13rd JCSDA Technical Review Meeting & Science Workshop on Satellite Data Assimilation,
NCWCP, College Park, MD, 13-15 May, 2015

Data Assimilation Activities at the Developmental Testbed Center (DTC)

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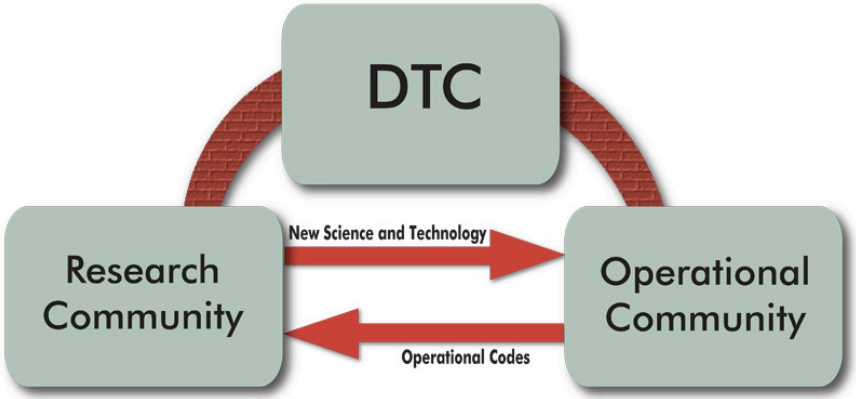
Developmental Testbed Center

What is the DTC?

- **Purpose**: facilitate the interaction & transition of NWP technology between research & operations
  - **O2R**: Support operational NWP systems to the community
  - **R2O**: Perform Testing & Evaluation (T&E) on promising NWP innovations for possible operational implementation
  - **Interaction between R & O**: Workshops, Visitor Program, Newsletter, Training
- Jointly sponsored by NOAA, Air Force, NSF, & NCAR



Software Systems

- Gridpoint Statistical Interpolation (GSI):
  - Annual community release since 2009
- Ensemble Kalman Filter (EnKF):
  - First beta release in January 2015

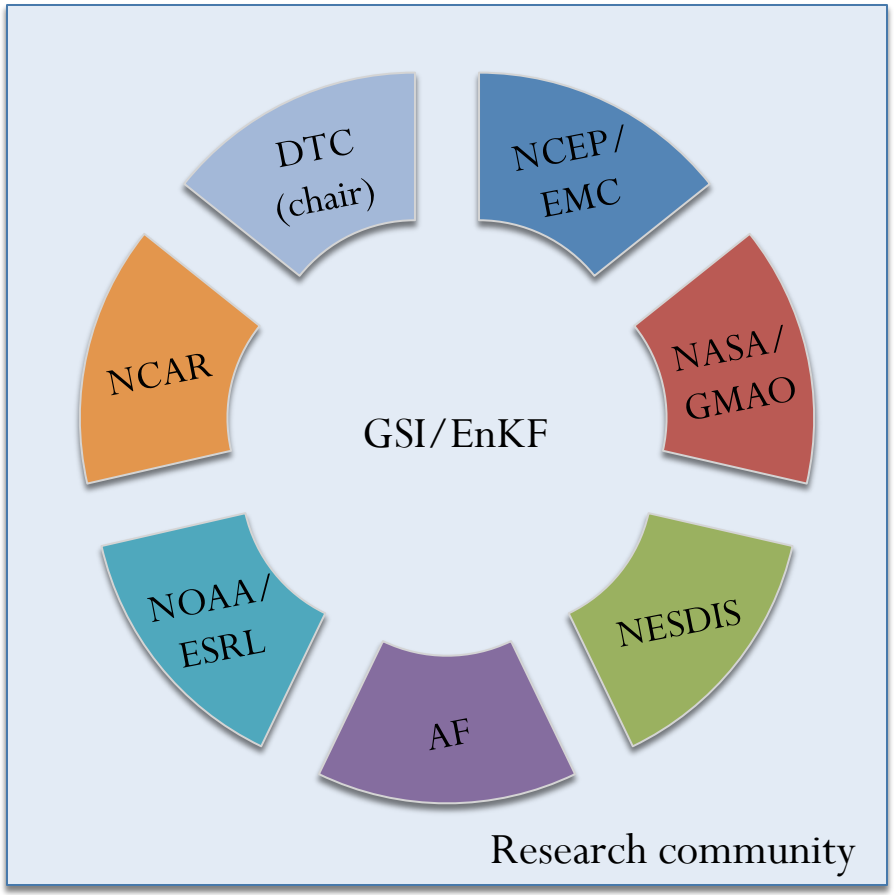
Upcoming GSI/EnKF events:

- Release: community GSI v3.5, EnKF v1.0, July 2015
- Onsite tutorial (including hands-on practical sessions): GSI-August 11-13, EnKF-August 13-14, 2015, Boulder, CO

Close collaboration between DTC & developers is critical to the success of this work!

