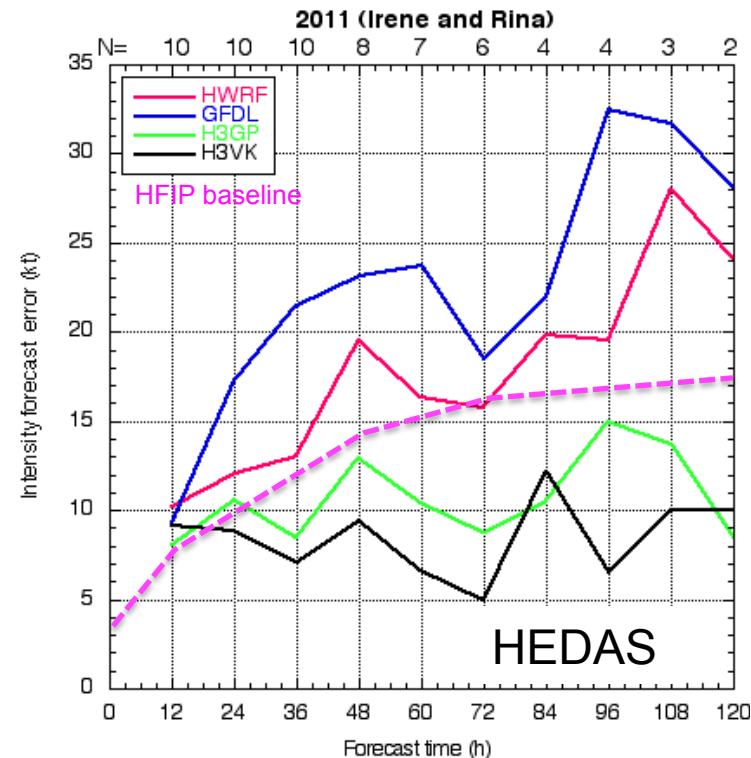


Performance of the 2011 Real-time Forecasts
with assimilation of P-3 airborne radar (Irene & Rina)

Track Error (km)



Intensity Error (kt)



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Improved Use of Observations:

Assimilate Doppler Radar



The Good:

- Radar data appears to be critical in initializing regional models (likely requires EnKF background error covariances to use effectively)
 - May solve intensity problem for storms effecting U.S.
 - Need increased use of satellite data for storms further away

The Not So Good (needs improvement):

- There is a short-term forecast bias. Good initial analysis do not lead to improved intensity forecast until 36-48 h. Why?



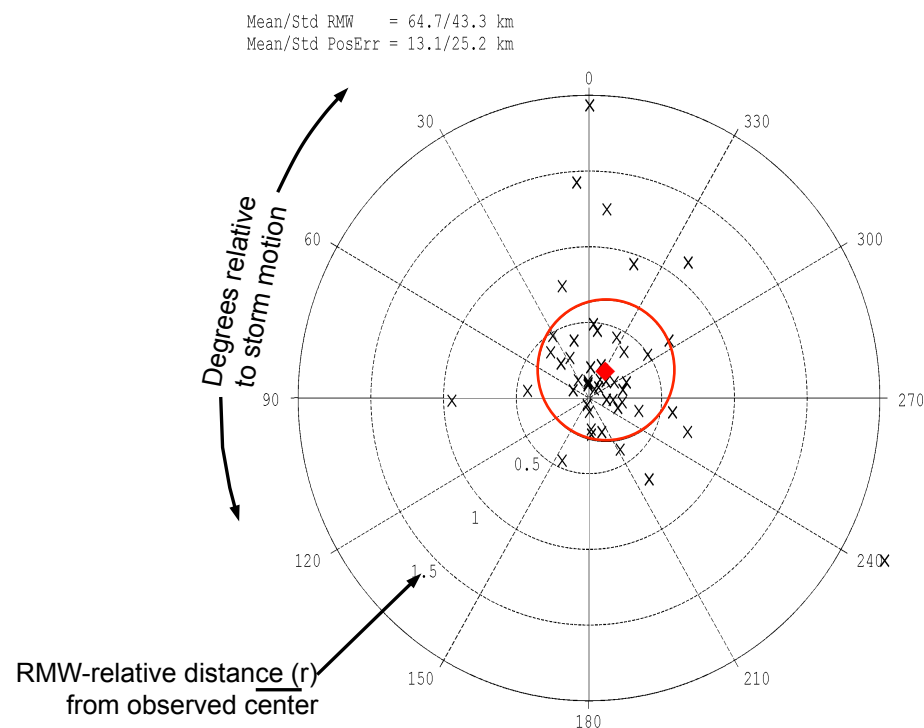
Improved Use of Observations: Assimilate Doppler Radar



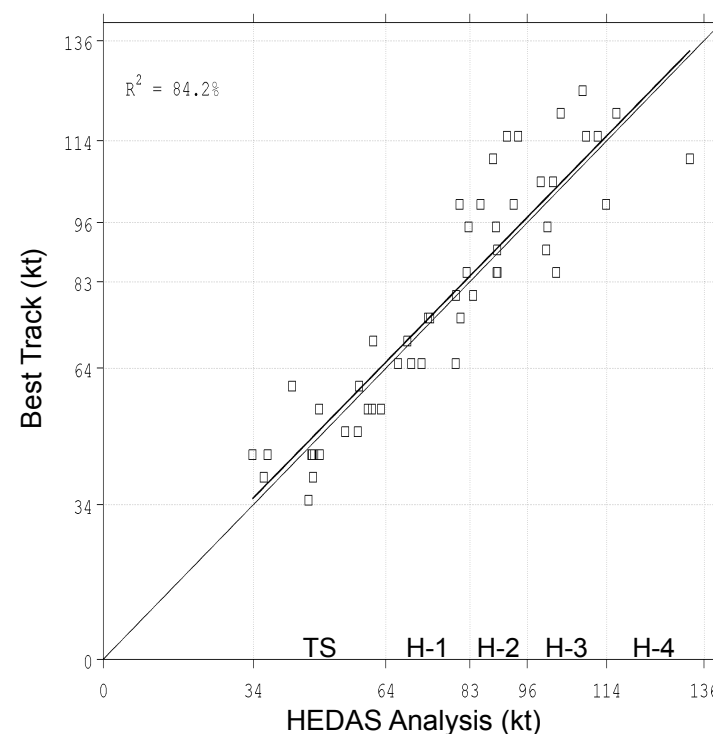
The good:

