Indirect impact of ozone assimilation using Gridpoint Statistical Interpolation (GSI) data assimilation system for regional applications

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Overview and Motivation

- Assess utility of SBUV profile ozone when assimilated into Gridpoint Statistical Interpolation (GSI) for regional applications without prognostic ozone
  - Evaluate forecast performance for regional scale model forecasts (ARW)
- Determine forecast impact from increasing model top from 10 hPa to 2hPa
  - Necessary for ozone assimilation
- Explore use of ozone data in GSI/ARW
  - Does this data provide impact without being propagated into model variables?

Experiment Design

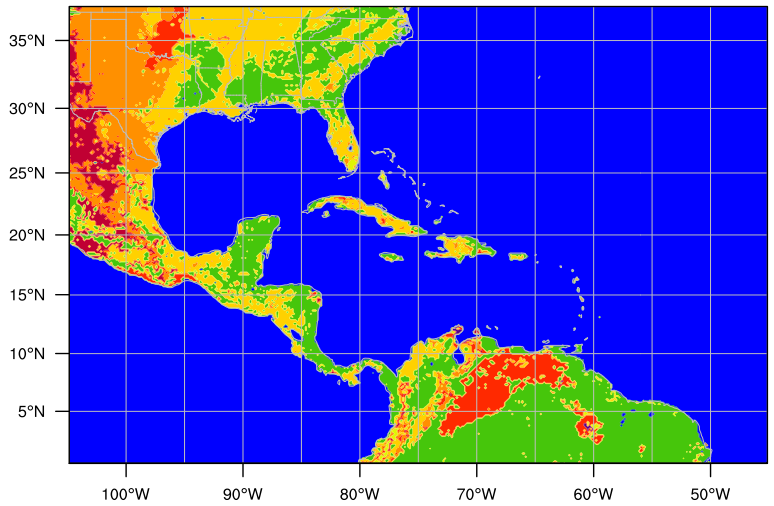
- GSI v3.3 (3d-var) coupled with WRF-ARW v3.6.1
  - Partial cycling scheme – cold start 06/18, warm start 12/00
- Testing period: 2014 August 1-31
- 15 km horizontal resolution, 62 (57) vertical levels, 2 mb (10 mb) model top
- 48-hr deterministic forecasts initialized at 00/12

Observations Assimilated		
Conventional	Air Force conventional observations	
	GPS-RO	
Satellite Radiances	AMSU-A (noaa-15,-18,-19, metop-a,-b, aqua)	MHS (noaa-18,-19, metop-a,-b)
	ATMS (npp)	IASI (metop-a,-b)
	HIRS4 (noaa-18,-19, metop-a,-b)	CrIS (npp)
	AIRS (aqua)	
Ozone	SBUV (noaa-19)*	

