Task 1. Sensitivity tests on traditional and non-traditional observation sources
Task 4. Mitigation of GSI issues

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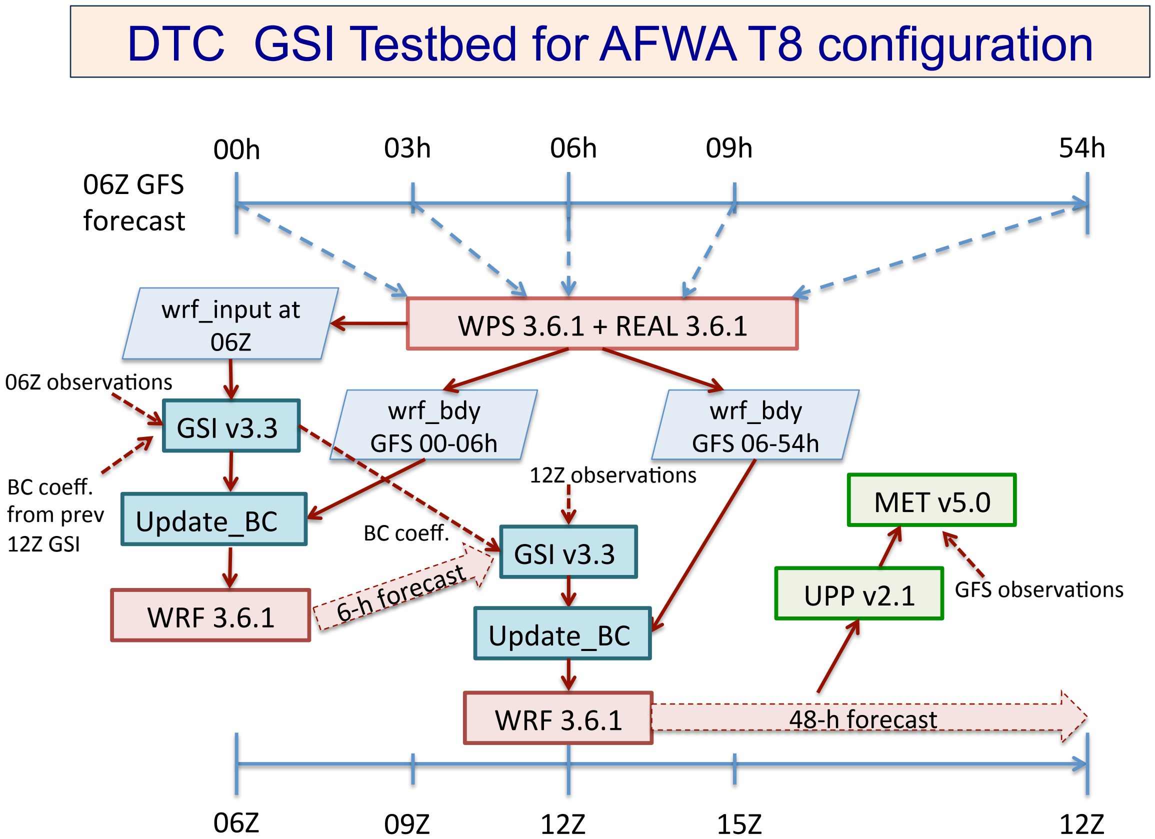
* Cost shared by other partners. Air Force GSI work leverages insight/experience from larger DTC DA team.

Task 1. Sensitivity tests on traditional and non-traditional observation sources

Test at least 2 types from list:

1. ~~GCOM-W1 AMSR2 (microwave radiances)~~ Lack GSI capability
2. NPP CRIS (IR radiances)
3. NOAA-16/17/19 SBUV/2 (Ozone)
4. METOP-A GOME-2 (Ozone)

Functionally-similar testing environment

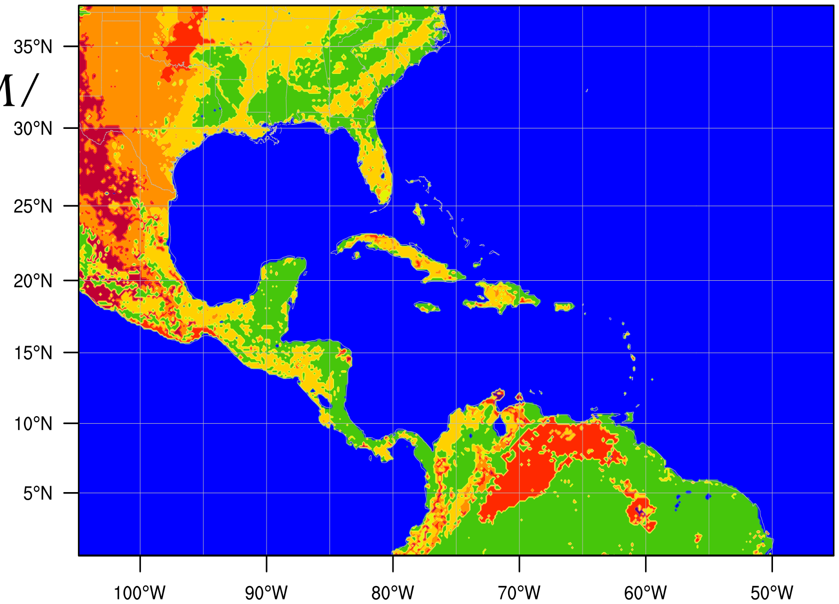


- Difference:
  - Background and boundary conditions
    - DTC - GFS
    - Air Force – UM
  - Updated system
    - ARW 3.6.1 (enable model top increase)
    - GSI v3.3 (2014)
- SBUV and GOME obtained from NCEP BUFR

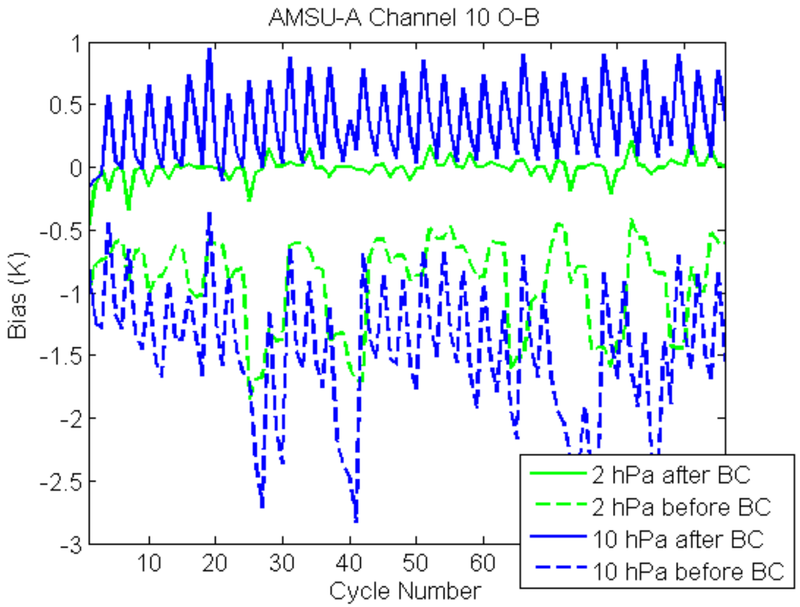
Model top test

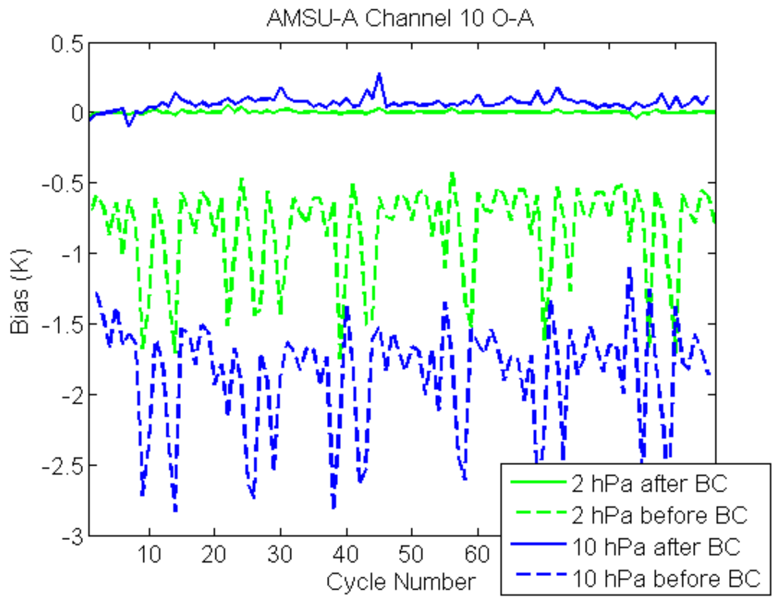
Experiments:

- CTL10: control
  - Air Force operational configuration, except RRTMG used rather than RRTM/Dudhia
  - 57 vertical sigma levels
  - 10 hPa model top
- CTL02:
  - Stratospheric lapse rate applied
  - 62 vertical levels
  - 2 hPa model top



Model top test - GSI diagnostics





- Same channel selection for both configurations
- 2 hPa model top shows smaller bias

Model top test: Verification against ERA-I

99% CI Statistical Significance Table (RMSE): CTL02 vs. CTL10

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	EXPT	EXPT	EXPT	--	--	--	--	--
250	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	--	EXPT
400	--	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL
500	CTRL	--	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT
700	CTRL	--	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT
850	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT
925	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT

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	--
100	--	CTRL	CTRL	CTRL	--	--	--	--	--
250	EXPT	EXPT	EXPT	EXPT	--	--	EXPT	EXPT	EXPT
400	--	CTRL	--	--	EXPT	EXPT	EXPT	EXPT	EXPT
500	--	CTRL	--	--	EXPT	EXPT	EXPT	EXPT	EXPT
700	--	CTRL	--	--	--	--	EXPT	EXPT	EXPT
850	EXPT	CTRL	--	EXPT	--	--	--	EXPT	EXPT
925	EXPT	CTRL	--	EXPT	--	--	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	EXPT
100	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT
250	EXPT	EXPT	--	--	--	--	--	--	--
400	EXPT	--	--	--	--	EXPT	--	--	--
500	--	CTRL	--	CTRL	--	--	CTRL	CTRL	--
700	--	--	EXPT	--	EXPT	--	EXPT	--	EXPT
850	--	EXPT	EXPT	--	EXPT	--	--	--	--
925	--	EXPT	EXPT	EXPT	EXPT	EXPT	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	--	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	--
400	EXPT	--	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT
500	EXPT	--	--	--	--	EXPT	EXPT	EXPT	EXPT
700	EXPT	EXPT	EXPT	--	EXPT	--	EXPT	EXPT	EXPT
850	EXPT	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL
925	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL

