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Testing and Evaluation of GSI-Hybrid Data Assimilation and Its Applications for HWRF at the Developmental Testbed Center

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DTC Developmental Testbed Center

Data Assimilation Activities at DTC

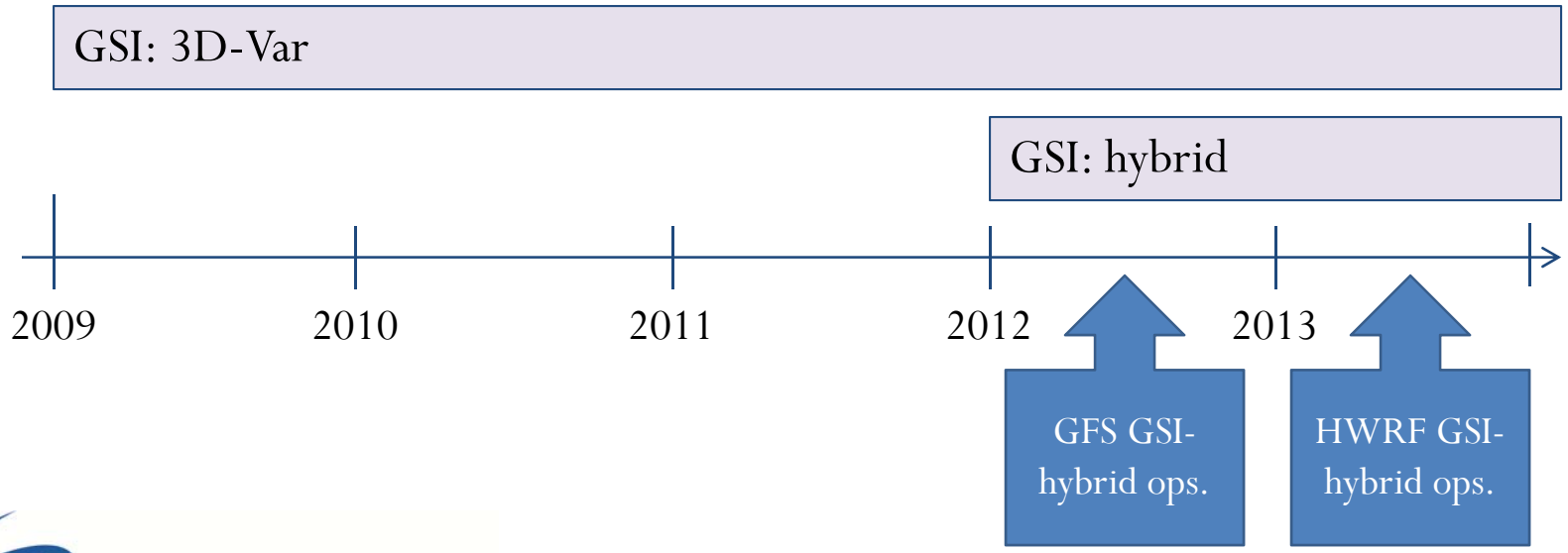
- Gridpoint Statistical Interpolation (GSI) Code Management

Global
- GFS*
- NASA GEOS

Regional
- NAM*:NMM-B
- HWRF*:NMM
- RAP*:ARW
- AFWA meso:ARW
- RTMA*

* NOAA ops.

- Community Support
- Testing and Evaluation (T&E)



GSI-hybrid T&E for HWRF

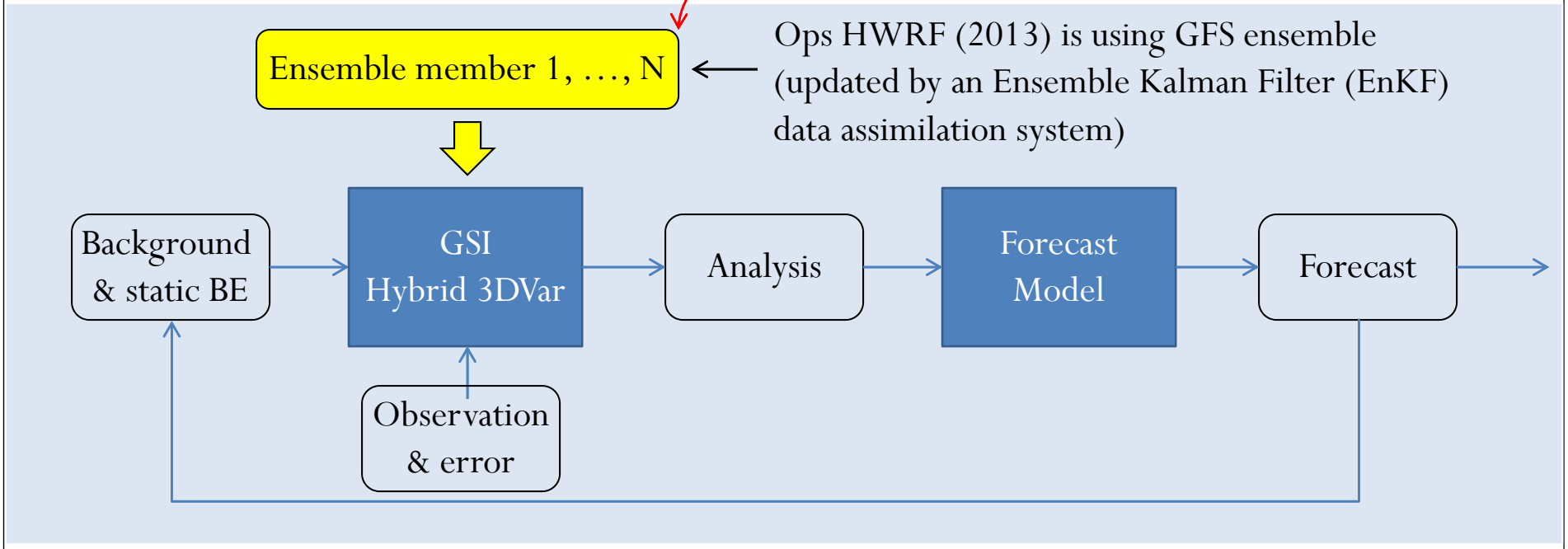
- Data assimilation in outer domain (large scale) (2012)
  - GSI-hybrid (using GFS ensemble) versus GSI (3D-Var)
  - Cycling scheme for GSI-hybrid: cold start, partial cycling
  - Tuning relative contributions of ensemble and static background errors (BE)
  - Data impacts: conventional, GPS radio occultation (RO) data
- Data assimilation in high-resolution moving nests (2013)
  - GSI-hybrid using regional ensembles vs. using GFS ensembles
  - Vortex initialization vs. data assimilation

