GSI Data Assimilation System Support and Testing Activities: 2013 Annual Update

Hui Shao[1], Ming Hu[2], Chunhua Zhou[1], Kathryn Newman[1], Mrinal K. Biswas[1], Don Stark[1], Ligia Bernardet[2], Mingjing Tong[3], and John Derber[3]

[1]National Center for Atmospheric Research (NCAR) Research Applications Laboratory(RAL)

[2]National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL)

[3]National Centers for Environmental Prediction (NCEP) Environmental Modeling Center (EMC)

Special Acknowledgement: AFWA, NOAA/OAR, HFIP, NCAR, and NSF

Gridpoint Statistical Interpolation (GSI)

- Techniques:
  - 3D-Var
  - 4D-Var, EnsVar
  - Hybrid
- Models:
  - GFS, GEOS
  - WRF-NMM, ARW, NMM-B

Currently in operations

Global DA:

- ✓ Global Forecasting System (GFS)
- ✓ NASA Goddard Earth Observing System (GEOS)

Regional DA (WRF-NMM, NMM-B, ARW):

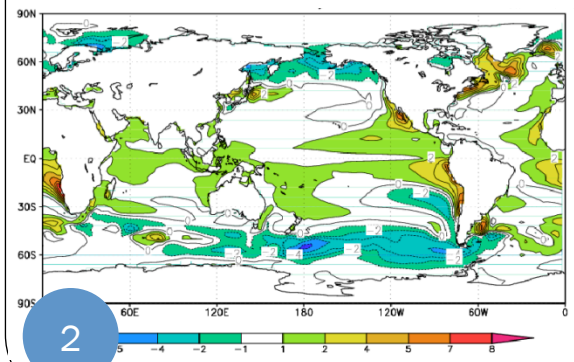
- ✓ North America Mesoscale (NAM) Model
- ✓ Hurricane WRF (HWRF)
- ✓ RAPid Refresh (RAP)
- ✓ AFWA forecasting and data assimilation system

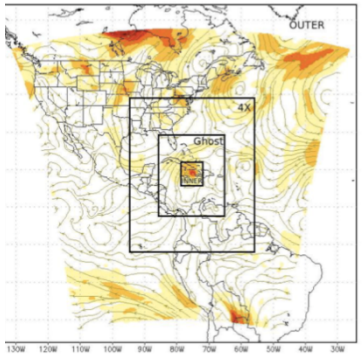
Analysis system:

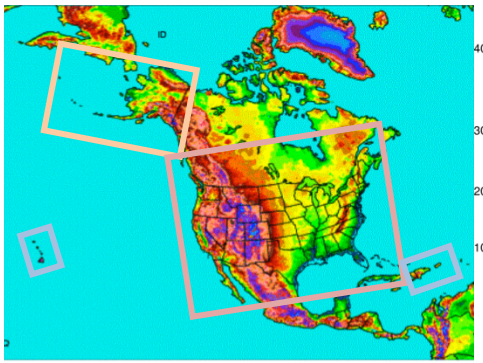
- ✓ Real Time Mesoscale Analysis (RTMA) system
- ✓ GFS reanalysis system

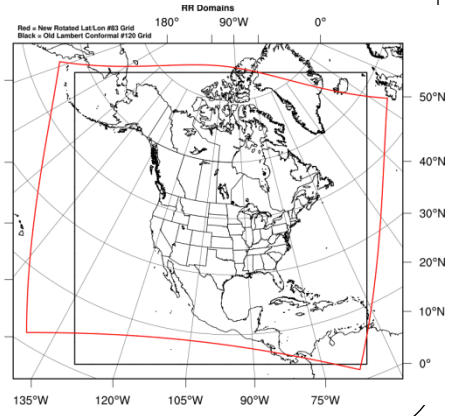
- GSI Review Committee: coordination and code review

  NCEP/EMC, NASA/GMAO, NOAA/ESRL, NCAR/MMM, NESDIS, AFWA, DTC









GSI Users Webpage: www.dtcenter.org/com-GSI/users/

GSI V3.2 Annual Release

Beta release available NOW at http://www.dtcenter.org/com-GSI/users/
Official release in July 2013: Update users guide (new chapter on RTMA), further code tests

New Features:

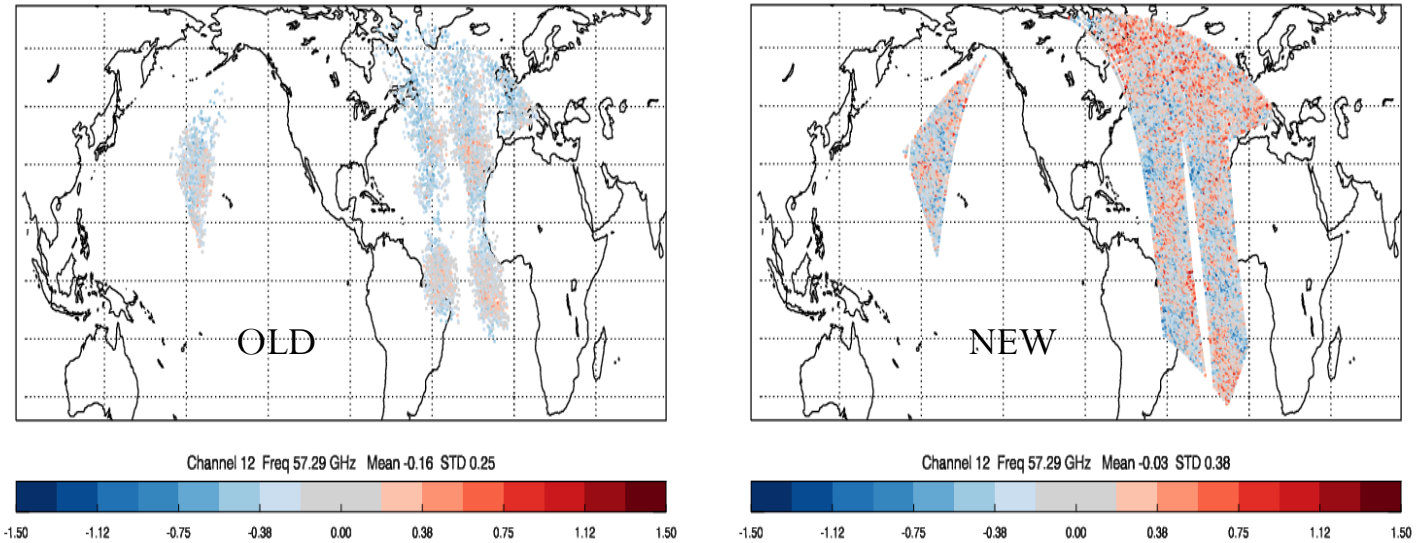
- New regional radiance bias correction scheme
- BUFRlib update, no bite endian dependency
- Dual-resolution option added to GSI-hybrid regional option
- Adjoint check for the observation operators (complement existing check in coding)
- Satinfo format changed
- Code updated for better portability on Linux platforms (operational)
- Gfortran

