Task 3.3.2: GSI Testing and Evaluation

Hui Shao and Kathryn Newman

Acknowledgement: DTC's GSI testing and evaluation work for AFWA has greatly benefited from insights provided by Ming Hu (ESRL/GSD) as part of the larger DTC DA team.

Background

- GSI implemented for global coverage domains in July 2013
- Ongoing testing and implementation of GSI for regional domains
  - GSI is implemented mostly for global and CONUS domains (NOAA, NASA)
  - Regional theaters have unique forecast challenges
- DTC task priority: assist AFWA in determining an appropriate initial configuration for the impending GSI operational implementation
  - Mitigation of sea level pressure (SLP) analysis errors
  - Domain-specific background error covariance (BE) impact studies

Mitigation of Sea Level Pressure (SLP) Analysis Errors

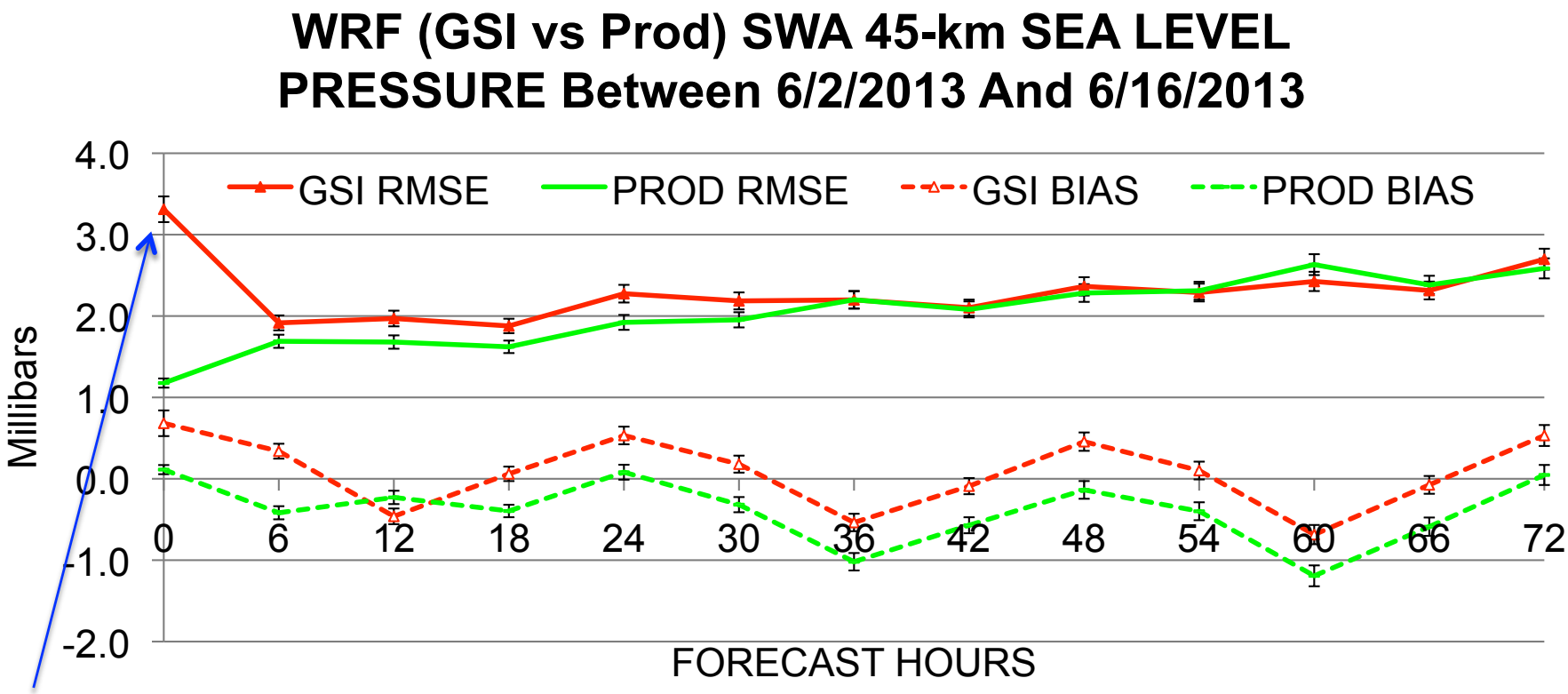
Reported issues

Potential error sources

Investigation of surface data assimilation

Summary and future plans

Reported SLP Issues

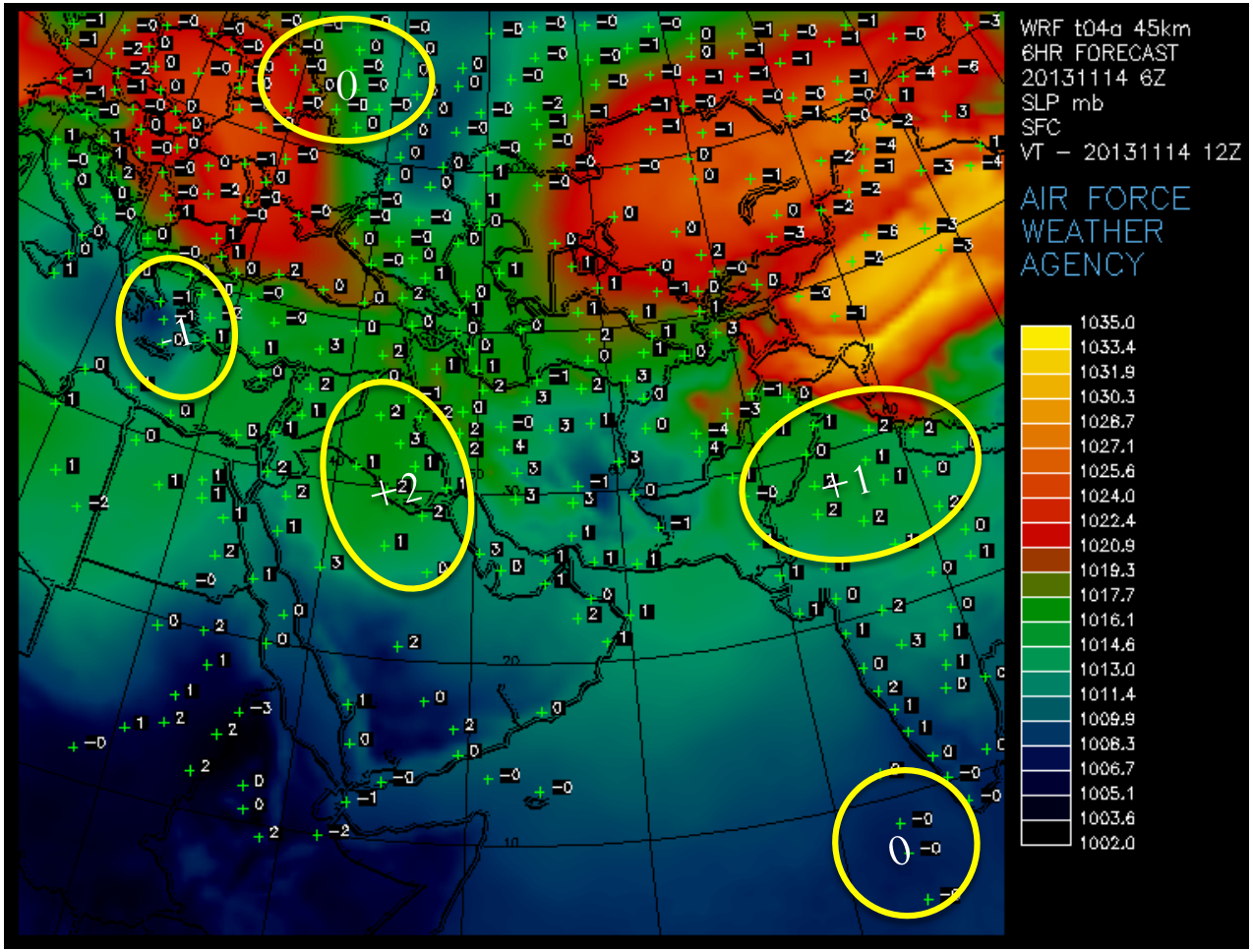


Large RMSE for sea level pressure (SLP) derived from GSI analysis

Reported SLP Issues

SLP background:

