Performance and Plans of the PSU Realtime Hurricane EnKF Analysis and Forecast System

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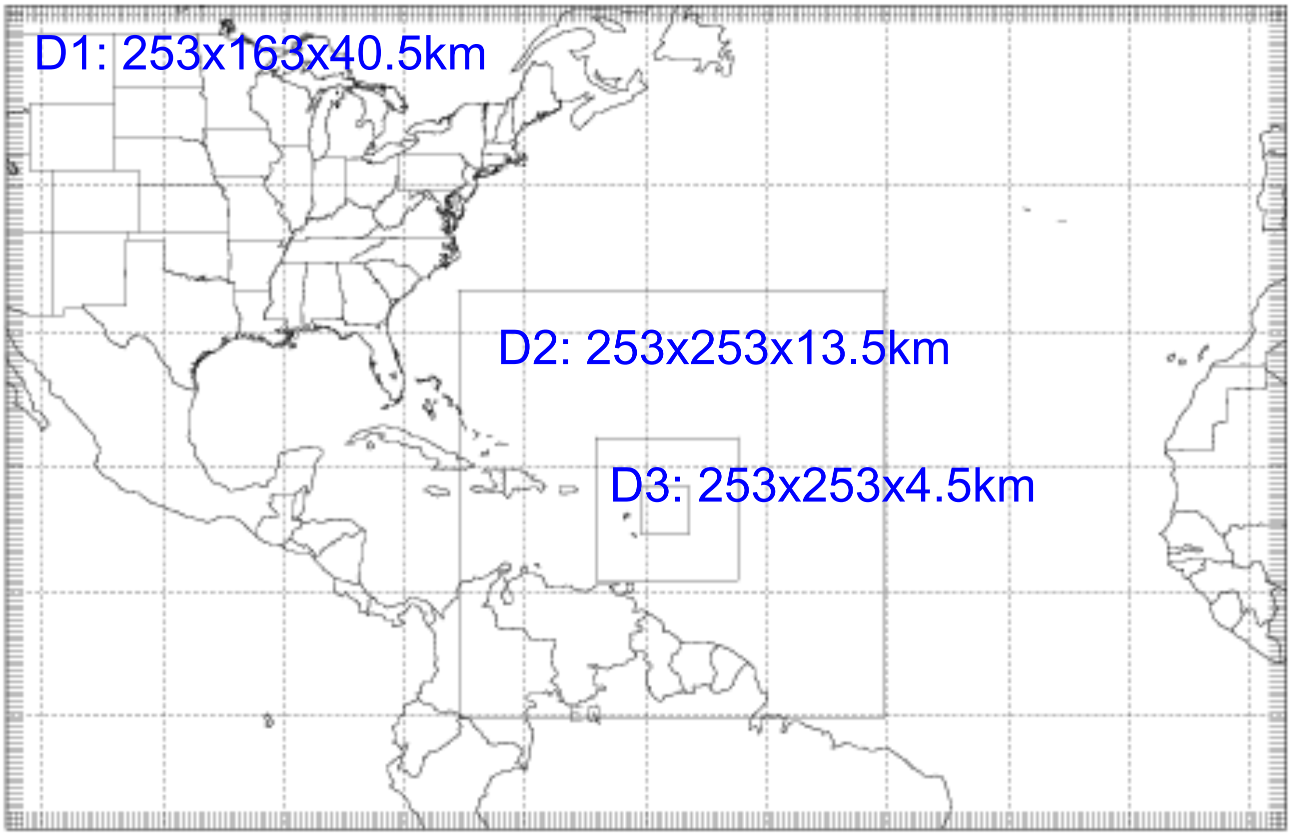
Motivation

- Motivation
  - No improvement on hurricane intensity prediction over the last few decades. Part of the difficulties may come from the hurricane vortex initialization;
  - Airborne Tailor Doppler Radar (TDR) had being observed hurricane vortexes for more than 30 years, but the observations never been ingested by operational dynamic models;
  - As an advanced data assimilation method, EnKF has the ability to ingest high-resolution hurricane inner-core observations and provide more realistic hurricane vortex;
  - As a researcher in academics, contributing to operational prediction directly is a challenge.
- Current Status
  - PSU ARW-EnKF hurricane analysis and prediction system;
  - AOML HWRF Hurricane Ensemble Data Assimilation system.

System Introduction

PSU ARW-EnKF Real-time (ATCF id: A4PS)



- The inner domains are centered by tcvitals

- WRF-ARW V3.3.1;
- 35 vertical levels;
- WSM 6-class microphysics;
- YSU PBL;
- Grell-Devenyi CPS

- 60-member ensemble;
- Gaspairi&Cohn 99' covariance localization with varying RoI

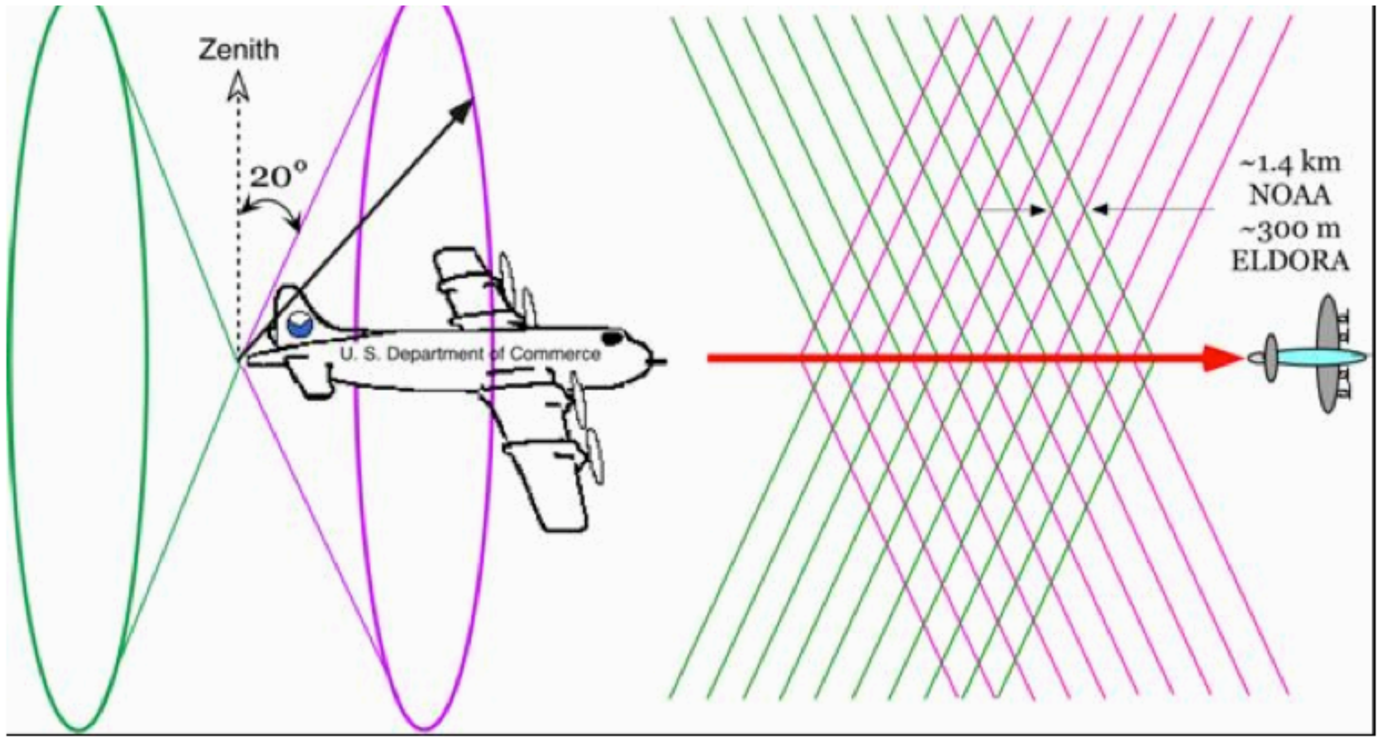
- IC & BC: GFS using 3DVAR background uncertainty

- Assimilation is performed over D1-3. D4 is used only for high-res forecast.

- NOAA P3 Tailor Doppler Radar (TDR) Vr.

System Introduction

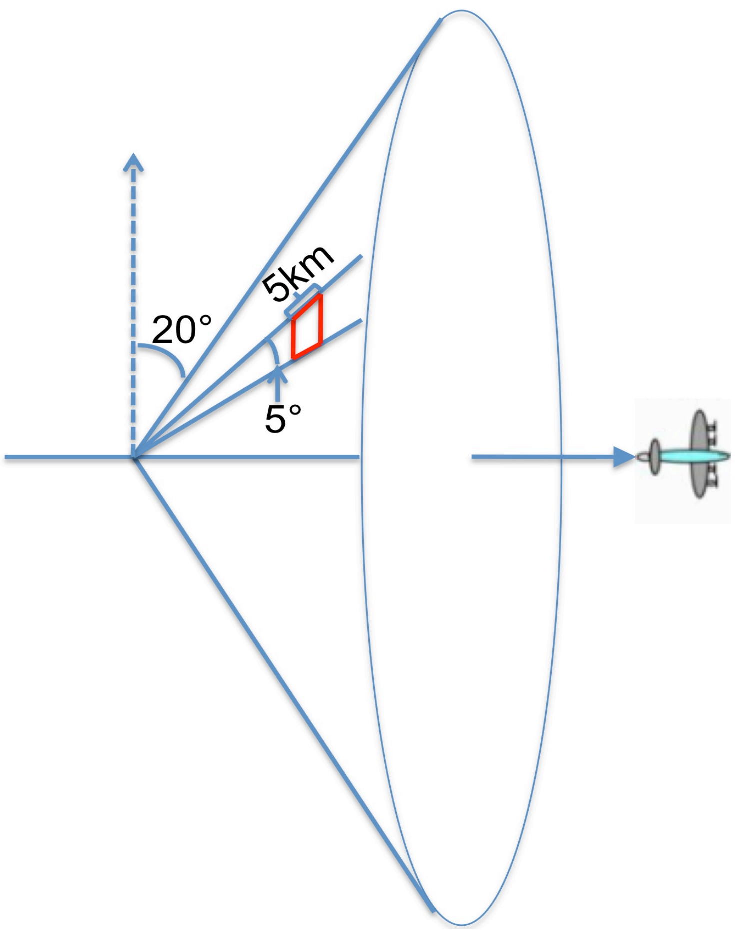
Airborne radar scanning geometry



1982: First NOAA airborne Doppler mission to hurricanes
2009: Still no airborne Doppler data has been used in operational NWP models at real time
Reasons: model resolution, data volume, DA methods, …

System Introduction

TDR Supper Observation (SO)



Geometry and schematics of an example SO bin selected for airborne Doppler radar quality control and data thinning.