Improvement from 2 hPa model top

- Overall improvement throughout T field
- Strong signal of improvement for longer lead times for zonal wind, upper and lower level meridional wind
- Mixed results for specific humidity

Statistically Significant (SS) pairwise differences (99%):

Green shading: 2 hPa model top better Blue shading: 10 hPa model top better

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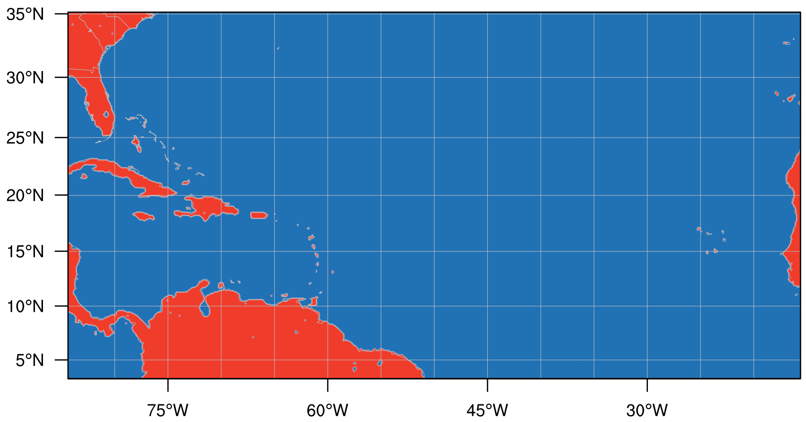
Observation sensitivity experiment design

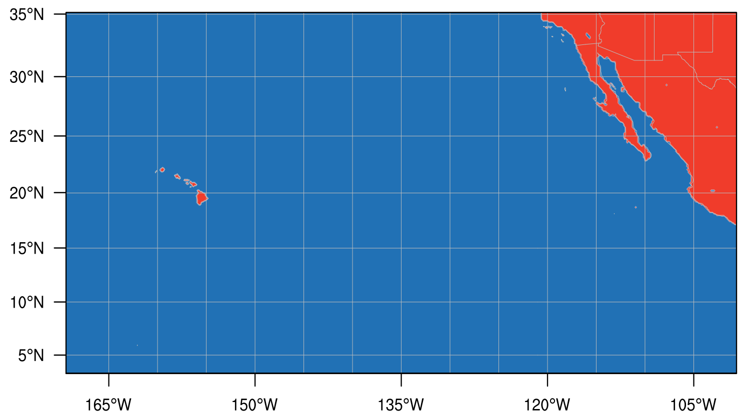
- Testing period: 1-31 August 2014
- 48-h deterministic forecasts initialized at 00/12
- Experiments:
  - **CTL**: performed in each of individual testing domains, with same configuration as in CTL02, with all current AFWA conventional and radiance data assimilated
  - **SBUV**: with additional assimilation of Solar Backscatter Ultraviolet (SBUV/2; v8) profile ozone
    - NOAA 19
  - **GOME**: with additional assimilation of Global Ozone Monitoring Experiment (GOME-2) total ozone
    - Metop-a, Metop-b
  - **CrIS**: excluded CrIS data assimilation
- Verification against ERA-Interim (ERA-I) reanalysis using Model Evaluation Tools (MET)

Caveats

- Two additional domains created to capture satellite overpasses
- O_3 not forecast variable in ARW
  - GFS ozone used for background
  - Indirect impact on analysis and forecasts



Atlantic Domain – GOME



E. Pacific Domain – SBUV, CrIS

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SBUV/2 Impact: verification against ERA-I

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	--	--	--	--	--

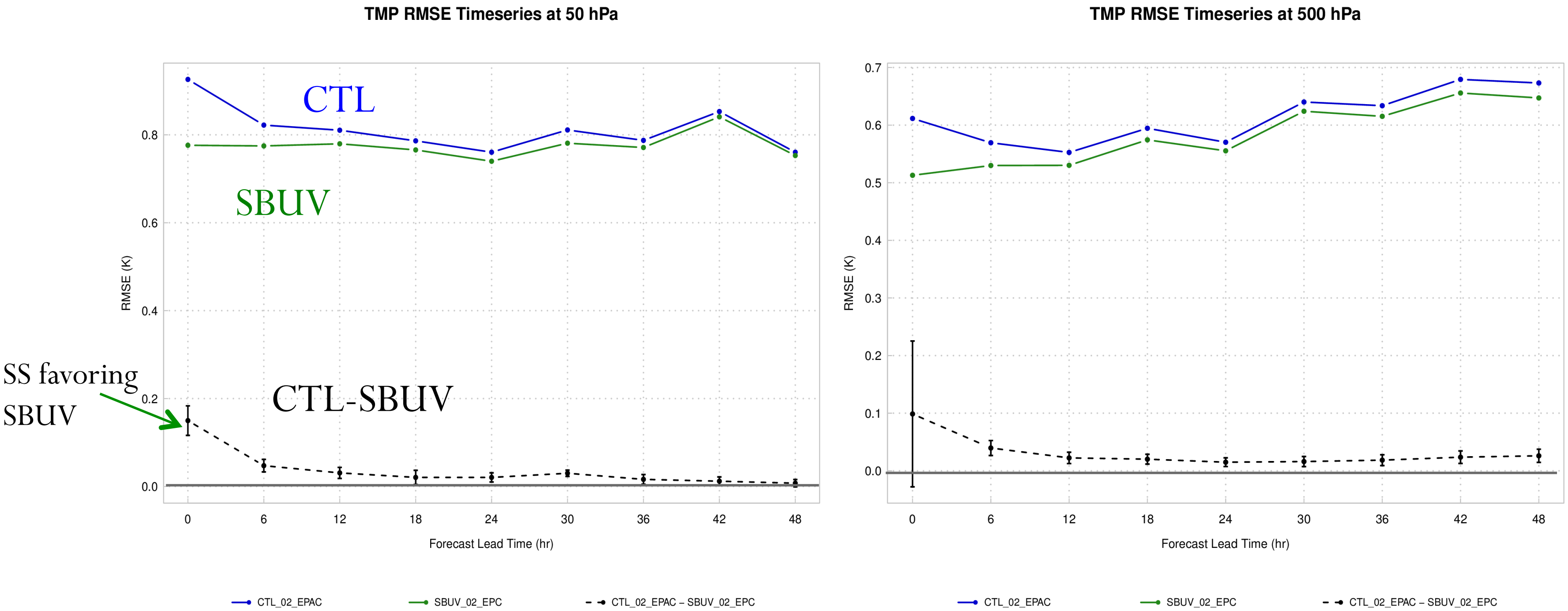
V-Wind RMSE	Forecast Lead Time (hr)								
Pressure Levels (hPa)	0	6	12	18	24	30	36	42	48
50	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT	--	EXPT
100	EXPT	--	--	--	--	--	--	--	--
250	--	EXPT	EXPT	--	--	--	--	--	--
400	EXPT	EXPT	EXPT	EXPT	--	--	--	--	--
500	EXPT	EXPT	EXPT	--	--	--	--	--	--
700	EXPT	EXPT	EXPT	EXPT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

Green shading: SBUV better Blue shading: CTL better

- 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

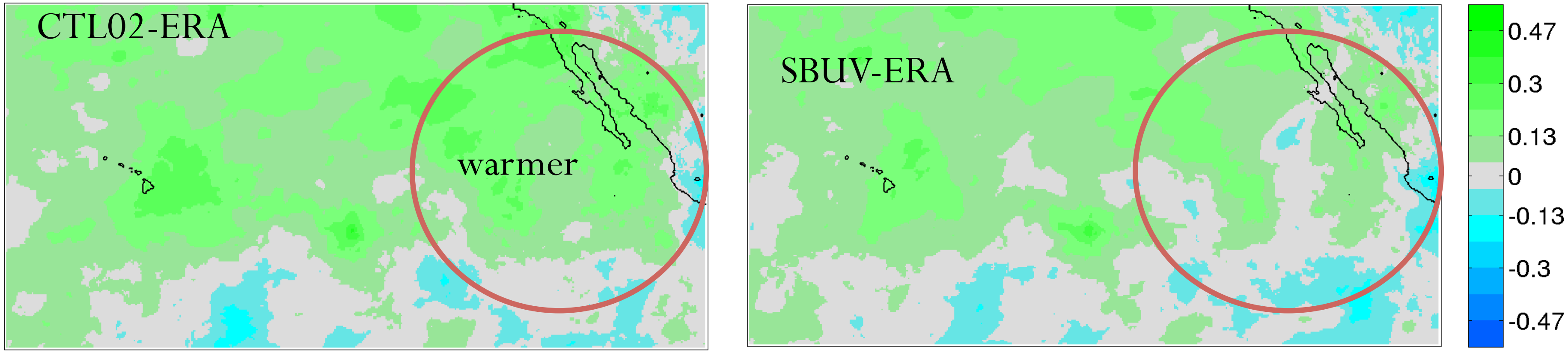
SBUV/2 Impact: verification against ERA-I

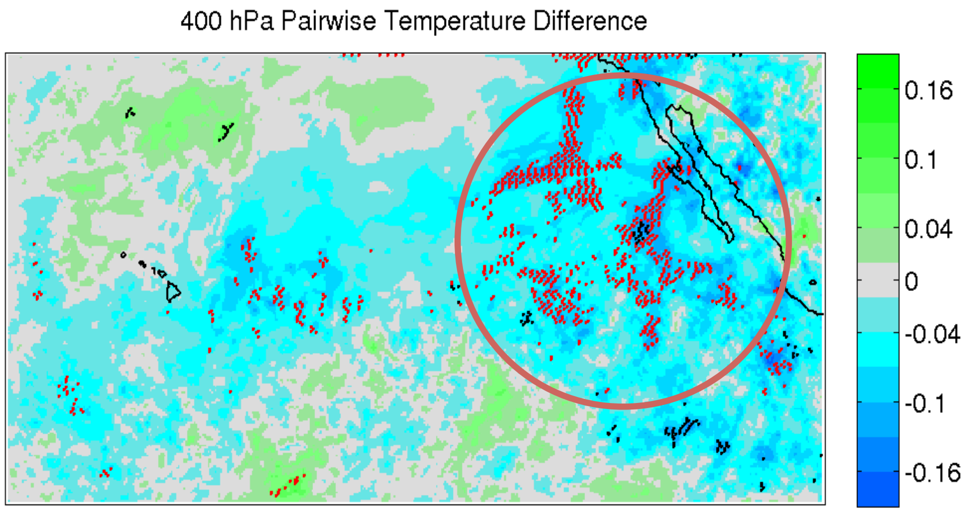


RMSE of temperature forecasts at 50 hPa and 500 hPa

SBUV ozone forecast impact

Temperature 12 hr forecasts @400hPa





Generally cooling effects from SBUV assimilation

Red points: pairwise SS positive impacts from SBUV

GOME-2 Impact: verification against ERA-I

99% CI Statistical Significance Table (RMSE): GOME vs. CTL02 (ATL)