Observations:

- TDR data assimilation
- CrIS data assimilation
- New VAD wind radar assimilation

New regional radiance bias correction scheme

- Use global-regional blended vertical coordinate to obtain better vertical resolution in stratosphere and extend bias correction up to 0.3 hPa
- Use bias correction estimation from GFS beyond the model top
- Use ozone profiles from GFS



- More data assimilated in the upper troposphere and stratosphere
- Cost function for minimization greatly reduced for IR instruments

(Courtesy from Emily Liu, NCEP/EMC)

	IASI	AIRS
OLD	0.62 307743	0.60 176881
NEW	0.23 382407	0.26 218753

Penalty Used Obs. Count

GSI V3.2 Annual Release (cont.)

Beta release available NOW at http://www.dtcenter.org/com-GSI/users/
Official release in July 2013: Update users guide (new chapter on RTMA), further code tests

Application specific request:

- RAP:
  - Add soil temperature and moisture nudging based on the first level atmosphere analysis increments
  - METAR partial cloud in the cloud analysis
  - update the surface 2-m temperature based on the 1st level temperature analysis increment.
- 2D-var enhancement for RTMA implementation
  - Adds the option to use diurnal-dependent rejectlists for temperature and moisture observation, and direction-stratified accept lists for mesonet winds.
  - Adds cross-validation for visibility and gust
  - Adds a wind-direction based gross-error check to the 2DVar option
  - Removes, for the visibility analysis, the artificial escarpment in the (terrain-mapped) background error covariances along the coastlines
  - Adds fog observations to the visibility analysis.
  - Improves the weak-constraint for the analysis of visibility, wind gust, and PBLH.

2013 Upcoming Events: the Week of GSI

- **2013 GSI Annual Tutorial, August 5-7 (Mon-Wed), College Park, MD**
  - Onsite at the NOAA Center for Weather and Climate Prediction (NCWCP) for the first time!
  - Speakers from NCEP/EMC, NASA/GMAO, NCAR/MMM, U. of Maryland, NESDIS/JCSDA, NOAA/ESRL
  - Lectures: GSI basics (how to compile and run), specifics (radiance, background error, obs pre-processing), new topics (aerosol data, active sensor), advanced developers (GSI code structure)
  - Practical Sessions for **GSI V3.2 (will be released in July)**
- **2013 GSI Workshop, August 8 (Thur), College Park, MD** : data assimilation research workshop. Free to public, remote access available, invited speakers. Agenda will be out in July.

Please register at
http://www.dtcenter.org/com-GSI/users/tutorials/2013.php

DTC Test & Evaluation Activities

Activity Description	Tasks
GSI (3D-Variational) baseline tests for AFWA	• Background error (BE) impact & estimation methods • Global Positioning System (GPS) Radio Occultation (RO) data impact • Radiance channel selection • Model top configuration
NCEP GSI-based hybrid variation-ensemble system for Hurricane WRF (HWRF)	• Cross co-variance examination • System/technique comparison • Cycling scheme • BE tuning • Radiance Data Assimilation • GPS RO data impact • Binary capability of the HWRF components (user interface development)
NCAR DART Ensemble Data System	Microwave Humidity Sounder (MHS) radiance data assimilation and impact study

* All DA tests were conducted in a functionally-similar environment

GSI 3D-Var/Hybrid Ensemble-3DVar Cost Functions

$$J_{3DVAR}(\mathbf{x}') = \frac{1}{2}(\mathbf{x}')^T \mathbf{B}_f^{-1}(\mathbf{x}') + \frac{1}{2}(\mathbf{H}\mathbf{x}' - \mathbf{y}')^T \mathbf{R}^{-1}(\mathbf{H}\mathbf{x}' - \mathbf{y}')$$

Fit to background — Fit to observations

$$J_{hybrid}(\mathbf{x}') = \frac{\beta}{2}(\mathbf{x}')^T \mathbf{B}_f^{-1}(\mathbf{x}') + \frac{1-\beta}{2}(\mathbf{x}')^T \mathbf{B}_{ens}^{-1}(\mathbf{x}') + \frac{1}{2}(\mathbf{H}\mathbf{x}' - \mathbf{y}')^T \mathbf{R}^{-1}(\mathbf{H}\mathbf{x}' - \mathbf{y}')$$

$\mathbf{x}'$: Analysis increment ($\mathbf{x}^a - \mathbf{x}^b$); where $\mathbf{x}^b$ is a background

$\mathbf{B}_f$: (Fixed) Background error covariance (estimated offline)

