Impact of Aircraft Reconnaissance on Convection-permitting Hurricane Intensity Prediction by WRF-EnKF at PSU

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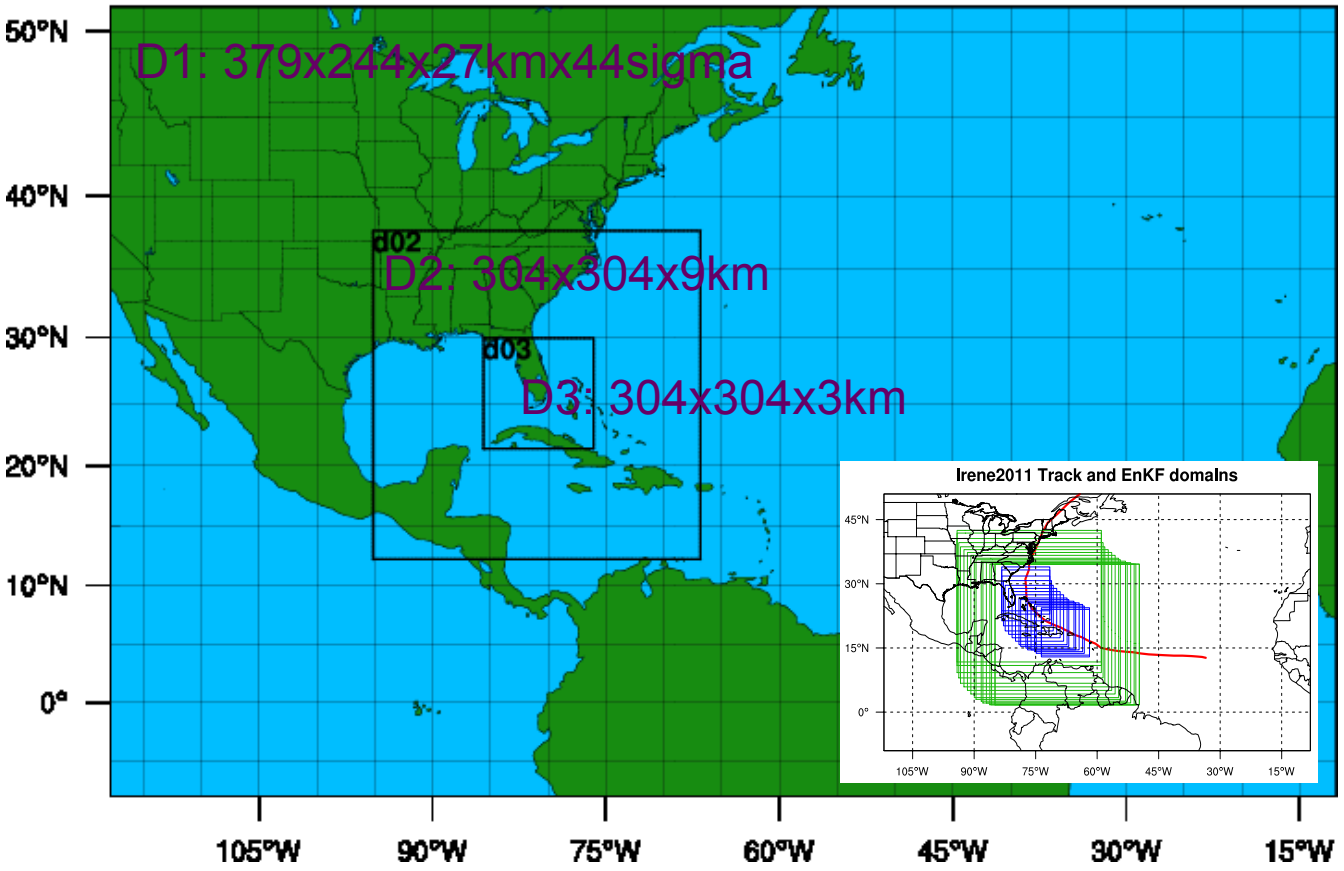
WRF-ARW Configurations for the PSU Cycling EnKF



ARW	V3.4.1
Cumulus	Grell-Devenyi ensemble (27 km domain only)
Microphysics	WSM 6-class graupel
PBL	YSU
Surface Layer	Monin-Obukov
Land Surface	thermal diffusion
Radiation	Rrtm / Dudhia
Air-sea flux	Modified option 2
Ocean	NO
• 60-member ensemble	
• Gaspairi & Cohn 99' covariance localization with varying RoI	
• IC & BC: GFS using 3DVAR background uncertainty	
• Observation window: 3hrs cycling	

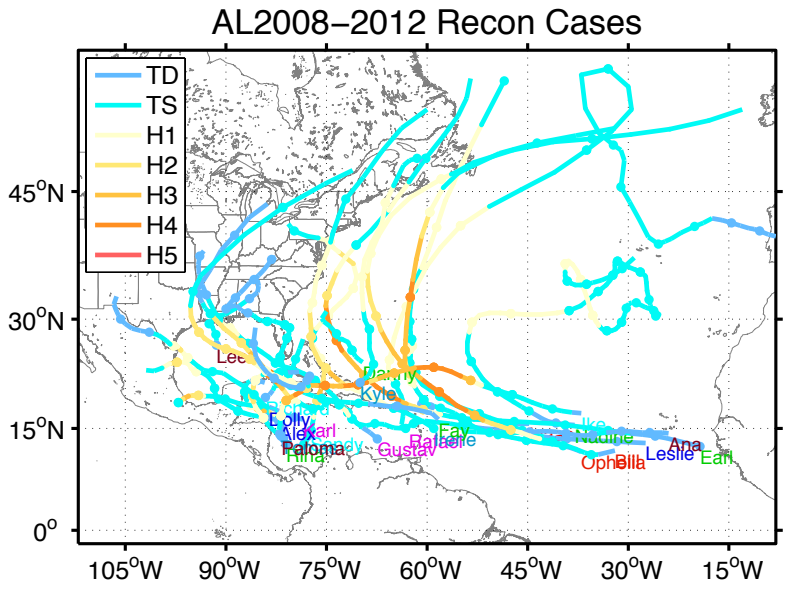
ANPS – no EnKF assimilation: WRF is initialized with operational GFS analysis
APCT – control run: EnKF assimilation of conventional data only
APRC – recon run: APCT + flight-level and dropsonde observations
APAR – recon with TDR run: APCT + flight-level and dropsonde obs + TDR Vr

