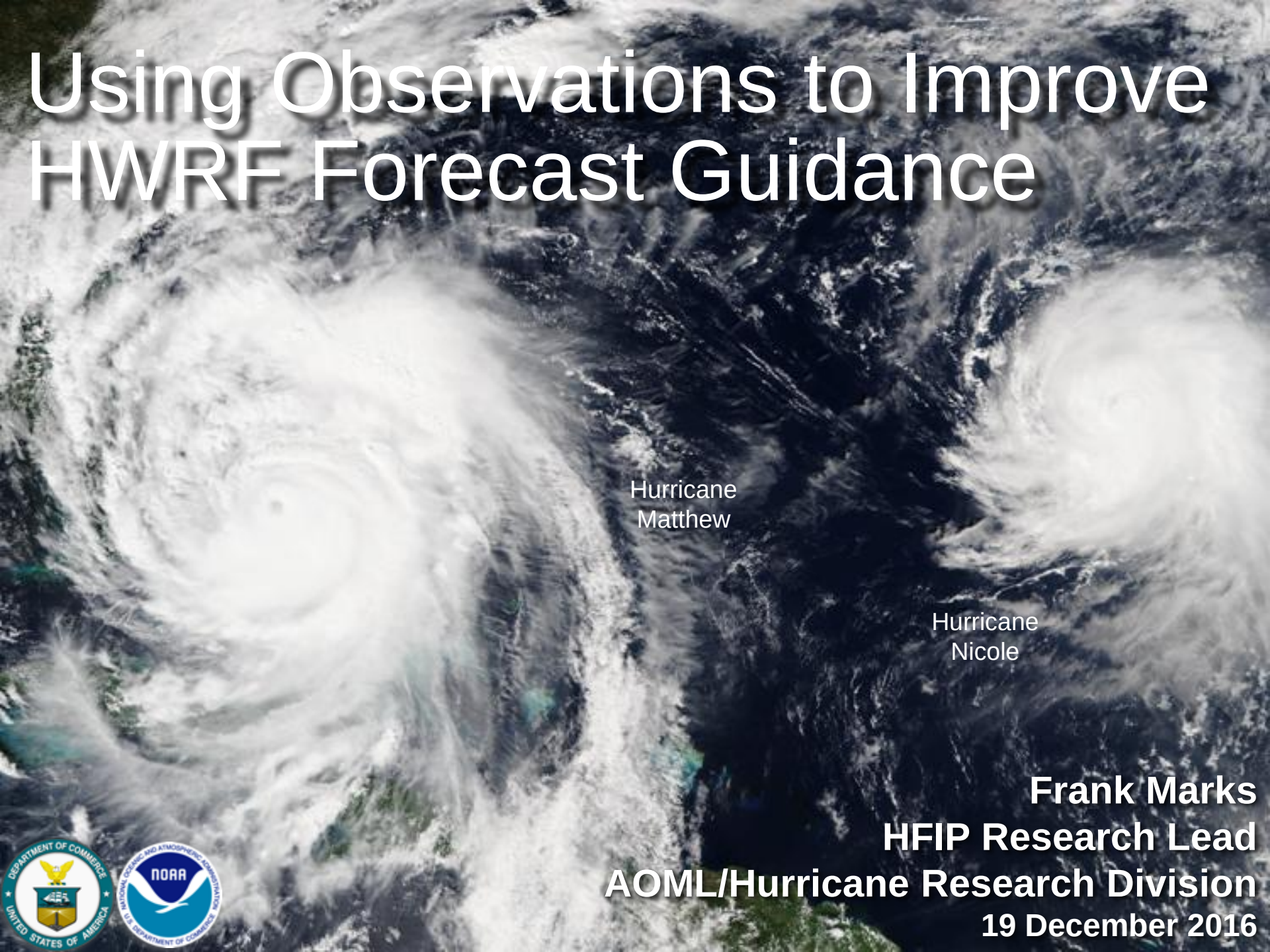
Using Observations to Improve HWRF Forecast Guidance



Frank Marks
HFIP Research Lead
AOML/Hurricane Research Division
19 December 2016

Vision

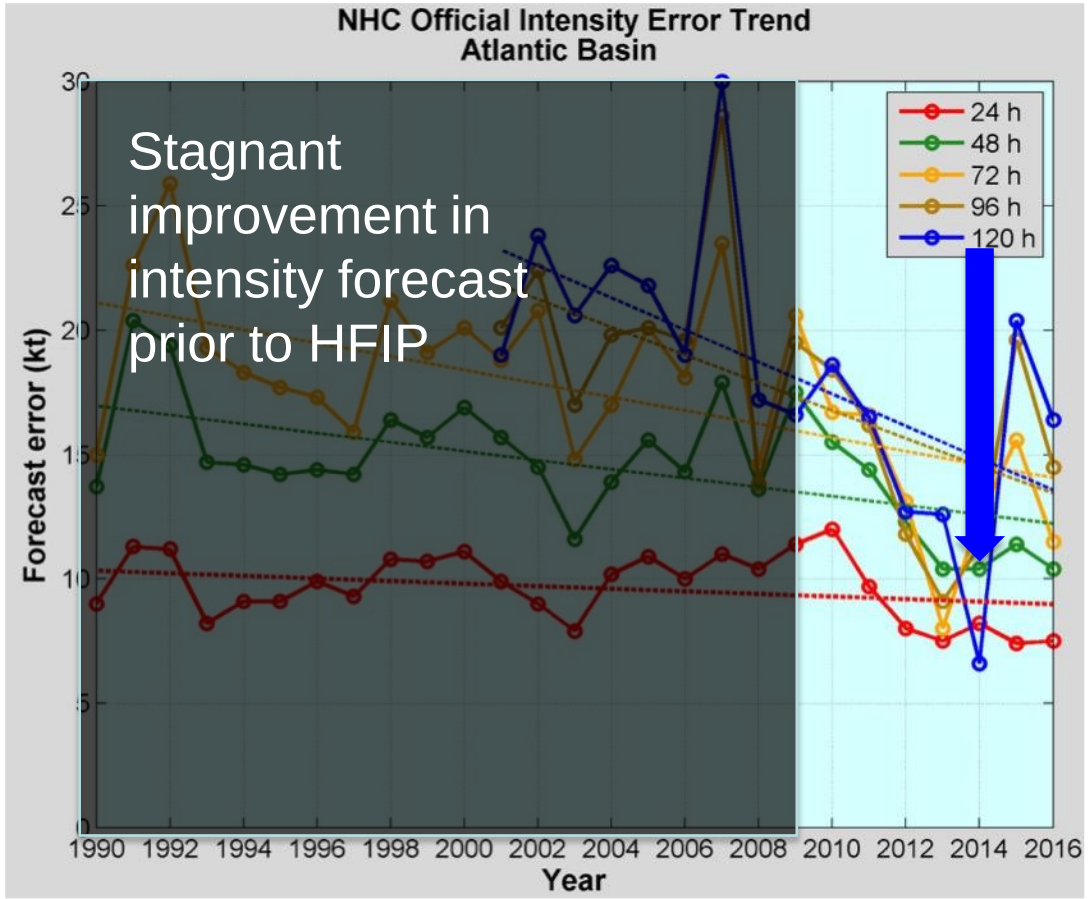
- Organize hurricane community to dramatically improve numerical forecast guidance to NHC in 5-10 years