GSI Hybrid Variational-Ensemble System

$$J(\mathbf{x}) = \frac{\beta}{2}(\mathbf{x}-\mathbf{x}_b)^T \mathbf{B}_{Var}^{-1}(\mathbf{x}-\mathbf{x}_b) + \frac{1-\beta}{2}(\mathbf{x}-\mathbf{x}_b)^T \mathbf{B}_{Ens}^{-1}(\mathbf{x}-\mathbf{x}_b) + \frac{1}{2}(\mathbf{y}-H\mathbf{x})^T \mathbf{R}^{-1}(\mathbf{y}-H\mathbf{x}) + J_c$$

Background term

Observation term+Constraint



x: Analysis vector

$\mathbf{x}_b$: background vector

$\mathbf{B}_{Var}$: Static background error estimated offline

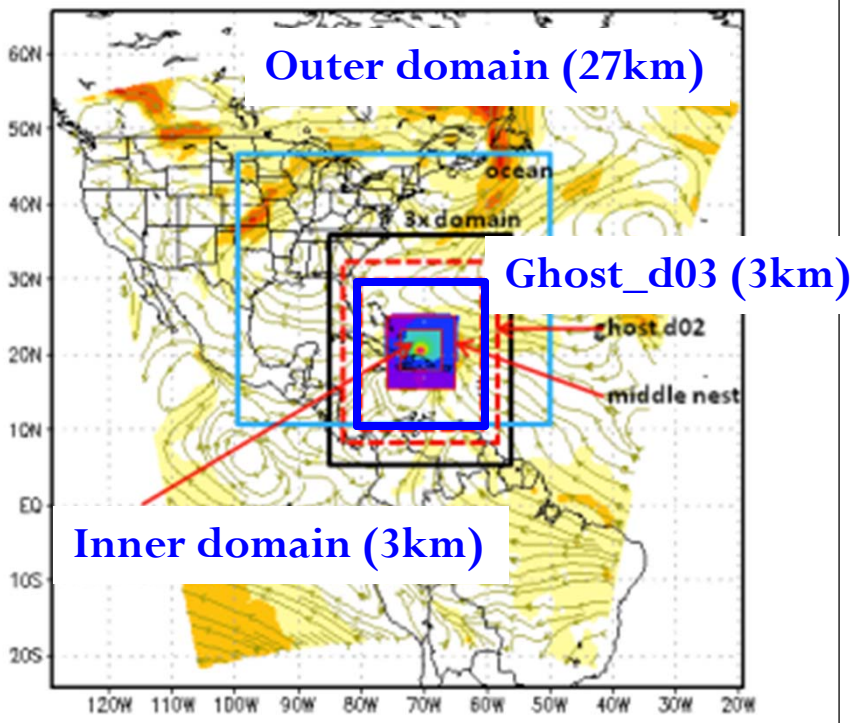
$\mathbf{B}_{Ens}$: (Flow-dependent) background error estimated from ensemble

β: Weighting factor (0.25 means total **B** is ¾ ensemble)

Data assimilation in moving nests

- Generated ensemble for ghost_d03 domain
  - Merged from HWRF ensembles for outer domain & middle nest (domains move following TC)
- Conducted 2 sets of experiments for Isaac (2012) and Sandy (2012):

  6 hourly DA in outer and ghost_d03, then forecasts in outer and inner domains
  - **GLBL**:
    - GSI-hybrid using GFS ensemble (80 members, 0.46 deg)
    - Outer domain: conventional data
    - Ghost_d03 domain: conventional and NOAA P3 tail Doppler radar (TDR)
  - **RGNL**: Same as GLBL, except DA for ghost_d03 used HWRF ensemble (20 members, 9km) from step 2.

