Testing and Evaluation of the GSI-Hybrid Data Assimilation and it Applications for High-resolution Tropical Storm Forecasts

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Motivation

GSI-Hybrid 3DVAR

$$J(x,\alpha) = \beta_1 J_b + \beta_2 J_e + J_o$$

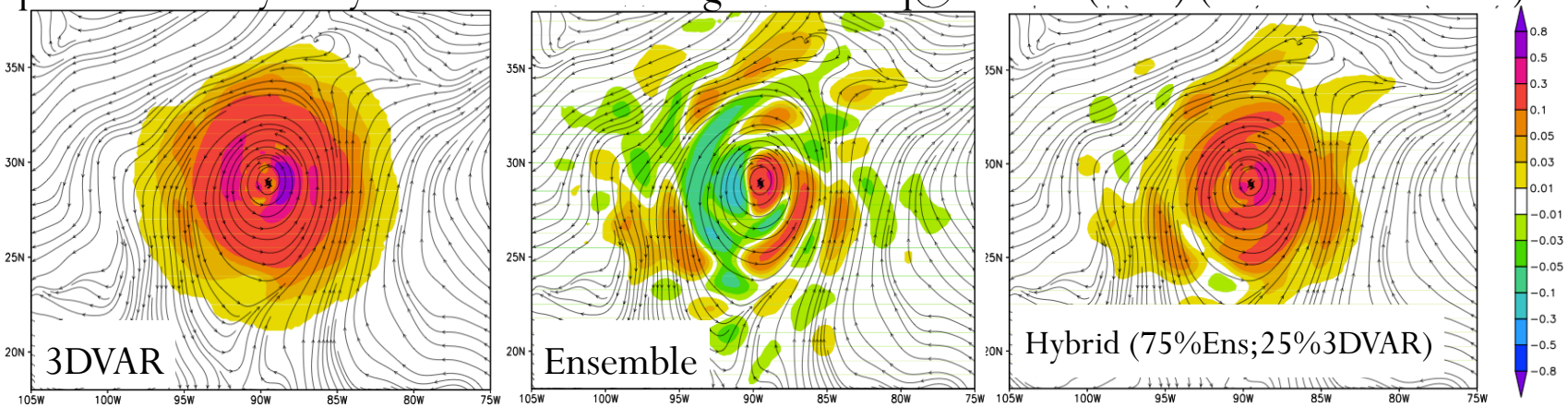
3DVAR

ensembles

extended control variables

$$= \beta_1 \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \beta_2 \frac{1}{2}\alpha^T A^{-1}\alpha + \frac{1}{2}[y - H(x + x_e)]^T R^{-1}[y - H(x + x_e)]$$

Specific humidity analysis increments for single obs test q@ 700mb (Isaac) (HWRF 2012 Basin)



Even with 75% ens. contributions, the 3DVAR contribution is still overwhelmingly dominant.

- Tune the variance of static background errors (BE)
- Improve ensemble representation -
  - Ensemble selection: HWRF ensemble versus GFS ensemble

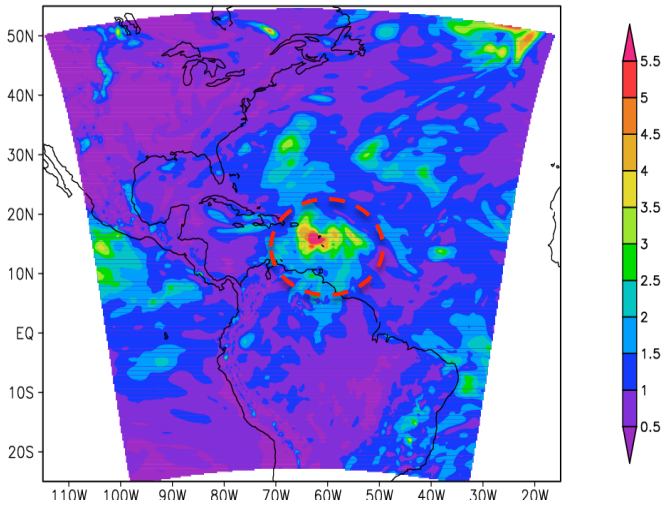
Ensemble Selection: HWRF vs GFS

- HWRF ensemble:

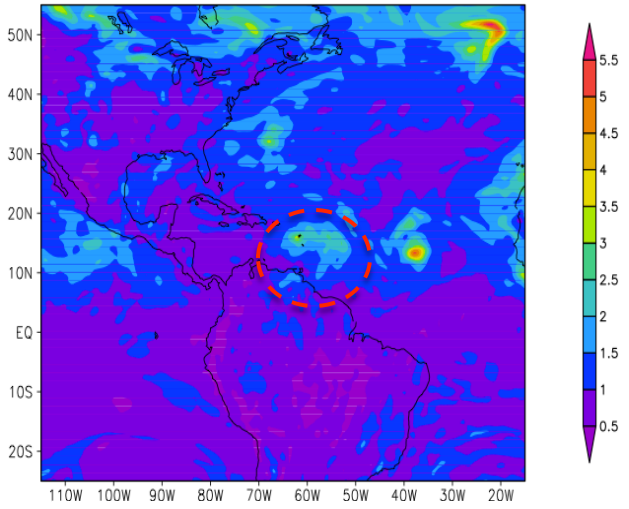
  Generated by DTC using EMC 2013 code & configuration (provided by Zhan Zhang)

  -- Model physics perturbation with stochastic convective trigger

  -- 20 member GEFS (Ensemble Transform with Rescaling (ETR) based) for IC/ BC perturbations



