



# Plans for Operational Hurricane Modeling in FY17

*Avichal Mehra and the EMC Hurricane Team*

**Environmental Modeling Center  
NOAA / NWS / NCEP**





# Outline



- Long term plans for HWRF
- Planned 2017 HWRF upgrades
- Preliminary test results
- Current and future plans
- Quad chart and resources



## HWRF Long-Term Plans

2016	2017	2018	2019	2020
HWRF Operational Model Continues Followed by Ensembles				
GFDL	HNMMB	10-member HWRF/ HNMMB Ensembles	NEMS Global Nests (NGGPS)	
Basin-Scale HWRF/NMMB		Tropical/Global NMMB Domain		
Hurricane Models take over Hurricane Wave Forecasts				

### Development, T&E and Implementation Plans for HWRF (supported by HFIP)

- 2016 Dec: H217 configuration ready
- 2017 Jan- Feb: H217 pre-implementation testing
- 2017 March: EMC CCB and code hand-off
- 2017 May: H217 Implementation



# **FY17 HWRF v11.0.0 Implementation plans**



# Scope of FY17 HWRF Upgrades



## ➤ System & Resolution Enhancements

- Framework upgrade to HWRFV3.8a
- T&E with new 2017 GFS IC/BC
- Consider storm's meridional movement when determining parent domain center
- New Tracker (still waiting for changes from Tim)
- Code optimization (IBM analyst)
- Increase vertical resolution with 75 vertical levels and 10-hPa top, with adjusted domain sizes for do2 (256 x 472) and do3 (256 x 472) (H216: 288 x 576)
- More products: MAG and AWIPS2

-- Green:

Included in Baseline

-- Blue:

Included in Baseline (if ready)

-- Orange:

Tested separately as an option

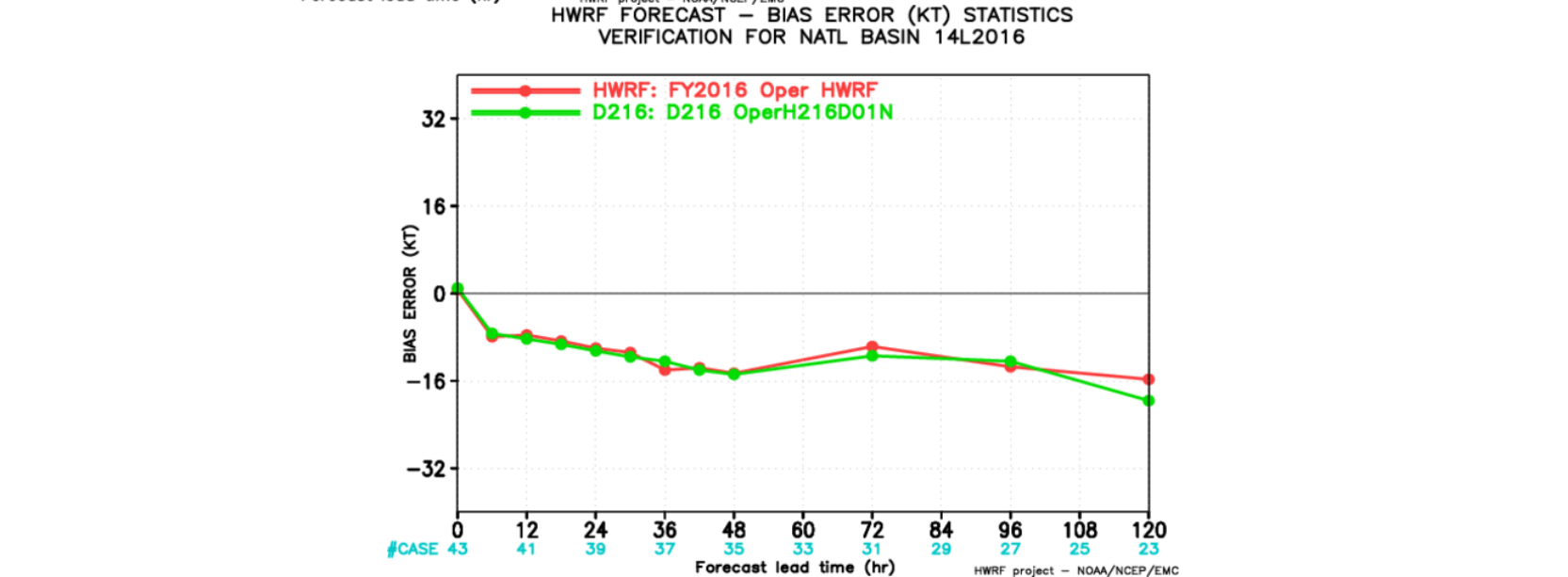
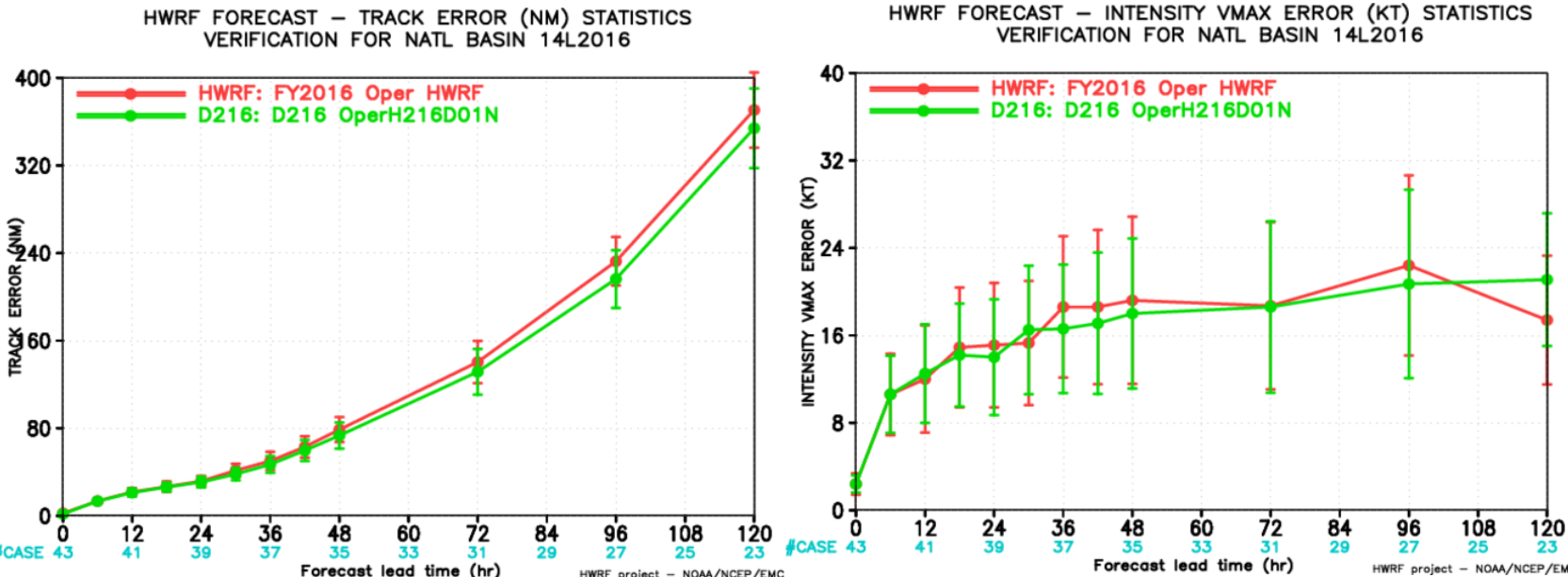


## Summary of 2017 GFS changes

- NEMS superstructure and infrastructure (NEMSIO)
- Upgraded land parameterizations, higher resolution land surface climatologies (should improve near-surface fields and reduce patchiness)
- Fix to excessive cooling of 2m temperatures during sunset (00Z)
- Changes to cumulus convection parameterization that should help to **improve summertime precipitation forecasts**
- NSST's that represent diurnal warming effects and sub-layer cooling
- Assimilation of additional data (some GPS data, AMVs, and some radiances), minor bug fixes mostly related to cloud water
- Rayleigh damping reduced by 50% in the upper stratosphere above 2 hPa
- GFS hurricane track and intensity forecasts are neutral with 2017 NEMS-GSM upgrade (based on 2014-2016 retrospectives)

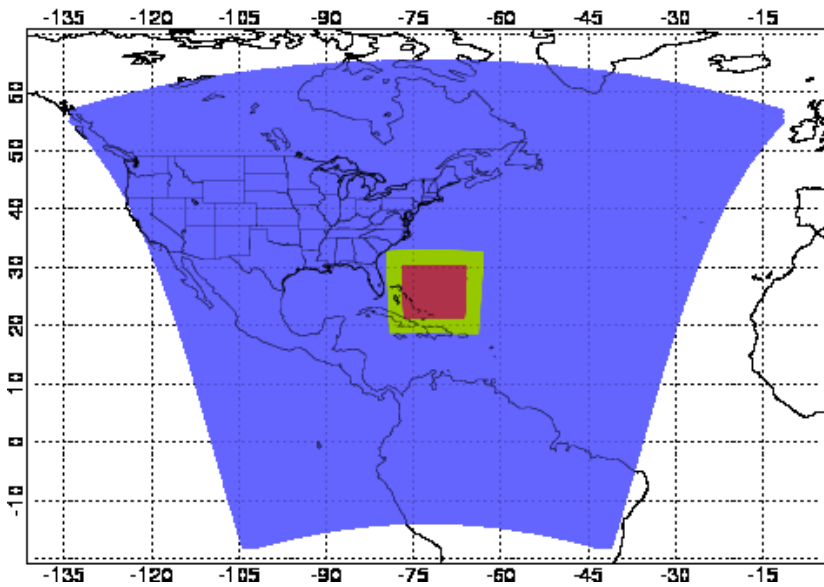


# Impact of Considering Storm's Meridional Movement on Hurricane Matthew



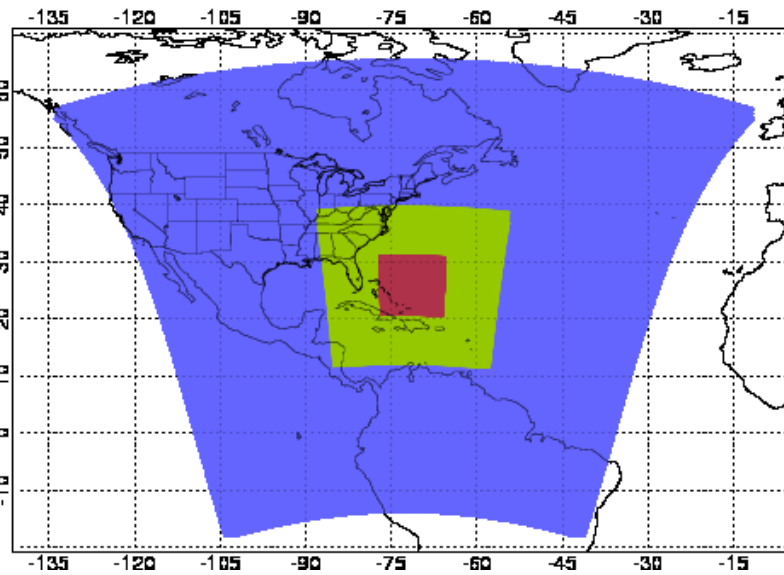
# Adjusted Domain Sizes for H217 with higher vertical resolution: Hurricane Joaquin (2015)

