Aircraft Doppler Versus Flight Level Data Impact Study using FY13 Operational HWRF with vortex initialization and One-Way Hybrid Data Assimilation

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Results from 2008-2012 hurricane seasons

HFIP Telecon, Jan 22, 2014

Data Inventory for RDITT Experiments 2008-2012 Atlantic

Year	Storm#	Name	HDOB	TDR	Year	Storm#	Name	HDOB	TDR
2008	2	Bertha	24	0	2011	1	Arlene	5	0
	3	Cristobal	15	0		4	Don	9	0
	4	Dolly	16	6		5	Emily	11	0
	5	Edouard	9	0		7	Gert	4	0
	6	Fay	27	3		8	Harvey	8	0
	7	Gustav	29	5		9	Irene	28	7
	8	Hanna	24	0		13	Lee	3	0
	9	Ike	31	7		14	Maria	5	0
	11	Kyle	10	4		15	Nate	11	0
	15	Omar	11	0		16	Ophelia	10	0
	17	Paloma	13	3		18	Rina	14	3
total	11		209	28	total	11		108	10
2009	3	Bill	21	4	2012	2	Beryl	5	0
	5	Danny	11	5		4	Debby	12	0
	6	Erika	9	0		5	Ernesto	24	0
	11	Ida	17	0		9	Isaac	31	9
total	4		58	9		12	Leslie	3	3
2010	7	Earl	25	12		17	Rafael	11	0
	8	Fiona	13	0		18	Sandy	26	8
	11	Igor	13	0	total	7		112	20
	13	Karl	13	0					
	15	Matthew	4	0					
total	5		68	12					
Total number of storms: 39			**HDOB (FL+SFMR): 555**			**TDR: 84**			

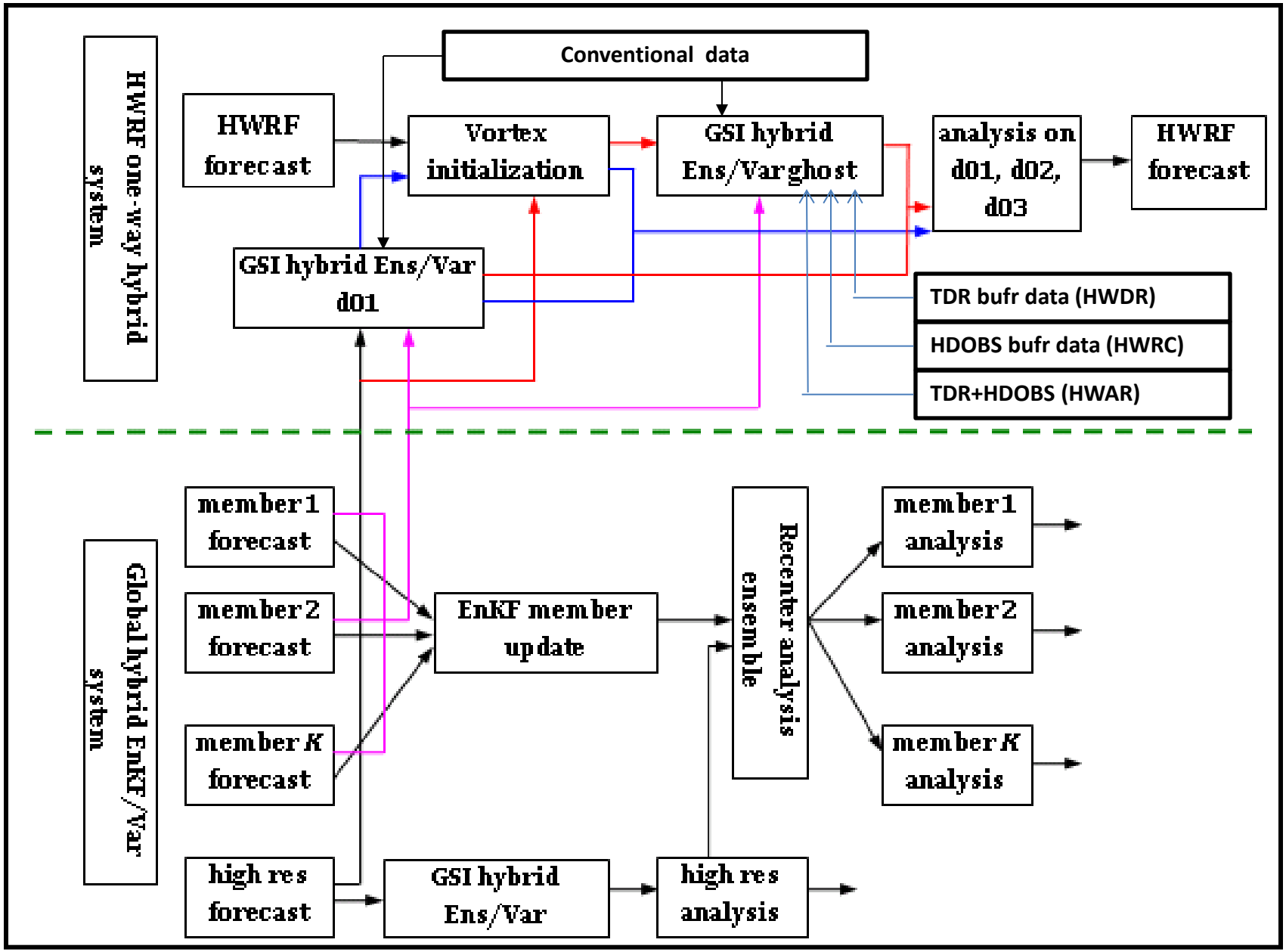
Data Assimilation Methodology

- ***HWRF GSI Hybrid variation-ensemble data assimilation using GFS EnKF ensemble forecasts:***
  - 80 GFS ensemble members at T254L64 with 75%/80% weight given to ensemble B on outer/ghost domain
  - Horizontal localization: Outer domain (27km resolution) ~ 1546km; Ghost domain (3km resolution) ~ 387 km
  - Vertical localization: Outer domain: 1.2 in $\ln(p/p_{ob})$; Ghost domain (e-folding scale): 10 vertical model levels for weak storms and 20 vertical model levels for strong storms (equal or greater than category 1)
  - First guess: Outer domain: GDAS forecast after relocation; Ghost: GDAS forecast (TC environment) + modified GDAS/HWRF vortex

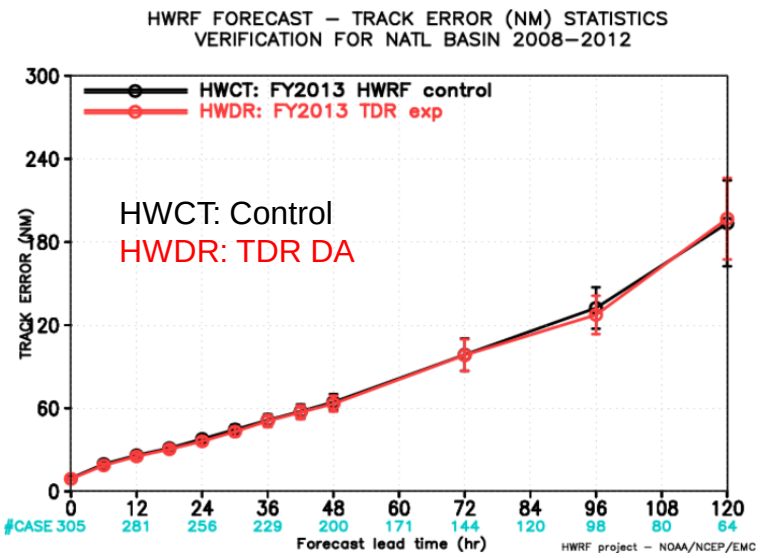
Observational Data sets

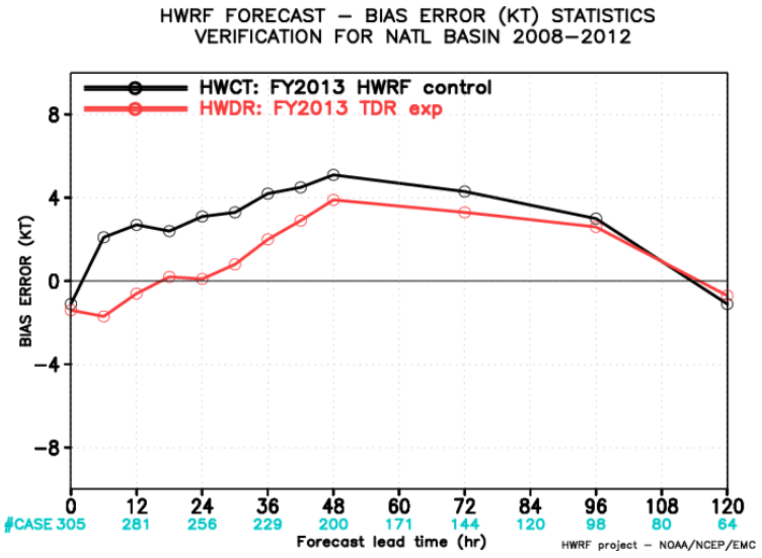
- ***For control experiment(HWCT) Outer Domain Only, No Inner-Core DA:***
  - prepbufr data: Radiosondes, Dropsondes, Aircraft reports, Surface ship and buoy observations, Surface observations over land, Pibal winds, Wind profilers, VAD wind, WindSat, ASCAT scatterometer winds, GPS-derived integrated precipitable water
  - Dropsonde wind within radius=max(111km, 3*RMW) are flagged (not assimilated).
- ***For TDR DA experiment (HWDR):***
  - HWCT + TDR in bufr format or superobs if bufr data are not available
- ***For Recon DA experiment (HWRC):***
  - HWCT + HDOBS in bufr format
- ***For TDR+RECON experiment (HWRA):***
  - All above