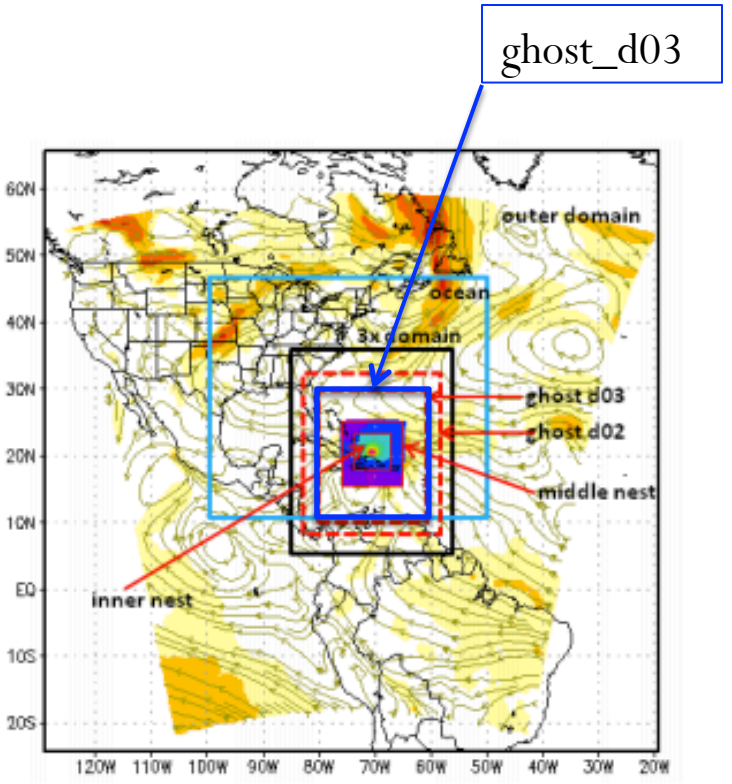
HWRF (20) ensemble spread



GFS (80) ensemble spread

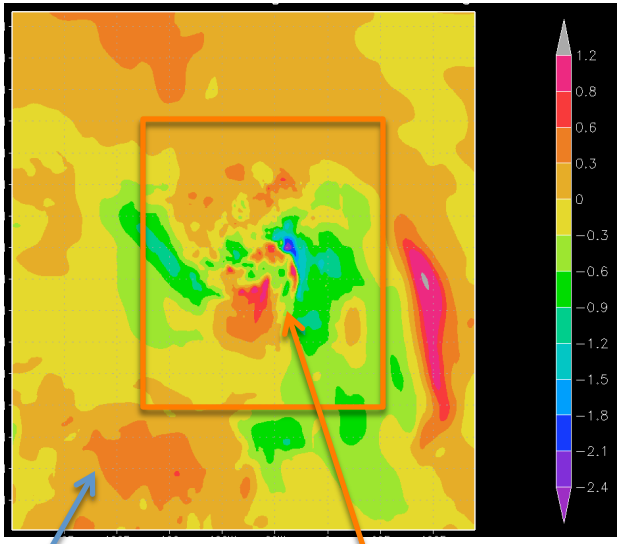
Experimental design

- Generated HWRF regional ensemble (20 members)
  - Analysis time
  - 6-hr forecasts
- Generated ensemble for ghost_d03 domain
  - Merging HWRF ensemble for outer domain & HWRF ensemble for inner nest, using prior 6-h forecasts (domains move following TC)
- Conducted 2 sets of experiments for Isaac (2012):
  - **GLBL**: GSI-hybrid & HWRF runs using GFS ensemble (80 members, 0.46 deg) for both outer (0.18 deg, 27km) and ghost domains (0.02 deg, 3km). Only conventional data and TDR (when available) were assimilated. -- similar to 2013 HWRF operational configuration
  - **RGNL**: Similar to GLBL, except DA for ghost_d03 used merged ensemble from step 2.



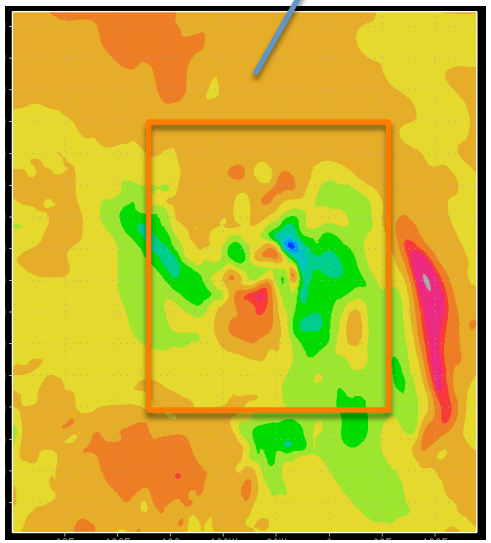
2013 HWRF operational domains

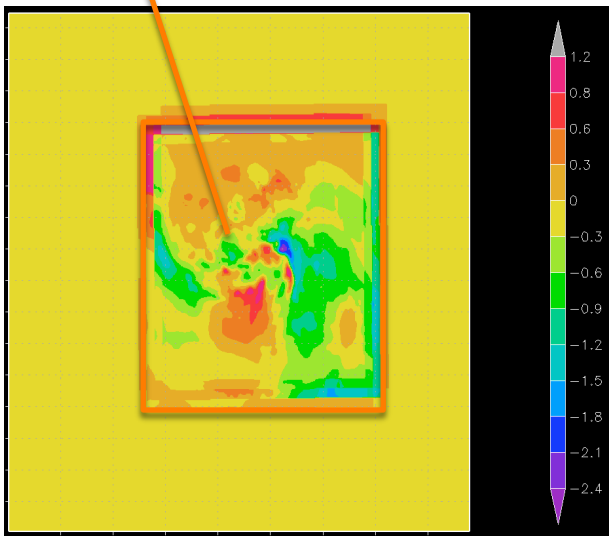
How does the ensemble merging work for ghost_d03?