H215



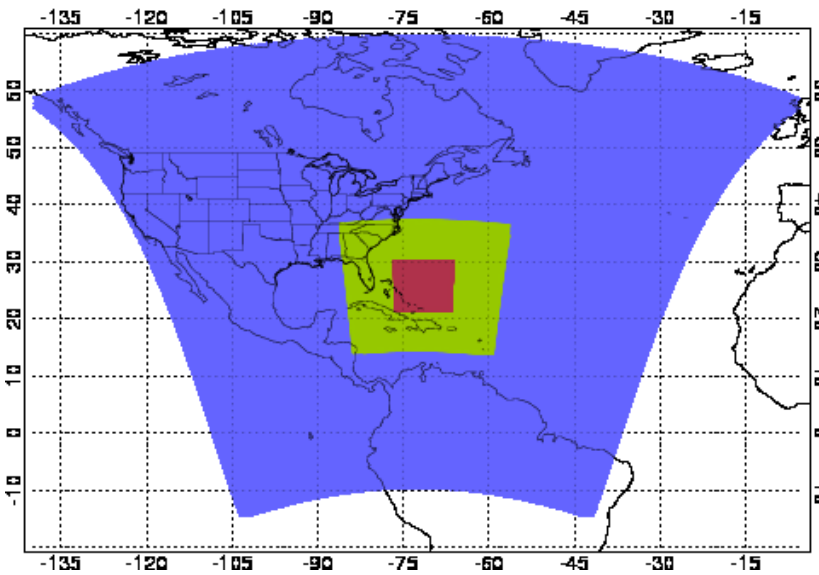
d02: 142 x 274  
d03: 265 x 472  
Levels: 61  
Top: 2 mbar

H216



d02: 288 x 576  
d03: 288 x 576  
Levels: 61  
Top: 2 mbar

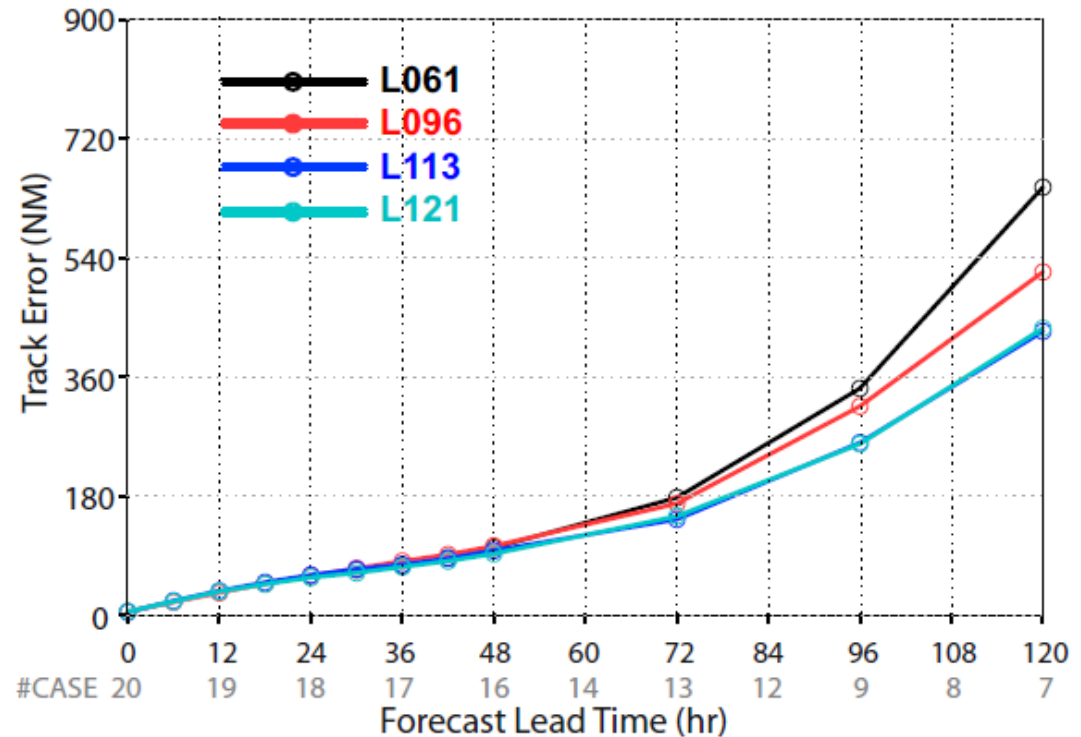
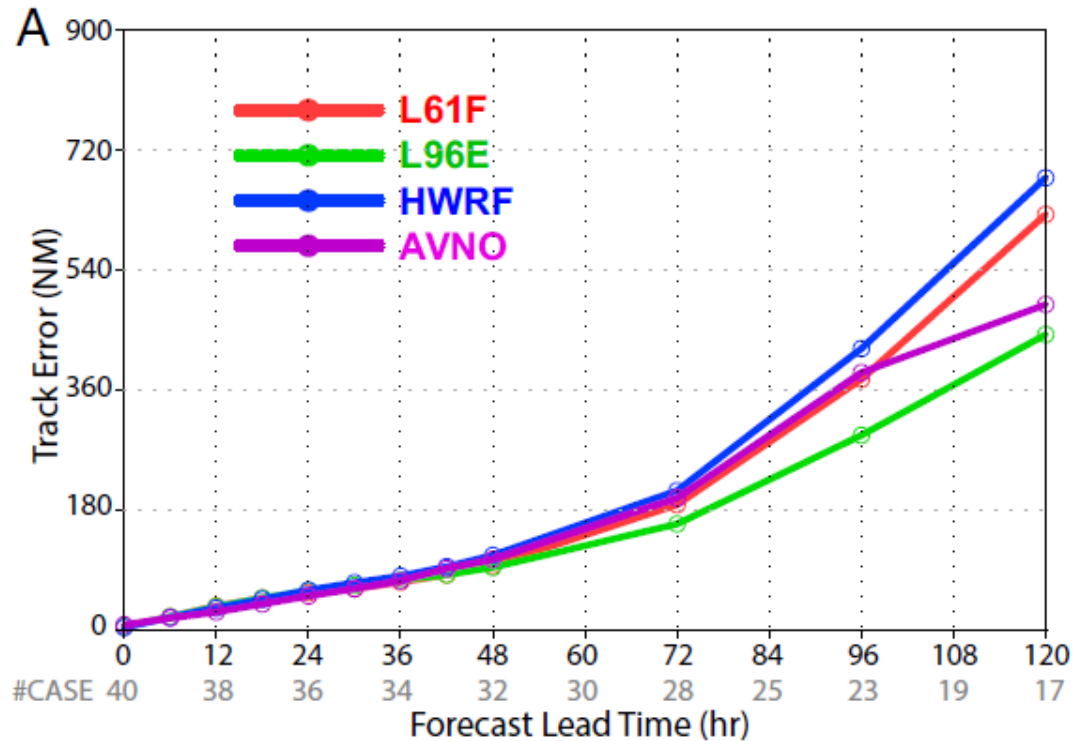
B217L



d02: 256 x 472  
d03: 256 x 472  
Levels: 75  
Top: 10 mbar



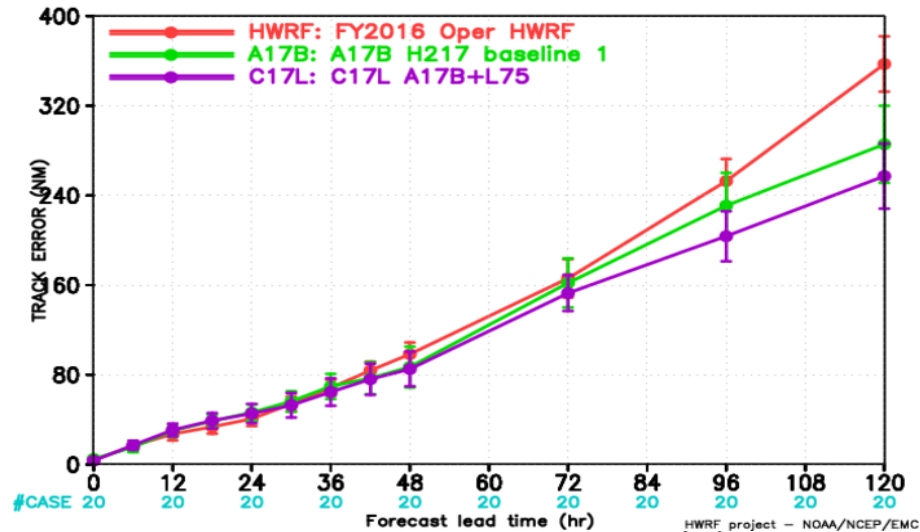
# Hurricane track and vertical resolution for Hurricane Joaquin (2015)



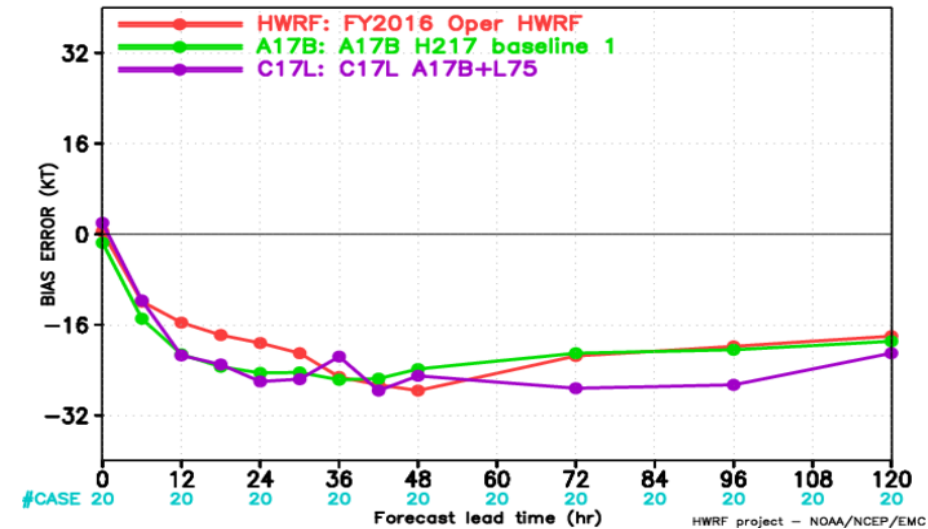
From B. Zhang et al. (2016), which shows that the track forecasts of Hurricane Joaquin (2015) were greatly improved by increasing the vertical resolution of HWRF.

