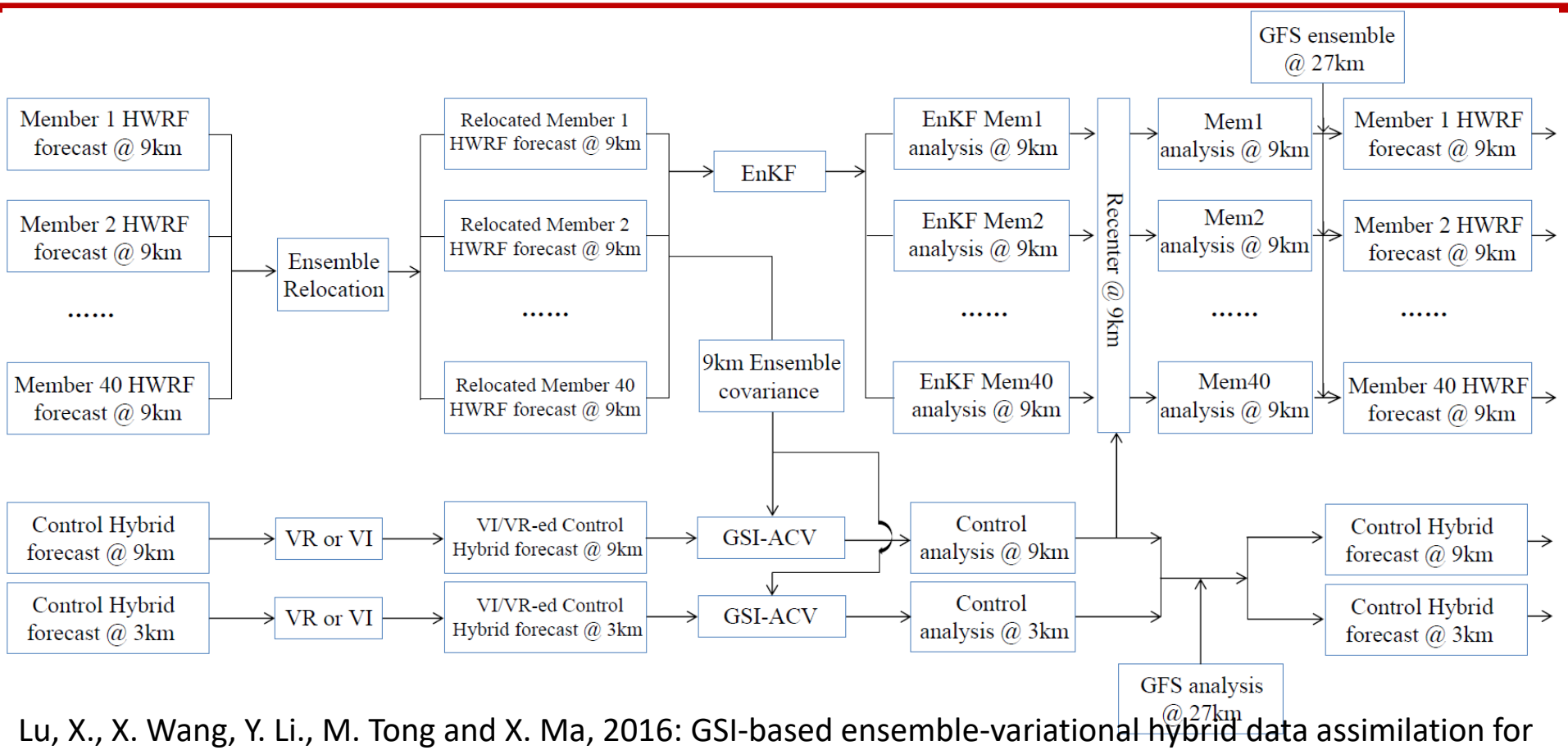
DA/Initialization/Ensemble Development Team Milestones and Priorities

Presented by Xuguang Wang

HFIP annual review meeting
Jan. 11-12, 2017, Miami, FL

Fully cycled, self-consistent, dual-resolution, GSI based hybrid ensemble-variational DA system



Lu, X., X. Wang, Y. Li., M. Tong and X. Ma, 2016: GSI-based ensemble-variational hybrid data assimilation for HWRF for hurricane initialization and prediction: impact of various error covariances for airborne radar observation assimilation. Q. J. R. Meteo. Soc. In press.

Lu, X. and X. Wang 2017a: GSI-based, Continuously Cycled, Dual Resolution Hybrid Ensemble-Variational Data Assimilation System for HWRF: System Description and Experiments with Edouard (2014). Mon. Wea. Rev., submitted.

Fully cycled, self-consistent, GSI based hybrid ensemble-variational DA system

Summary of past findings: Lu et al., 2016, QJRMS; Lu and Wang 2017a, MWR

- The hybrid system using self-consistent HWRF EnKF ensemble was found to improve both the analyzed TC structures, track and intensity forecasts relative to GSI-3DVar and the hybrid ingesting GFS ensemble.
- High resolution analysis produced through dual resolution hybrid DA improves structure analysis and intensity (Vmax and MSLP) forecasts.
- Vortex relocation/initialization integrated with 6-houlry Hybrid DA improves TC analysis and subsequent forecasts.
- 4DEnVar improves the intensity forecasts for early lead times compared to using 3DEnVar.
- The new hybrid system improves Vmax forecast due to the alleviation of spin down issue during RI.
- Analyzed storm by hybrid is more consistent with an intensifying TC (e.g. larger inertial stability)

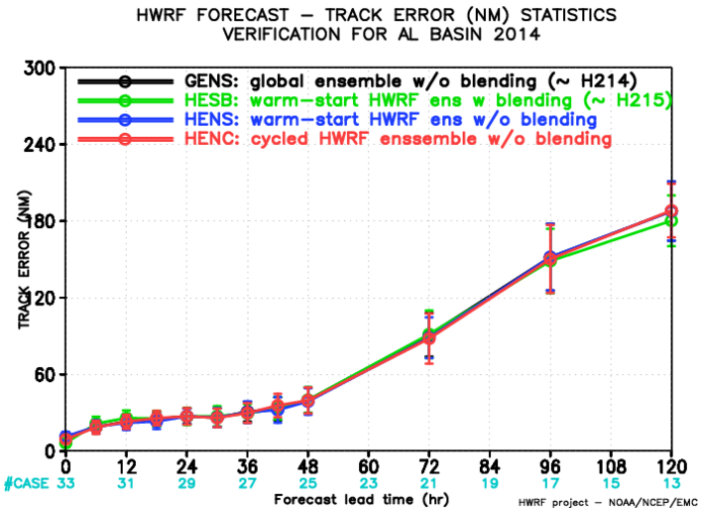
EMC

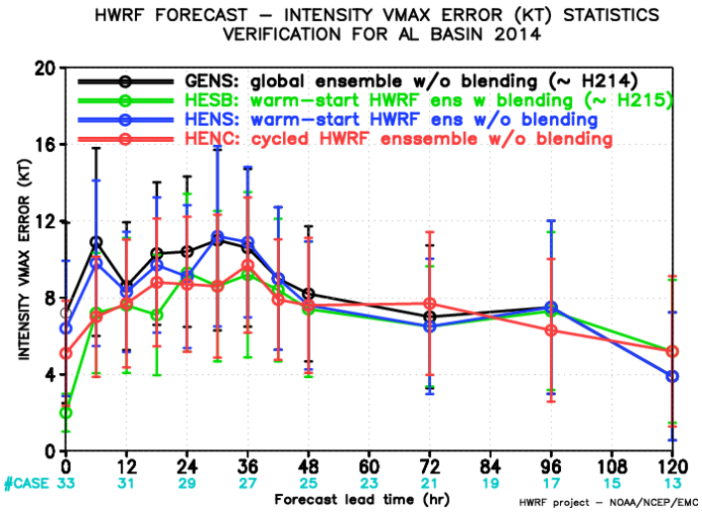
Pre-implementation test of fully cycled HWRF hybrid data assimilation system

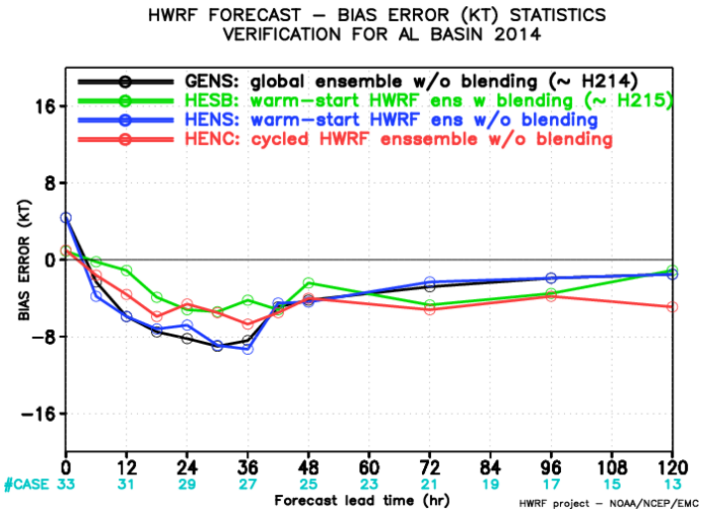
- A fully cycled HWRF ensemble hybrid data assimilation system has been developed through collaboration with OU and ESRL.
- The system has been fully tested and is now available from HWRF trunk.
- The cycled HWRF ensemble hybrid DA system improves the estimate of the storm initial intensity compared to hybrid using global ensemble and warm-start HWRF ensemble.
- The fully cycled system also improves intensity forecast up to 2 days compared with hybrid using global ensemble and warm-start HWRF ensemble
- Compared to the experiment with blending turned on, the cycled system shows comparable track and intensity forecast.
- Plan to test the cycled system with blending turned on.