u perturbation on ghost_d03 -- merged ensemble member 001

u perturbation on ghost_d03 -- d1 ensemble member 001

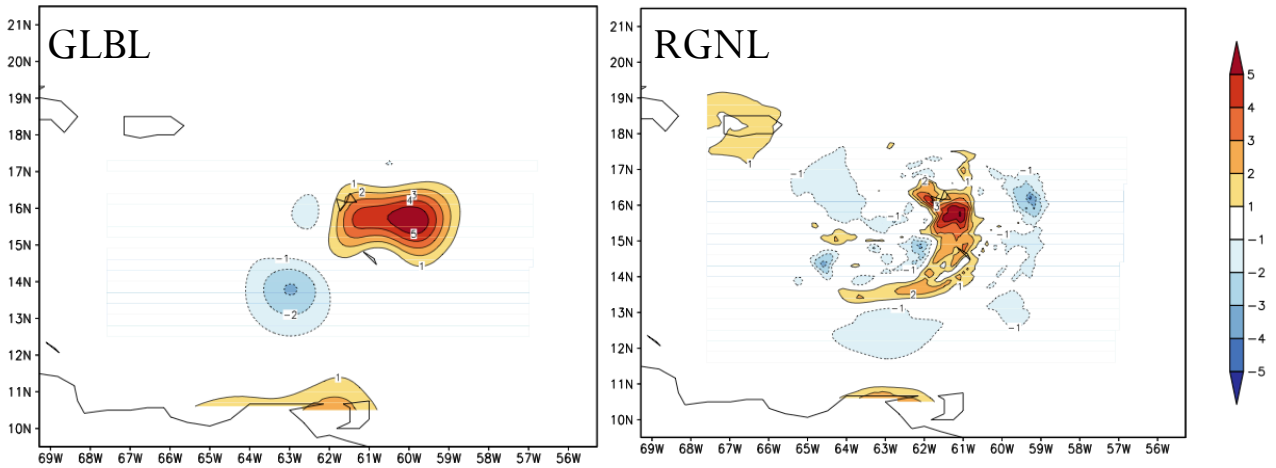




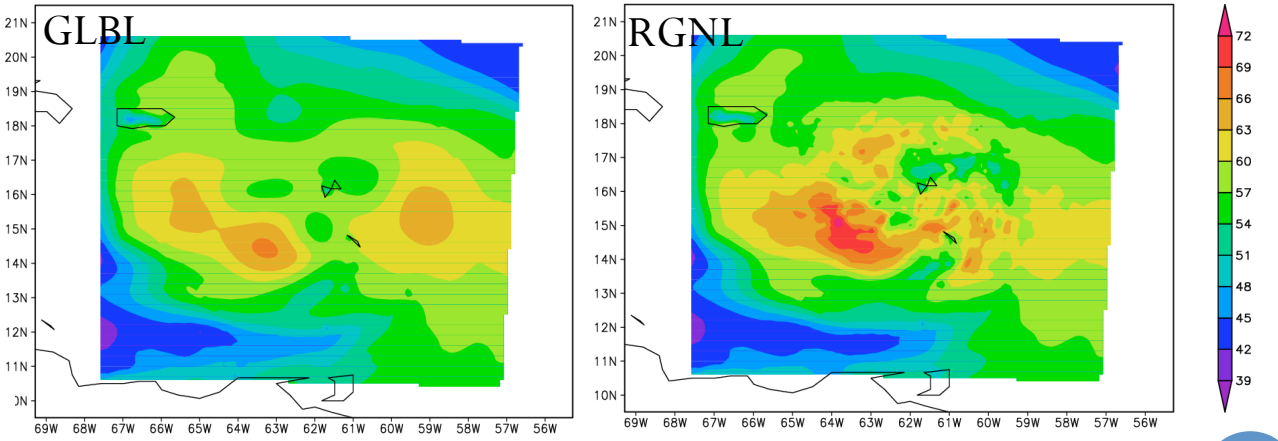
u perturbation on ghost_d03 -- d2 ensemble member 001

Analysis results

- RGNL analyses provides better flow-dependent and finer scale structures.
- Similar results were found for other analysis times and fields.



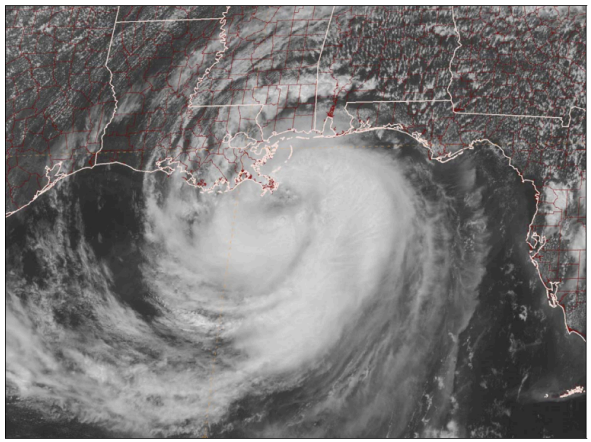
Analysis increments for 850hPa geopotential height



Column precipitable water at analysis time

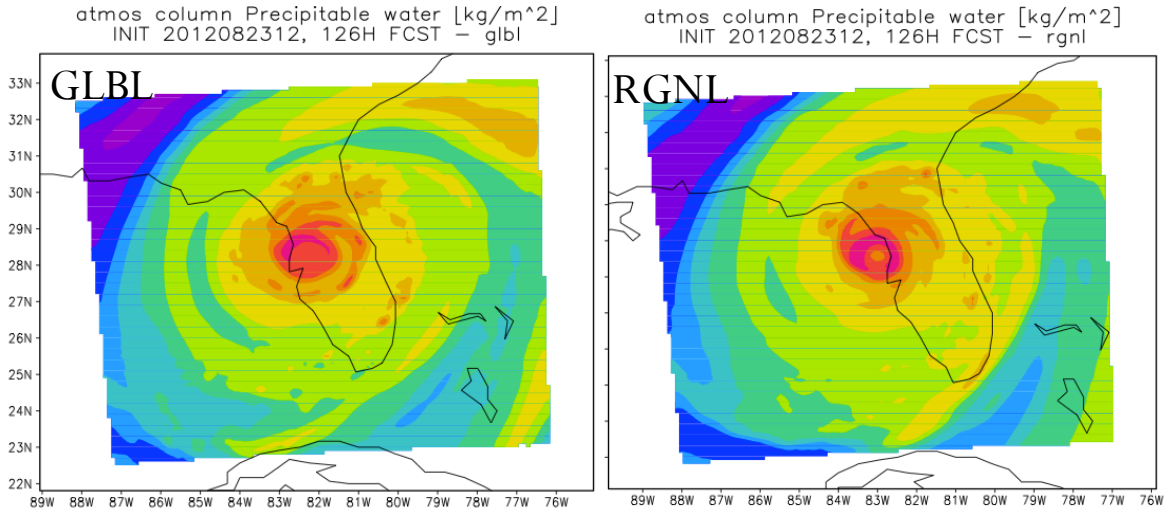
Forecast verification

RGNL (using HWRF ensemble for inner domain DA) gives more realistic hurricane structure than GLBL



e 4. GOES-13 visible satellite image of Hurricane Isaac approaching the coast of Louisiana at 1815 UTC 28 August 2(when it reached its peak intensity of 70 kt.

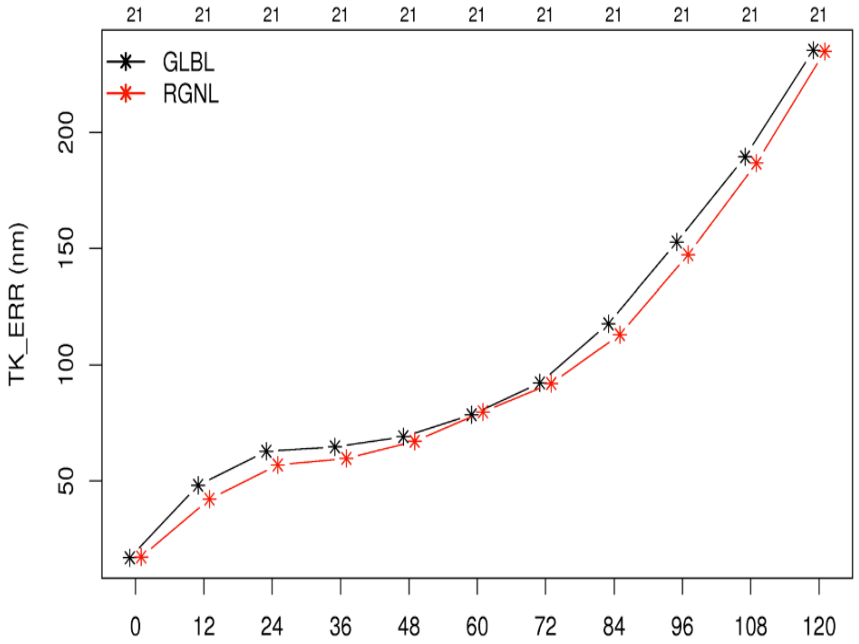
GOES visible image at 1815Z Aug 28, 2012



