Data Assimilation Activities at the Developmental Testbed Center (DTC)

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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

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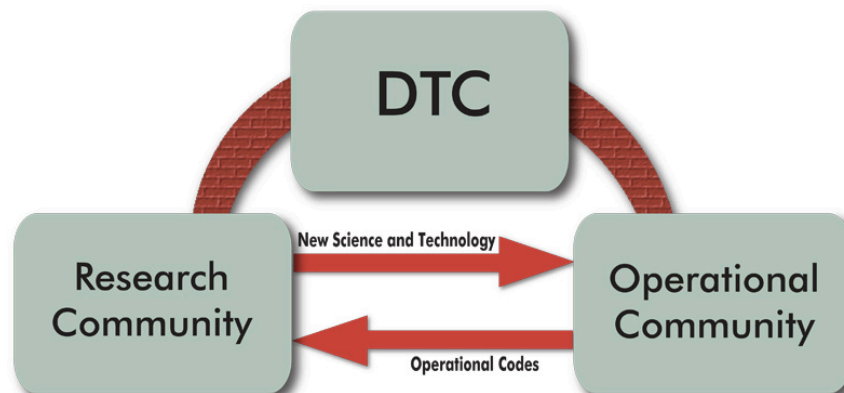
Software Systems

- Gridpoint Statistical Interpolation (GSI):
  - Annual community release since 2009

- Ensemble Kalman Filter (EnKF):
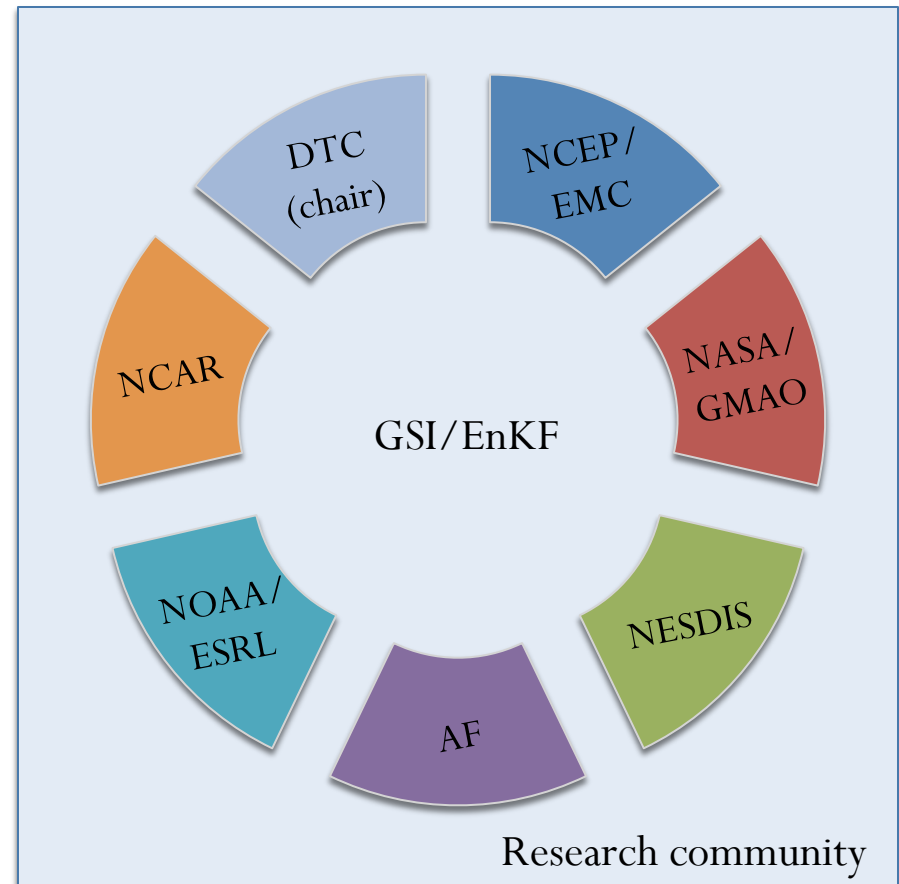 - First beta release in January 2015

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!