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

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

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	--
100	--	--	--	CTRL	--	--	--	--	--
250	--	--	--	--	--	--	--	--	--
400	EXPT	--	--	--	--	--	--	--	--
500	--	--	CTRL	--	CTRL	--	--	--	--
700	--	--	--	--	--	--	--	--	--
850	--	--	--	--	--	--	--	--	--
925	--	CTRL	--	CTRL	CTRL	CTRL	--	--	--

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	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL
500	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL	CTRL
700	EXPT	EXPT	EXPT	--	--	--	--	--	--
850	EXPT	--	--	--	CTRL	CTRL	CTRL	CTRL	CTRL
925	EXPT	--	--	EXPT	EXPT	EXPT	EXPT	EXPT	EXPT

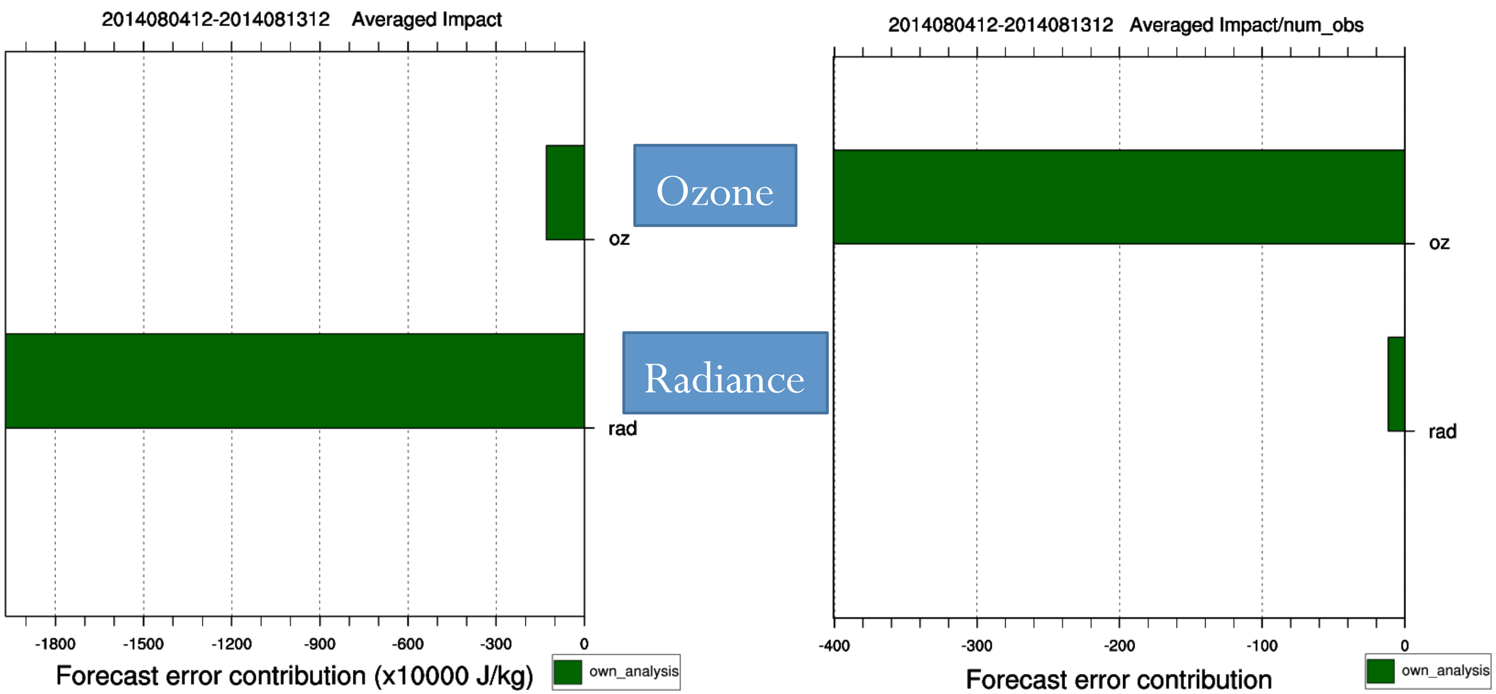
- Fewer SS differences relative to SBUV experiments
- Mixed or overall neutral results

Green shading: GOME better Blue shading: CTL better

Forecast Sensitivity to Observations (FSO)

- Observation sensitivity tests were conducted using the GSI-based FSO tool developed by NCAR MMM
  - WRF-ARW / WRFPLUS v3.6.1
  - 4DVAR branch of GSI, based on GSI v3.2 (2013)
- Testing period: 4-13 August 2014, focus on impact of 12-h forecasts
- E. Pacific domain with same model & data assimilation system configurations, observations and radiance bias correction coefficients as data impact tests
- Impact determined using own analysis

FSO: ozone impact

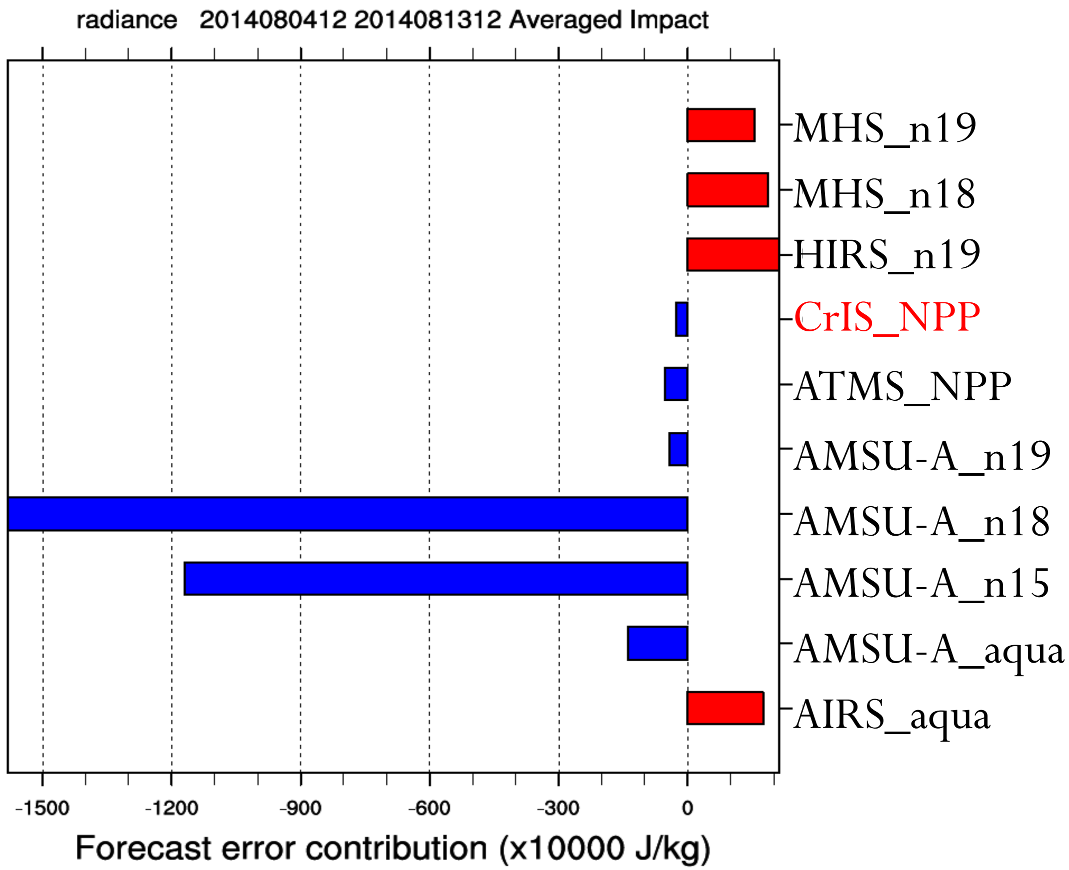


Forecast error reduction from ozone and radiance data

- Radiance data gives large total impact
- Ozone data impact per observation large

CrIS impact

- Verification against ERA-I showed neutral impact
  - Overlapping with existing radiance data
- FSO shows slight positive impact in total



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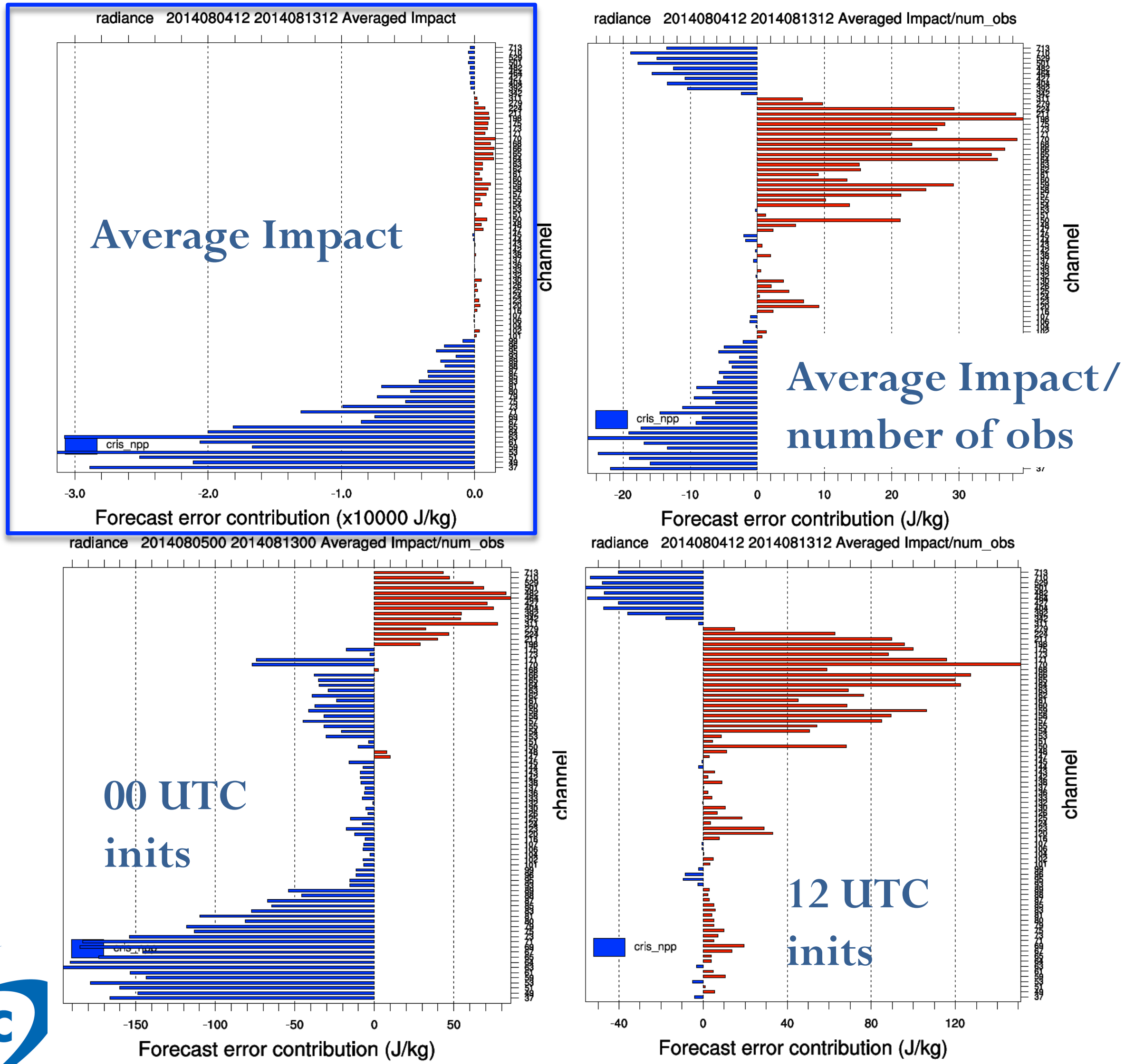
CrIS impacts per channel