Goals

- Improve forecast accuracy for track & intensity by 20% in 5 years, 50% in 10 years
- Extend forecast guidance to 7 days with skill comparable to current 5 day forecasts
- Increase probability of predicting (POD) Rapid intensification (RI) at Day 1 to 90% & 60% at Day 5

Current State of the Art

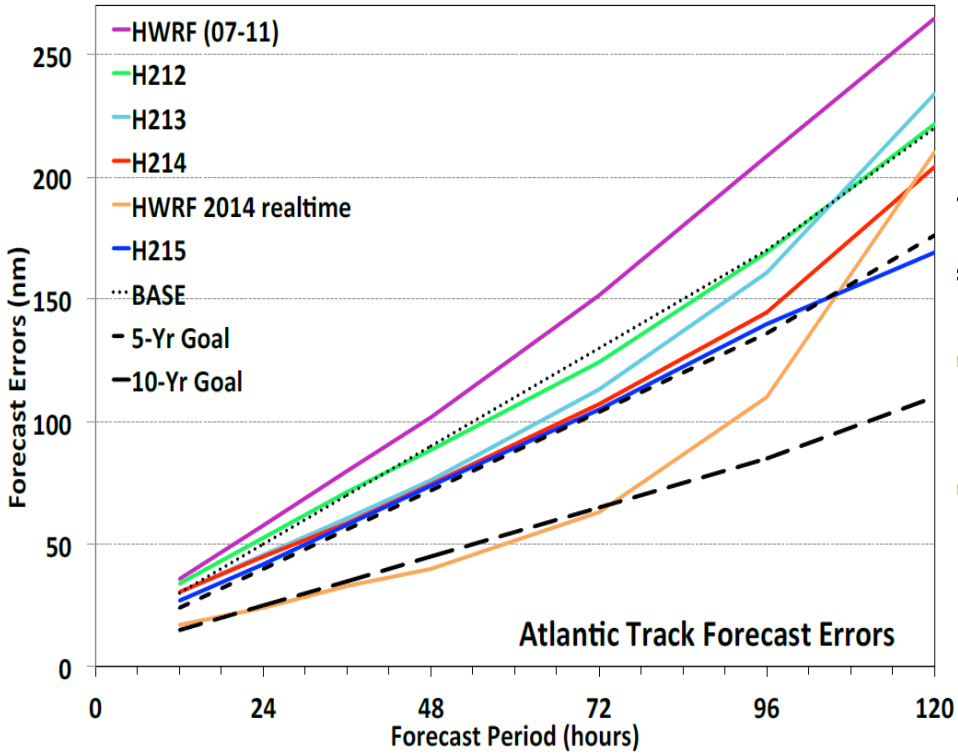
Operational Forecast Performance

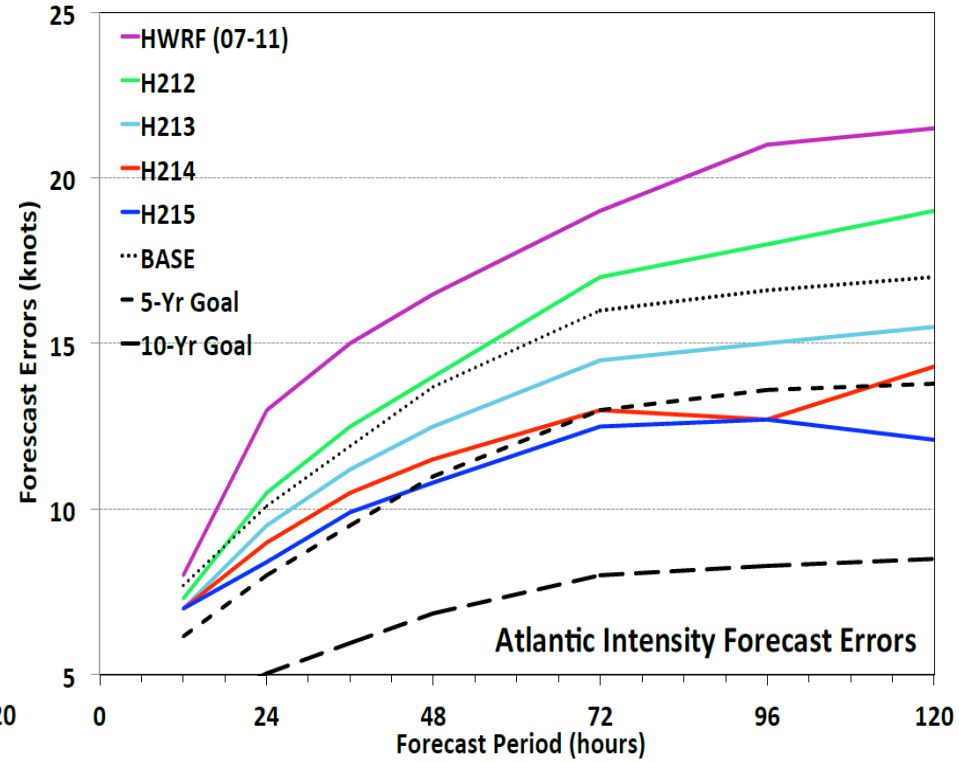


- Since HFIP began in 2008, forecast error has decreased by 20-25% for 1-5 day forecasts.
- NOAA upgraded HWRF model resolution; now 2 km
- Remarkable improvements in HWRF since HFIP*

HWRF Improvements

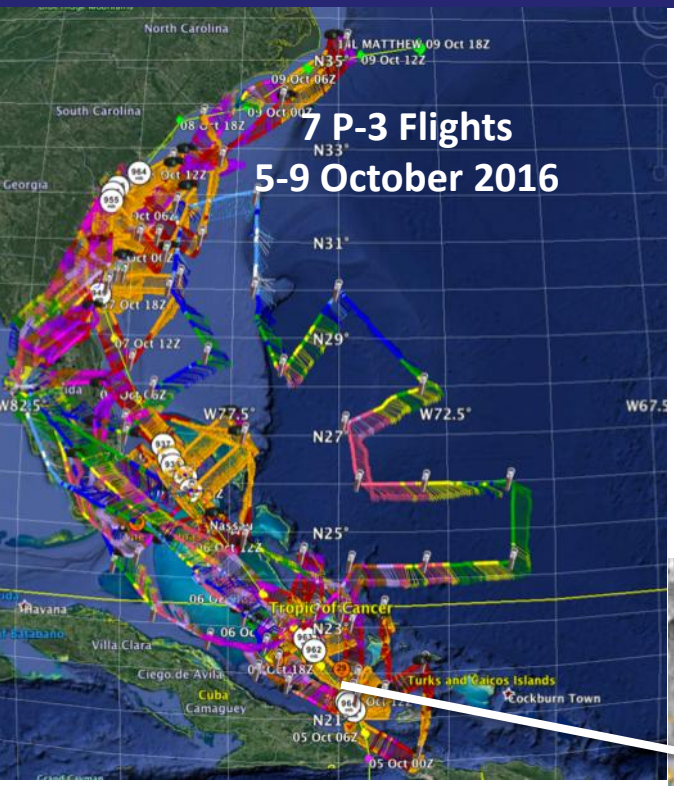
Improvements of the order of 10-15% each year since 2012