RMSE=1.4, Bias=0.1

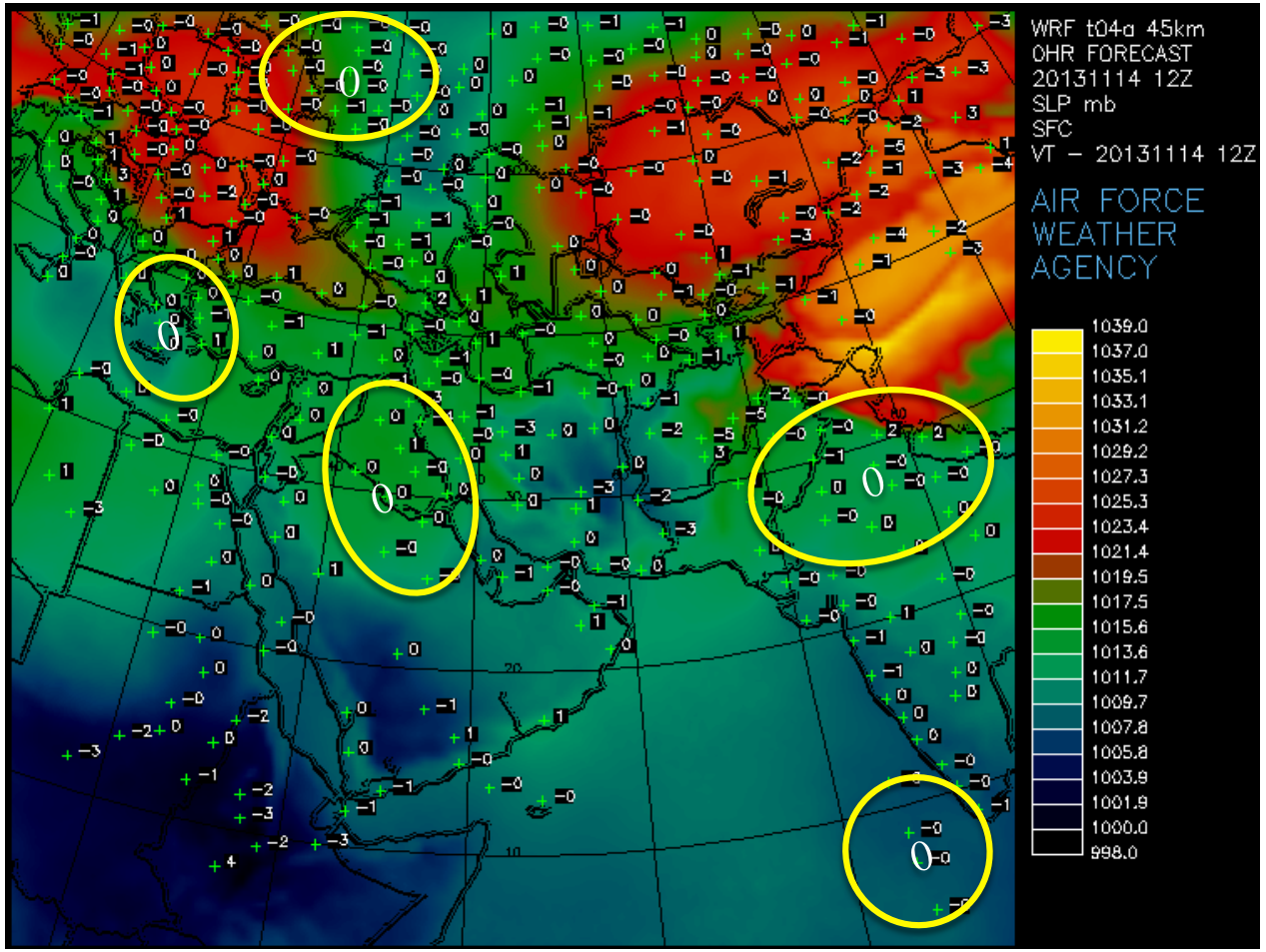


Verification for SLP "analysis" (Anal-obs) at 12Z 20131114

Reported SLP Issues

SLP background:
RMSE=1.4, Bias=0.1

SLP derived from WRFDA analysis:
RMSE=1.2, Bias=0.1



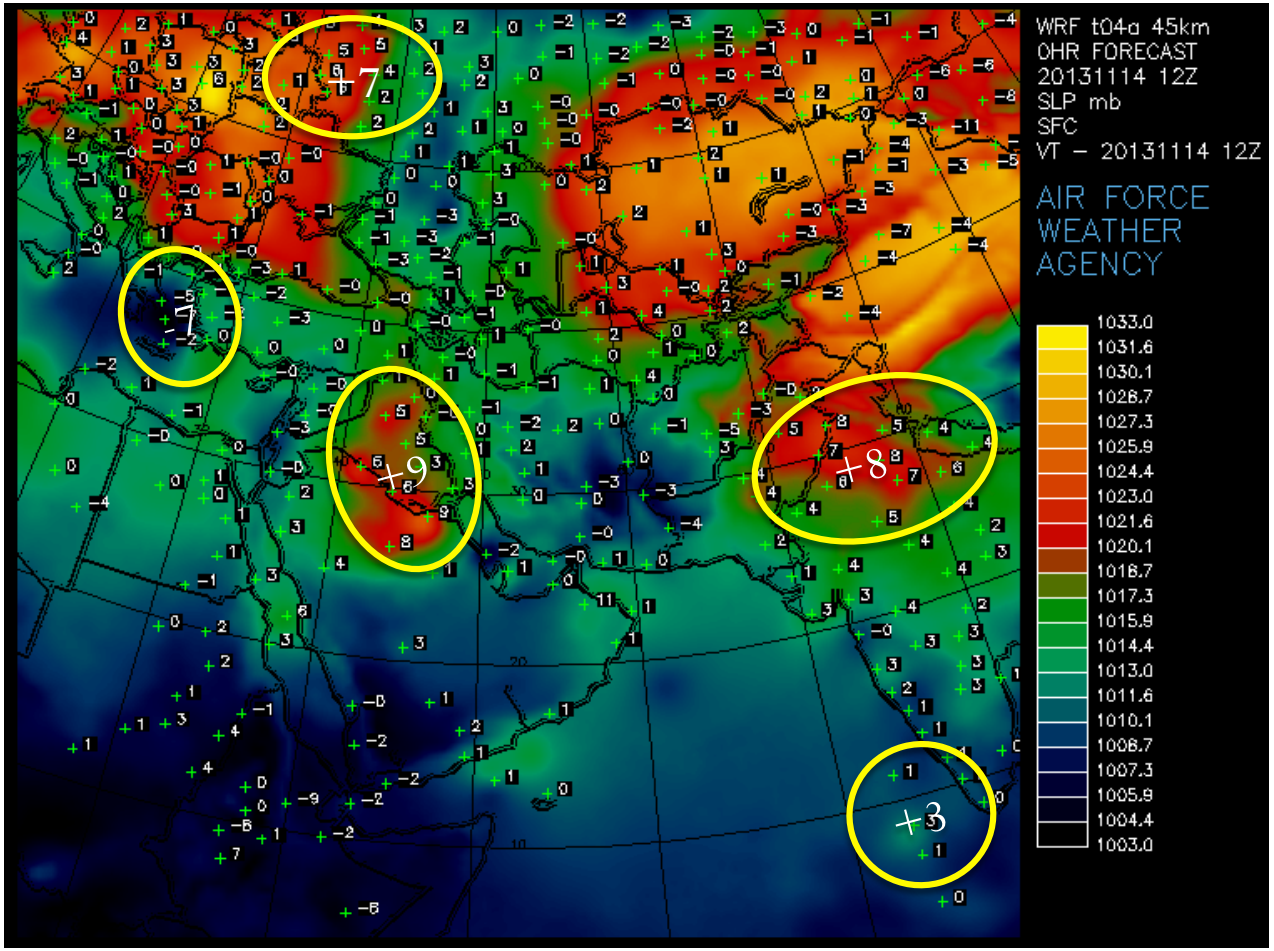
Verification for SLP "analysis" (Anal-obs) at 12Z 20131114

Reported SLP Issues

SLP background:
RMSE=1.4, Bias=0.1

SLP derived from WRFDA analysis:
RMSE=1.2, Bias=0.1

SLP derived from GSI analysis:
RMSE=2.9, Bias=1.0



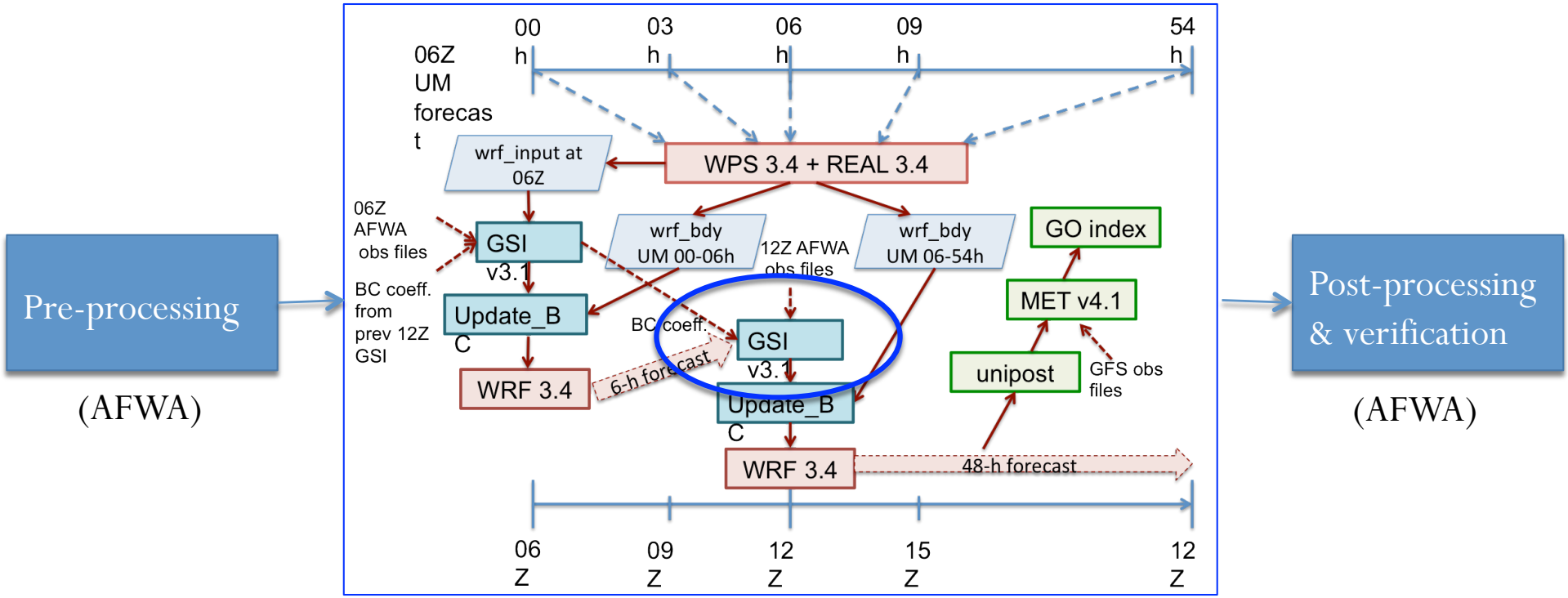
Verification for SLP "analysis" (Anal-obs) at 12Z 20131114

Potential Error Sources

- SLP is not an analysis variable, nor a forecast variable - not directly updated by GSI, WRFDA, or ARW
  - Derivation of SLP depends on which & how analysis/forecast variables are adopted in the computational formula
  - (In)Consistency of update/computation of the associated variables among the specific DA, forecast & post-processing procedures
- SLP is associated w/ pressure, temperature & moisture at surface, which can be updated through DA
  - Undesired assimilation of associated observations
- Due to differences in quality control (QC) steps, either performed in the pre-processing procedure and/or inside the DA system, types, locations & number of assimilated data by GSI & WRFDA can be different
  - "False alarm" is possible from verification of SLP "analysis" against certain data sets (especially those considered as bad data in one of the DA systems)

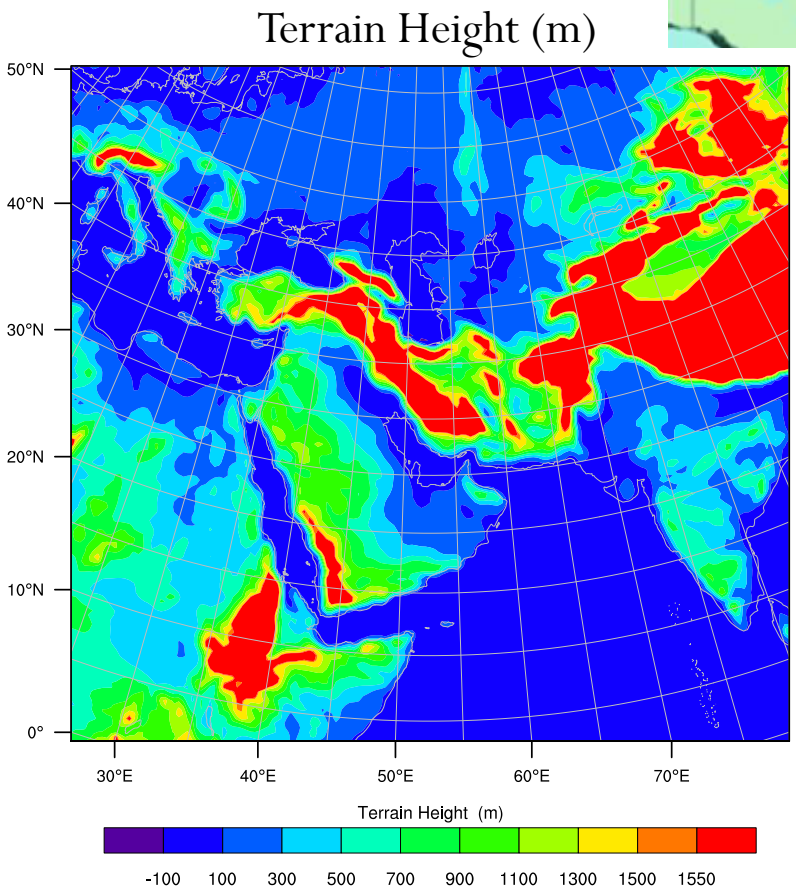
DTC focus on debugging the SLP issues from DA side only