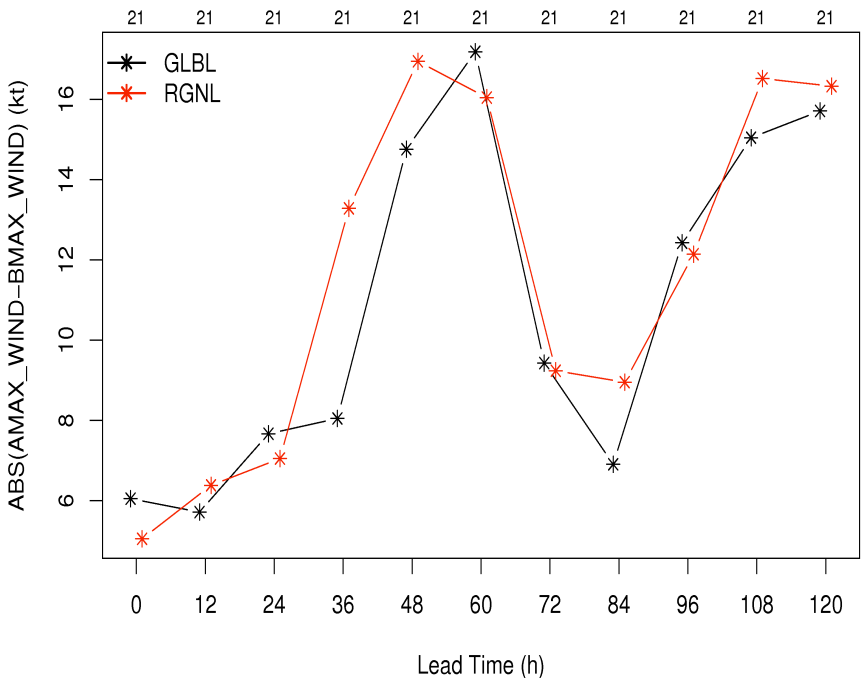
Column precipitable water 126-h forecasts initialized at 12Z Aug 23, 2012

Forecast verification (Isaac 2012)

Track Errors (nm)



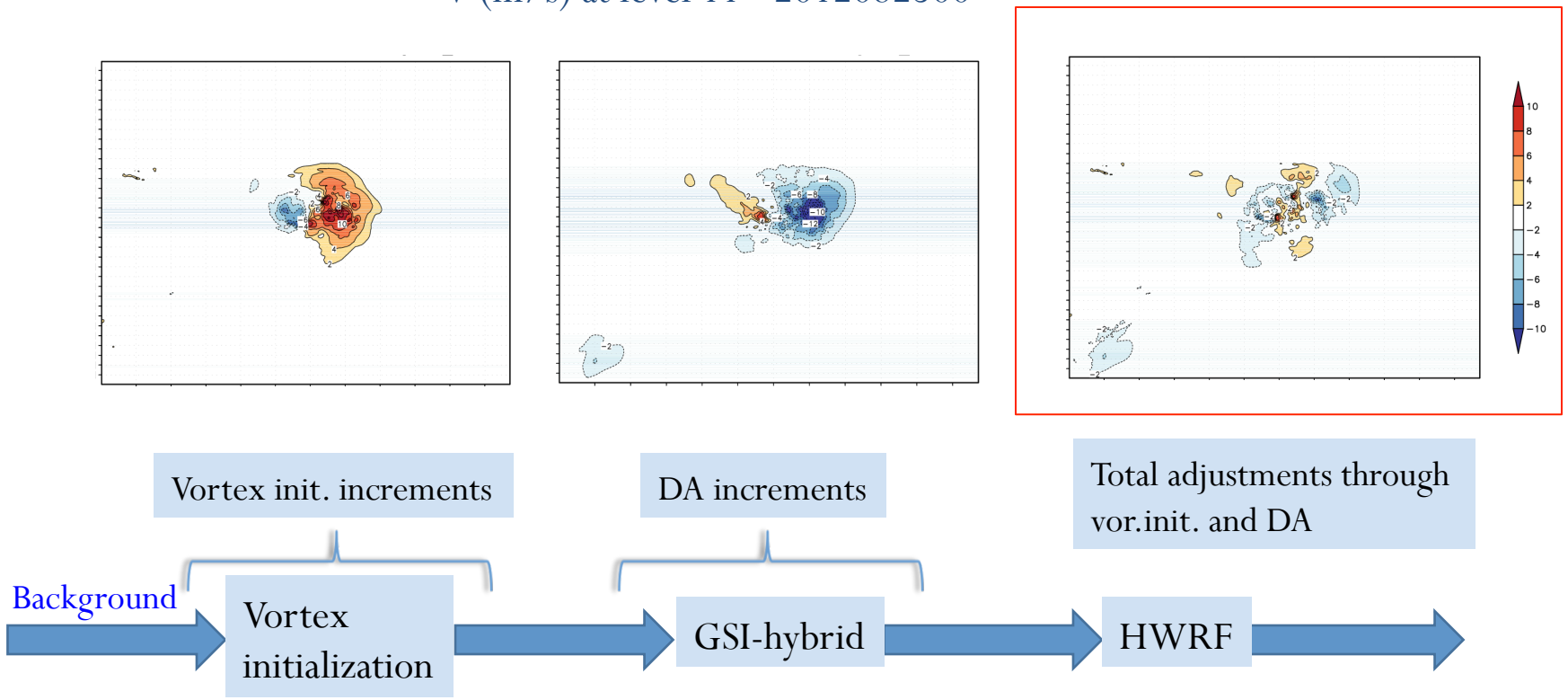
Intensity Errors (kt)



RGNL (using HWRF ensemble for inner domain DA):

- Improvements on track forecasts
- Neutral or negative impact on intensity forecasts