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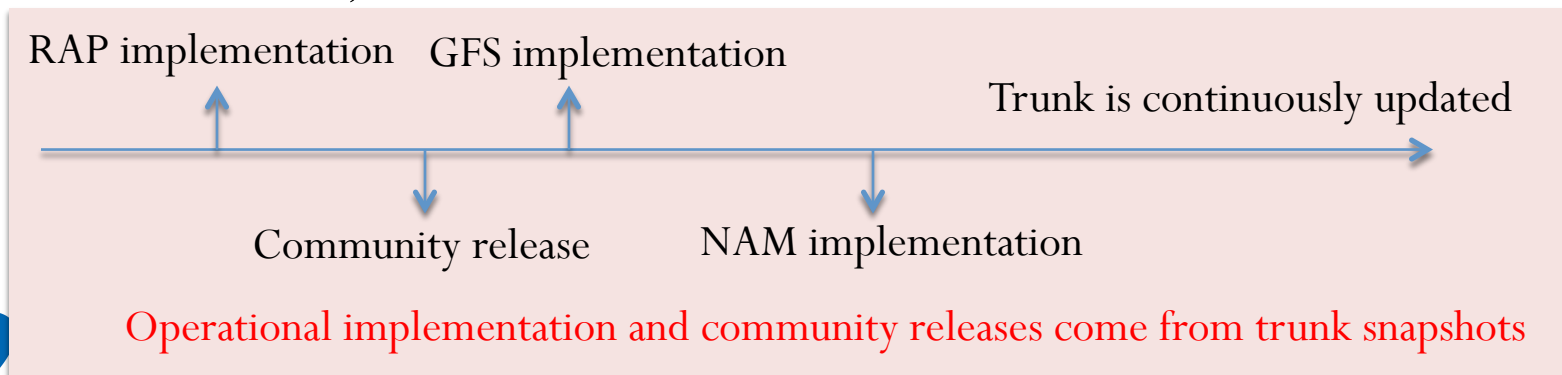
Code Management

- 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

DTC (chair) · NCEP/EMC · NASA/GMAO · NESDIS · AF · NOAA/ESRL · NCAR · GSI/EnKF

Research community

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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.