$\mathbf{H}$: Observations (forward) operator

$\mathbf{R}$: Observation error covariance (Instrument + representativeness)

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

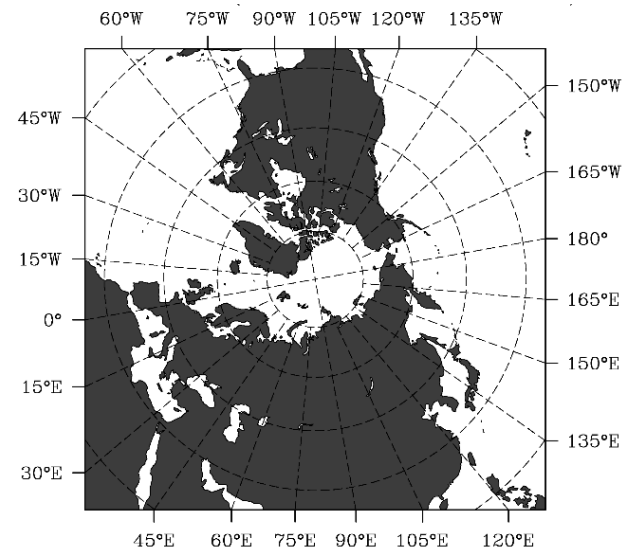
$\mathbf{y}' = \mathbf{y}^o - \mathbf{H}\mathbf{x}^b$, where $\mathbf{y}^o$ are the observations

β: Weighting factor (0.25 means total $\mathbf{B}$ is ¾ ens and ¼ $\mathbf{B}_f$)

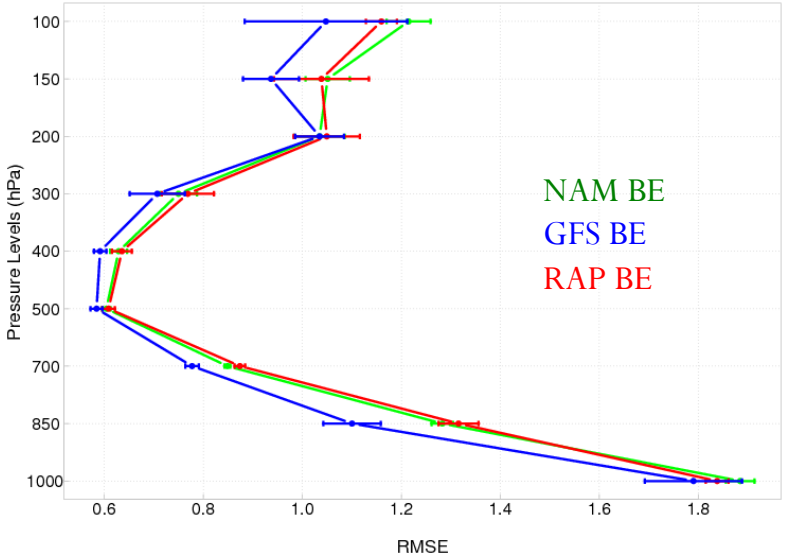
Cost function (J) is minimized to find solution, $\mathbf{x}' [= \mathbf{x}^a - \mathbf{x}^b]$

(Courtesy from Jeff Whitaker, GSI Tutorial, 2012)

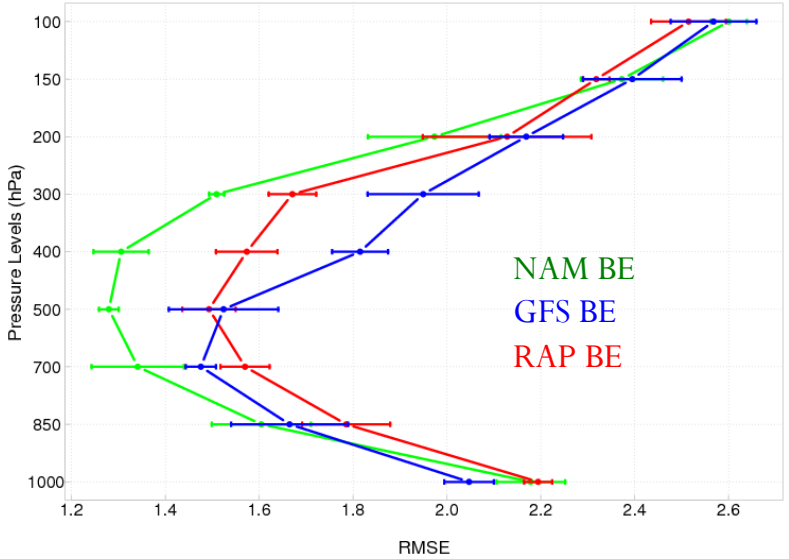
Static Background Errors Impacts



- ✓ NAM BE: Northern Hemisphere BE computed based on NCEP/North America Mesoscale System (NAM) forecasts.
- ✓ GFS BE: Global BE computed based on NCEP/ Global Forecasting System (GFS) forecasts.
- ✓ RAP BE: Global BE tuned for the NOAA/RAPid Refresh (RAP). combination of global/regional *(balance = GFS, Lengthscales/variance = NAM)*