# Impact of Vertical Resolution/Distribution for Hurricane Matthew: **Early results**

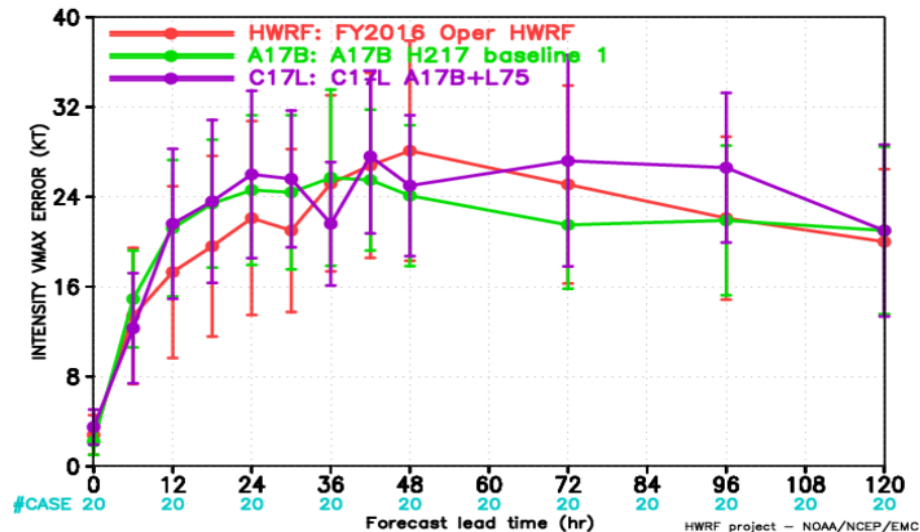
HWRF FORECAST — TRACK ERROR (NM) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



HWRF FORECAST — BIAS ERROR (KT) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



HWRF FORECAST — INTENSITY VMAX ERROR (KT) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



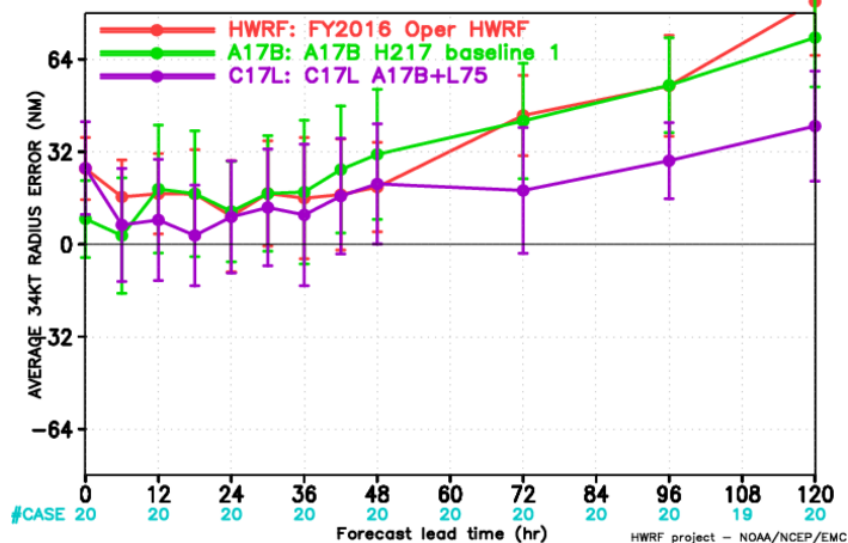
A17B and C17L have the same domain sizes as FY2016 HWRF.



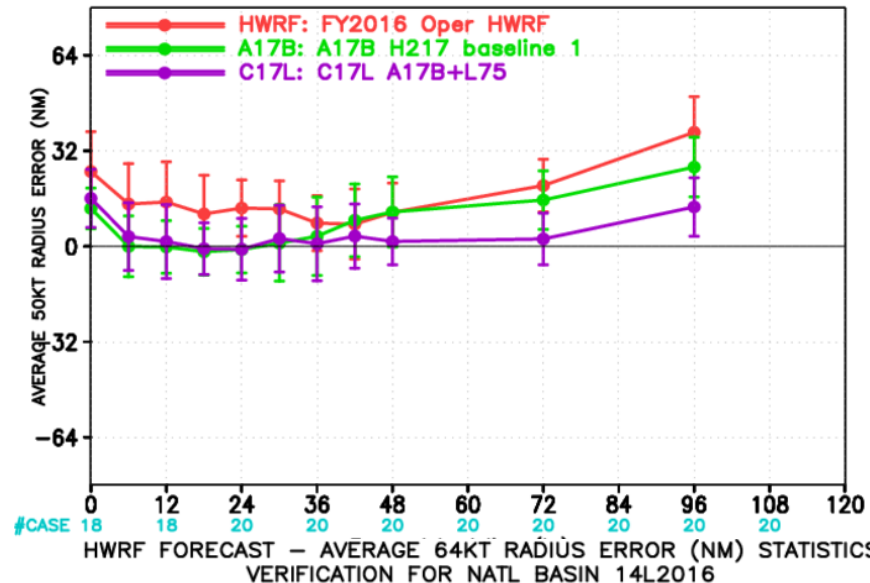
# Impact of Vertical Resolution/Distribution for Hurricane Matthew : Early results



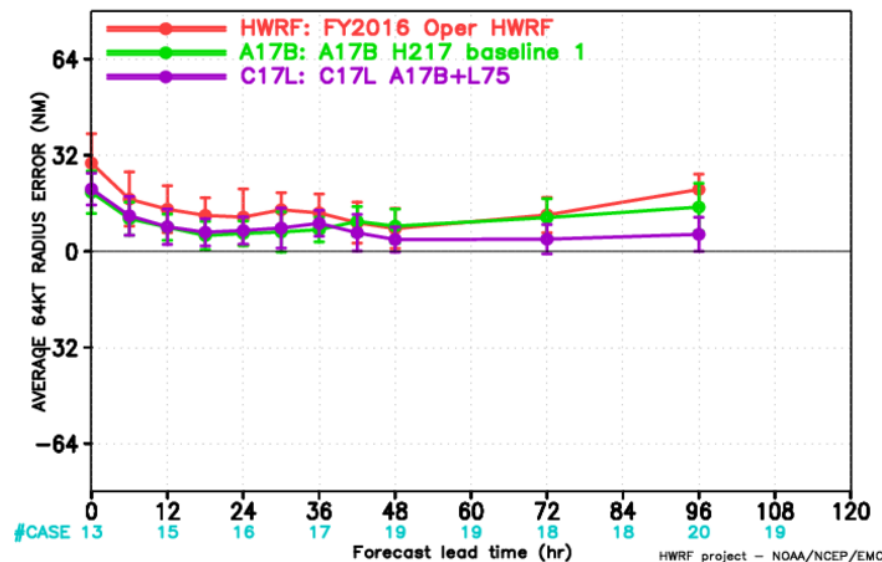
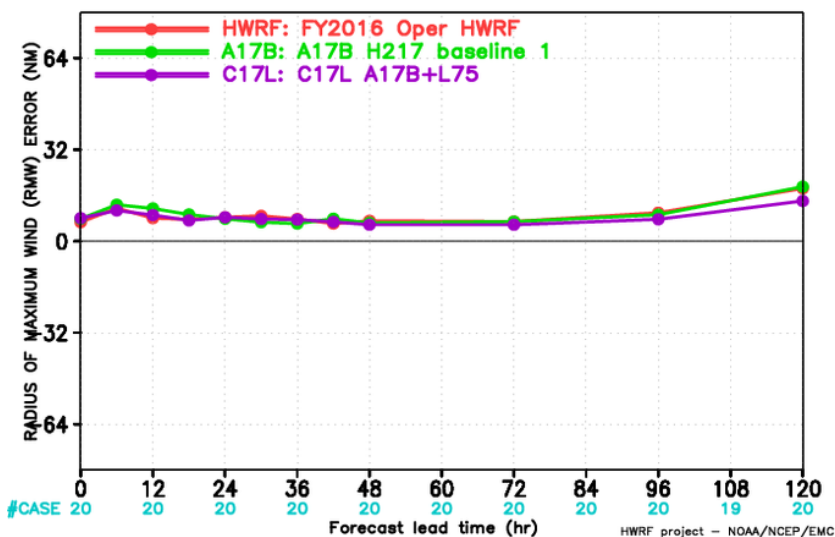
HWRP FORECAST — AVERAGE 34KT RADIUS ERROR (NM) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



HWRP FORECAST — AVERAGE 50KT RADIUS ERROR (NM) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



HWRP FORECAST — RADIUS OF MAXIMUM WIND (RMW) ERROR (NM) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016





# Scope of FY17 HWRF Upgrades



## ➤ Physics Advancements

- Bug fix for 10 meter wind (already in HWRFV3.8a)
  - Removing the residual impact of the bias correction for  $U_{10}$  (H216), using consistent algorithm when calculating  $U_{10}$  from the lowest model level at model initial time and when nests move
- Update F-A Microphysics (Sergio's talk)
- Updates to PBL/EDMF (Sergio's talk)
- Update scale-aware SAS scheme or G-F cumulus scheme (DTC)

-- Green:

Included in Baseline

-- Blue:

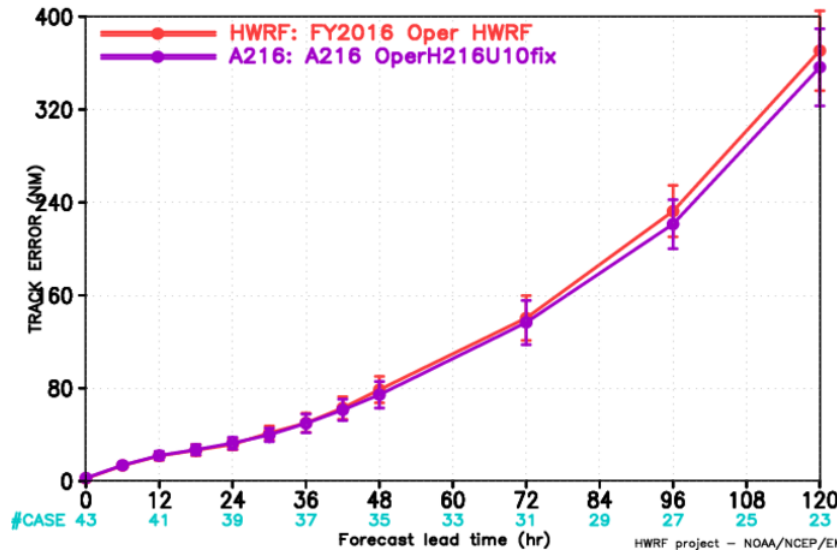
Included in Baseline (if ready)