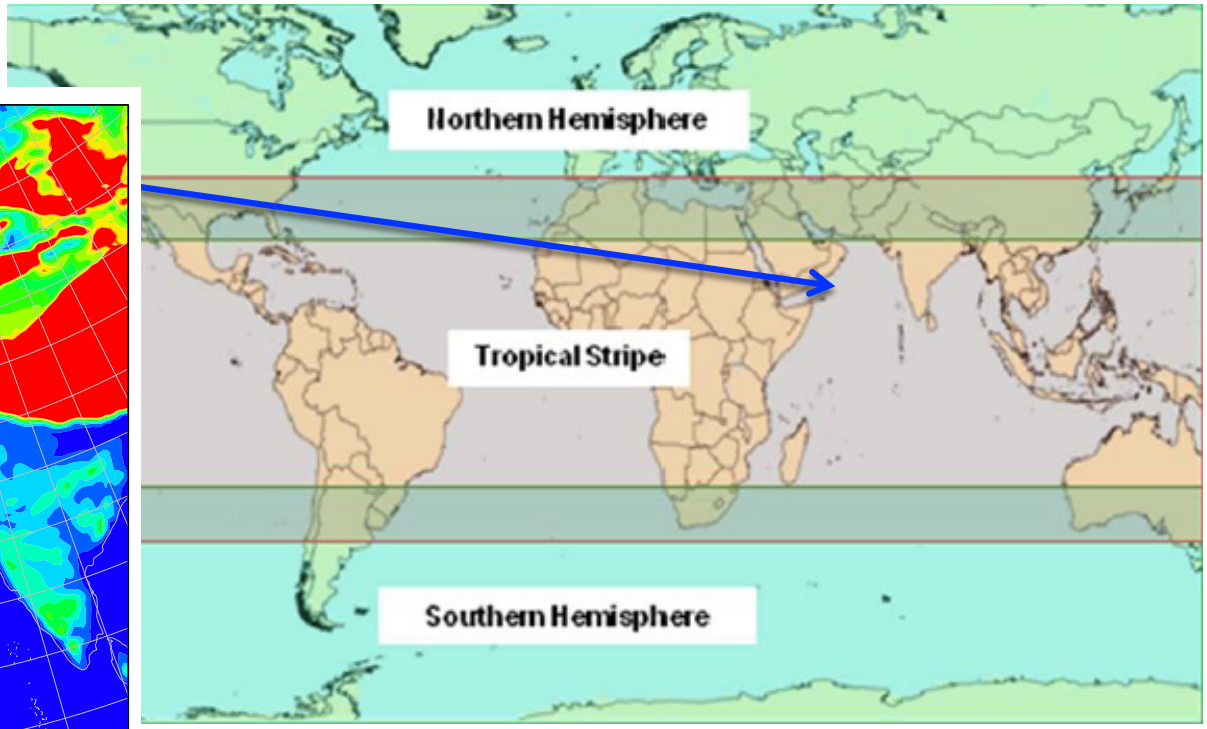
System Setup and Beyond



- Same versions & configurations (GSI and ARW) as AFWA parallel runs
- DTC collected cases (background, observations, diagnostic files) from AFWA runs for GSI debugging purpose->test & put forth recommendations (focusing on DA aspects)
- AFWA test & verify

Test Domain & Periods





SW Asia (T4) Domain

- 162x152 model grid
- 45 km horizontal grid spacing
- 57 sigma levels
- 10 hPa model top

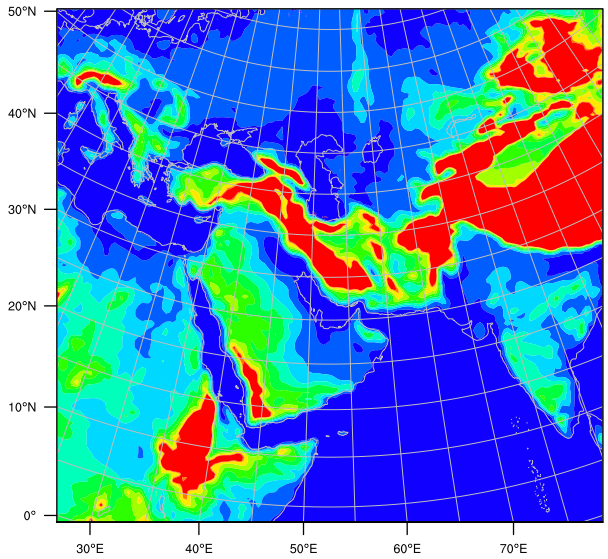
Test cases:

20130602-20130616	20130829
20130620-20130626	20130905
20130730	20130912
20130819	20131030
20130826	20131114

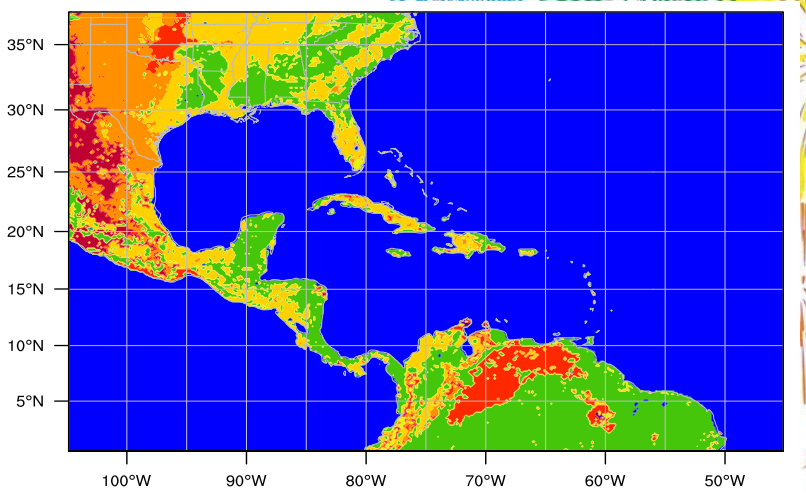
Real-time runs, archiving of specific files required

Error Source: Terrain Problem?

- DTC conducted similar tests in the Caribbean domain (T8) and no anomalous SLP values were present



vs



Surface Temperature

- Review: comparing difference between GSI & WRFDA data feed:
  - Observation types 181 & 187 were turned off for T, Q, UV (following GFS setup), but not for pressure in GSI. These data were used in the verification step.
- Trials: Ran GSI w/ 181 and/or 187 turned on (& other surface observations 183, 180).
- Finding:
  - GSI analysis did not fit the surface observations very well (7-10% compared to the background).
  - Limited obs impacts on the surface analysis
  - Surface temperature fit showed a similar pattern to SLP fit to observations
- Hypotheses:
  - Limited amount of data available
  - Surface temperature DA issues

Surface Temperature

Fixes:

(1) GFS BE was used. Switched to NAM BE & anavinfo (as/tsfc_sdv) (tuning obs. error variance): Slight positive improvement to SLP (RMS=3.3->2.5)

(2) RAP terrain adjustment to sfc T (currently GSI has terrain adjustment to sfc pressure only): Neutral impact

(3) Reduced observation error inflation: improved sfc T fit to obs (7%->19%)

(4) Bug fix in pre-processing step - much more data are able to feed into GSI

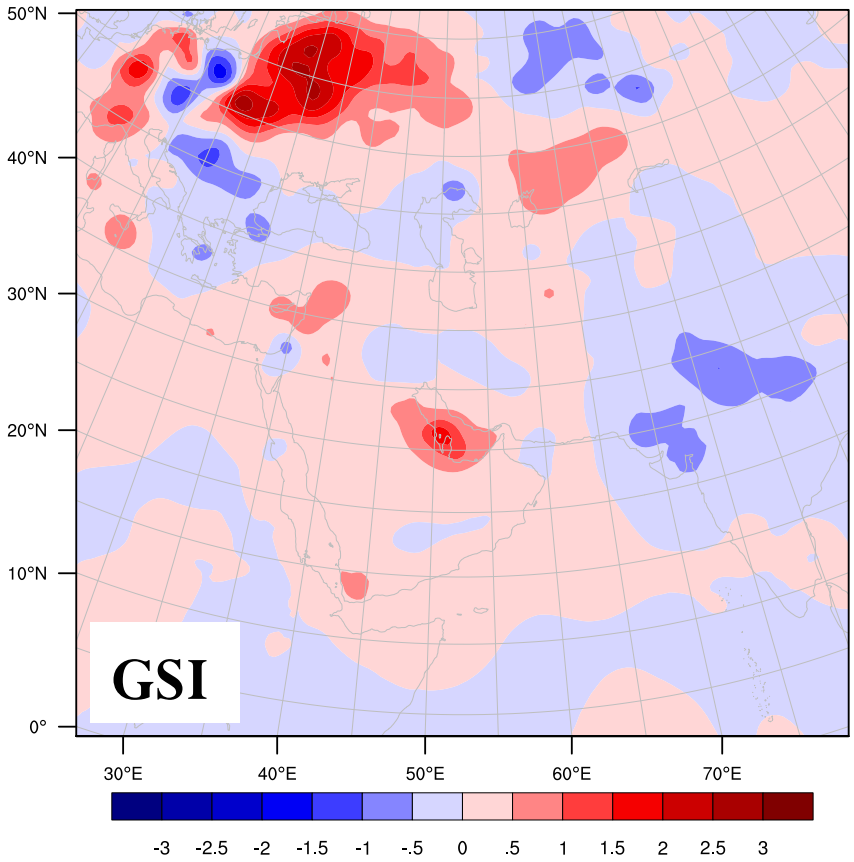
(5) Code changes to improve the usage of temperature under the model sfc:

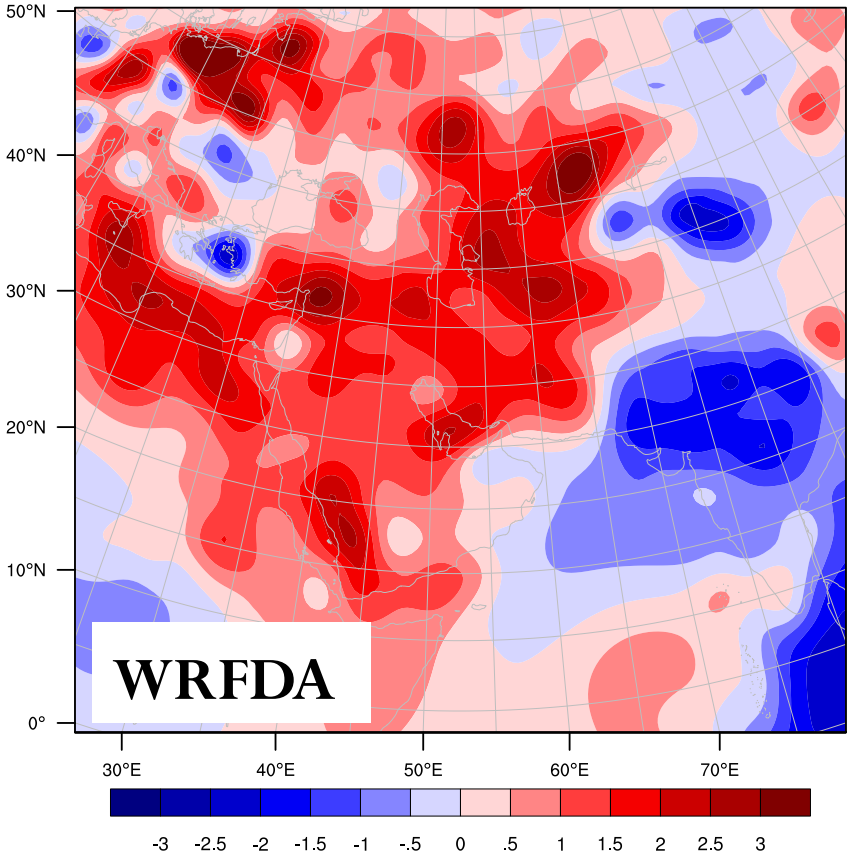
- Results: T discrepancy comparable w/ WRFDA. SLP for GSI still showing issues.