Supper-Observing

- Primary data quality control is made by HRD;

- **Splitting the forward and backward scans;**
- **A volume includes 1-minute iso-directional scans;**
- **Dividing the volume into smaller bins;**
- **Quality control for each bin;**
- **Creating SOs.**

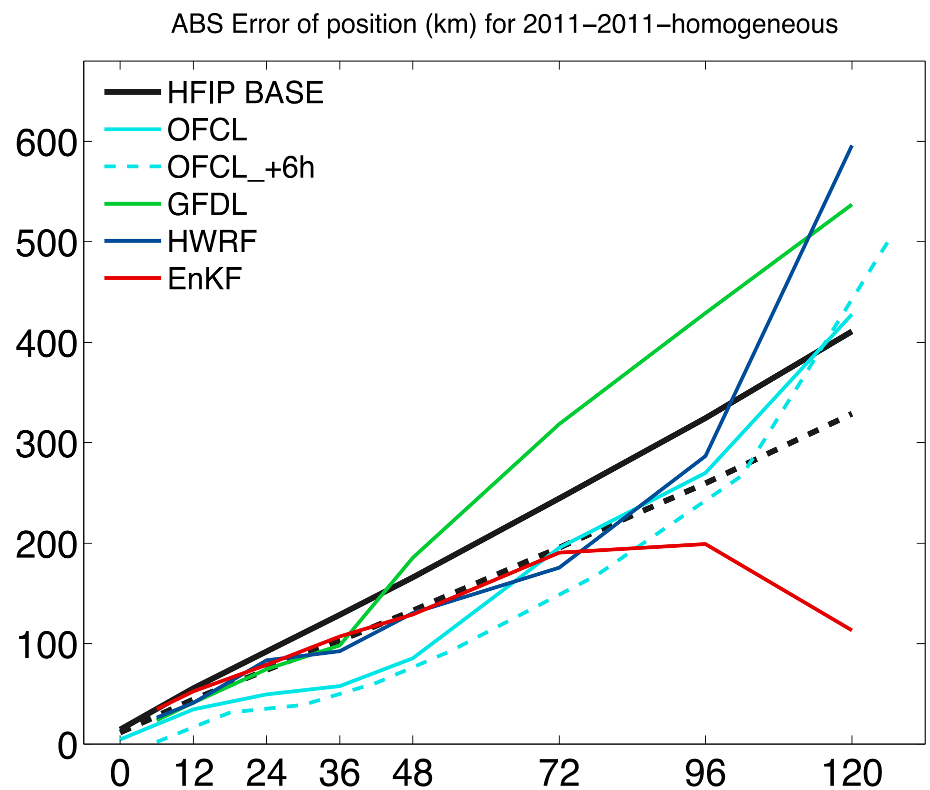
- Further thinning and randomly sorting.
- During the EnKF analysis, observation errors for SOs are set to 3 m s^{-1}.
- Further data quality control based on model fields;
- The observation time for SOs in each leg will be rounded to the nearest 30 minutes;
- Their geographical positions will be adjusted according to the hurricane's motion in order to maintain the SOs' relative position around the hurricane center.

Weng and Zhang 2012 MWR

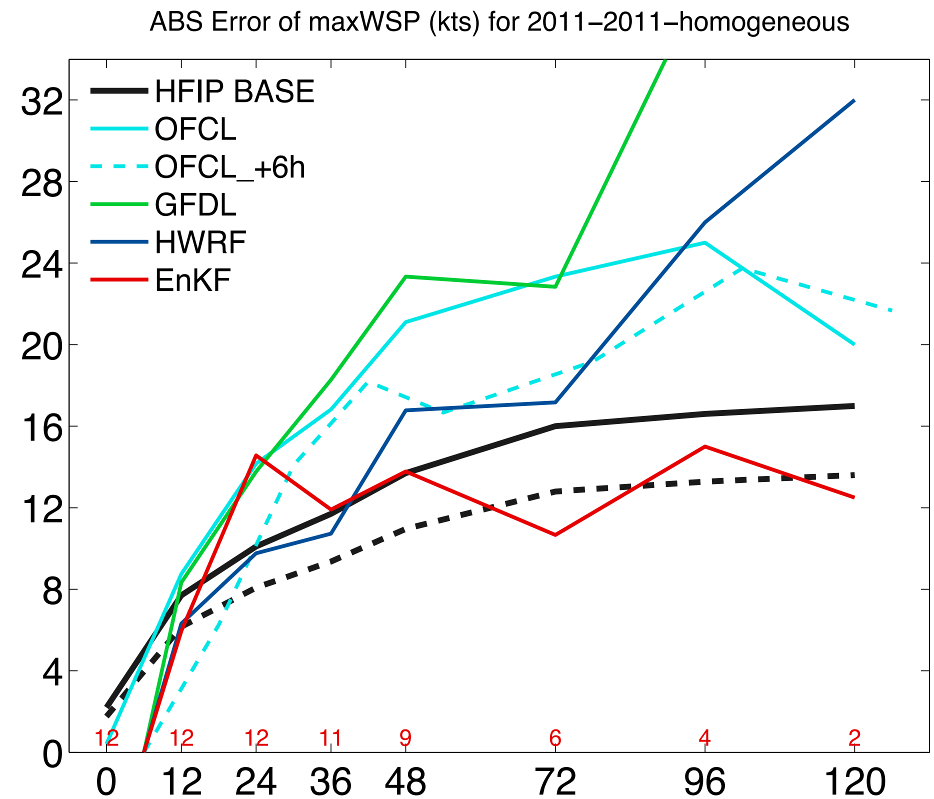
Performance

2011 PSU HFIP Stream-1.5 A4PS with ARW-EnKF Realtime assimilation of airborne Vr obs

12 P3 TDR Missions of 2011 (7 Irene + 5 Rina)



Position Error (km)

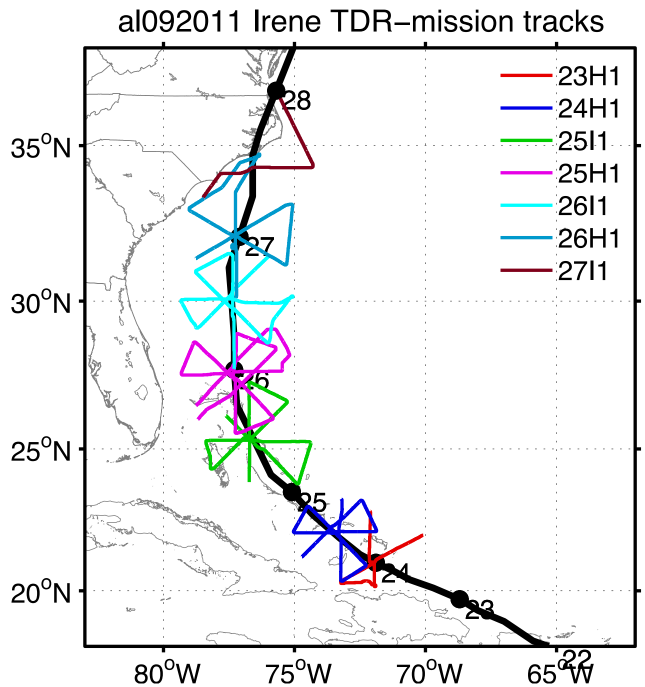


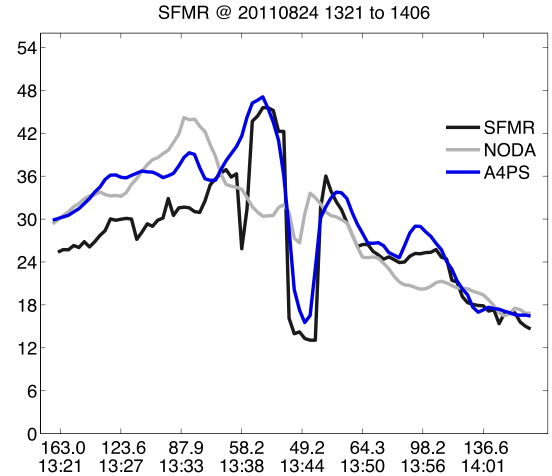
Intensity Error with Bias-correction (kt)