Impacts of vortex initialization vs DA

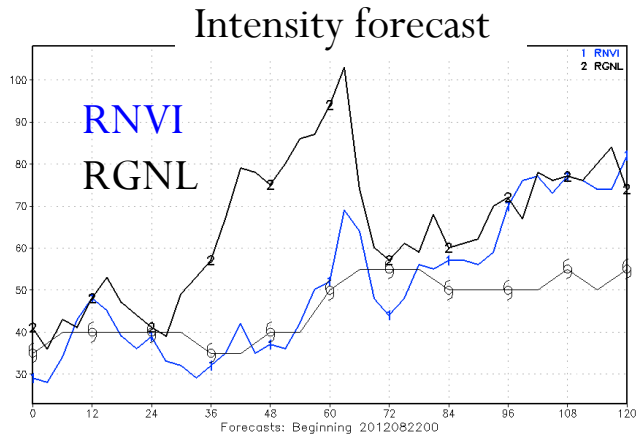


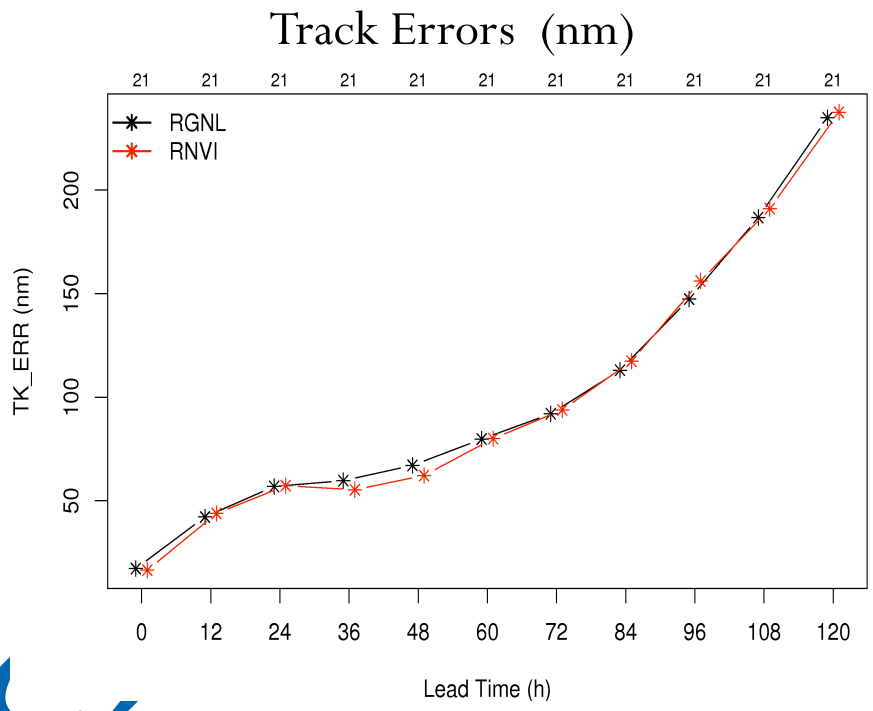
- For this case study (with TDR data and using HWRF ensemble), the vortex initialization counter-acts with the DA analysis increments in the inner domain.

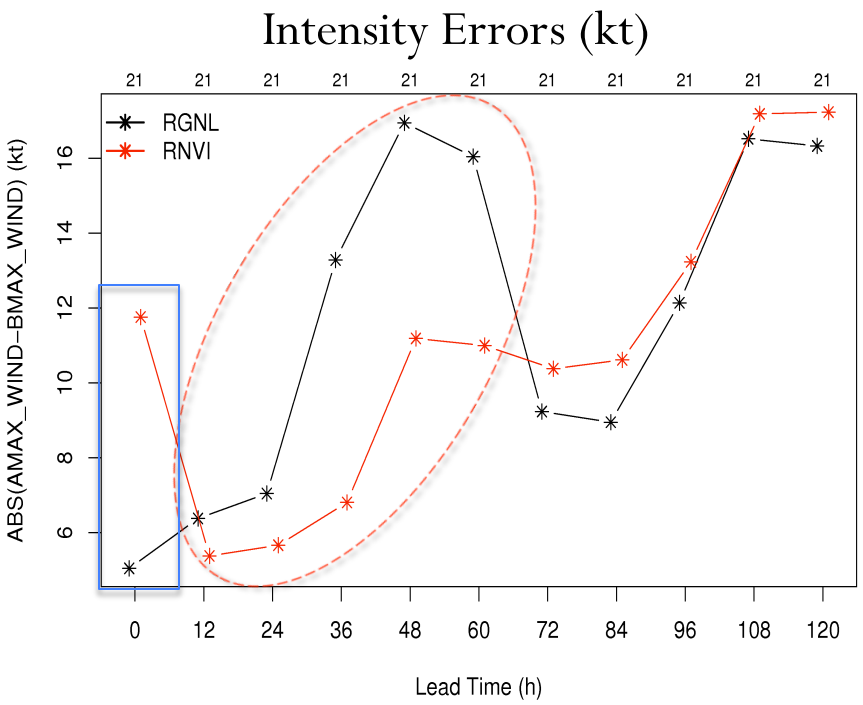
Impact of vortex initialization

- RNVI: similar to RGNL, but without vortex initialization (Isaac 2012)

✓ Since there is no vortex initialization involved, the total adjustment to the background is through GSI, or, GSI analysis increment.