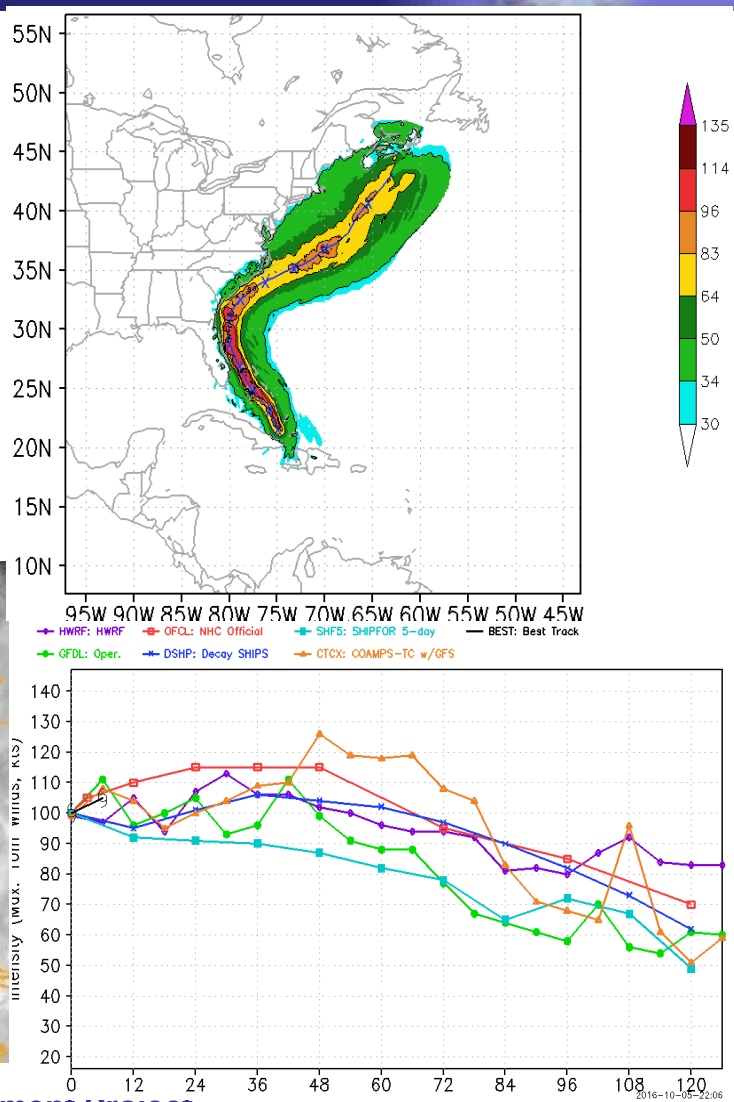


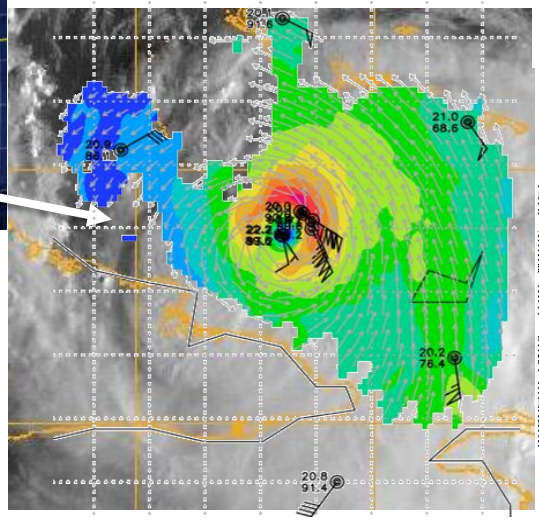
Dramatic improvement in first 5 years of HFIP

Better Initialization - TDR:
Hurricane Matthew (2016)



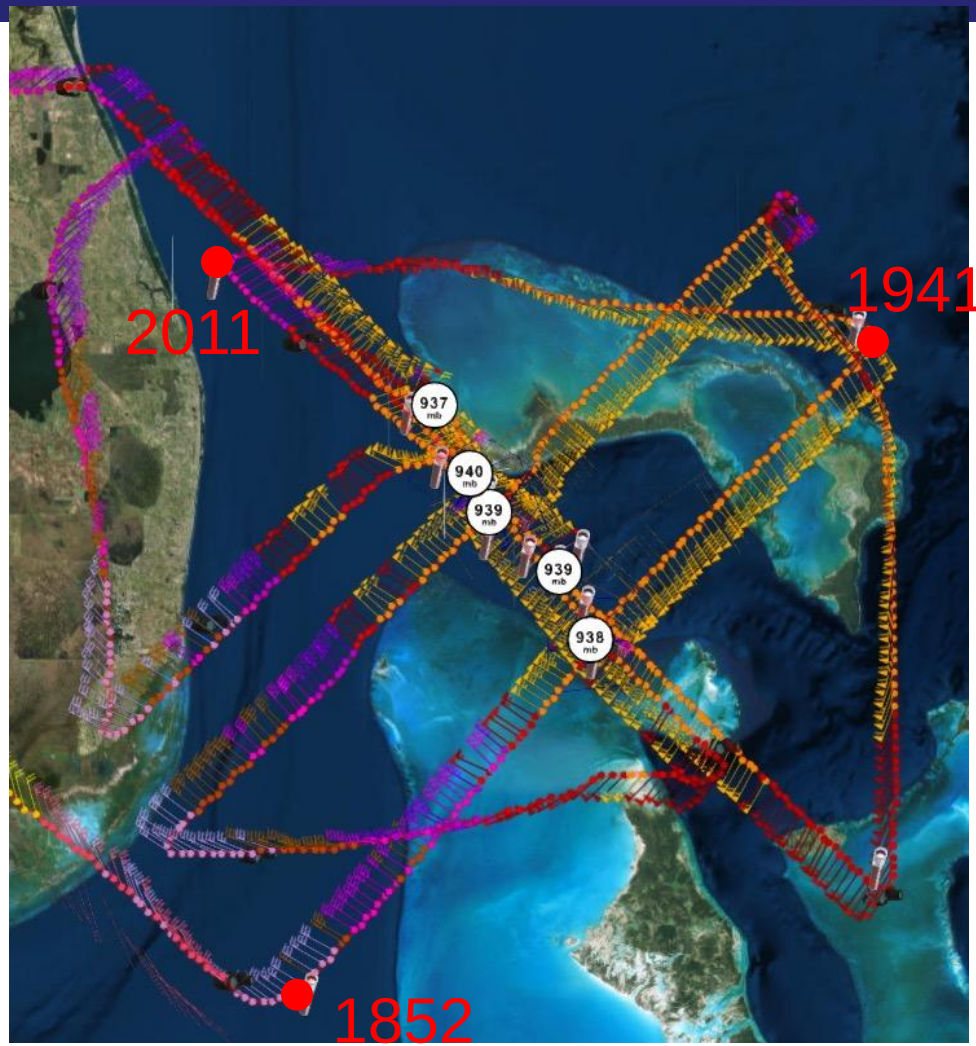
Doppler data transmitted in real-time for assimilation into HWRF