RAP implementation   GFS implementation

Trunk is continuously updated

Community release   NAM implementation

Operational implementation and community releases come from trunk snapshots

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

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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
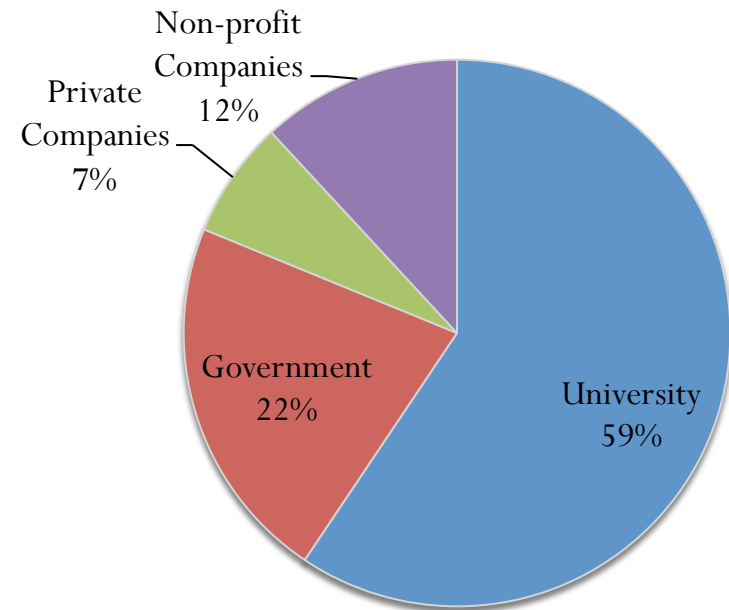
Affiliation of registered users
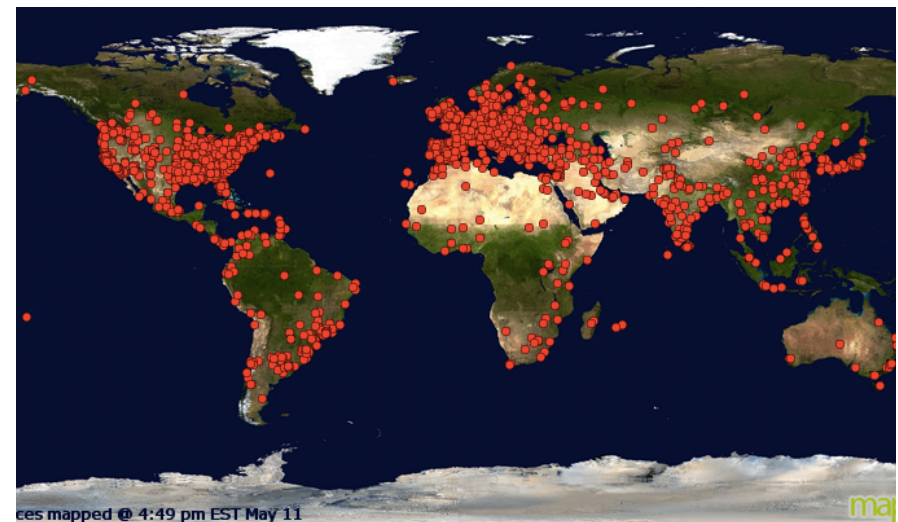
Who is accessing the GSI User's Webpage?

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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

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T&E in Support of R2O

Air Force	DTC tests

2014

AF Regional theatres: Phased implementation

AF Global-coverage: Jul, 2013

2013

2012

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*

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)

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

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SBUV/2 Impact: AF GSI-ARW Meso System

TMP RMSE Timeseries at 50 hPa
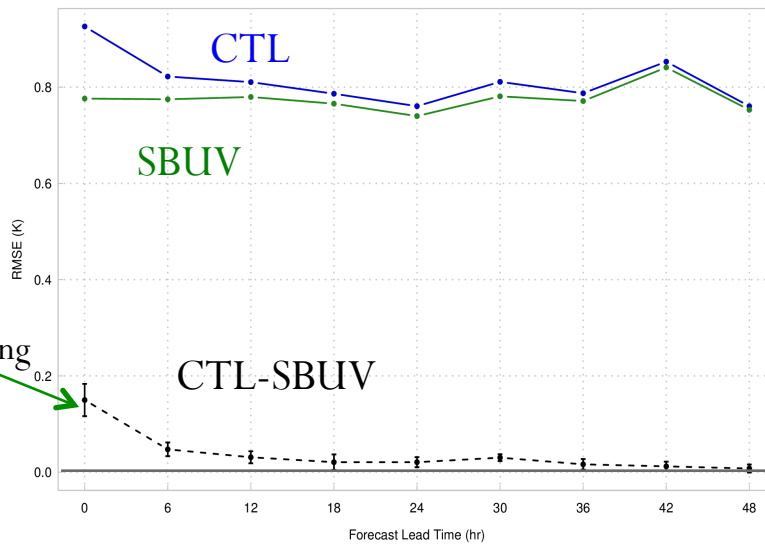
TMP RMSE Timeseries at 500 hPa