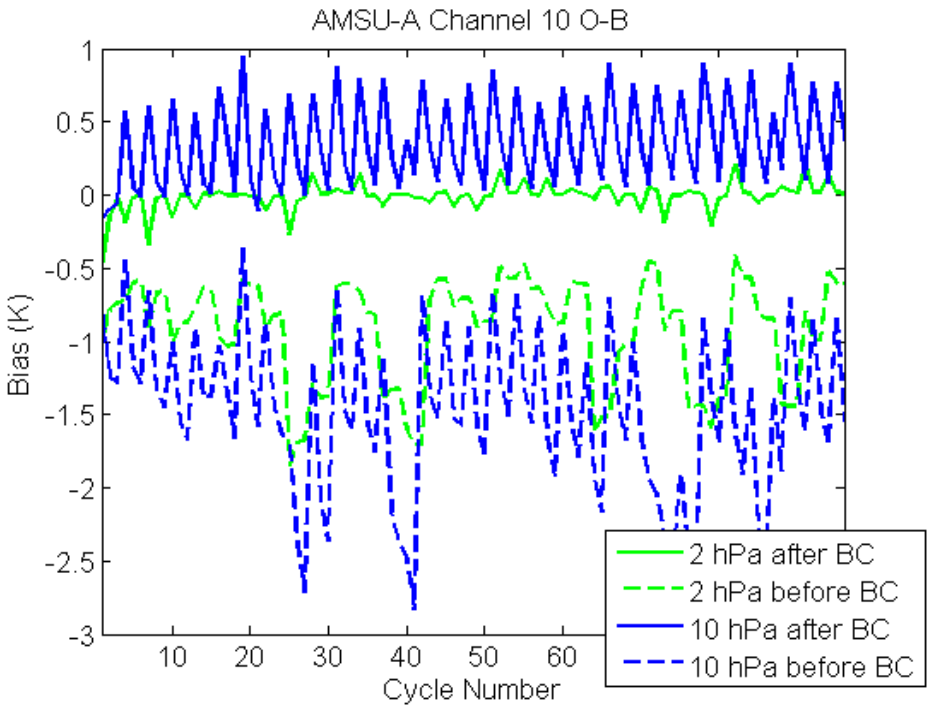
Model Top Test

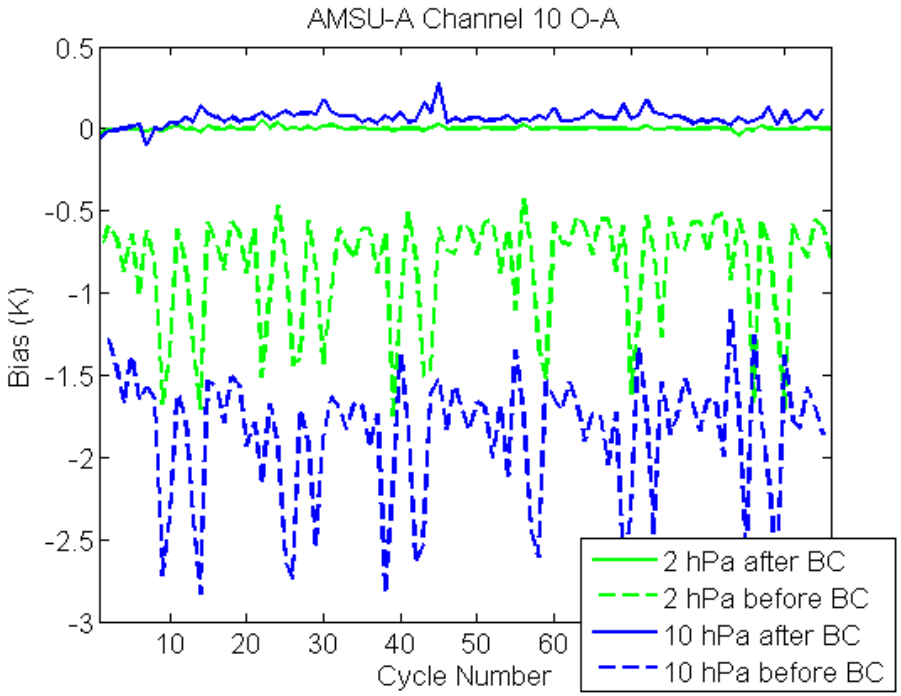
Experiments:

- **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
- Verification against ERA-Interim reanalysis using Model Evaluation Tools (MET)