	Data Type	Before	After
q_s	187	128	839
	287	118	748
	281	182	2035
T_s	181	191	2212
	187	126	874

Error Source Re-Examination

Analysis Increments for 1st Level T (K)





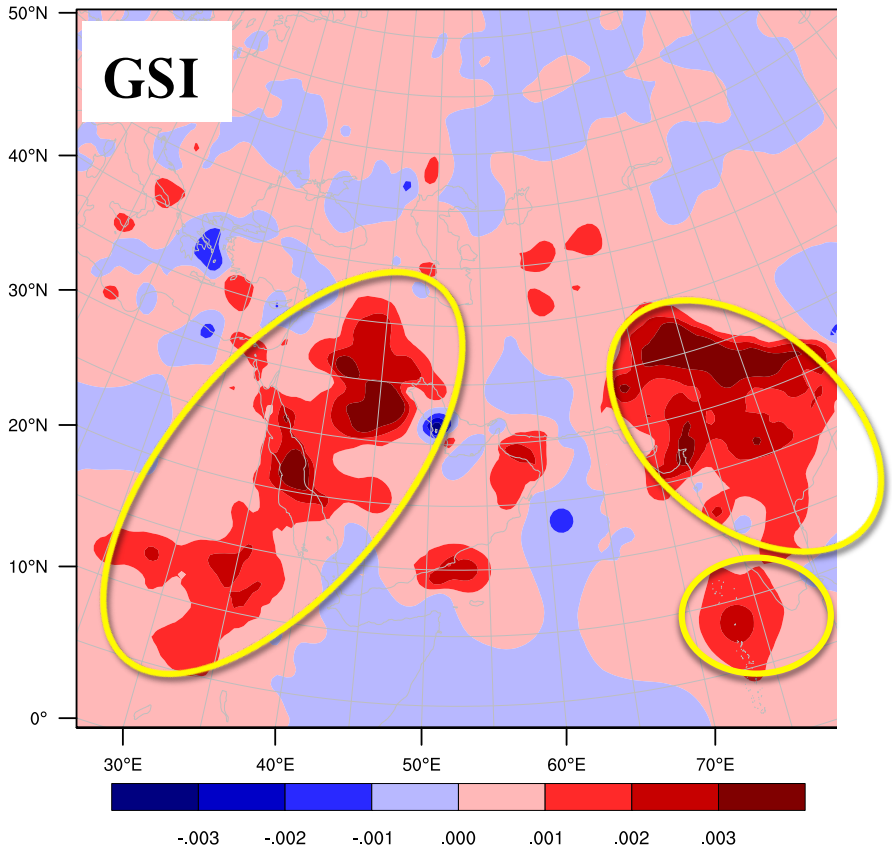
Analysis increments: WRFDA >> GSI

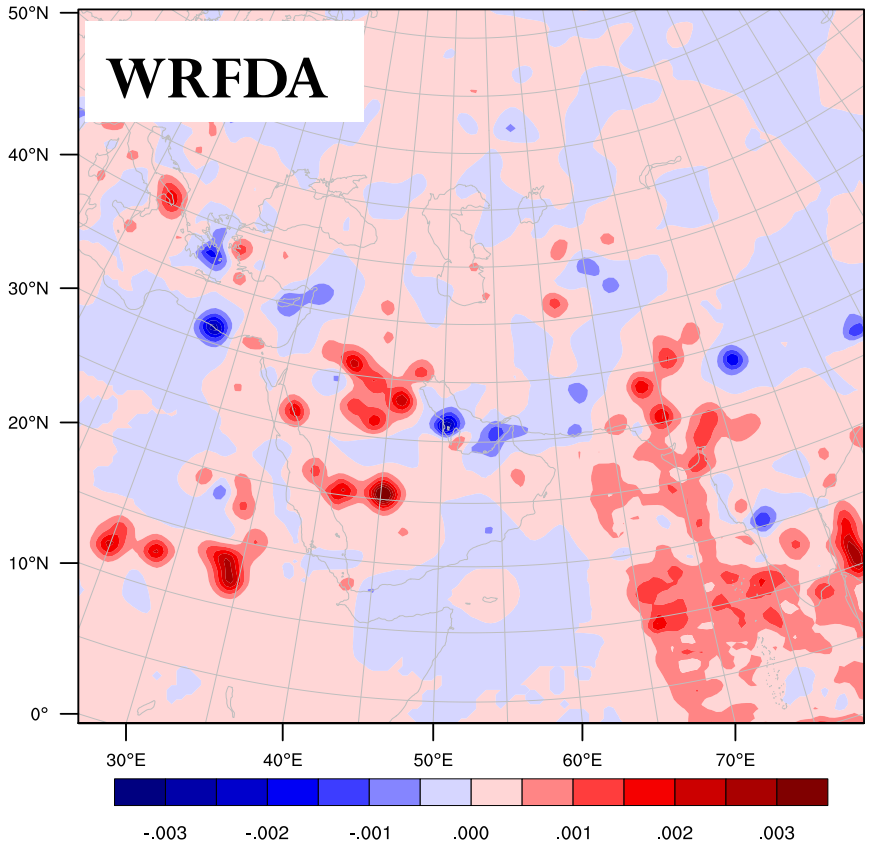
Impact scale: WRFDA > GSI

* All sfc T obs turned on

Error Source Re-Examination

Analysis Increments for 1st Level Mixing Ratio (kg/kg)



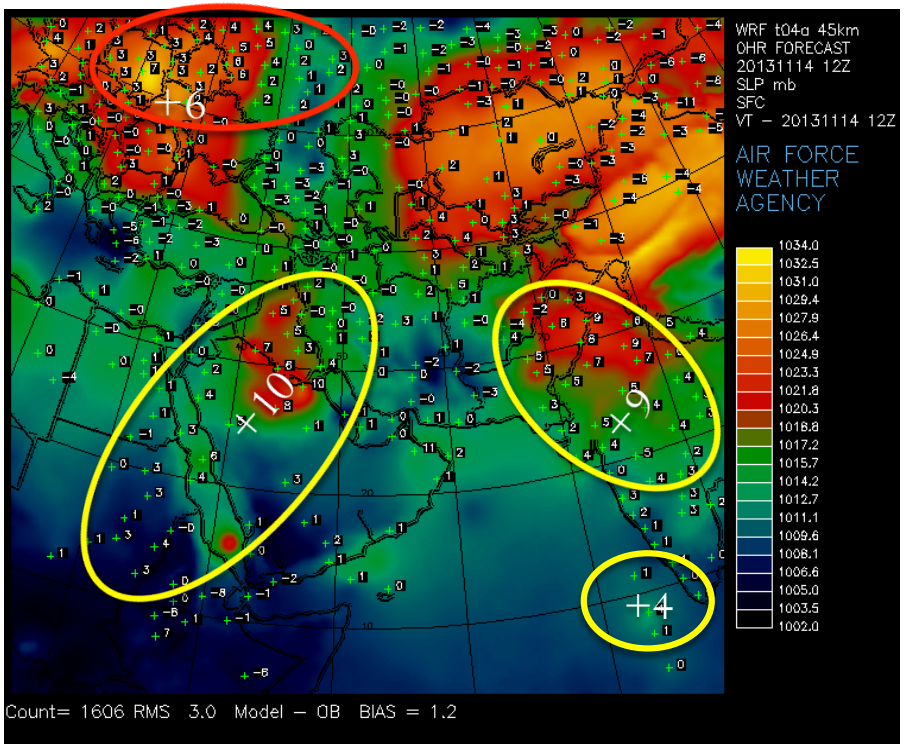


Analysis increments: WRFDA << GSI

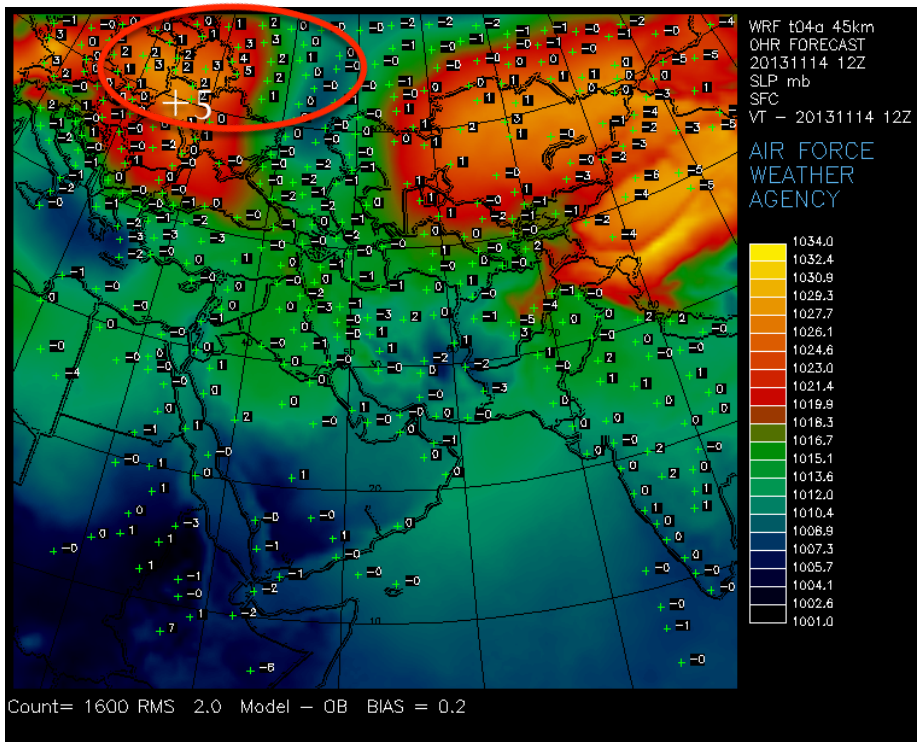
Impact scale: WRFDA < GSI

Surface Moisture DA Impact

SLP analysis increments and contour (hPa)



with q_s assimilated

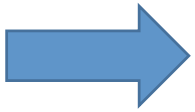


without q_s assimilated

Both exps. had obs. type 180 (Ts) turned on (AFWA config)

Findings

- GSI analysis added lots of moisture into surface & low level moisture field
  - Maximum analysis increment was 9g/kg and many points had analysis increments larger than 3g/kg
  - Most analysis increments were positive. These large increment areas matched well with the SLP problematic areas
  - Surface analysis increments covered (influenced) larger areas than the WRFDA analysis



Improve GSI surface moisture analysis

Surface Moisture QC in GSI

- All surface moisture observations (181, 183, 187) passed gross check

  ratio=residual/obserrlm is compared with **qcgross**

  - residual=ddiff/qsges *100, ddiff is innovation (O-B), and qsges is saturated background.
  - obserrlm is inflated obs error (mostly inflated to 2 or 5 times larger)
  - qcgross is QC threshold (qcgross=7)

ddiff	qsges	ratio	residual	obserrlm	qcgross	ratio_errors
7.388	16.473	1.861	44.846	24.096	7.000	0.245
6.327	16.864	5.077	37.517	7.390	7.000	0.800
5.865	17.038	1.710	34.420	20.134	7.000	0.294

Changes to Surface Moisture QC

GSI QC checks

- qcgross threshold: 7.0 → 2.0
- obserrlm: inflated obs error → original obs error

  Results: maximum Q analysis increment reduced from 9g/kg to 4.5g/kg. However, rejected data were added back during 2nd outer loop.