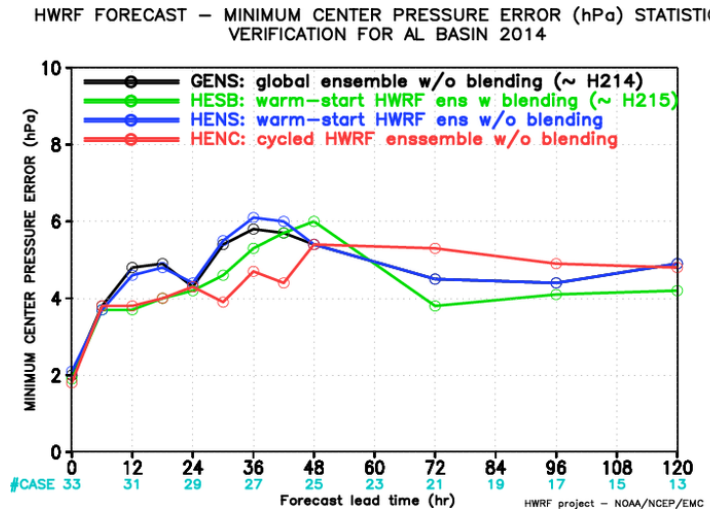
EMC

Edouard 06L 2014



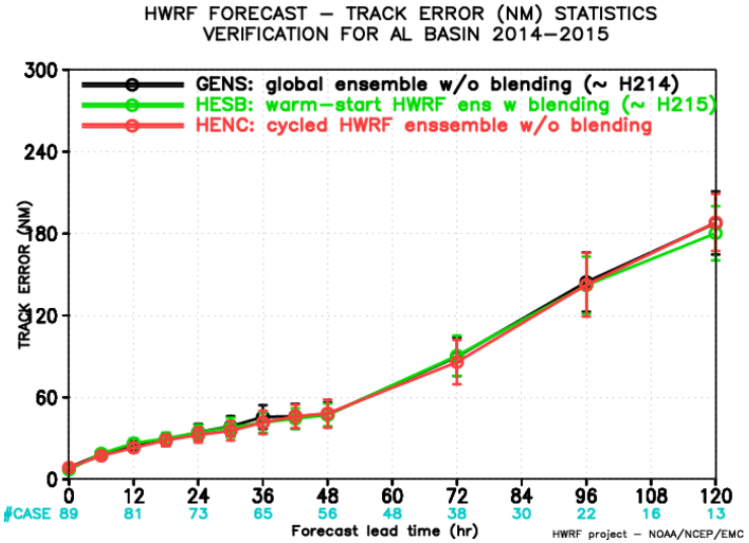


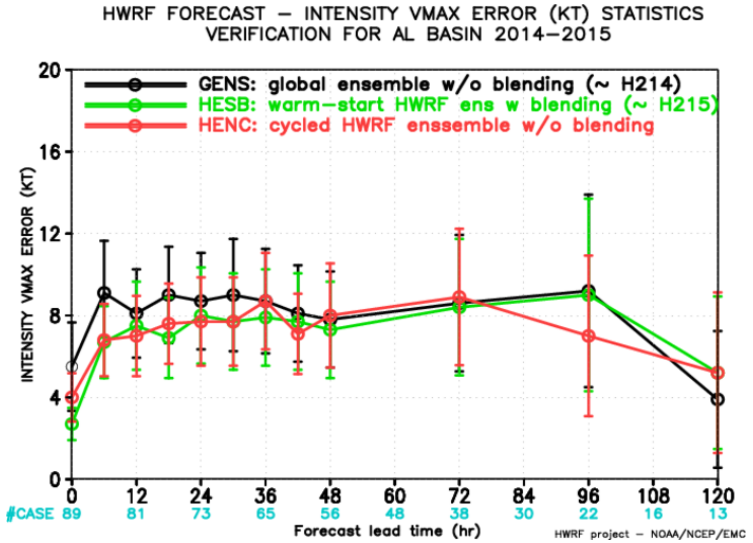


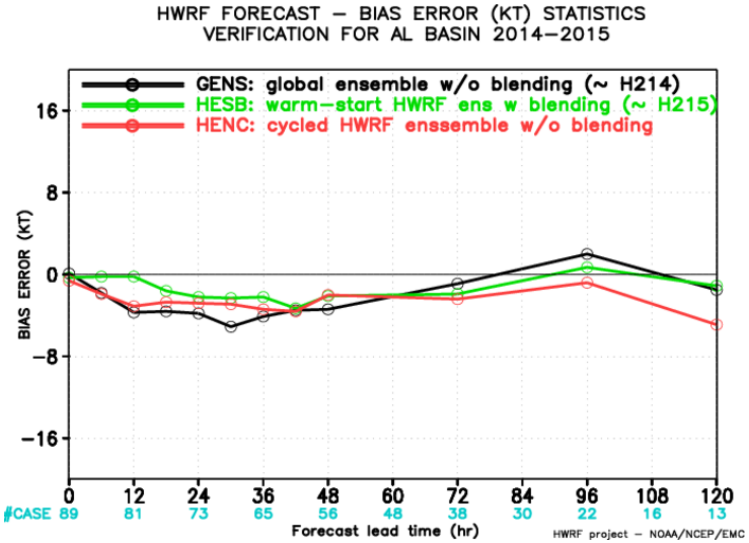


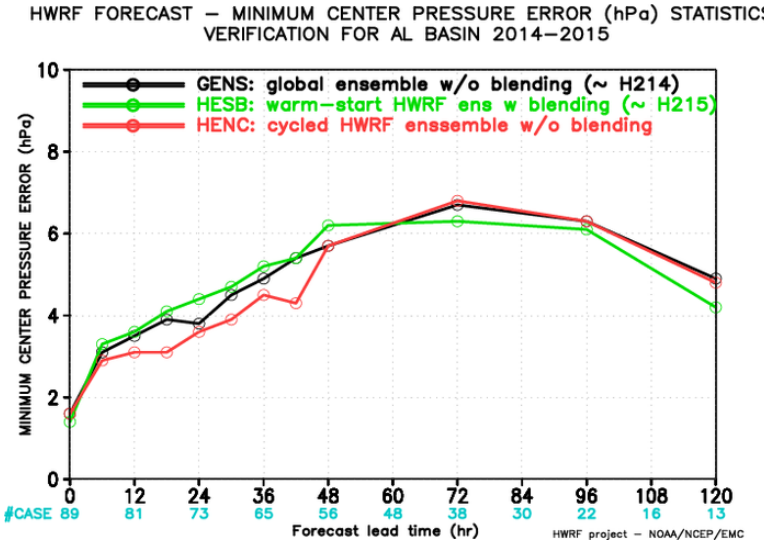
EMC

2014-2015 four storms with TDR data available





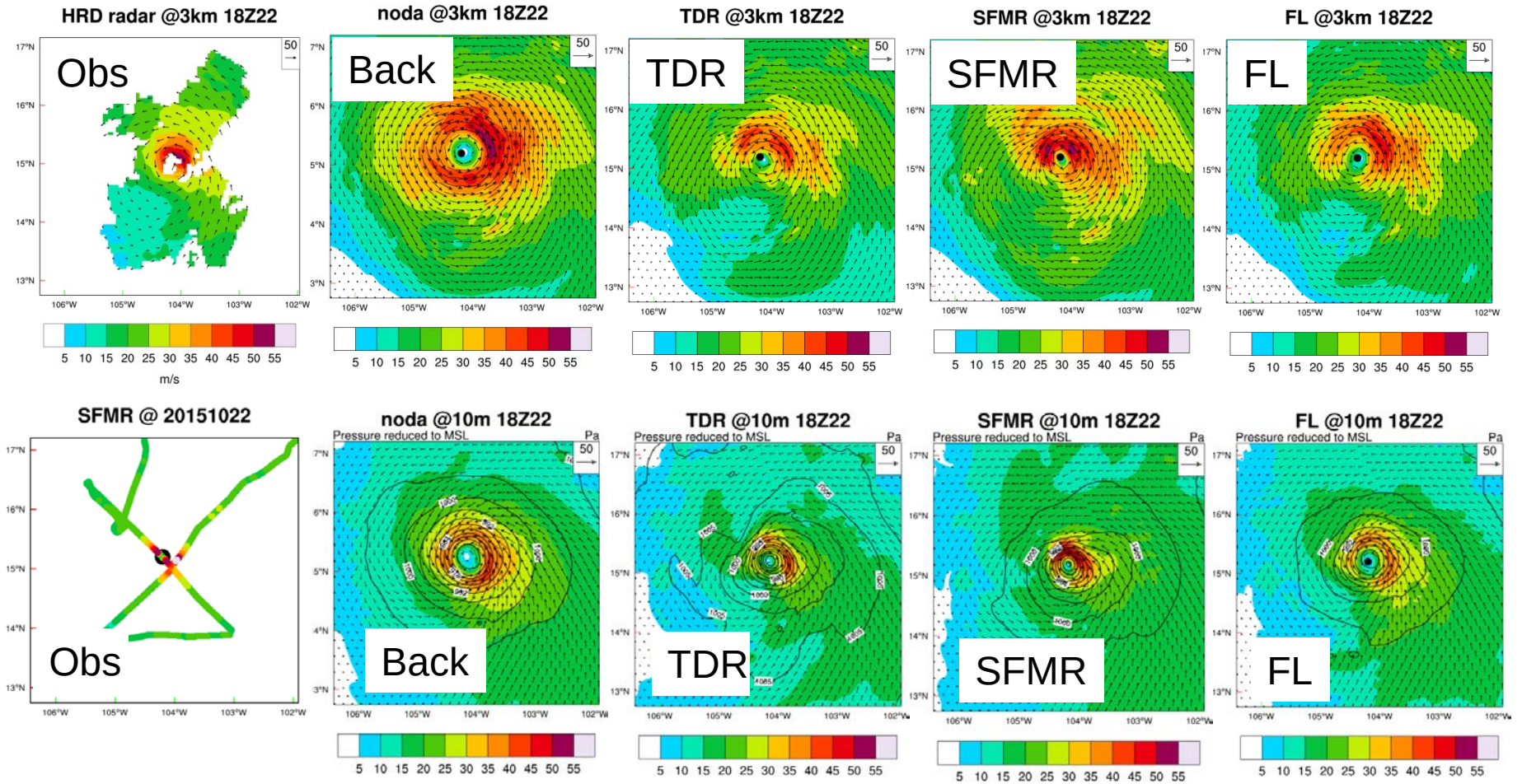