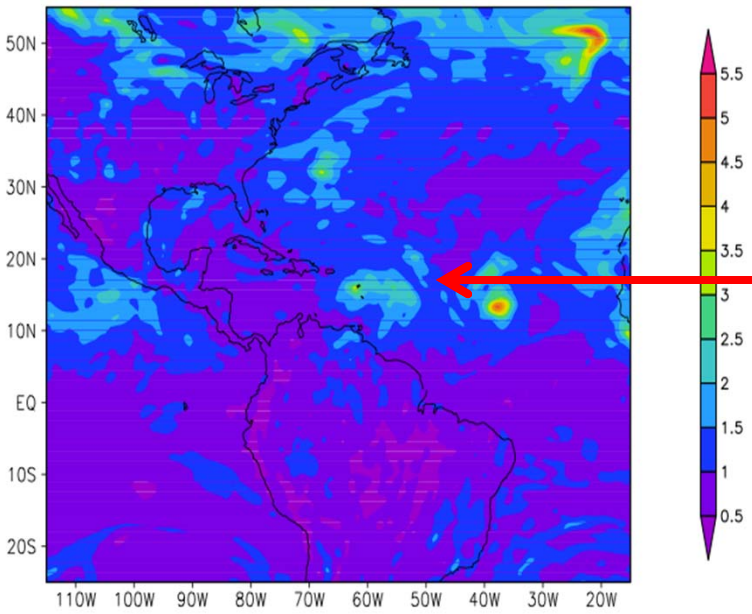


2013 HWRF operational domains

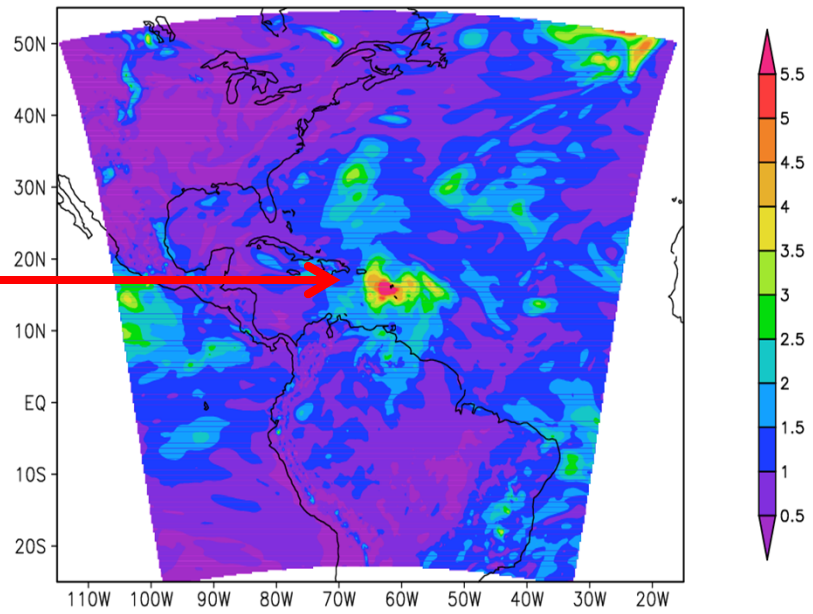
GFS vs. HWRF ensemble

HWRF ensemble generated by DTC using EMC's HWRF ensemble code (provided by Zhan Zhang, 2013):

- Model physics perturbation with stochastic convective trigger, 20 member GEFS (Ensemble Transform with Rescaling (ETR) based) for IC/BC perturbations



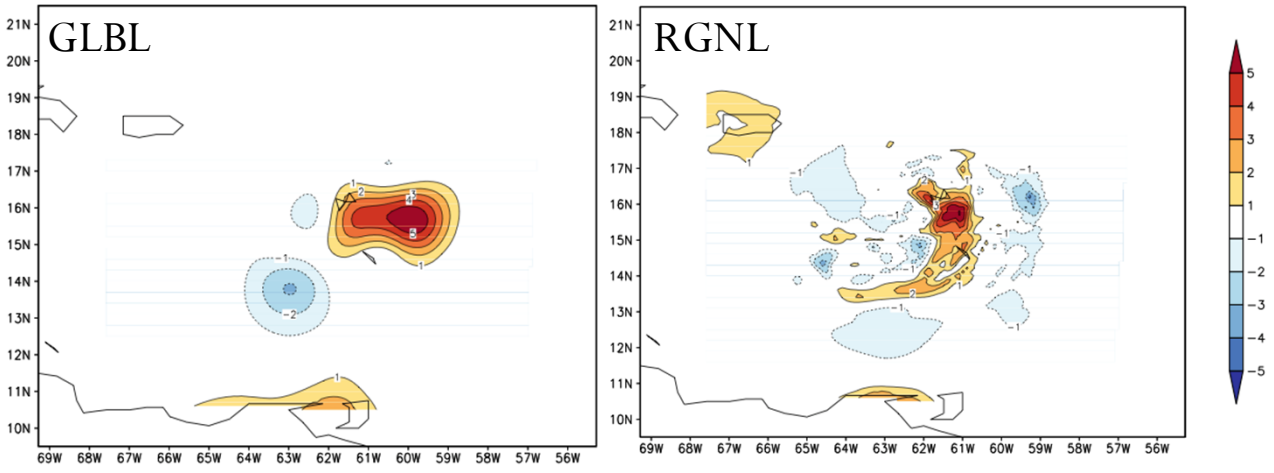
GFS ensemble (ENKF based, 80 members) spread



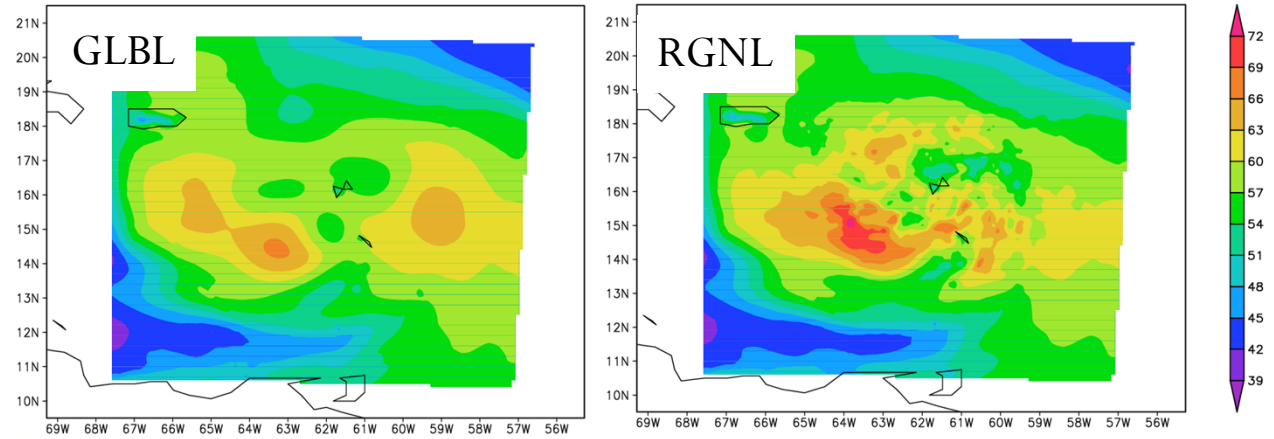
HWRF ensemble (20 members) spread

Analysis results

- RGNL analyses (with TDR assimilated) provide better flow-dependent and finer scale structures.
- GSI analysis increment mostly generated by TDR DA (limited amount of conv. data)