- Code changed to retain 1st outer loop rejections

Before

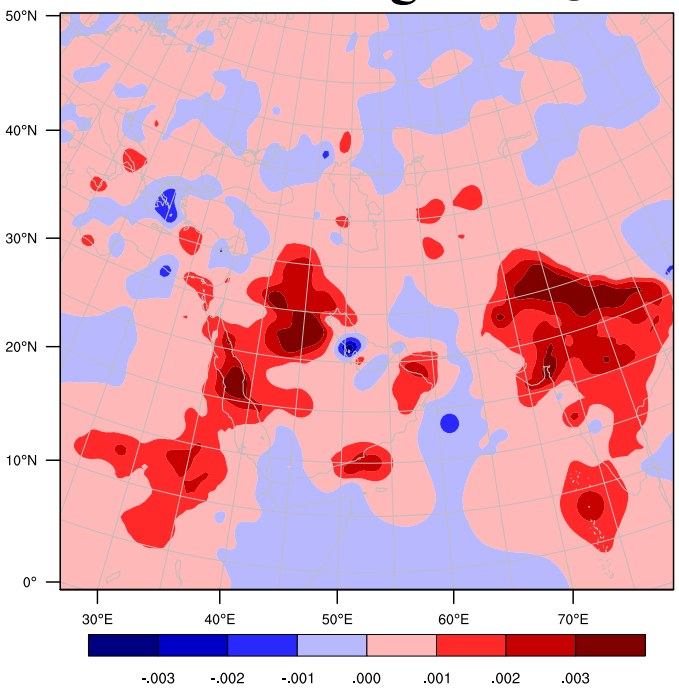
```
o-g 01          q       181 0000 count      1871
o-g 02          q       181 0000 count      1952
o-g 03          q       181 0000 count      1961
```

After

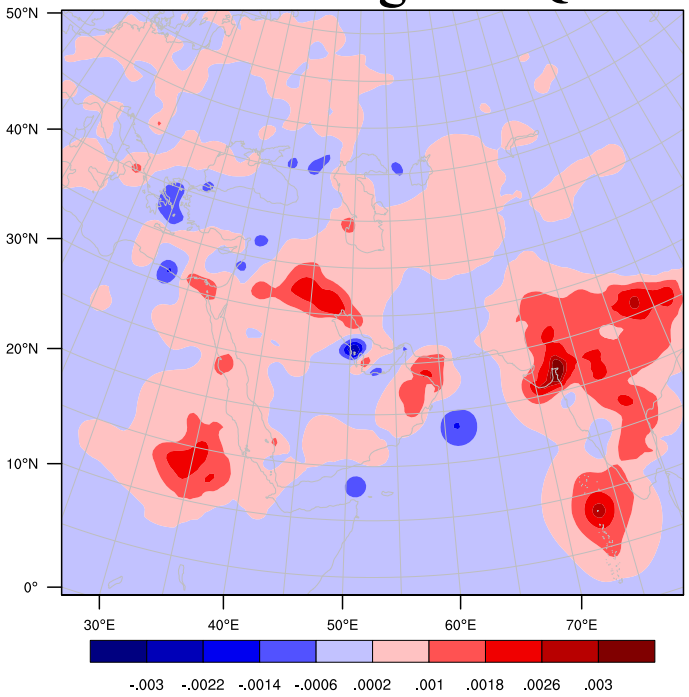
```
o-g 01          q       181 0000 count      1871
o-g 02          q       181 0000 count      1857
o-g 03          q       181 0000 count      1855
```

Analysis Impacts

Before changes to QC



After changes to QC

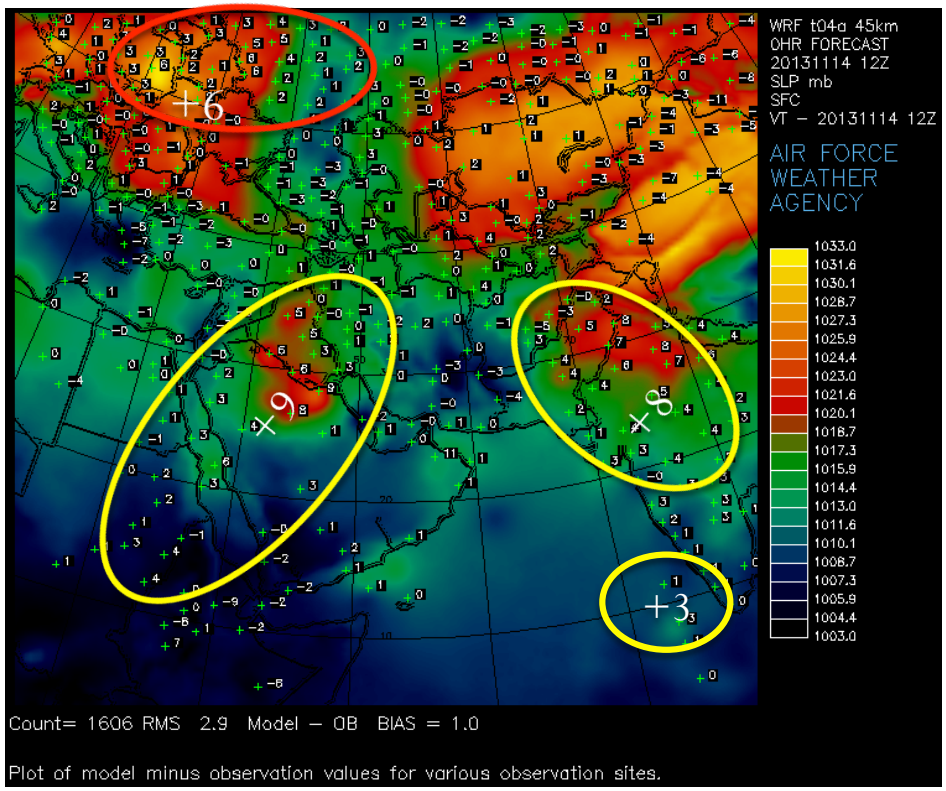


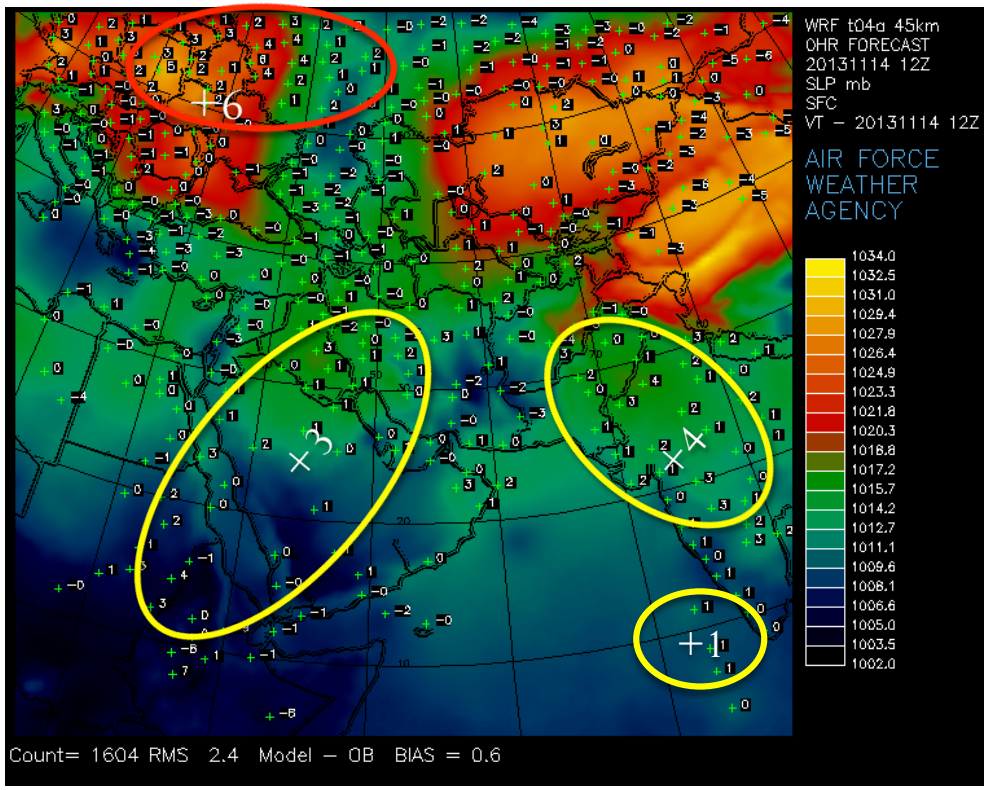
Maximum moisture analysis increment reduced to 2.2g/kg

Q Data type	Number kept	Number Rejected
180	25	4
181	1682	516
183	81	51
187	645	228

30% rejected

SLP with Surface Moisture QC Changes





Before

RMS=2.9 Bias=1.0

After

RMS=2.4 Bias=0.6

What Else?

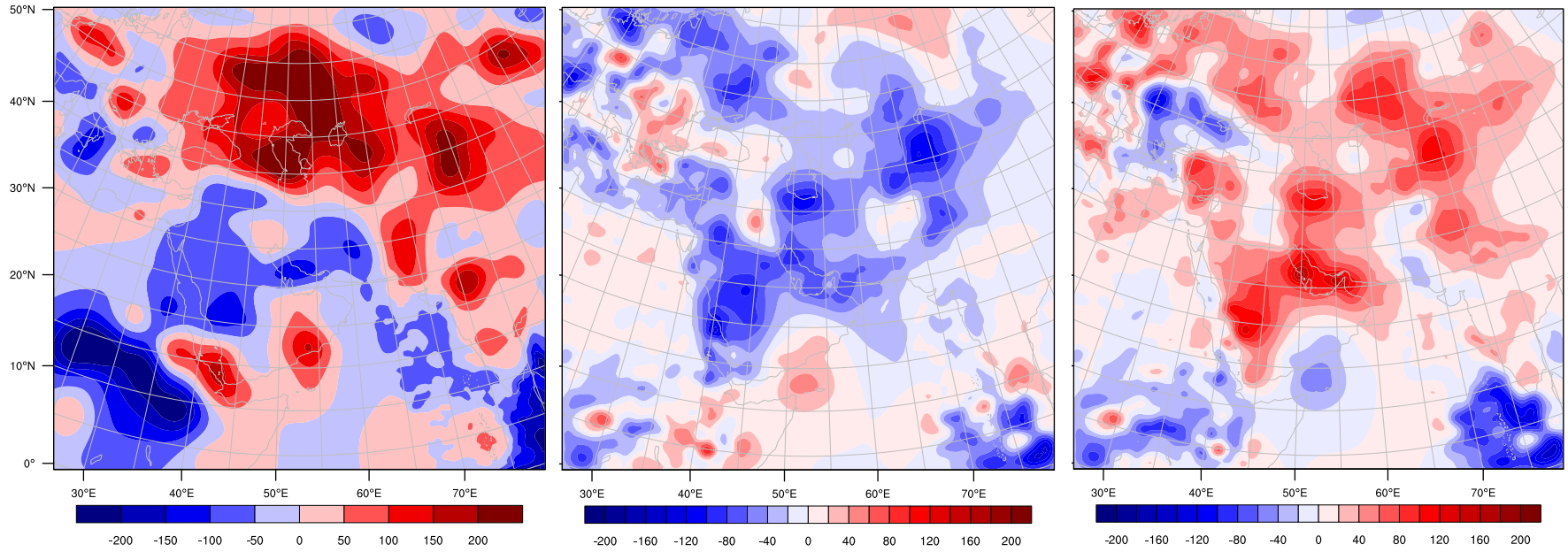
	Background	With surface T*	With surface P*
Bias	0.1	0.9	0.2
RMSE	1.4	4.2	2.0

Further examination of which sfc T & pressure data is assimilated is needed.