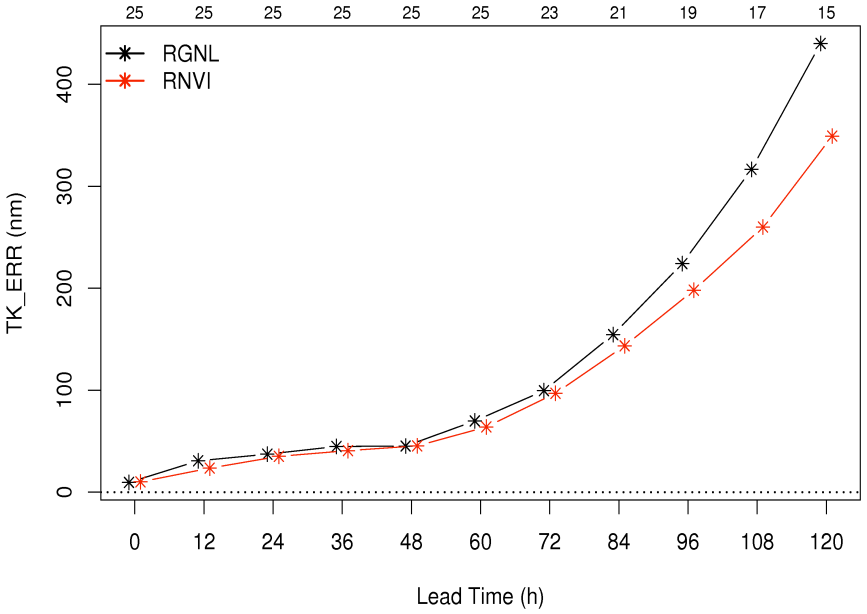




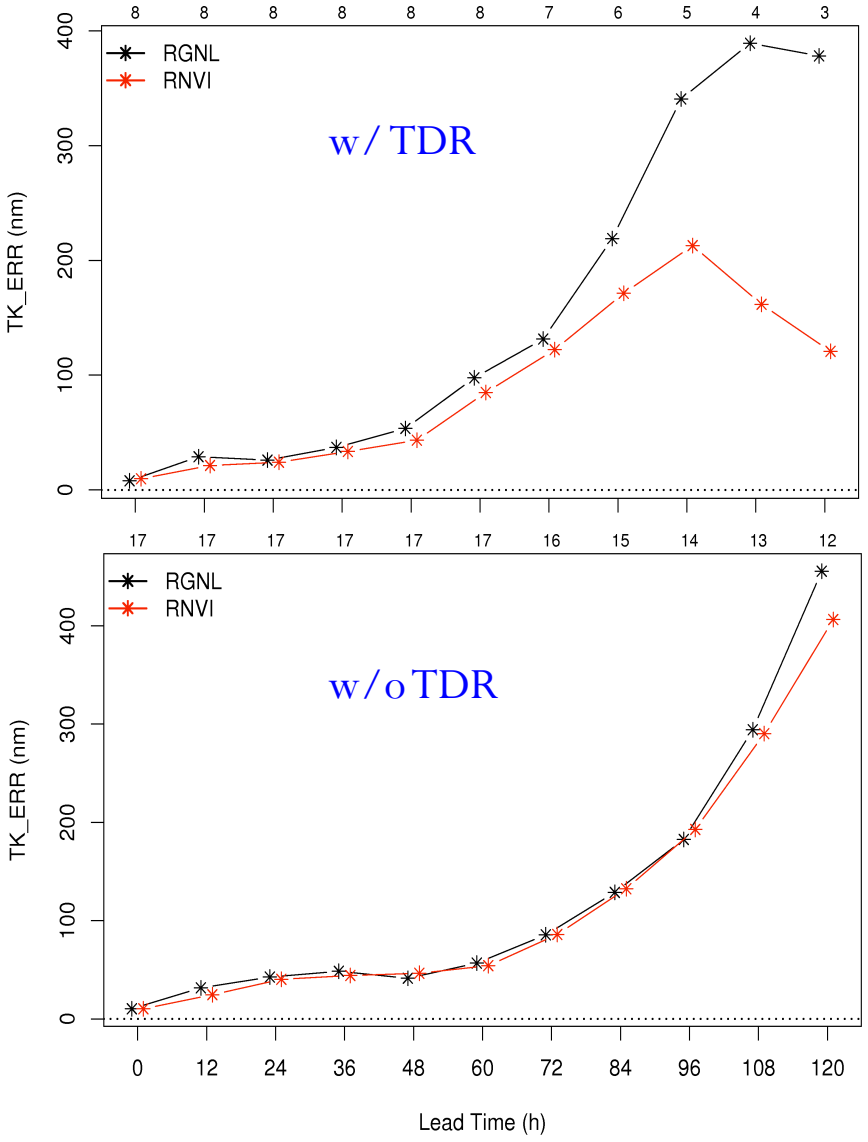


Impact of vortex initialization

- RNVI: similar to RGNL, but without vortex initialization (Sandy 2012)



Track Errors



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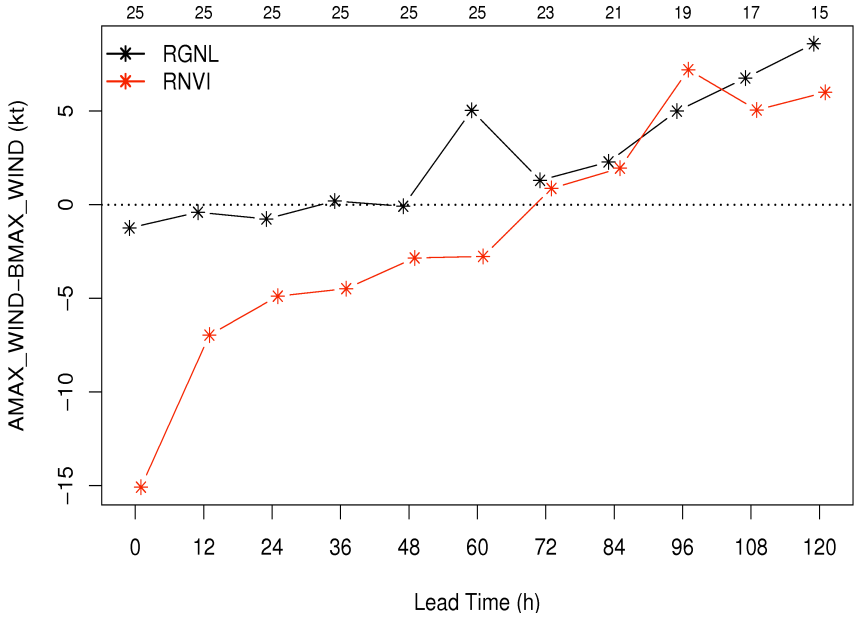
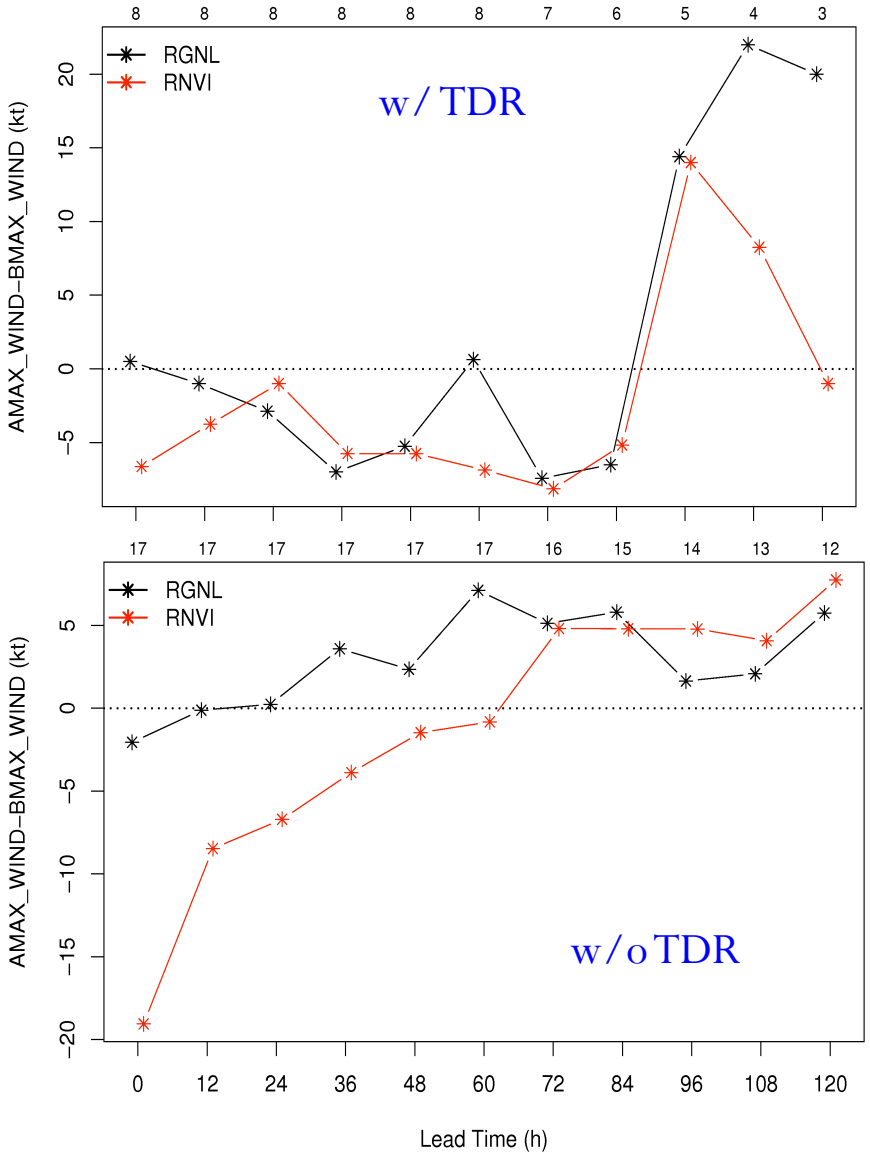
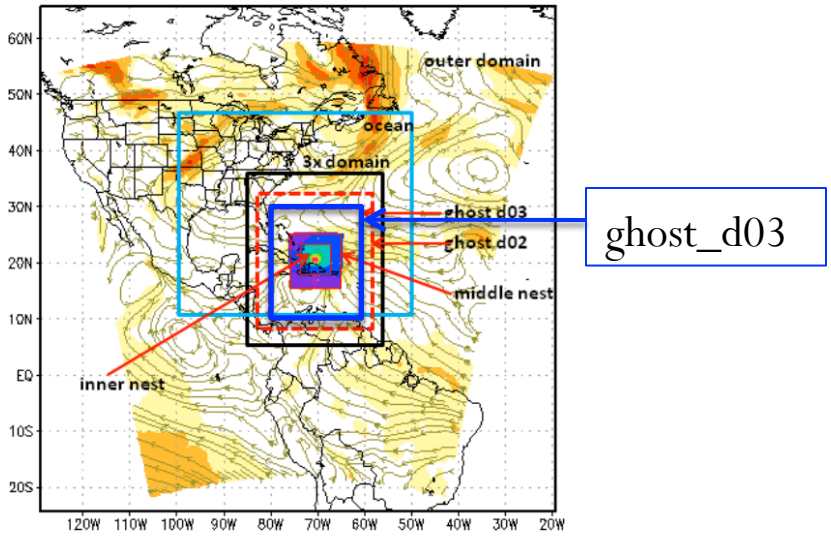