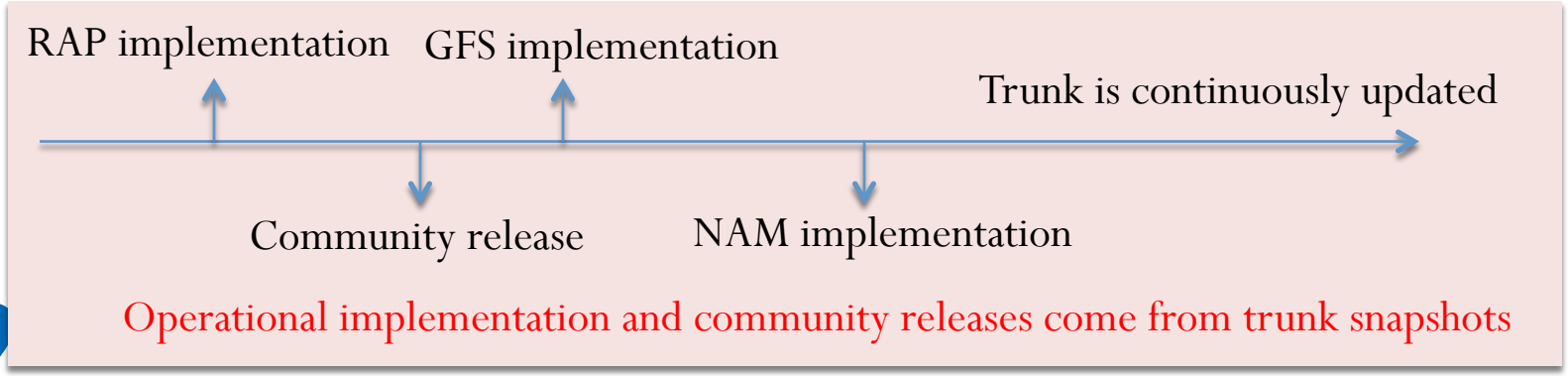
Code Management

- Data Assimilation (DA) Review Committee (DRC)
  - Goal: connecting the GSI/EnKF operational agencies and the broader research community under a unified community framework
  - Transitioned from GSI Review Committee (since 2010), with new membership for EnKF
  - Coordinate GSI and EnKF development
  - Perform code review
    - Over past 4 years, ~100 tickets were received. Many combined changes from multiple teams
    - All GSI updates, including those for operations at NOAA, NASA, AF and other research facilities, come from the GSI trunk code the GRC has reviewed and approved



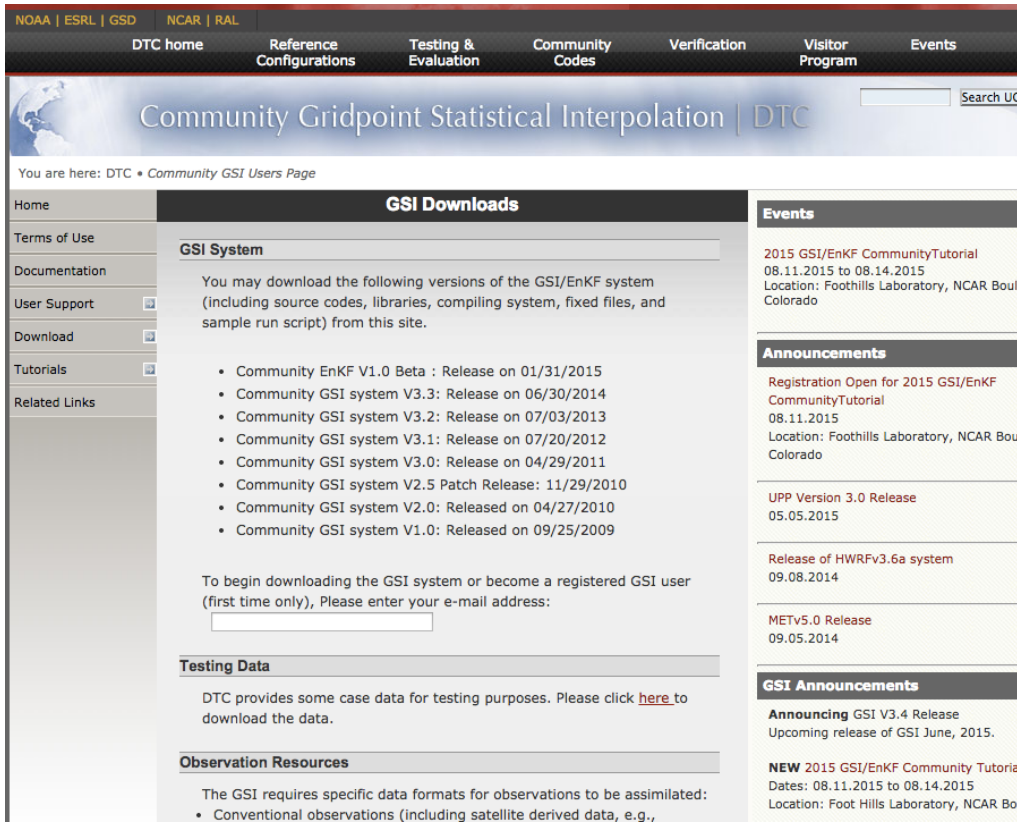
Code Repository
- Access to the latest code