- 7 P-3 missions from 5-9 October 2016 at 12 h Doppler sampling (HEDAS/GSI) & 3 G-IV missions
- Sampled Matthew until landfall in NC

Real-time, Storm-scale Diagnostics Derived from TDR



20161006I2 (Matthew)

Inbound Start: 1852 UTC

Fix Time: 1917 UTC

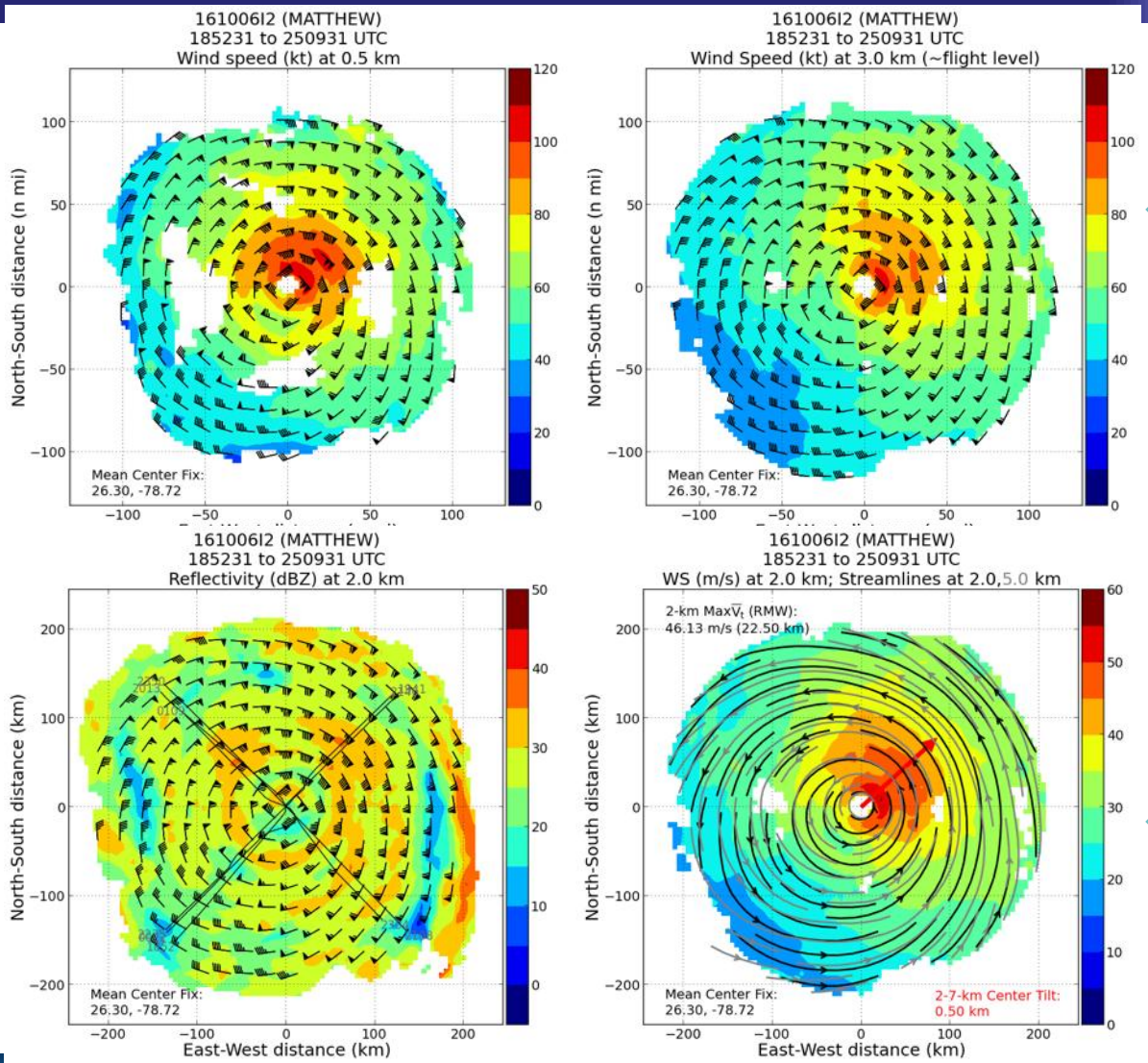
Outbound End: 1941 UTC

Downwind End: 2011 UTC

Analysis Transmit: 2043 UTC

For ~ 80 min of TDR data, storm-scale diagnostics available 1 h 25 min after fix time.

Example: 20161006l2 (First Pass)