Advancement of assimilation of HDOB using fully cycled, self consistent hybrid DA

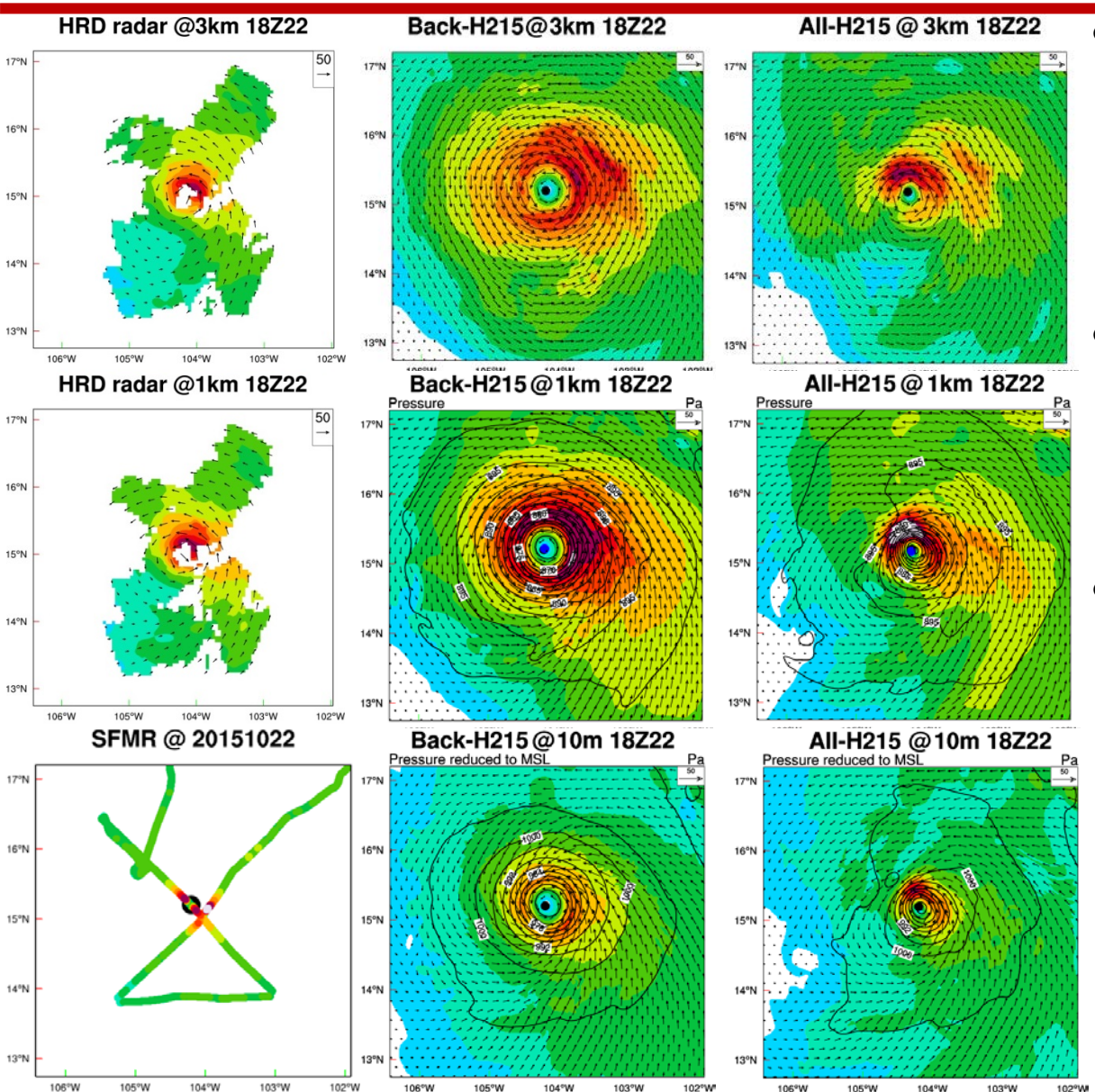
Lu and Wang 2017b

Patricia 2015



- Assimilation of HDOB improved TC structure in both analysis and forecast

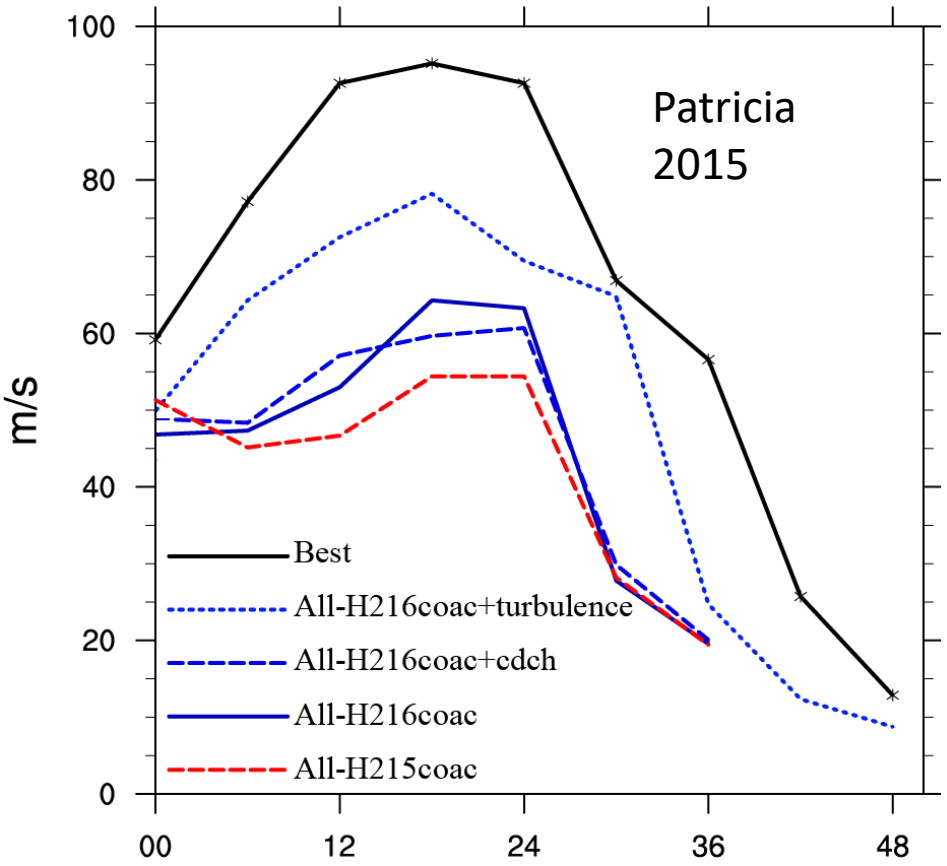
Use hybrid DA to identify HWRF model issue to improve intensity forecast (e.g. spin down for strong hurricanes) Lu and Wang 2017b