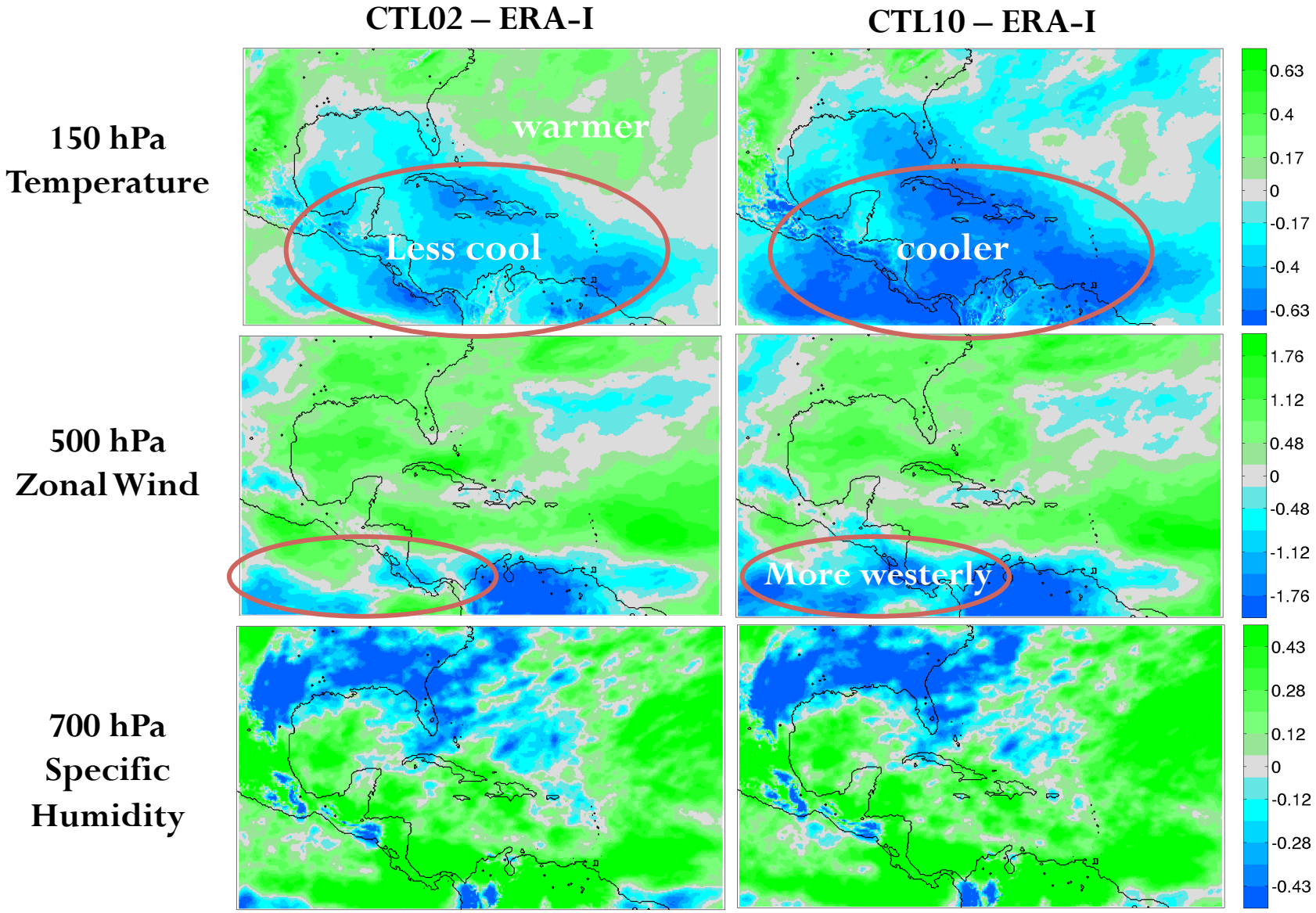
Model Top Test – GSI Diagnostics





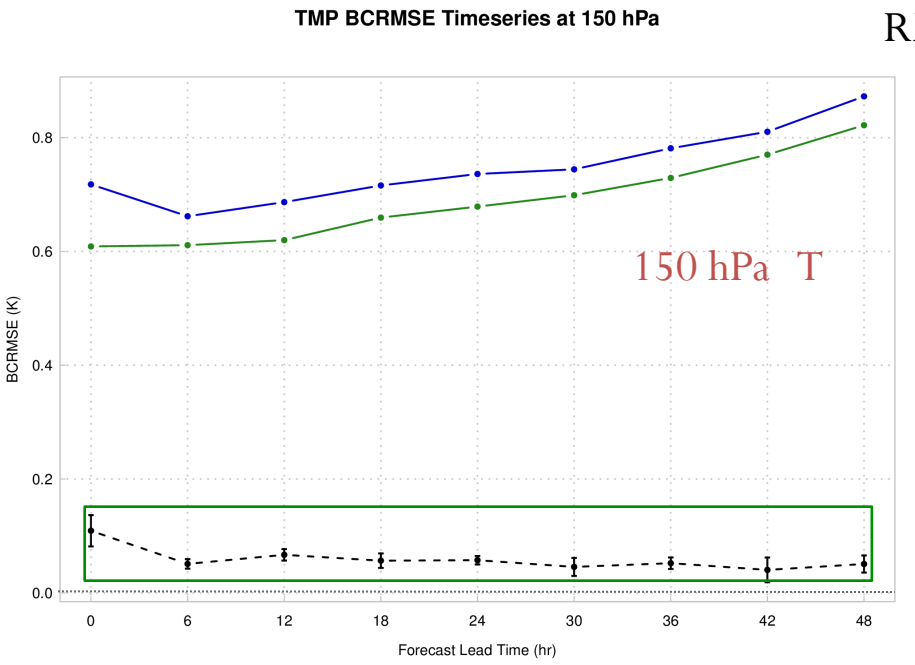
- Same channel selection for both configurations
- 2 hPa model top shows smaller bias

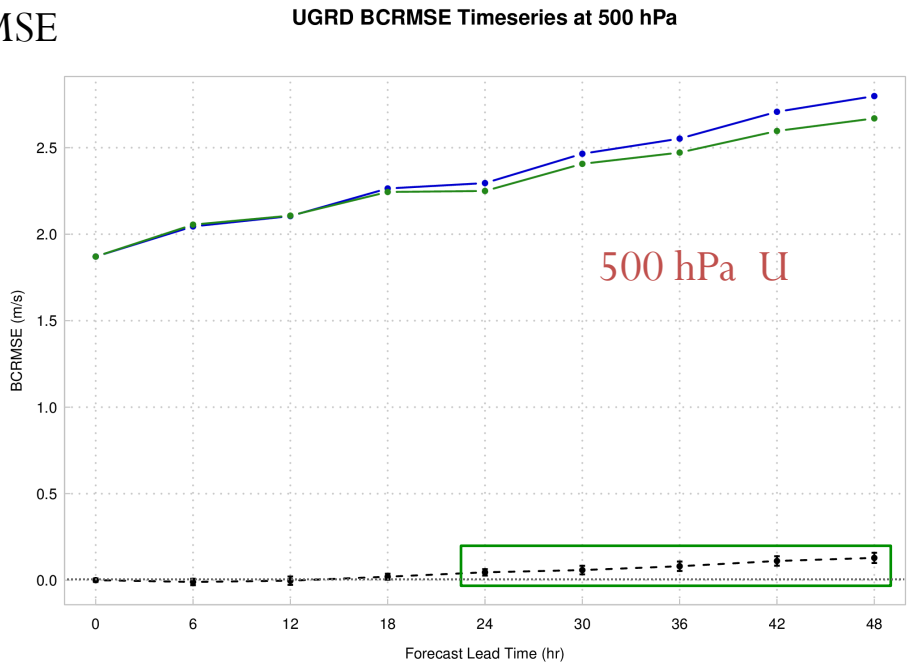
24-hr Forecast Verification (ERA-I)



Model Top Test: Verification (ERA-I)

Bias Corrected RMSE





CTL02 **CTL10** **CTL02-CTL10 (pairwise)**

- Consistent statistically significant (SS) improvements for CTL02 in temperature for all lead times
- Zonal wind field SS improvement for CTL02 for longer leads: 24-48 hr

Model Top Test: Verification (ERA-I)

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

TEMP BCRMSE

Pressure Levels (hPa)	Forecast Lead Time (hr) 0	6	12	18	24	30	36	42	48
50	CTL								02
100	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	L02
250	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02
400	--	CTL10	--	CTL10	--	CTL10	CTL10	CTL10	--
500	CTL10	--	--	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02
700	CTL10	CTL10	--	--	CTL02	CTL02	CTL02	CTL02	CTL02
850	CTL02	CTL02	CTL02	--	CTL02	--	CTL02	--	--
925	CTL02	CTL02	CTL02	--	CTL02	CTL02	CTL02	CTL02	CTL02

Model Levels

Lead Time (0-48 hr)

U-Wind BCRMSE

Pressure Levels (hPa)	Forecast Lead Time (hr) 0	6	12	18	24	30	36	42	48
50	--	CTL02	CTL02	--	--	CTL02	CTL02	--	--
100	--	--	--	CTL10	--	--	--	--	--
250	CTL02	CTL02	CTL02	CTL02	--	--	CTL02	--	CTL02
400	--	--	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02
500	--	--	--	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02
700	--	CTL10	--	--	--	--	CTL02	CTL02	CTL02
850	CTL02	CTL10	CTL10	--	--	--	--	CTL02	CTL02
925	CTL02	CTL10	CTL10	CTL02	--	--	CTL02	CTL02	CTL02

V-Wind BCRMSE

Pressure Levels (hPa)	Forecast Lead Time (hr) 0	6	12	18	24	30	36	42	48
50	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02
100	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02
250	CTL02	CTL02	--	--	--	--	--	--	--
400	CTL02	--	--	CTL10	CTL10	--	--	--	--
500	--	CTL10	--	CTL10	CTL10	CTL10	--	CTL10	--
700	--	--	CTL02	--	CTL02	--	CTL02	--	CTL02
850	--	CTL02	CTL02	--	CTL02	--	CTL02	--	--
925	--	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02	CTL02