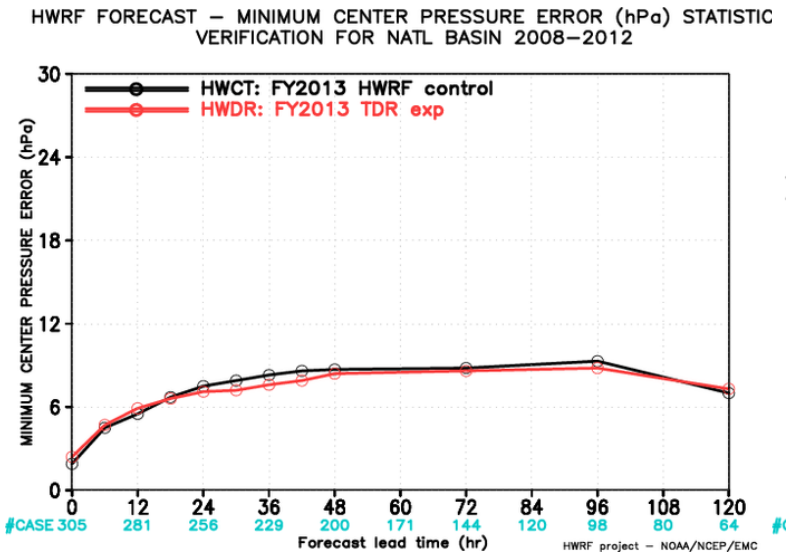
HWRF Data assimilation System (HDAS)

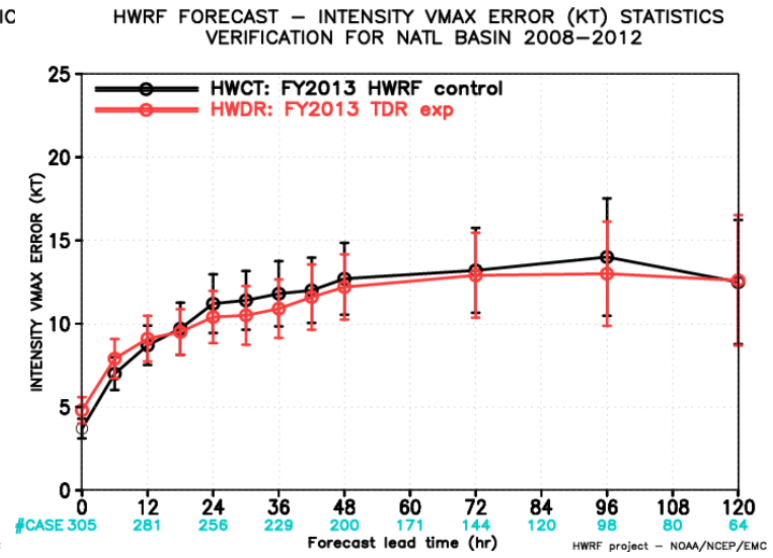


TDR data impact (all cycles)

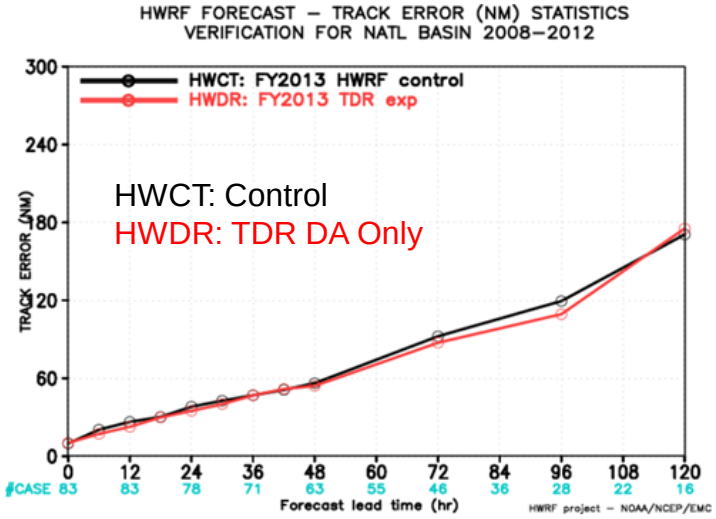


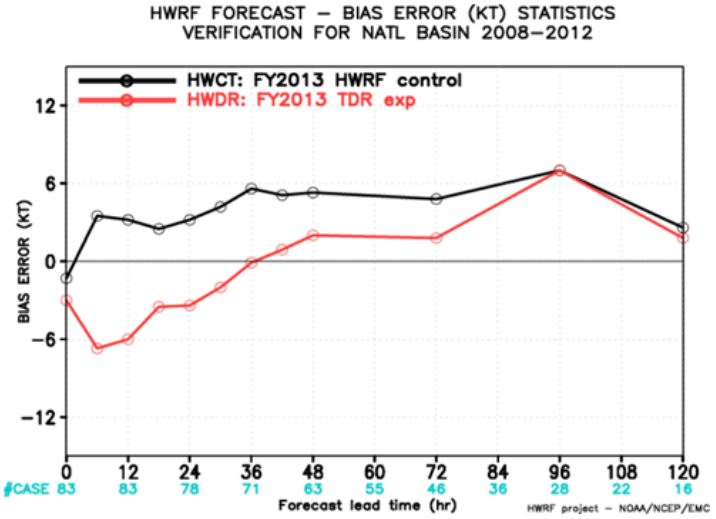


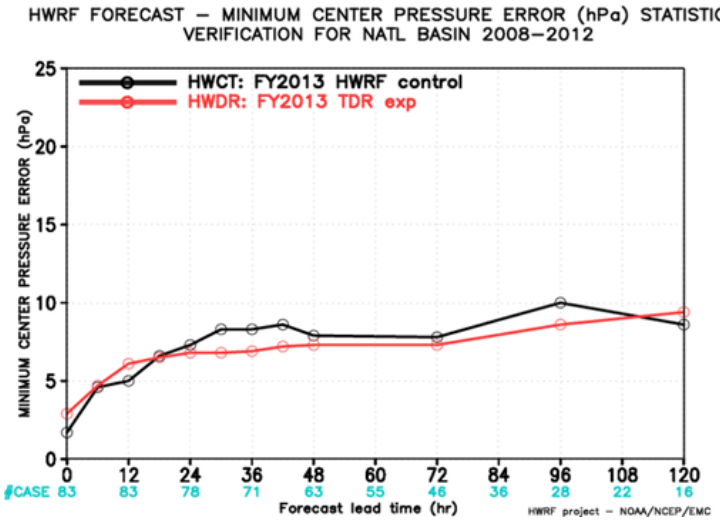


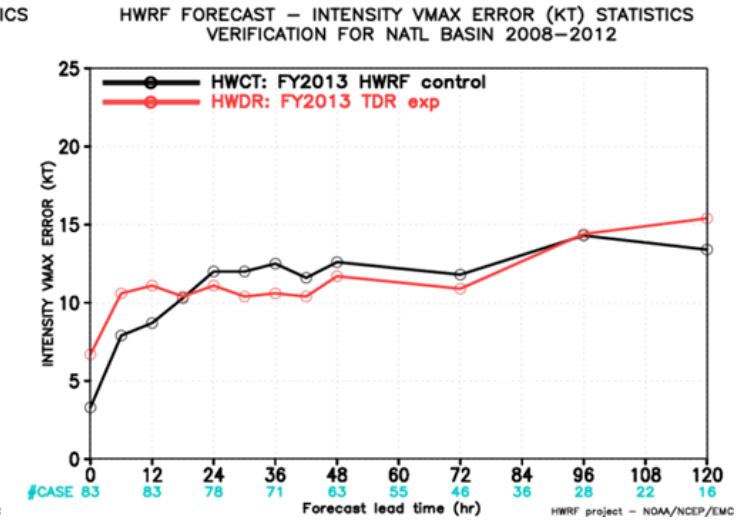


TDR data impact (TDR cycles only)