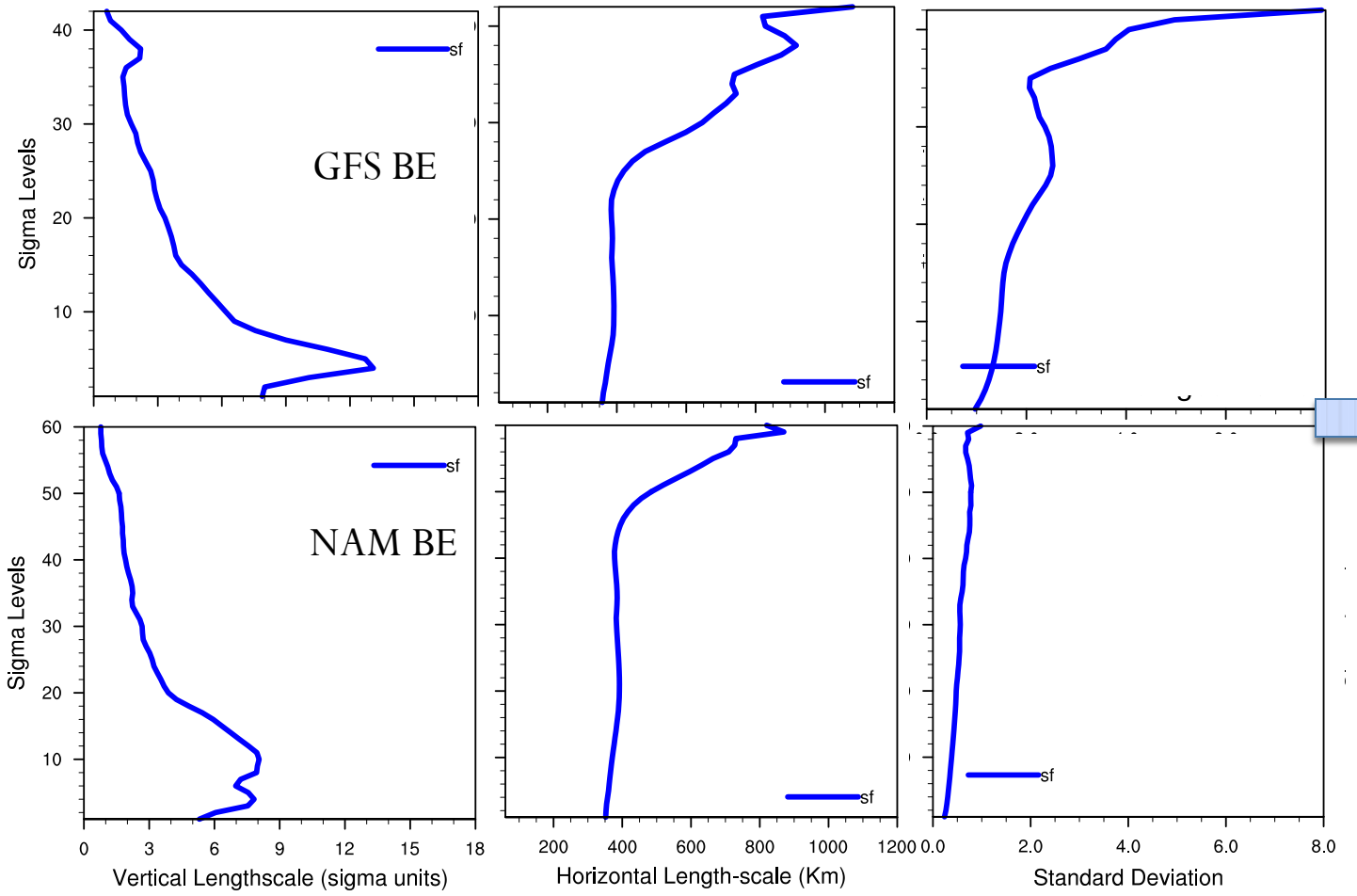


Temperature Analysis RMSE



Wind Analysis RMSE

Background Error scaling factors and variance

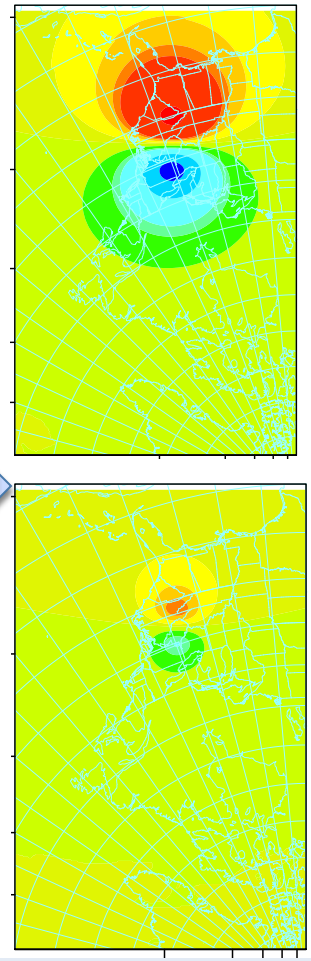


Vertical Lengthscale

Horizontal Lengthscale

Standard Deviation

BE factors for Stream Function



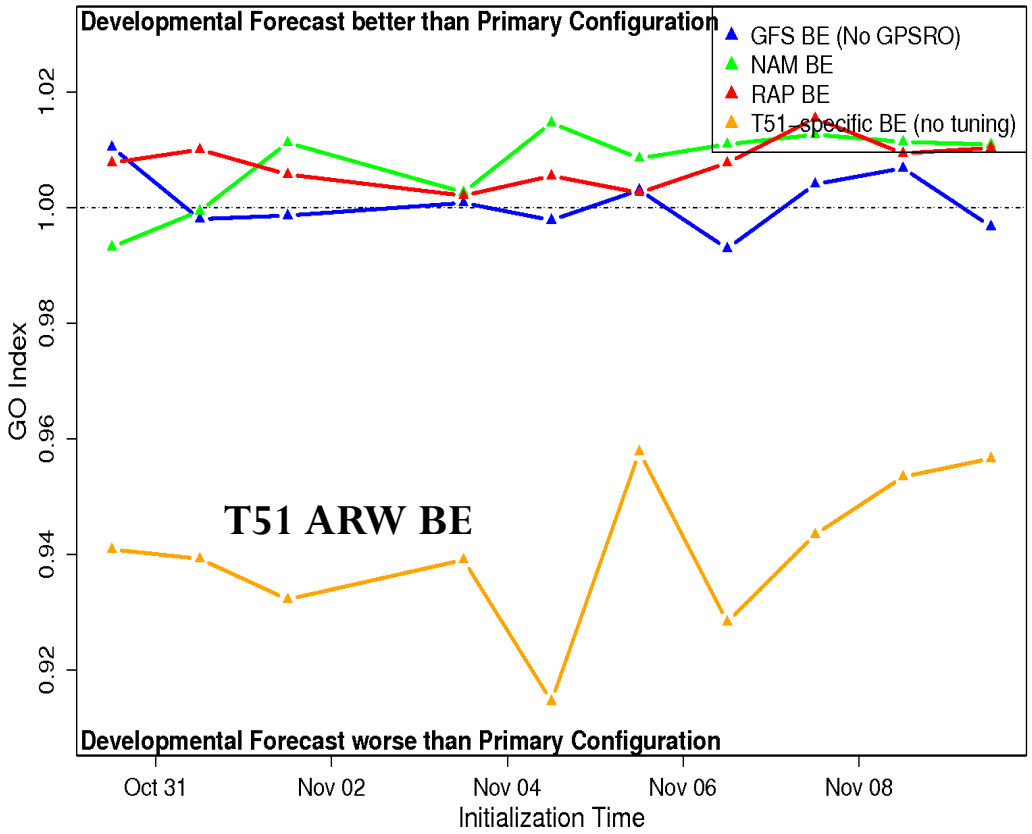
Analysis Inc. from single T obs test

Domain-Specific BE: Impacts

T51 ARW BE-Northern Hemisphere BE computed based on ARW forecasts:

GO Index< 1: GFS BE (with GPSRO) better