- Certain channels have negative impacts
- Diurnal changes for channel behaviors

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Summary (Task 1)

- Increasing model top from 10 hPa to 2 hPa presents overall improvement to analysis and forecasts
- Assimilating SBUV presents generally positive impacts
  - Improved T analysis for most levels
  - Wind improvements for short term forecasts (~18 h)
  - Cooling pattern from SBUV
- Assimilating GOME presents generally neutral (mixed) results
- Assimilating CrIS produces neutral impacts
  - Overlaps with other existing radiance data
  - Further study on channel selections recommended
- FSO shows potential for detailed observation impact studies
  - Timely update to the adjoint code is required

Task 4. GSI mitigation for AFWA

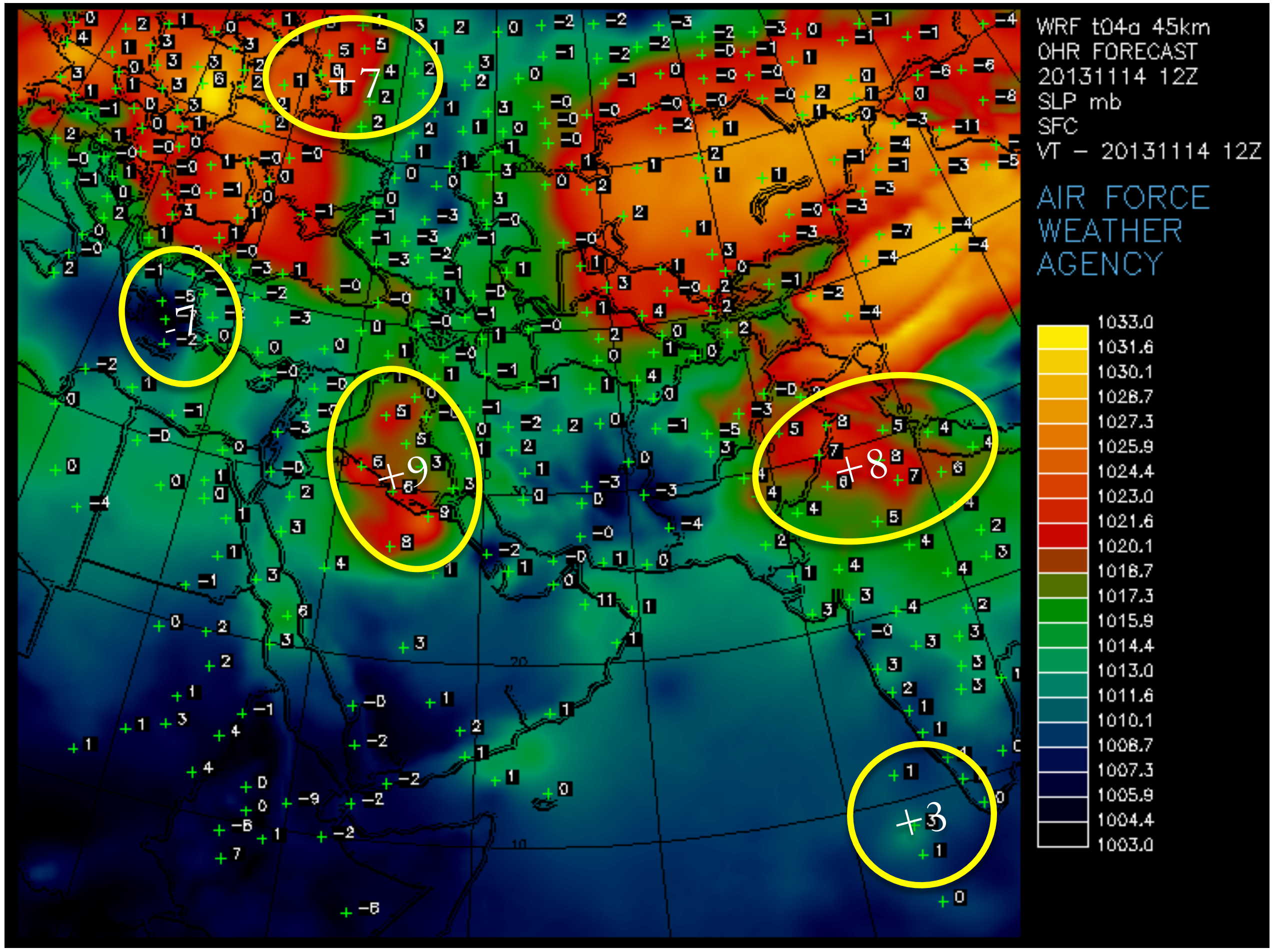
- Sea level pressure (SLP) errors
- CrIS data usage reduction

Reported 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

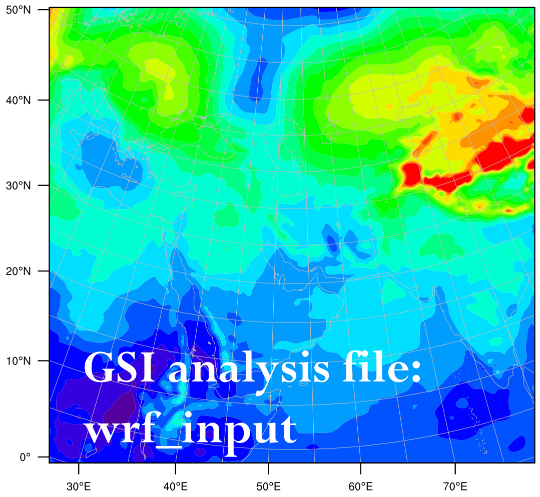


Verification for GSI SLP "analysis" (Analy-obs) at 12Z 20131114

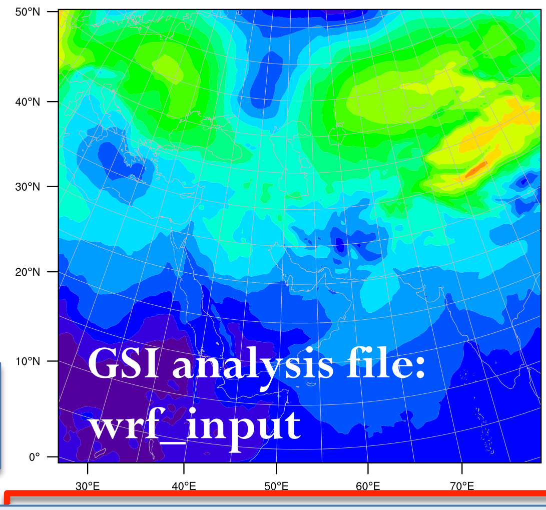
Post-processing discrepancies

- AFWA delivered post-processing (PP) subroutines for SLP to DTC

UPP

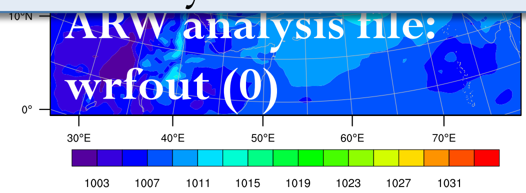


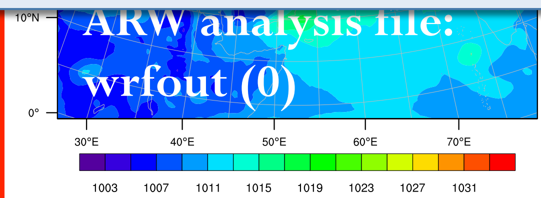
DTC AFWA PP



2 keys to reproducing problem:

1. Must use wrfout at analysis time (NOT wrfinput directly generated by GSI)
2. First level pressure perturbation P' (0,:,:) needs to be used for surface pressure (Psfc) in MSLP computation – not dry air mass (MU) or Psfc directly from GSI analysis



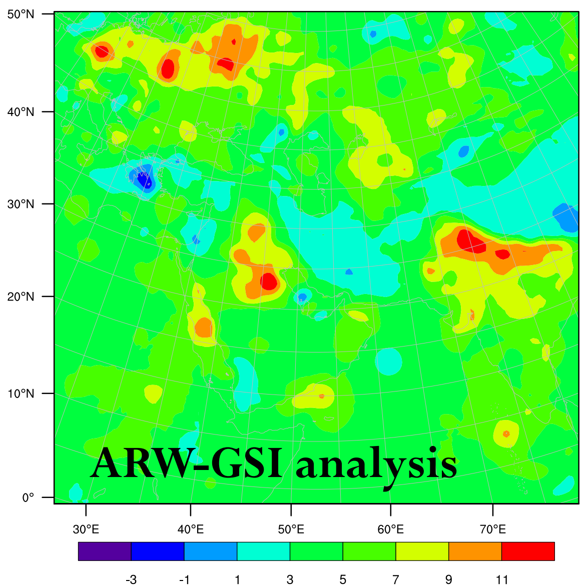


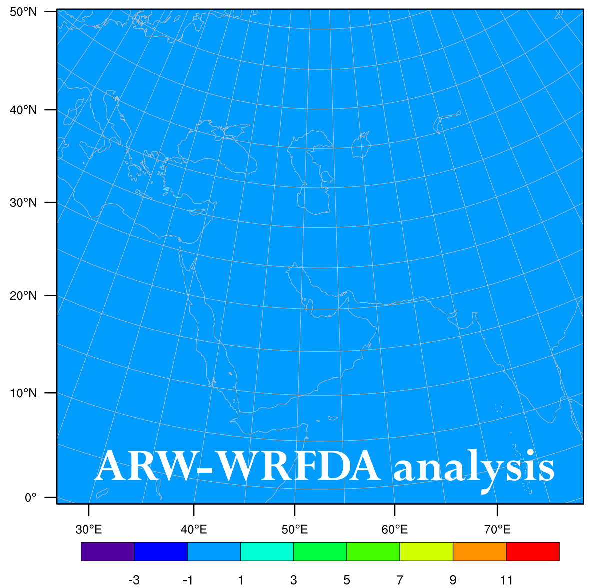
Wrfout and wrfinput files

- Why are there differences between the GSI analysis and the ARW analysis files?

wrfout (0) -wrfinput

1st level Perturbation Pressure + Base Pressure (P+Pb)





- Inconsistency between GSI and ARW for P' field
  - WRFDA shows a consistent field (NOTE: GSI doesn't update P', therefore background)
  - Is the output from GSI different than ARW expects?