- Position error to within 0.2 RMW (~12 km)
- Good fit of analysis intensity to best track intensity

Position Error (x RMW)



Intensity (kt)

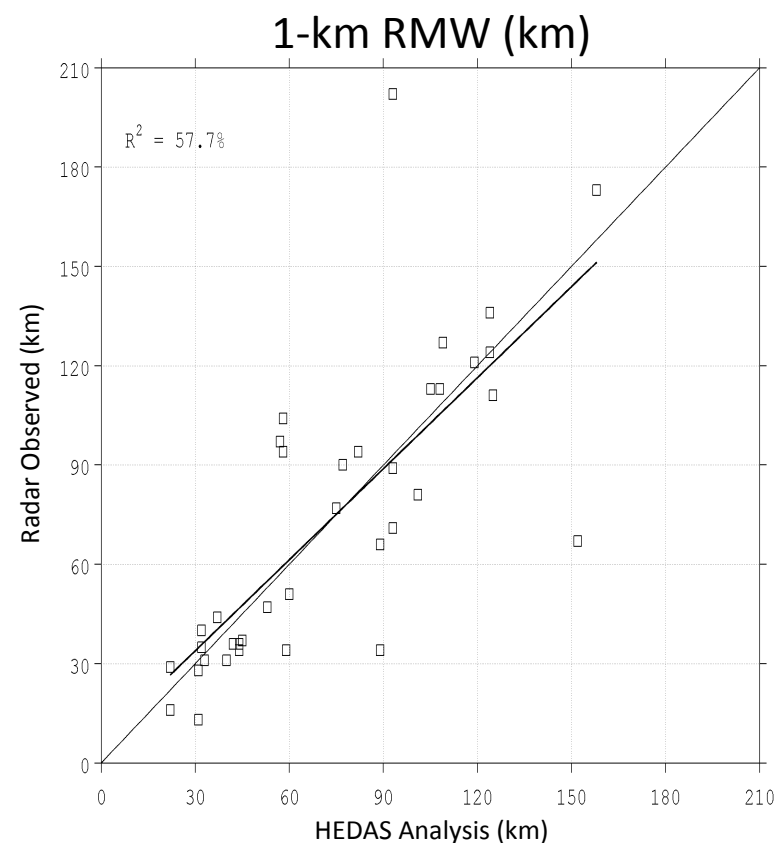
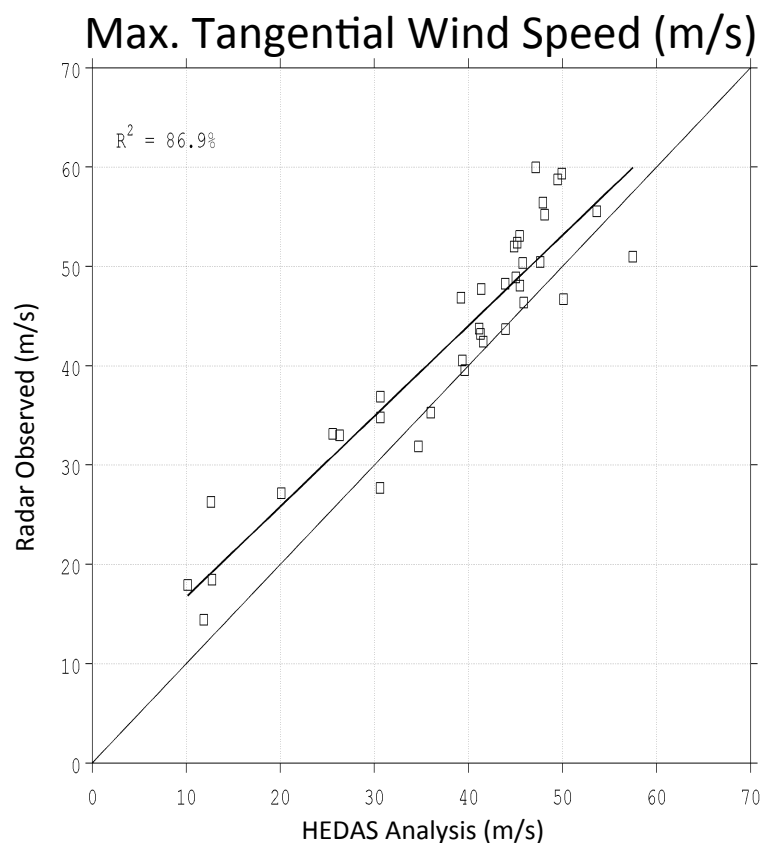


Improved Use of Observations: Assimilate Doppler Radar



The good:

- RMW captured to within 10 km



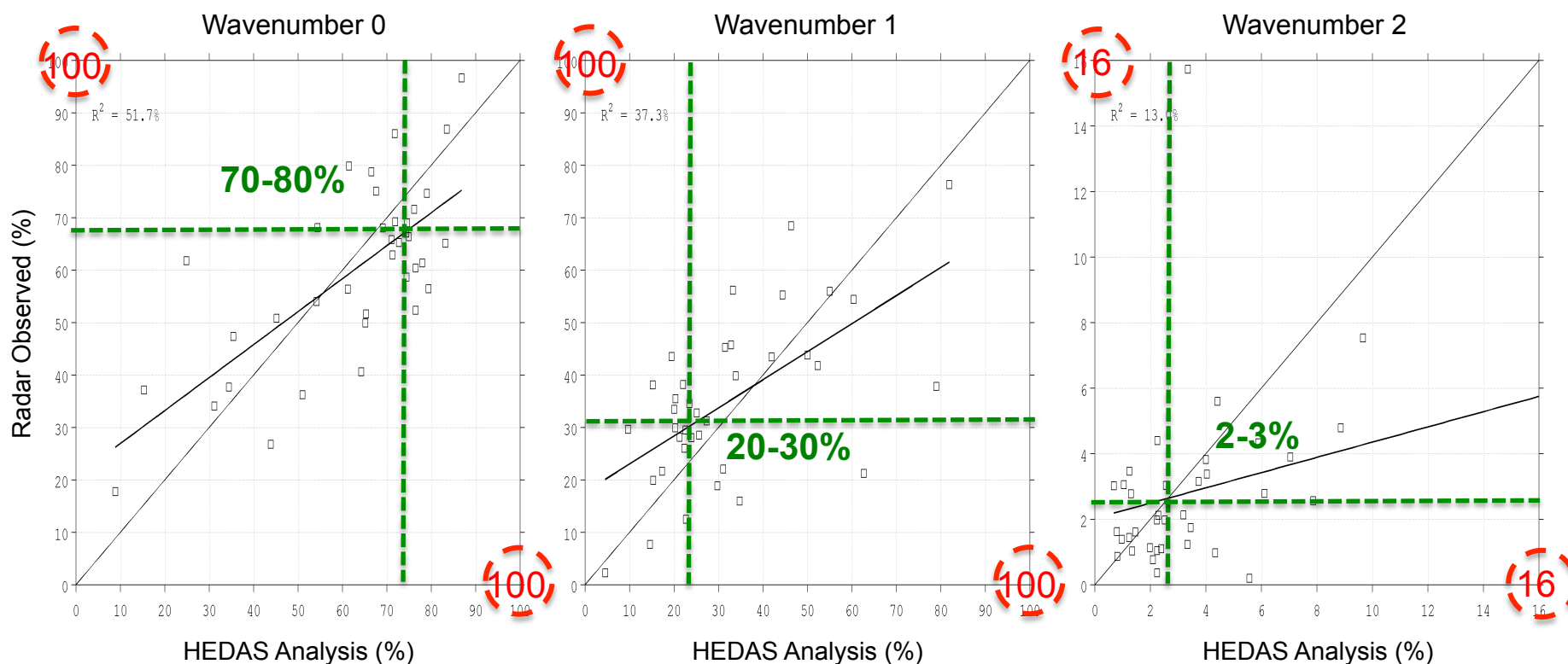
Improved Use of Observations: Assimilate Doppler Radar