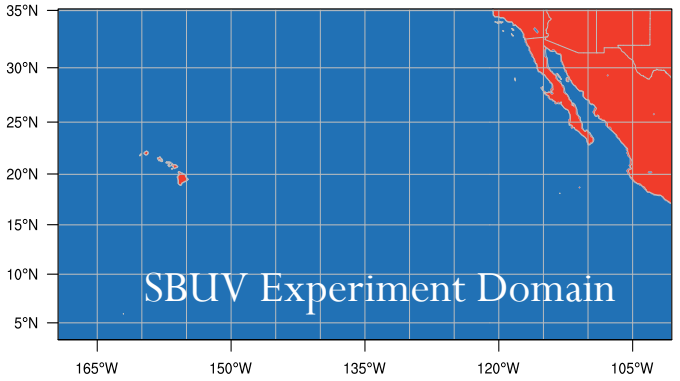
Improvement from 2 hPa model top

- Consistent improvement throughout T field
- Strong signal of improvement for zonal & meridional wind fields.
  - U: longer lead times
  - V: upper levels
- Mixed results for specific humidity (not shown)

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

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

SBUV: Experiment Design

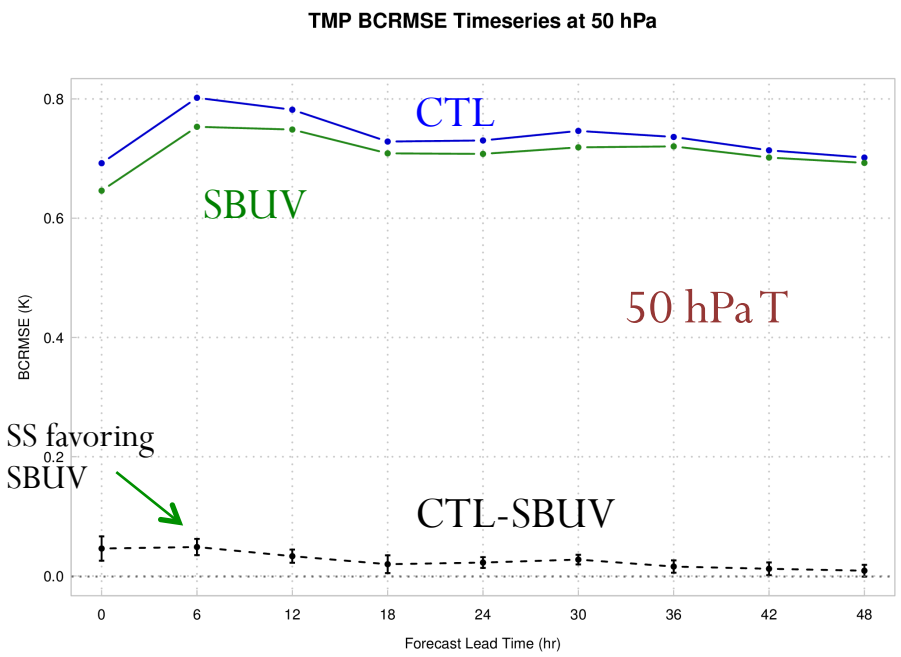


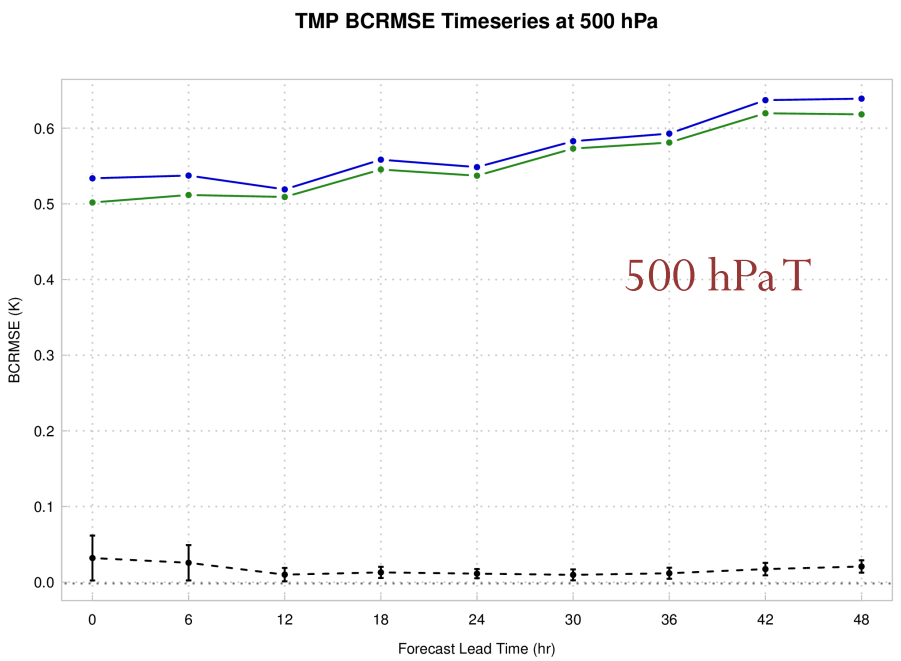
- Testing period: 1-31 August 2014
- 48-h deterministic forecasts initialized at 00/12
- Experiments:
  - **CTL**: Same configuration as in **CTL02**, including standard conventional and radiance data assimilated
  - **SBUV**: with additional assimilation of Solar Backscatter Ultraviolet (SBUV/2; v8) profile ozone
    - NOAA 19
- Verification against ERA-Interim (ERA-I) reanalysis using Model Evaluation Tools (MET) and comparison to radiance observations.
- O_3 not prognostic variable in ARW
  - GFS ozone used for background
  - Indirect impact on analysis and forecasts

Forecast Verification Against ERA-I

- ✓ Verification against ERA-interim reanalysis

SBUV Impact: Verification (ERA-I)





- Bias Corrected RMSE of temperature forecasts at 50 hPa and 500 hPa
- Strongest improvement within first 24-hr forecast
- Small SS improvements present at longer leads at mid-level T

SBUV Impact: Verification (ERA-I)