GO Index>1: other BE experiments better



P10: GSI background error sensitivity for AFWA pre-operational implementation testing. Kathryn Newman, Ming Hu, and Hui Shao.

2012 HWRF Basin Scale T&E Configuration

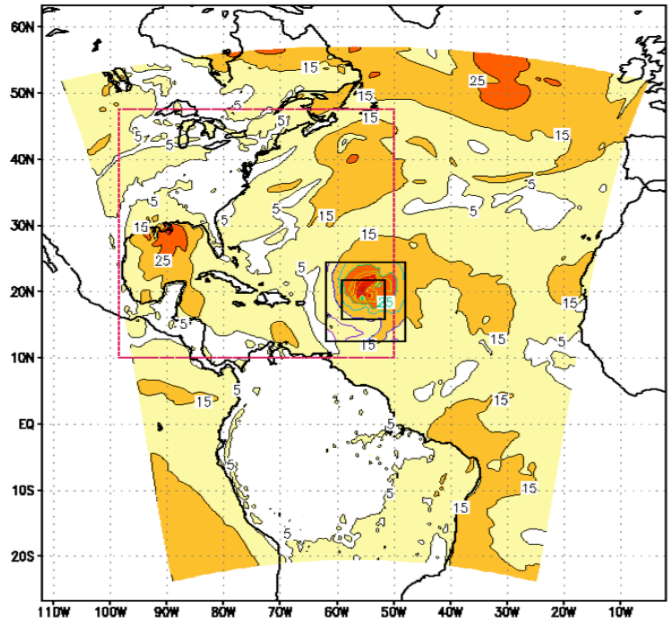
Operational HWRF config:

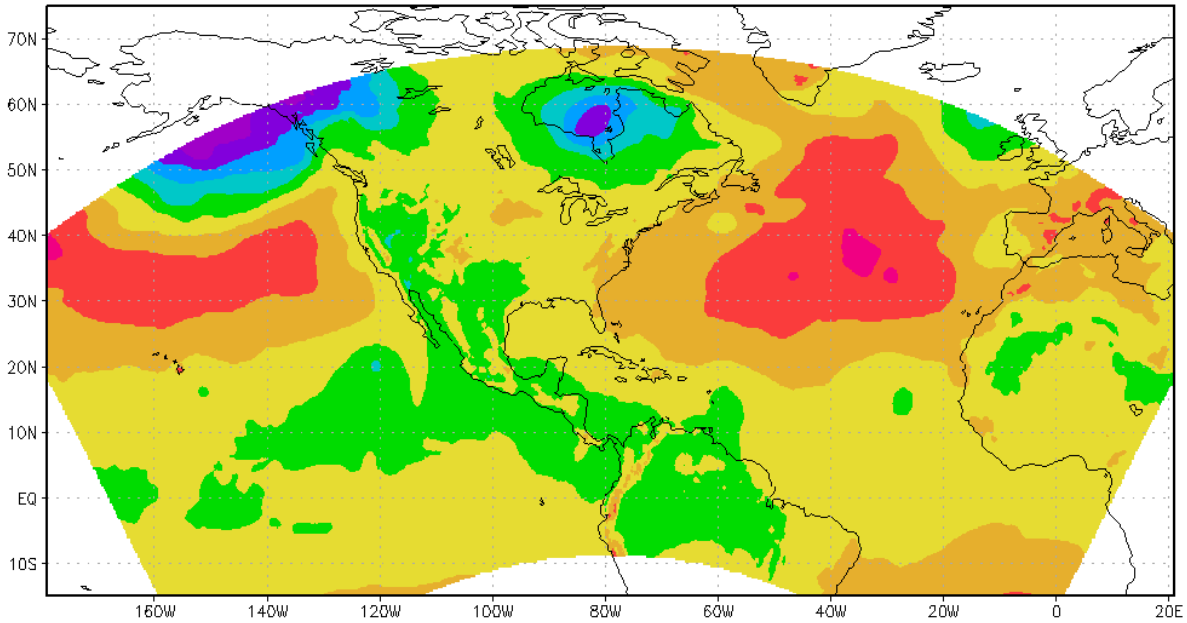
Horizontal grid spacing: 27, 9, 3 km

- Inner nests move to follow storm
- Domain location vary from run to run depending on storm location
- 42 vertical levels
- Model top 50 hPa