n mi

km

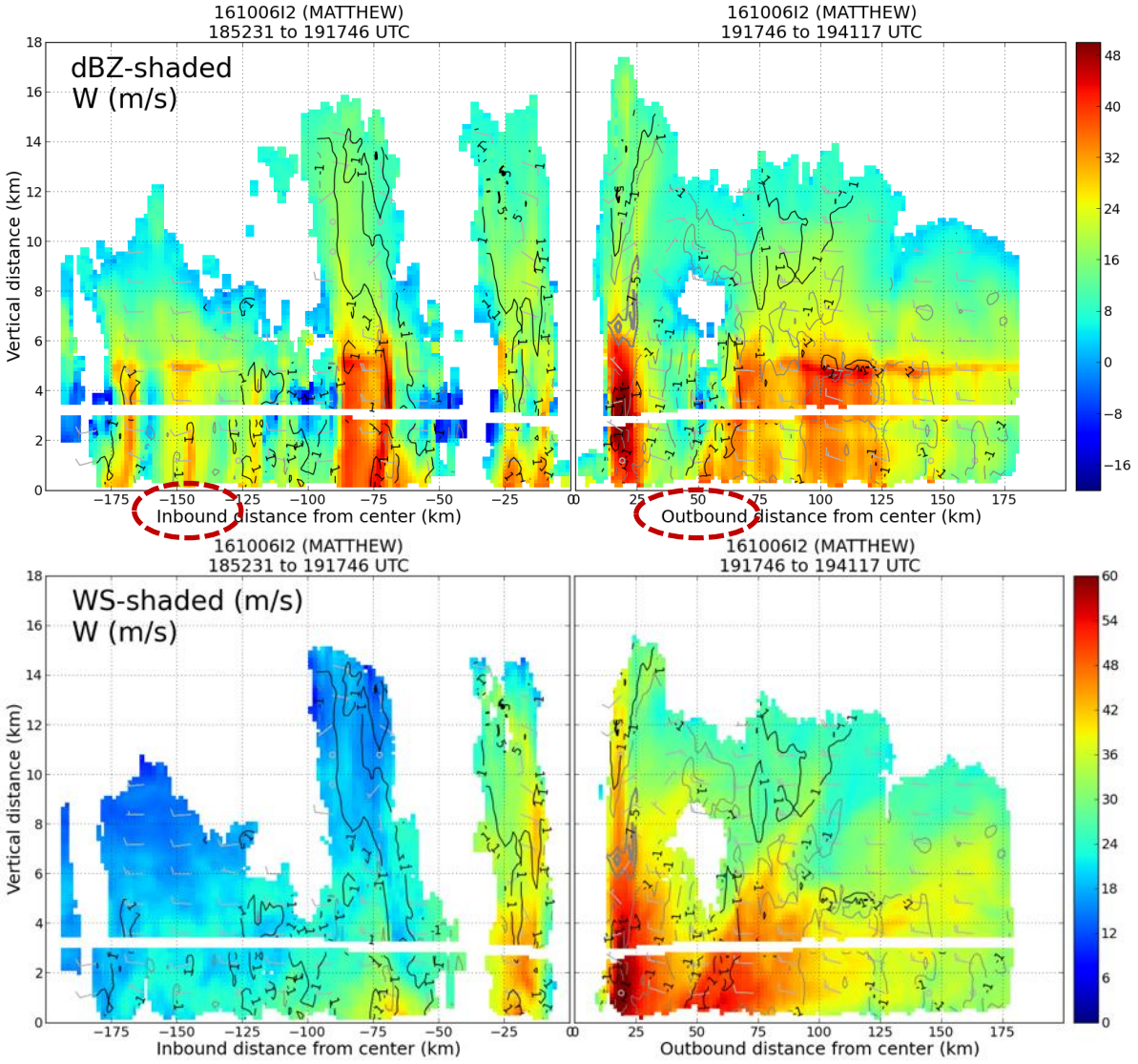
kts

m/s

dX = 5 km

dY = 5 km

Example: 20161006I2 (First Pass)



dR = 1.5 km

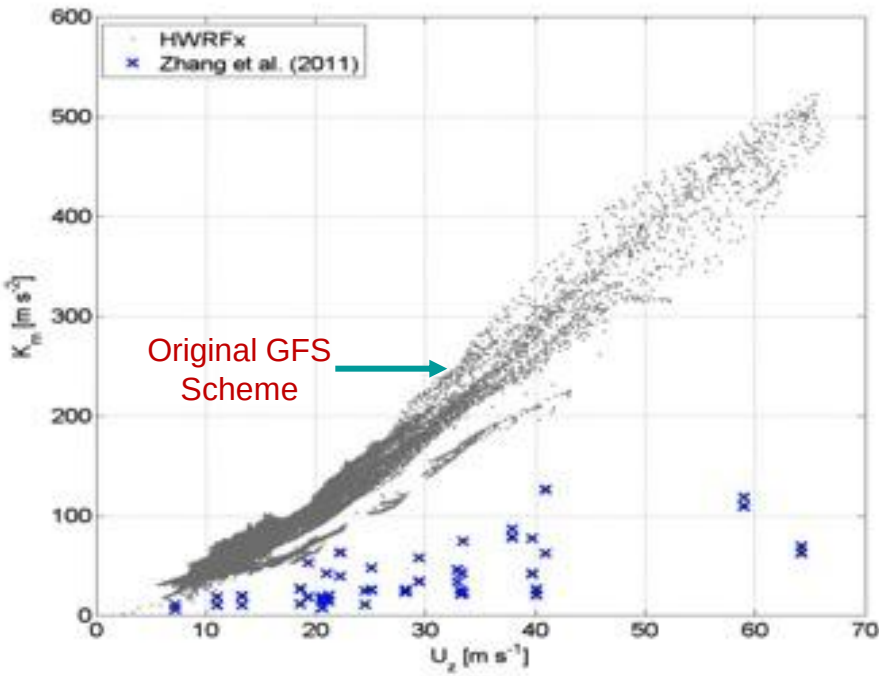
dZ = 150 m

Using Observations to Improve HWRF Boundary Layer

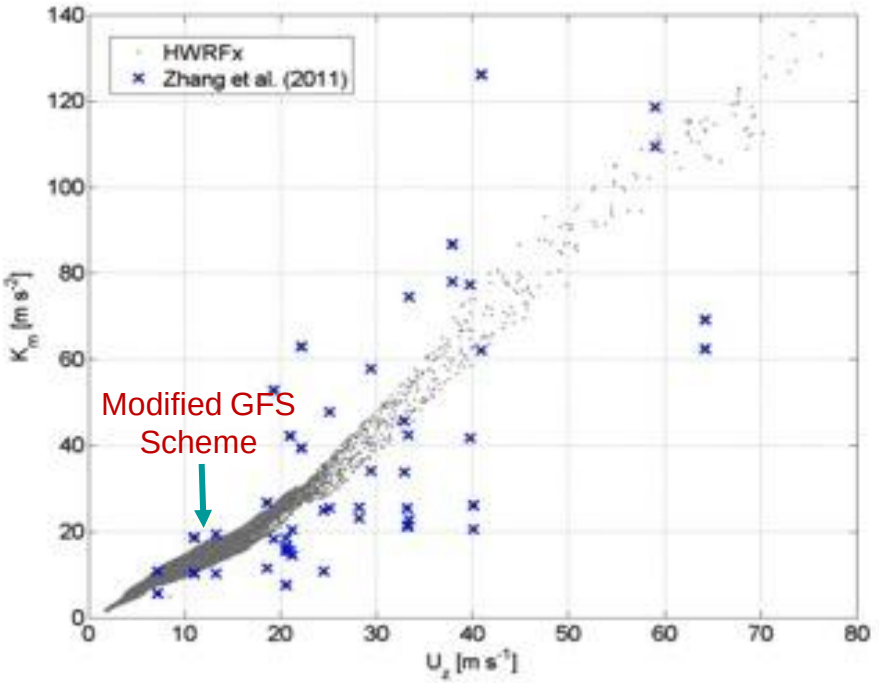
Vertical Eddy Diffusivity:

$$K_m = k\,(U_*/\Phi_m)\,Z\,\{\alpha(1 - Z/h)^2\}$$

Original Formulation (α=1.0)



Latest Formulation (α=0.25)



Gopalakrishnan et al. (2012)