99% CI Statistical Significance Table: SBUV vs. CTRL

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

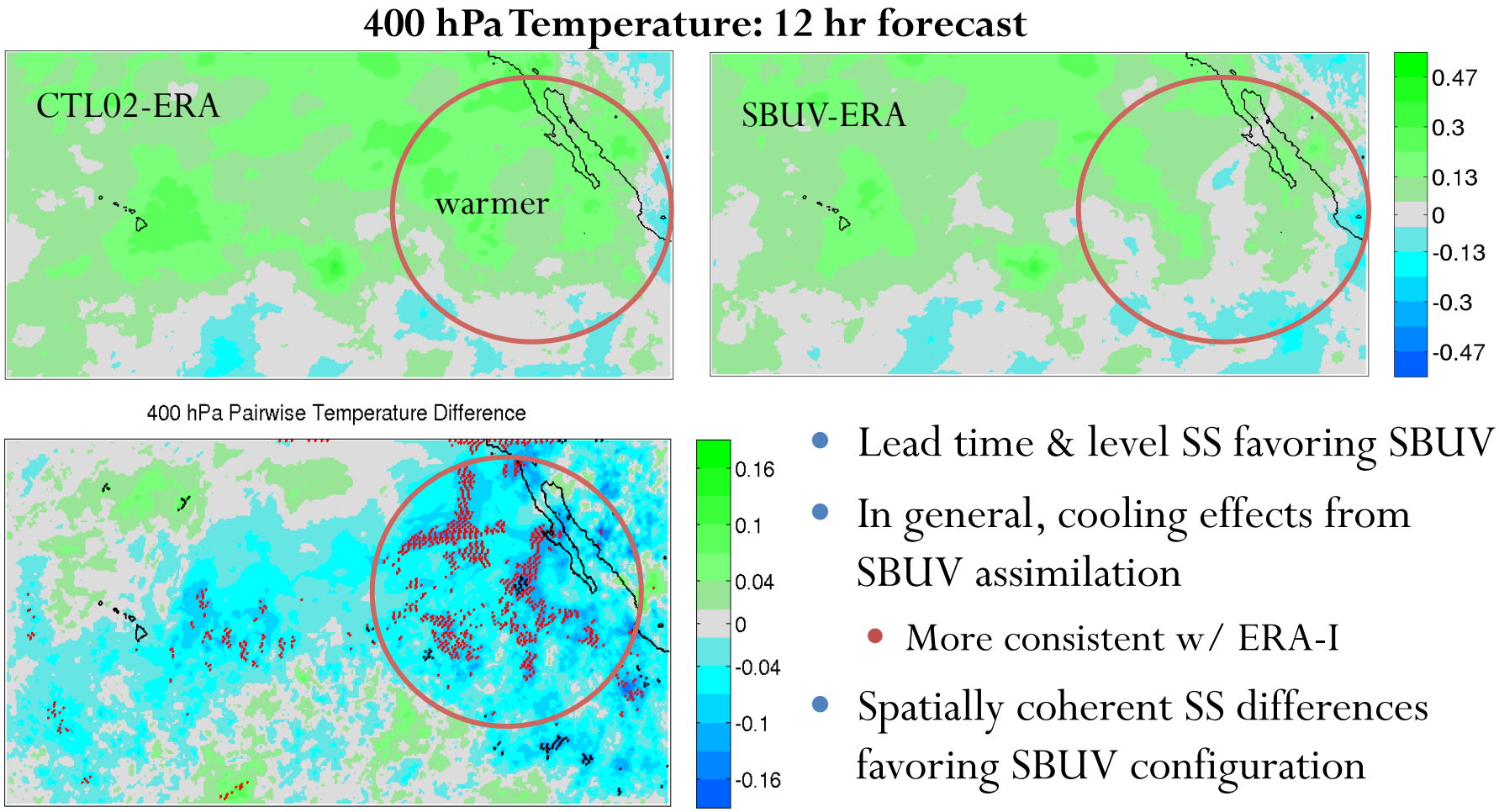
U-Wind BCRMSE		Forecast Lead Time (hr)								
		0	6	12	18	24	30	36	42	48
Pressure Levels (hPa)	50	SBUV	SBUV	SBUV	SBUV	SBUV	SBUV	--	SBUV	SBUV
	100	SBUV	SBUV	--	--	--	--	--	--	--
	250	--	SBUV	--	--	--	--	--	--	--
	400	SBUV	SBUV	SBUV	SBUV	--	--	--	--	--
	500	SBUV	--	SBUV	SBUV	--	--	--	--	--
	700	--	SBUV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

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

- Temperature:
  - Positive impacts at upper- and mid-levels
  - Degradation at 250 hPa after 24-hrs
- Winds:
  - Positive impacts particularly at early lead times
- Mixed results for specific humidity (not shown)

Green shading: SBUV better *Blue shading: CTL better*

SBUV Ozone Forecast Impact



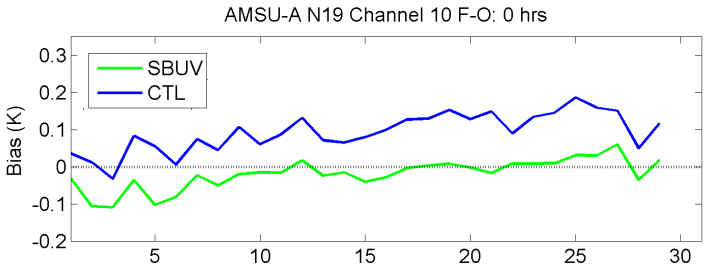
- Lead time & level SS favoring SBUV
- In general, cooling effects from SBUV assimilation
  - More consistent w/ ERA-I
- Spatially coherent SS differences favoring SBUV configuration
  - Cooling trend for SBUV SS