Exp. HWRF config:

- Horizontal grid spacing: 27 km
- No inner nests yet
- Domain is fixed
- 61vertical levels
- Model top 2 hPa
- GSI-hybrid using GFS ensembles
- w/o vortex reloc, coupled ocean, wave model

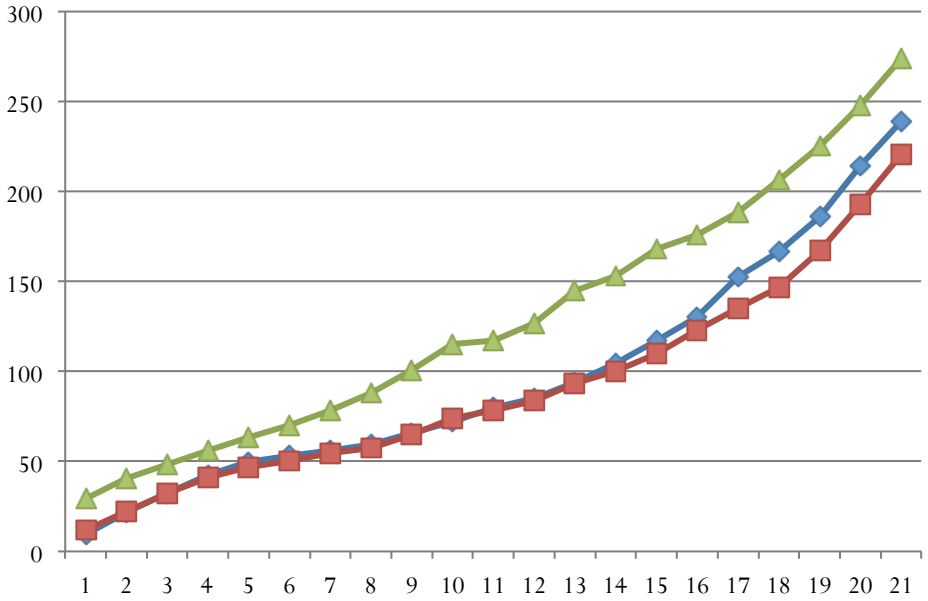




“Minimal” GSI-hybrid Versus GFS

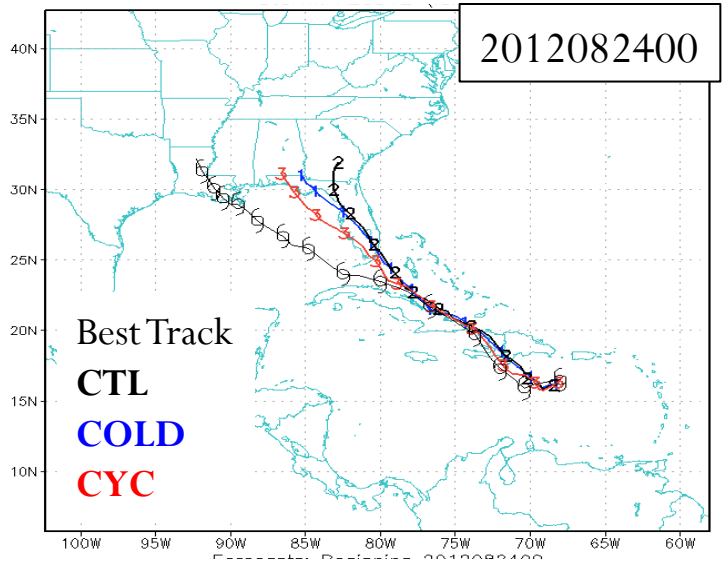
Conventional DA only:

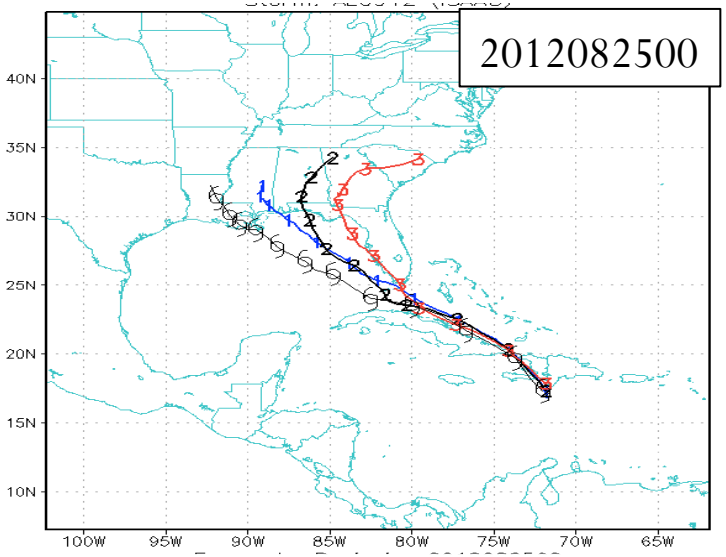
CTL: GFS ana. as background
COLD: cold-start with GFS 6hr forecast
CYC: 1-day cycling priori to ana. time