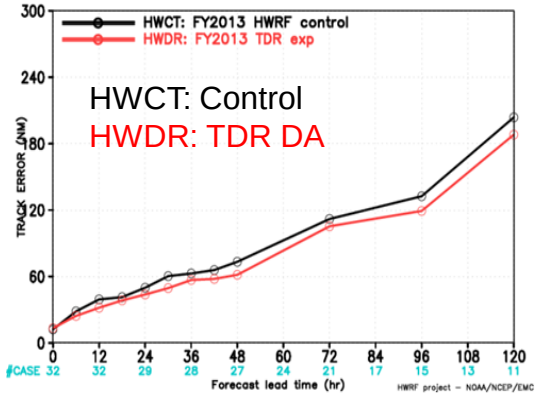


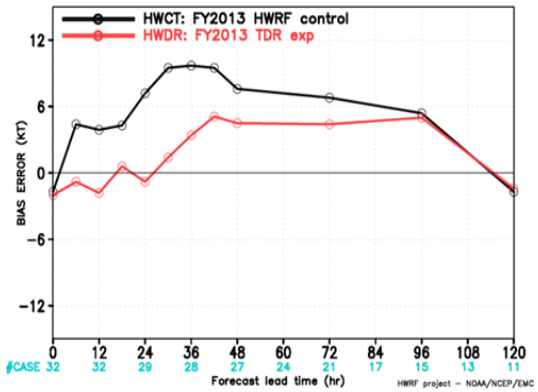


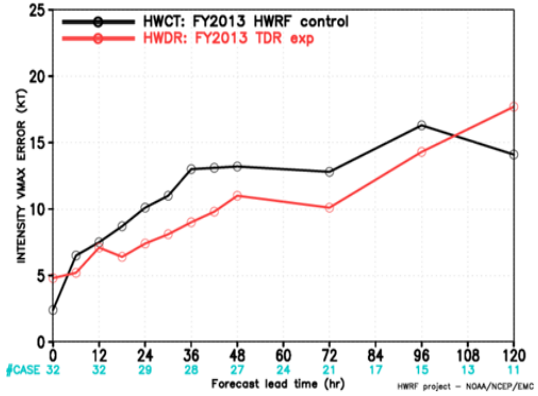


TDR data impact

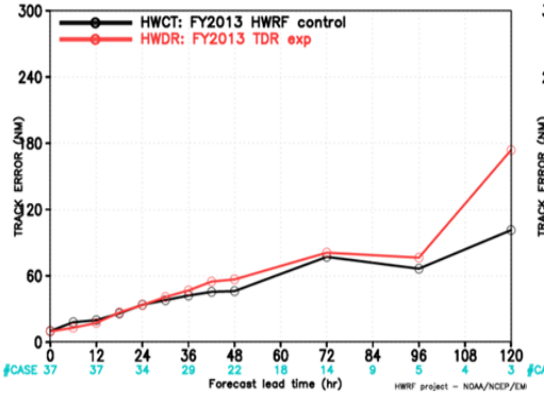
Category: TS

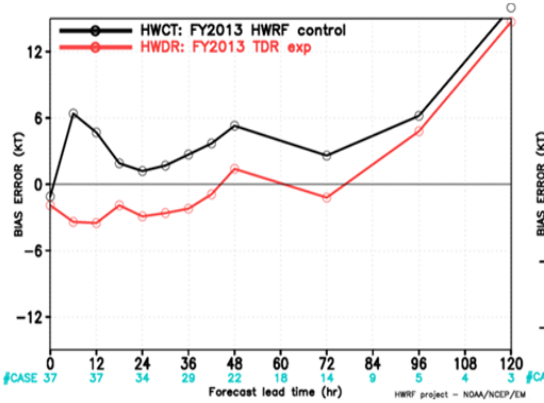


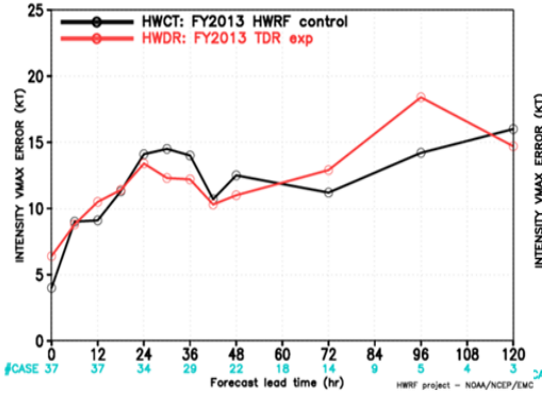




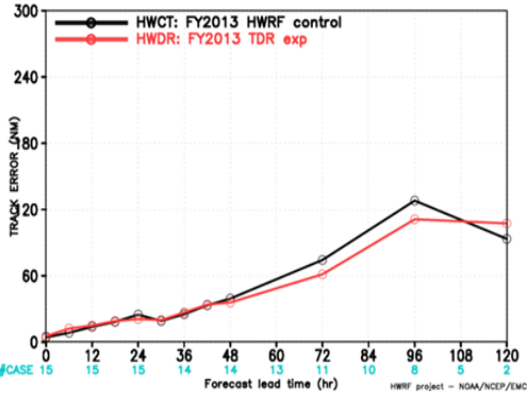
Category: H1-2

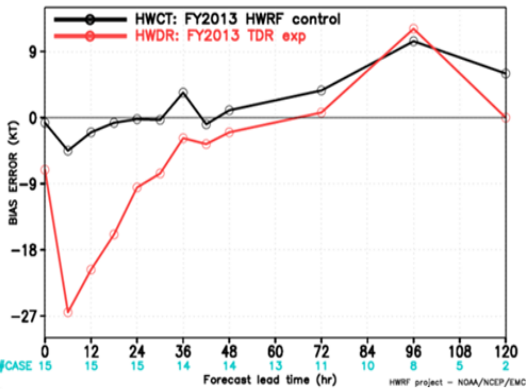


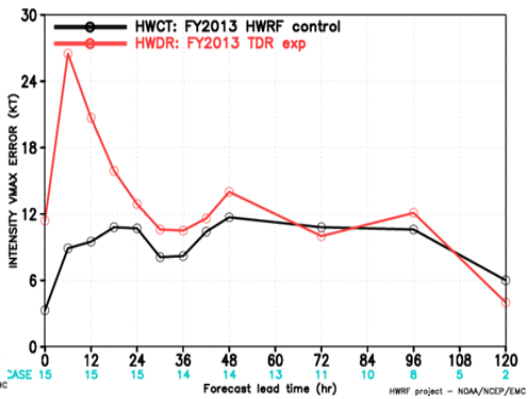




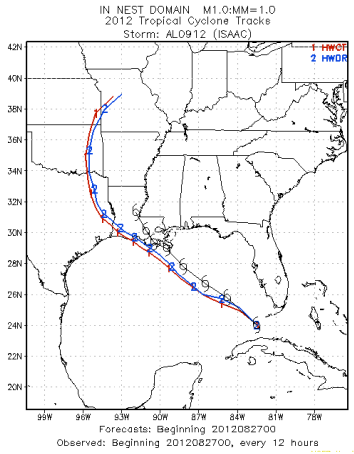
Category: MH

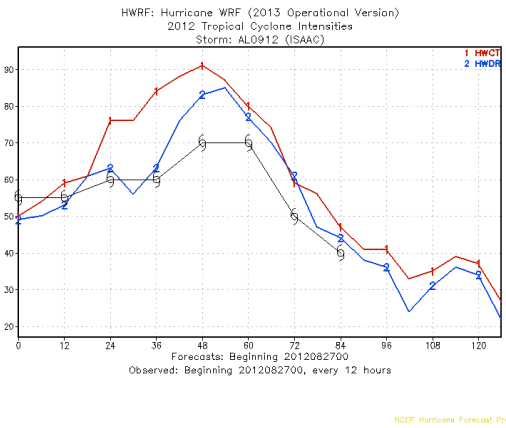




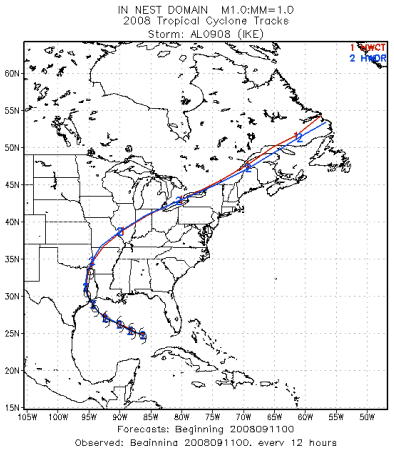


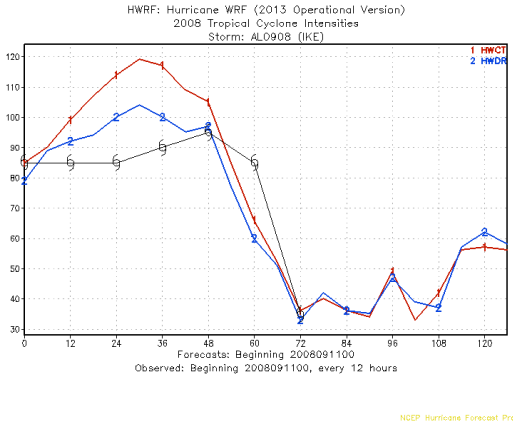
TS: isaac 2012082700



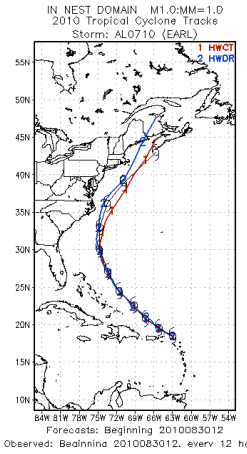


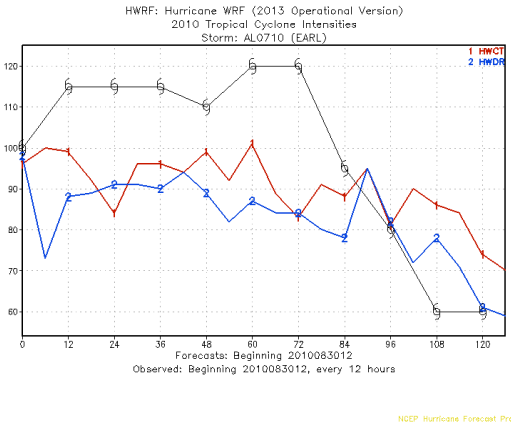
H2: Ike 2008091100





MH: earl 2010083012

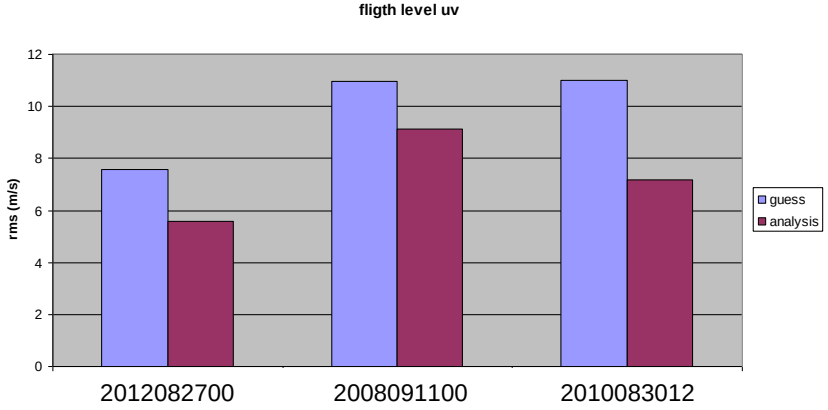




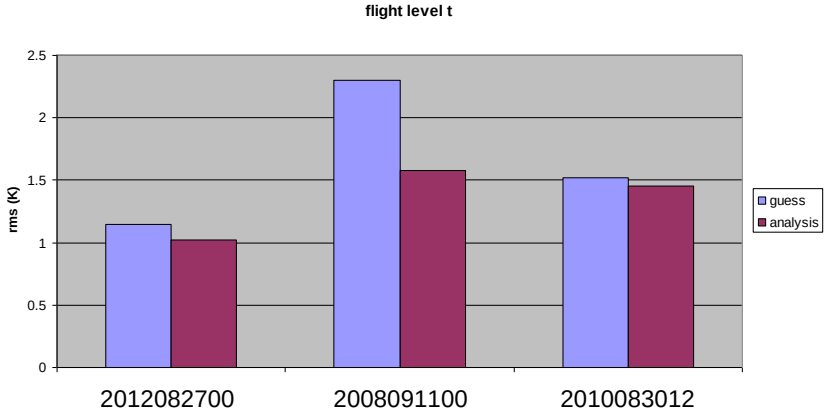
HWCT: Control
HWDR: TDR DA

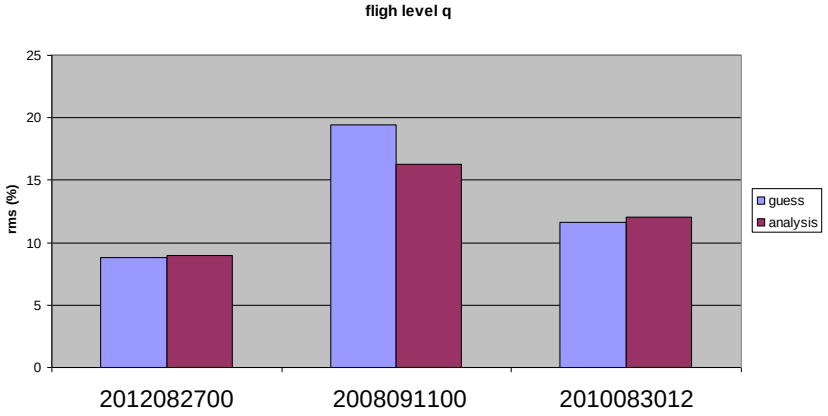
rms innovations for independent Flight level and SFMR observations isaac 2012082700, ike 2008091100, earl 2010083012; TDR cases (HWDR)