Intensity Bias



RWRM: new experiment with HWRF background for the inner domain DA

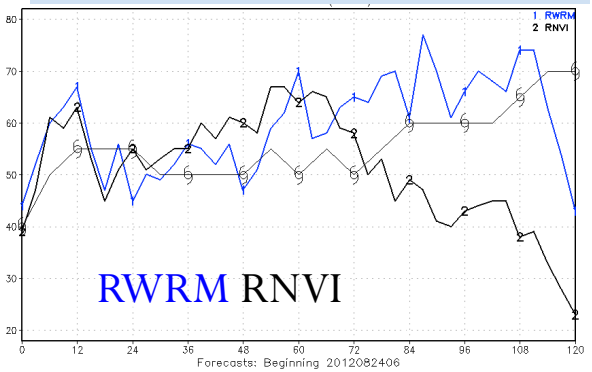
Cases: Isaac and Sandy for 2012 season

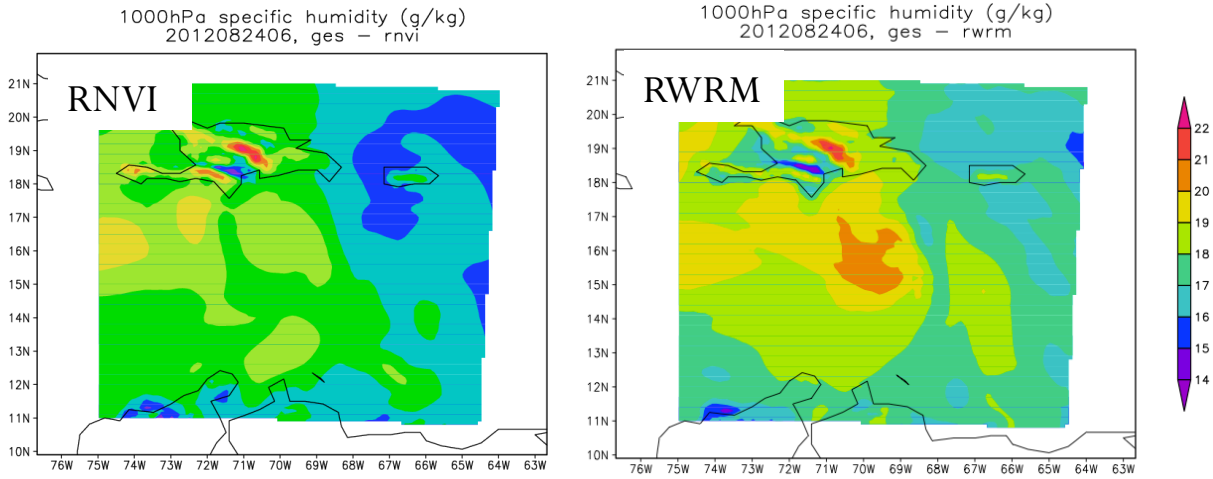


Experiment	Outer domain DA	Inner domain (ghost_d03) DA
RNVI (no vortex init.)	GDAS 6hr fcst background, GFS ensemble	GDAS 3hr,6hr and 9hr fcst background (FGAT), HWRF ensemble
RWRM (no vortex init.)	GDAS 6hr fcst background, GFS ensemble	HWRF 3hr,6hr and 9hr fcst background (FGAT), HWRF ensemble