Aggregated track errors

5 Storms in August, 2012 Hurricane:
# of cases: 84 81 79 75 71 67 64 61 58
55 50 48 46 43 41 39 35 33 31 29 28

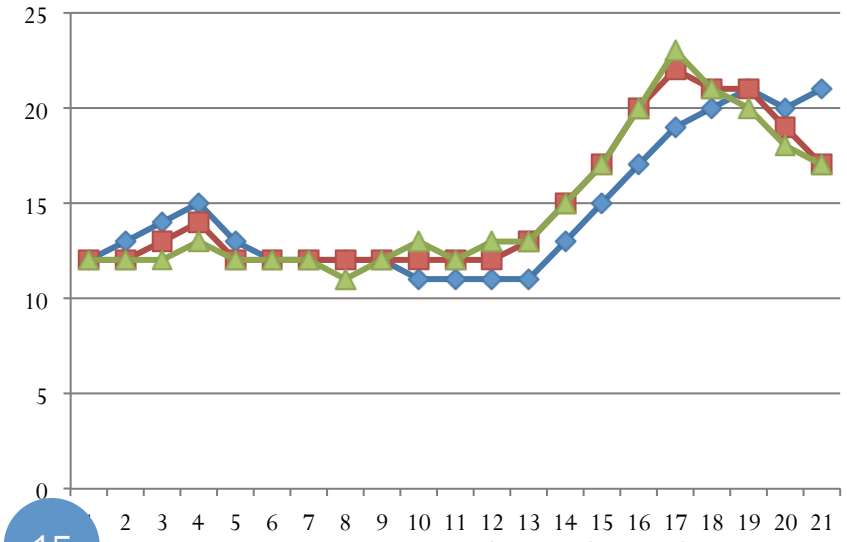


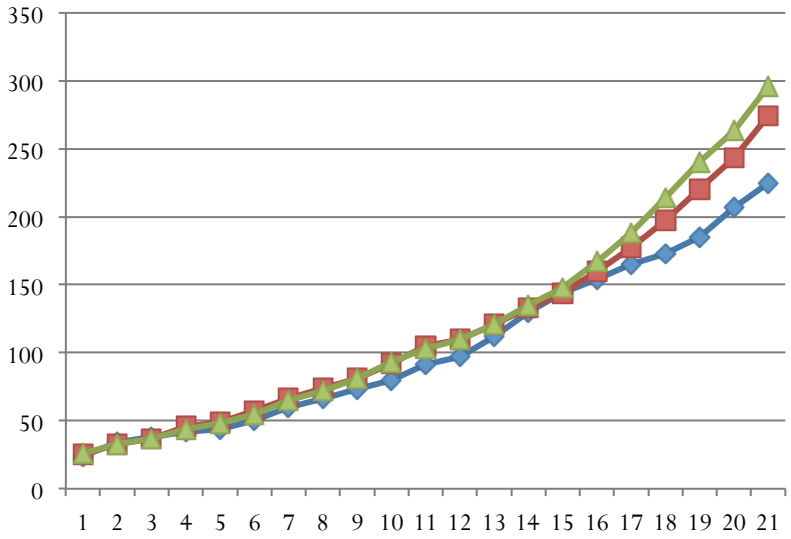


Hurricane Isaac

Background Error Tuning: Static BE variance

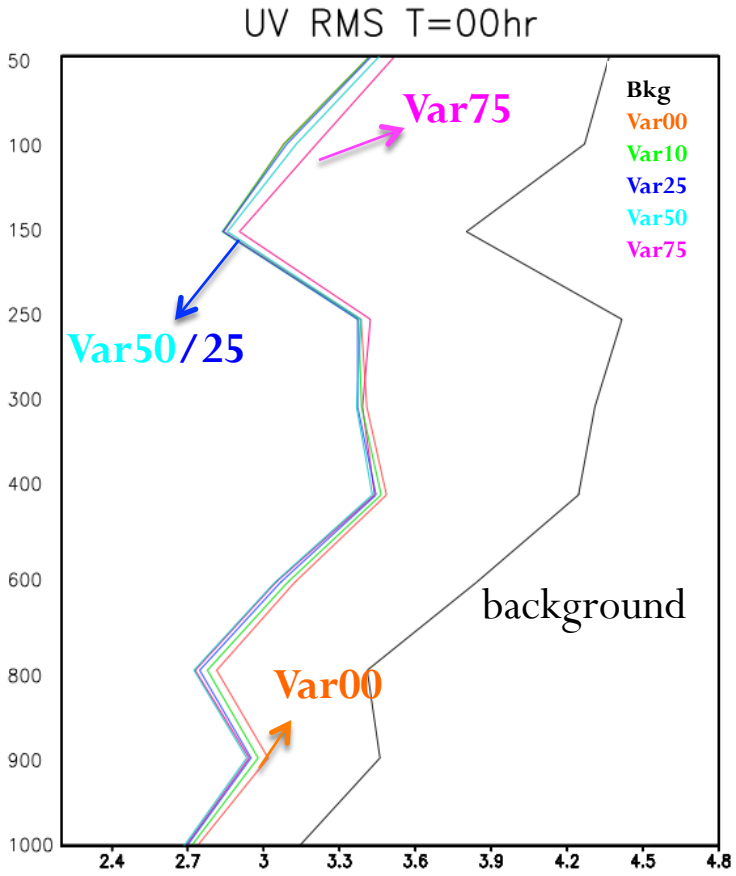
anavinfo file	Normalized scale factor for static BE variance				
	sf	vp	ps	t	q
hwrf_basinscale (basin)	0.2	0.2	0.3	0.7	0.2
ndas_netcdf (ndas)	1.0	1.0	0.5	0.7	0.7
nems_nmmb (nmmb)	0.28	0.28	0.3	0.7	0.1