- The DTC and EMC decided to merge the EnKF and GSI repositories in 2014, avoiding potential code divergence
  - EnKF uses GSI for innovation calculation. Changes in GSI's observation operators and resulted diagnostic files will affect EnKF
  - The DTC hosts a community repository
    - Mirrors all components residing within EMC's GSI operational repository
    - Contains files not necessarily required by internal EMC users, e.g., supplemental libraries required for running GSI and EnKF, multiple-platform compilation tools, simplified run scripts, community- shared diagnostic utilities, etc.



Publicly Released Package

- GSI source code
- EnKF source code
- Auxiliary files and reference configurations
- NCEP library source code
- Multiple-platform compilation tool for EnKF, GSI, and libraries
- Simplified run scripts
- Diagnostic and display utilities
- User's Guide
- Testing cases
- Online practice

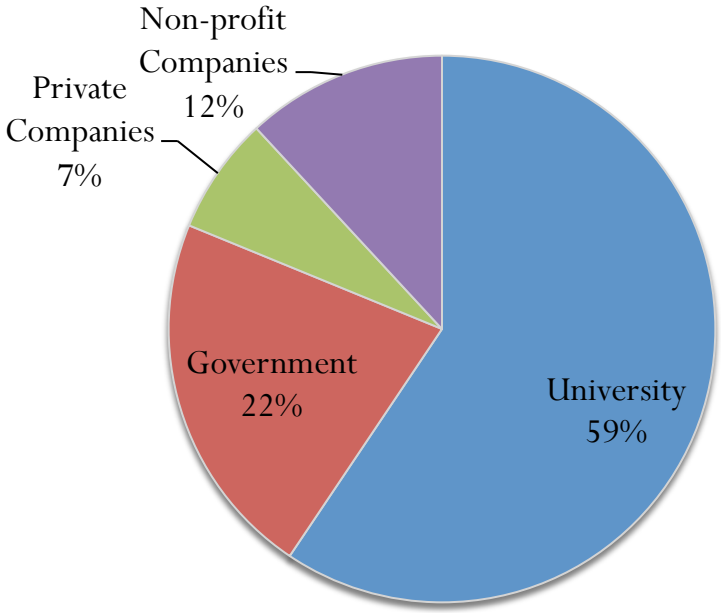


- GSI user's webpage: http://www.dtcenter.org/com-GSI/users/index.php
- EnKF user's webpage: under construction
- Both share the same download page

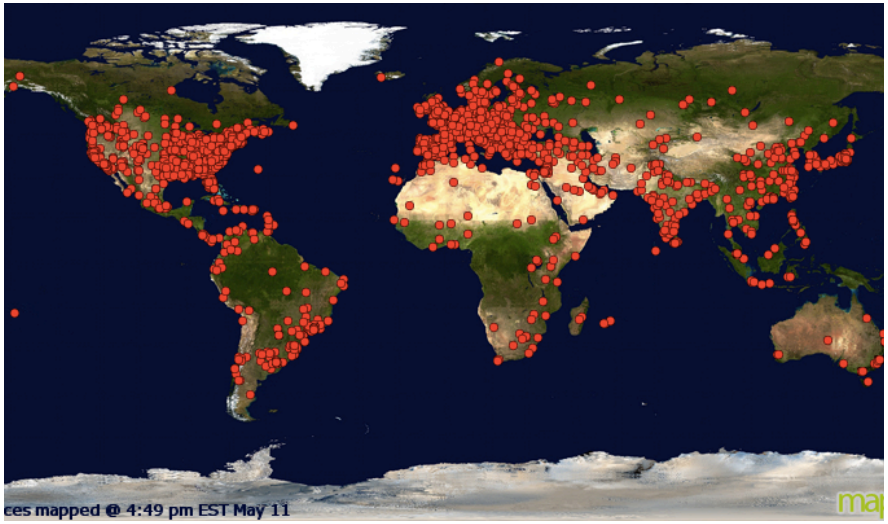
Community Users

- 7 annual releases since 2009
- On-site training:
  - 5 GSI residential tutorials
    - 2013: co-hosted with EMC and JCSDA at NCWCP
  - 3 GSI instructional sessions
  - 1 BUFR/PrepBUFR tutorial
  - 1 EnKF instructional session

  ~400 participants from U. S. and international communities
- 2 GSI workshops
  - NCAR, Boulder, CO
  - NCWCP, Maryland, MD
- Registered users:
  - ~1300 (up to April, 2015)
  - Additional registered through the HWRF community release



Affiliation of registered users



Who is accessing the GSI User's Webpage?