NHC Selected Cases for RDITT

Aircraft ReconCcases for the 2008-2012 Atlantic Storms (by NHC)

Year	Storm	APCT MMDDHH-MMDDHH	APRC MMDDHH-MMDDHH
2008	04-Dolly	072012-072418	072012-072418
	06-Fay	081400-082400	081400-082400
	07-GUSTAV	082512-090200	082512-090200
	09-Ike	090200-091312	090512-091312
	11-Kyle	092300-092812	092318-092812
	17-Paloma	110600-111000	110600-111000
2009	02-Ana	081200-081700	081612-081700
	03-Bill	081600-082312	081812-082312
	05-Danny	082612-082900	082612-082900
2010	01-Alex	062512-070112	062512-070112
	07-Earl	082600-090400	082712-090400
	13-Karl	091412-091800	091412-091800
	19-Richard	102012-102600	102012-102600
	21-Tomas	102912-110806	102912-110806
2011	09-Irene	082000-082900	082012-082900
	13-Lee	090200-090612	090200-090612
	16-Ophelia	092100-100218	092312-092900
	18-Rina	102212-102818	102312-102800
2012	09-Isaac	082000-083018	082112-082906
	12-Leslie	083000-091100	090712-090812
	14-Nadine	091000-100318	091118-100318*
	17-Rafael	101300-101718	101300-101718
	18-Sandy	102100-103018	102212-102918
Total	23 storms	758 cases	636 cases

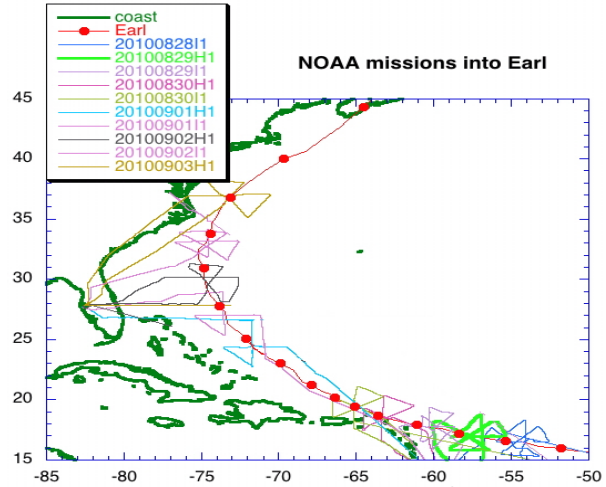
* NASA Globe-Hawk dropsondes.



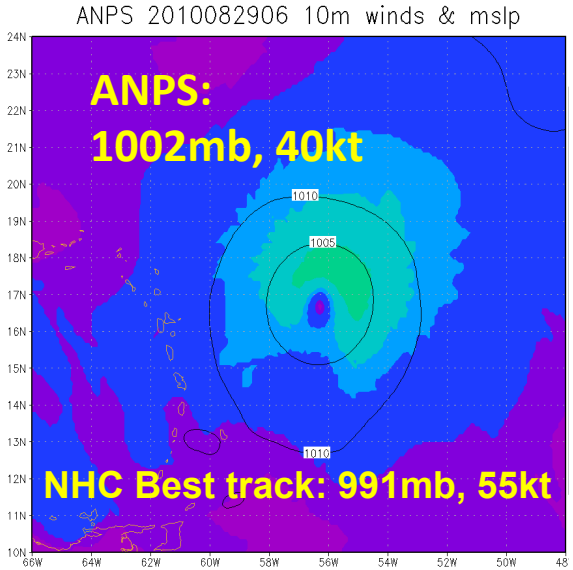
Atlantic storm tracks with recon missions during 2008-2012

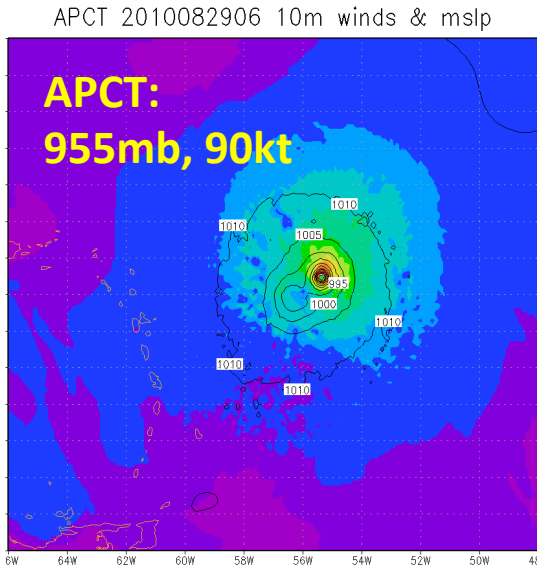
PSU Recon Experiment:

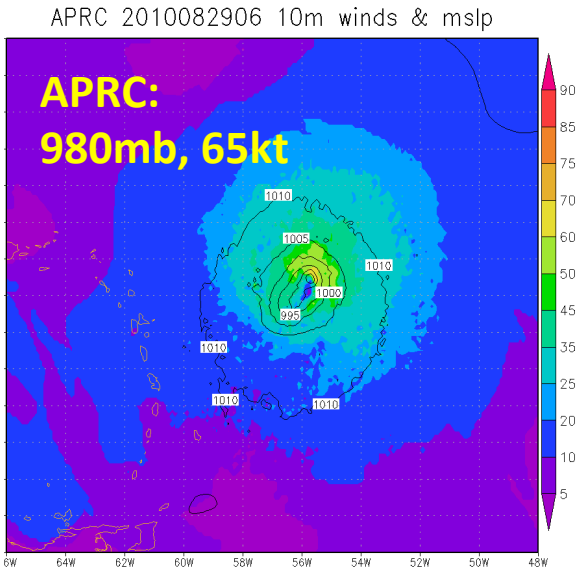
A sample of Hurricane Earl (2010) initialization