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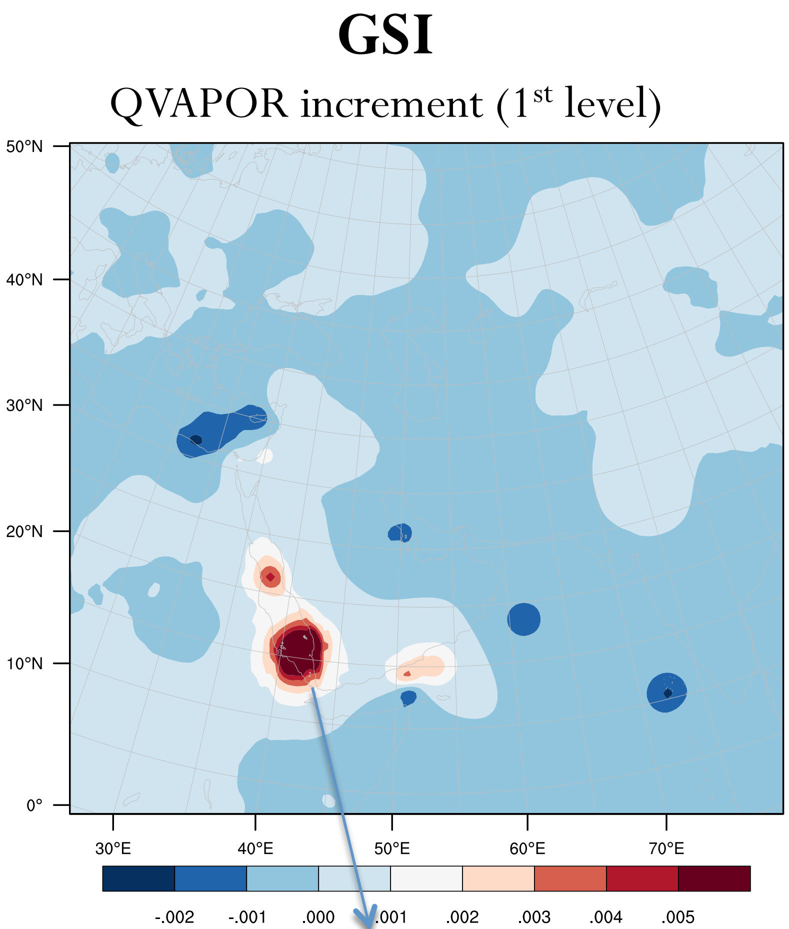
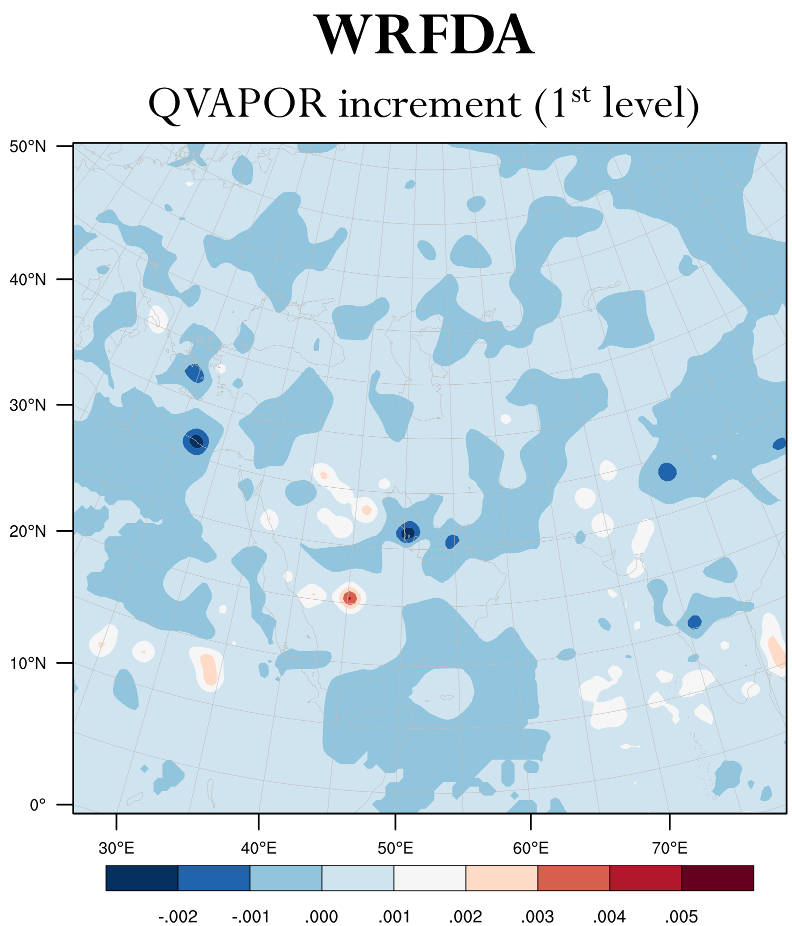
GSI vs. WRFDA QVAPOR increments





Likely bad observation … surface Q qc from last year not implemented for this test

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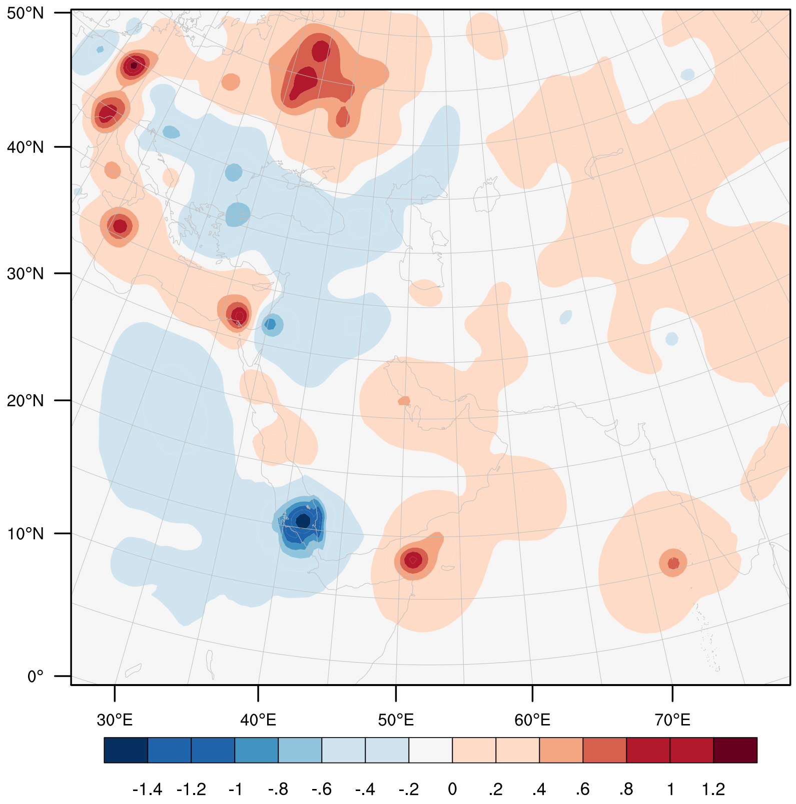
GSI vs. WRFDA temperature increments

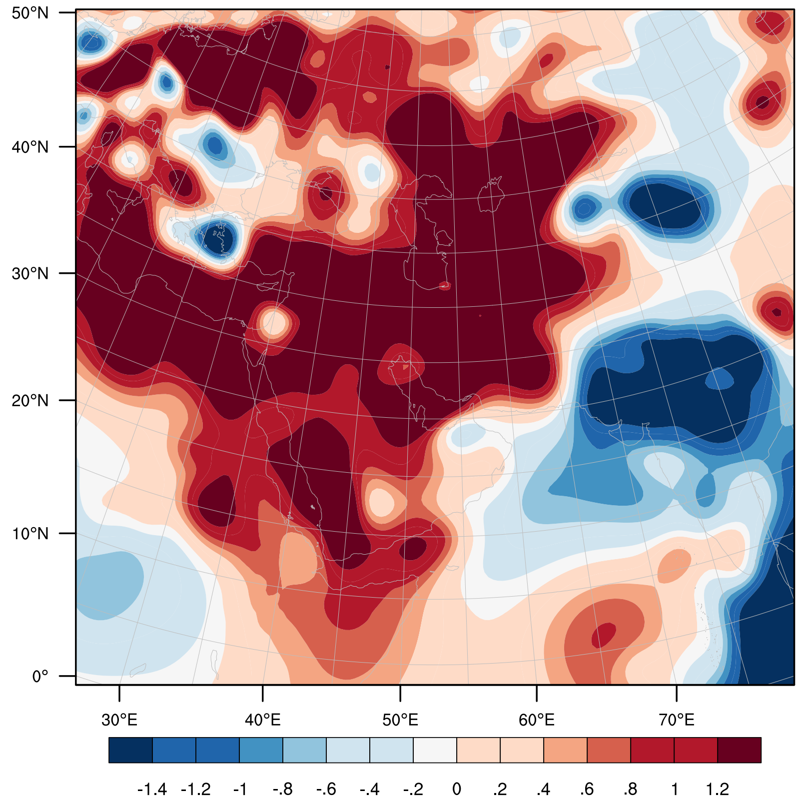
GSI

T increment (1st level)



WRFDA

T increment (1st level)