CTL

SBUV

SS favoring SBUV

CTL-SBUV
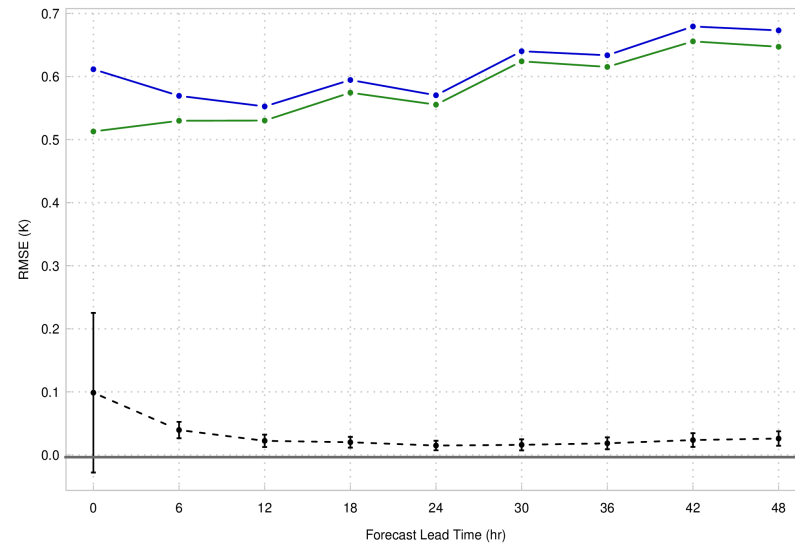
RMSE of temperature forecasts at 50 hPa and 500 hPa

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

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SBUV/2 Impact (cont.)

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

TEMP RMSE

Pressure Levels (hPa)	Forecast Lead Time (hr)								
	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

Pressure Levels (hPa)	Forecast Lead Time (hr)								
	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

Pressure Levels (hPa)	Forecast Lead Time (hr)								
	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

Pressure Levels (hPa)	Forecast Lead Time (hr)								
	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

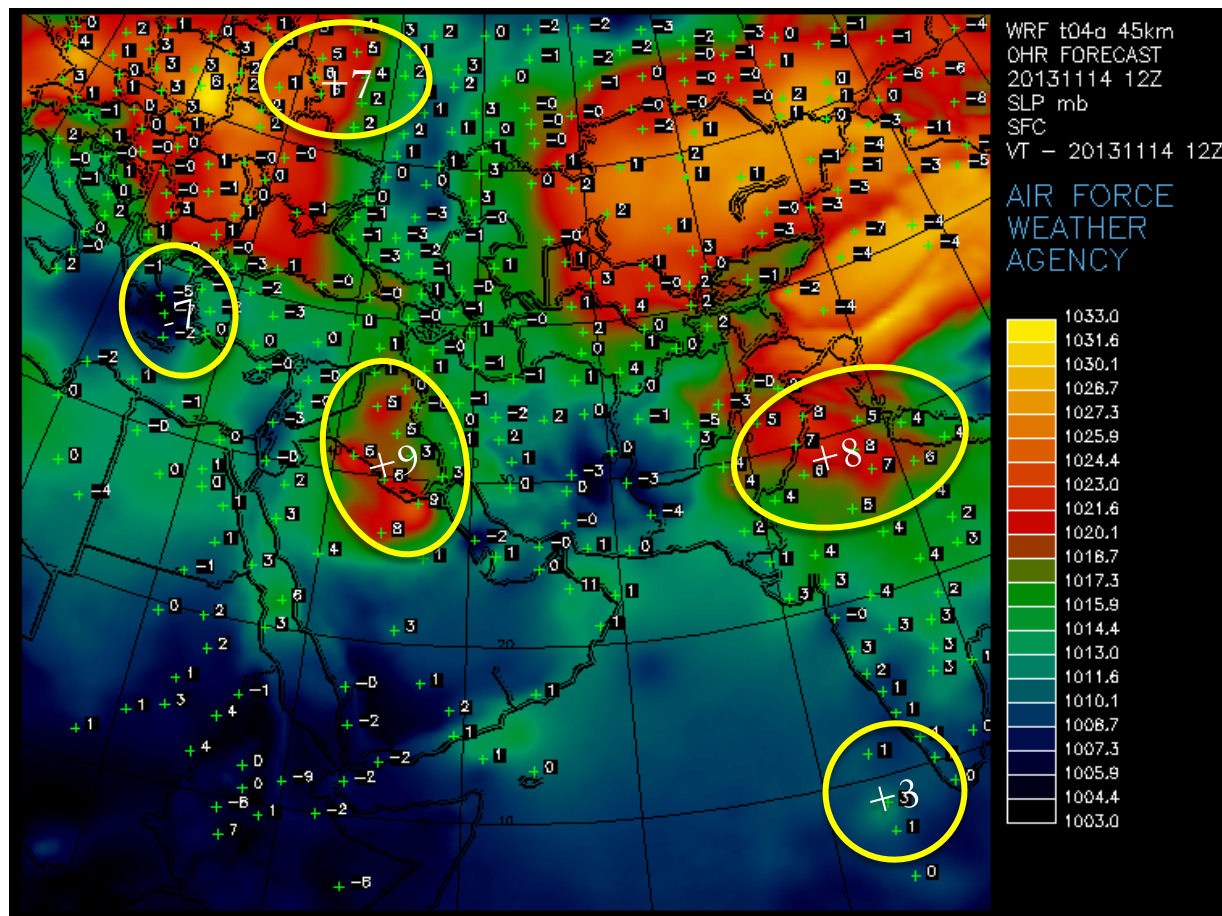Green shading: SBUV better Blue shading: CTL better