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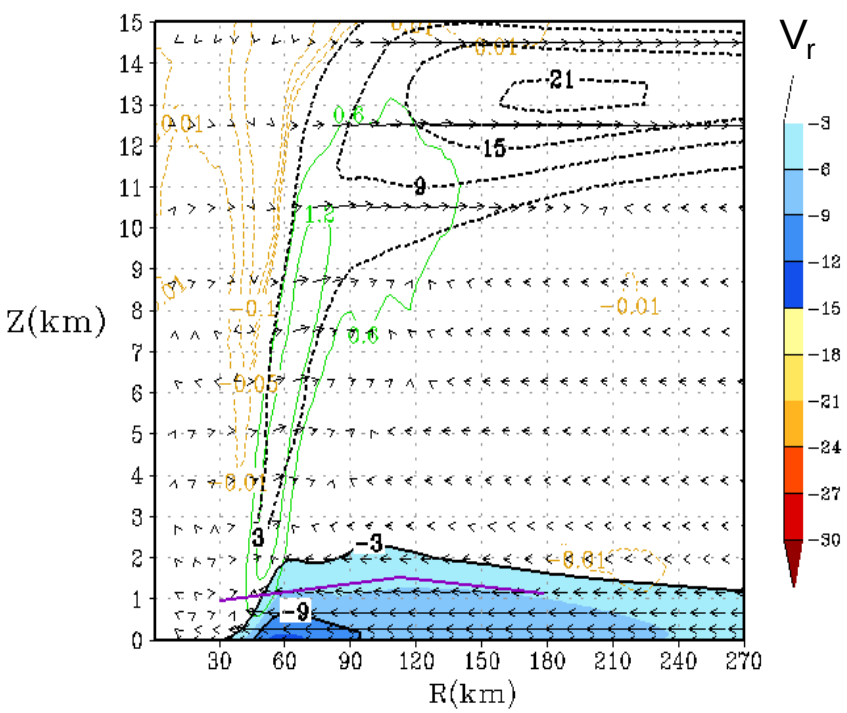
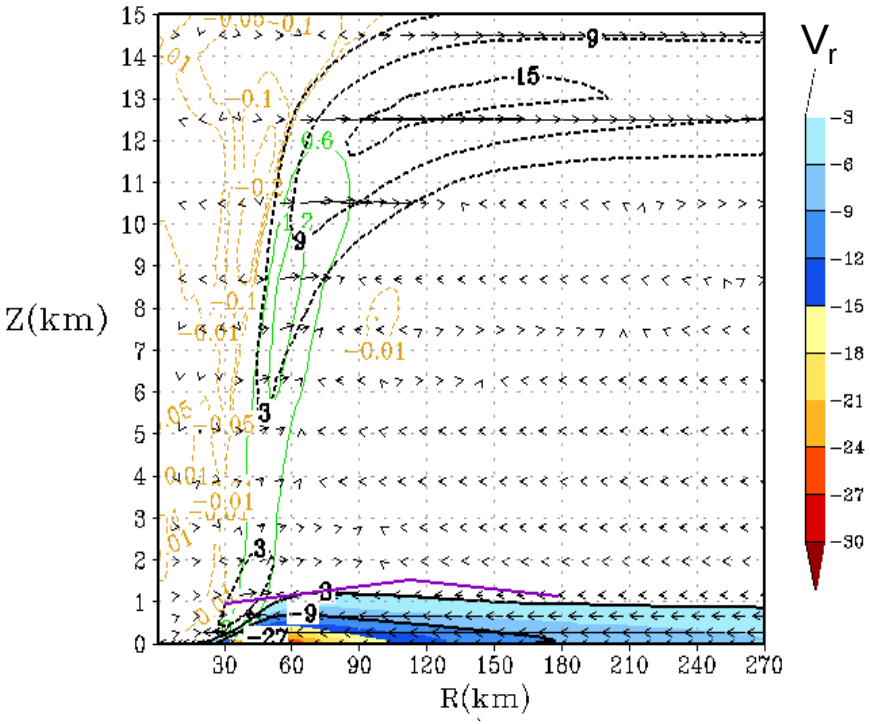
Using Observations to Improve HWRF Boundary Layer

Original Formulation (α=1.0)



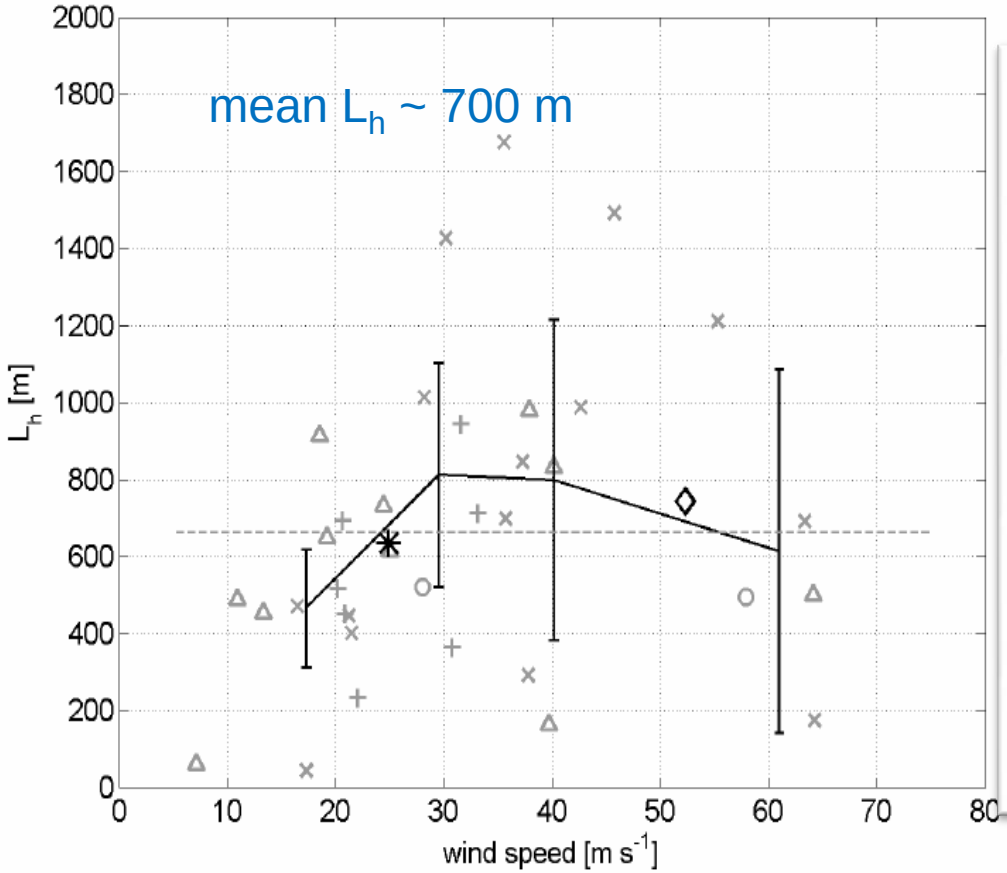
Latest Formulation (α=0.25)



Azimuthally averaged secondary circulation: Radial and Vertical Wind

Gopalakrishnan et al. (2012)

Horizontal mixing length from observations



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Observational Estimates of the Horizontal Eddy Diffusivity and Mixing Length in the Low-Level Region of Intense Hurricanes

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(Manuscript received 29 June 2011, in final form 10 November 2011)

ABSTRACT

This study examines further the characteristics of turbulent flow in the low-level region of intense hurricanes using in situ aircraft observations. The data analyzed here are the flight-level data collected by research aircraft that penetrated the eyewalls of category-5 Hurricane Hugo (1989), category-4 Hurricane Allen (1980), and category-5 Hurricane David (1979) between 1 km and the sea surface. Estimates of horizontal eddy momentum flux, horizontal eddy diffusivity, and horizontal mixing length are obtained. It is found that the horizontal momentum flux and horizontal diffusivity increase with increasing wind speed. The horizontal mixing length increases slightly with wind speed also, but the mixing length is not significantly dependent on the wind speed. The magnitude of the horizontal momentum flux is found to be comparable to that of the vertical momentum flux, indicating that horizontal mixing by turbulence becomes nonnegligible in the hurricane boundary layer, especially in the eyewall region.