Code Test

- Repository code tests
  - Multiple platforms/compilers (DTC)
  - Multiple operational configurations (EMC)
- Pre-implementations (operational centers, e.g., EMC, AF,…)
- DTC community tests
  - Functionally similar testing environment
    - End-to-end system and archived operational data and background files
    - Can be tuned to operational setup (model versions, workflow, namelists)
  - Facilitate community development tests
    - DTC Visitor Program
  - Pre-release tests: testing GSI/EnKF, as well as libraries and scripts
  - Independent code tests in support of operational applications, providing recommendation for pre-implementation tests and identifying research areas
    - Existing capabilities
    - Developmental community research

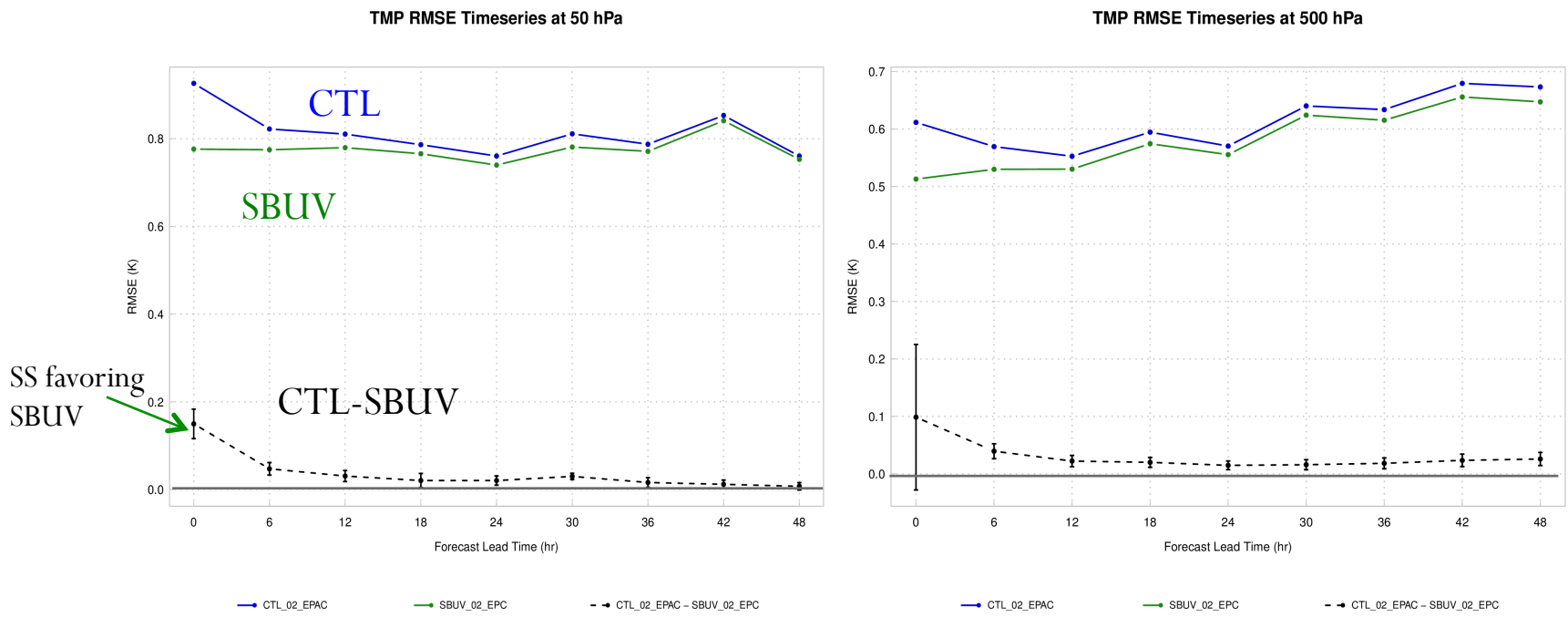
T&E in Support of R2O

Air Force	DTC tests	
2014 AF Regional theatres: Phased implementation	Test GSI for enhancing GSI regional operations	Observation impact studies and in-house GSI mitigation: • Sea level pressure bias: GSI-ARW inconsistencies • Observation Impact: SBUV, GOME (inc. ozone channels) • Raised model top (10 to 2 mb) • Forecast Sensitivity to Observations*
2013 AF Global-coverage: Jul, 2013	Test for GSI regional pre-implementation	Test configuration for regional theaters & community contributions: • Sea level pressure bias: GSI surface DA QC issues • Regional background errors*
	Tests for AF global-coverage GSI pre-implementation	Test configuration for AF outer domains-> configuration in 2013 implementation (global coverage domains)

2012	Alternative DA system/technique T&E	• System/technique comparison:
		  • WRFDA, DART versus GSI
		  • PrepBUFR (GSI data format) versus Little_r (WRFDA data format)
		• Background error generation
		• Data impact study

* Community utilities

SBUV/2 Impact: AF GSI-ARW Meso System



RMSE of temperature forecasts at 50 hPa and 500 hPa

- O_3 not forecast variable in ARW
  - GFS ozone used for background
  - Indirect impact on analysis and forecasts

SBUV/2 Impact (cont.)