Analysis increments for 850hPa geopotential height at 12Z Aug 23, 2013 (with TDR)

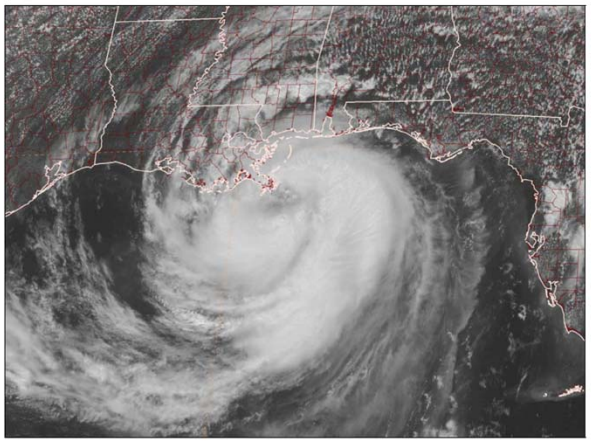


Analysis for column precipitable water at 12Z Aug 23, 2013 (with TDR)

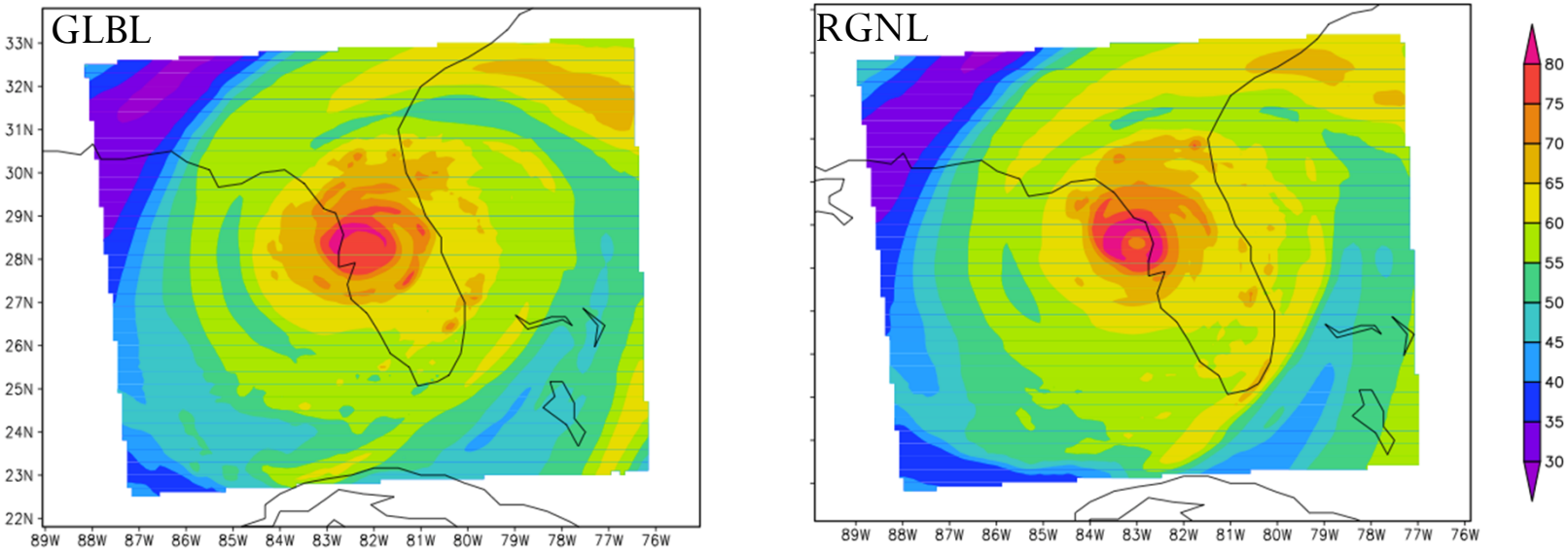
Forecast verification

RGNL (using HWRF ensemble):

- More realistic hurricane structure
- Marginal impacts on track forecasts



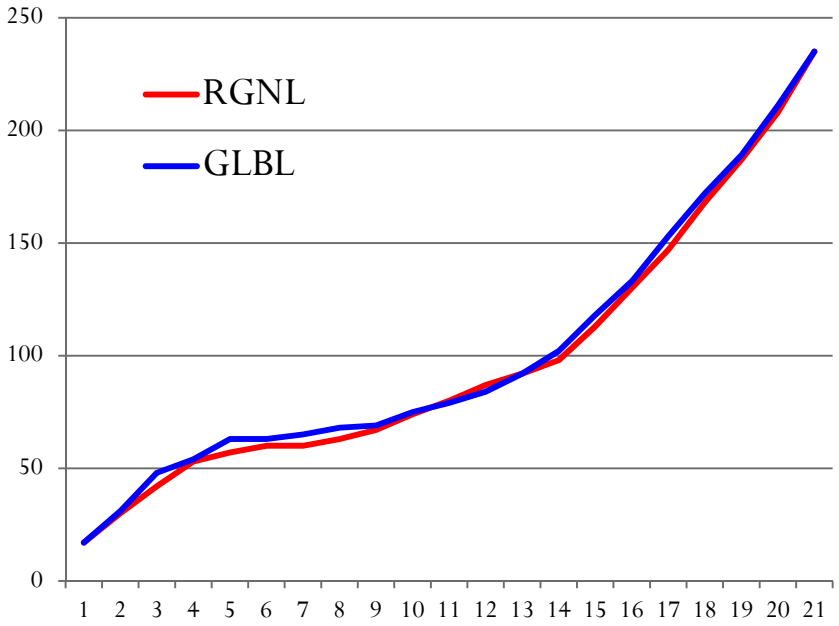
GOES visible image at 1815Z Aug 28, 2013