* Obs type 180 was turned on with surface T (AFWA config.)

Update to Dry Air Mass in Column (MU)

- MU is updated based on surface pressure obs.
- Different strategies to update MU in WRFDA and GSI

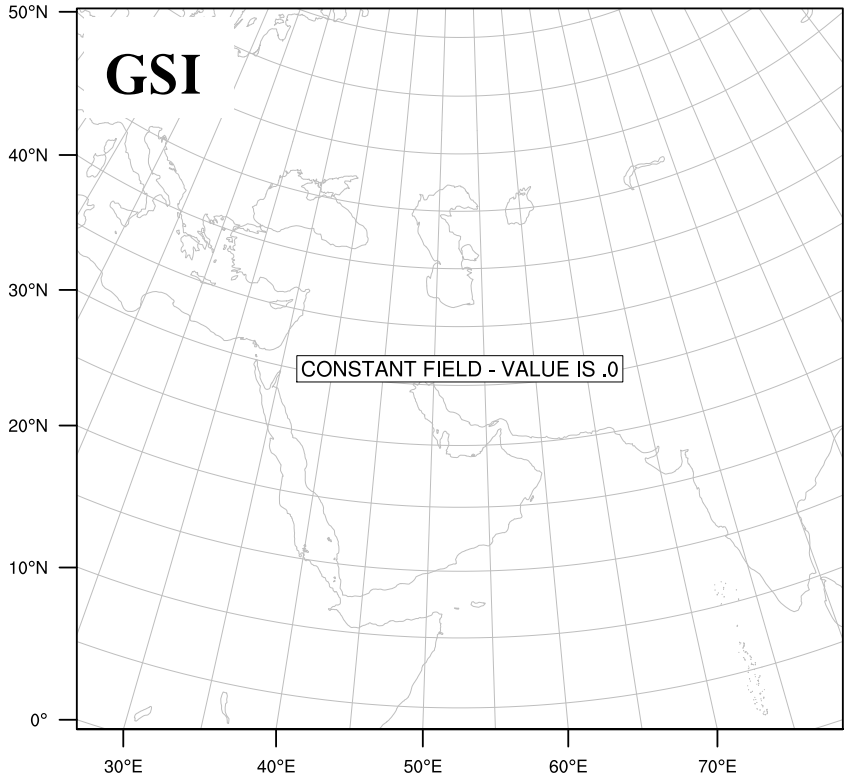


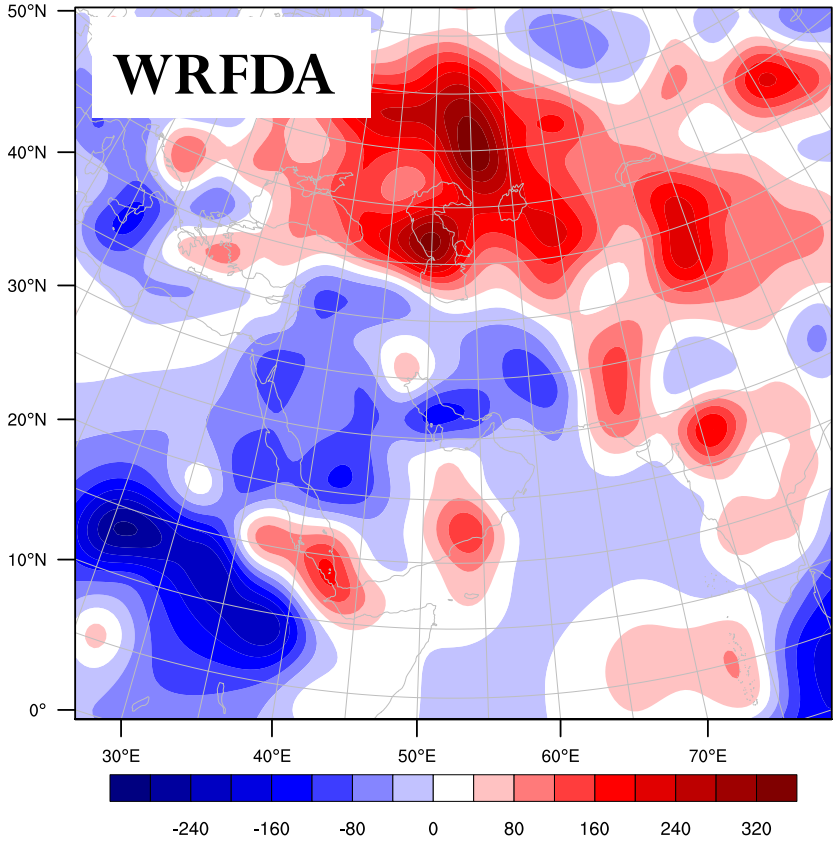
WRFDA GSI (original formula) GSI (WRFDA formula)

New GSI code passed to AFWA for further testing

Update to Surface Pressure

Analysis Increments Ps (Pa)





Analysis increments: WRFDA >> GSI

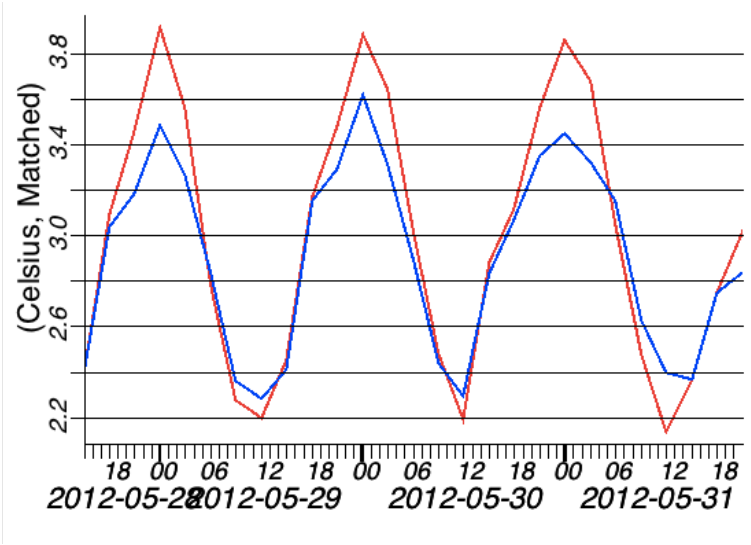
Impact scale: WRFDA > GSI

Summary and Future Plans

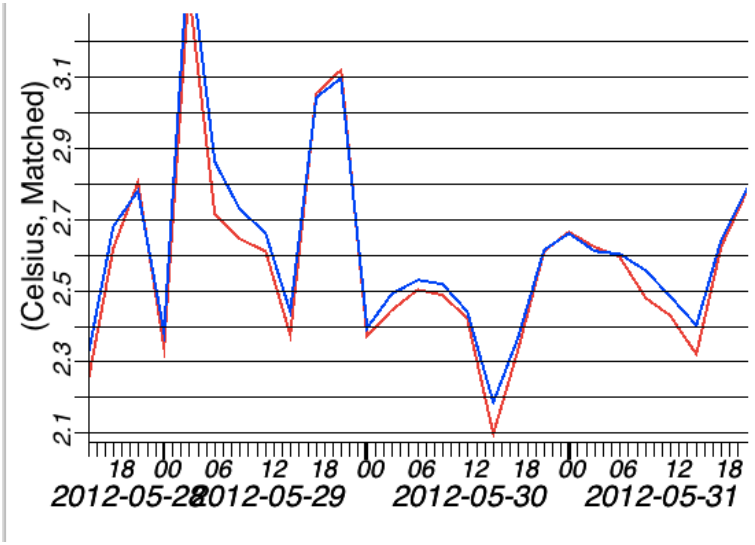
- SLP issues may originate from multiple sources associated with various components of the system
- Surface data assimilation in GSI requires insightful investigation, especially in domains with complex terrain
- Improvement made to surface moisture data assimilation through QC adjustment
- Some other configuration adjustments were also suggested to improve surface temperature data assimilation
- Further tests are pending for alternative MU computation
- Some other areas (e.g., post-processing, alternative surface background) may need further investigation as well

Alternative Surface Moisture Background

- GSI: background from 1st model level moisture
- RAP:
  - Background from 2-m moisture
  - Adjust 2-m moisture using 1st level analysis increments