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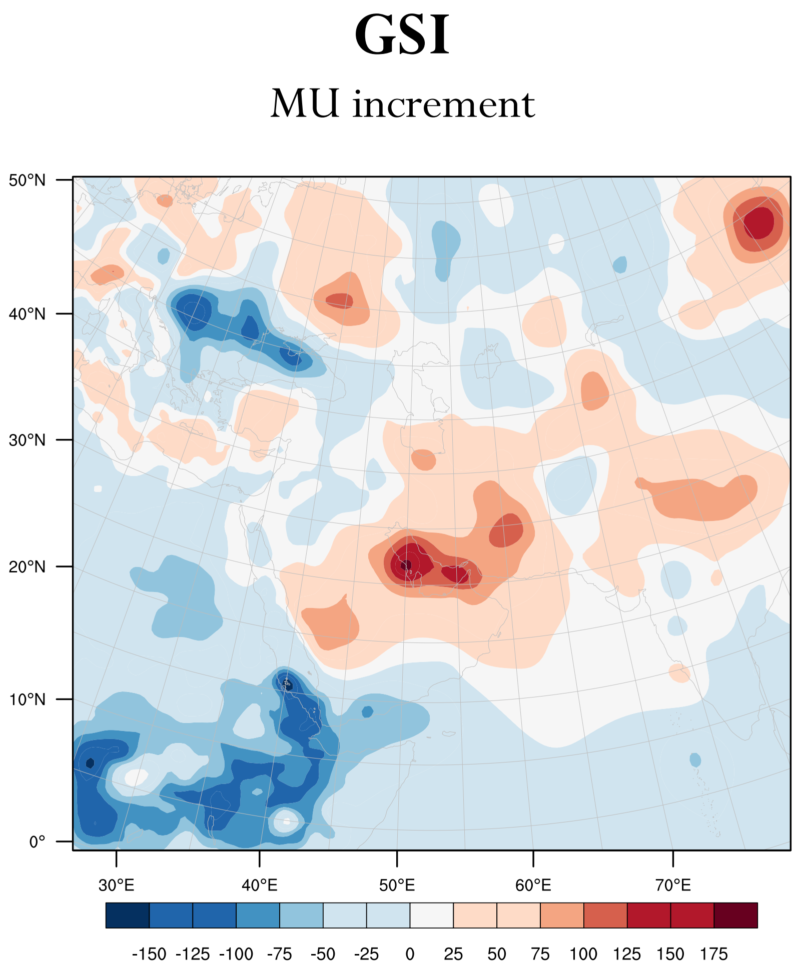
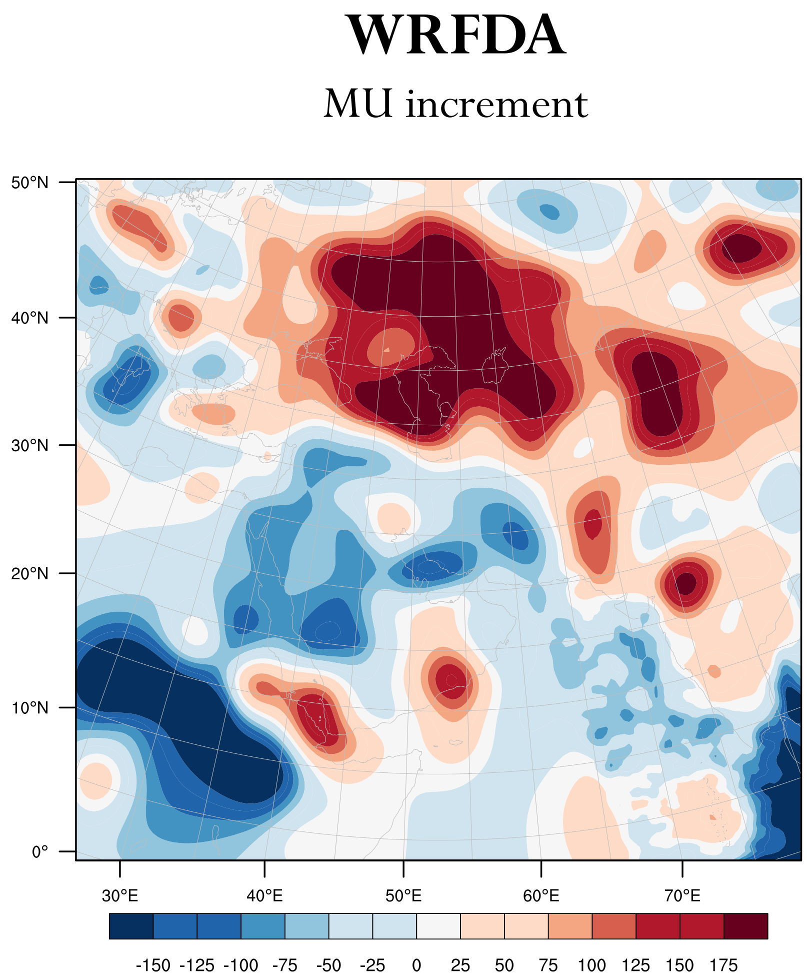
GSI vs. WRFDA dry mass (MU) increments





WRFDA formulation

- WRFDA code includes `da_transfer_xatowrf` which computes $\Delta\theta, \Delta P, \Delta\phi, \Delta\mu$ using $\Delta T, \Delta P_s, \Delta q$ to initialize WRF model

Increments of mixing ratio water vapor at levels η_k: $q'_k = \frac{qv'_k}{(1-qv_k)^2}$

Increments of dry air mass in column: $\underline{\mu}' = \frac{p'_{sfc} - (\mu+\mu') \times \int_0^{1.0} q'_k \, d\eta w}{1 + \int_0^{1.0} q_k \, d\eta w} = -\frac{p'_{sfc} + (\mu+\mu') \times \int_{1.0}^{0} q'_k \, d\eta w}{\int_{1.0}^{0} (1+q_k) d\eta w}$

Increments of the pressure at levels η_k obtained from increments of Ps and wv mixing ratio:

$$p'_{\eta w\_k} = p'_{\eta w\_k+1} + \int_{\eta w\_k}^{\eta w + k+1} \left\{ \underline{\mu}' \times (1+q_k) + (\overline{\mu} + \mu') \times q'_k \right\} d\eta w \quad k = kte, \ldots, kts. \qquad \text{where} \quad p'_{\eta w\_kte+1} = 0.0$$

$$p'_k = \frac{p'_{\eta w+k+1} + p'_{\eta w+k}}{2}$$

Increments of potential temperature at levels η_k: $\theta_k = t_k \times \left(\frac{p_k}{p_{00}}\right)^{-\frac{R}{c_p}}$ $\quad \theta'_k = \theta_k \times \left(\frac{t'_k}{t_k} - \frac{R}{c_p}\frac{p'_k}{p_k}\right)$

Increments of geopotential height at levels ηw_k: $\varphi'_{k+1} = \varphi'_k - \int_{\eta w\_k}^{\eta w\_k+1} \left(\frac{\underline{\mu}'}{\rho_k} + (\mu+\mu') \times \frac{\rho'_k}{\rho_k^2} \right) d\eta w, \quad k = kts, \ldots, kte.$

- GSI has no such subroutine: $\Delta T, \Delta P_s, \Delta q, \Delta\mu$ -> computes θ from T, P_s (bkgd)

WRF-ARW initialization

- What happens between wrfinput and 00H wrfout?

Prognostic variables

$$
\begin{aligned}
\partial_t U + (\nabla \cdot \mathbf{V} u) + \mu_d \alpha \partial_x p + (\alpha/\alpha_d)\partial_\eta p \partial_x \phi &= F_U \\
\partial_t V + (\nabla \cdot \mathbf{V} v) + \mu_d \alpha \partial_y p + (\alpha/\alpha_d)\partial_\eta p \partial_y \phi &= F_V \\
\partial_t W + (\nabla \cdot \mathbf{V} w) - g[(\alpha/\alpha_d)\partial_\eta p - \mu_d] &= F_W \\
\partial_t \Theta + (\nabla \cdot \mathbf{V} \theta) &= F_\Theta \\
\partial_t \mu_d + (\nabla \cdot \mathbf{V}) &= 0 \\
\partial_t \phi + \mu_d^{-1}[(\mathbf{V} \cdot \nabla \phi) - gW] &= 0 \\
\partial_t Q_m + (\nabla \cdot \mathbf{V} q_m) &= F_{Q_m}
\end{aligned}
$$

u
v
w
θ
M
Φ
$q, q_i, q_c \ldots$

Diagnostic variables

diagnostic equation for dry inverse density

$$\partial_\eta \phi = -\alpha_d \mu_d$$

α

diagnostic relation for the full pressure (vapor plus dry air)

$$p = p_0 (R_d \theta_m / p_0 \alpha_d)^\gamma$$

p

- ϕ is a prognostic variable in WRF-ARW
- WRFDA computes $\Delta\ \phi$, whereas GSI does not touch ϕ

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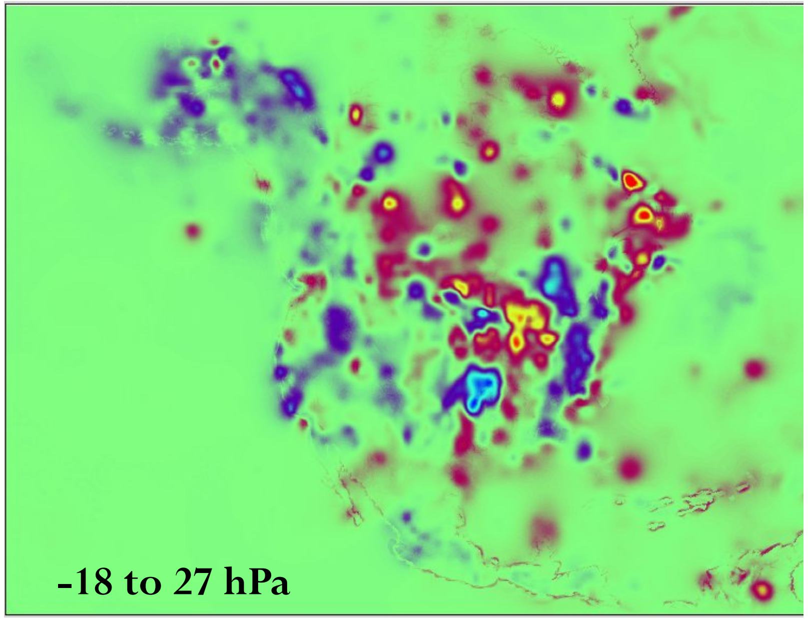
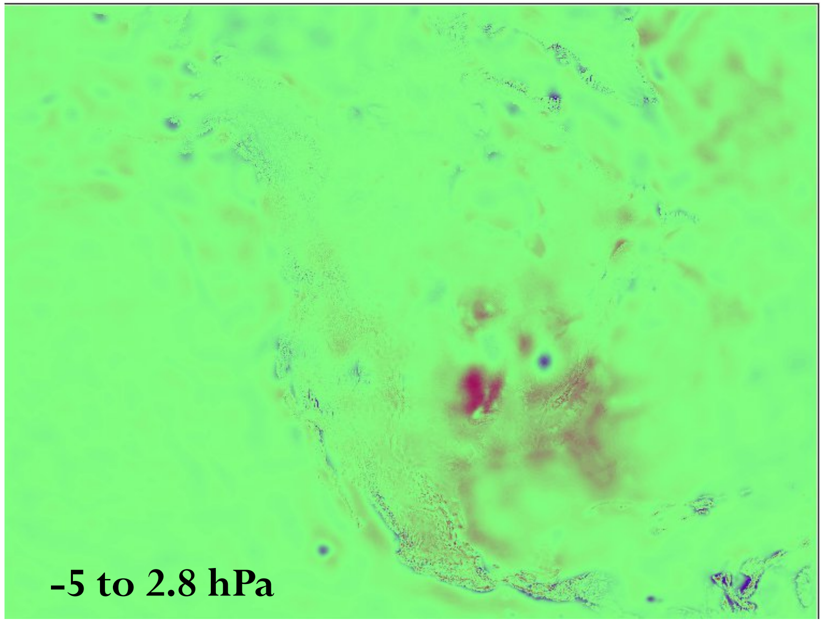
What about RAP?