99% CI Statistical Significance Table: SBUV vs. CTL02 (EPAC)

TEMP RMSE	Forecast Lead Time (hr)								
Pressure Levels (hPa)	0	6	12	18	24	30	36	42	48
50	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	--
100	EXPT	--	--	--	--	CTRL	--	--	--
250	--	--	--	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL
400	--	EXPT	EXPT	--	--	--	EXPT	--	--
500	--	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT
700	--	--	--	--	--	--	--	--	--
850	--	--	--	--	--	--	--	--	--
925	EXPT	--	--	--	--	CTRL	CTRL	--	--

U-Wind RMSE	Forecast Lead Time (hr)								
Pressure Levels (hPa)	0	6	12	18	24	30	36	42	48
50	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	--	EXPT	EXPT
100	EXPT	EXPT	--	--	CTRL	--	--	--	--
250	--	--	--	--	--	CTRL	--	--	--
400	EXPT	EXPT	EXPT	EXPT	EXPT	--	--	--	--
500	EXPT	--	EXPT	EXPT	--	--	CTRL	--	--
700	--	EXPT	EXPT	EXPT	--	--	--	--	--
850	EXPT	EXPT	--	--	--	--	--	--	--
925	CTRL	EXPT	EXPT	EXPT	--	--	--	--	--

V-Wind RMSE	Forecast Lead Time (hr)								
Pressure Levels (hPa)	0	6	12	18	24	30	36	42	48
50	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	--	EXPT
100	EXPT	--	--	--	--	--	--	--	--
250	--	EXPT	EXPT	--	--	--	--	--	--
400	EXPT	EXPT	EXPT	EXPT	--	--	--	--	--
500	EXPT	EXPT	EXPT	--	--	--	--	--	--
700	EXPT	EXPT	EXPT	EXPT	--	--	--	--	--
850	EXPT	--	--	--	--	EXPT	--	--	--
925	--	EXPT	EXPT	--	--	EXPT	--	--	--

SPFH RMSE	Forecast Lead Time (hr)								
Pressure Levels (hPa)	0	6	12	18	24	30	36	42	48
50	--	--	--	--	--	--	--	--	--
100	--	--	--	--	--	--	--	--	--
250	--	--	--	--	--	CTRL	--	CTRL	--
400	CTRL	--	EXPT	EXPT	EXPT	--	--	--	--
500	--	CTRL	--	--	EXPT	EXPT	EXPT	EXPT	--
700	--	--	--	--	--	--	EXPT	--	--
850	--	--	--	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL
925	--	--	--	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL

- Temperature:
  - Positive impacts at upper- and mid-levels
  - Degradation at ~250 hPa
- Winds:
  - Positive impacts particularly at early lead times
- Mixed results for specific humidity
  - Negative at lower levels