-- Orange:

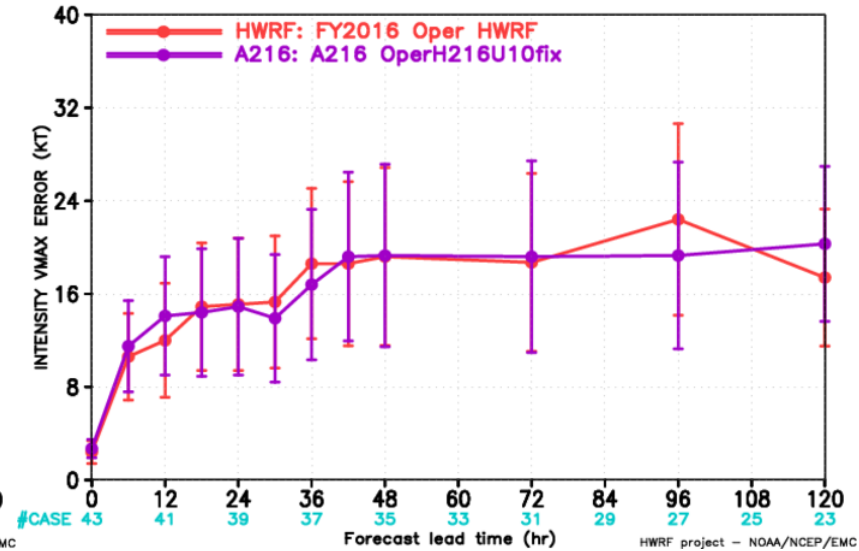
Tested separately as an option

# Impact of U10fix for Matthew

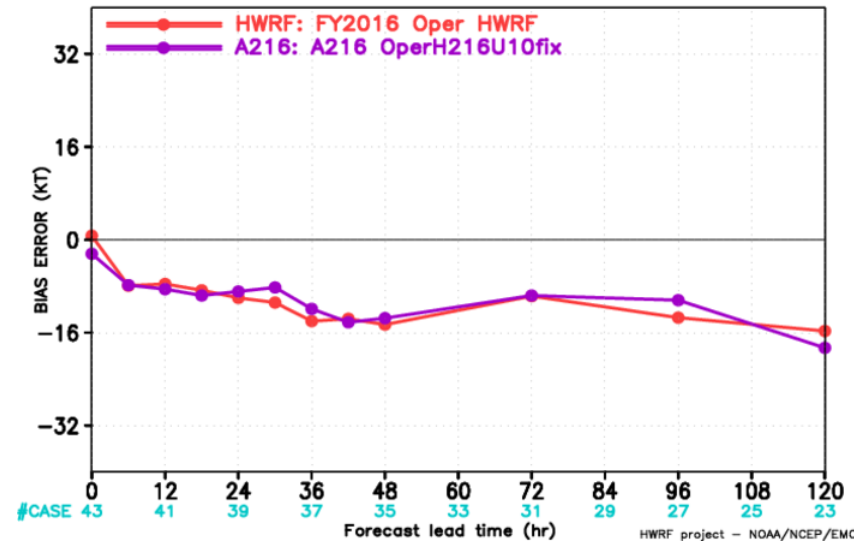
HWRf FORECAST — TRACK ERROR (NM) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



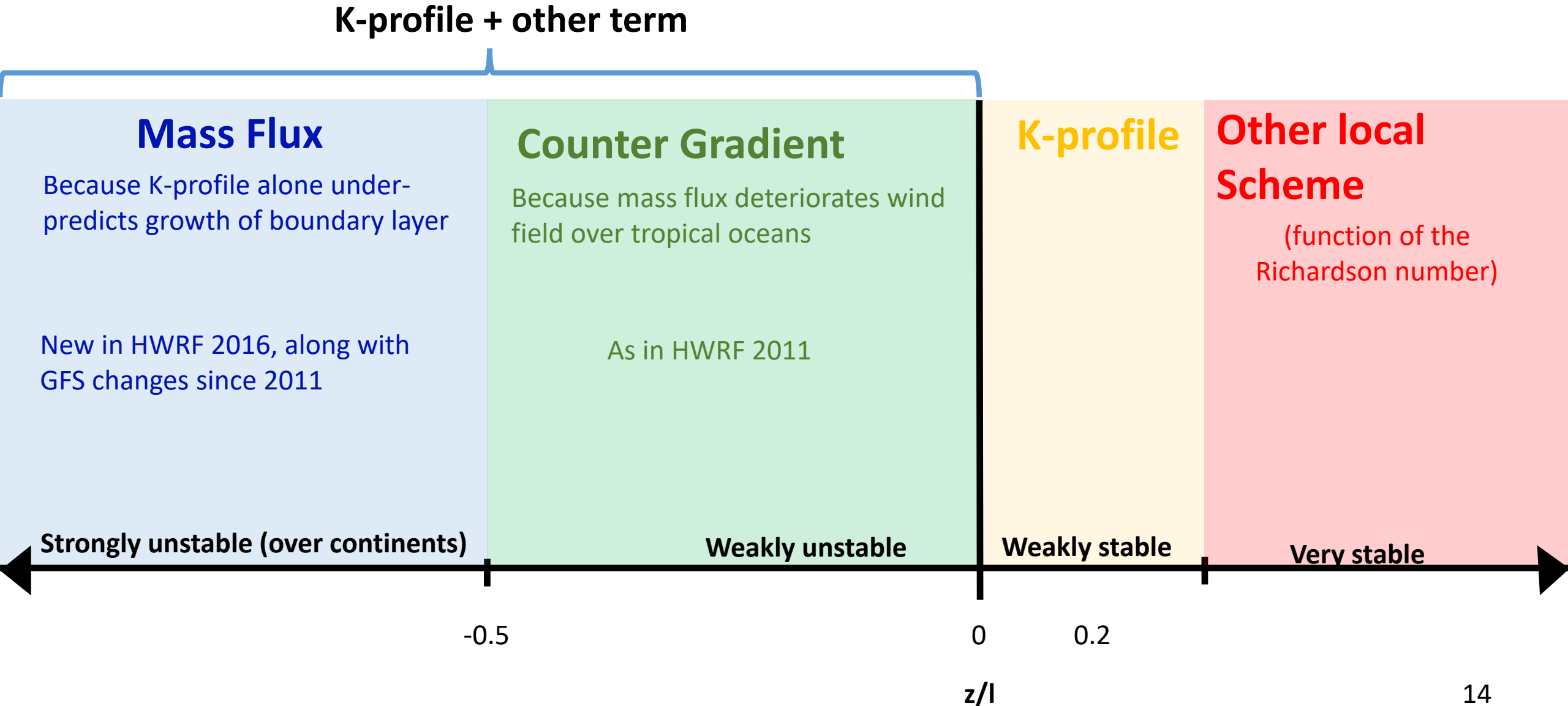
HWRf FORECAST — INTENSITY VMAX ERROR (KT) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



HWRf FORECAST — BIAS ERROR (KT) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



# HWRF 2016, “Hybrid” PBL





# Ferrier-Aligo Microphysics Changes

Problem

Solution

High reflectivity bias  
in PBL clouds

Added a drizzle  
parameterization (allows  
larger number of droplets)

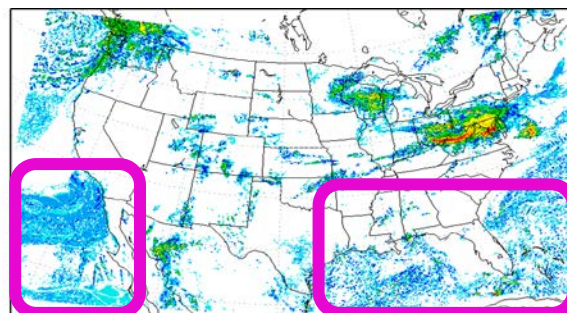
High reflectivity  
bias at anvil

Increased largest  
possible number  
concentration of snow

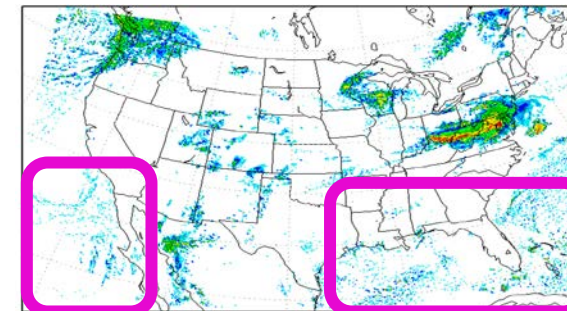
Lack of stratiform  
precipitation

Constant rain drop size  
during rain evaporation  
(reduces evaporation)

Old

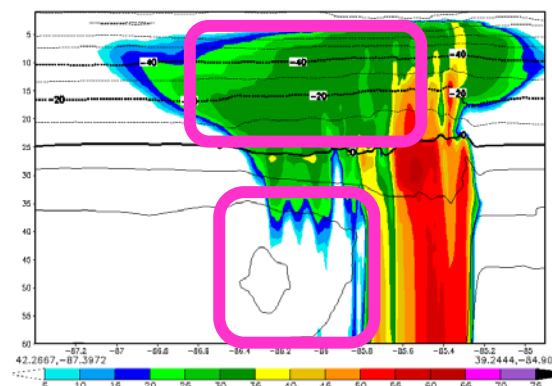


New

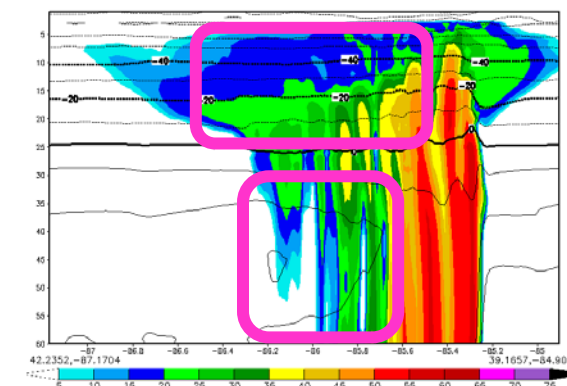


12Z 23 June 2016

REFLECTIVITY (dBZ)



REFLECTIVITY (dBZ)