NOAA Recon missions into Earl (2010) from www.aoml.noaa.go

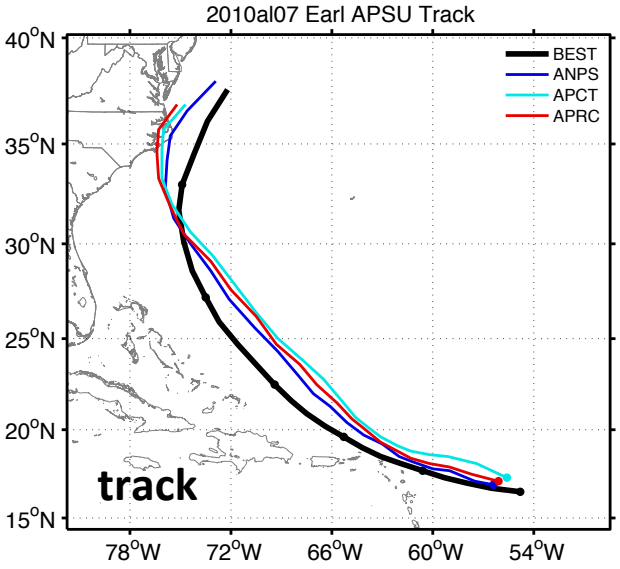


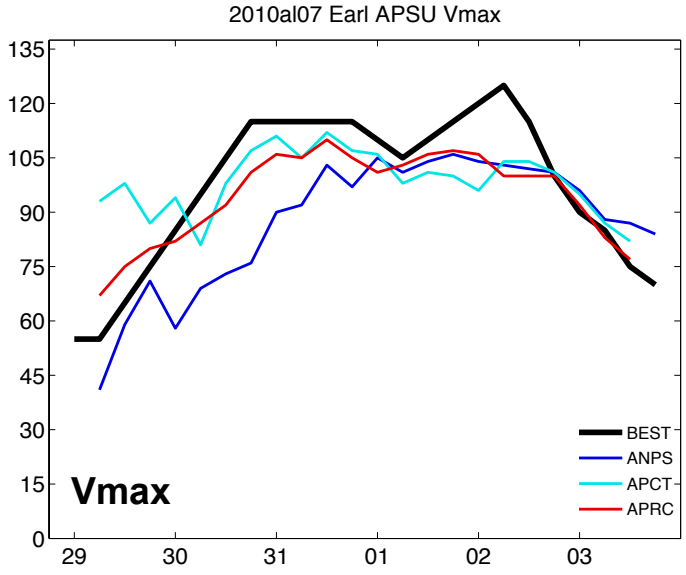


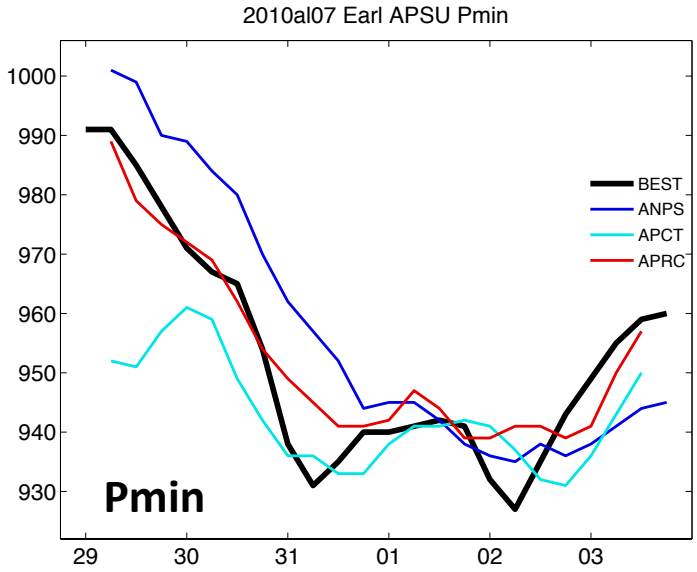


PSU Recon Experiment:

A sample of hurricane Earl (2010) forecasts

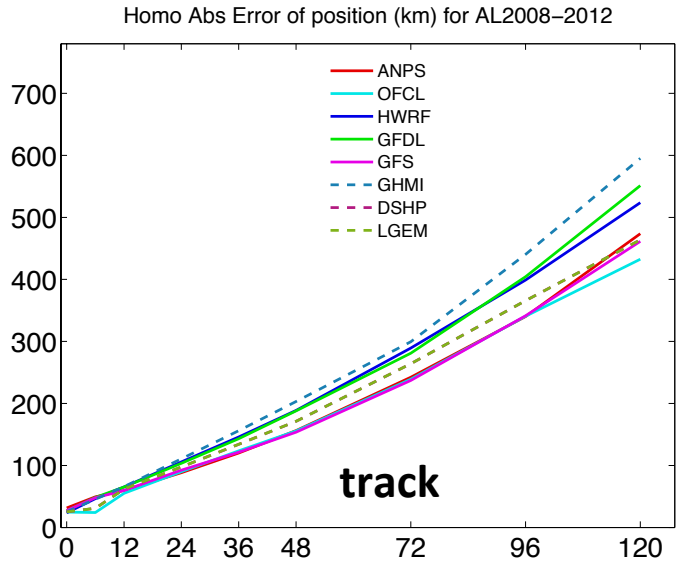


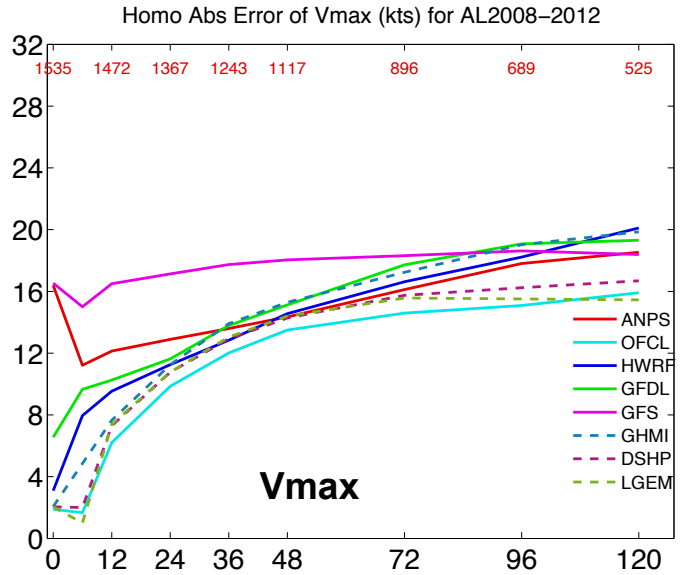


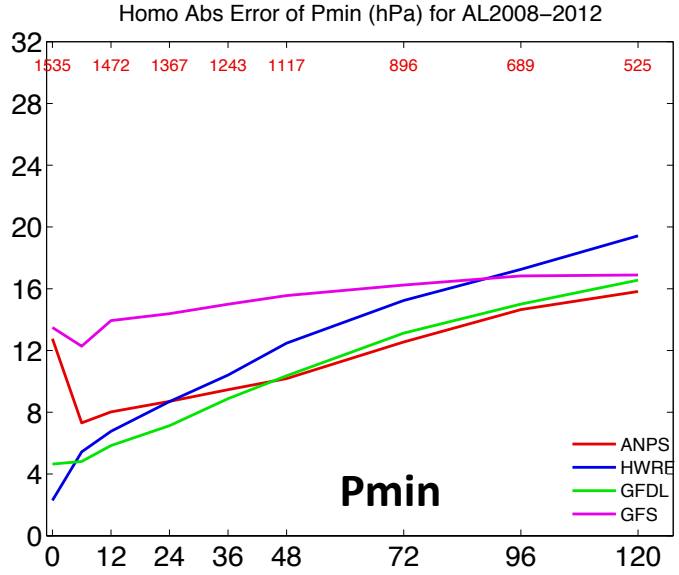


Hurricane Earl (2010) track and intensity forecasts initialized at 06Z 9 Sept 2010 for ANPS (blue), APCT (cyan) and APRC (red) by comparing to the NHC best track (black)

Baseline tests (ANPS): ARW forecasts started from operational GFS analyses

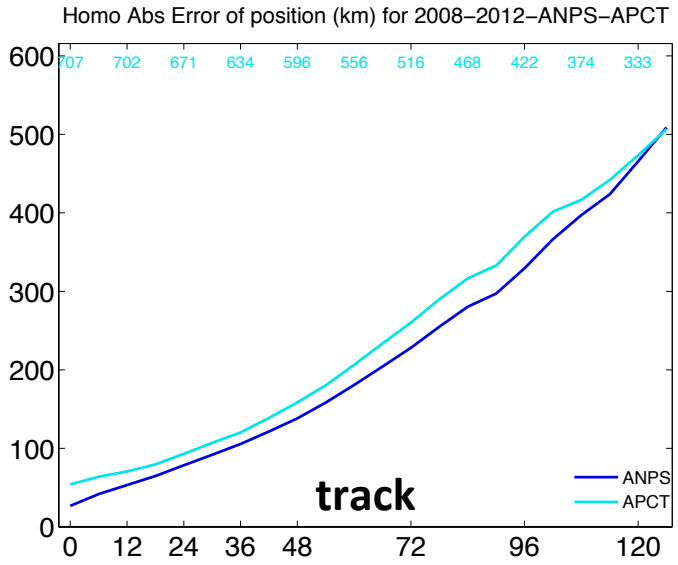


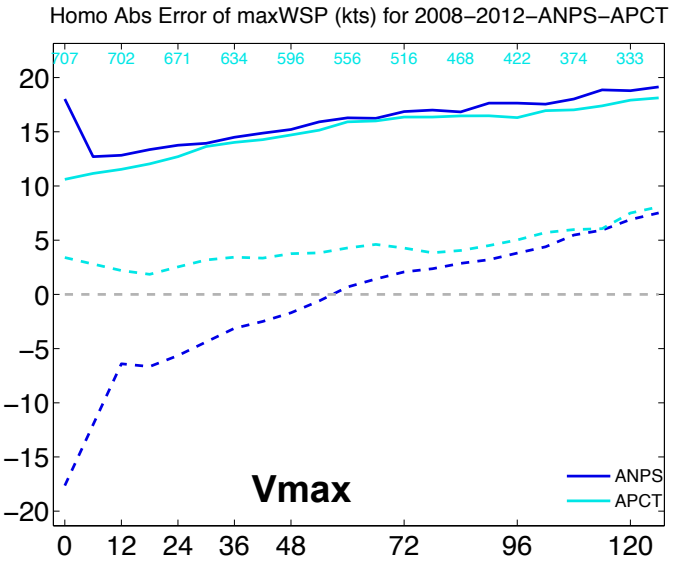


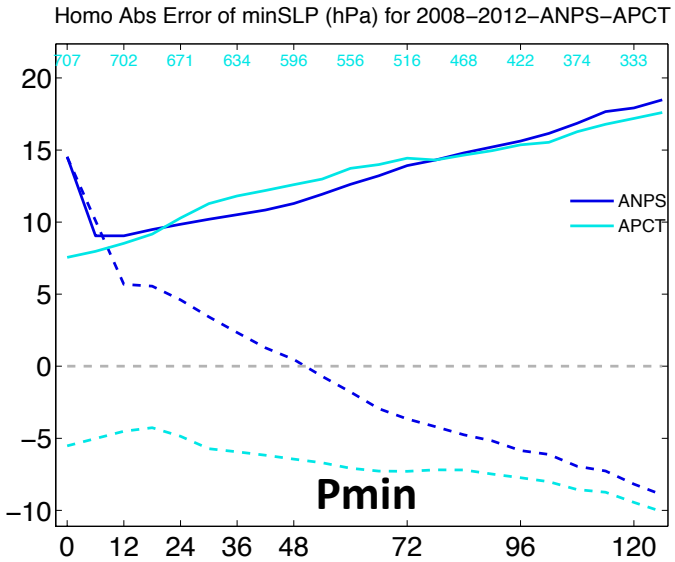


Mean absolute forecast errors averaged over all Atlantic storms during 2008-2012 against the NHC Best Track by homogeneously verified with the WRF deterministic forecasts initialized with operational GFS analysis. The numbers of homogeneously samples are list on the top of the intensity error panels.

PSU Cycling WRF-EnKF with Conventional Data (APCT) *in comparison to WRF from GFS analysis (ANPS)*