The good:

- Wavenumbers 0 and 1 captured well

Variance Explained (%) by Wavenumber Components of 1-km Tangential Wind Speed



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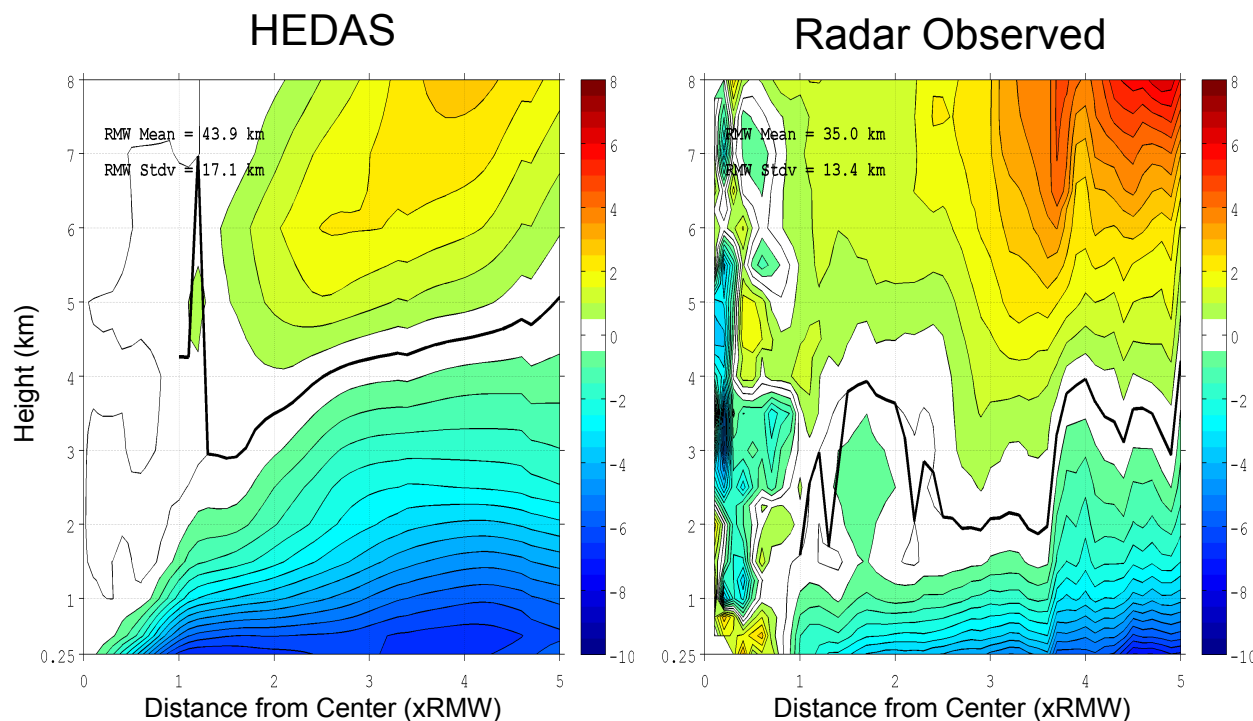
Meeting the Nation's Needs

A. Aksoy, T. Vukicevic (AOML/HRD)

Improved Use of Observations: Assimilate Doppler Radar



RZ-Mean Radial Wind Speed (m/s)
Composited for 13 Major Hurricane Cases



- Where research is needed:
 - Importance of higher-wavenumber structure (e.g., Shear vs track)
 - Boundary layer structure (HWRF V3.2 better than HWRF-x)
 - Vertical correlations and localization in DA
 - How well does the radar sample the radial wind?