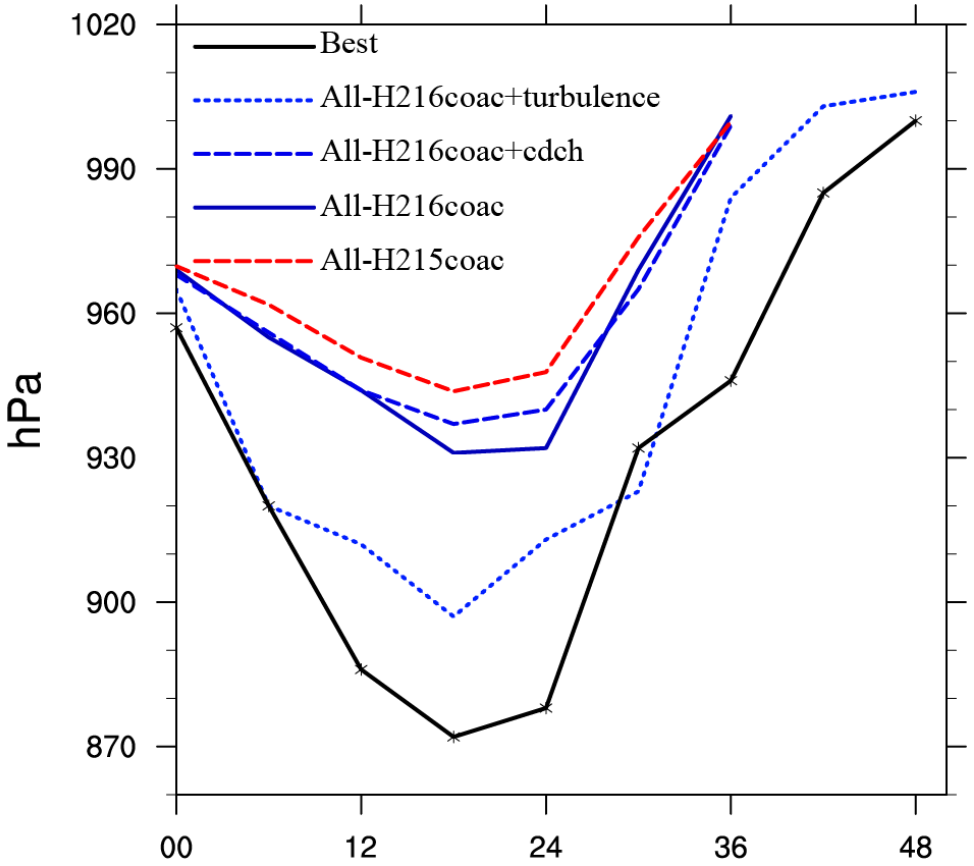


- Inner core structures are much improved upon the background or VI after assimilating TDR, FL, SFMR, dropsondes using the new hybrid DA system
- However, HWRF still experiences spin down even initialized with a much improved analysis.
- Efforts were made to identify why

  Patricia
  2015

Use hybrid DA to identify HWRF model issue to improve intensity forecast (e.g. spin down for strong hurricanes) Lu and Wang 2017b



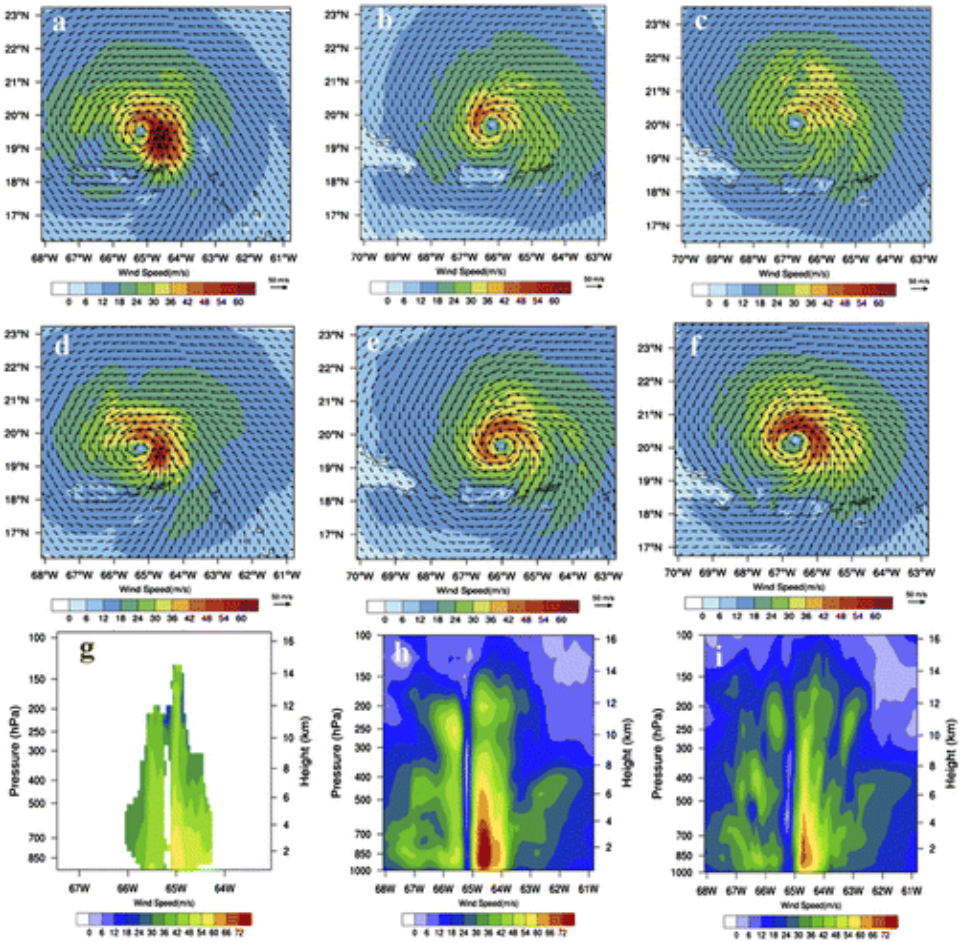


- Vmax forecast initialized by hybrid DA during RI for Patricia 2015 is sensitive to physics in HWRF (turbulent mixing provided by Ping Zhu, discussion with HRD and EMC).
- Solving spin down issue should not consider DA or model issue in isolation. Advanced DA provides opportunity to identify issue in the model that is responsible for spin down and vice versa.

UTAH

Influence of the self-consistent regional ensemble background error covariance on hurricane inner-core data assimilation

Zhaoxia Pu and Shixuan Zhang, *Univ. Utah*; Mingjing Tong and Vijay Tallapragada, *EMC/NCEP*



The use of self-consistent regional ensemble background error covariance (GSI-R) in GSI hybrid ensemble-3dVar leads better vortex structure and also mitigates the initial vortex spin-down.

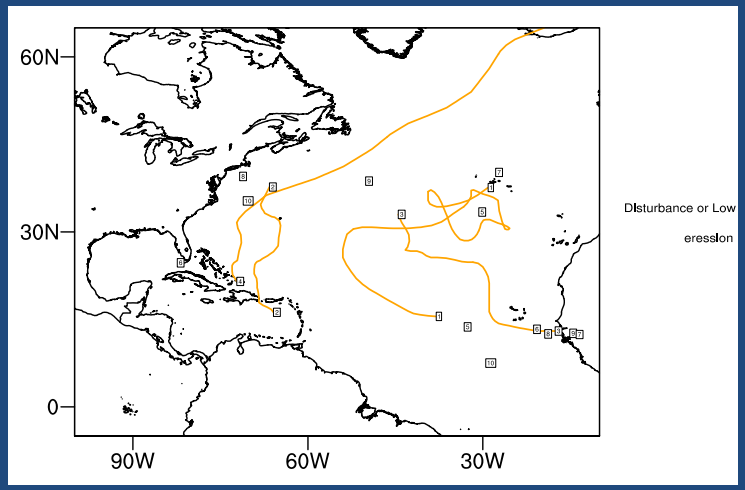
Fig. Vortex structure of Hurricane Earl as revealed by wind fields. (a)–(f) Wind speeds (shaded; m s^{-1}) and vectors at 10-m height from (a)–(c) experiment GSI-G and (d)–(f) experiment GSI-R at 0000 UTC (analysis time), 0300 UTC (3-h forecast), and 0900 UTC (9-h forecast) 31 Aug 2010. (h),(i) West–east cross section of wind speed through the hurricane center at 0000 UTC 31 Aug 2010 [(h) is from GSI-G and (i) from GSI-R], compared with (g) the wind analysis from TDR at 0015 UTC 31 Aug 2010.

Pu, Z., S. Zhang, M. Tong and V. Tallapragada, 2016: Influence of the self-consistent regional ensemble background error covariance on hurricane inner-core data assimilation with the GSI-based hybrid system for HWRF, *J. Atmos. Sci.*, 73. 4911-4925. http://dx.doi.org/10.1175/JAS-D-16-0017.1

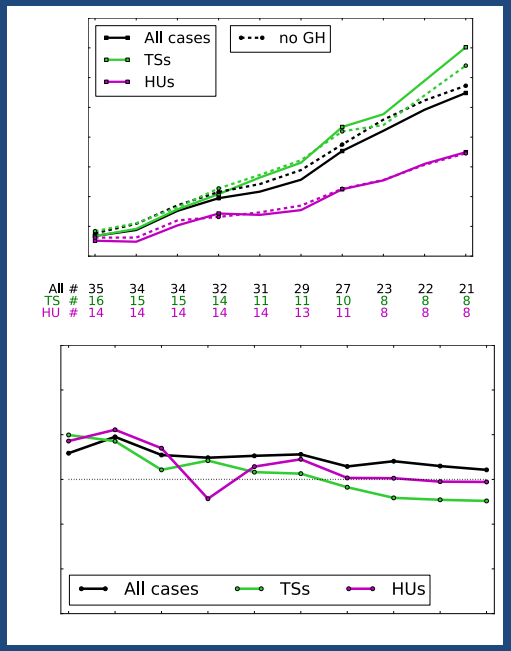
Recent Results from Ongoing HRD Projects