Green shading: SBUV better Blue shading: CTL better

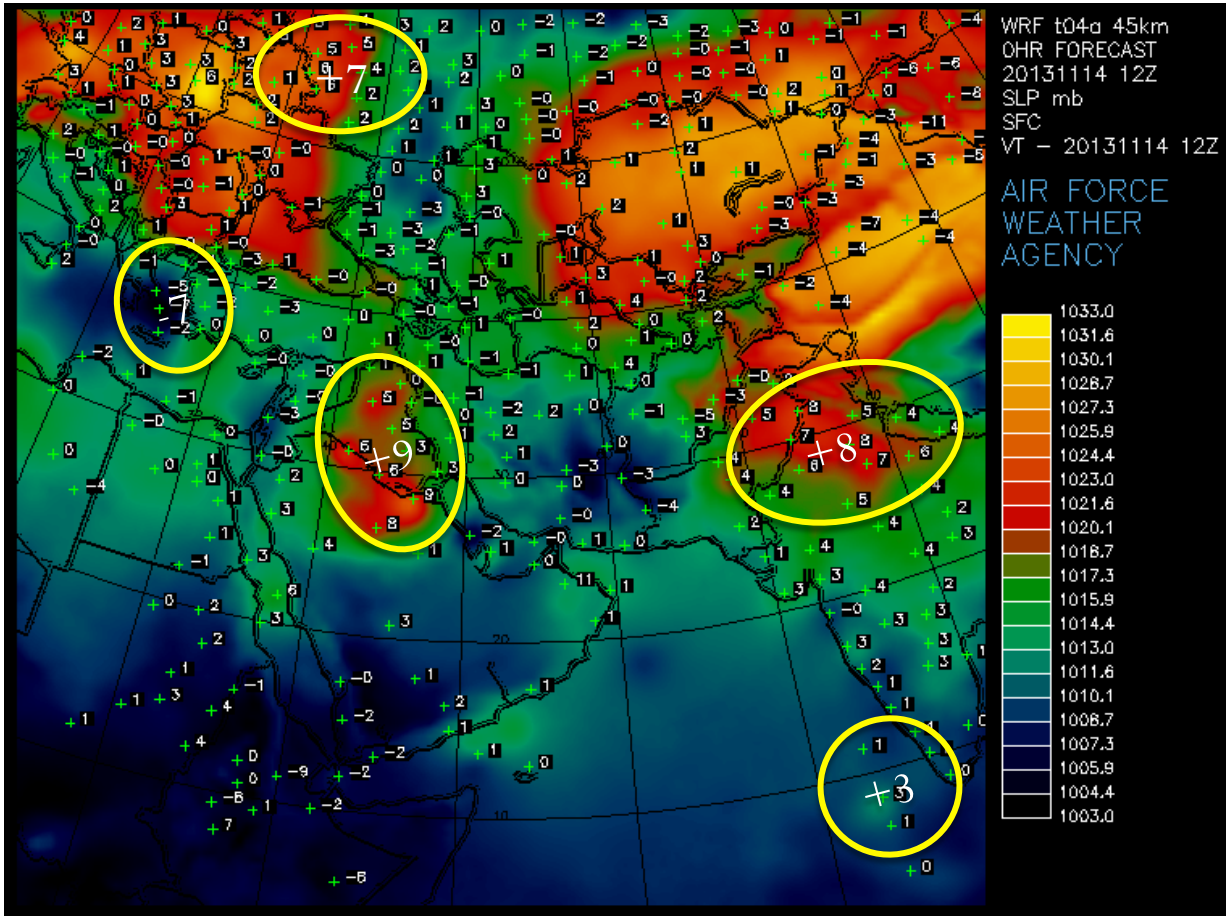
verification against ERA-I

Reported Real-Time SLP issues

SLP is not an analysis variable, nor a forecast variable:

- Both DA and DA beyond (post-processing) investigated

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



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

Inconsistency between ARW and GSI Control/ Prognostic Variables

- Geopotential height (ϕ): prognostic variable in ARW; no update from GSI
- Lowest model level pressure perturbation (P) is used in ARW for MSLP computation – not dry air mass (μ) or surface pressure (Ps) perturbation directly from GSI analysis

	GSI	WRF-ARW
Control/ Prognostic variables	ΔT ΔP_s Δq $\Delta \mu$	ϕ μ θ
Computed/ diagnostic variables	$\Delta \theta$ *(from* ΔT*)*	α P

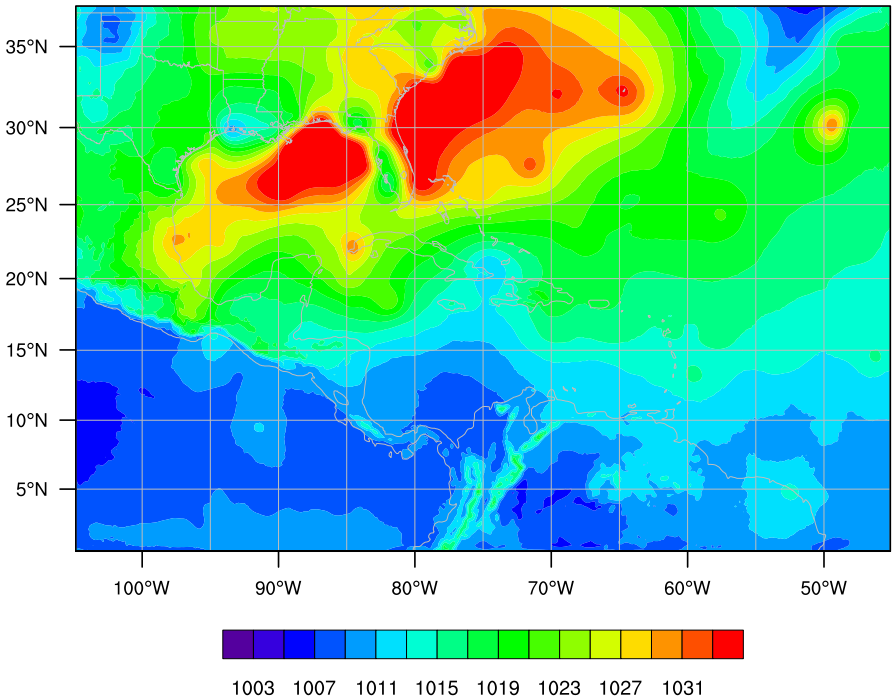
Inconsistency between ARW and GSI Control/ Prognostic Variables (cont.)