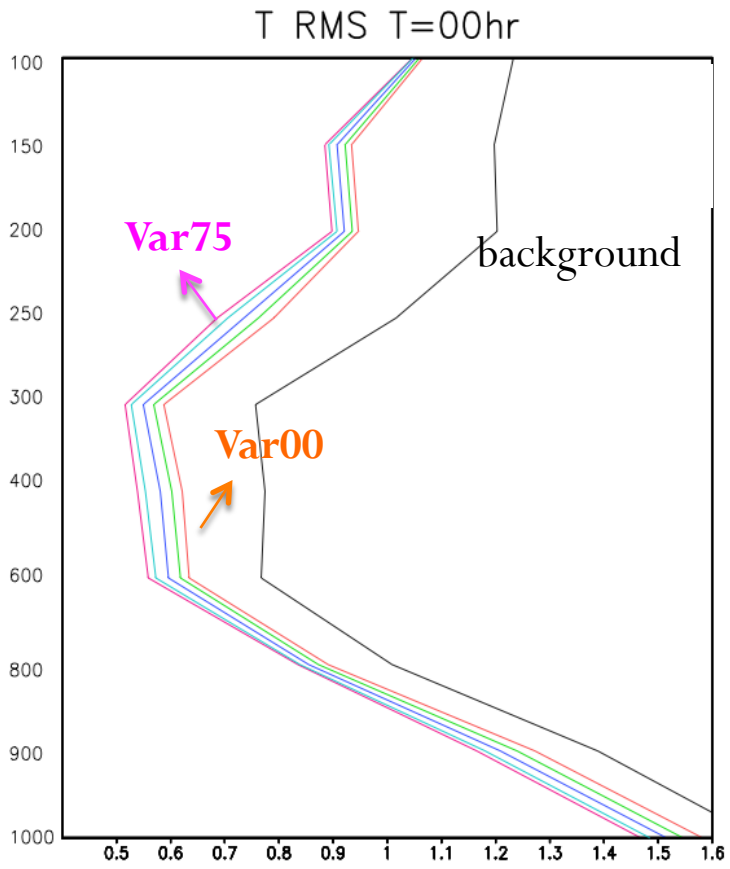




Aggregated track and intensity errors for Isaac (2012082200-2012082818)

Isaac: Weighting of Static and Ensemble BE

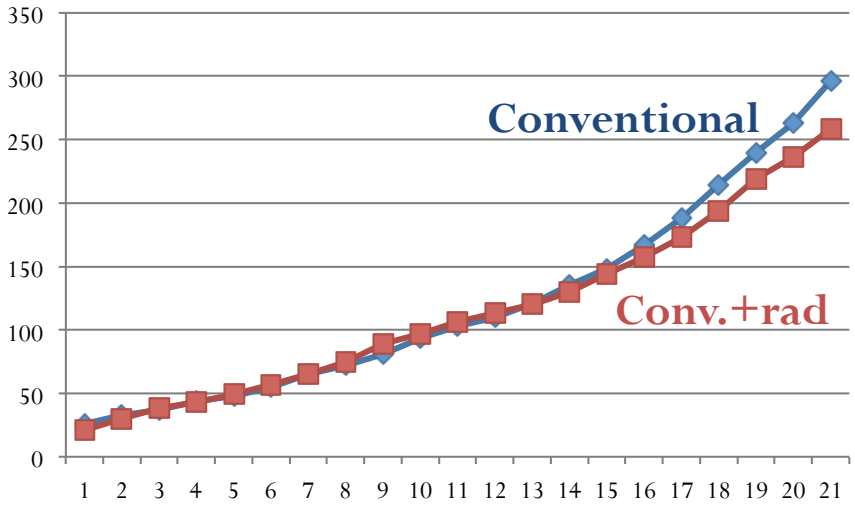




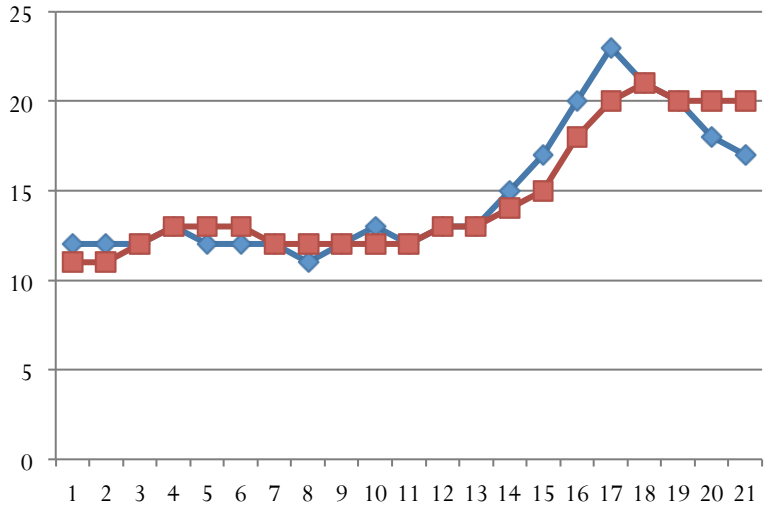
* Var 25: 25% Static BE and 75% ensemble BE

Isaac: Radiance (clear-sky) vs Conventional DA

Aggregated track errors
(AL092012, 2012082200-2012082818)



Aggregated intensity errors
(AL092012, 2012082200-2012082818)



# of cases: 28 28 28 28 28 28 28 28 28 27 26 25 24 23 22 21 20 19 18 17 16

P9: Testing and evaluation of the GSI-Hybrid data assimilation and its applications for hurricane forecasts. Chunhua Zhou, Hui Shao, and Ligia Bernardet

Future Work

- GSI: code management, annual release, user support
- EnKF: code management
- Testing & Evaluation
  - GSI tests
    - Baseline tests. Next version of GSI versus v3.2
    - Regional background error generation and tuning
    - Surface data assimilation
  - GSI-hybrid tests for HWRF: set up based on HFIP DA milestones and in consultation with the HFIP team. Possible tests include (not limited to):
    - Examine the error representation, alternative ensemble products or ensemble parameters
    - Radiance data assimilation: new bias correction, cloudy radiance
    - Vortex scale data assimilation (moving nests)