2014061515 Partial cycle

1st Level P difference: wrfinput-wrfout(0)





Without DFI & rebalance

After DFI & rebalance

Rebalance formulation – P'

Perturbation of the pressure at level h_{kte}:

$$p'_{kte} = -\frac{1}{2}\int_{\eta w_{kte}}^{\eta w_{kte+1}} \left(\mu' + q'_{kte} \times \left(\mu' + \overline{\mu}\right)\right) d\eta w = -\frac{1}{2}\int_{\eta w_{kte}}^{\eta w_{kte+1}} \frac{\left(\mu' + \frac{q'_{kte}}{1+q'_{kte}} \times \overline{\mu}\right)}{\left(\frac{1}{1+q'_{kte}}\right)} \times \frac{1}{\left(\frac{1}{d\eta w}\right)}$$

WRF-real code

From the levels h_{kte-1} to h_{kts},

$$p'_k = p'_{k+1} - \int_{\eta_k}^{\eta_{k+1}} \left(\mu' + \frac{\left(q'_{k+1} + q'_k\right)}{2} \times \left(\mu' + \overline{\mu}\right)\right) d\eta = p'_{k+1} - \int_{\eta_k}^{\eta_{k+1}} \frac{\left(\mu' + \frac{0.5 \times \left(q'_{k+1} + q'_k\right)}{1 + 0.5 \times \left(q'_{k+1} + q'_k\right)} \times \overline{\mu}\right)}{\left(\frac{1}{1 + 0.5 \times \left(q'_{k+1} + q'_k\right)}\right)} \times \frac{1}{\left(\frac{1}{d\eta}\right)}$$

WRF-real code

Rebalance formulation – α, ϕ

Perturbation of the specific volume at level h_k

$$\alpha'_k = \frac{R}{p_{00}} \times \left(\theta'_k + \theta_0\right) \times \left(1 + \frac{R_v}{R_d} q'_k\right) \times \left(\frac{p'_k + \overline{p}_k}{p_{00}}\right)^{-\frac{c_v}{c_p}} - \overline{\alpha}_k$$

Perturbation of the geopotential height at levels hw_{kts+1} *to* hw_{kte+1}:

$$\varphi'_k = \varphi'_{k-1} - \int_{\eta w_{k-1}}^{\eta w_k} \left(\left(\mu' + \overline{\mu}\right) \times \alpha'_{k-1} + \mu' \times \overline{\alpha}_{k-1} \right) d\eta w$$

- Rebalance applied to P, α , ϕ
- T, μ , q used to calculate P, ϕ , α

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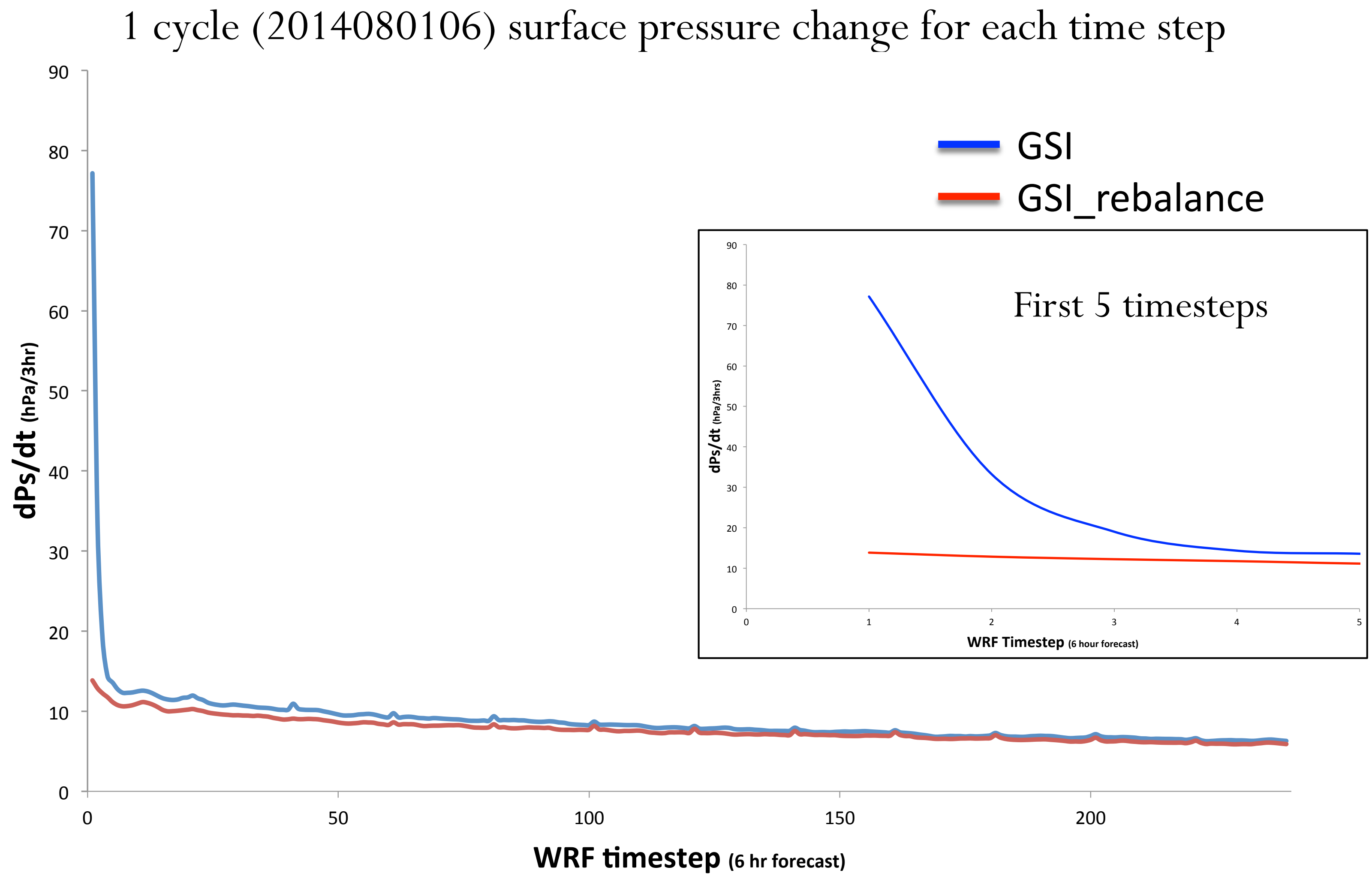
Comparison of analysis, prognostic and diagnostic variables

- WRFDA uses increment fields
- Rebalance uses full fields
- Geopotential height:
  - Prognostic variable in WRF-ARW
  - No update from GSI

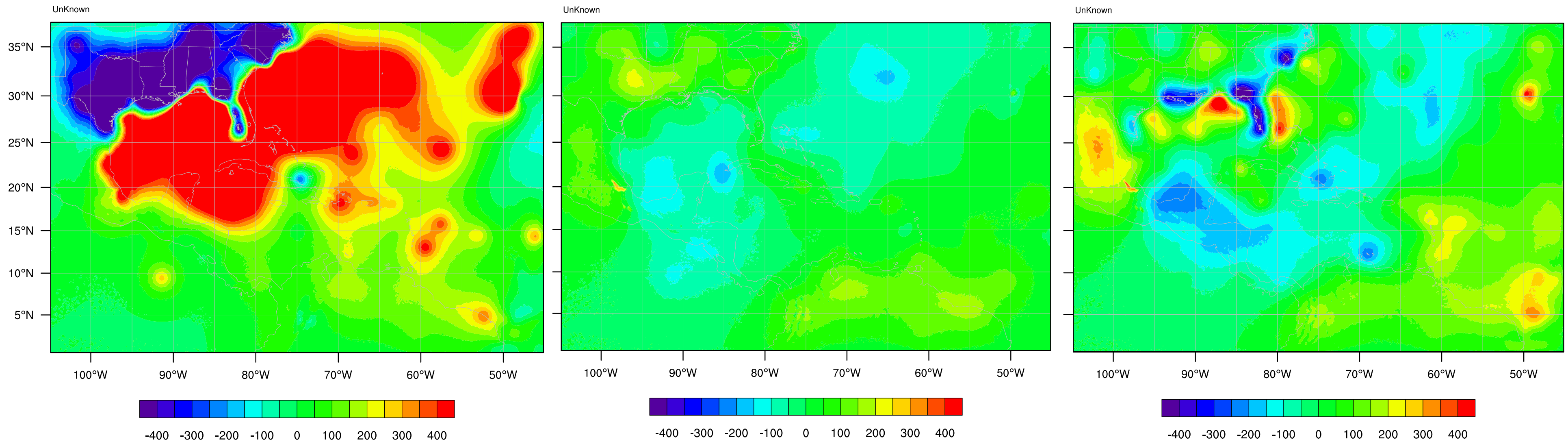
	WRFDA	GSI	Rebalance	WRF-ARW
Control/ Prognostic variables	ΔT ΔP_s Δq	ΔT ΔP_s Δq $\Delta \mu$	T μ q	ϕ μ θ
Computed/ diagnostic variables	$\Delta \theta$ ΔP $\Delta \phi$ $\Delta \mu$	$\Delta \theta$ *(from* ΔT*)*	P α ϕ	α P

Apply rebalance to test case



Note: rebalance tests use T8 domain.