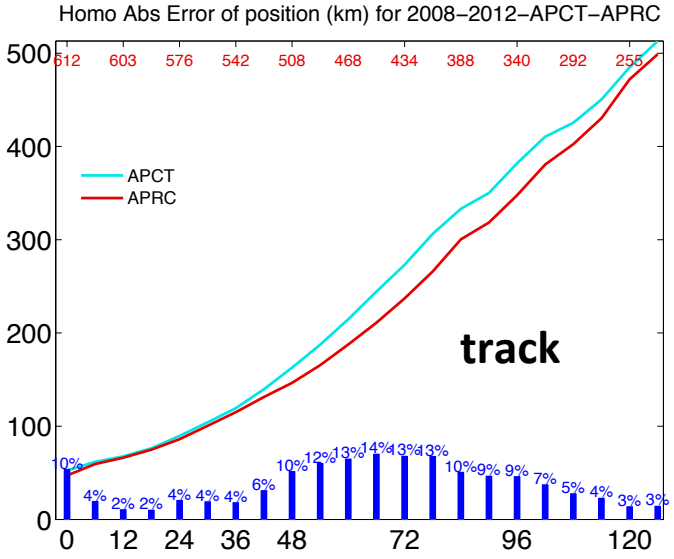


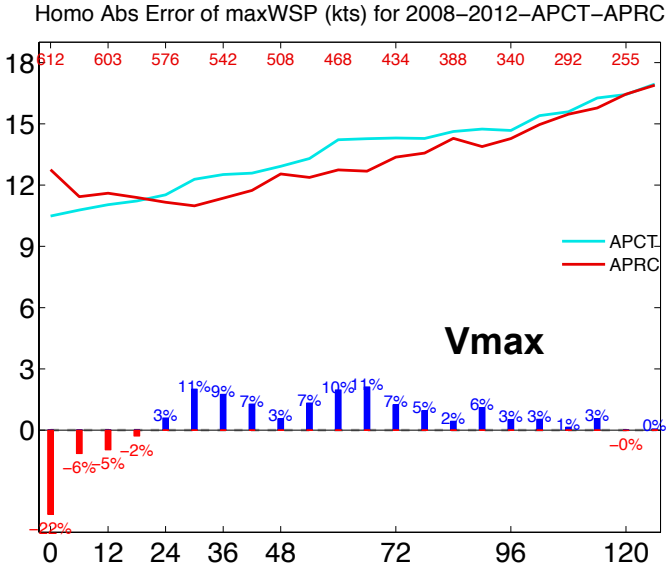


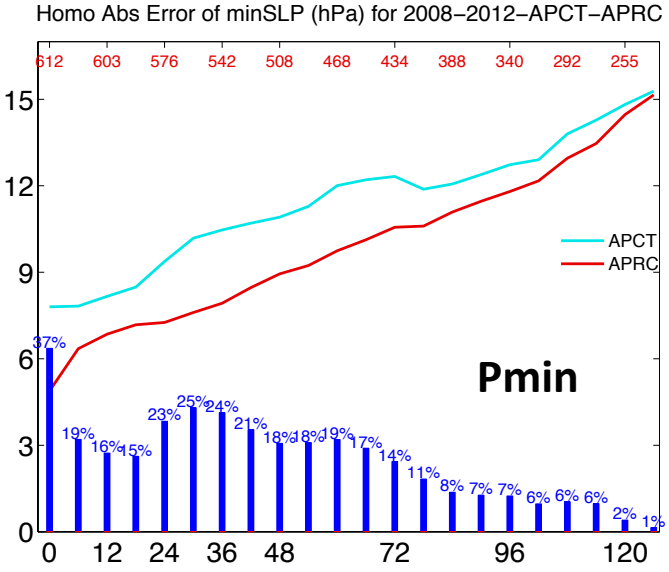


Mean absolute forecast error (solid lines) and bias (dash lines) averaged over all 758 APCT cases during 2008-2012 for the WRF deterministic forecasts initialized with operational GFS analysis ("ANPS", blue) and the WRF deterministic forecasts initialized with the cycling WRF-EnKF analysis with conventional observation assimilation ("APCT", cyan) .

PSU Cycling WRF-EnKF with Aircraft Recon and Conventional Data (APRC) versus "No Recon" (APCT)



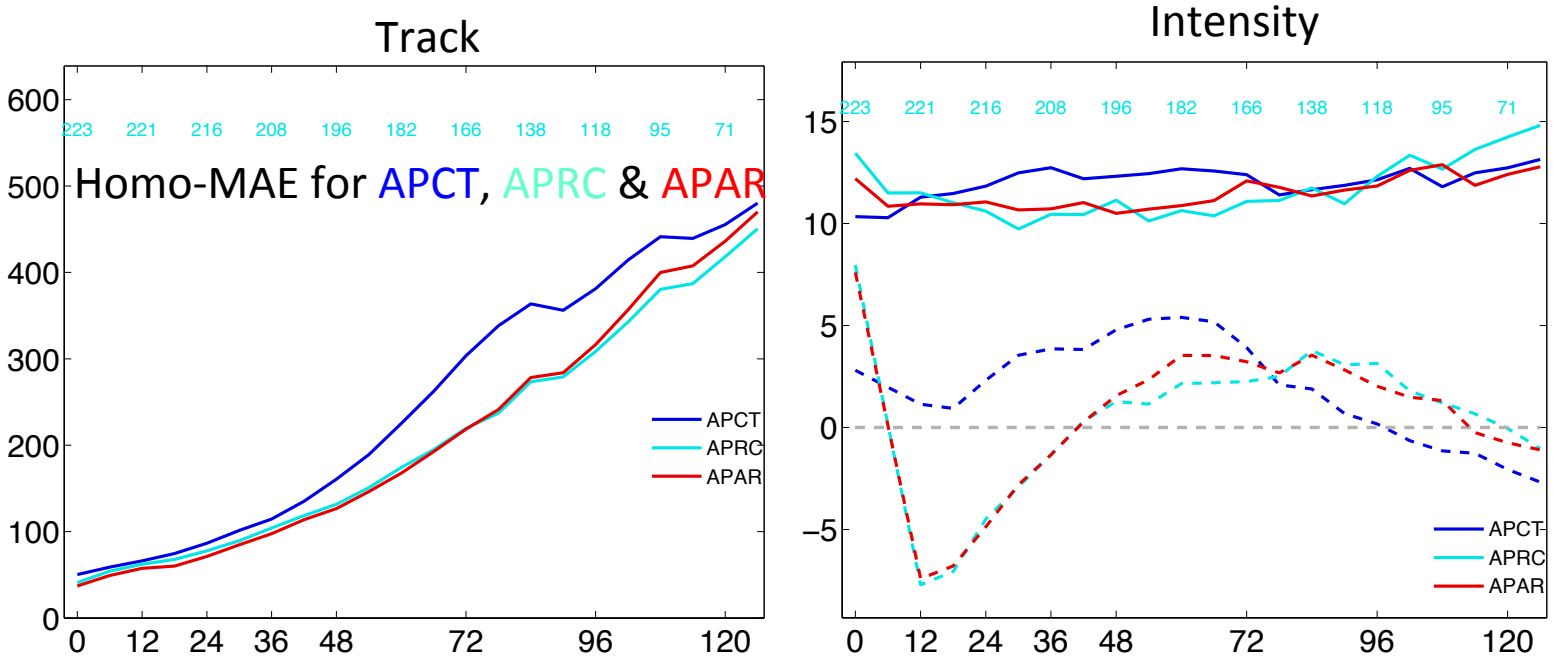




Mean absolute forecast error homogeneously averaged over all 636 APRC cases during 2008-2012 for APCT (cyan) and APRC (red). The blue bar on the bottom of each panel means the improvement of APRC in percent over APCT, while the red bar means APRC is worse than the APCT. The numbers of homogeneously samples are list on the top of each panel.