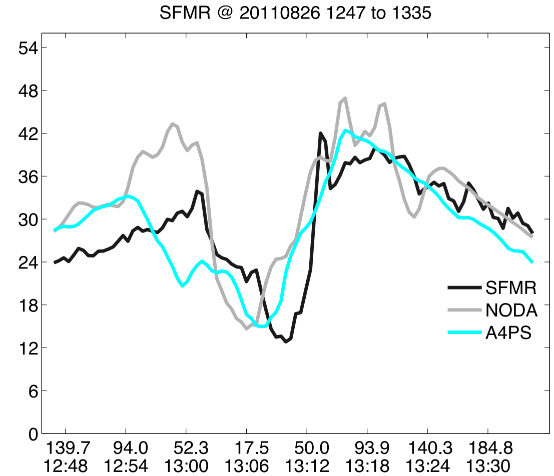
$$\mathit{Corrected}\ \mathrm{Vmax}_{6\le t\le 36} = \mathrm{Vmax}_{6\le t\le 36} - \left(\frac{36-t}{36-6}\times(V\max_{t=6h} - Vbest_{t=6h})\right)$$

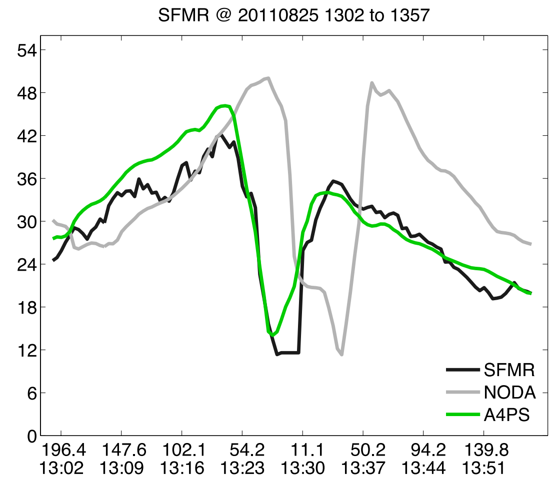
Compare to SFMR

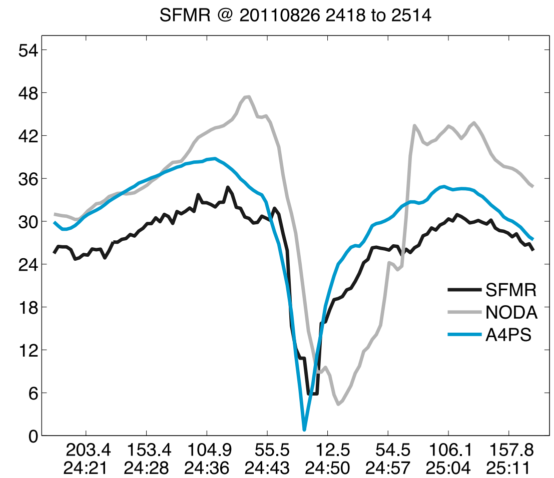
(last legs, with simple QC for SFMR)