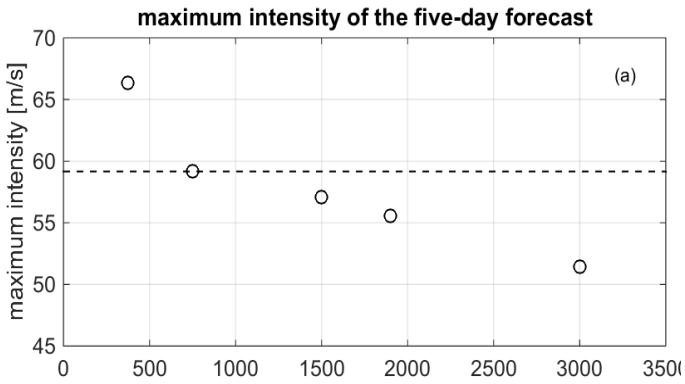
Within the context of simple K theory, the results suggest that the average horizontal eddy diffusivity and mixing length are approximately 1500 m^2 s^{-1} and 750 m, respectively, at about 500 m in the eyewall region corresponding to the mean wind speed of approximately 52 m s^{-1}. It is recalled also that the mixing length is a virtual scale in numerical models and is quantitatively smaller than the energy-containing scale of turbulent eddies. The distinction between these two scales is a useful reminder for the modeling community on the representation of small-scale turbulence in hurricanes.

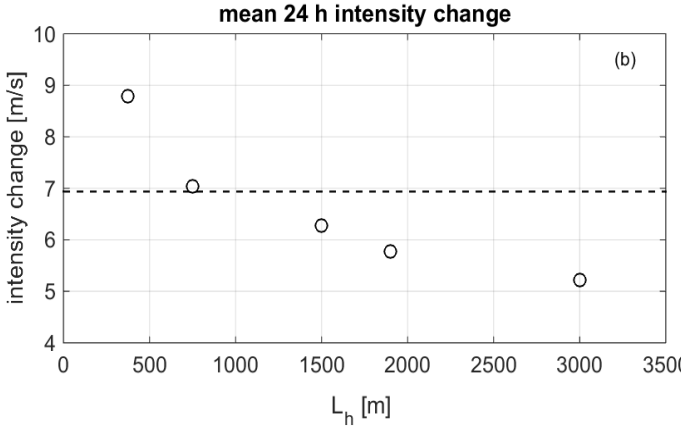
Flight-level data collected during low-level eyewall penetrations of Hurricanes Allen (1980), Hugo (1989) and David (1979).

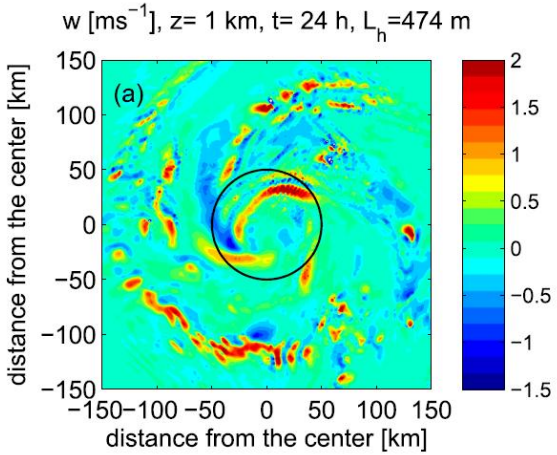
(Zhang and Montgomery, 2012 JAS)