PSU Cycling WRF-EnKF with Aircraft Recon and Conventional Data (APRC) versus with Addition of P3 Doppler Vr (APAR)

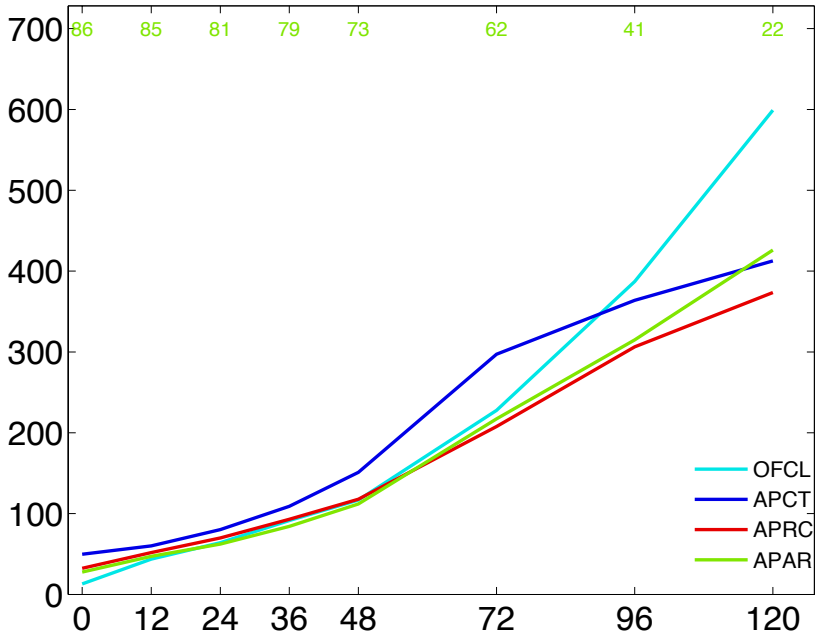
Verification of all storms at all times that have P3 TDR data



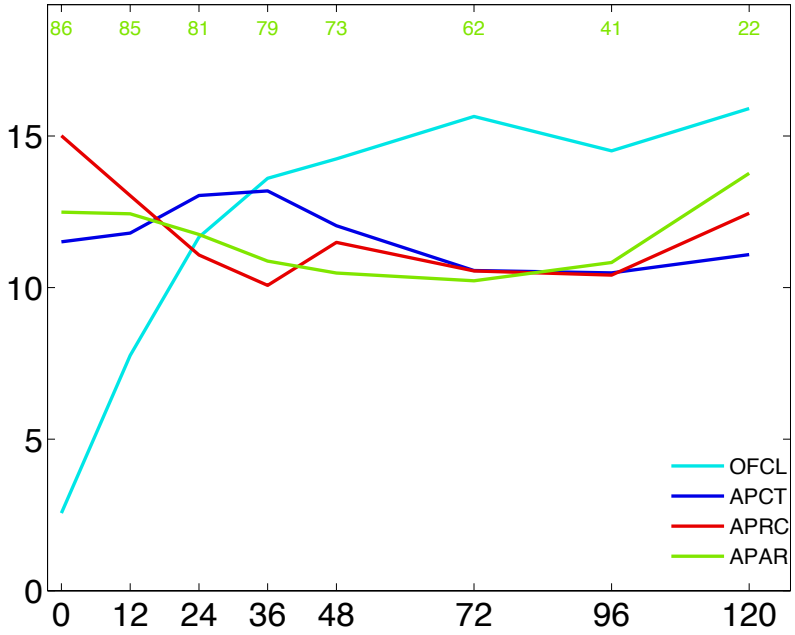
PSU Cycling WRF-EnKF with Aircraft Recon and Conventional Data (APRC) versus with Addition of P3 Doppler Vr (APAR)