21Z 29 June 2012



# Scope of FY17 HWRF Upgrades



## ➤ Initialization/Data Assimilation Improvements

- Improve vortex initialization (new composite storm vortex)
- GSI code upgrades; new data sets for GSI (hourly shortwave, clear air water vapor and visible AMV's, GH changes, G-IV TDR data)
- Bug fixes (TDR DA)
- Fully Cycled EnKF two-way hybrid DA when TDR data is available
- Change in blending threshold (to 64 kt) (Jason's talk)
- HDOBS data assimilation (Jason's talk)

-- Green:

Included in Baseline

-- Blue:

Included in Baseline (if ready)

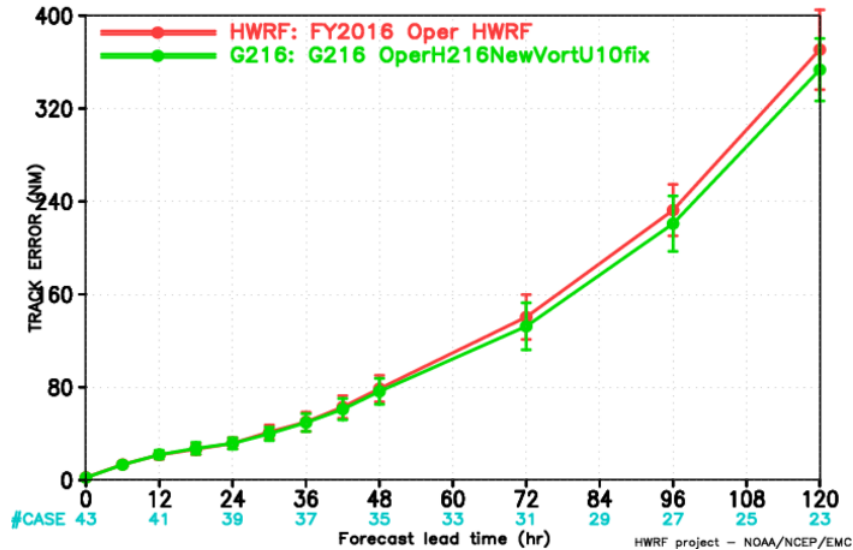
-- Orange:

Tested separately as an option

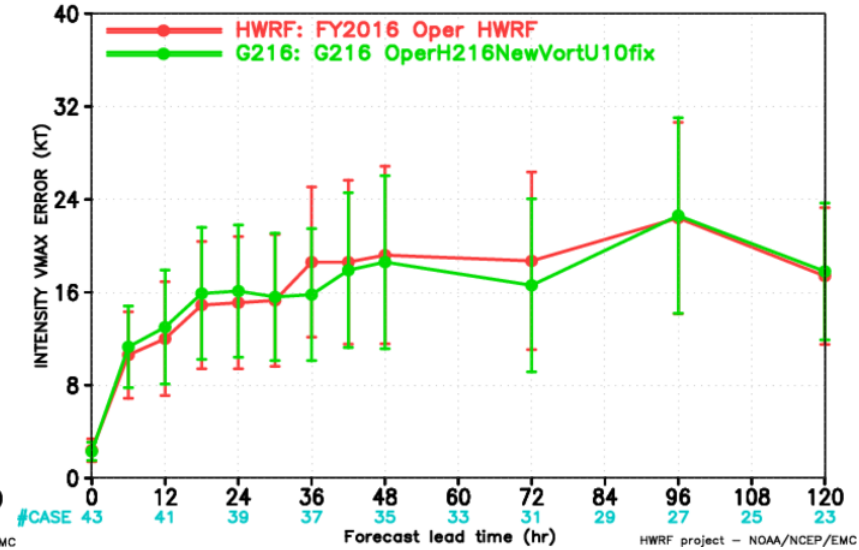


# Impact of New Composite Vortex

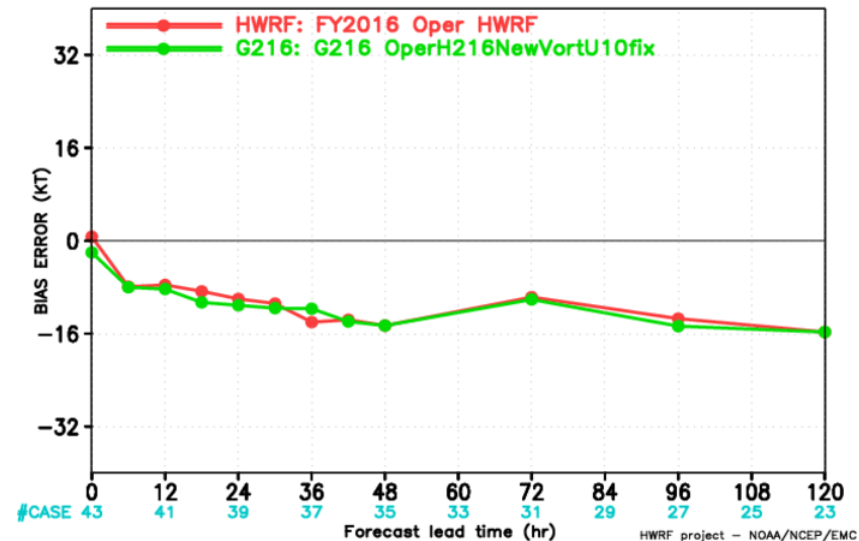
HWRP FORECAST — TRACK ERROR (NM) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



HWRP FORECAST — INTENSITY VMAX ERROR (KT) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016



HWRP FORECAST — BIAS ERROR (KT) STATISTICS  
VERIFICATION FOR NATL BASIN 14L2016

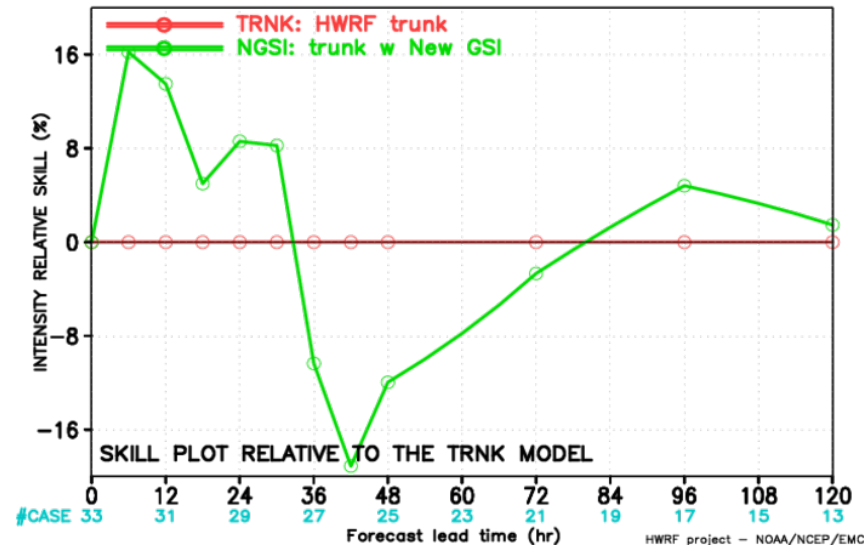
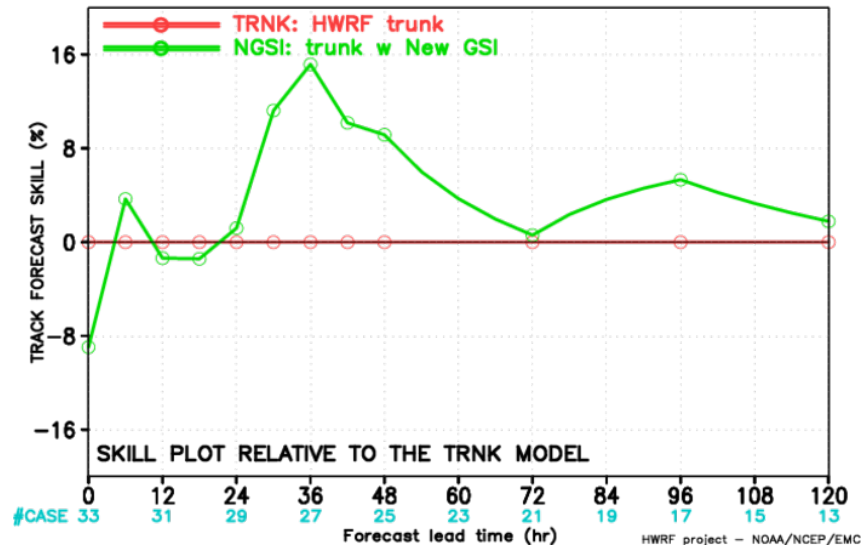
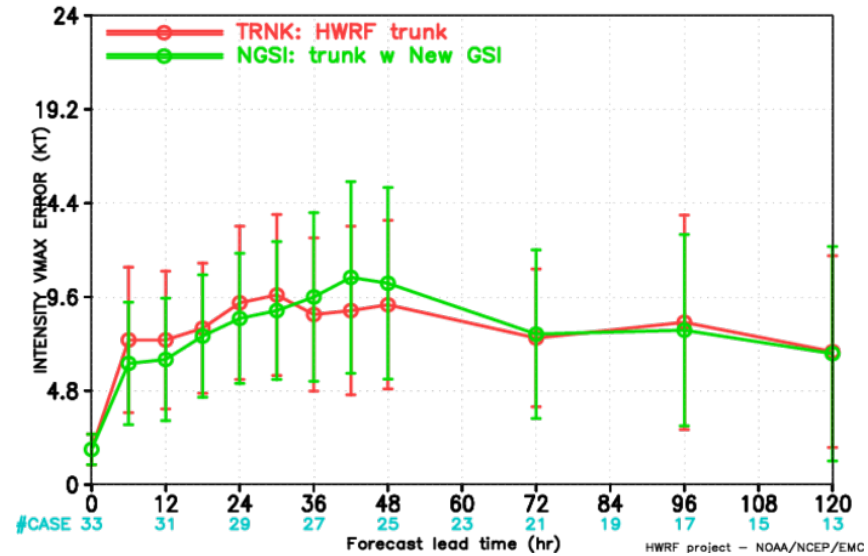
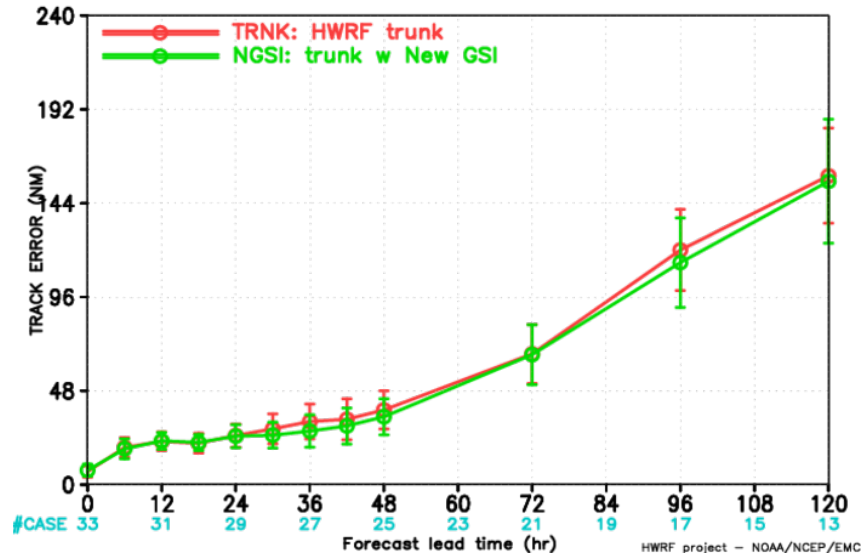