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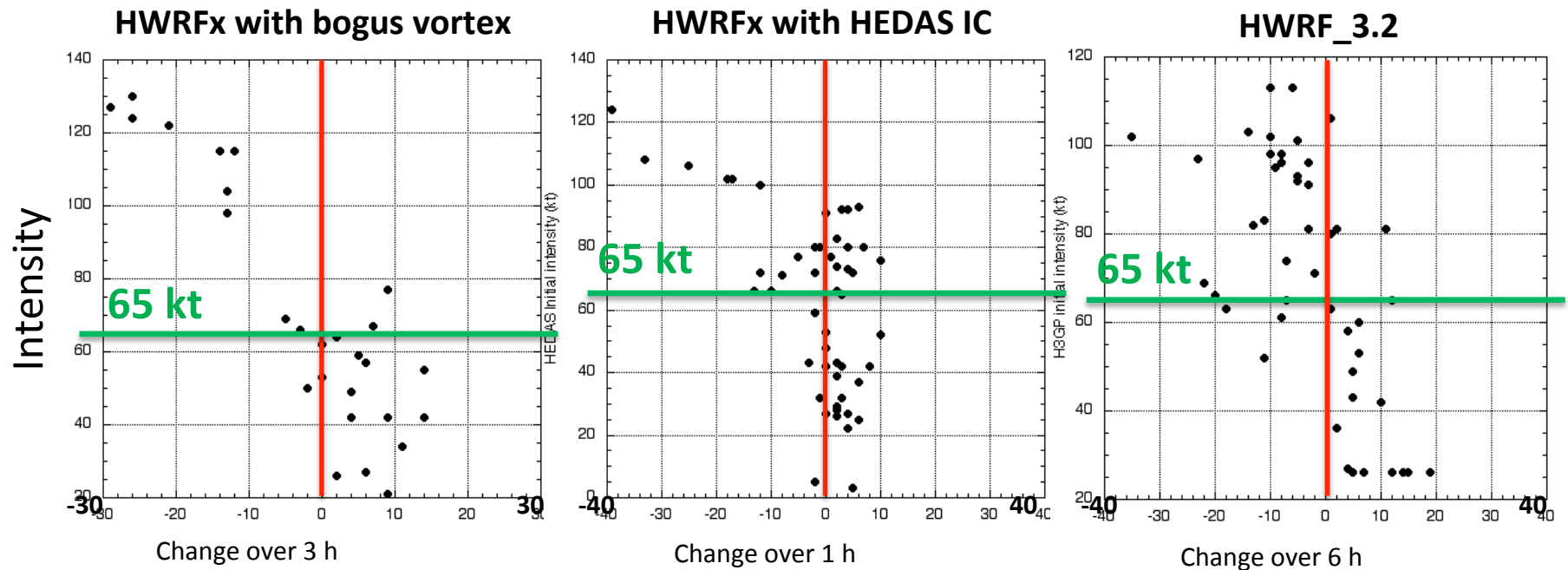
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Short-term forecast bias

Identifying the source of bias:



Vortex spin-down at hourly time scales creates large negative intensity bias for high intensity cases



- Spin-down occurs regardless of initialization method
- Strength of spin-down is dependent on initial intensity: more for higher intensities



Lessons learned & research challenges



- Negative intensity bias in short-term forecasts is common among high-resolution systems and causes significant errors in the forecast at 6-36 h range
- Bias most noticeable in high initial intensity cases
- In such cases vortex spin-down occurs at hourly time scales
- Spin-down profoundly affects data assimilation results and the impact of data assimilation on the forecast
- Other groups working on vortex-scale DA systems should look at similar diagnostics to evaluate model behavior
- Need theory of vortex adjustment to help eliminate loss of information in DA cycling and better analysis for forecast



Improving Physics:



The Good:

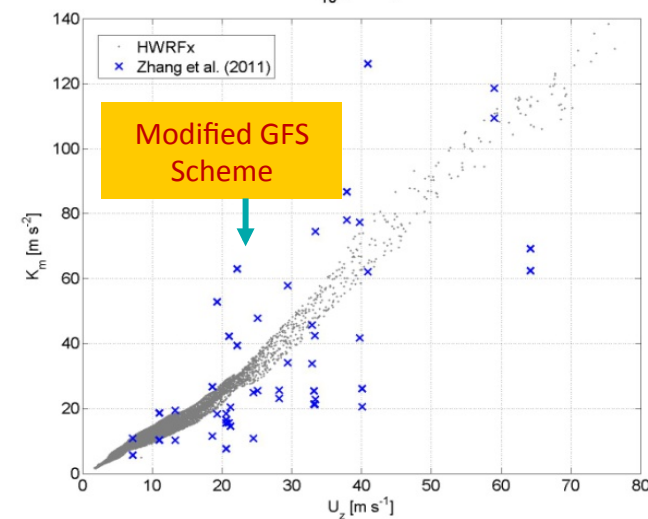
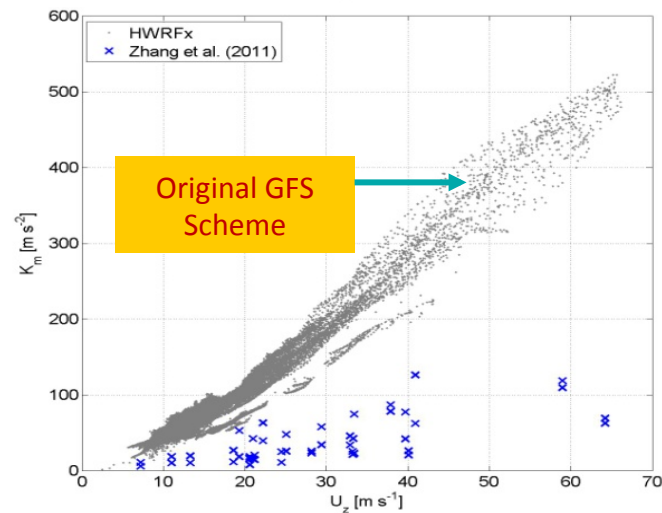
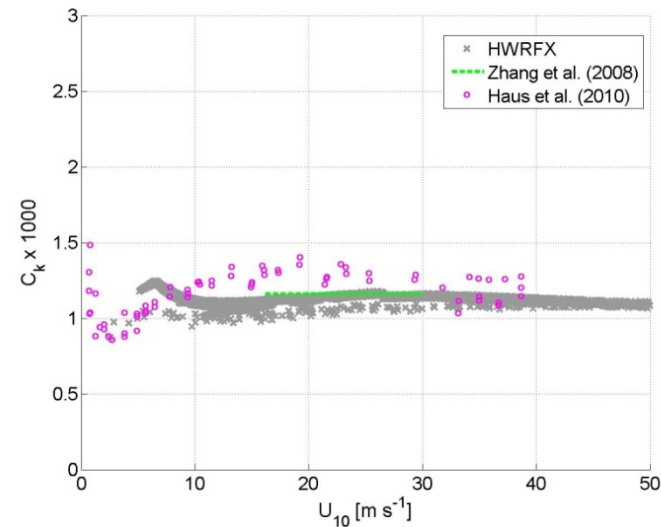
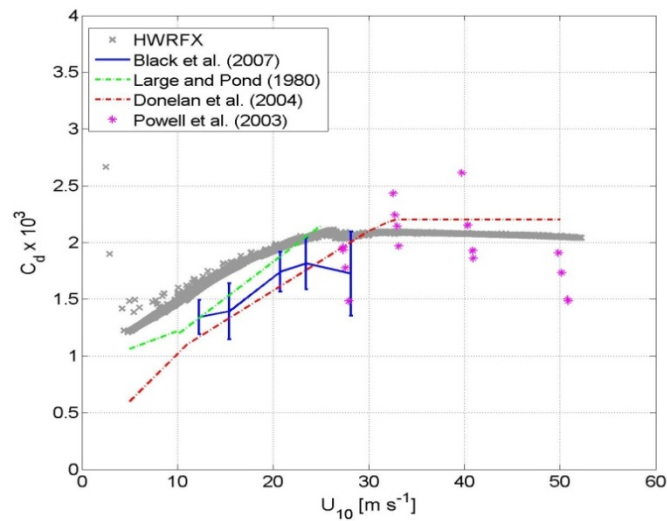
- HWRF V3.2 has improved structure a lower initial intensity bias than HWRFx
 - Improved PBL and surface exchange based on observations (e.g., CBLAST, IFEX) shows dramatic improvements