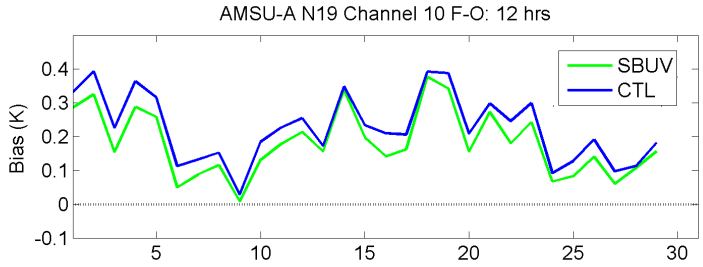
Red points: pairwise SS positive impacts from SBUV

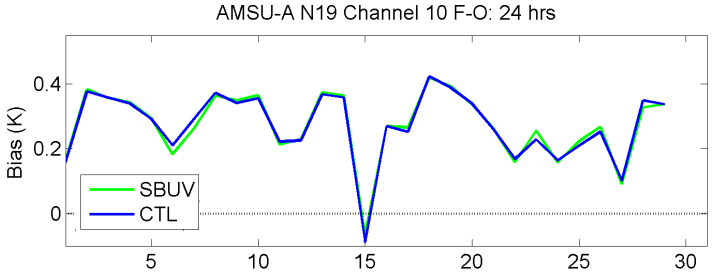
Forecast Verification Against Radiance Data

- ✓ F-O against AMSU-A radiances
- ✓ n19, n18 platforms chosen for coverage (n19 – largest coverage)
- ✓ Channel 10: Higher peaking for model domain, temperature sensitivity
- ✓ Channel 5: Mid-level weighting function peak, temperature sensitivity
- ✓ Spatial verification averaged over 1 degree box, 1 month testing period

Forecast Bias



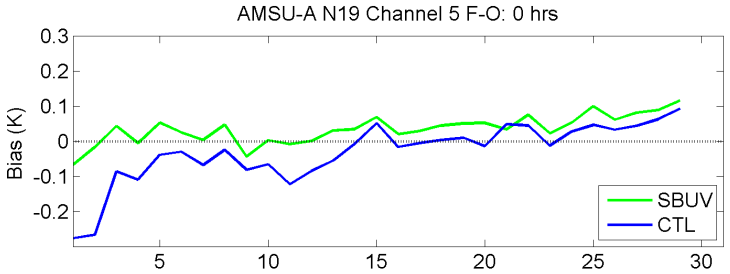


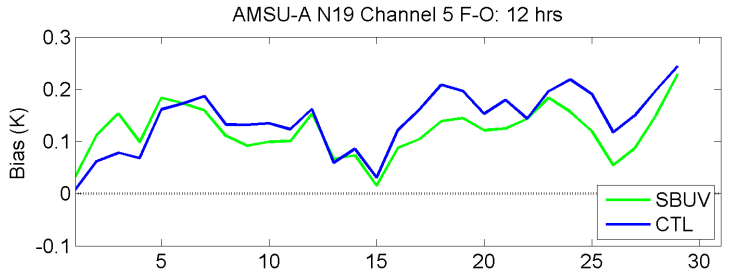


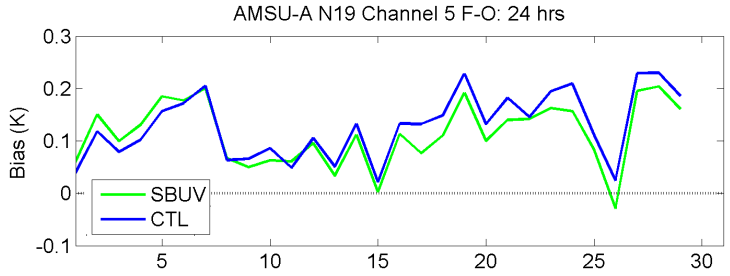
Analysis

12-hr

24-hr







Channel 10 AMSU-A:

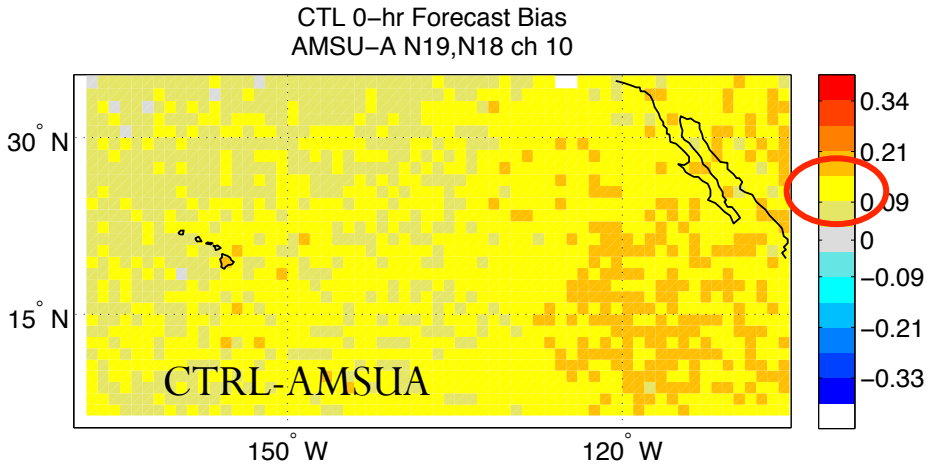
- Strong signature of improvement from SBUV at analysis time. 12-hr forecast consistently smaller bias in SBUV. 24-hr differences negligible