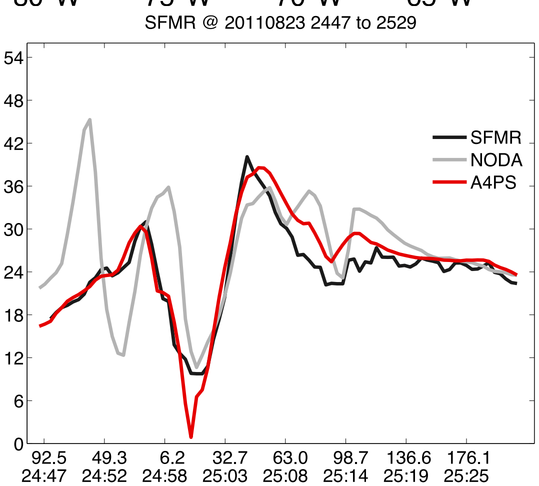


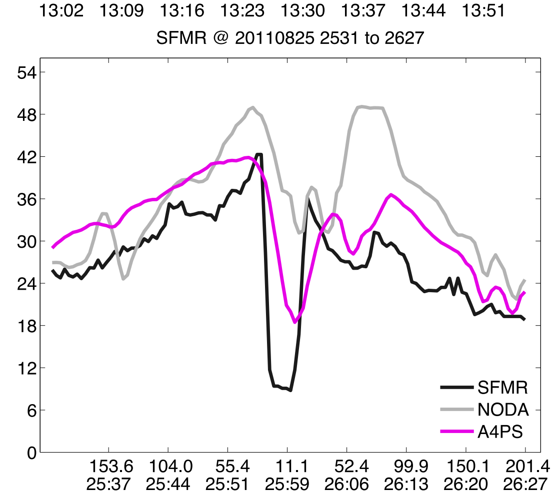


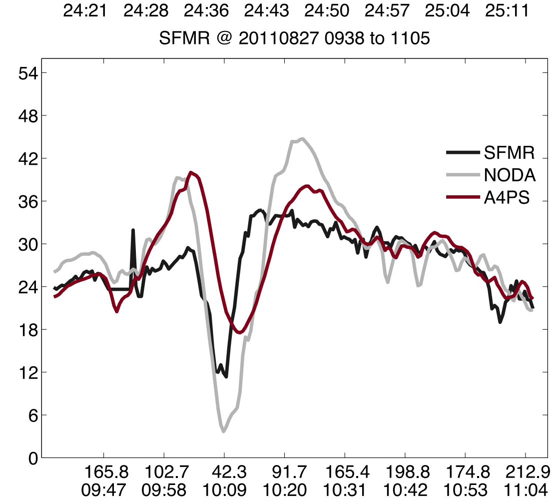




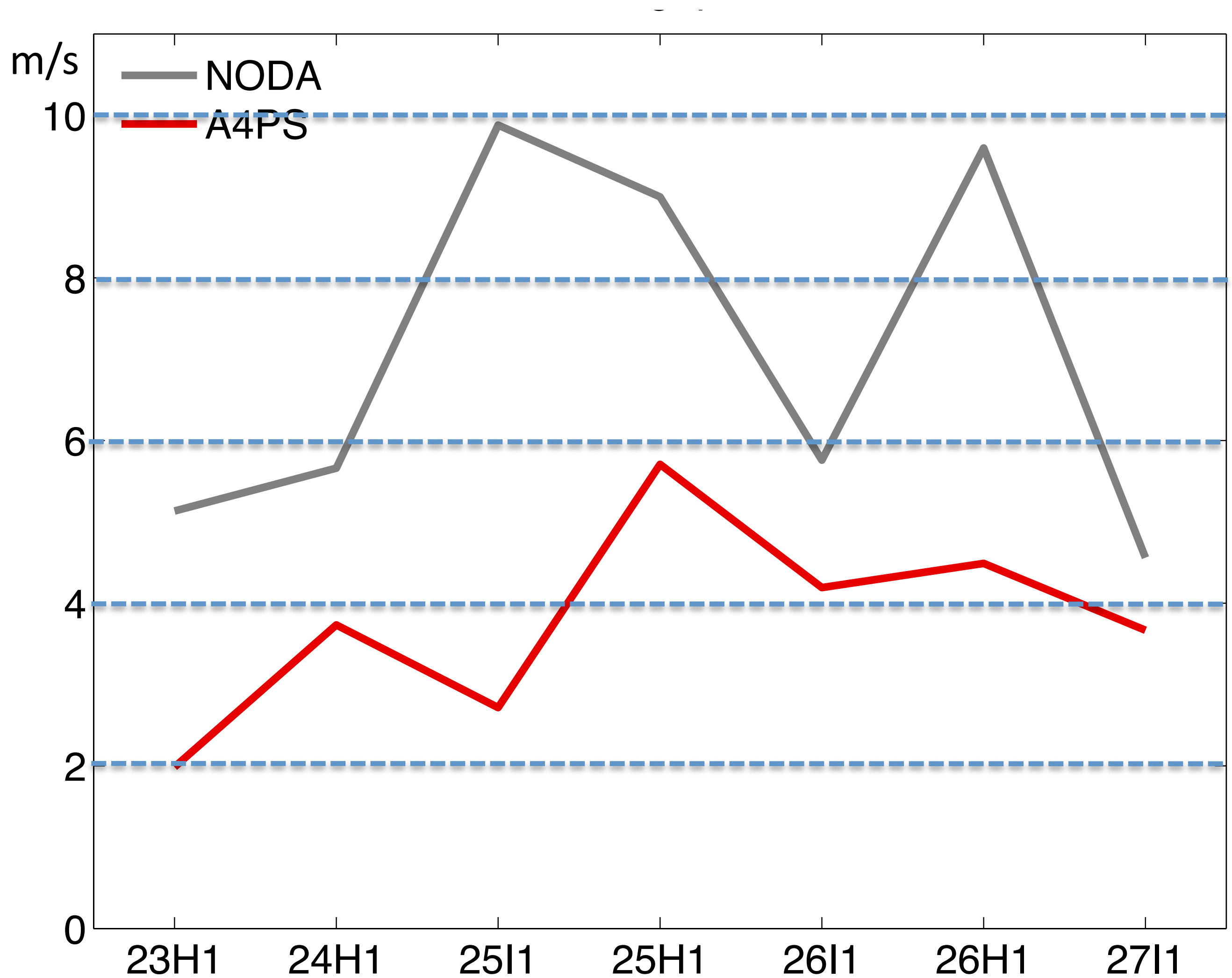






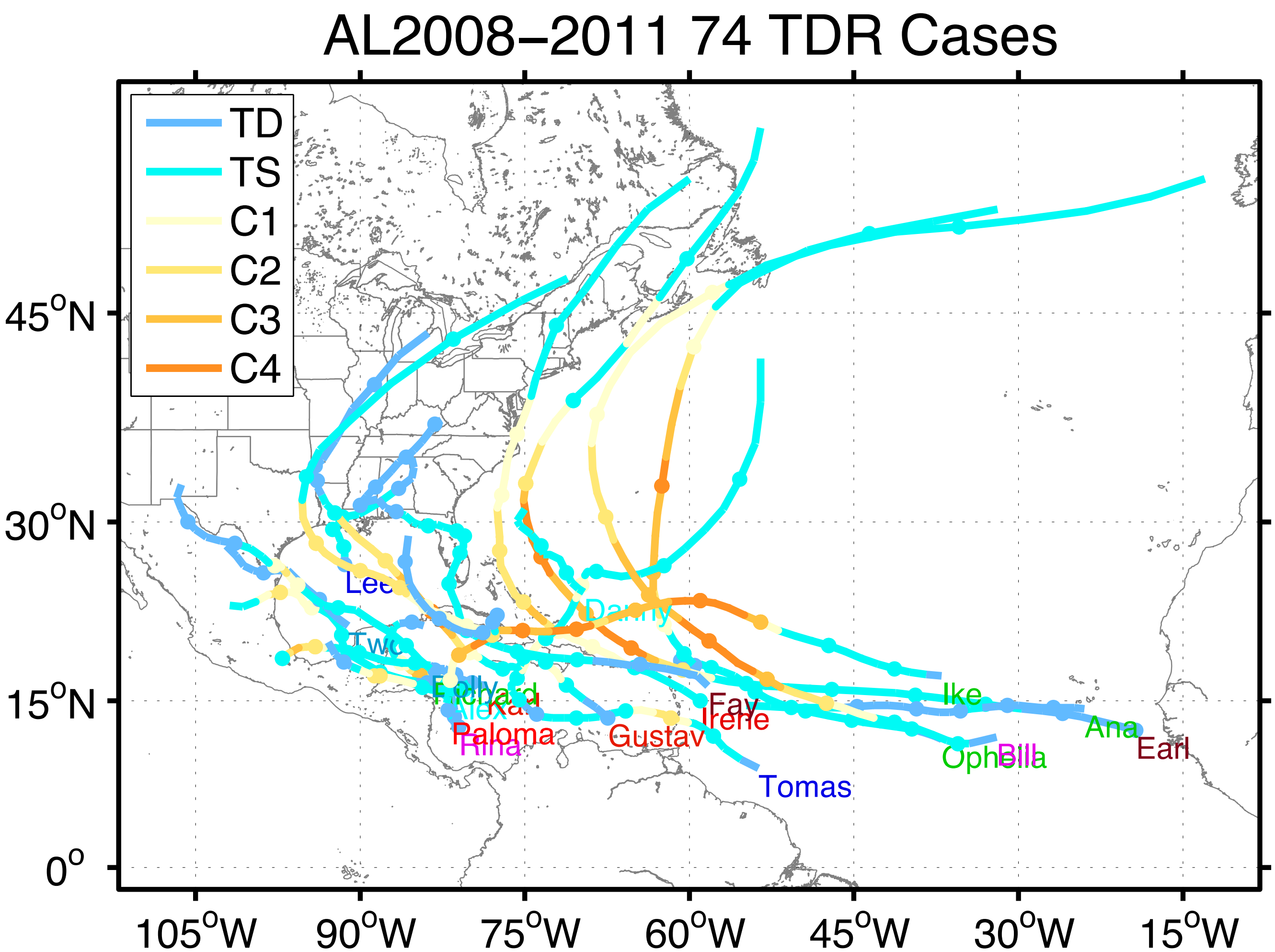


Compare to SFMR: Mean Absolute Error for Each Mission



Performance

Summary of 2008-2011 Cases with P3 Airborne Vr



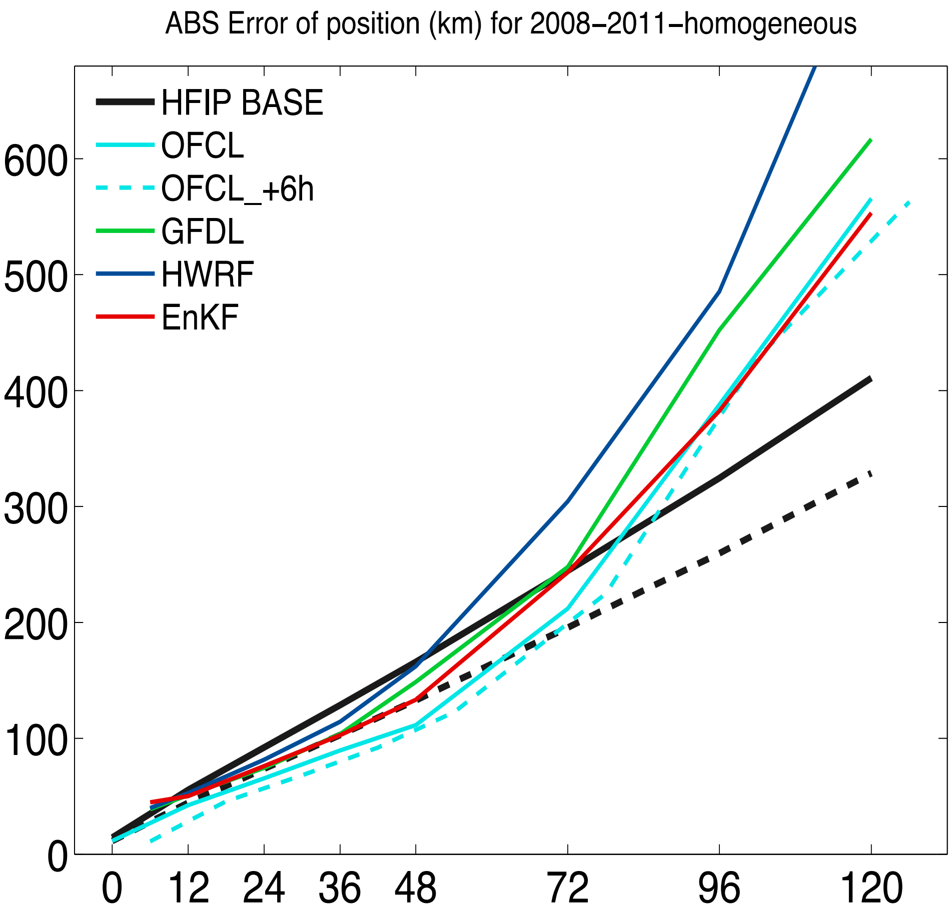
2008	**26**	**Dolly, Fay, Gustav, Ike Paloma**
2009	10	Ana, Bill, Danny
2010	25	Alex, Two, Earl, Karl, Richard, Tomas
2011	13	Irene, Lee, Ophelia, Rina

Special thanks to John Gamache at HRD and the rest of the IFEX team to make P3 TDR data available in or near realtime, and thanks to TACC and Jet teams for computing

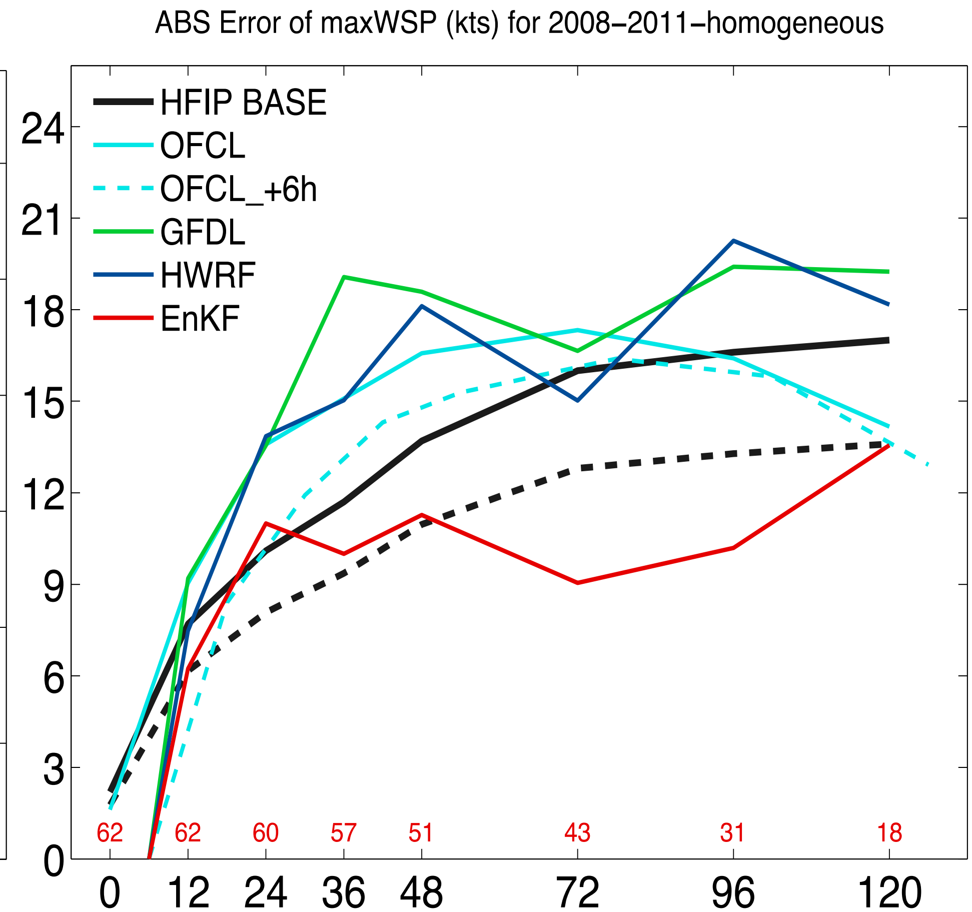
Performance

EnKF Performance Assimilating Airborne Radar OBS

Mean Absolute Error for 74 P3 TDR missions during 2008-2011



Position Error (km)