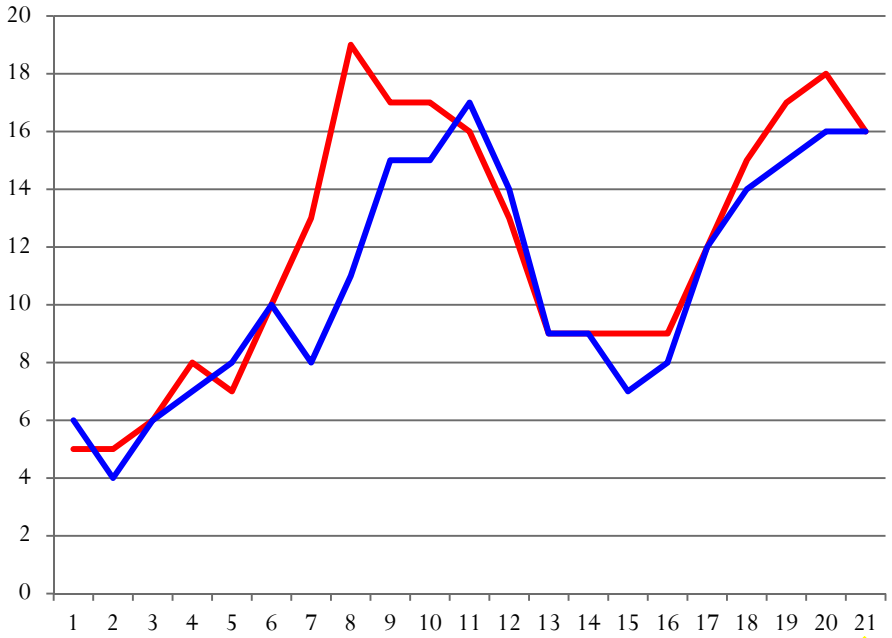


Column precipitable water 120-h forecasts initialized at 12Z Aug 23, 2013 (with TDR)

Forecast verification (cont)

Aggregated abs. track (nm) and intensity (kts) errors for Isaac (Aug 22-27, 2012)





Analysis Time

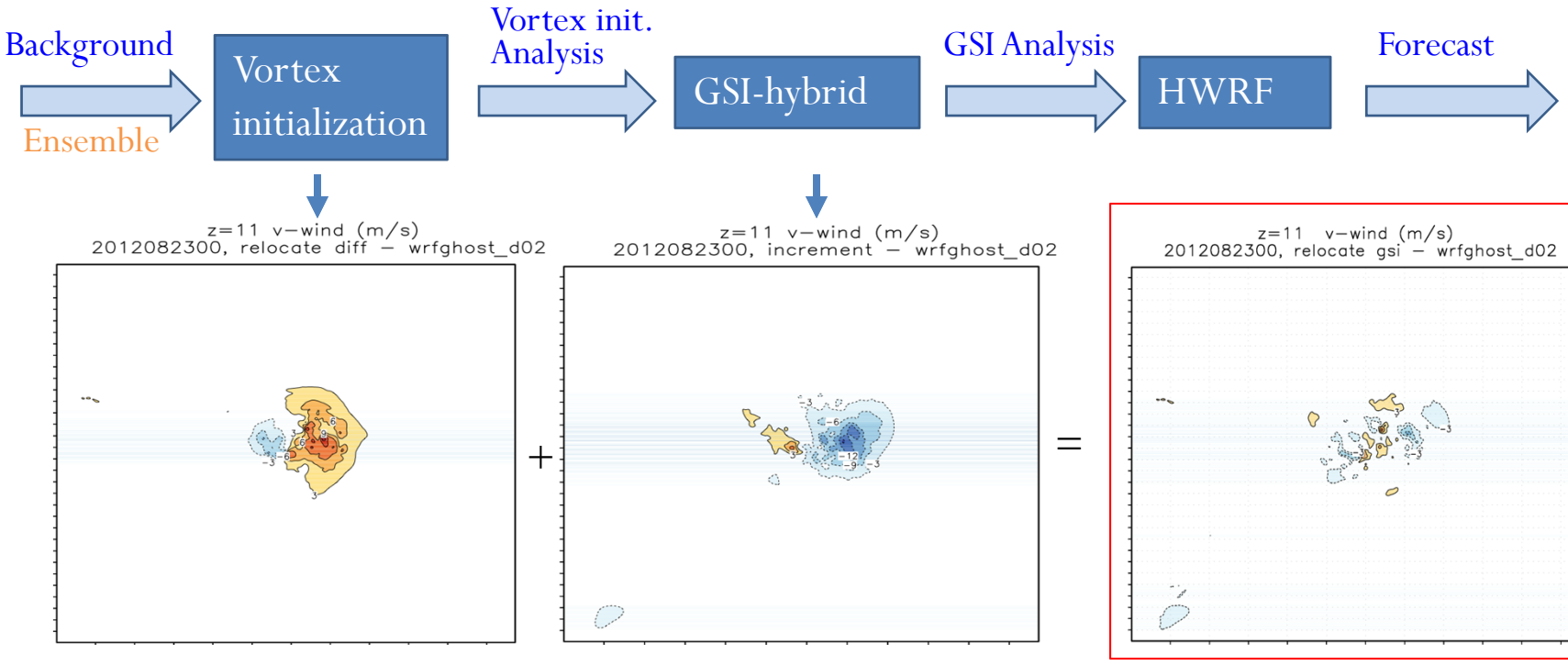
120 h forecast

RGNL (using HWRF ensemble):