Flight Level u,v

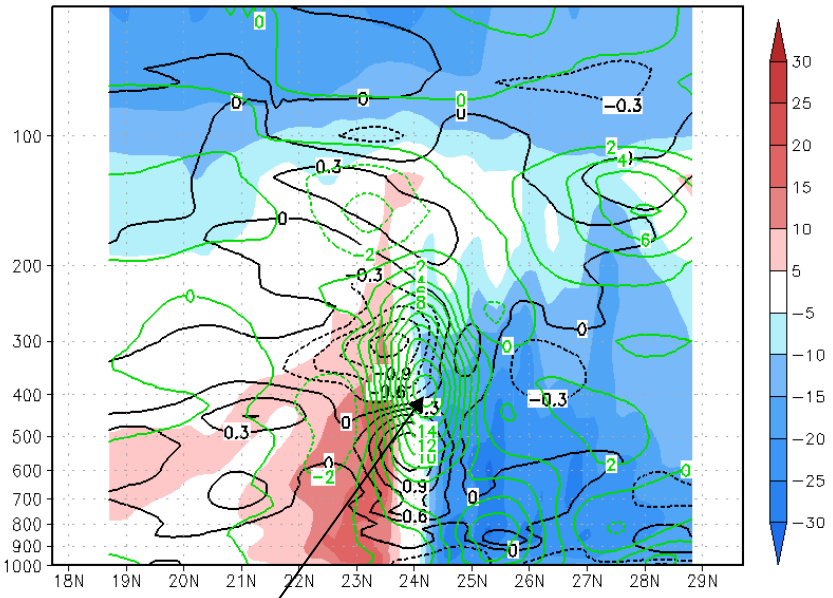


SFMR Wind Speed



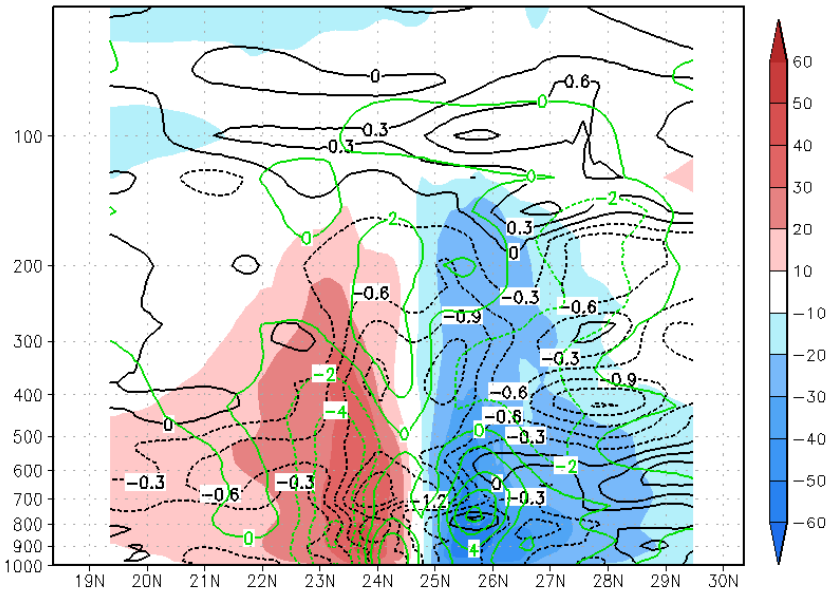


Isaac 09l 2012082700



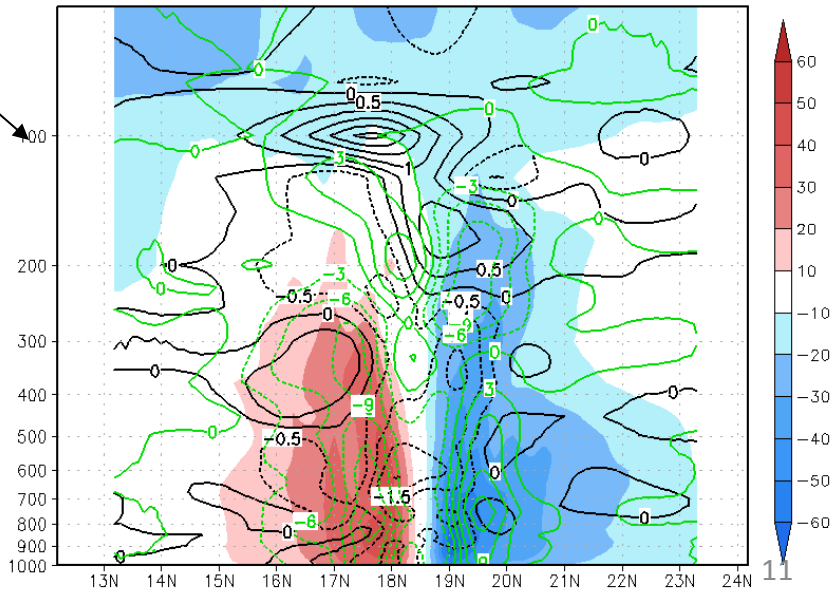
Make storm more northward tilted

Ike 09l 2008091100



Weakening the storm

Earl 07l 2010083012



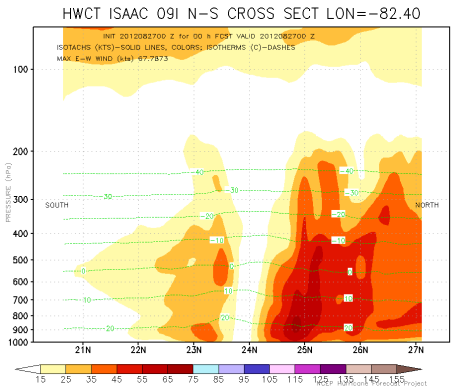
S-N cross section

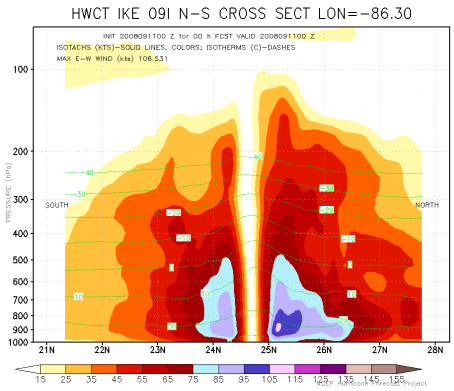
Color shade: first guess u

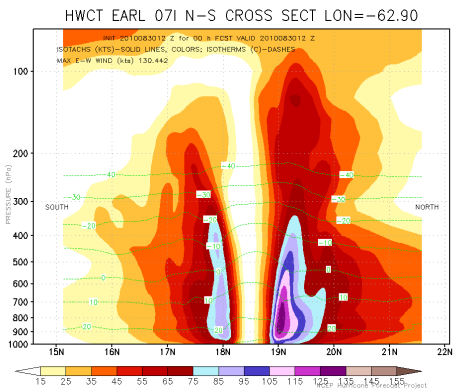
Black contour: temperature increment

Green contour: u increment

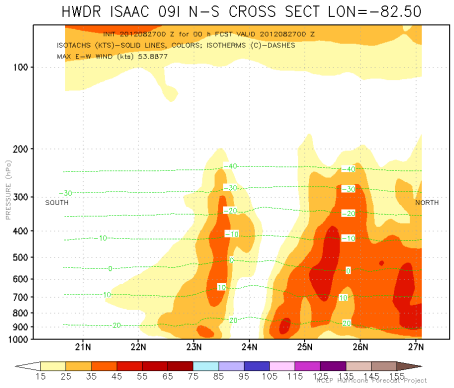
HWCT

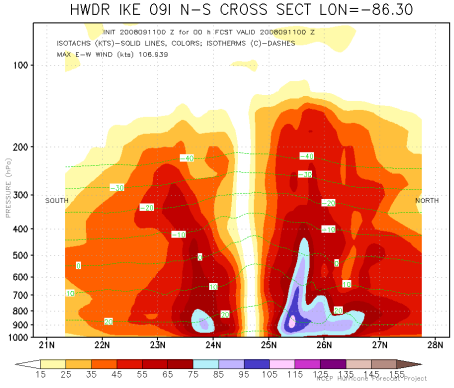


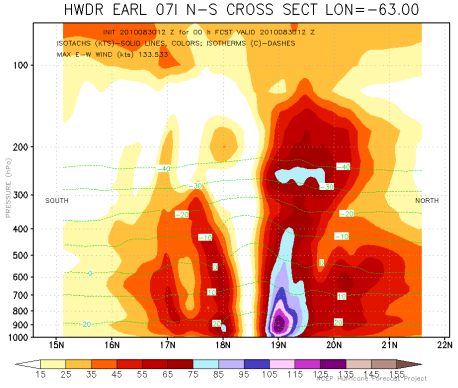




HWDR

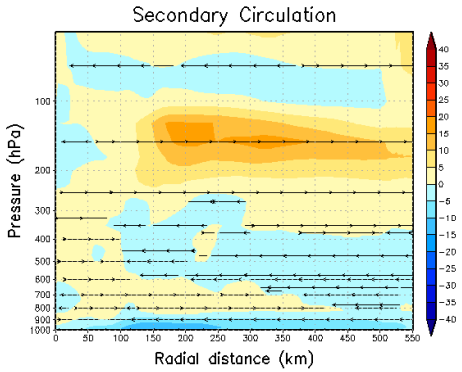




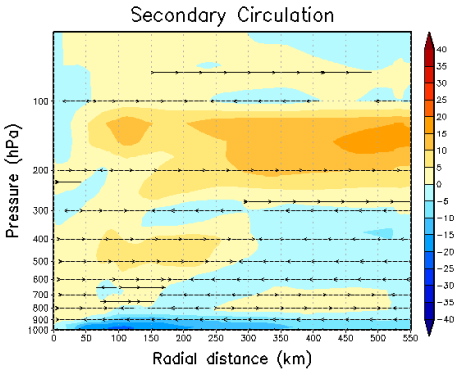


HWCT: Control
HWDR: TDR DA

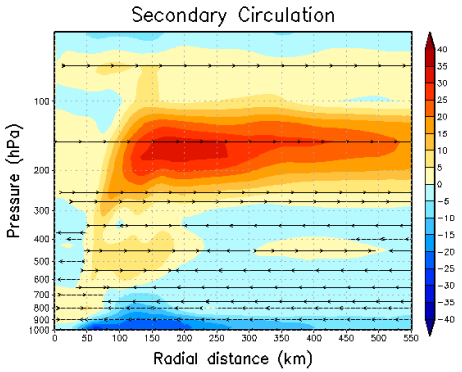
HWCT



ISAAC 09l, d23, Azimuthally averaged, 2012082700, 00 h FCST
Radial wind (shaded), Min=-13.9158, Max=16.8982 kts
Radial-vertical flow (streamline), Pressure velocity peak=0 Pa/s