2-m Dew point

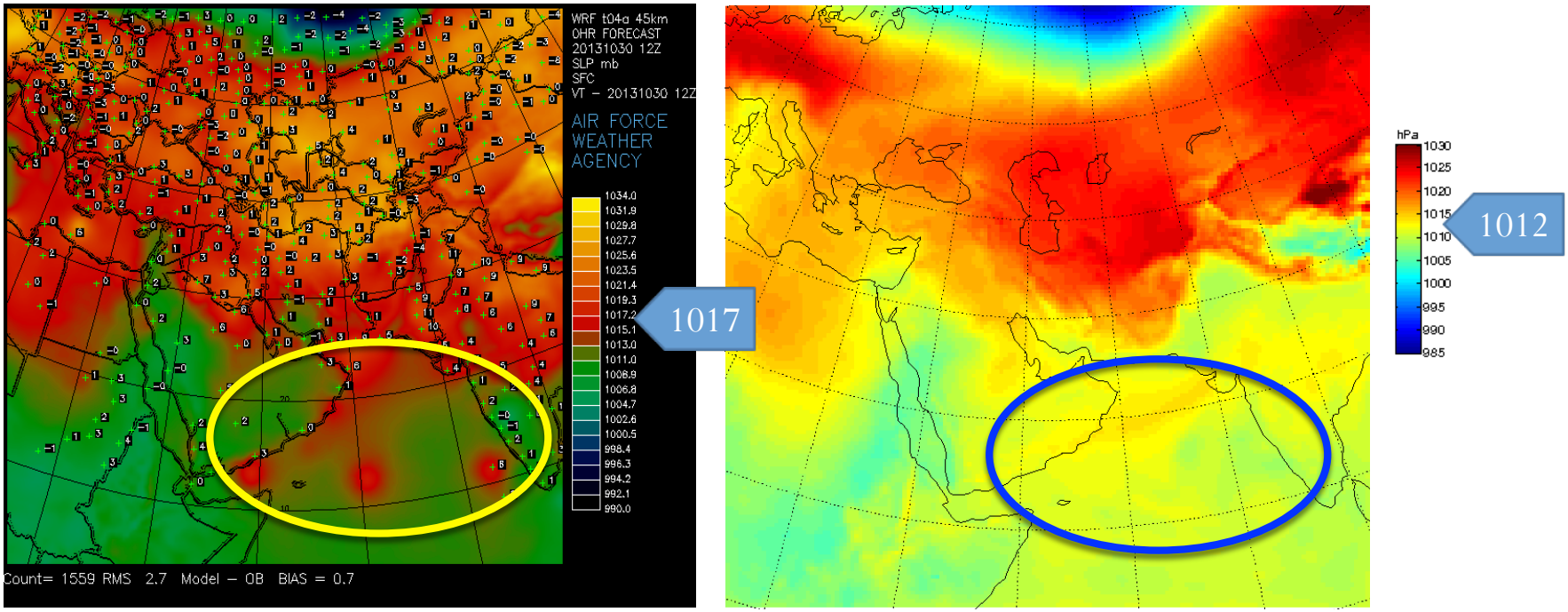


2-m T

BLUE: use 2-m Q as background **RED:** use 1st level Q as background

Post-processing

Mean Sea Level Pressure(hPa) for 2013103012

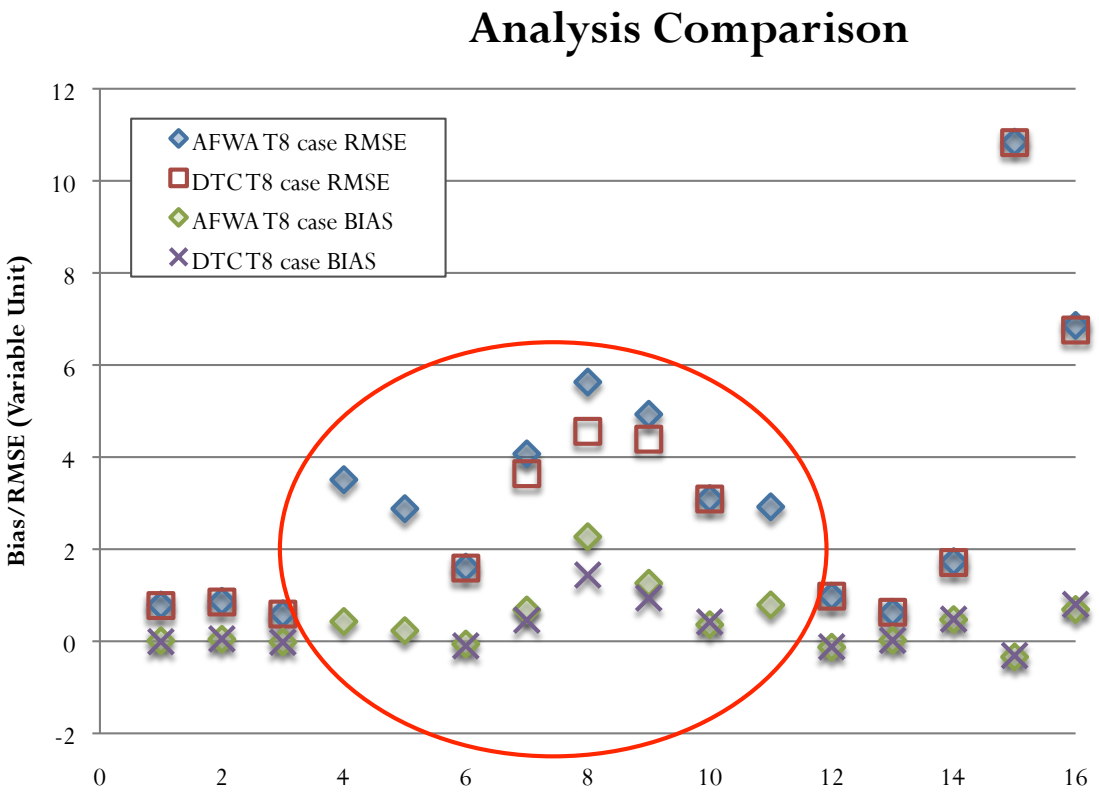


Produced by AFWA

Generated using UPP

Calculation of MSLP using the Unified Post Processor (UPP) with the same GSI analysis did not show those anomalous values

Extra…



Different ways of handling observation types in the pre-processing caused divergence of GSI code: potential difficulties in maintaining the code and its update

Var #	1-3	4-11	12-14	15-16
Var name	Ps 180, 181,187	UV 220, 231, 243, 245, 245, 246, 253, 280	T 120, 131, 180	Q 120, 180

Domain Specific BE Generation and Testing

Testing domain and system setup

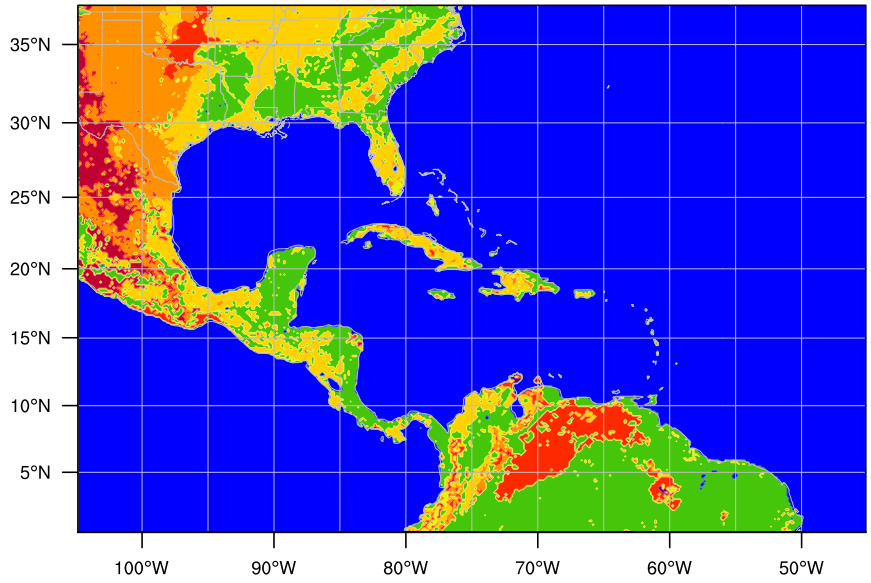
Investigation of GEN-BE v2.0

Impact studies

Summary

Testing Domain and System Setup

- Domain: Caribbean domain (T8)
- Model components:
  - GSI: v3.2
  - update_BC: 2012
  - WRF: v3.4
  - UPP: v1.0
  - MET: v4.1
- Config:
  - 212x122 model grid
  - 15-km horizontal grid spacing
  - 57 sigma levels
  - 10 hPa model top
  - Background: GFS
  - Data: NCEP prepBUFR files and satellite data



Investigation of GEN-BE v2.0

- Software package was delivered in August 2013
  - Users' Guide (draft)
  - GEN-BE v2.0 code
  - Converter (transfer GEN-BE code to GSI required format)
- DTC has been working with the development team at NCAR/ MMM interactively since original code delivery

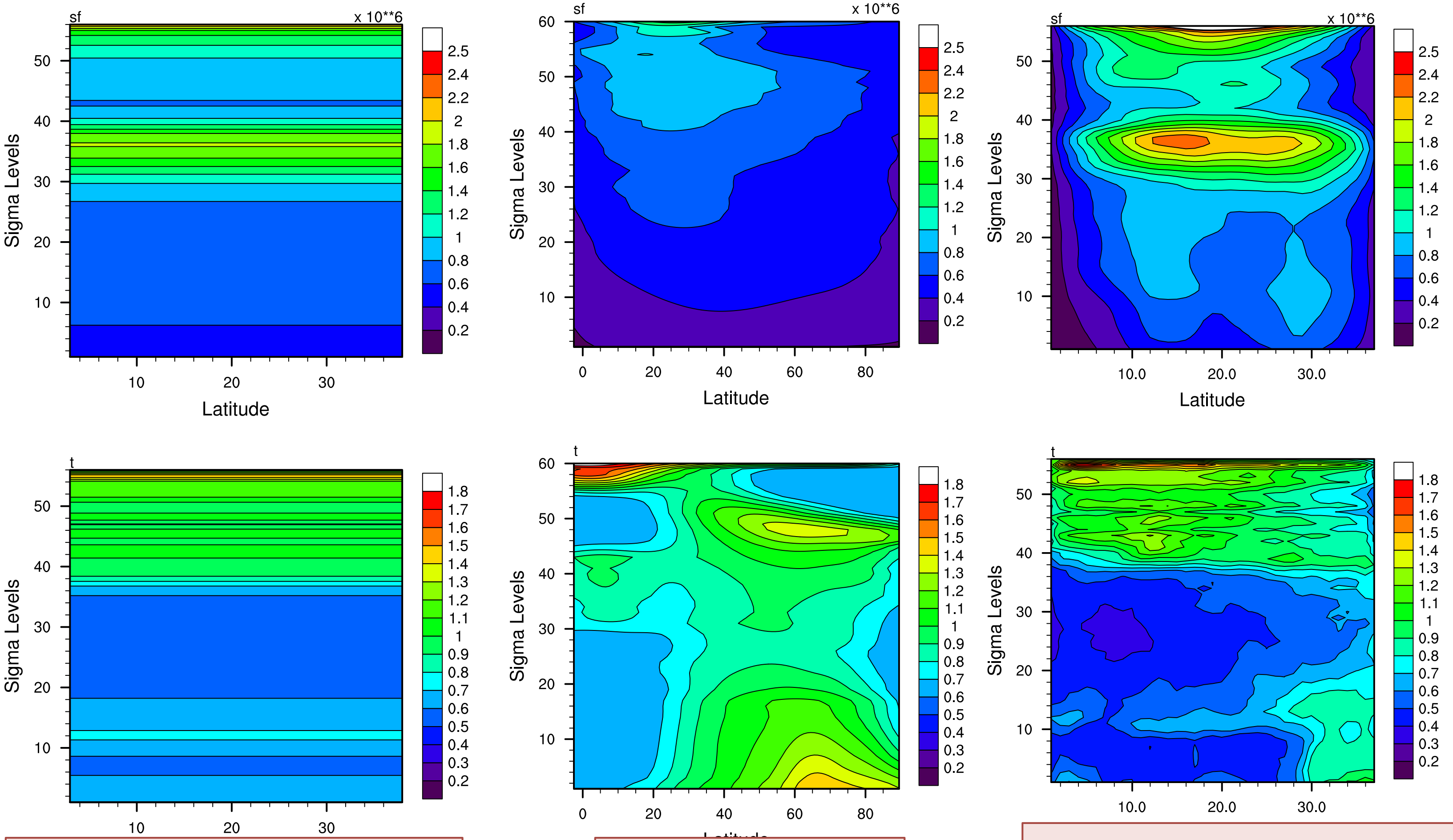
Test, Issues and Updates

Test/code update	Note
Original code release tested on multiple compliers (Aug, 2013)	Would not compile using intel or gfortran (fixed by developers), able to compile using pgi compilers
Linked missing libraries	Need to link grib libraries from WRF code, not included with source code
Small scripting changes made	Script changes needed to properly link display date for stage 0 perturbations
GSI converter code issues/code update (Sept, 2013)	Worked with developers to identify issues in converter code to convert netCDF output to binary file readable by GSI
Namelist option sensitivity tests	• Tested various namelist options to identify options that worked and produced most reasonable results (relative to NAM BE and code used for FY2012 BE tests). • A working version of namelist is provided in the final report
Latitude variation issues/bin_bype=3 test (Sept-Oct, 2013)	• BE diagnostics of sensitivity tests reveled no latitude variation in horizontal lengthscale, standard deviation and streamfunction regression coefficients • Developers recommended bin_type=3 (rather than 5) to gain latitude dependence. Test run failed due to memory deallocation error

Test, Issues and Updates (II)

Test/code update		Note
Follow up to latitude variation issues/ bin_type=3 test	Real definition work-around	Tested suggested work-around to fix memory deallocation error when using bin_type =3. This option did not work due to missing stage 2 output. Cannot use this option without bug fix.
	Bug fix code testing	Developers provided bug fixed code, however bin_type =3 still had no latitude variation present. A bug in the code (da_gen_be.f90) was identified
	2nd bug fix code testing	Test showed latitude variation in the netCDF file, but would not run using the GSI converter code
	Converter code fix testing	DTC met with developers to discuss converter code issues and went through how GSI reads file to ensure proper reading of the BE by GSI
New code (v2.1) delivered with bug fix for real definition and updated converter code (Dec, 2014)		• Code included updates to fix memory deallocation error issues, as well as converter code reworked to handle the bin_type =3 option for GSI • Tests with new code showed values that were not in the appropriate range for GSI
Update to v2.1 delivered (Dec, 2014)		• Tests showed code now readable by GSI, but only working for GSI moisture analysis option 'qoption=1'. AFWA system uses 'qoption=2' • Due to magnitude of changes, developers recommended proceeding with qoption=1 until updates to the code to use qoption=2 can be added to GEN-BE