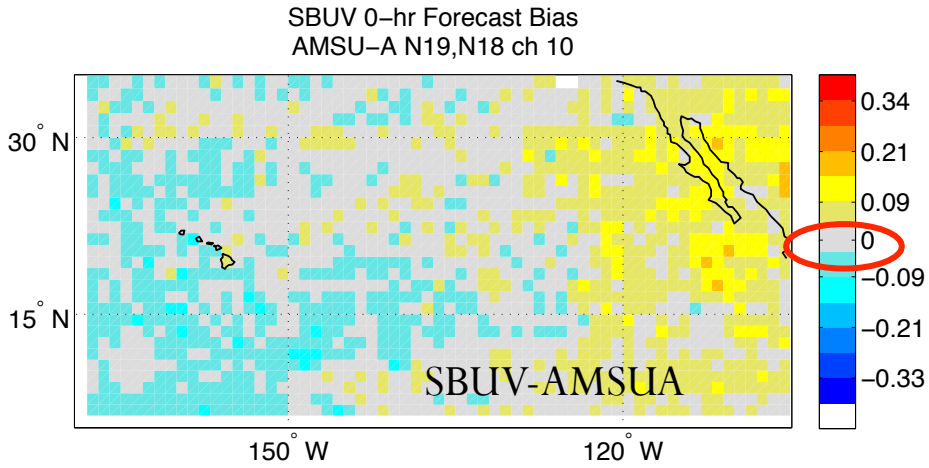
Channel 5 AMSU-A:

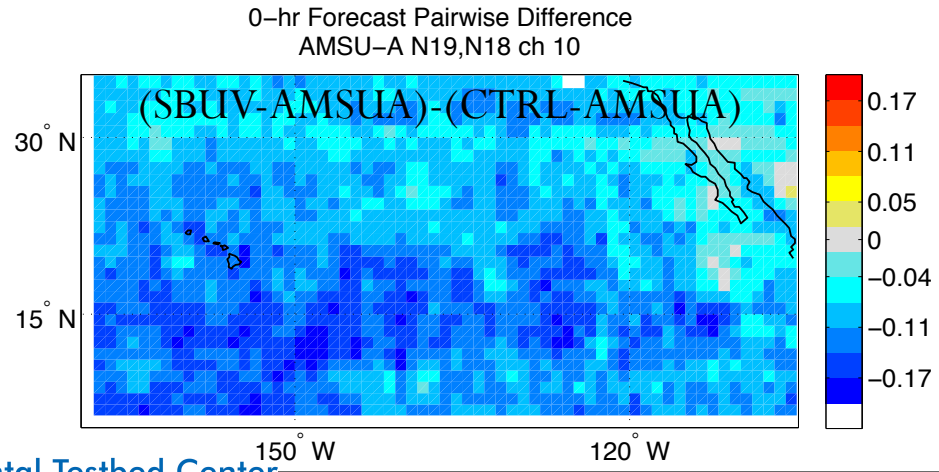
- Improvement for SBUV at analysis time in first 15 days. 12-hr SBUV bias smaller after day 5. 24-hr forecast consistently smaller biases in SBUV.