- Slight improvements on track forecasts
- Bigger intensity errors

Max # of cases: 21

Impacts of HWRF initialization: inner domain (Isaac 2012)



Vortex init. increments

DA increments

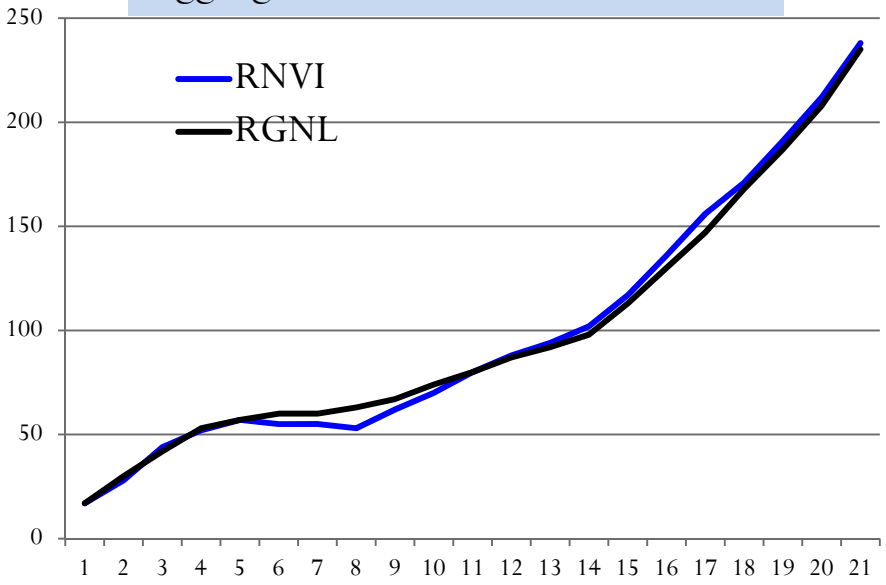
Total increments due to DA and vortex init.

- The increments generated from vortex initialization are not consistent with (or even counter-act) analysis increments from DA
- Similar results were found for Sandy (2012) case as well

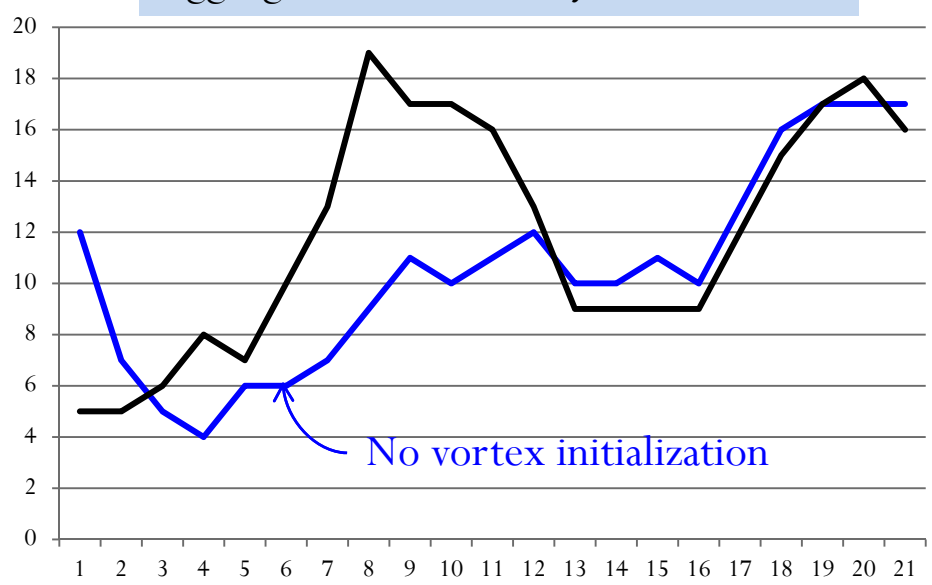
Impacts of vortex initialization: inner domain (Isaac 2012)

- RNVI: Same as RGNL (using HWRF ensemble), except the vortex initialization step was removed:
  - Adjustment to the background came from data assimilation only.

Aggregated abs. track errors (nm)



Aggregated abs. intensity errors (kts)