verification against ERA-I

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Developmental T...

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

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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	$\Delta T \quad \Delta P_s$ $\Delta q \quad \Delta \mu$	$\phi \quad \mu \quad \theta$
Computed/ diagnostic variables	$\Delta \theta$ *(from* $\Delta T)$	$\alpha \quad P$

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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

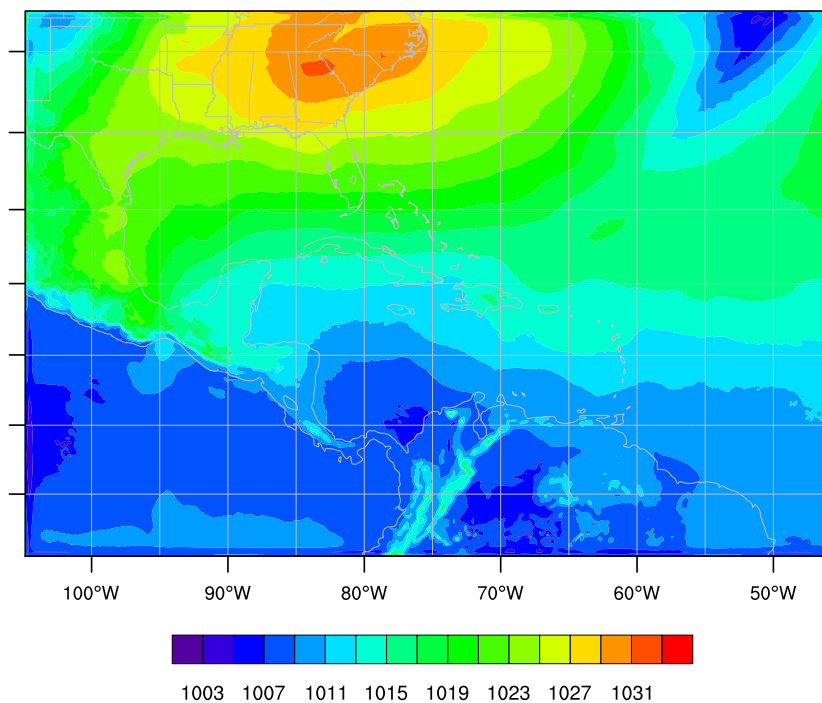- Apply a "rebalance" code to compute the missing variables