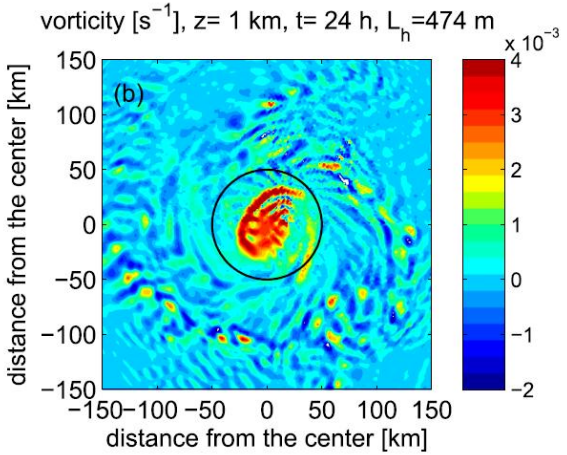
Horizontal mixing length impact on HWRF

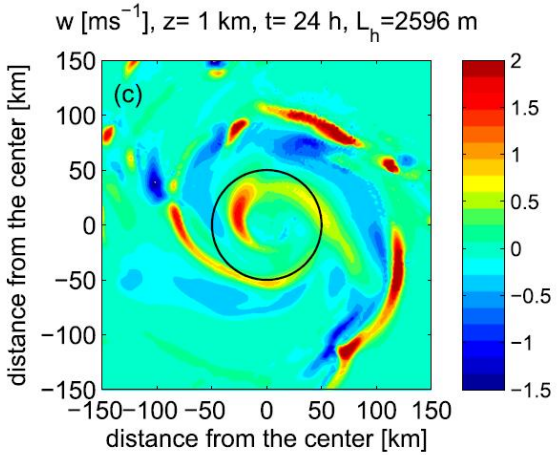
H215 forecasts

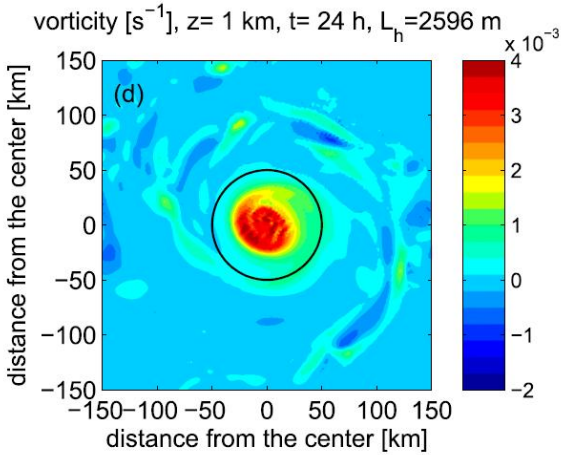






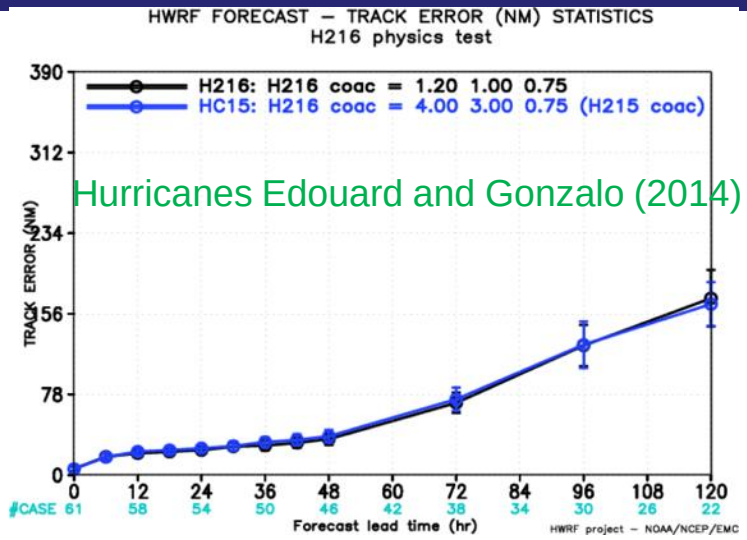




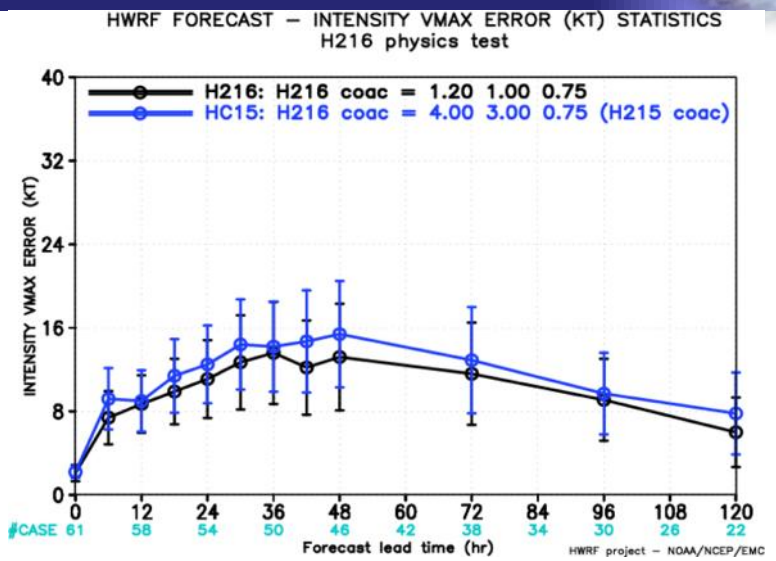


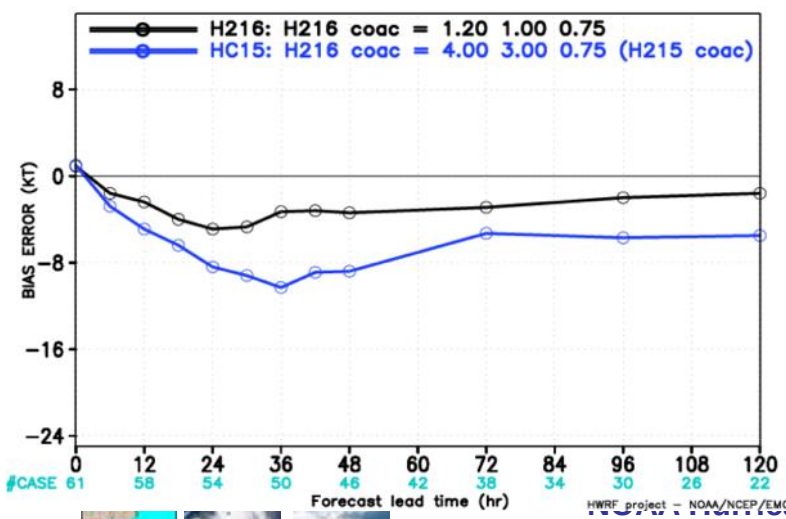
(Jun Zhang et al. 2016 WAF, under review)

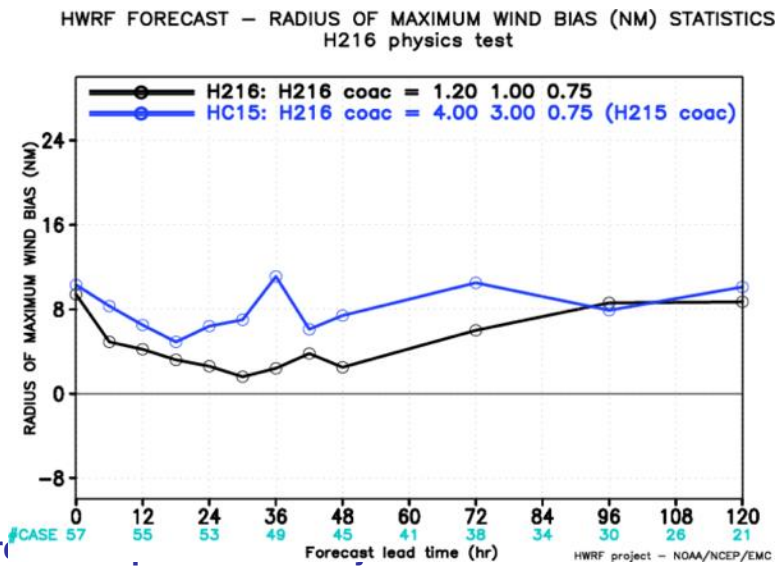
Impact of reducing horizontal mixing length in H216



Hurricanes Edouard and Gonzalo (2014)







What in 2016 & 2017?:

IFEX 2016

- NOAA aircraft flew 32 P3 and 17 G-IV missions
- Highlights include Tropical Cylones Colin, Earl, Javier (East Pacific), Hermine, Karl, and Matthew
- 8 NOAA SHOUT Global Hawk missions.
- For details see: https://noaahrd.wordpress.com/2016/11/30/2016-hurricane-season-ends/

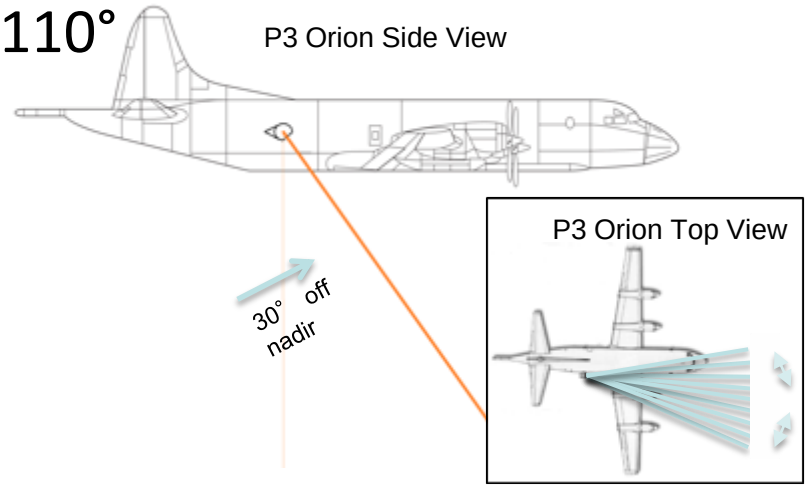
IFEX 2017

- 1 WP-3D, G-IV – 200 flight hours (1 June-30 Nov.)
- Crews available 2/day missions starting July

IFEX 2016: Doppler Wind Lidar

Doppler Wind Lidar (DWL)

- Compliments P-3 & G-IV Tail Doppler radar
- 5 flights into Hurricanes Earl (3) and Javier (2, EPAC)
  - 7 flights collected data
- Elevation angle range of -110° to +110°
- Azimuth angle range +/- 30°
- Preset scanning modes: conical, sweeps, etc.
- Access DWL computer via laptop



IFEX 2016: SHOUT

- **GOAL**: Test prototype UAS concept of operations that could mitigate the risk of diminished high impact weather warnings in case of polar-orbiting satellite observing gaps

- **Global Hawk**
  - Flight level: ~55-60,000 ft
  - Duration: ~24 h
  - Range: 11,000 nm
  - Payload: 1500+ lbs
  - Deployment site: NASA Wallops Flight Facility, VA
  - 5 week deployment (late August through September)
  - Instrumentation: AVAPS, HAMSR, & HIWRAP

Communicating in the field

- Our blog

http://noaahrd.wordpress.com

- HRD Web page

http://www.aoml.noaa.gov/hrd

- Facebook (4,475 likes)

http://www.facebook.com/noaahrd

- Twitter (20,150 followers)

http://twitter.com/#!/HRD_AOML_NOAA

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