Verification of only initial times right after P3 TDR mission

Track

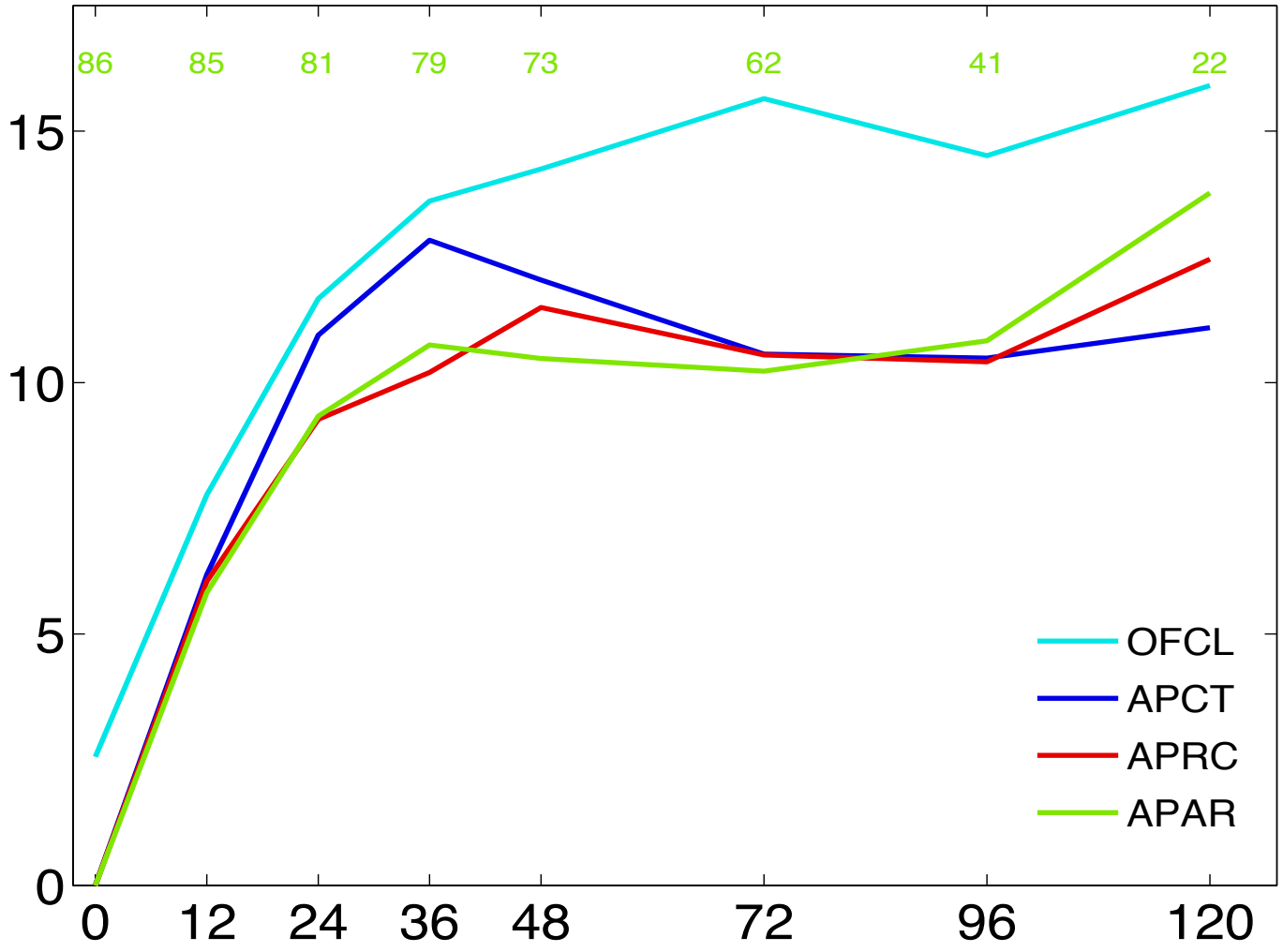


Intensity



PSU Cycling WRF-EnKF with Aircraft Recon and Conventional Data (APRC) versus with Addition of P3 Doppler Vr (APAR)

Verification of only initial times right after P3 TDR mission



Brief Summary

- Aircraft dropsonde and flight-level observations adds to the enhanced hurricane intensity prediction by the cycling convection-permitting PSU WRF-EnKF system.
- Given the intensity forecast error for limited number of test cases is already very low, there is no apparent further improvement in intensity forecast in further assimilating high-resolution airborne Doppler data.

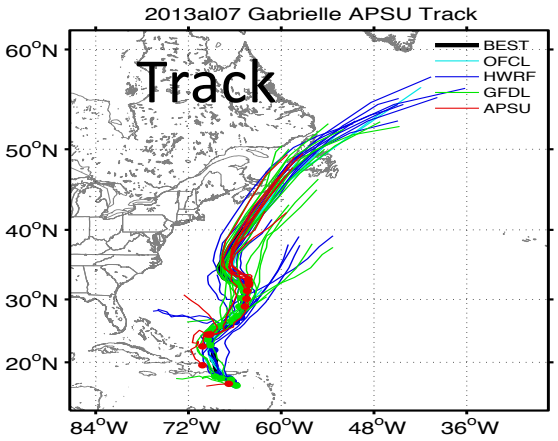
PSU 2013 Stream 1.5: Real-time Cases

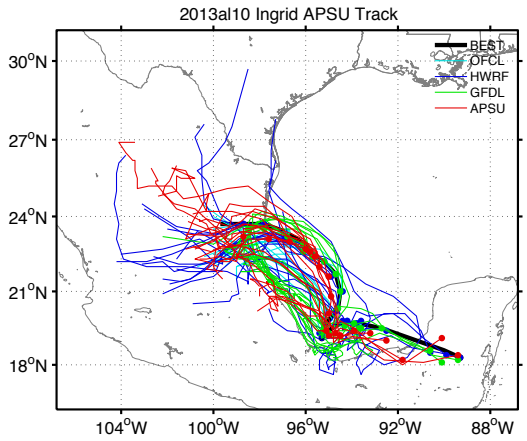
Table , APSU cases in NHC ATCF system.

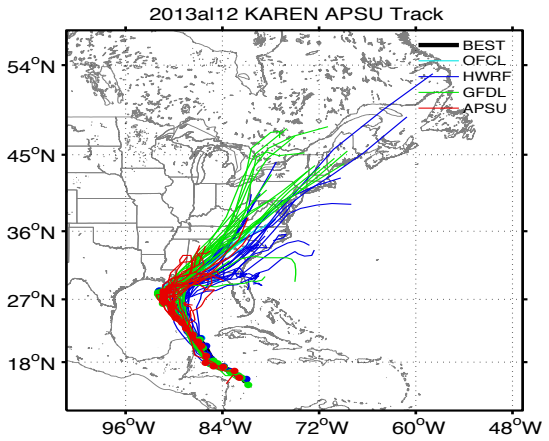
Storm	Sample size	Cases	Aircraft missions
Al03 Chantal	6	201307: 0912, 1000, 1006, 1012, 1100, 1106	08-10/07 USAF 5 missions
Al04 Dorian	9	201307: 2400-2612 every 6h	28-29/07 USAF 2 missions
Al05 Erin	4	201308: 1800-1818	NO
Al06 Fernand	6	201308: 2500-2512, 2600-2612	25/08 USAF 1 mission
Al07 Gabrielle	14	201309: 0418-0500, 0518, 0618, 0706, 0718-0806, 1006-1112	30/08-12/09, 14 NOAA + 5 USAF
Al10 Ingrid	21	201309: 1118-1618	12-16/09, 9 NOAA + 8 USAF
Al11 Jerry	7	201309: 3000-3012, 201310: 0112-0118, 0206, 0218, 0300	NO
Al12 Karen	22	201310: 0100-0606	02-05/10, 5 NOAA + 7 USAF
Al13 Lorenzo	12	201310: 2118-2412	NO
Al95 Invest	11	201309: 1800-2012	NO
Al98 Invest	11	201310: 0706-0918	NO
Total: 11 storms	123	Data source: ftp://ftp.tpc.ncep.noaa.gov/atcf	

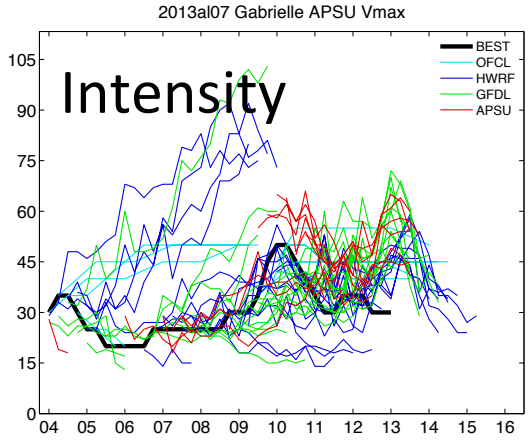
PSU WRF-EnKF 2013 Stream 1.5: Recon Cases