- New composite vortex according to H216
- Only adjust low level vortex intensity and structure for weak storms



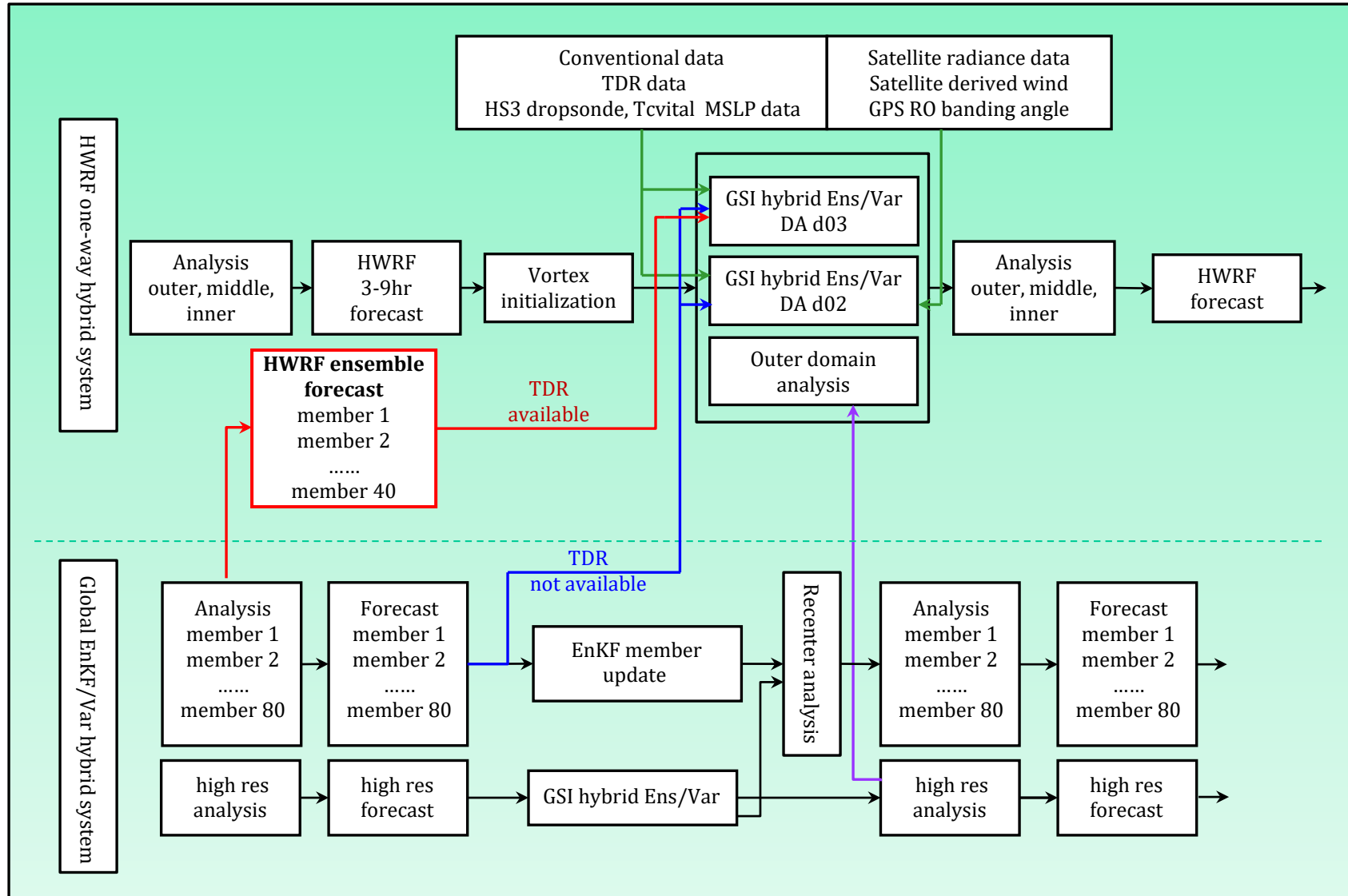
# GSI upgrades sensitivity test

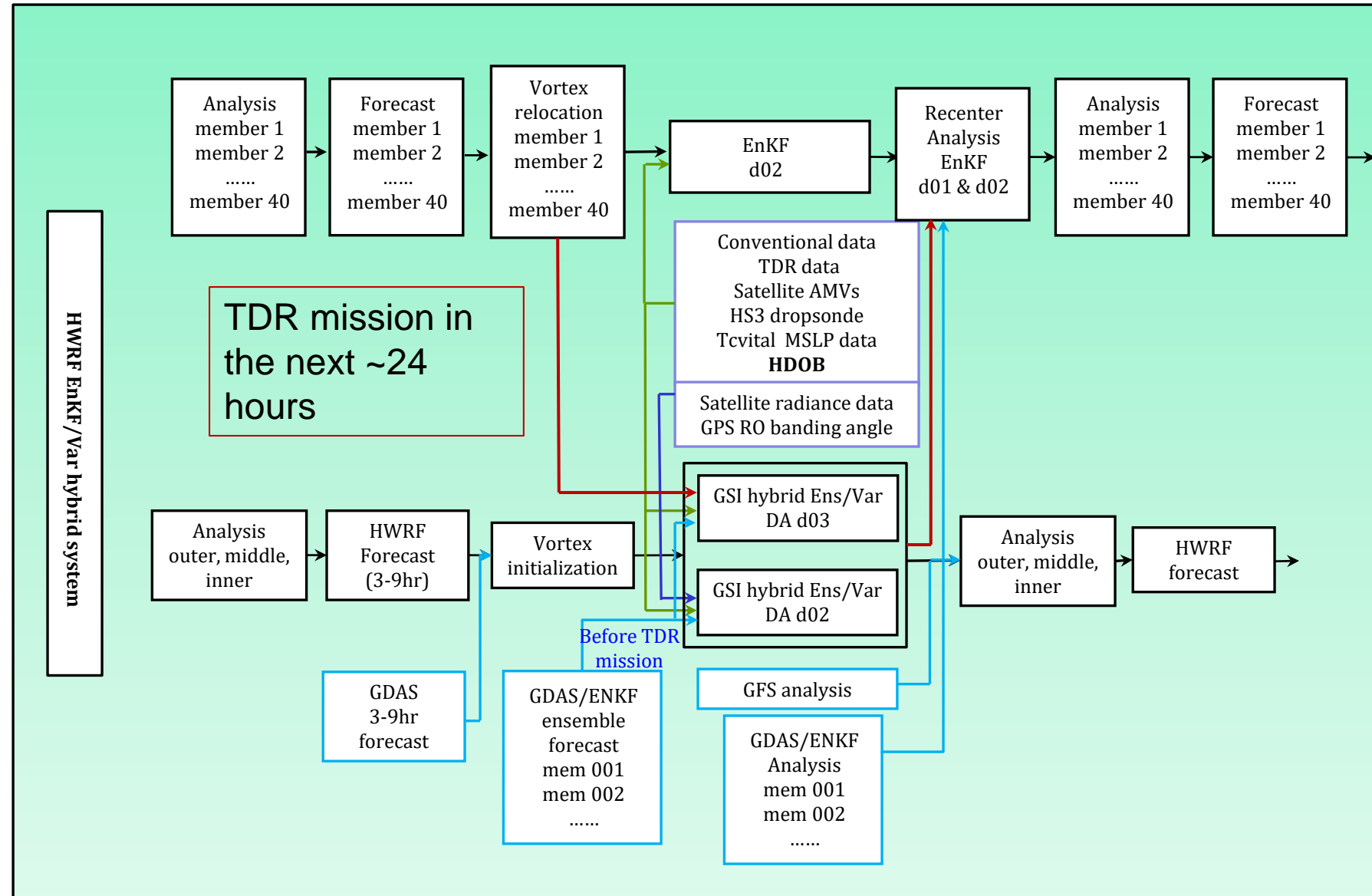
## EDOUARD 06L 2014



# 2016 HWRF Hybrid Data Assimilation System

## Warm-start HWRF ensemble when TDR available



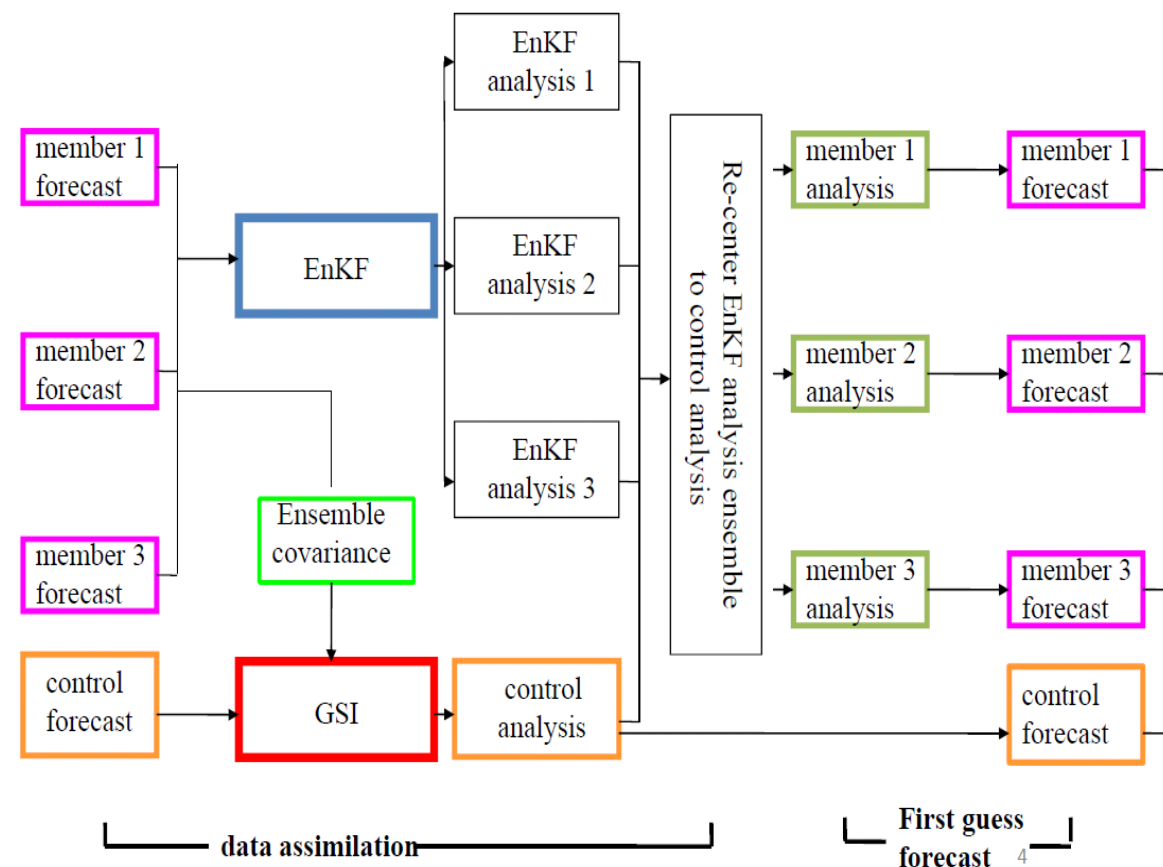