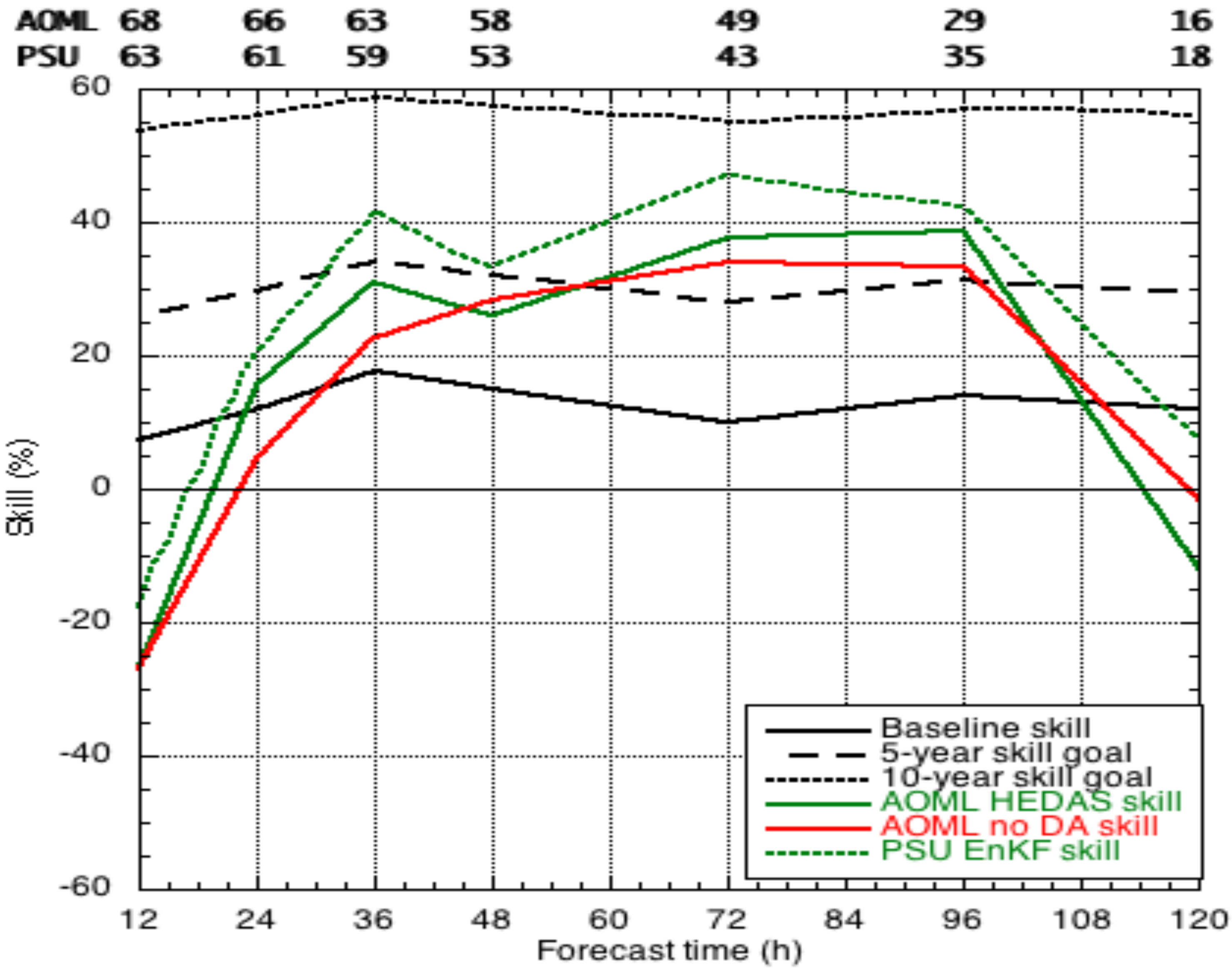


Intensity Error with Bias-correction (kt)

$$\textit{Corrected}\ \mathrm{Vmax} = \mathrm{Vmax} - \left(\frac{30\mathrm{h} - t}{30\mathrm{h}} \times Bias\_at\_initial\_time\right)$$

Zhang, Weng, Gamache & Marks 2011 GRL

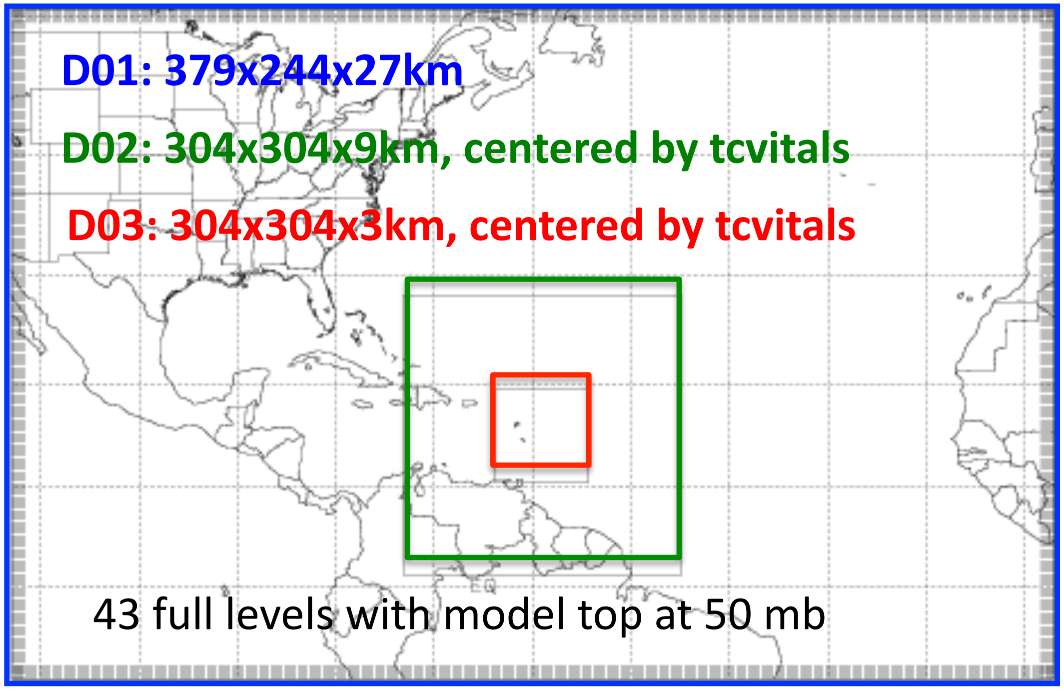
Impacts of TDR Vr on Intensity forecasts 2008-2011
PSU ARW-EnKF vs. HRD HWRF-HEDAS



Thanks to Sim Aberson and Altug Aksoy at HRD, and James Franklin at NHC

Updating

APSU: 2012 PSU Stream-1.5 Realtime System



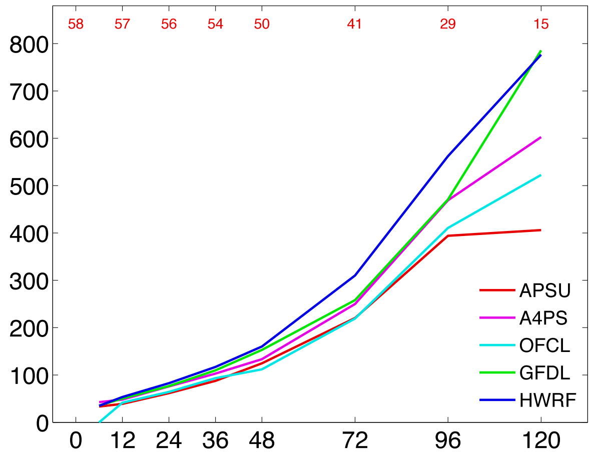
- WRF V3.3.1 – 27,9,3 km
- Grell-Devenyi ensemble (D01)
- YSU PBL
- Monin-Obukov Surface Layer
- thermal diffusion Land Surface
- Rrtm for longwave
- Dudhia for shortwave
- Garratt Ck, Cd formulation

- 60 members
- Radius of Influence: SCL
- Mixing: 0.6

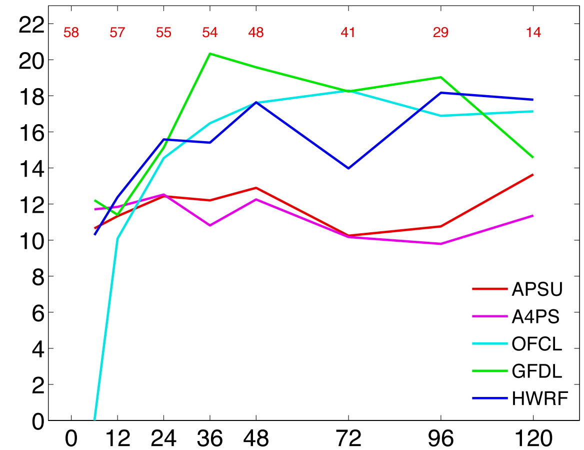
- Ics & BCs: GFS analysis and its forecasts