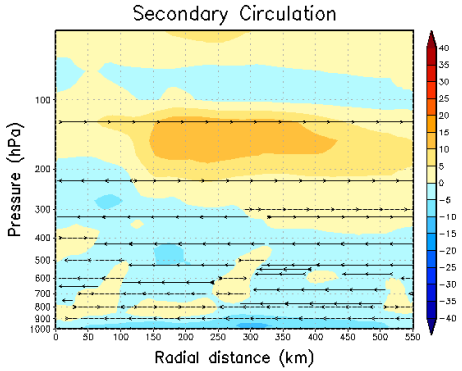


IKE 09l, d23, Azimuthally averaged, 2008091100, 00 h FCST
Radial wind (shaded), Min=-21.0243, Max=16.8905 kts
Radial-vertical flow (streamline), Pressure velocity peak=0 Pa/s

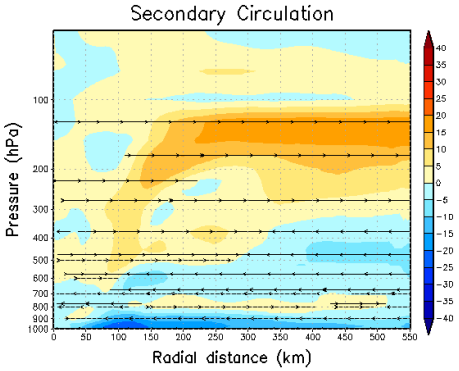


EARL 07l, d23, Azimuthally averaged, 2010083012, 00 h FCST
Radial wind (shaded), Min=-26.7409, Max=32.7263 kts
Radial-vertical flow (streamline), Pressure velocity peak=0 Pa/s

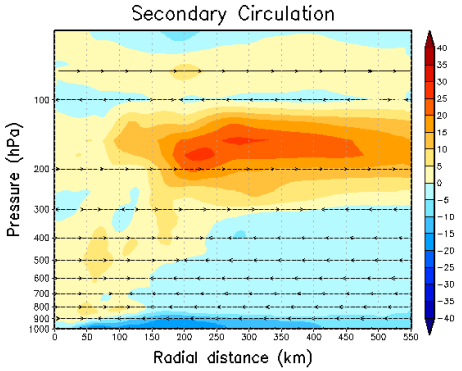
HWDR



ISAAC 09l, d23, Azimuthally averaged, 2012082700, 00 h FCST
Radial wind (shaded), Min=-10.5898, Max=13.8858 kts
Radial-vertical flow (streamline), Pressure velocity peak=0 Pa/s



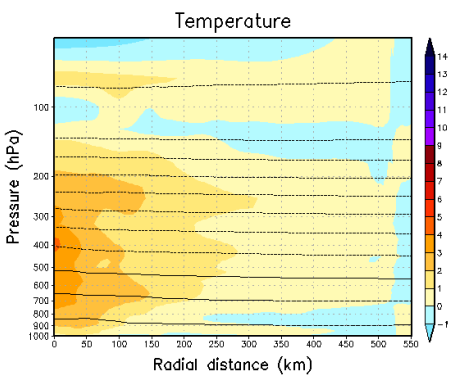
IKE 09l, d23, Azimuthally averaged, 2008091100, 00 h FCST
Radial wind (shaded), Min=-24.9926, Max=19.3195 kts
Radial-vertical flow (streamline), Pressure velocity peak=0 Pa/s



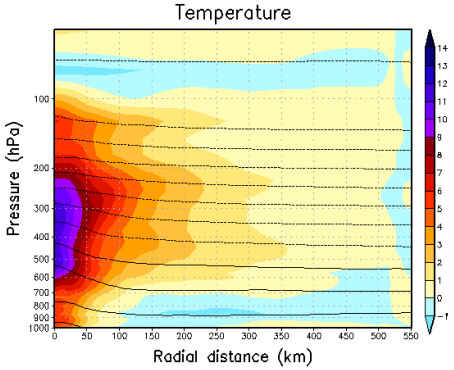
EARL 07l, d23, Azimuthally averaged, 2010083012, 00 h FCST
Radial wind (shaded), Min=-20.0132, Max=26.9787 kts
Radial-vertical flow (streamline), Pressure velocity peak=0 Pa/s

HWCT: Control
HWDR: TDR DA

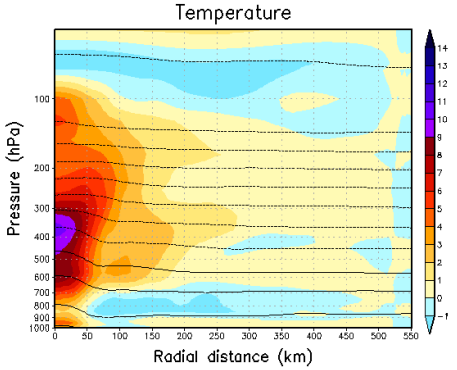
HWCT



ISAAC 09l, d23, Azimuthally averaged, 2012082700, 00 h FCST
Temperature deviation (shaded), Min=−1.7462B, Max=4.11655 °C
Temperature (contour), Min=−76.2563, Max=28.8563 °C

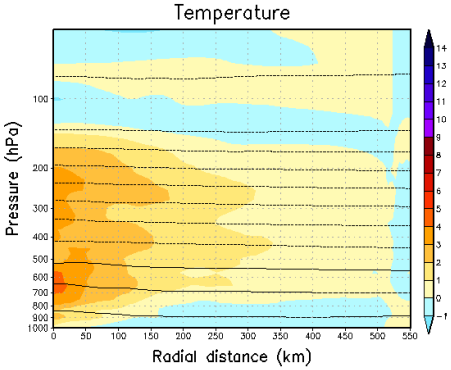


IKE 09l, d23, Azimuthally averaged, 2008091100, 00 h FCST
Temperature deviation (shaded), Min=−1.5612B, Max=11.6109 °C
Temperature (contour), Min=−78.8106, Max=33.4037 °C

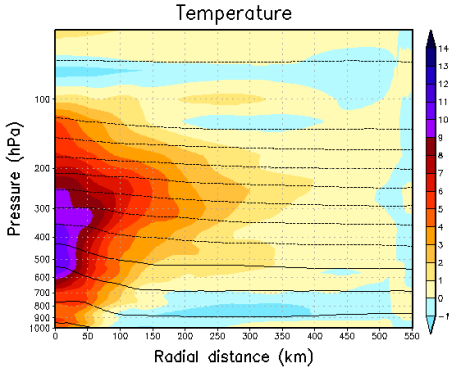


EARL 07l, d23, Azimuthally averaged, 2010083012, 00 h FCST
Temperature deviation (shaded), Min=−2.61196, Max=10.3809 °C
Temperature (contour), Min=−79.9359, Max=31.4557 °C

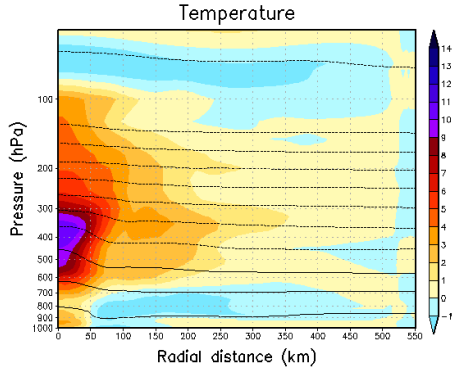
HWDR



ISAAC 09l, d23, Azimuthally averaged, 2012082700, 00 h FCST
Temperature deviation (shaded), Min=−1.0934B, Max=4.20051 °C
Temperature (contour), Min=−75.6134, Max=28.3252 °C



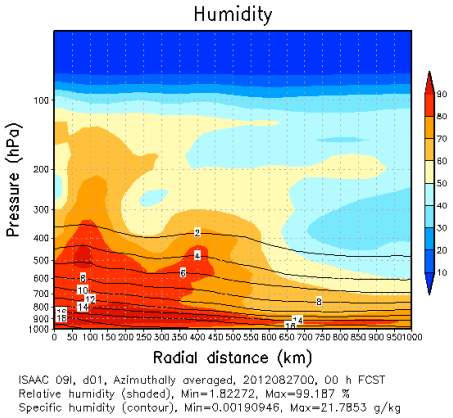
IKE 09l, d23, Azimuthally averaged, 2008091100, 00 h FCST
Temperature deviation (shaded), Min=−1.68197, Max=10.9068 °C
Temperature (contour), Min=−78.7747, Max=33.0275 °C