1. Global Hawk Dropsonde Composite Study

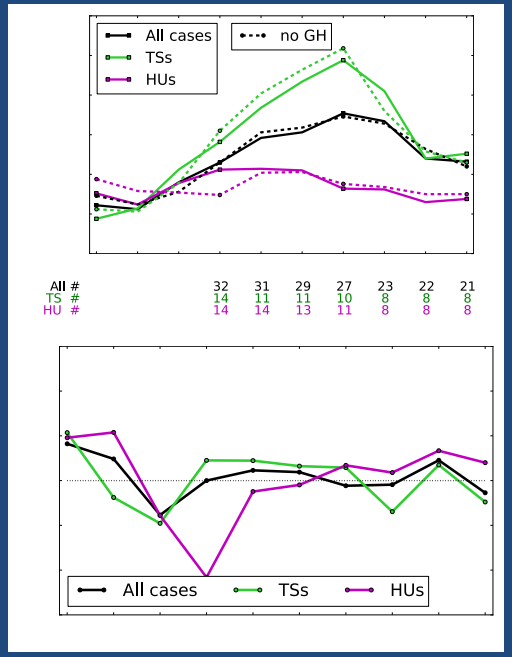
Cases



Track Errors



Intensity Errors



- In 35 Cases: Consistent Positive Improvements in Track
  Mostly Positive Improvements in Intensity
-
- Based on our findings prior to 2016, lawnmower patterns no longer implemented in tropical storms in 2016, which has improved 2016 forecast statistics for tropical storms

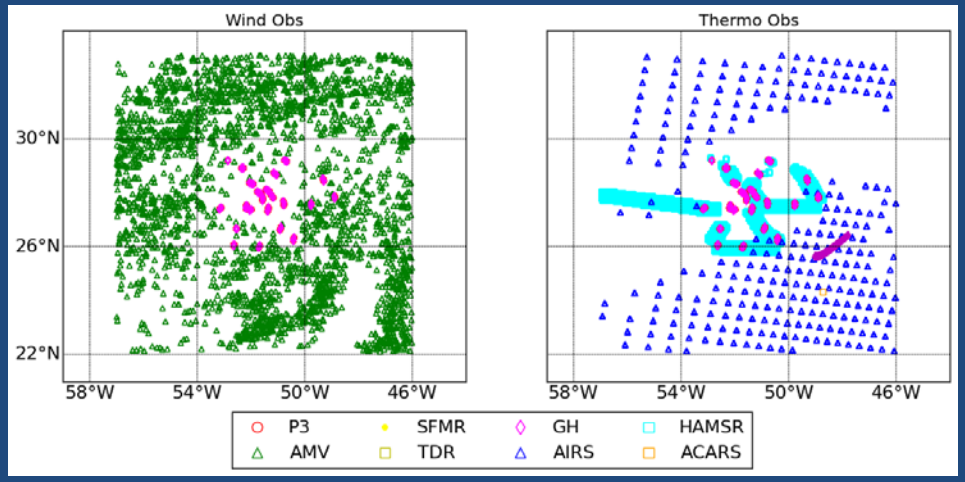
Christophersen & Aksoy (SHOUT Project)

Recent Results from Ongoing HRD Projects

2. Assimilation of Global Hawk HAMSR Retrievals (T/Q)

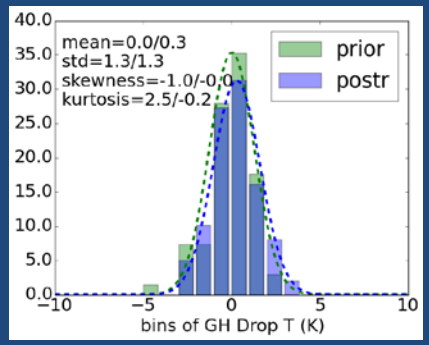
Observation Distribution

(Gaston 08/27/2016 06Z)

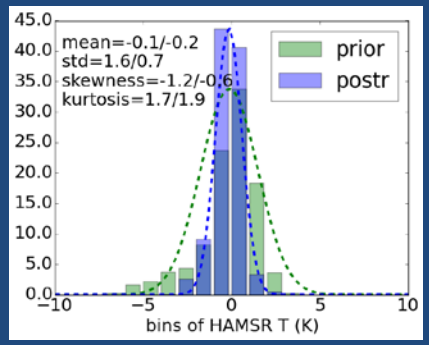


Innovation PDFs

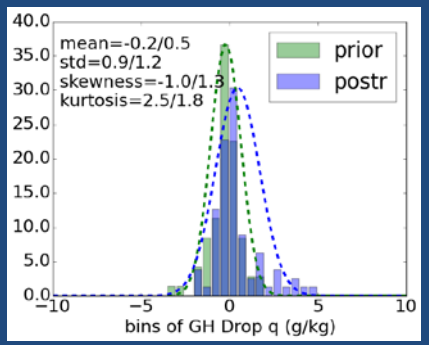
GH Dropsonde T



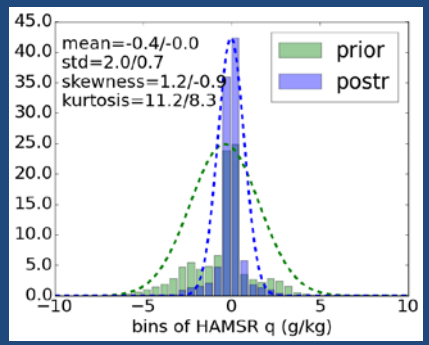
GH HAMSR T



GH Dropsonde Q



GH HAMSR Q



- Preliminary tests indicate that the assimilation of HAMRS retrievals behaves similarly to the assimilation of Global Hawk dropsonde T and Q observations in terms of observation-space statistics

- Experiments ongoing to investigate the impact on overall structure and forecasts

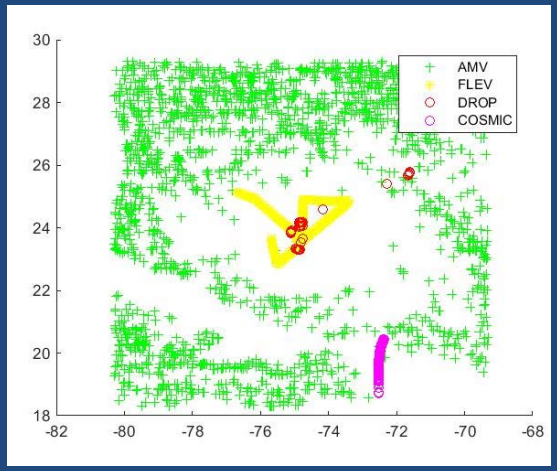
Christophersen & Aksoy (SHOUT Project)

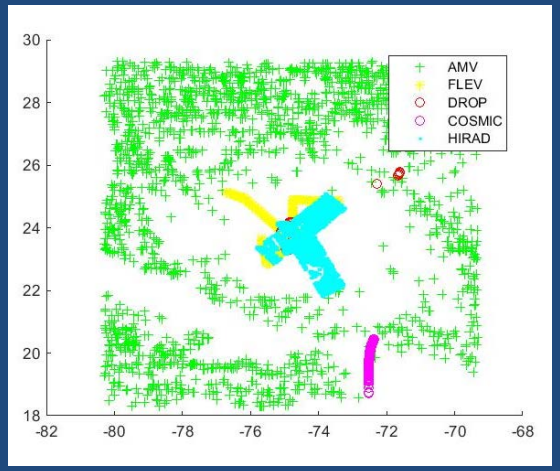
Recent Results from Ongoing HRD Projects

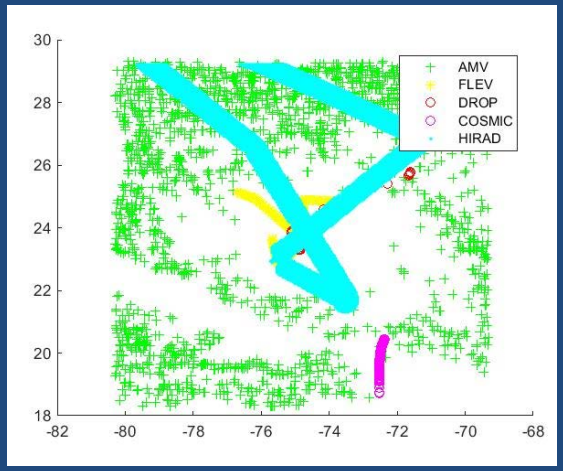
3. Assimilation of Global Hawk HIRAD Retrievals (Sfc Wind Speed)

Observation Distribution

(Joaquin 10/02/2015 18Z)