Updating

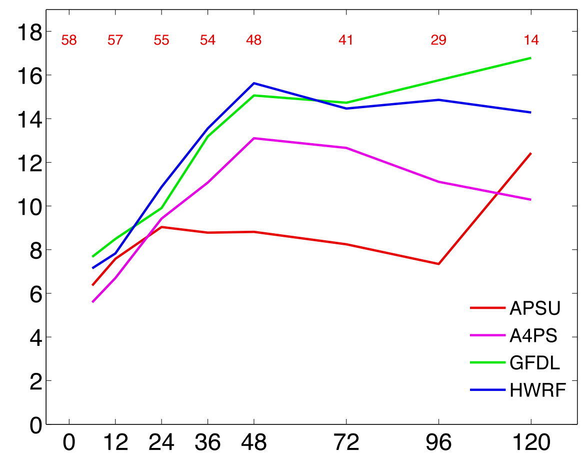
2008-2011 Performance of 2012 APSU vs. 2011 A4PS track/intensity forecast error (homogeneous comparison)



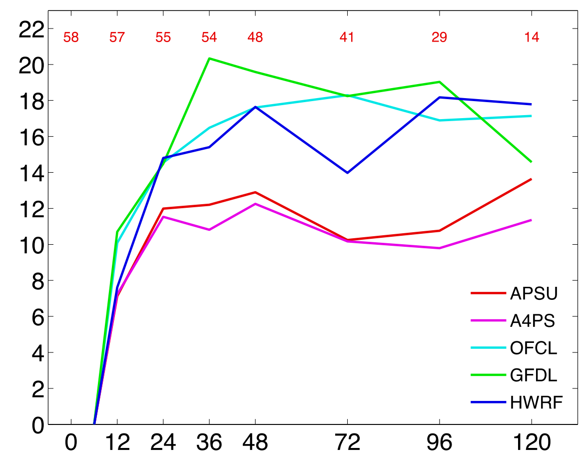
(a) Position error (km)



(b) Vmax error (kt)



(c) Pmin error (mb)

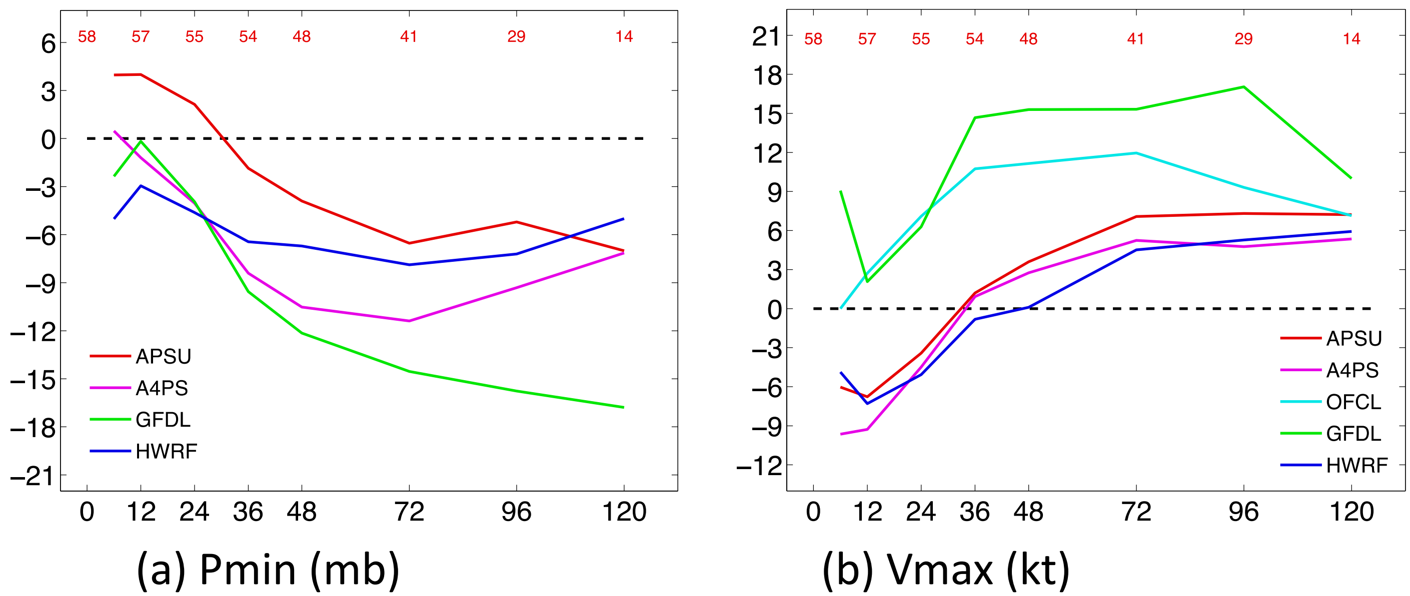


(d) Vmax error (kt) with Bias-correction

Bias-correction: applies the full adjustment at 6h to the time-lagged forecast out to 18 h, applies a linearly decreasing adjustment from 18 to 30 h, and then no adjustment for the remainder of the forecast.

Updating

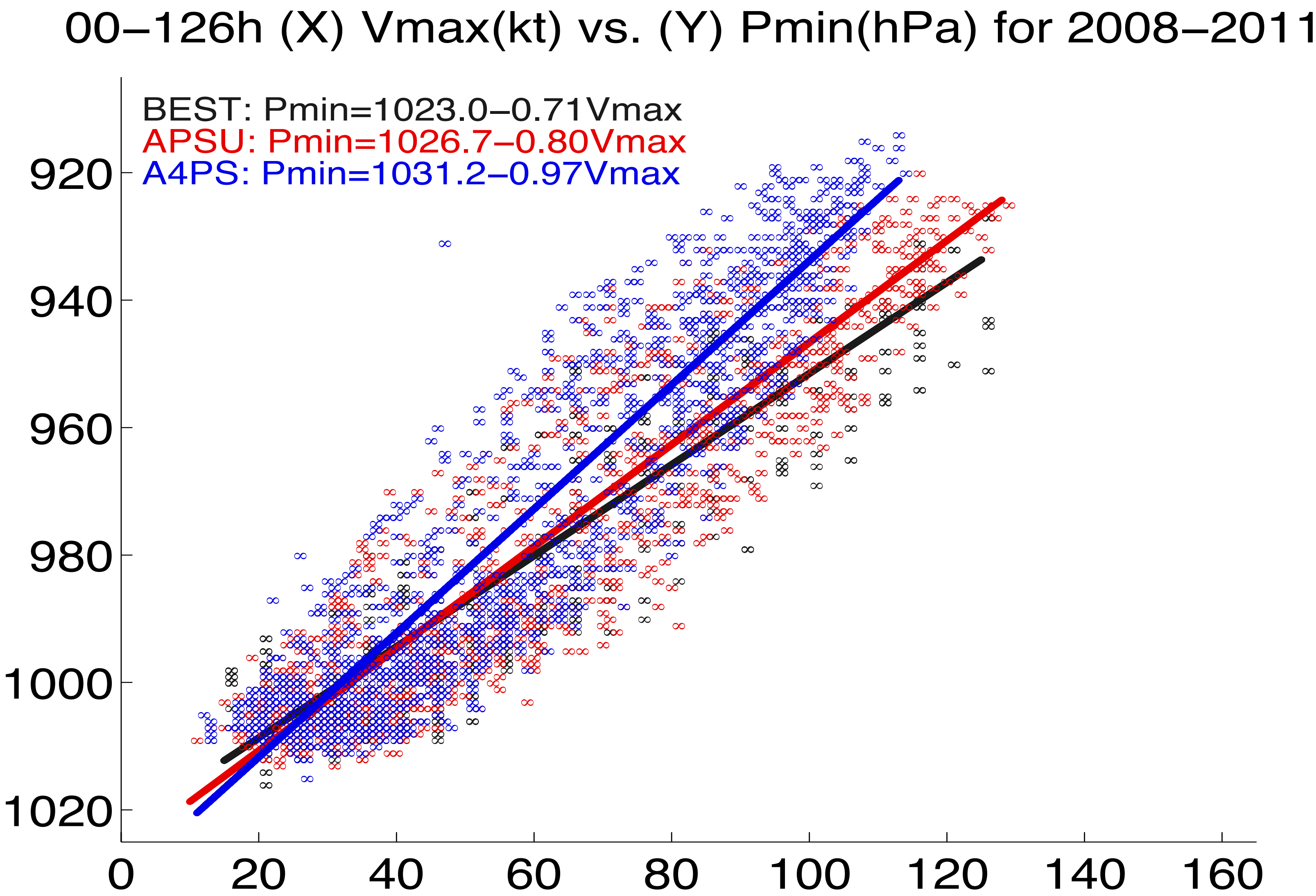
2008-2011 Performance of 2012 APSU vs. 2011 A4PS intensity forecast bias (homogeneous comparison)