- Geopotential height (ϕ): prognostic variable in WRF-AR; no update from GSI
- Lowest model level pressure perturbation is used in ARW for MSLP computation – not dry air mass (μ) or surface pressure (Ps) perturbation directly from GSI analysis
- Apply a "rebalance" code to compute the missing variables

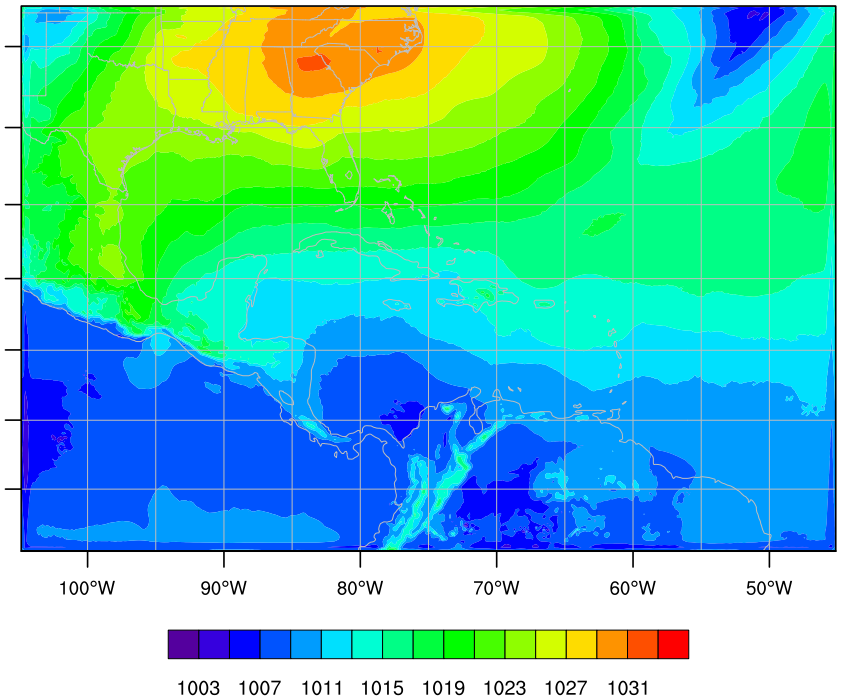
	GSI	"Rebalance"	WRF-ARW
Control/ Prognostic variables	ΔT ΔP_s Δq $\Delta \mu$	T μ q	ϕ μ θ
Computed/ diagnostic variables	$\Delta \theta$ *(from* ΔT*)*	P α ϕ	α P

Resulting MSLP field

MSLP (UPP using P'):
WRF-ARW v3.6

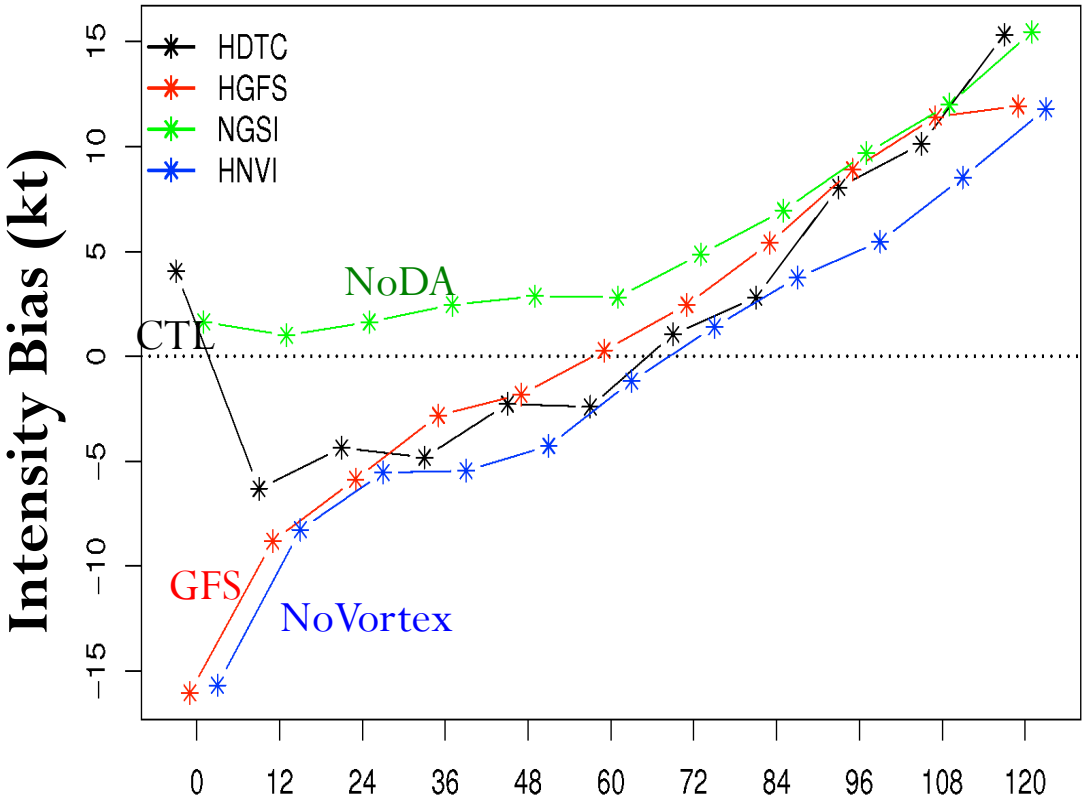


MSLP (UPP using P'):
WRF-ARW v3.6 w/ rebalance



However, analysis improvement for some variables was found reduced. Further study is ongoing…