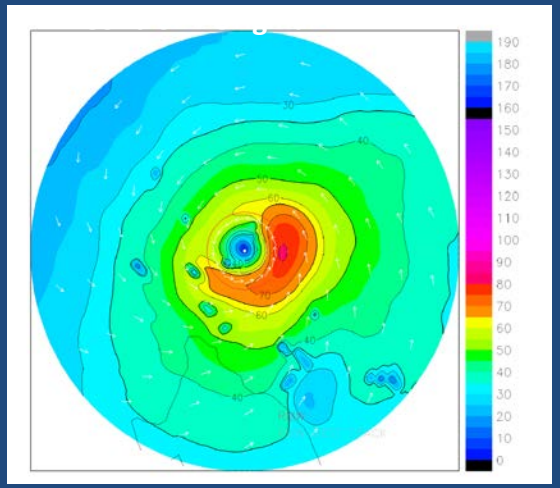


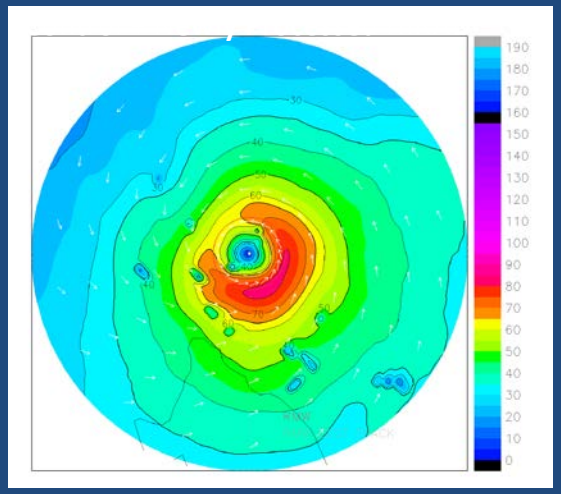




- New HIRAD processing leads to:
  - Smoother analysis
  - Better distribution of max. wind speed region
  - Better analysis of intensity

Surface Wind Speed Analyses





Sellwood & Aksoy (SHOUT Project)

Recent Results from Ongoing HRD Projects

4. Assimilation of CYGNSS Observations (OSSE)

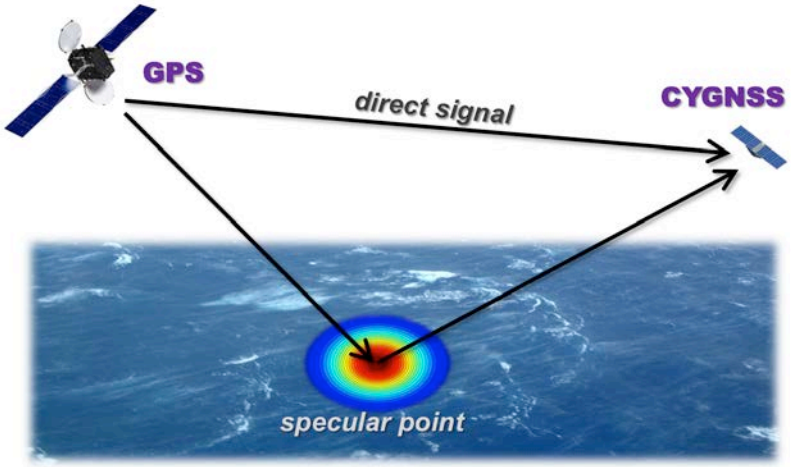


Fig 1. Geometry of GPS-based quasi-specular surface scattering. The GPS direct signal provides location, timing, and frequency references, while the forward scattered signal contains ocean surface information.

- Successful launch on Dec 15, 2016
- First good data on Jan 5, 2017
- Expected to provide accurate wind speed retrievals of up to 70 m/s in cloudy conditions with mean revisit time of 90 minutes

- OSSE results using HWRF & GSI indicate potential improvements in hurricane track and intensity forecasts using either CYGNSS wind speed scalar retrievals or CYGNSS-based VAM analyses of wind vectors

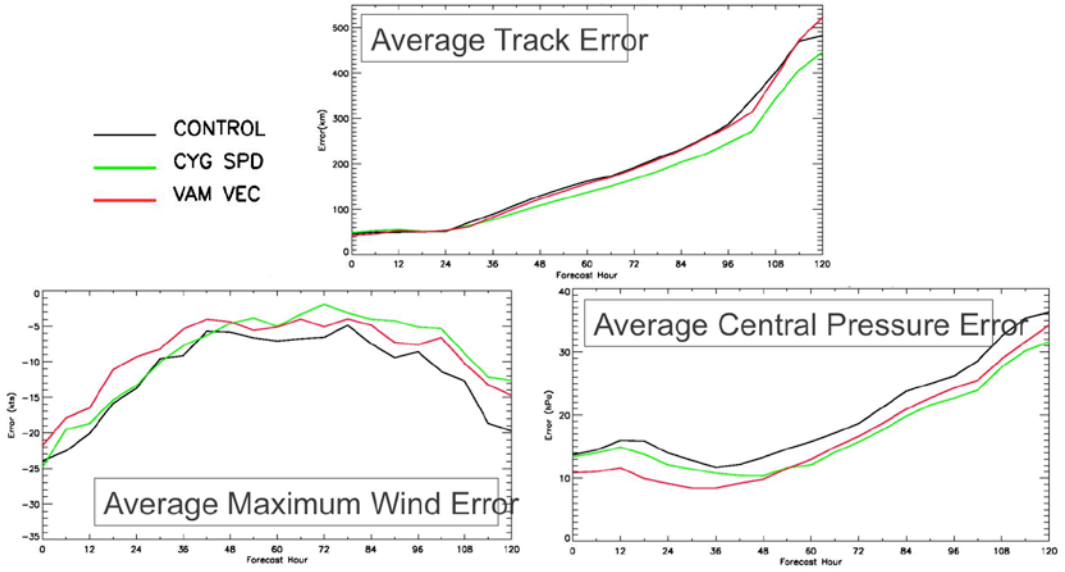
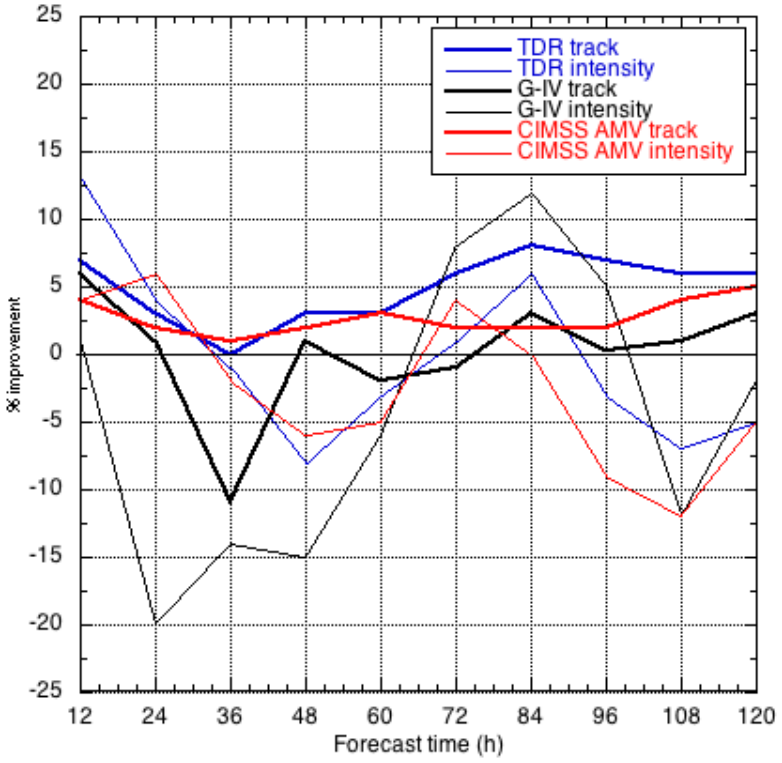


Fig 2. Average hurricane track, maximum wind and central pressure errors as a function of forecast time for Control, CYGNSS scalar winds and CYGNSS winds with vector information from HWRF OSSE. N=12 forecasts.

Annane & Leidner (CYGNSS Project)

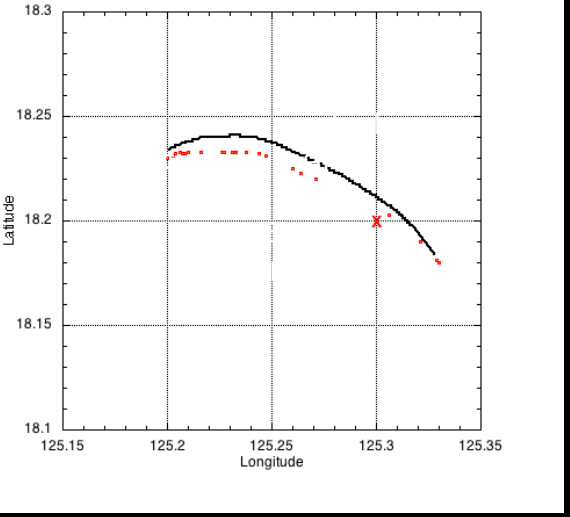
HRD

All cases with TDR data 2011-2015 using the same versions of the GFS ensemble run with updated version of HEDAS: 238 cases from 47 TCs, more than twice the sample size as the original RDITT study. G-IV sample size - 56 cases.



95% statistical significance (serial correlation removed), degradations in bold.