	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

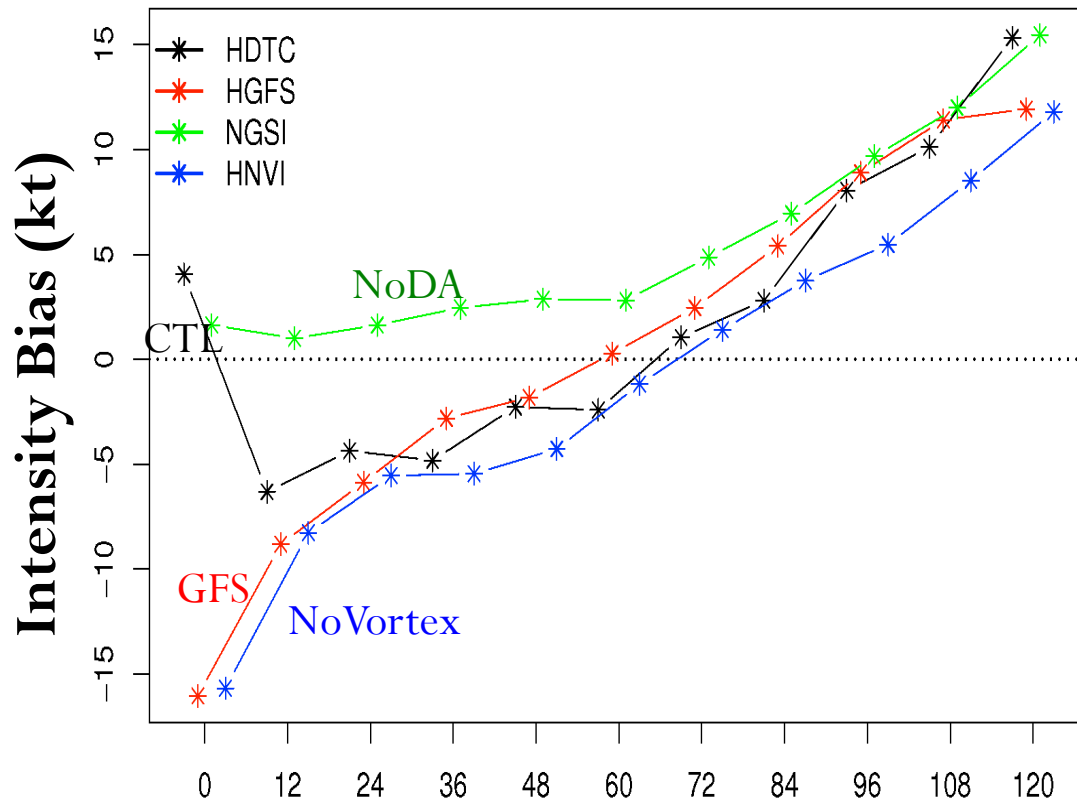# Resulting MSLP field

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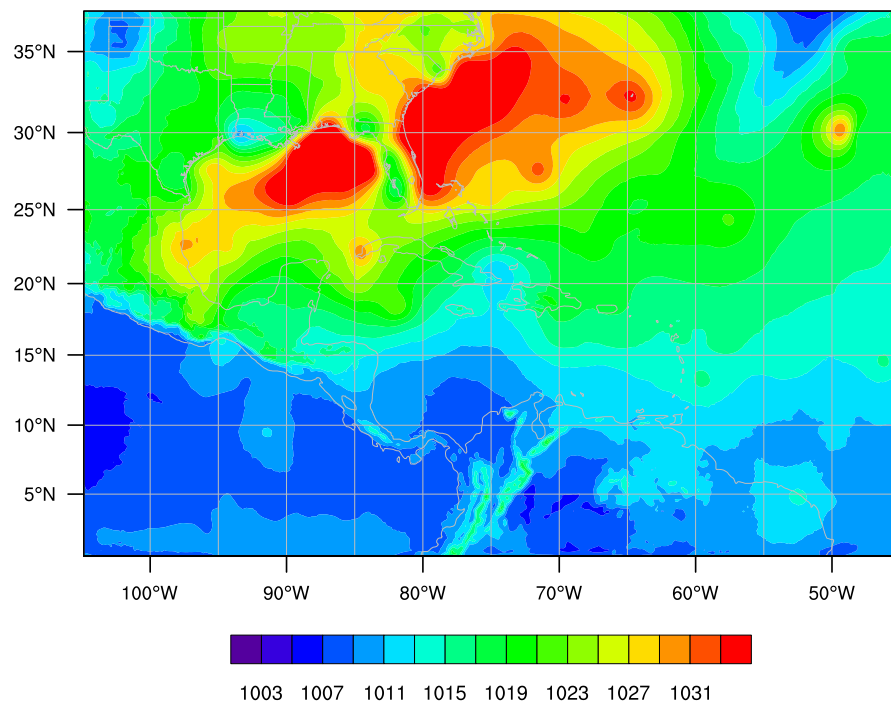
MSLP (UPP using P'):
WRF-ARW v3.6 w/ rebalance

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

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TC Inner-Core DA

HDTC: control as 2014 ops.