The Not So Good (needs improvement):

- Appears that surface layer & PBL may be too warm & moist. Why? Assumptions in PBL diffusion for enthalpy?
- 37-GHz and 85-GHz synthetic satellite imagery compare well to observations, however, synthetic IR satellite observations have warm bias. Why?
- Appears to be too much condensate when compared to observations, particularly above melting level and at top of PBL. Why?
- What about the ocean impacts? Few HFIP models are coupled.



Improving Physics: PBL Physics Consistent with Observations



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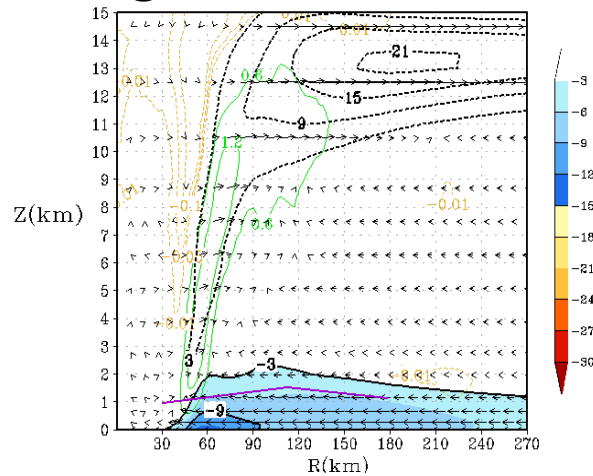
Meeting the Nation's Needs

Gopalakrishnan et al. 2011

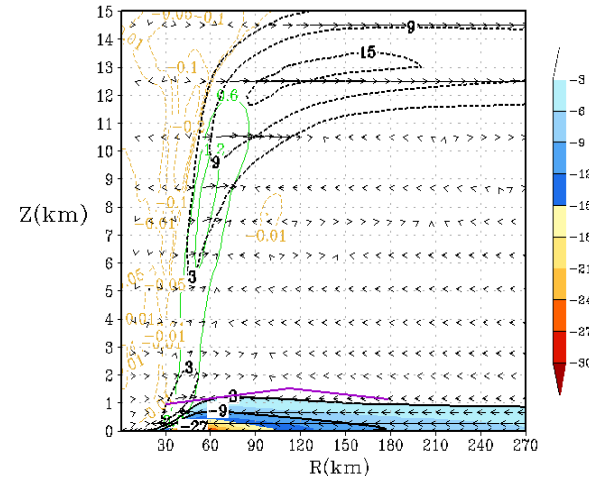
Improved Structure Predictions: 3 KM HWRF



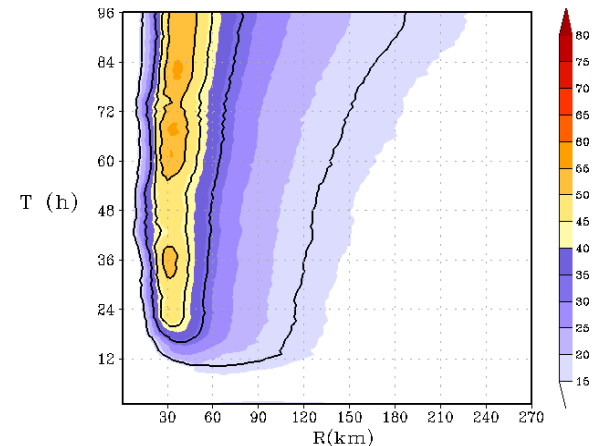
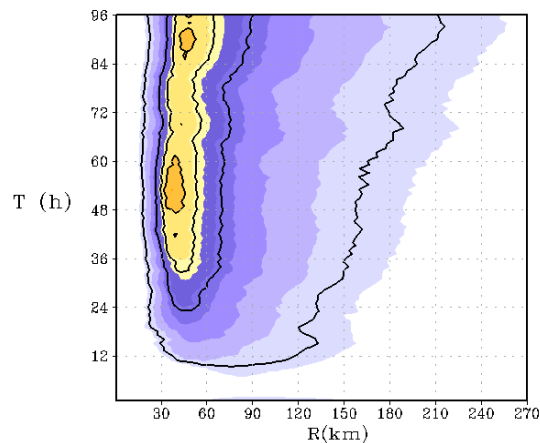
Original Formulation



Latest Formulation



Azimuthally averaged secondary circulation: Radial Wind and W



Hovmöller of 10-m wind speed

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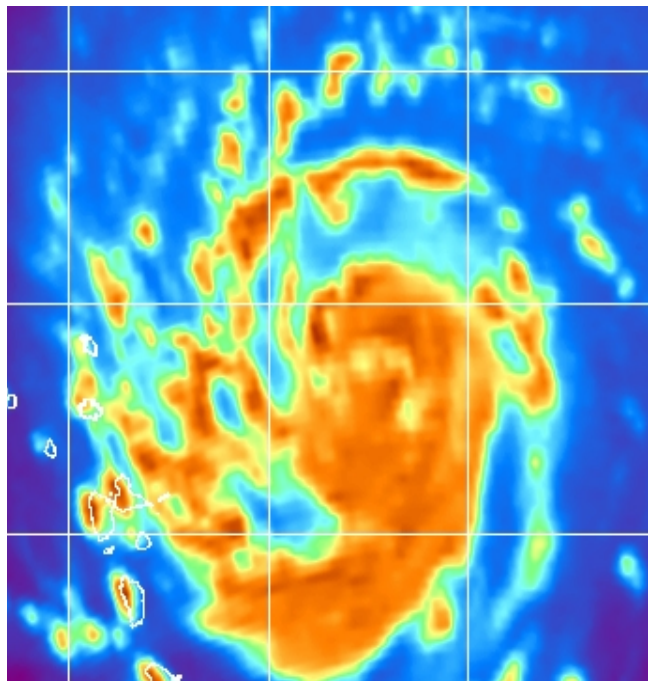