TC Inner-Core DA



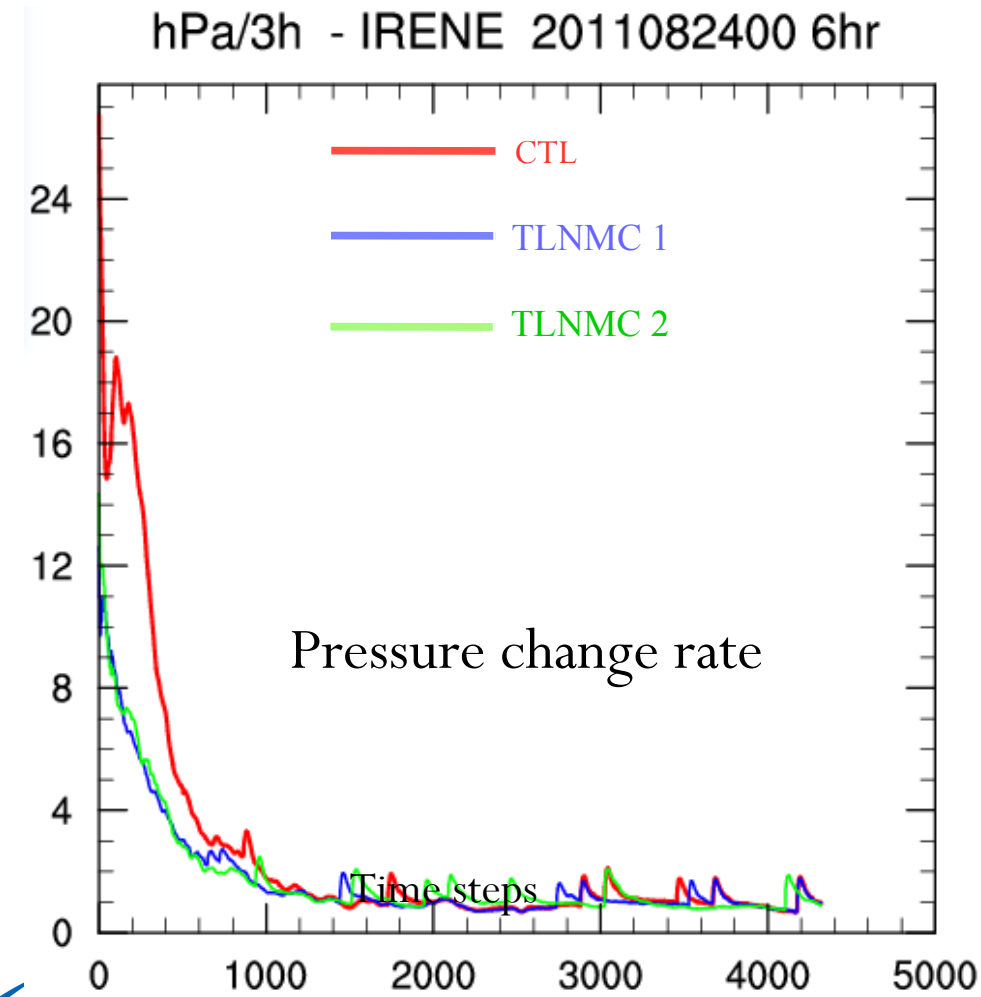
HDTC: control as 2014 ops.
(Uses DA and vortex init)
Spin down in first 6 hours
Why? How to improve?

Remove DA (NGSI)
Improved bias

Remove Vortex Init (HNVI)
Remove both (HGFS)
No spin down, but low bias

- Spin down only occurs when both DA and vortex initialization present
- Points to an imbalance introduced by DA, which is done after the vortex init

Improving Balance in DA



Control (CTL)

Large pressure fluctuations in beginning of simulation

TLNMC

Two options in **Tangent Linear Normal Mode Constraint** applied lead to improvement in balance in initial fields

Ongoing additional tests show promising results

Future Plans

- Continue to provide community support of GSI and EnKF
  - Encourage more contributions from the research community
- Testing and evaluation of new development and in-depth study of operational/research issues
  - EnVar for regional applications
  - High resolution DA
  - Extreme events (hurricanes, etc)
  - Global applications