Analysis Departure From AMSU-A

- Channel 10: higher peaking, temperature sensitive



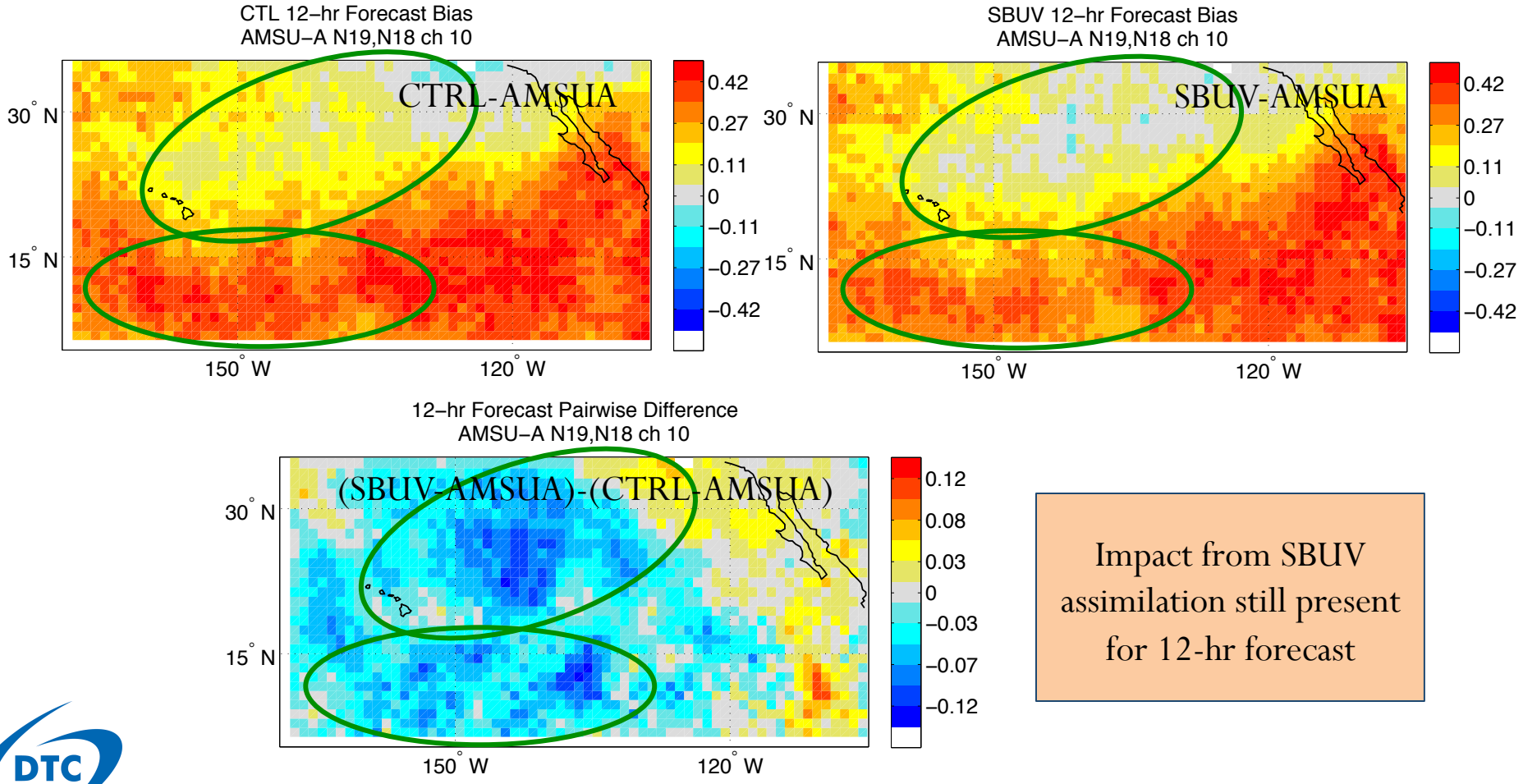




Consistent with large T improvements from SBUV at analysis time in upper levels

12-hr Forecast Departure from AMSU-A

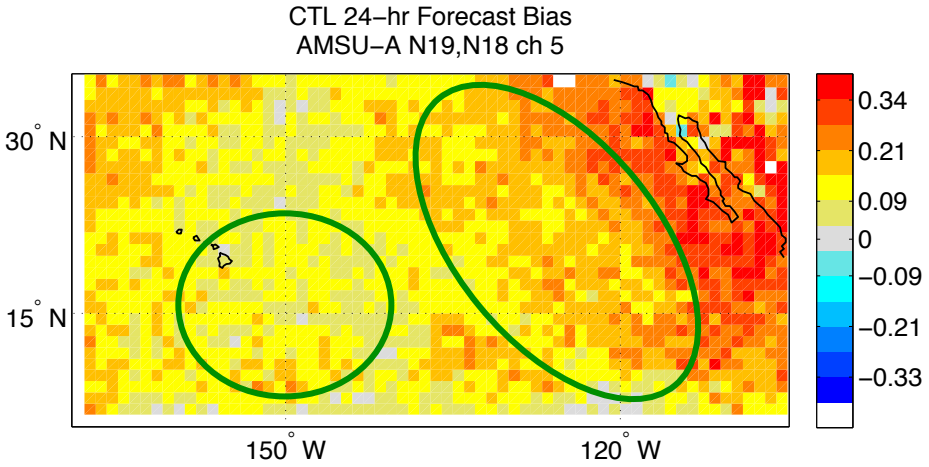
- Channel 10: higher peaking, temperature sensitive

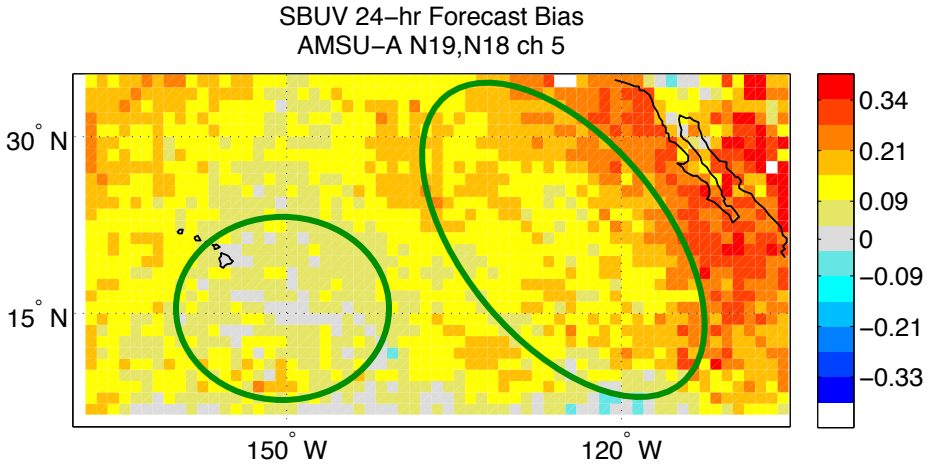


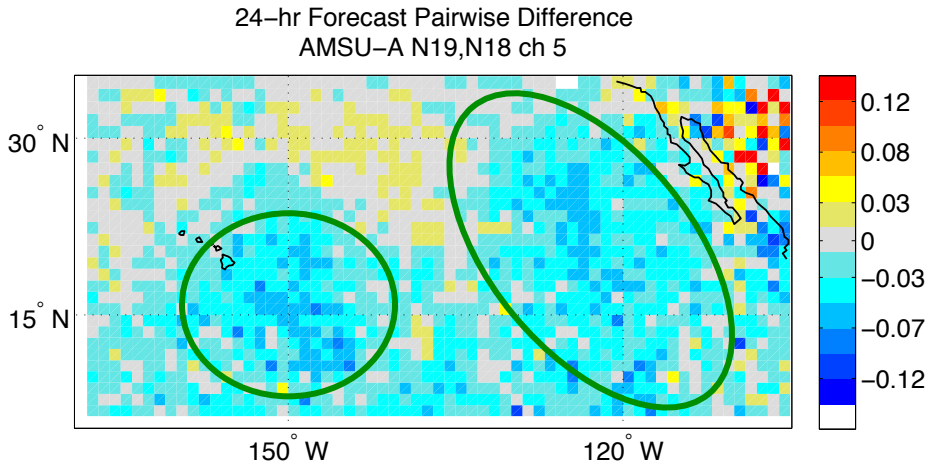
Impact from SBUV assimilation still present for 12-hr forecast

24-hr Forecast Departure from AMSU-A

- Channel 5: mid-level peak, temperature sensitive







Mid-level Temp bias reduction from SBUV configuration still evident at 24-hrs

Summary

- Increasing model top from 10 hPa to 2 hPa presents overall improvement to analysis and forecasts
- SBUV ozone were assimilated into GSI, GFS ozone used for background
  - Only analysis update, indirect impact on radiances
- Assimilating SBUV presents generally positive impacts
  - Improved T analysis for most levels
  - Wind improvements for short term forecasts (~18 hrs)
  - Cooling pattern from SBUV, more consistent w/ observations & reanalysis

GSI Diagnostics in MET

- Model Evaluation Tools (MET) v5.1 (planned release fall 2015) will include GSI diagnostics capabilities
- Reformat binary GSI diagnostic output files (conv, rad)
- Ability to threshold, filter, subset and produce statistics on diagnostic output