Zhang, Weng, Gamache & Marks 2011 GRL

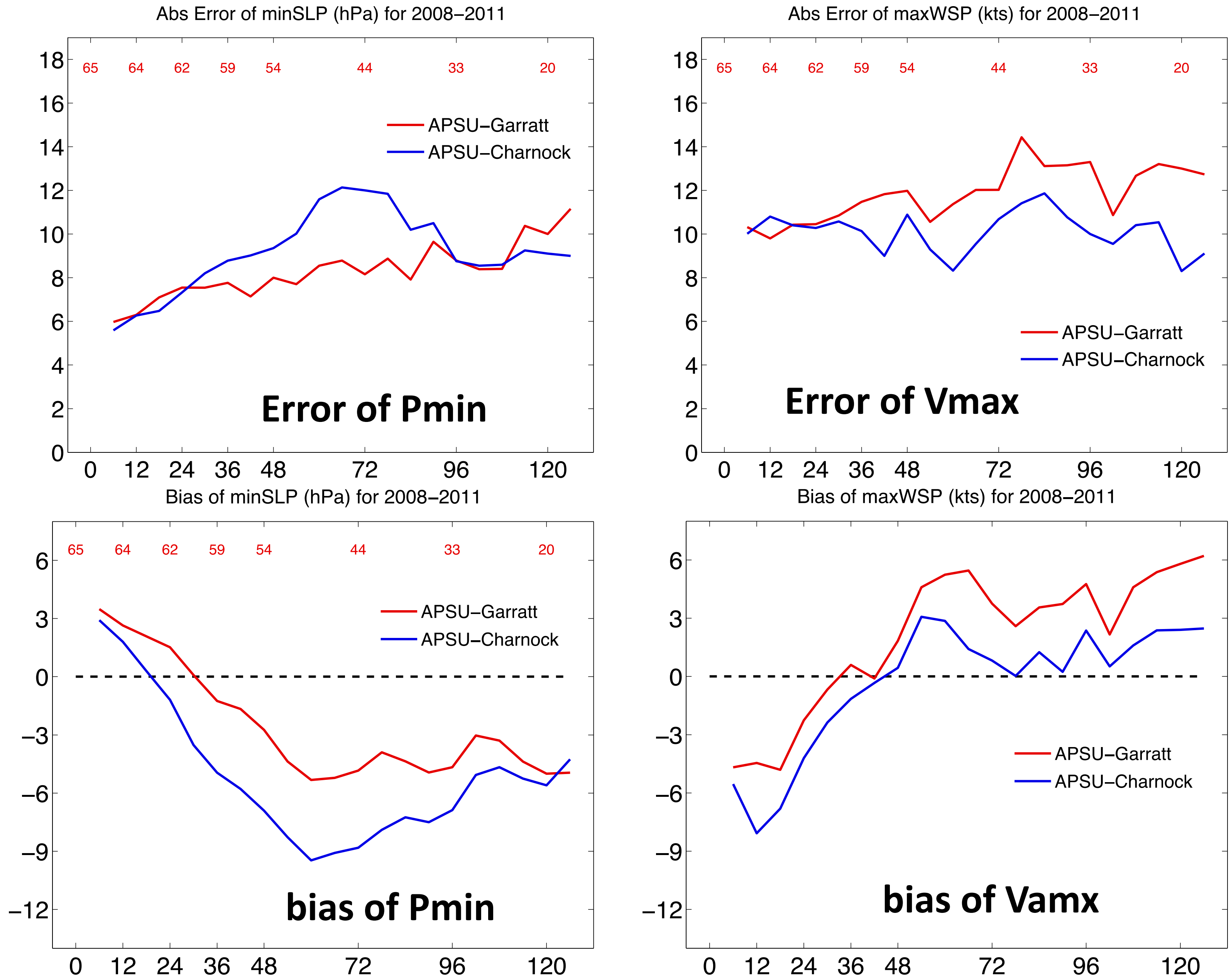
Updating

Improvement in Wind-Pressure Relationship: APSU, A4PS vs. Best Track



Updating

TC surface flux schemes: Charnock vs. Garratt

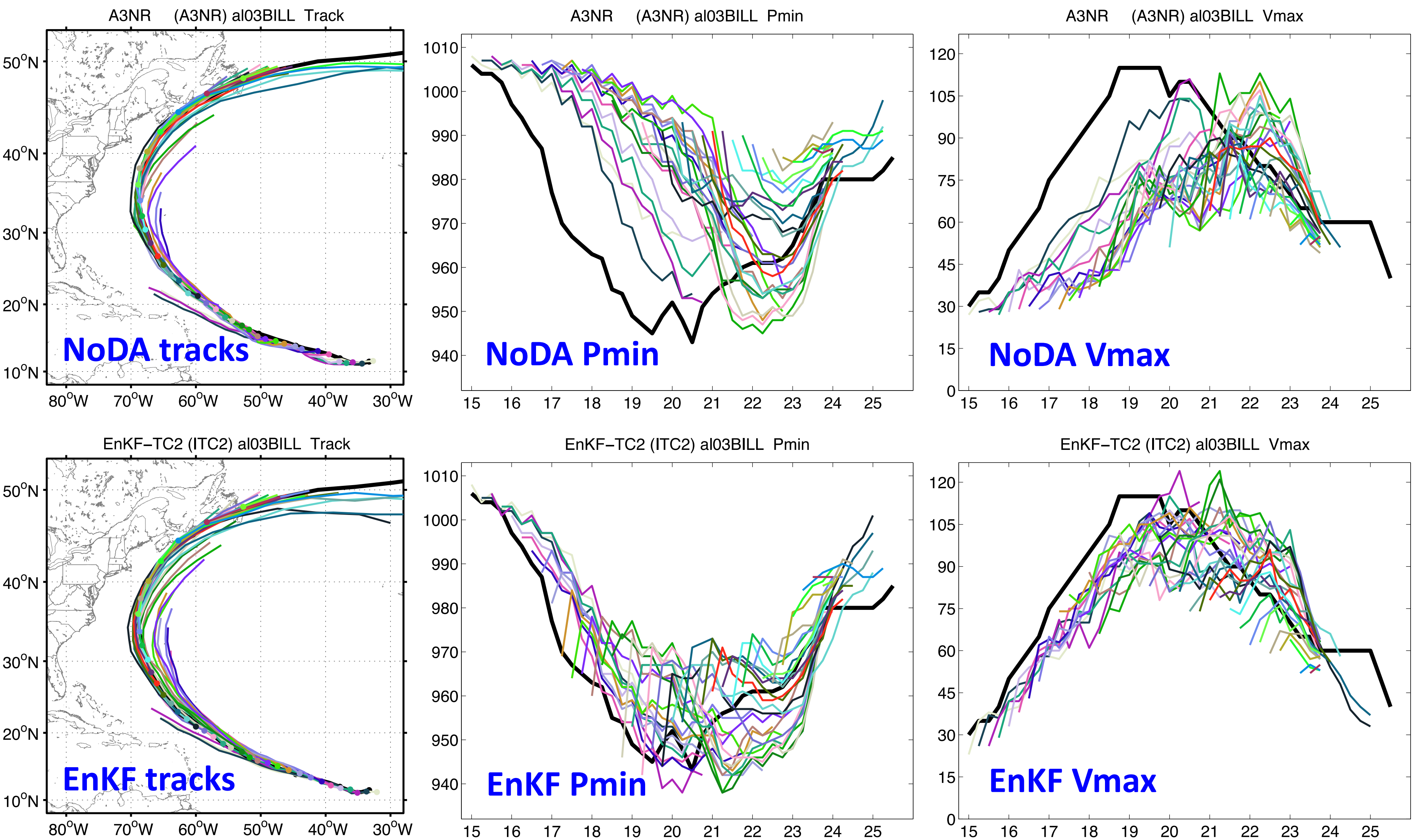


Plan 1

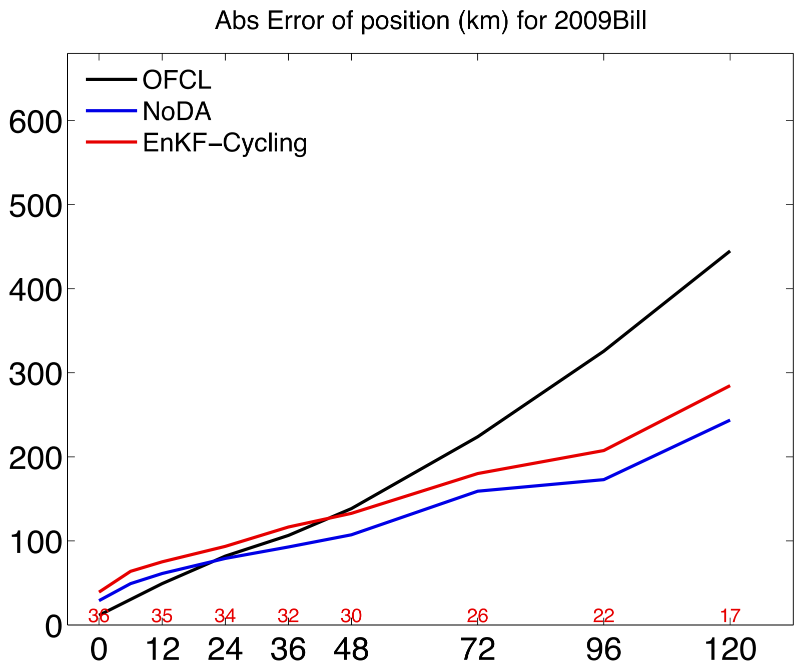
Cycling WRF-EnKF system design

- Same configurations as APSU;
- Cold-start for each storm when it generated or entered the west of 20W based tcvitals;
- cycling every 6 hours;
- Assimilating TCVitals and all conventional observations, GOES satellite winds around the storm;
- Inner domains following OFCL or CLP5 forecasts.