Improving Physics: Synthetic Satellite

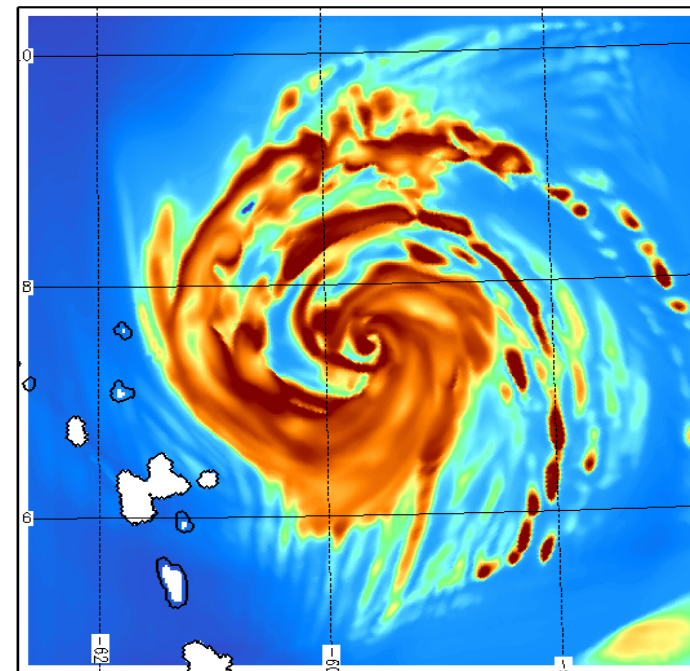


Use Model (HWRFV3.2) to evaluate Microwave satellite imagery (37- & 85-GHz)

Observed



37H Brightness Temperature [K] for 3hr



initial time:2010082912

The good:

- Structure & peak similar

The not so good:

- Distribution is slightly skewed



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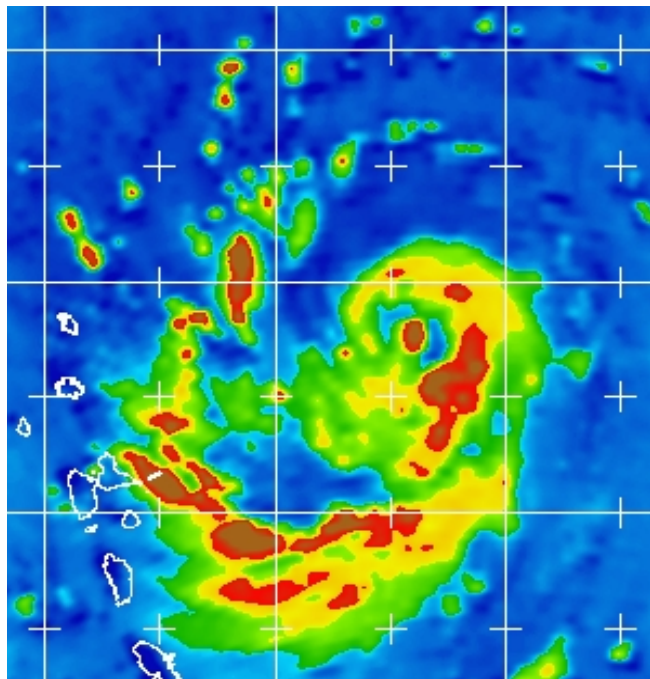
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Hristove-Veleva (NASA/JPL) & Vukicevic (AOM/HRD)

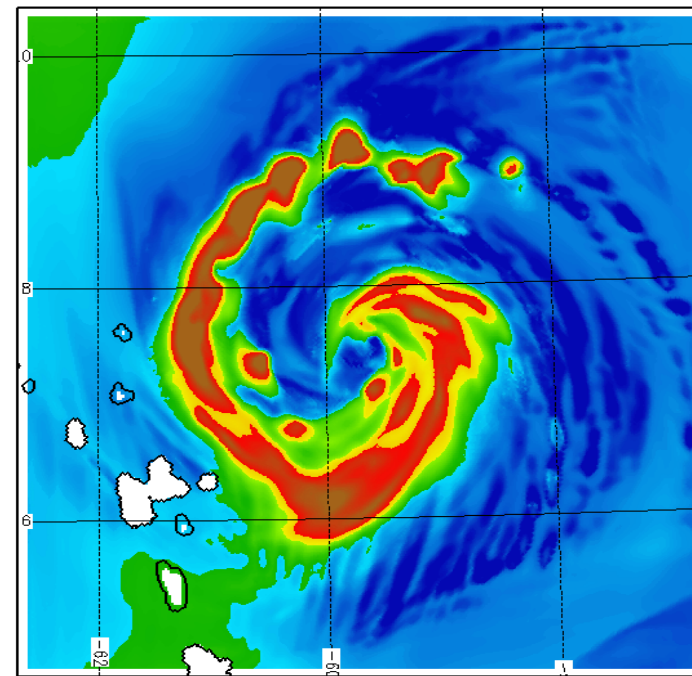
Improving Physics: Synthetic Satellite



Use Model (HWRFV3.2) to evaluate Microwave satellite imagery (37- & 85-GHz)



85H Brightness Temperature [K] for 3hr



initial time:2010082912

The good:

- Structure & peak similar

The not so good:

- Distribution is slightly skewed



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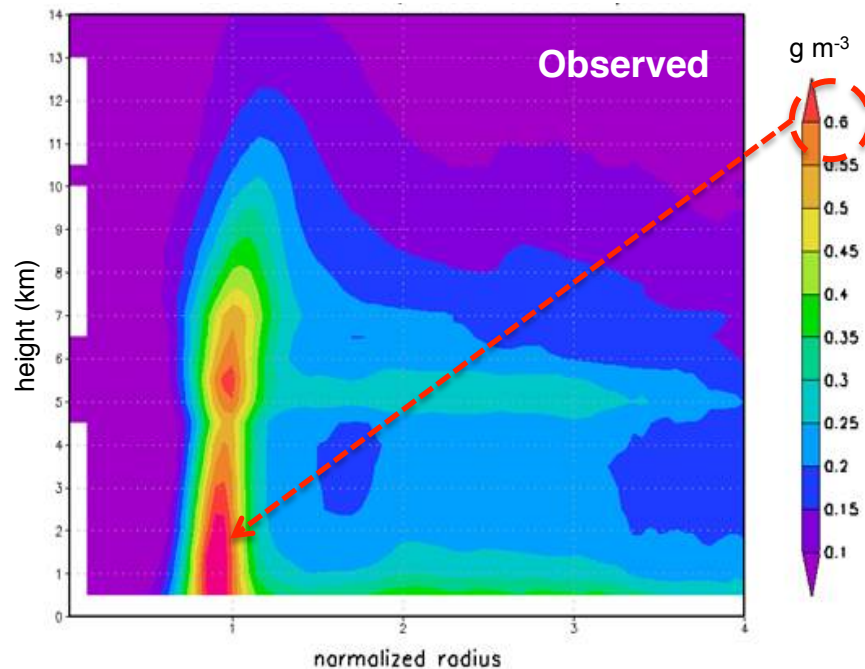
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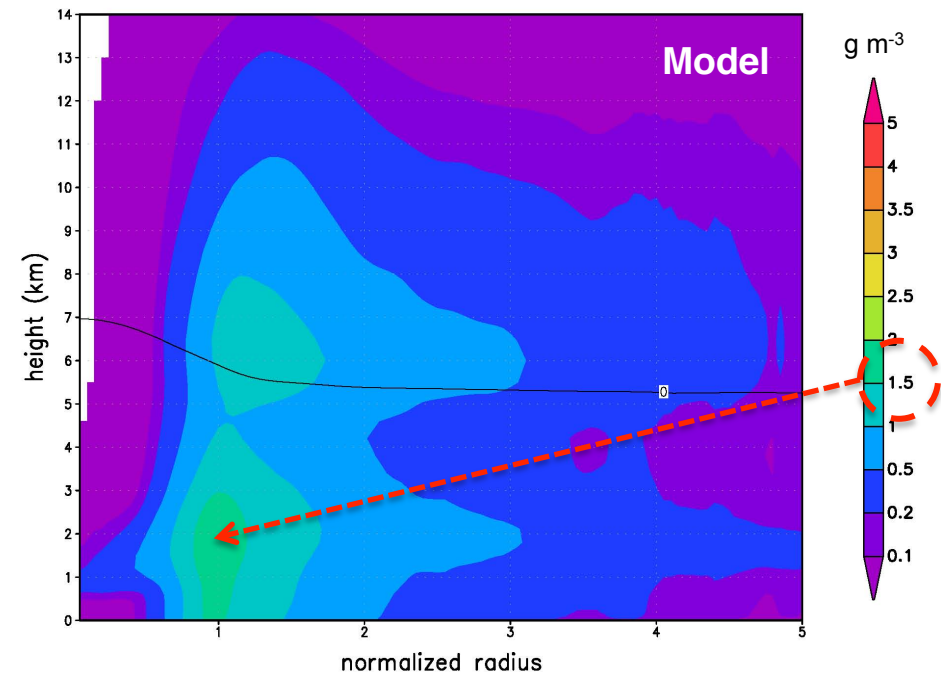


Use Model (HWRFV3.2) to evaluate total condensate to observed radar estimate



The good:

- Structure in eyewall similar with double peak



The not so good:

- Model values three times those in observations
- Model PBL vertical distribution is opposite observed



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Improving Diagnostics:



The Good:

- HFIP models are showing improved intensity (peak 10-m wind) verifications

The Not So Good (needs improvement):

- Some models with improved intensity do not show improved tracks. Why?
- Intensity verification has little correlation with improved modeling of storm evolution or structure. Why?
- Model intensity estimates poorly represent sampling errors in time and space appropriately for intensity estimates. Estimates at coarse time and space resolutions are compared as if they are the same.
- No model team is diagnosing the low wavenumber (#0 & #1) structure which is more closely related to vortex evolution. Why?