P’ difference (wrfout(0)-wrfinput)



WRFV3.6

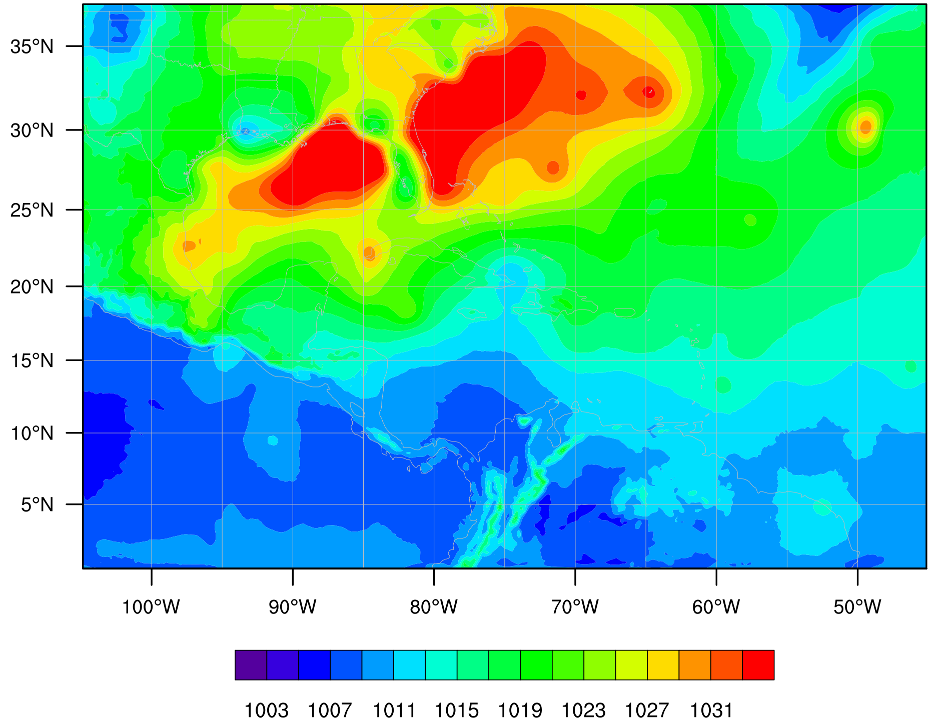
WRFV3.6 w/ rebalance

WRFV3.6 w/ rebalance-φ

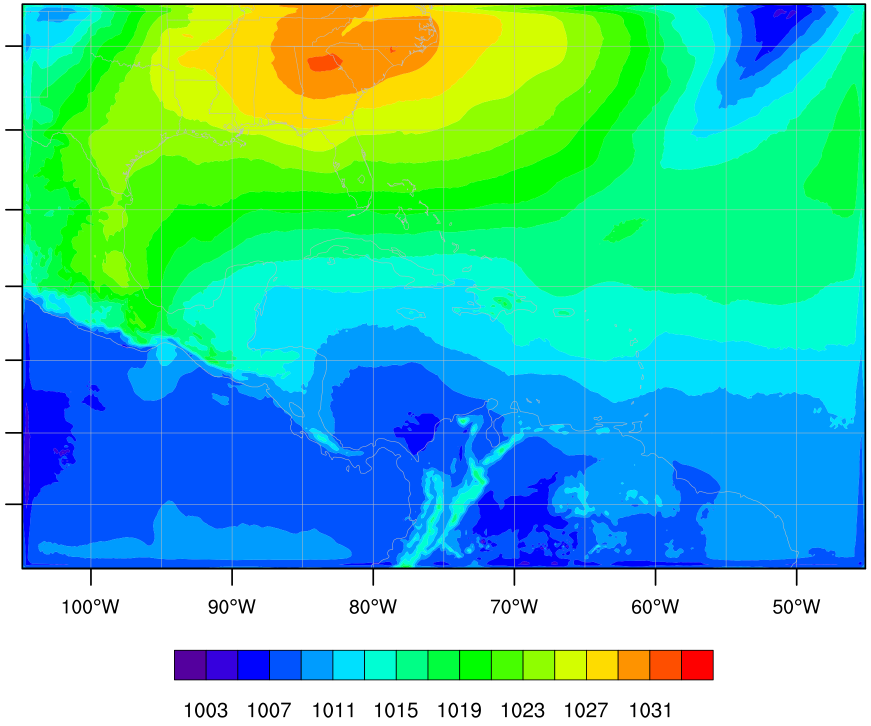
P’ after rebalance very close to background

Resulting MSLP field

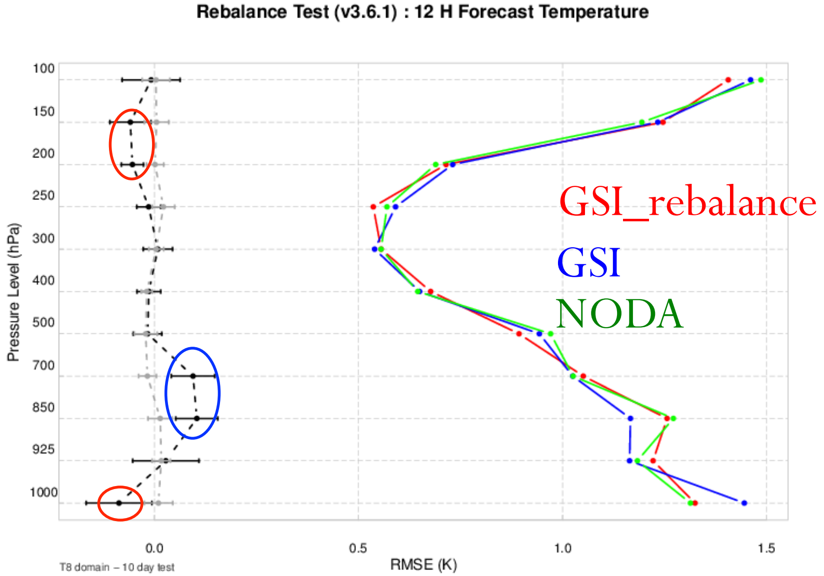
MSLP (UPP using P'):
WRF-ARW v3.6

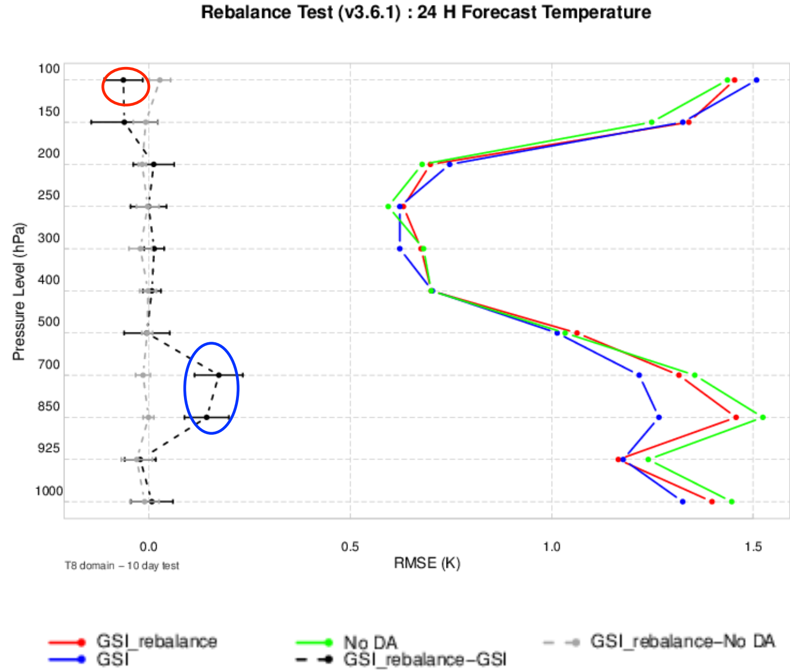


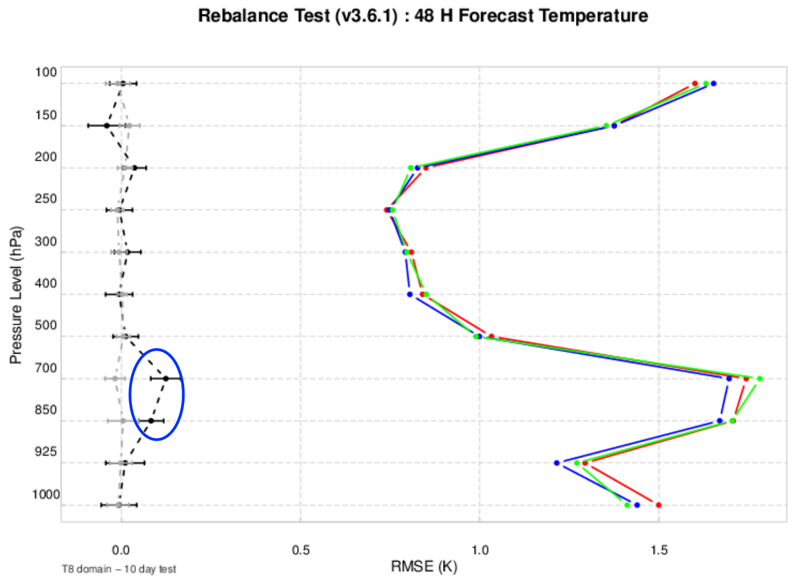
MSLP (UPP using P'):
WRF-ARW v3.6 w/ rebalance



Forecast results: Temperature







Mid-level temperature forecasts degraded by rebalance

Use of CrIS data

- Significant decrease in the CrIS data assimilated when using GSI v3.2 versus GSI v3.1
- Identified issues:
  - GSI v3.1: dval=1
  - GSI v3.2: dval=0 for CrIS (other radiance types dval=1)
  - dval: allows for relative weighting of different satellite radiance instruments in a thinning box
- Solution:
  - Set dval=0 to all radiance data types
    - no specific types are unequally weighted during the thinning process (therefore increasing the CrIS usage)
    - EMC plans to remove this namelist option so the default value will be set as 0

Summary (Task 4)

- Key issues contributing to the SLP problem
  - Mismatch of GSI analysis variables and ARW prognostic and diagnostic variables
  - Mismatch of GSI analysis variables and SLP computation formulation in the post-processing procedure
- Rebalance of the diagnostic fields shows promise for improving SLP analysis field, but degrades some other forecast fields
  - Pushes analysis and forecasts closer to the background
- Recommendation:
  - Rebalance algorithm posterior to GSI when interfacing with ARW
  - Further study needed to determine how to perform rebalance (e.g, applied to increment fields or full fields) and to which fields it should be applied
  - Implement new GSI surface observation QC (FY2013)
  - Use dval=0 for all radiance data types