GSI background

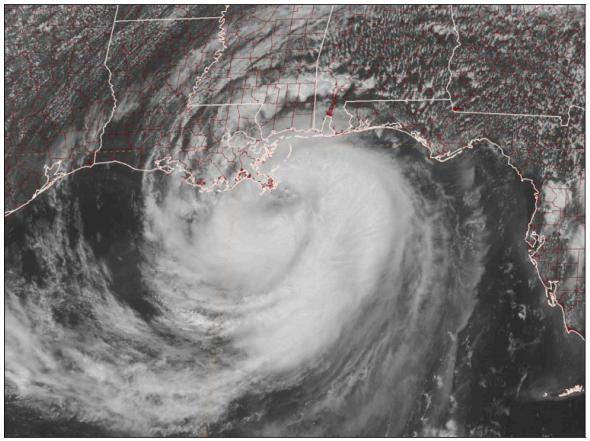
Intensity forecast at 06Z Aug 24, 2012





Specific humidity@1000mb at 06Z Aug 24, 2012

Forecast verification



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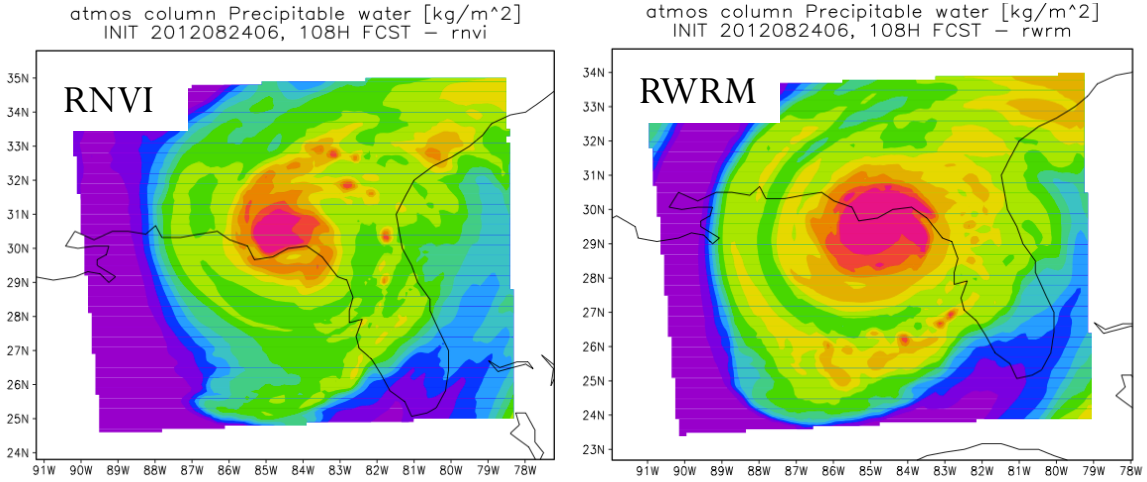
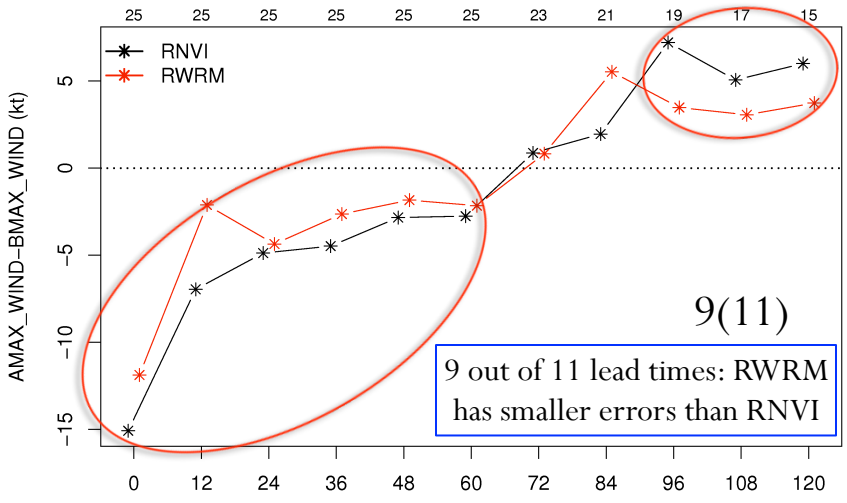


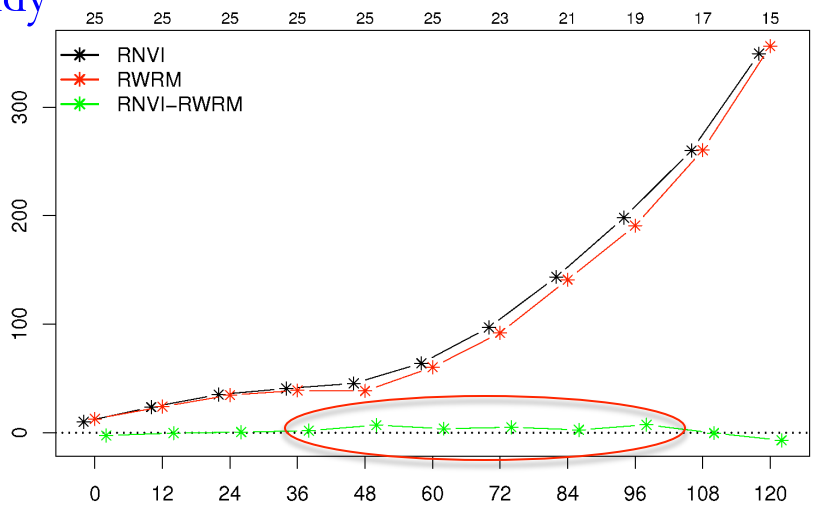
Column precipitable water 108-h forecasts initialized at 06Z Aug 24, 2012

Mean Intensity Bias

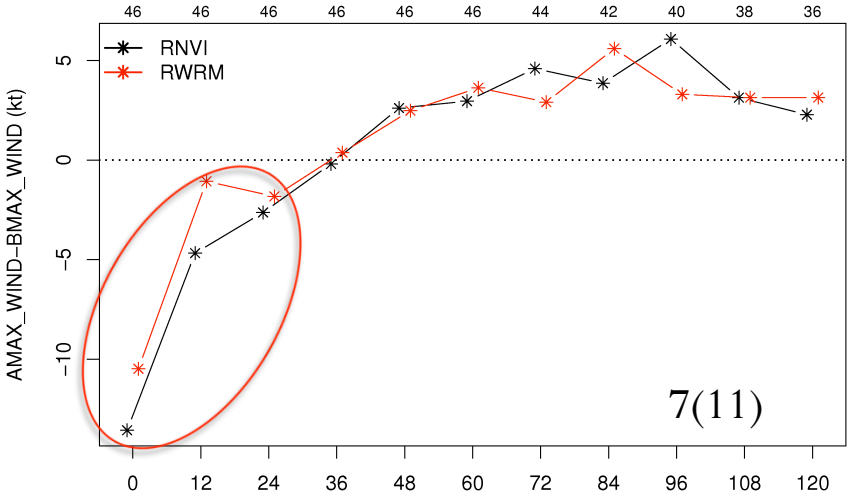
Mean Track Errors

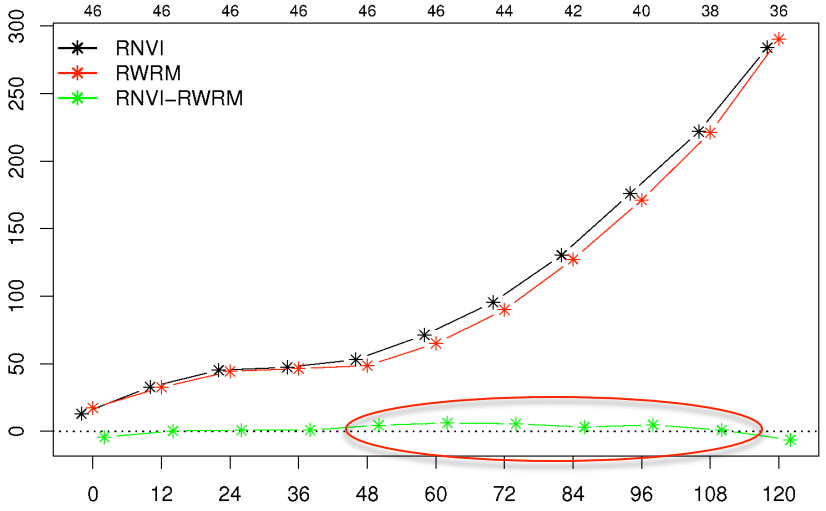
Sandy





Aggregated errors for Isaac and Sandy





Summary

- HWRF regional ensemble provides
  - Larger ensemble spread around TC areas (inner domain)
  - More realistic analysis increments with better flow-dependent features
- Minimal impacts on TC track and intensity forecasts were found by using HWRF ensemble vs GFS ensemble
  - Vortex initialization and DA not working well together
  - Removing vortex initialization gives better intensity forecast in this case study, when TDR assimilated for the inner domain
- Using HWRF background for the inner domain DA gives some improvements on the track and intensity forecasts, compared to GDAS background for the inner domain DA
- Ongoing/future work
  - Further investigations on the the roles of vortex initialization and data assimilation, in the framework of 2014 HWRF
  - Extensive testing for one or more seasons, for both strong and weak storms
  - Data impacts for the inner domain DA
  - Two-way Hybrid Ensemble DA