Intensity evaluation: Sampling issues

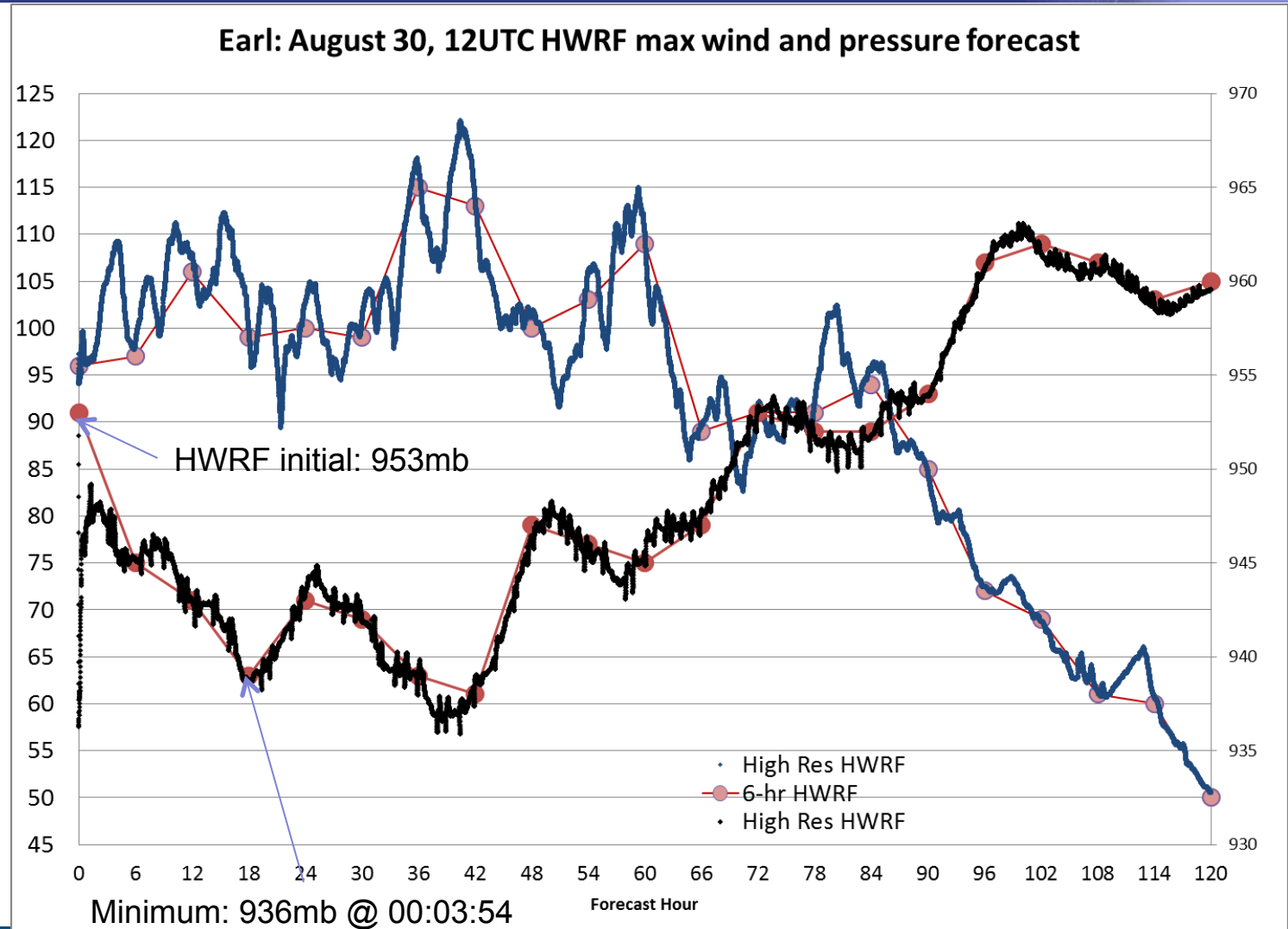


The good

- Model pressure & wind tracks best track intensity

The not so good

- Model peak wind much noisier than best track & pressure. Why?



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Dave Zelinsky (NHC)

Intensity evaluation: Sampling issues

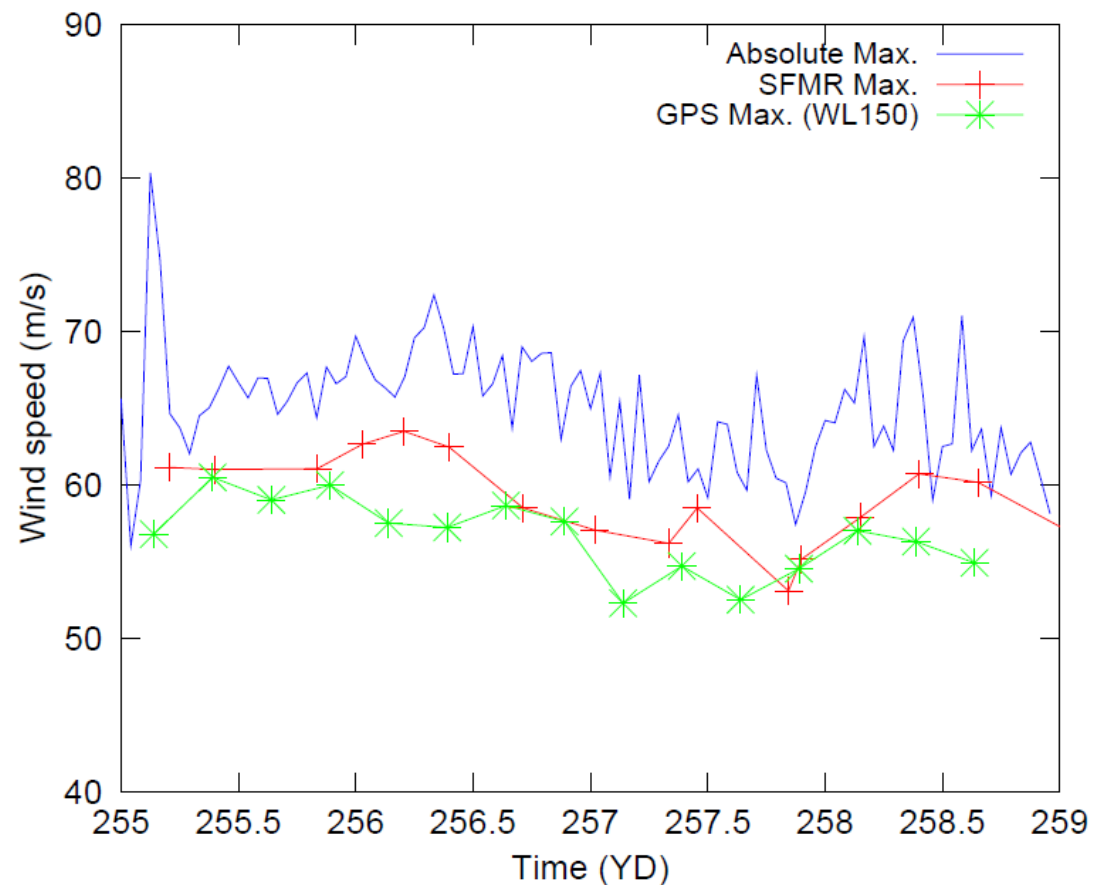


The good

- Used 1.3 km model run to generate simulated flight-level, SFMR & dropsonde max. wind for each flight to illustrate sampling issues

The not so good

- Retrieved max. wind is dependent on spatial and temporal resolution of model output
- Model groups are not evaluating sampling issues and NHC is unaware of impact



| SFMR | GPS (0.9Rmax) |
|------|---------------|
| 8.8% | 12.7% |



Summary



- NWS Strategic Plan is outlining plans for a “Weather Ready Nation” based around Decision Support Services (DSS) implying forecasts of all the impacts of hurricanes are essential
- Current forecast verification and metrics fall short of those needed to support NWS Strategic Plan goals
- HFIP research must expand diagnostics to include all impacts from hurricanes (e.g., wind, surge, inland flooding, severe weather)
- Next generation hurricane researchers must look beyond track and intensity!!



Plans for future generation



- In 1998 organized UCAR/ASP Summer Colloquium on Hurricanes at Landfall (<http://www.asp.ucar.edu/colloquium/1998/>).
- Provided current generation of hurricane researchers (11/22):

| Student | Student |
|--------------------------------|-------------------------|
| Paul Bogner | Chris Hennon |
| Ed Bracken | Daniel Jacob* |
| Parks Camp | Sharan Majumdar* |
| Dan Cecil* | Shirley Murillo* |
| Jennifer Collins | Shangyau Nong |
| Mark Croxford | Greg Postel |
| Jason Dunion* | Paul Reasor* |
| Sytske Drury (Kimball)* | Robert Rogers* |
| Matthew D. Eastin* | Douglas Schneider |
| Robert Hart* | John Schroeder* |
| Rita Hausmann | Holly Snell |

- Time for another colloquium to develop the next generation
- Use HFIP capacity to develop program
- Focus on key research issues and utilize models, DA, and observations
- Recommend organizers should be members of 1998 class



Questions?

Irene