(Uses DA and vortex init)

Spin down in first 6 hours

Why? How to improve?

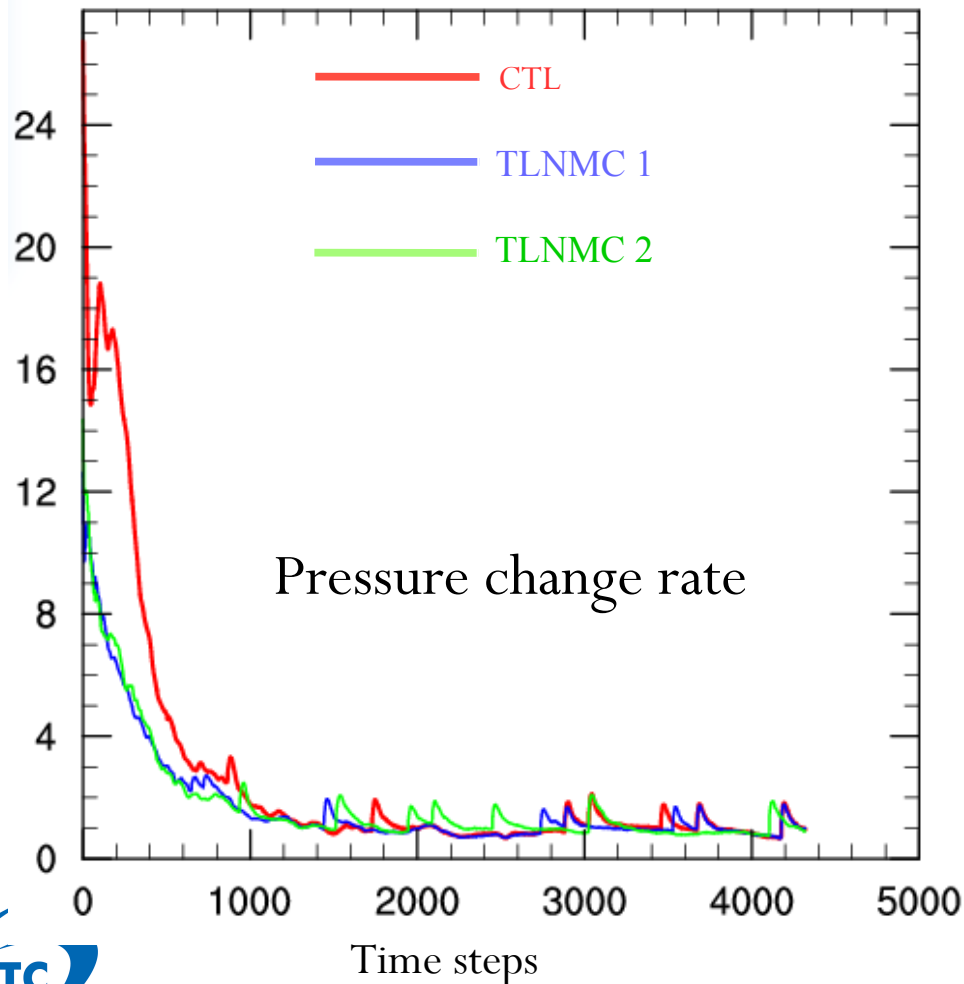**Remove DA (NGSI)**

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

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Improving Balance in DA

hPa/3h - IRENE 2011082400 6hr

CTL

TLNMC 1

TLNMC 2

Pressure change rate

Time steps

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

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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

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