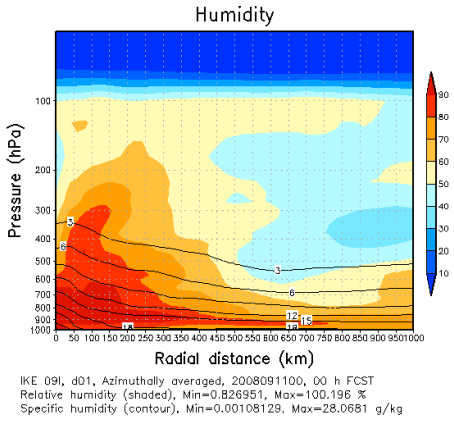
EARL 07l, d23, Azimuthally averaged, 2010083012, 00 h FCST
Temperature deviation (shaded), Min=−3.25795, Max=10.9157 °C
Temperature (contour), Min=−79.006, Max=30.0365 °C

HWCT: Control
HWDR: TDR DA

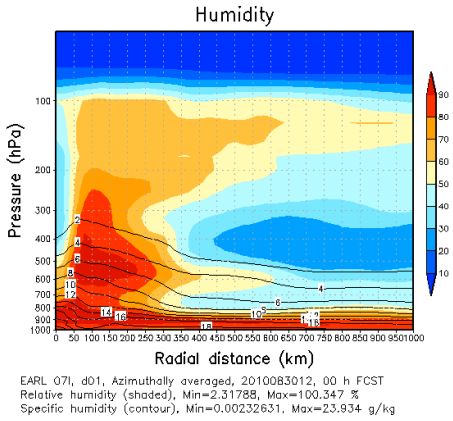
HWCT



ISAAC 09l, d01, Azimuthally averaged, 2012082700, 00 h FCST
Relative humidity (shaded), Min=1.82272, Max=99.187 %
Specific humidity (contour), Min=0.00190946, Max=21.7853 g/kg

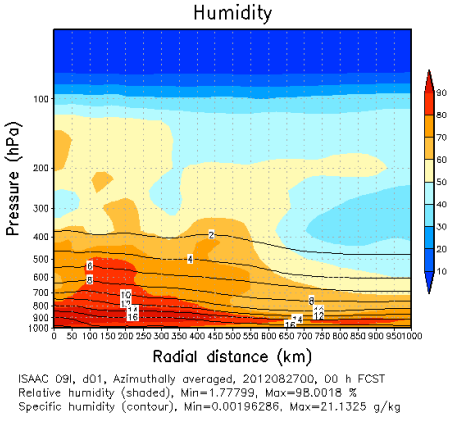


IKE 09l, d01, Azimuthally averaged, 2008091100, 00 h FCST
Relative humidity (shaded), Min=0.826951, Max=100.196 %
Specific humidity (contour), Min=0.00108129, Max=28.0681 g/kg

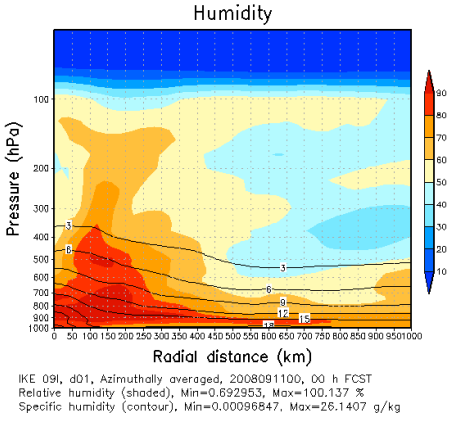


EARL 07l, d01, Azimuthally averaged, 2010083012, 00 h FCST
Relative humidity (shaded), Min=2.31788, Max=100.347 %
Specific humidity (contour), Min=0.00232631, Max=23.934 g/kg

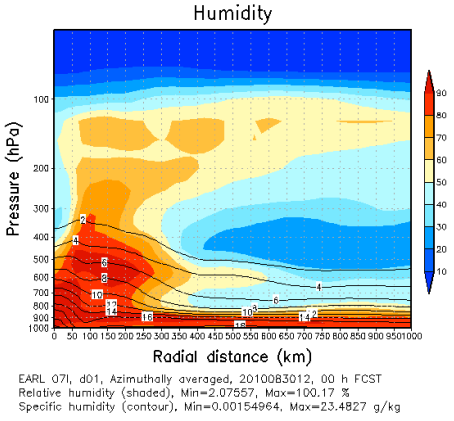
HWDR



ISAAC 09l, d01, Azimuthally averaged, 2012082700, 00 h FCST
Relative humidity (shaded), Min=1.77799, Max=98.0018 %
Specific humidity (contour), Min=0.00196286, Max=21.1325 g/kg



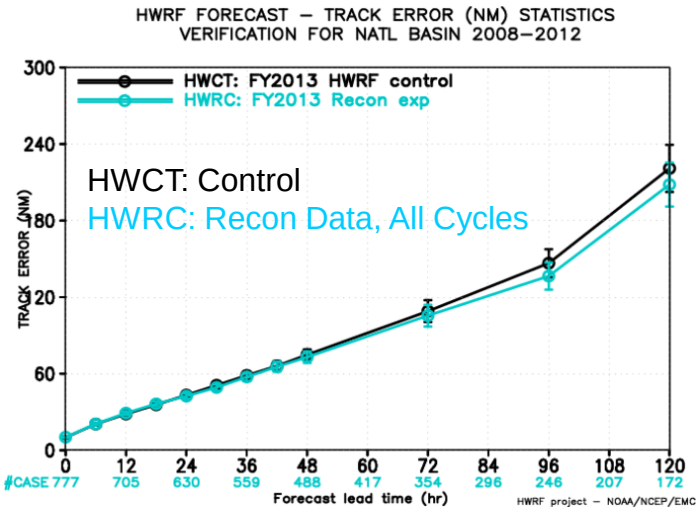
IKE 09l, d01, Azimuthally averaged, 2008091100, 00 h FCST
Relative humidity (shaded), Min=0.692953, Max=100.137 %
Specific humidity (contour), Min=0.00096847, Max=26.1407 g/kg

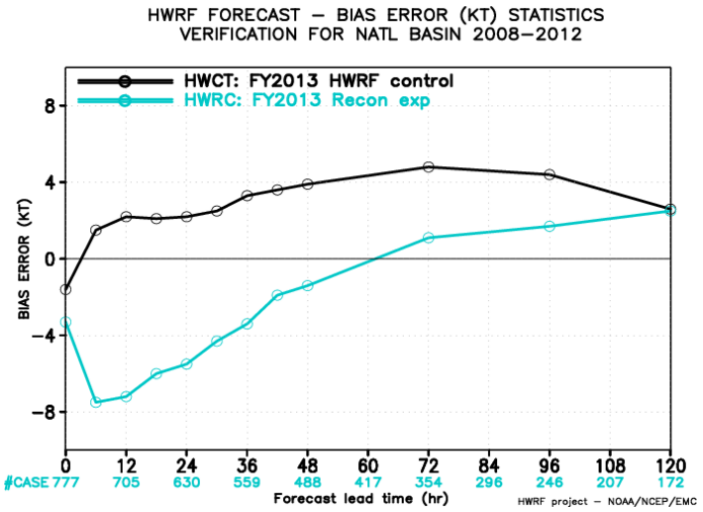


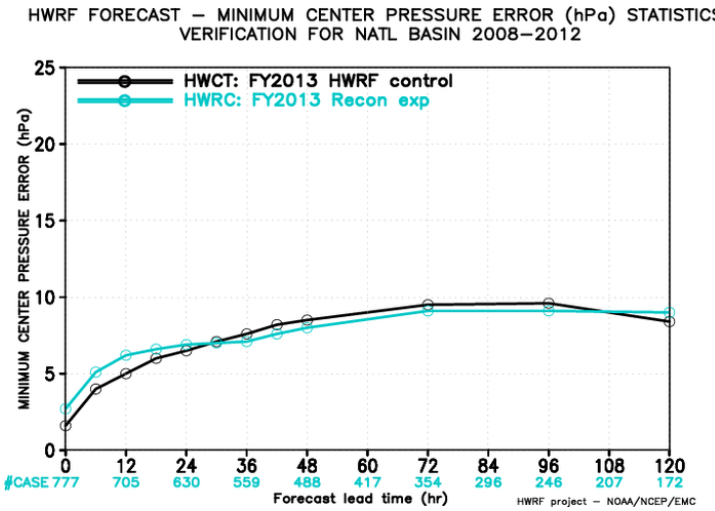
EARL 07l, d01, Azimuthally averaged, 2010083012, 00 h FCST
Relative humidity (shaded), Min=2.07557, Max=100.17 %
Specific humidity (contour), Min=0.00154964, Max=23.4827 g/kg

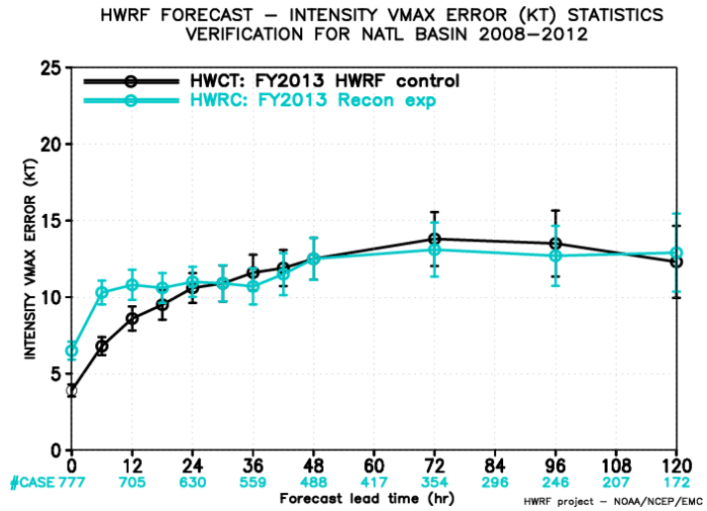
HWCT: Control
HWDR: TDR DA

HDOB data impact (all cycles)