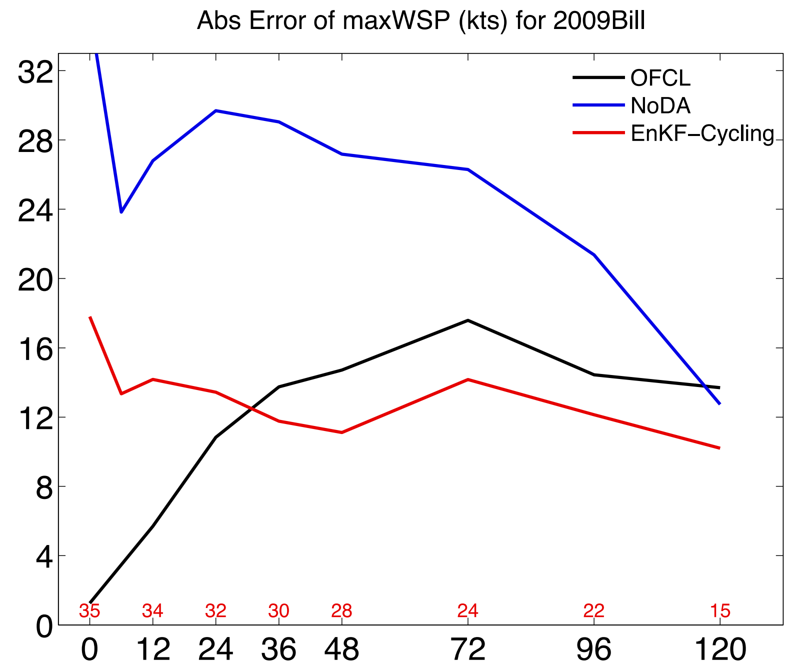
Testing: Cycling WRF-EnKF for Bill (2009)



Testing: Cycling ARW-EnKF for Bill (2009)



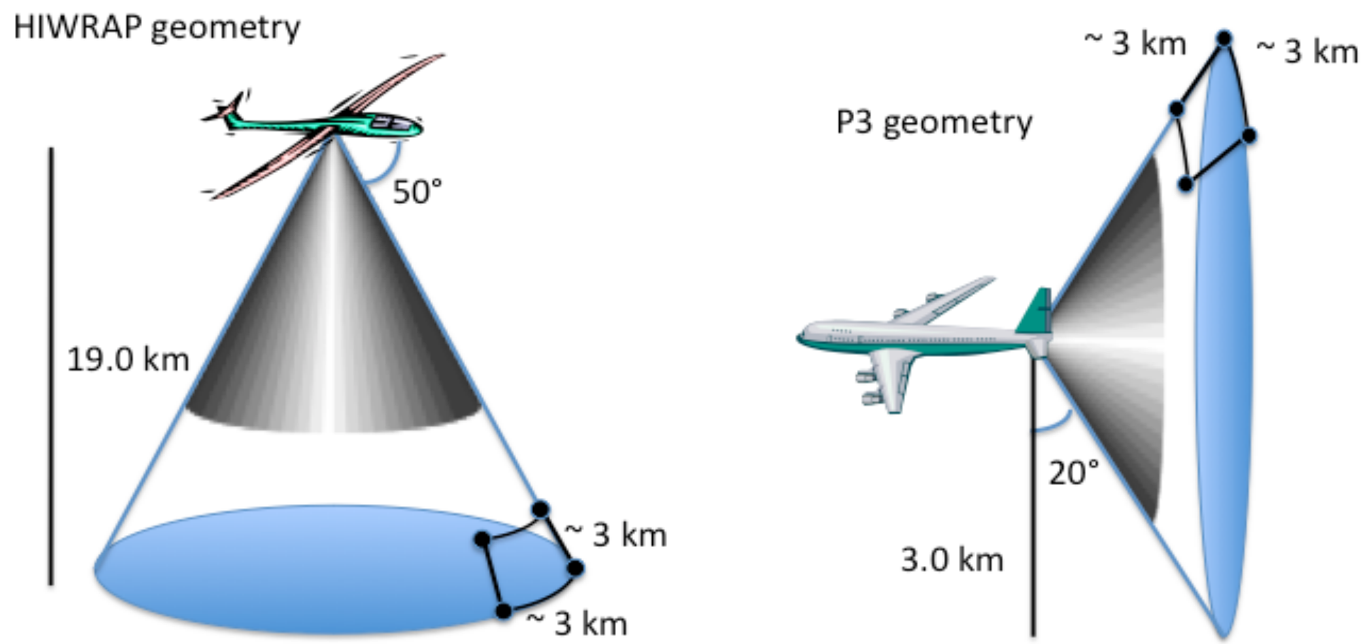
Position Error (km)



Intensity Error (kt)

Plan 2

Assimilating Global-Hawk Observations with PSU ARW-EnKF system



A comparison of the High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) conically scanning Doppler radar *and P3 TDR scanning geometries. Dots on the surface of the cone represent locations of the potential superobservations (SOs) relative to the radar. Vertical bars and accompanying numbers indicate the typical height at which the given aircraft flies. (Sippel et al. 2012)*

Plan 2

Assimilating Global-Hawk Observations with PSU ARW-EnKF system

- Develop a super-observation (SO) procedure for data thinning and quality control of HIWRAP Doppler observations so that it can be effectively assimilated by the PSU WRF-EnKF analysis and prediction system.

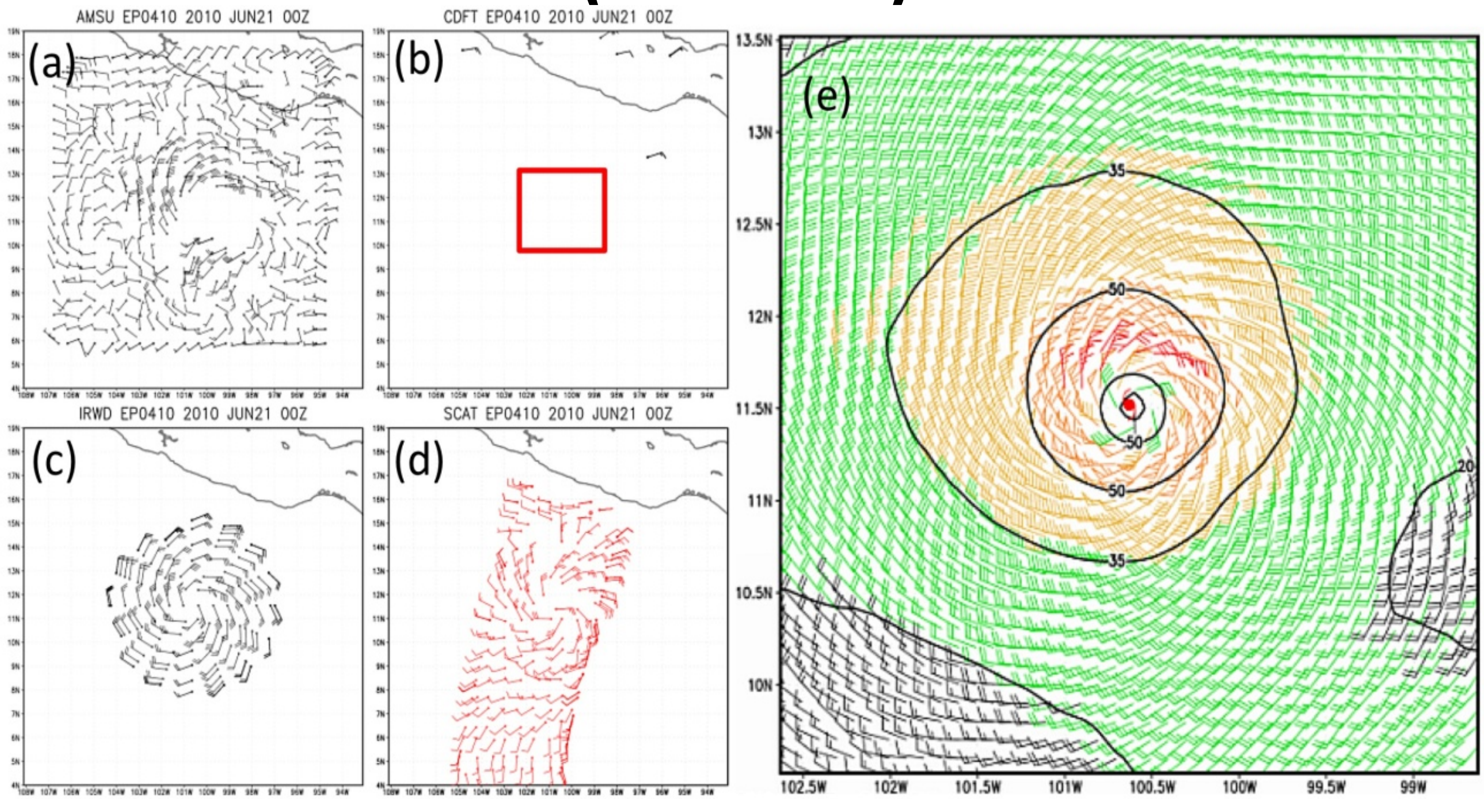
- Assimilate the HIWRAP and other Global Hawk observations and comparison to assimilating data from other platforms such as from the NOAA P3 aircrafts or satellite observations for selected cases during the GRIP and HS3 field experiments.

- Explore the dynamics and predictability of tropical cyclones with the EnKF analysis and prediction of the GRIP and HS3 cases.

- Perform real-time cloud-resolving ensemble analysis and forecast of tropical cyclones with the PSU WRF-EnKF system assimilate all applicable observations in support of the HS3 field phase.

Plan 3

Assimilating the routine high-resolution product of Multi-platform Tropical Cyclone Surface Wind Analysis (MTCSWA)



Examples of wind products generated for Hurricane Celia (EP0410) on 21 June 2010 at 00UTC. (a) AMSU, (b) CDFT, (c) IRWD, (d) ASCT and (e) MTCSWA. The red frame shown in (b) is the plotted area of MTCSWA wind in (e). (J. Knaff, 2011)

In collaboration with John Knaff at NESDIS

Summary Remarks

- **For most storms, the intensity forecast error still largely comes from large IC deficiencies that can be reduced through advanced DA techniques with high-resolution inner-core observations and a cloud resolving NWP model.**

- **No doubt there are also rooms in improving our forecast model.**

- **In the meantime, we need to better understand our limit of hurricane predictability and observability, both practically and intrinsically.**

- **As researchers in academics, we benefit tremendously from interacting directly with the operational community through the HFIP platform: it is not an easy job to deliver reliably products everyday and to be scrutinized on every forecasts.**