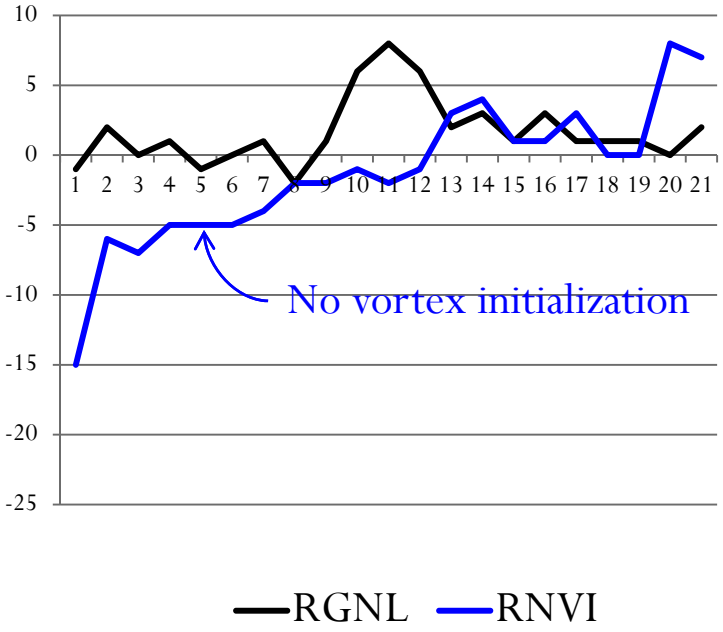


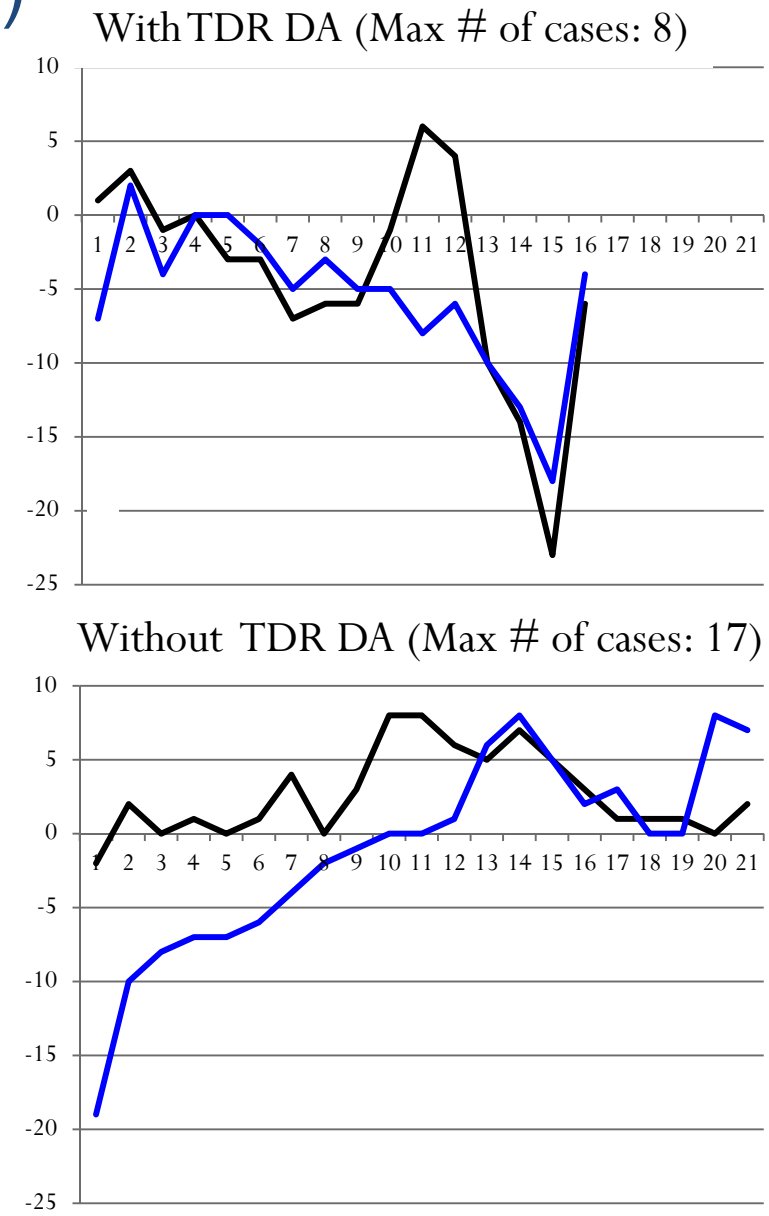
Analysis Time

120 h forecast

Impacts of vortex initialization: inner domain (Sandy 2012)

Aggregated intensity error (kts)





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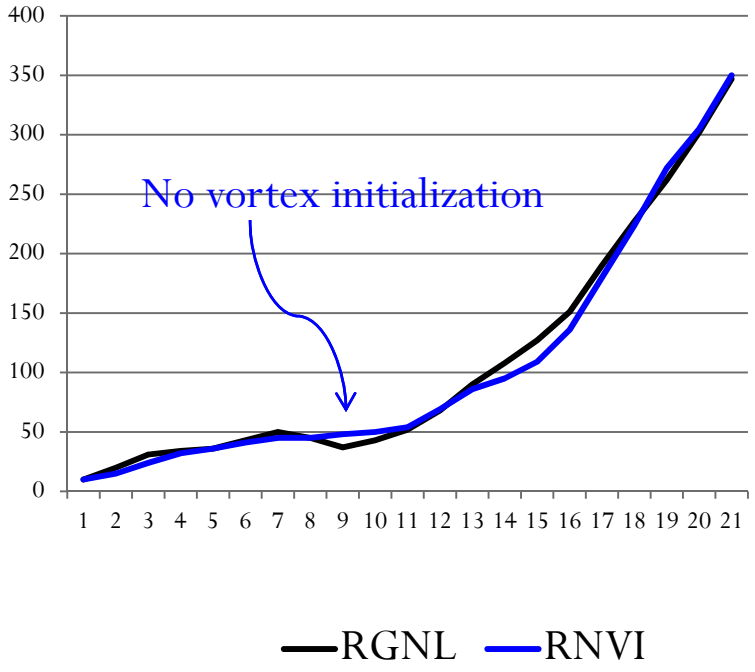
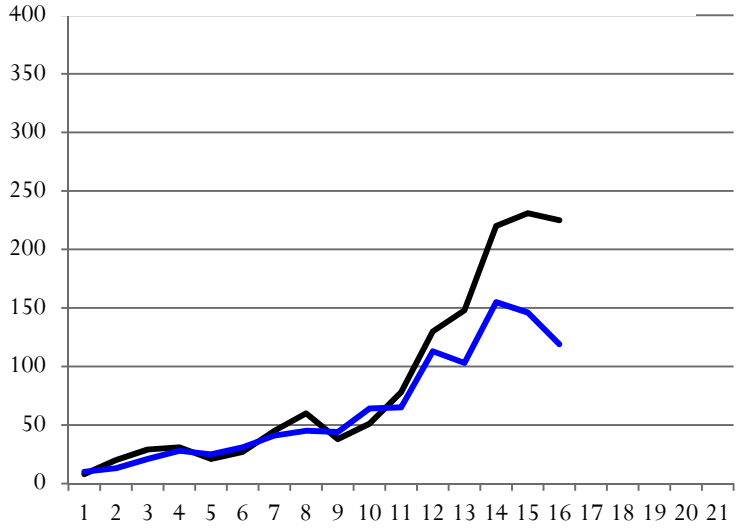
Impacts of vortex initialization: inner domain (Sandy 2012)