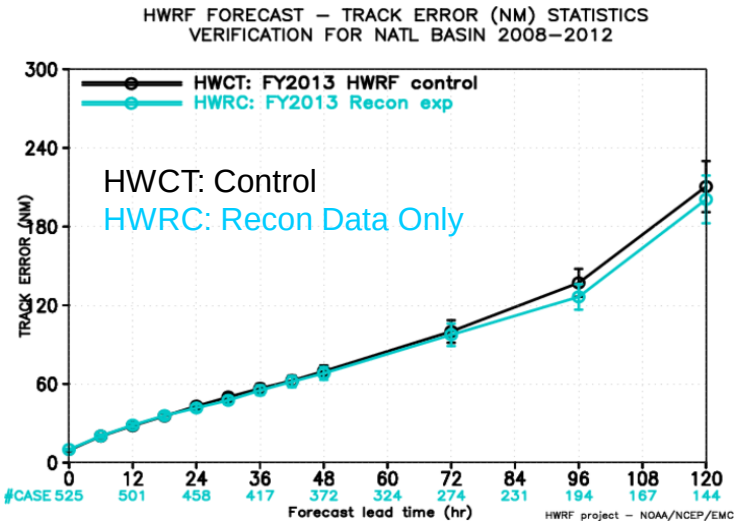


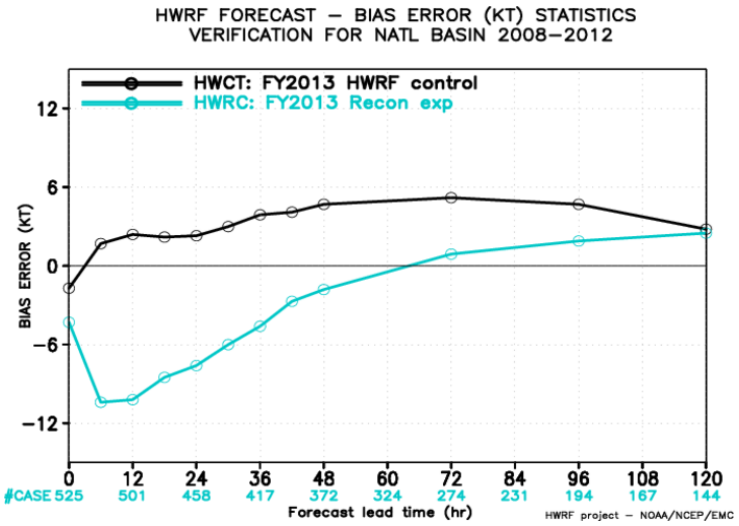


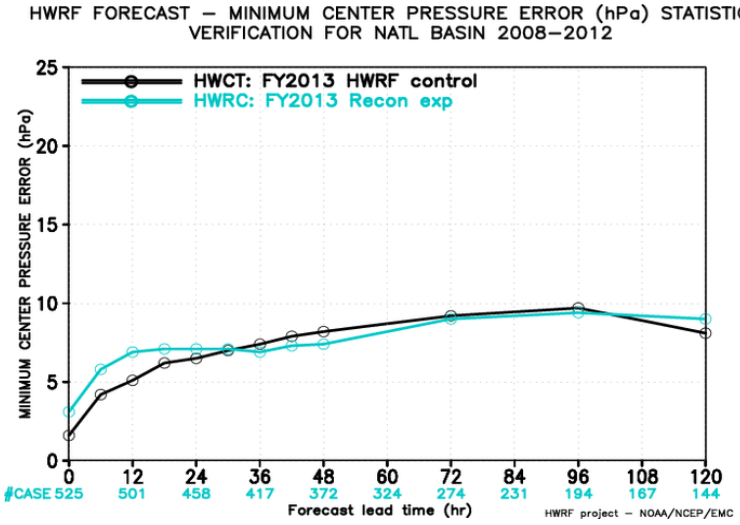


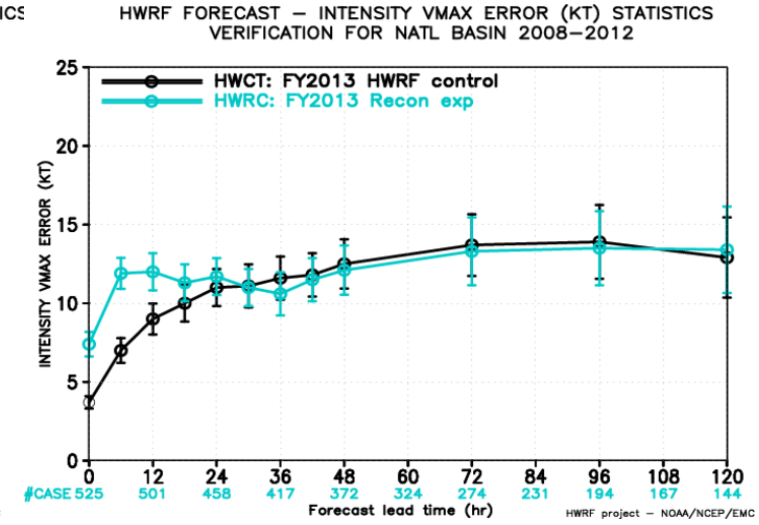


HDOB data impact (cycles with HDOB data available)

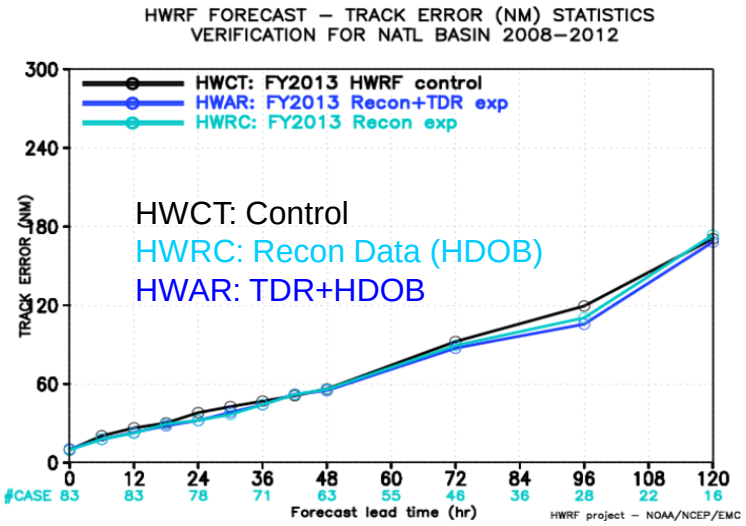


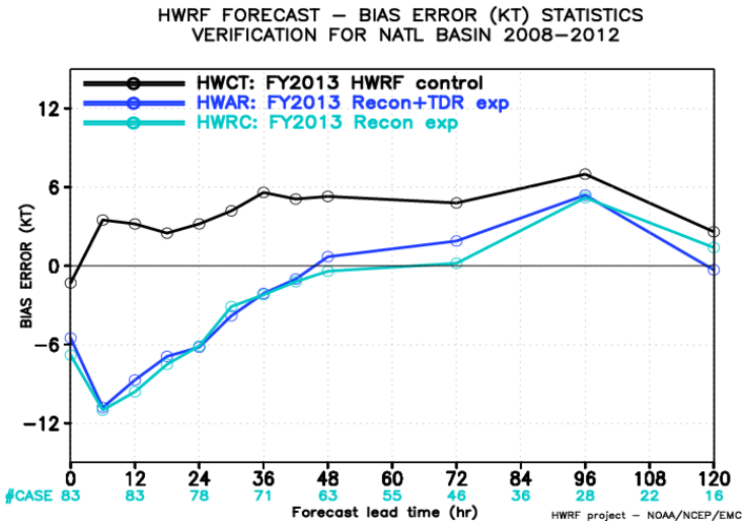


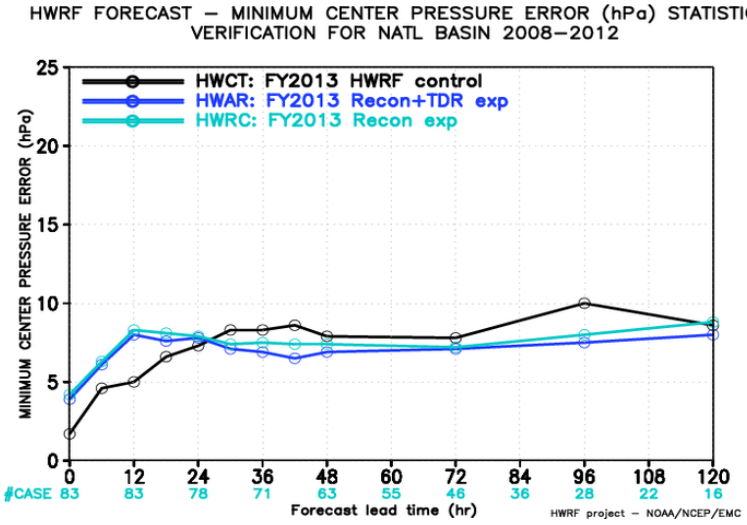


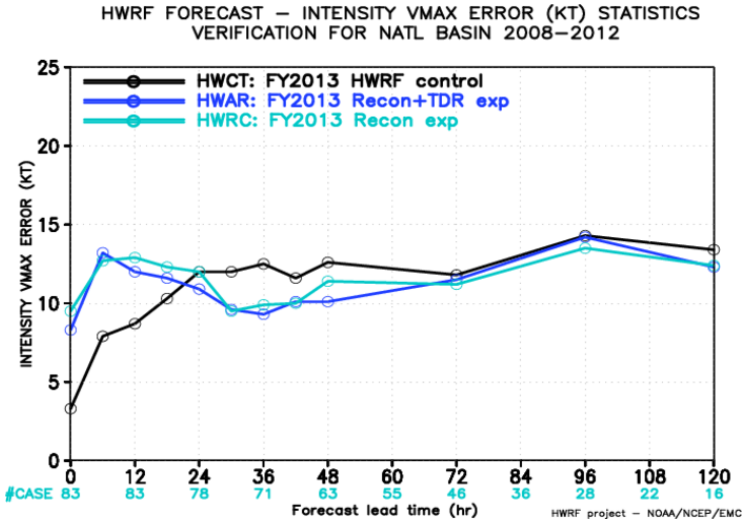


HDOB+TDR data impact (cycles with TDR data available)