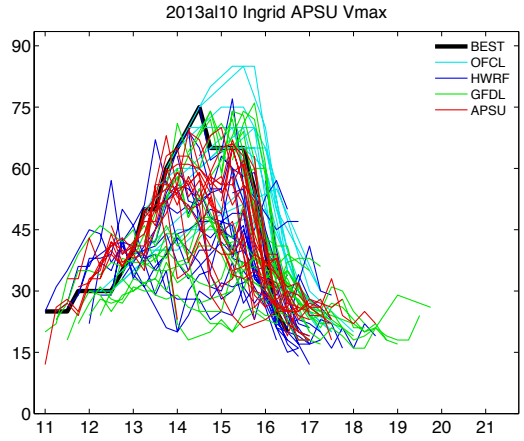
Total 56 recon missions: 48 missions for Gabrielle, Ingrid and Karen

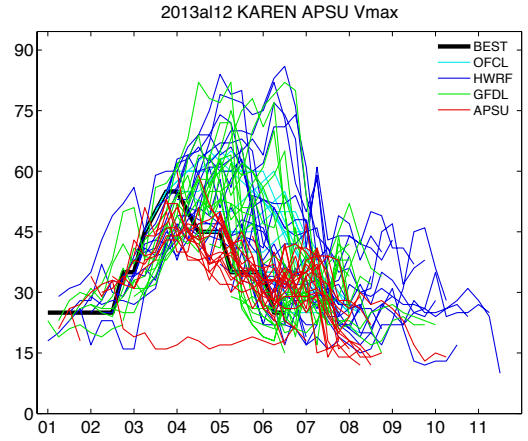






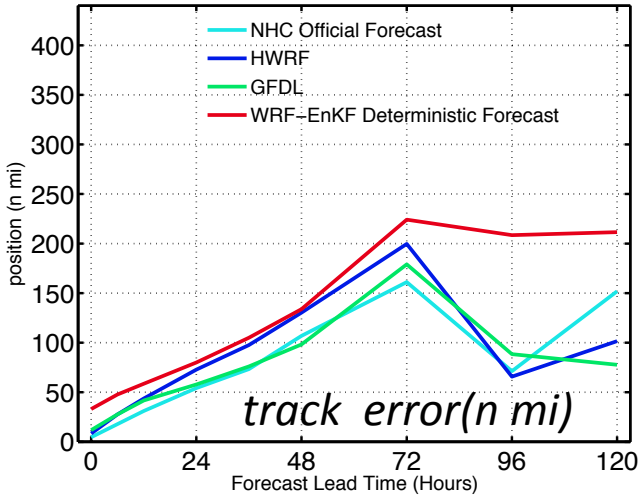


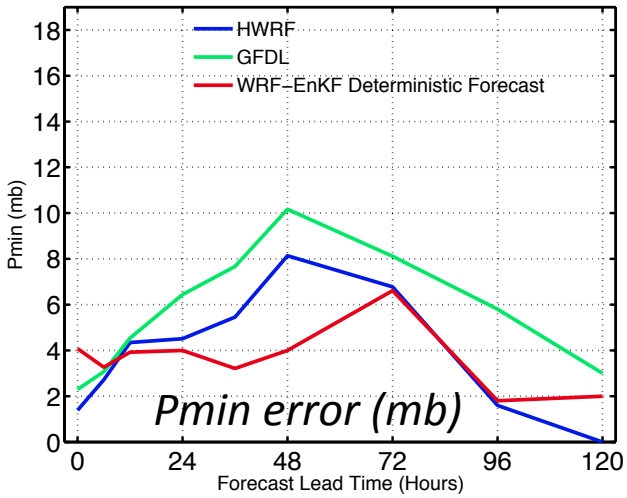


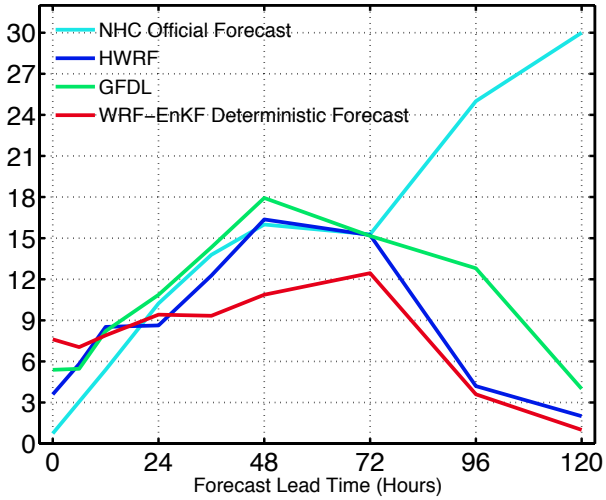


Gabrielle Ingrid Karen

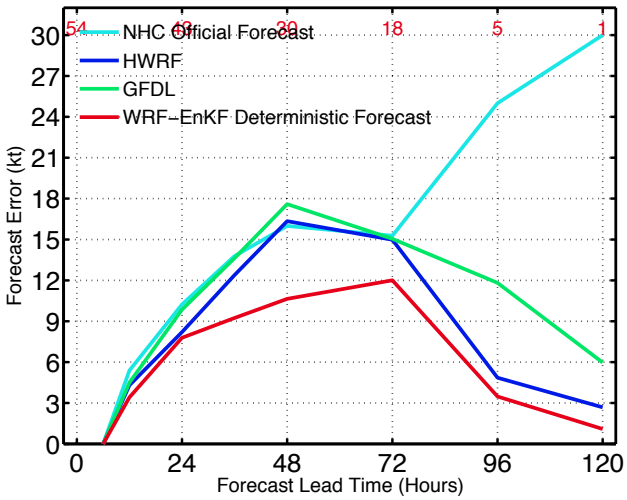
PSU WRF-EnKF 2013 Real-time Performance







Vmax error (kt)



Bias-corrected Vmax error (kt)

Mean absolute forecast errors homogeneously averaged for 2013 stream 1.5 APSU (red), operational OFCL (cyan), HWRF (blue) and GFDL (green).