Aggregated abs. track error (nm)

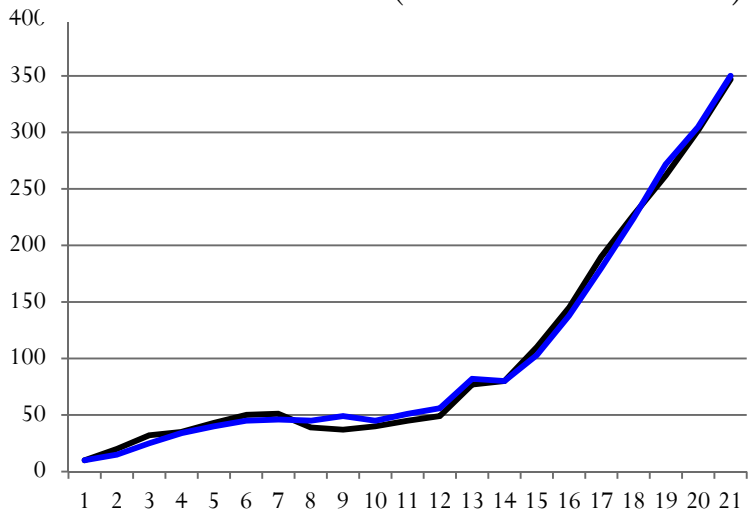
All (Max # of cases: 25)



With TDR DA (Max # of cases: 8)



Without TDR DA (Max # of cases: 17)



Summary and future plans

- HWRF regional ensemble provides
  - Finer resolution
  - 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 counter-acts DA analysis
  - Removing vortex initialization gives better intensity forecast, if inner core TDR data assimilation is available
- Challenges/future work
  - More data types for the inner core DA
  - Ensemble representation for TCs
  - Vortex initialization in the framework of data assimilation
  - Two-way hybrid (HWRF ensembles updated by ensemble DA and recentered using deterministic analysis): cycling of inner-core DA

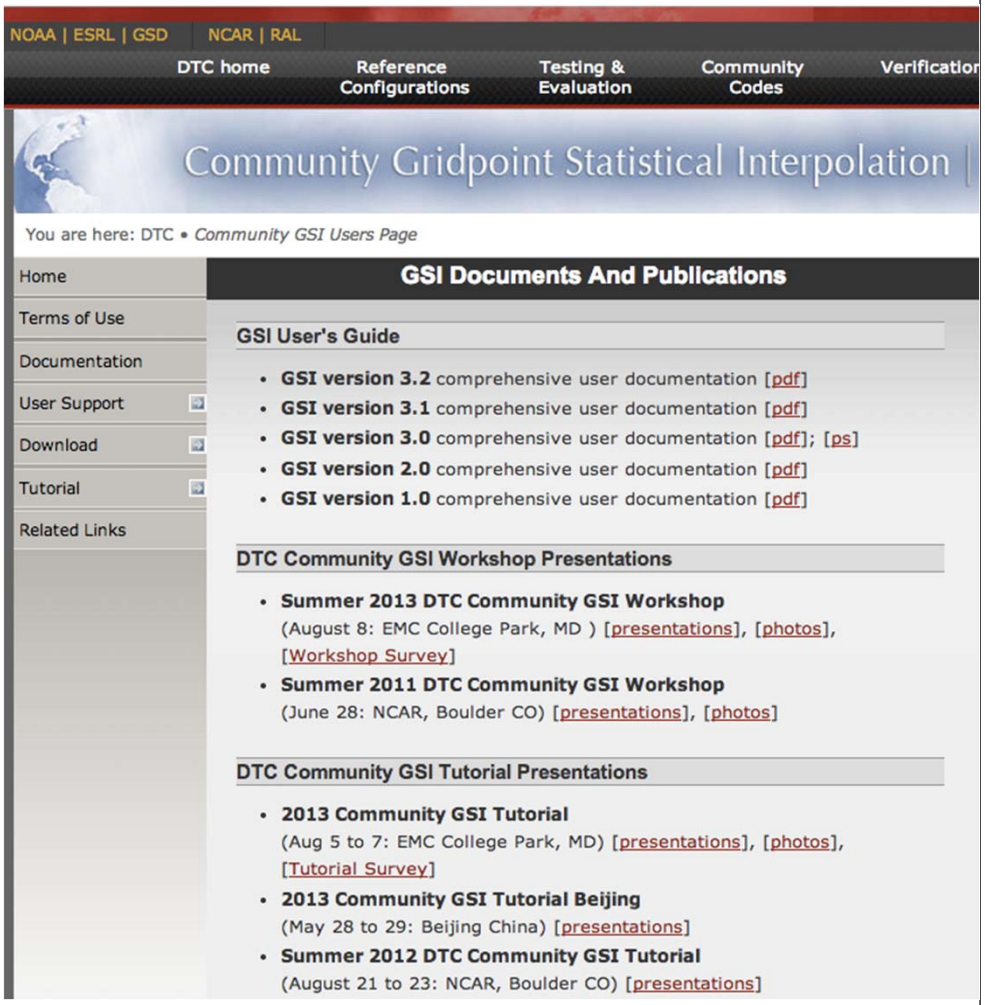
Summary and future plans (cont)

- Code management and community support:
  - GSI (current)
  - EnKF (Ensemble DA system used by GFS two-way GSI-hybrid system)

Upcoming Community GSI Annual Tutorial:

July 14-16, 2014, NCAR Foothills Lab, Boulder, CO

(Registration will open in March)



http://www.dtcenter.org/com-GSI/users/index.php or search "DTC GSI"