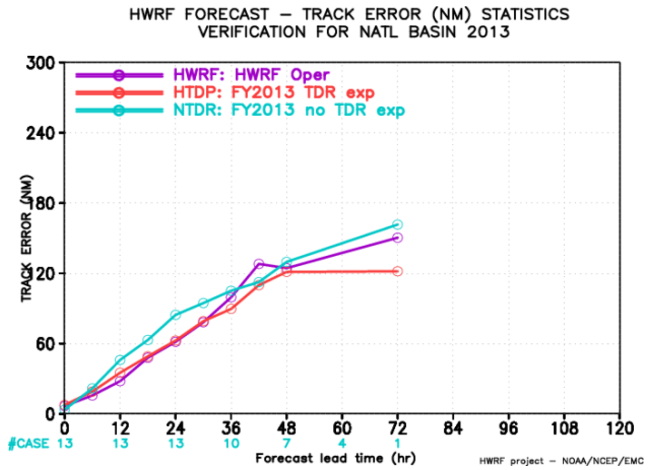


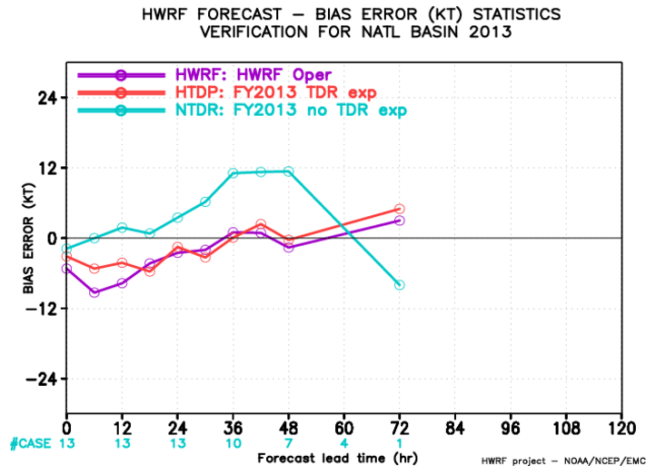
Five Year Aircraft TDR versus HDOB (Flight level and SFMR) Data Impact Study

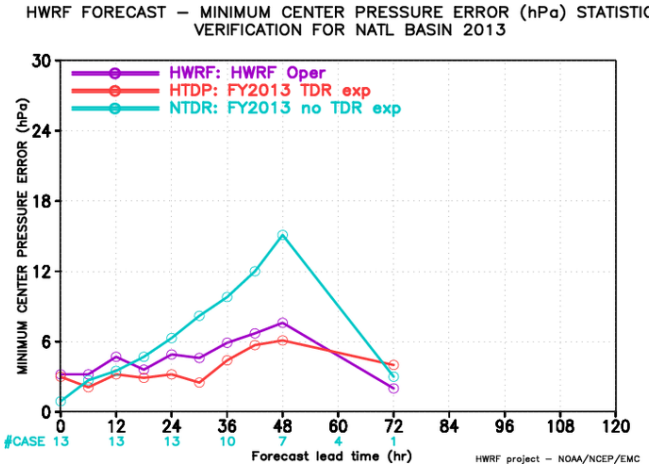
Summary and remarks:

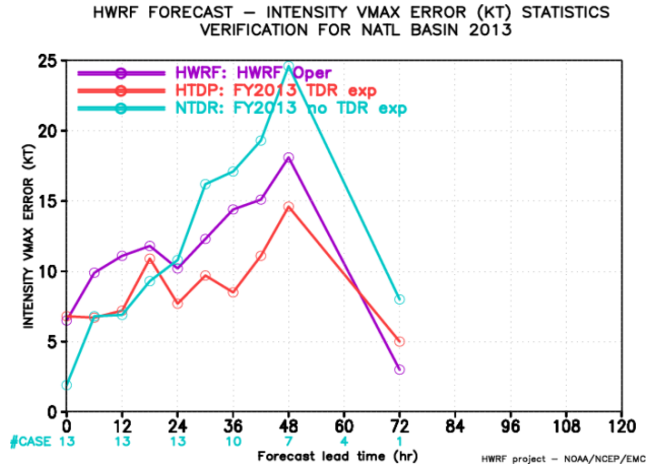
- **HWDR:** Inner-core data assimilation with TDR data improves or has neutral impact on track forecast. Experiments with TDR DA showed improved intensity forecasts from 24 hours forecast lead time. Intensity bias indicates short-term forecast spin-down.
- The assimilation of TDR almost consistently improves track and intensity forecast for tropical storms and significantly reduces spin-up and positive bias that happen when only vortex initialization is used to initialize TC vortex. The initial forecast spin-down mainly found in strong storms, especially major hurricanes. In most of the cases, TDR data assimilation helped reduce over-intensification of weak storms and minimal hurricanes, adding value to the vortex initialization.
- **HWRC:** The assimilation of HDOB data improves or has neutral impact on track forecasts. However, these experiments showed significant short-term intensity spin-down.
- **HWRA:** For the storms with TDR data available, the assimilation of HDOB data also improves intensity forecast beyond 24 hours forecast lead time. However, the initial spin-down is still prominent on these experiments.

2013 TDR+Dropsonde experiments



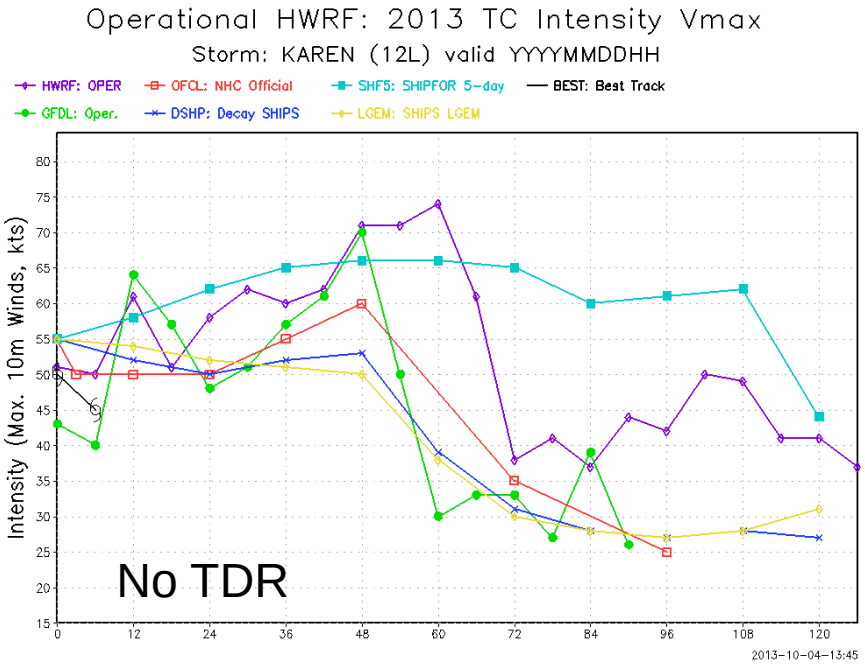


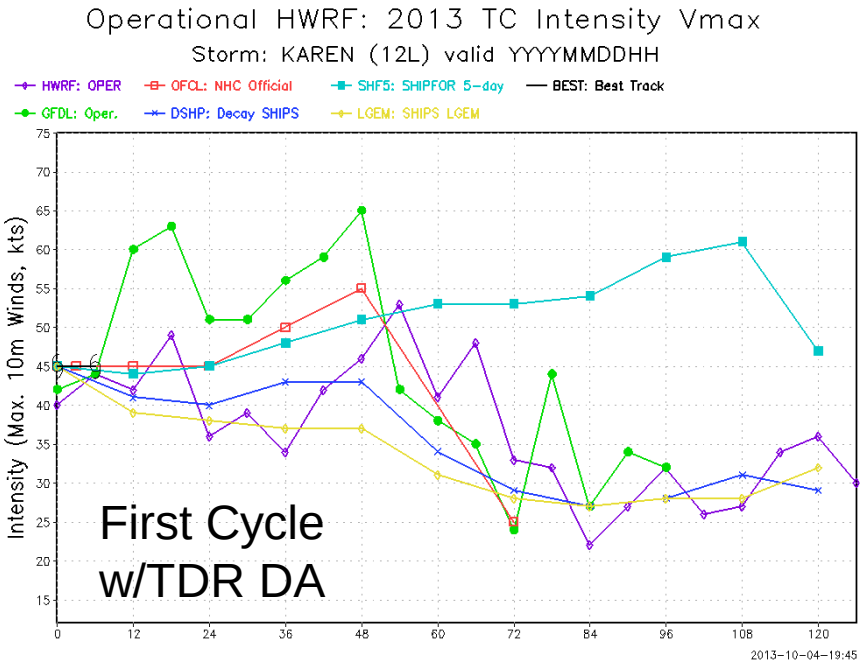




When surface pressure data within vortex area are flagged (not assimilated) in FY13 HWRF, the corresponding dropsonde temperature and moisture data are also not assimilated. When including all dropsonde thermodynamic profiles (HTDP), both track and intensity forecast can be improved.

Impact of TDR DA on operational HWRF for TS Karen:





Impact of HWRF forecasts with TDR DA on NHC Operational Forecasts

NHC Forecast Discussion on October 4, 5 PM:

- **THE 12Z HWRF RUN SHOWED CONSIDERABLY LESS INTENSIFICATION WITH KAREN COMPARED TO PREVIOUS RUNS AFTER ASSIMILATING DATA FROM THE FROM THE NOAA P-3 TAIL DOPPLER RADAR. THIS MARKS THE FIRST TIME DOPPLER RADAR DATA HAVE BEEN ASSIMILATIED INTO AN OPERATIONAL HURRICANE MODEL IN REAL TIME.**

-- Forecaster Brennan

Real-time assimilation of NOAA P3 TDR DA for operational HWRF – A First in many years of flying.

- Fix issues related to transmission of TDR data to NCO (storm id mismatch etc.)
- Conduct experiments to maximize the effective utilization of inner core data

Plans for FY14 Data Assimilation Upgrades

- **Inner-core:** always turn on data assimilation on ghost domain – dropsonde data as part of conventional data are always assimilated
- **Outer domain:** Add calibrated radiances (AMSU-A, ATMS, MHS, AIRS, IASI, HIRS4, GOES Sounders), GPSRO bending angles and satellite derived winds (IR/VIS cloud drift winds, water vapor winds) in outer domain analysis
- **Experimental Research:** Assimilation of TDR, Flight level and SFMR data

  - improving background error covariance (test higher resolution HWRF ensemble)

  - test hourly FGAT (provide more accurate first guess fields, especially for fast moving and developing storms)

  - test data thinning strategy

  - observation error tuning

  - test different way of using vortex initialization