Horizontal Length Scale



Domain-Specific BE (qoption=2)

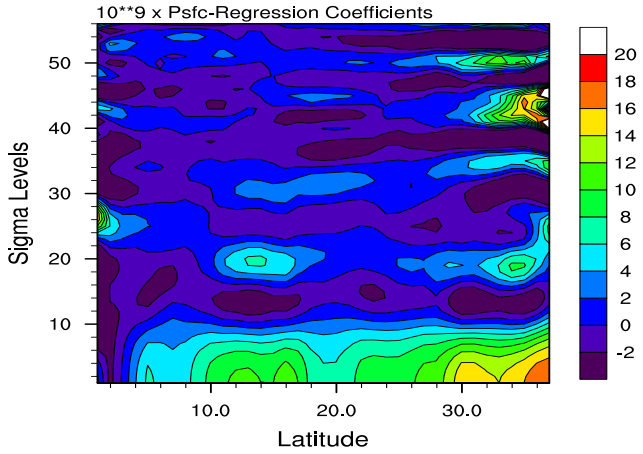
NAM BE

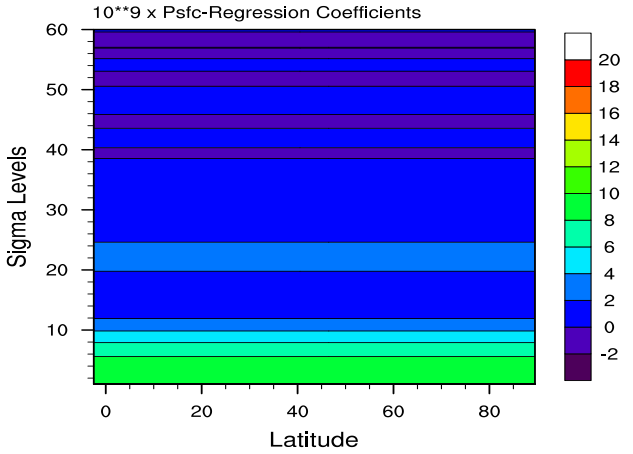
Domain-Specific BE (qoption=1)

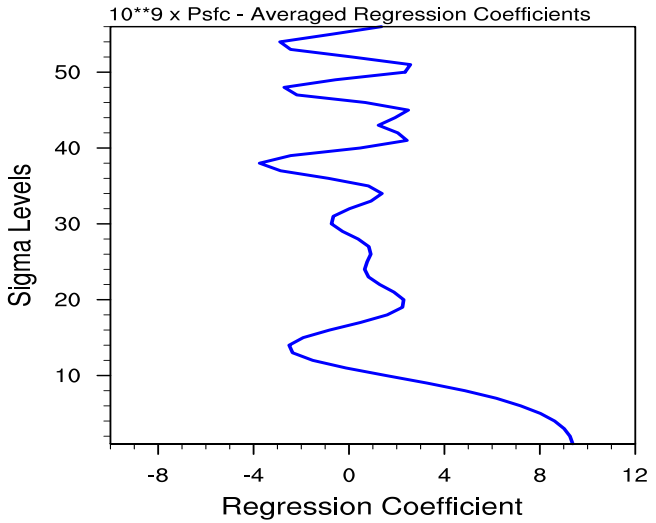
Developmental Testbed Center

Surface Pressure Regression Coefficient

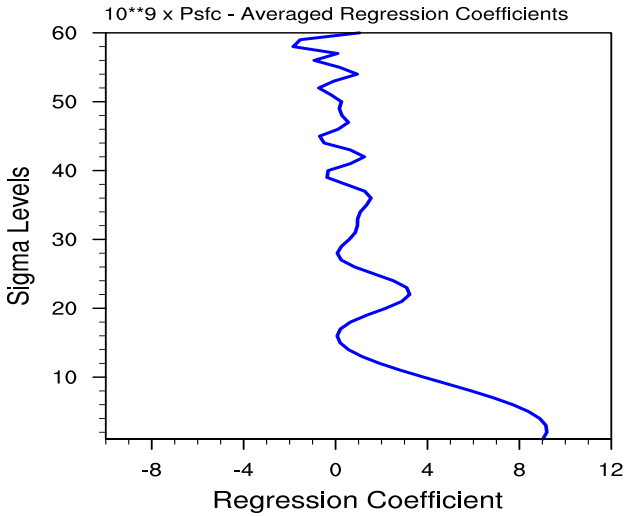
Psfc regression coeff. from domain-specific BE presents latitude dependence







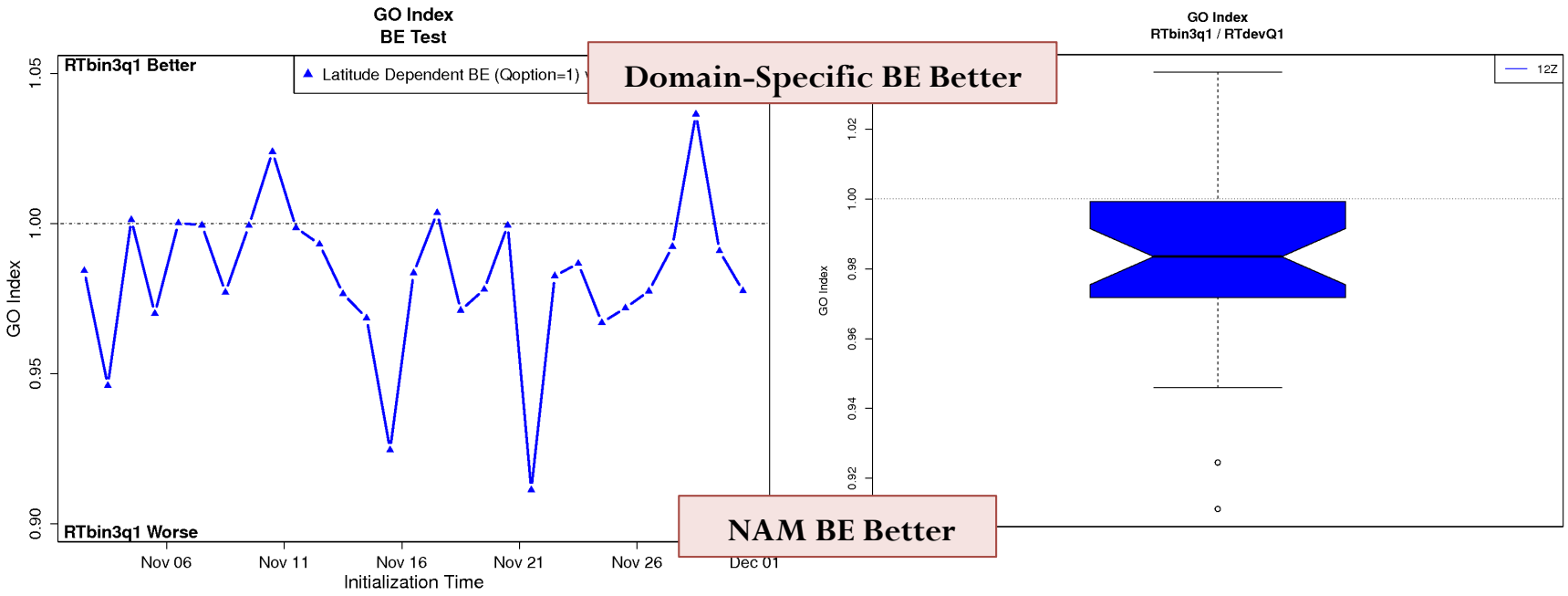
Domain-Specific BE (qoption=1)



NAM BE

Domain-Specific Background Error

- BE generated using 1-month forecasts with GEN-BE v2.1 (NMC method)
- Both BEs were tuned only using the tuning factors in the 'avavinfo' file following those of the NAM BE.

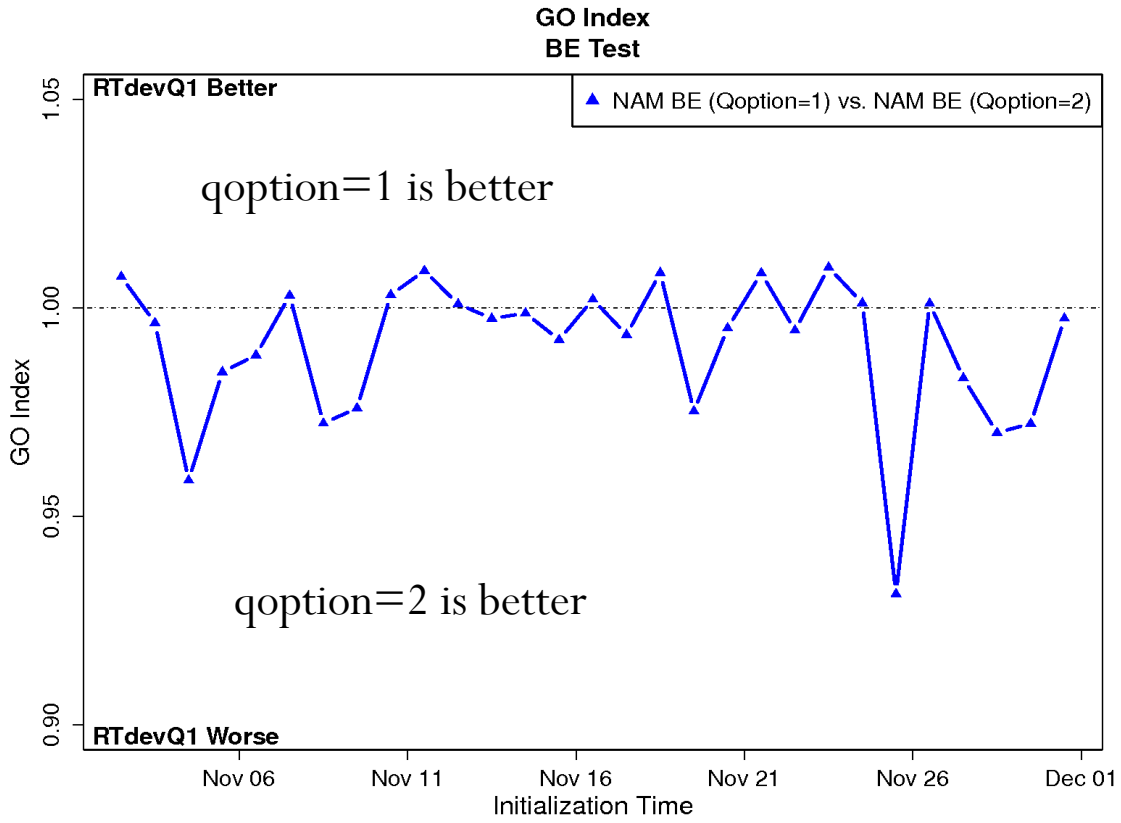


- Results favor NAM BE (qoption=1), instead of domain-specific BE (qoption=1)

Summary

- GEN-BE v2.0 was tested and associated issues were tackled with developers. However, there are still remaining issues (e.g., BE latitude dependence issues with GSI qoption=2)
- Background errors were generated using the latest capability of GEN-BE v2.1 for GSI
- NAM BE produces better overall forecast score (GO index>1) than the domain-specific BE generated by GEN-BE v2.1
- Further tests and work will be needed once the remaining issues are solved with the software, including BE tuning

qoption=1? or 2?



Go Index scores for NAM BE over a 1-month forecast period from 1–30 November 2013.