Doppler track - 12, 72-120 h
Doppler intensity - 12 h
G-IV track - **36 h**
G-IV intensity - **24 h**
CIMSS AMV track - 120 h
CIMSS AMV intensity - none



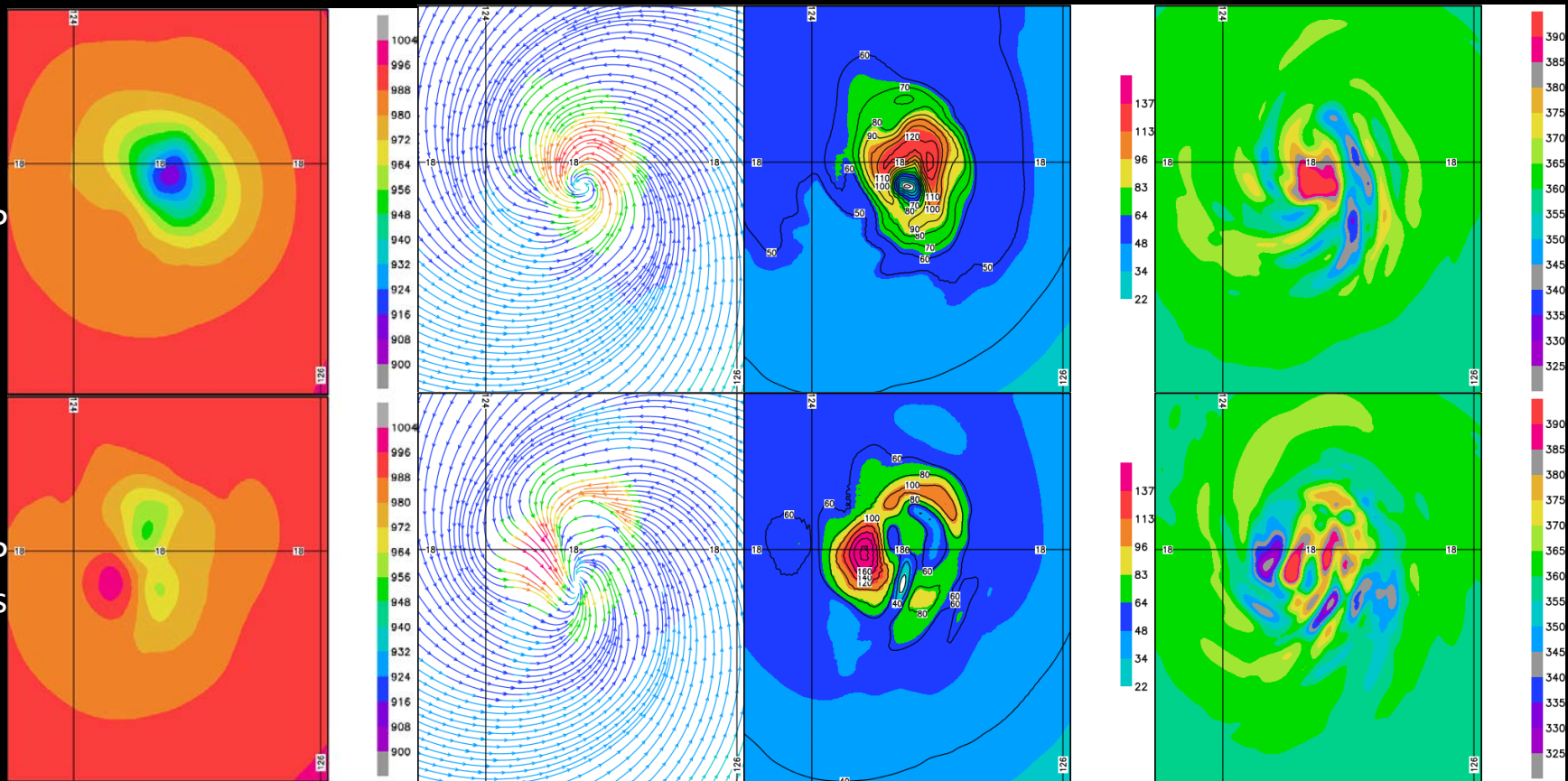
Accounting for dropwindsonde location in DA - Typhoon Megi

	P3 TEMPDROP	P3 calculated	G-IV TEMPDROP	G-IV calculated
Mean time error (min)	15.9338	0.105	16.2711	0.2697
σ time error (min)	8.6934	0.3108	10.7611	0.4537
Mean distance error (km)	5.1571	0.4256	5.57432	0.4139
σ distance error (km)	2.6824	0.3723	3.5386	0.2068
Maximum time error (min)	34.0	2.0	46.0	3.0
Maximum distance error (km)	20.0134	5.7953	29.3802	1.6102
Number of comparisons	2383	2383	18076	18076

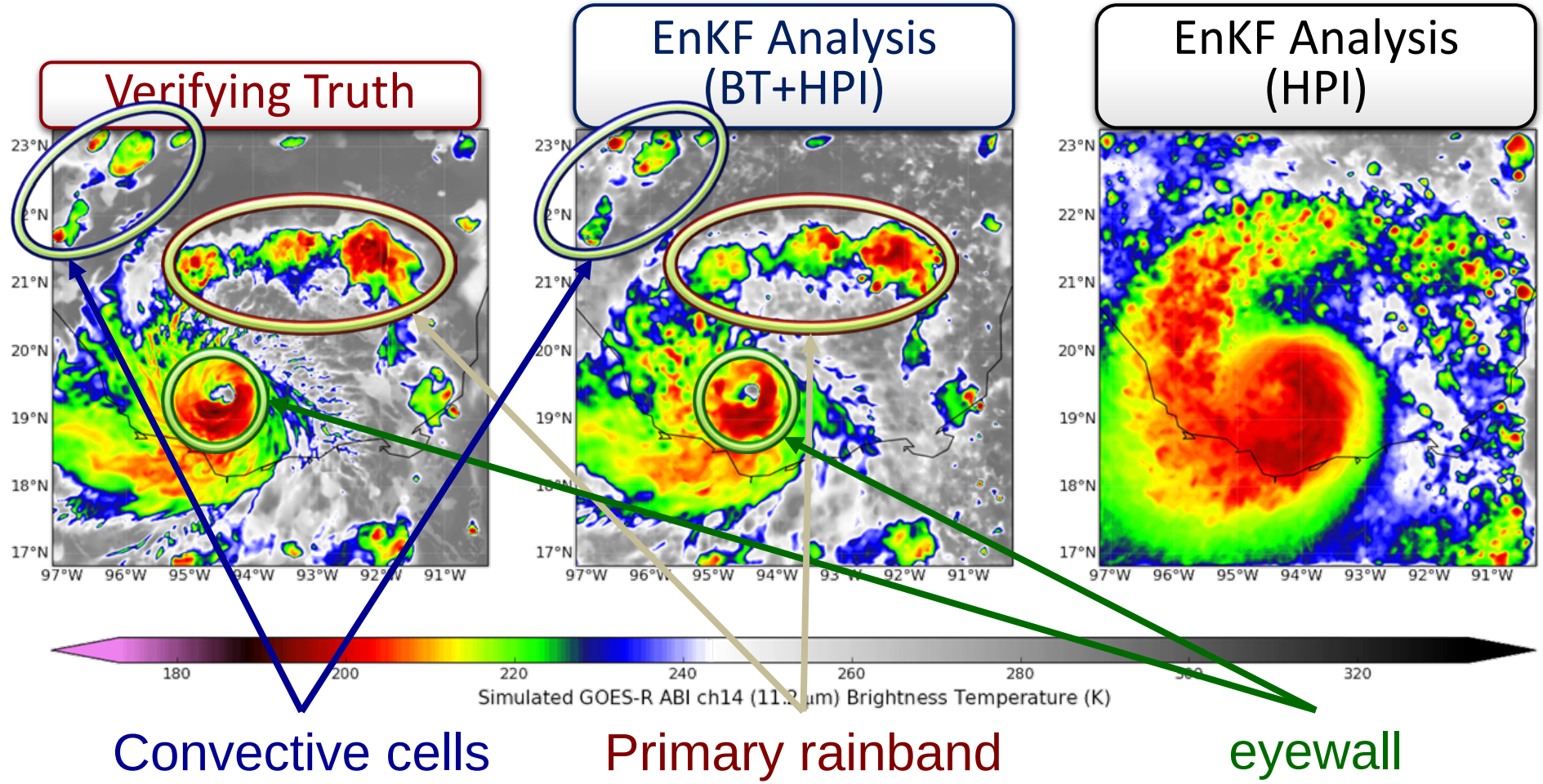
SLP (hPa) 10-m wind (ms^{-1}) 850-hPa θ_e

Locations calculated from TEMPDROP 62626 group

Locations from TEMPDROP (operations)



Assimilate Ch8-10 verified with an independent Ch14 (11.2 μm)



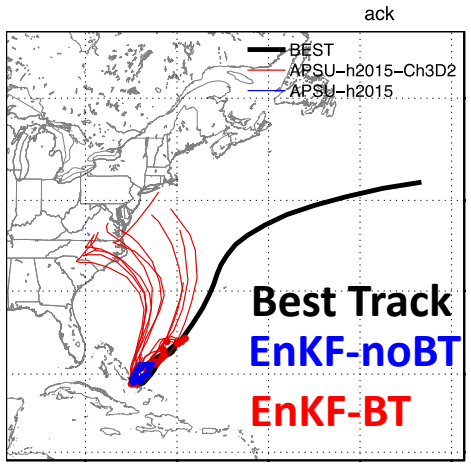
Proof–of-concept OSSE and real-data experiments in Zhang et al. (2016 GRL)

Adaptive Observation Error Inflation (AOEI) in Minamide and Zhang (2017 MWR in press)