# 2017 Data Assimilation Upgrades (ATL and EPAC)

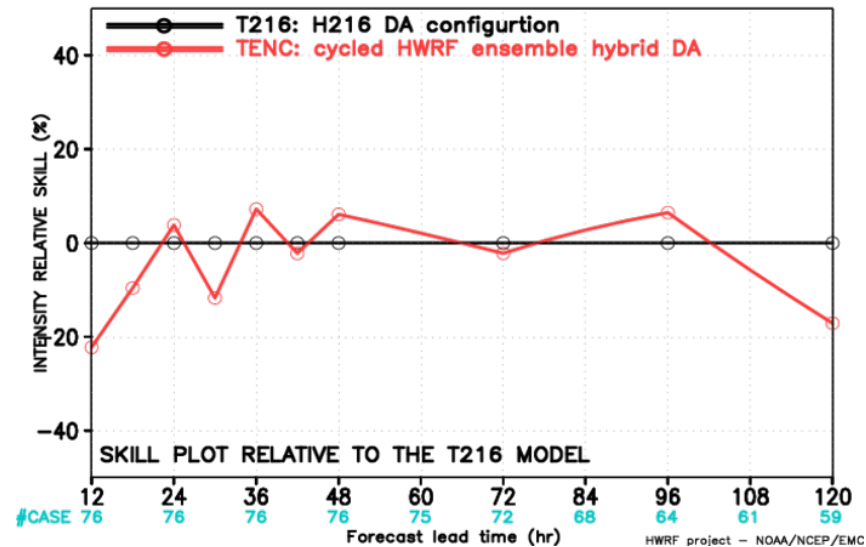
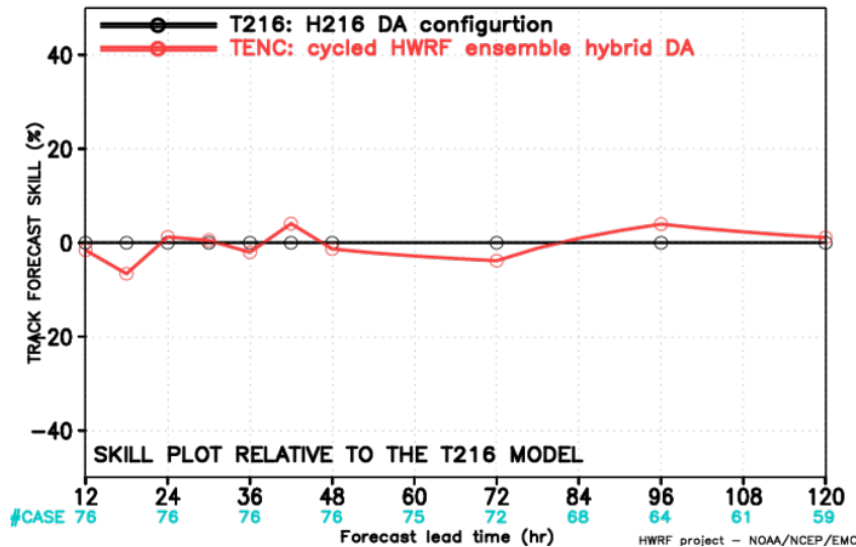
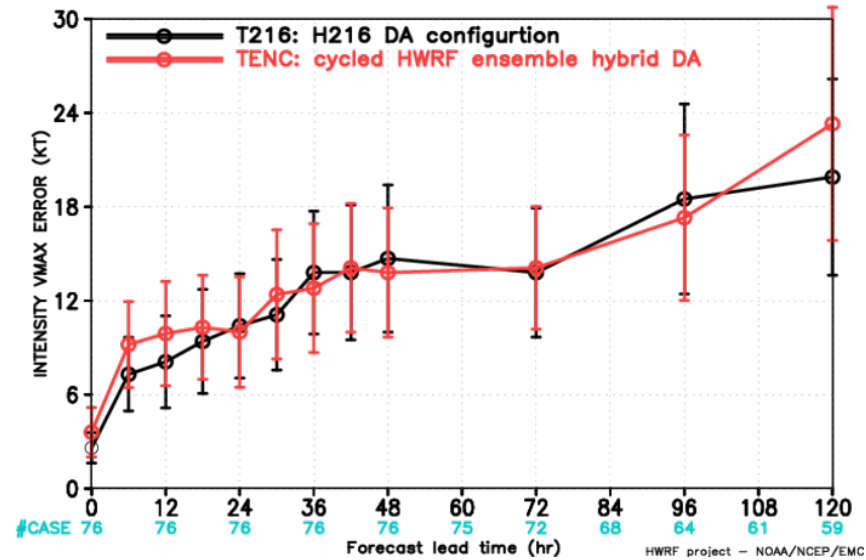
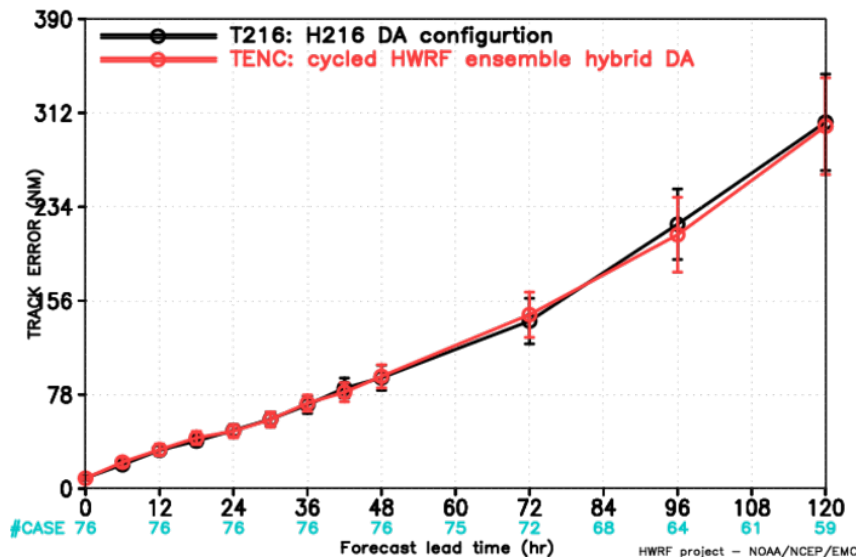


Hybrid EnKF-GSI DA system: 2 way coupling



Advanced self-cycled HWRF EnKF-GSI Hybrid Data Assimilation System (HDAS)

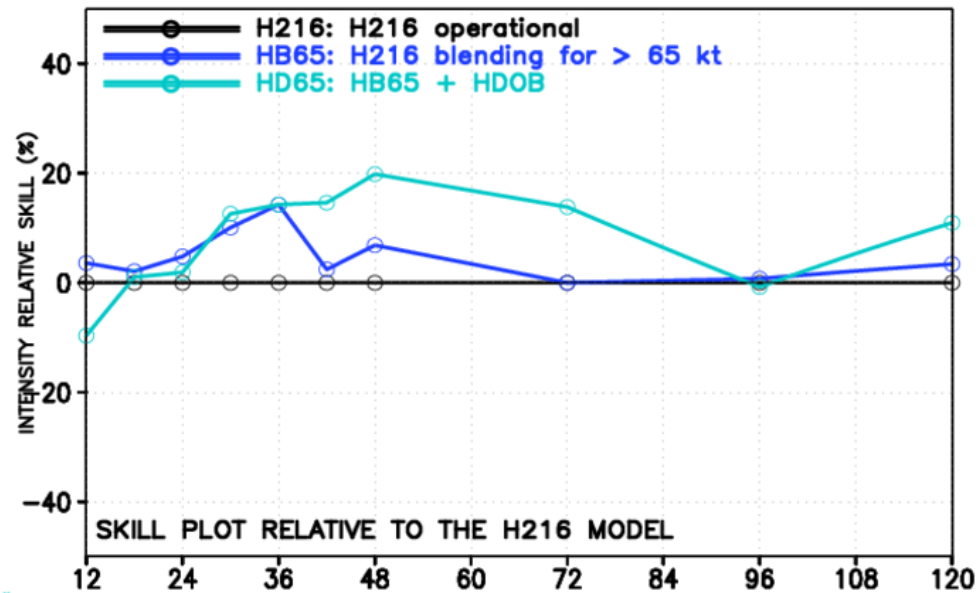
# Cycled HWRf ensemble hybrid DA 2016 AL storms with TDR data available



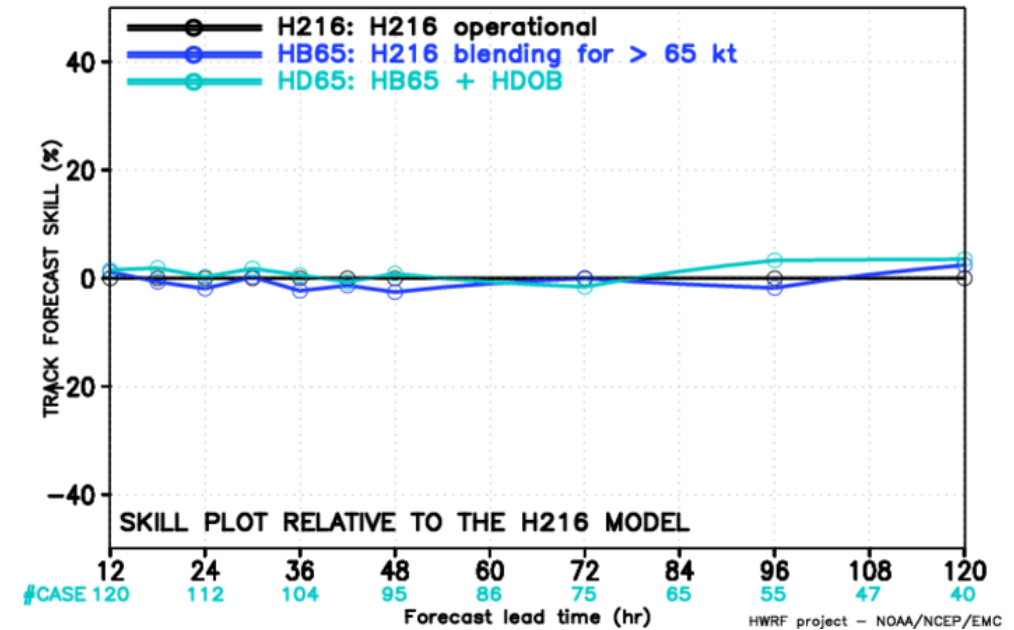


# Impact of changes to Blending and HDOBS (2014 Storms)

HWRF FORECAST — INTENSITY RELATIVE SKILL (%) STATISTICS  
H216 HDOB test

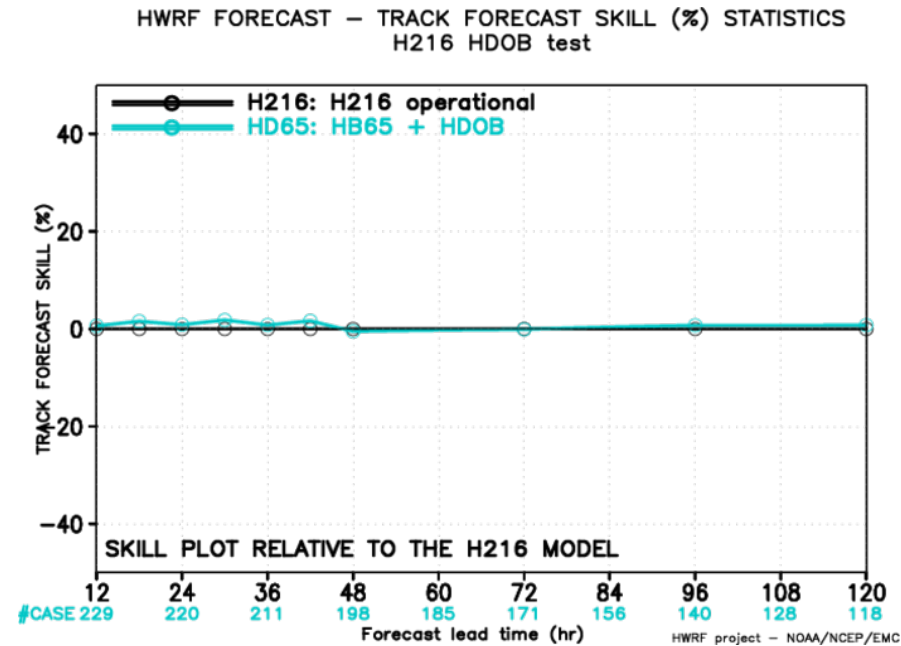
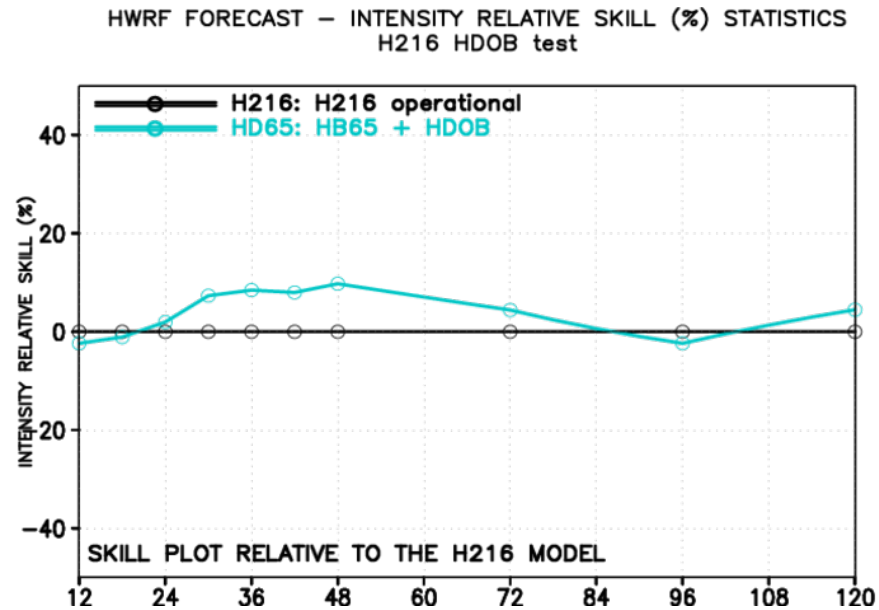


HWRF FORECAST — TRACK FORECAST SKILL (%) STATISTICS  
H216 HDOB test



- HB65: Increasing blending threshold results in better intensity forecasts
- HD65: Adding HDOBS significantly improves intensity
- No impact on track

# Impact of changes to Blending and HDOBS (2014 & 2016 Storms)



- Expanded sample to include Matthew & Hermine
- Consistent results of significant intensity improvement peaking at 48 h





# Scope of FY17 HWRF Upgrades



## ➤ Other upgrades in 2017....

- Use of NEMSIO (IC) and GRIB<sub>2</sub> (LBC) files for inputs
- Reduce coupling time step from 9min to 6 min for both waves and ocean
- Increase vertical resolution from 24 to 40 levels for POM with reduced time step
- Modify WW<sub>3</sub> frequency bins and time step with hourly wave products
- Revised early model interpolation method
- WW<sub>3</sub> boundary conditions from global wave model
- RTOFS initialization for NATL (??)
- HYCOM/RTOFS for WPAC, NIO
- Graphics included in workflow

-- Green:

Included in Baseline

-- Blue:

Included in Baseline (if ready)

-- Orange:

Tested separately as an option



# HWRF Upgrade Plan for 2017 Implementation

## *Multi-season Pre-Implementation T&E*



	Model upgrades	Physics and DA upgrades		Combined
	Baseline (H17B)	Data Assimilation changes (H17S)	Physics changes (H17P)	H217
Description	1. Framework upgrade to HWRFV3.8a; domain center; new tracker 2. New 2017 GFS upgrade 3. U10 fix, smaller coupling time step. 4. GSI upgrades, cycled EnKF	1. HDOBS 2. Blending threshold	Assess impact of physics changes	Baseline + DA changes + all physics changes + others
Cases	Three-season 2014-2016 simulations in ATL/EPAC cases (~2000)	Only Aircraft DA cases for 2014-2016	Priority cases (~500 cases in each basin)	<b>Three-season 2014-2016 retrospectives ~5000 simulations in all TC basins</b>
Platform	WCOSS/Jet/Theia	WCOSS/Jet/Theia	WCOSS/Jet/Theia	<b>WCOSS Cray</b>



# HWRF: Current and Future Tasks

- Further improvements to hurricane physics
- Further improvements to vortex initialization and data assimilation
- Increase/change vertical resolution, nested domain sizes
- Replace operational Hurricane Wave model with HWRF system
- 5-10 Member Ensembles
- Three-way Atmosphere-Ocean-Wave coupling
- Basin-scale configurations



# Q3FY17 Hurricane WRF V11.0.0

Project Status as of 10/19/16



## Project Information and Highlights

**Lead:** Avichal Mehra, EMC and Steven Earle, NCO

### Scope:

1. Improved air-sea-wave coupling for HWRF; replace operational Hurricane Wave model with HWRF system
2. Possible implementation of multi-storm configuration and/or single domain (basin-scale) configuration for improved multi-scale interactions and tropical cyclogenesis predictions;
3. Further improvements to hurricane physics (especially microphysics and air-sea-wave interactions)
4. Further improvements to vortex initialization; assimilate additional aircraft and satellite data
5. Increase vertical resolution in North West pacific, North Indian and Southern Hemisphere Ocean basins consistent with North Atlantic and Eastern North Pacific Basins;
6. Extend ocean coupling to Southern Hemisphere Ocean basins

### Expected Benefits:

1. Improved track & intensity forecast skill in all basins
2. Improved products **including AWIPS**



## Issues/Risks

**Issues:** Complex T&E due to dependency on NEMS/GSM and RTOFS upstream requirements

**Risks:** Implementation dates are dependent on completion of T&E

**Mitigation:** Conduct T&E as soon as (or along with) NEMS/GSM and RTOFS retrospective data are available.



## Scheduling

Milestone (NCEP)	Date	Status
Identify preliminary System Configuration	11/01/2016	
Start preliminary evaluation	11/01/2016	
Finalize System configuration	01/10/2017	
Initial coordination with SPA team	01/10/2017	
Freeze codes for real-time and retrospective runs	01/10/2017	
Pre-CCB Briefing to EMC management	02/15/2017	
Completion of full retrospective runs and external evaluation	02/15/2017	
EMC CCB/NCEP OD approval	02/28/2017	
Deliver final code to NCO (including downstream codes)	02/28/2017	
Technical Information Notice Issued	03/07/2017	
Special event if applicable		
Complete 30-day evaluation and IT testing	05/15/2017	
Final Management Briefing	05/22/2017	
Operational Implementation	05/31/2017	



## Resources

**Human Resources:** 3 FTE full time for 6 months.

**Funding Sources:** STI

**Compute:**

**Archive:**



Management Attention Required



Potential Management Attention Needed



On Target



## Targeted Resources for Hurricane Modeling (maximum per storm)

Operational System	2016 (nodes)	2017 (nodes)	Comments
HWRF	63	58	Optimization, with configuration changes
WW3-multi2	8	0	WW3 coupled to HWRF
GFDL	3	0	Discontinued
HNMMB	0	26*	Uses much less resources than HWRF
<b>TOTAL</b>	<b>74</b>	<b>84</b>	13.5% resource increase*

- Initial implementation is targeted for only 5 storms serving NHC areas of responsibility (ATL & EPAC)



## And one last thing for FY17----

**After 22 years of glorious service, GFDL Hurricane model is planned to be retired!**

**Thank you** Morris, Bob, Tim, Matt along with past research personnel at GFDL and their collaborators (NHC, HRD, EMC, FLEET, URI, others) for valuable operational guidance to NHC and JTWC and key contributions to the broader worldwide Tropical Storms research community!!