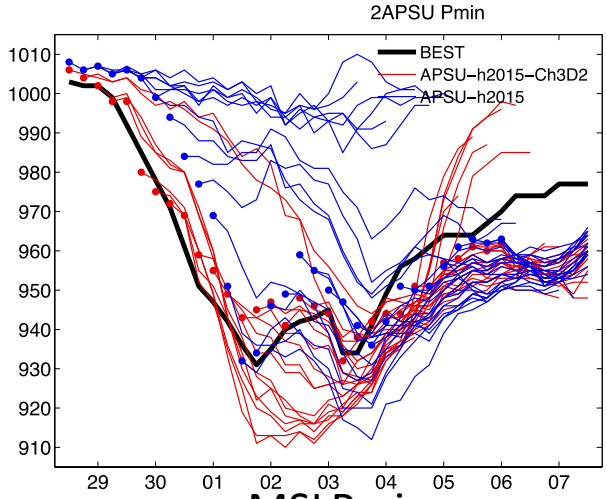
PSU: Convection-permitting EnKF Assimilation of All-sky Radiance: GOES-13

Deterministic Forecasts for Hurricane Joaquin (2015)： w/ & w/o Radiance

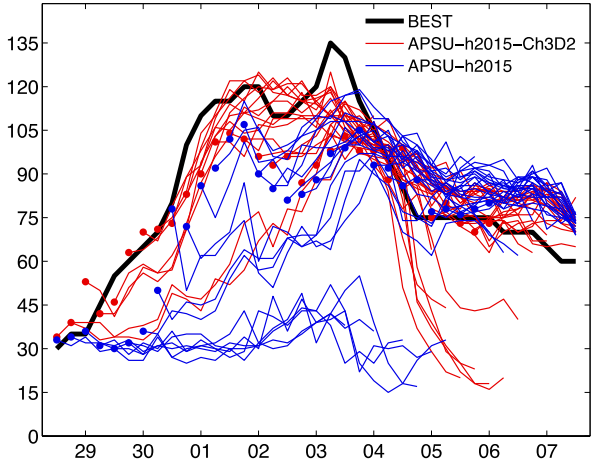
Deterministic forecasts from EnKF analysis every 6 hours



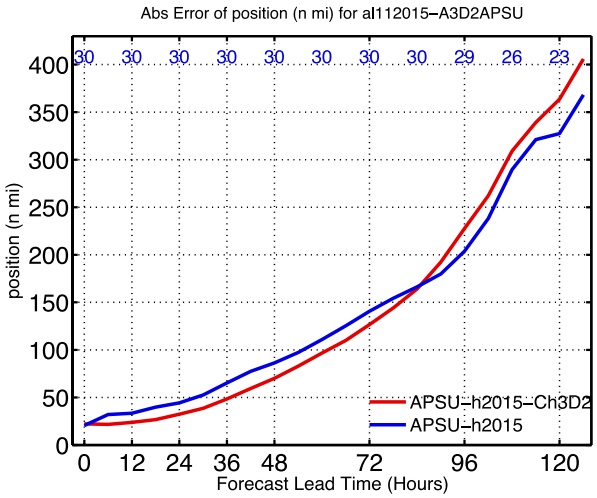
Track

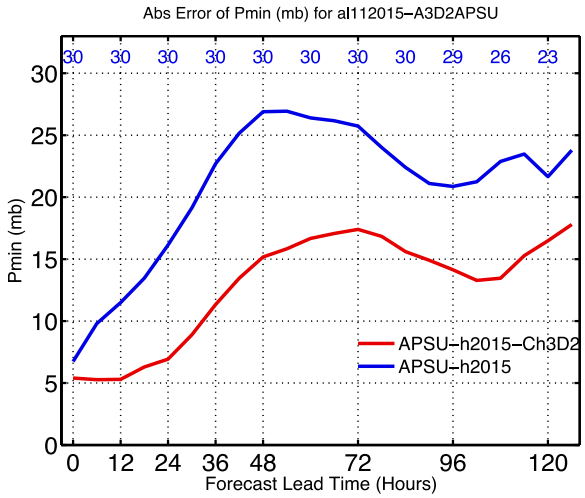


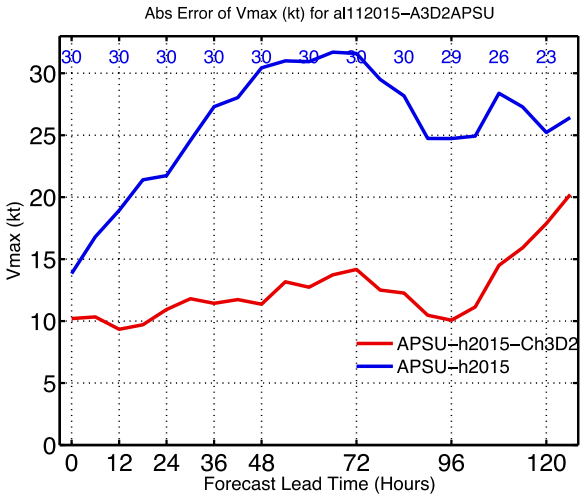
MSLPmin



10m-Vmax







Averaged absolute error reference to Best Track

Slides courtesy of Fuqing Zhang and Yonghui Weng

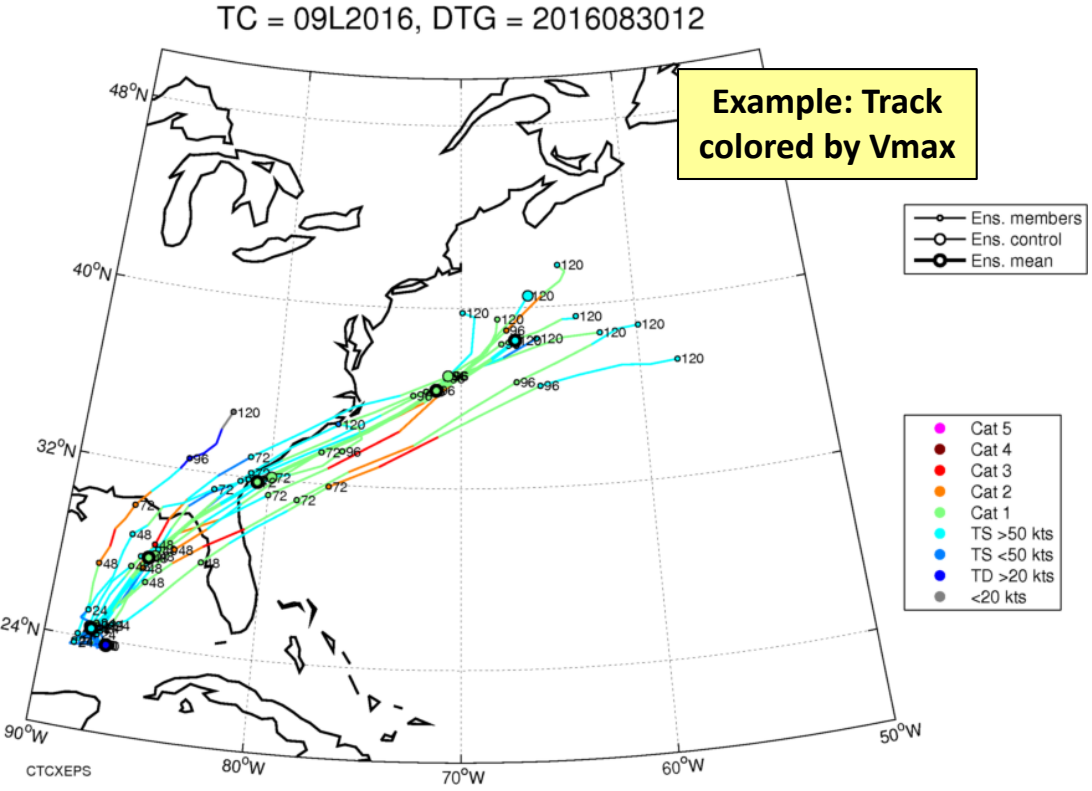
2016 COAMPS-TC Real-time Ensemble

2016 Real-time Forecast Sample & Ensemble Configuration

Basin	# storms
Atlantic	4
EastPac	4
WestPac	7
Total	**15**

- COAMPS-TC model same as 2015 ops model except 27/9/3 km resolution (instead of 45/15/5 km) and GFS as parent global model (instead of NAVGEM)
- Ensemble = 1 unperturbed control + 10 perturbed members
- Perturbations to synoptic-scale initial state and TC vortex initial state

Forecast Product Development



Future Plans

Goal is to have operational capability at FNMOC for 2017 NH TC season

- Testing is ongoing to determine best performing perturbation scheme, number of members, etc.
- Continuing ensemble product development, interfacing with forecasters at JTWC and NHC
- Contribution to multimodel ensemble

Summary

Primary accomplishments

- Implementation of the newly developed fully cycled, self consistent GSI hybrid DA system for HWRF
- Advancement of assimilation of existing or new observations using hybrid or EnKF
- Using hybrid DA to identify model issues that are responsible for spin down
- Advancement on TC ensemble forecast system design and product development

Summary

Future priorities

- ❑ Systematic pre-implementation tests of the hybrid DA system
- ❑ Continue R&D on HWRF hybrid DA
  - ➢ Best DA configuration (4DEnVar, hourly 3DEnVar, IAU, blending or not)
  - ➢ Further develop HWRF hybrid DA to include hydrometeors, w
- ❑ Using hybrid DA to investigate issues associated with spin down issue for strong hurricanes. Coordination between DA and model development (e.g. physics) is required
- ❑ Continue exploring and developing the assimilation of new observations (HDOB, dropsondes, GOES-R, etc.) and test beyond single case study.
- ❑ Ultimately replace VI completely with DA