Status of the Geostationary Hyperspectral IR OSSE effort in NOAA/JCSDA

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with contributions from:

Zhenglong Li[4] (geostationary AIRS simulation)

Michiko Masutani[1, 2, 5] (control radiance simulation)

Jack Woollen[2, 5] (conv obs, GPSRO simulation)

Tong Zhu[2, 3] (random-error addition)

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Outline

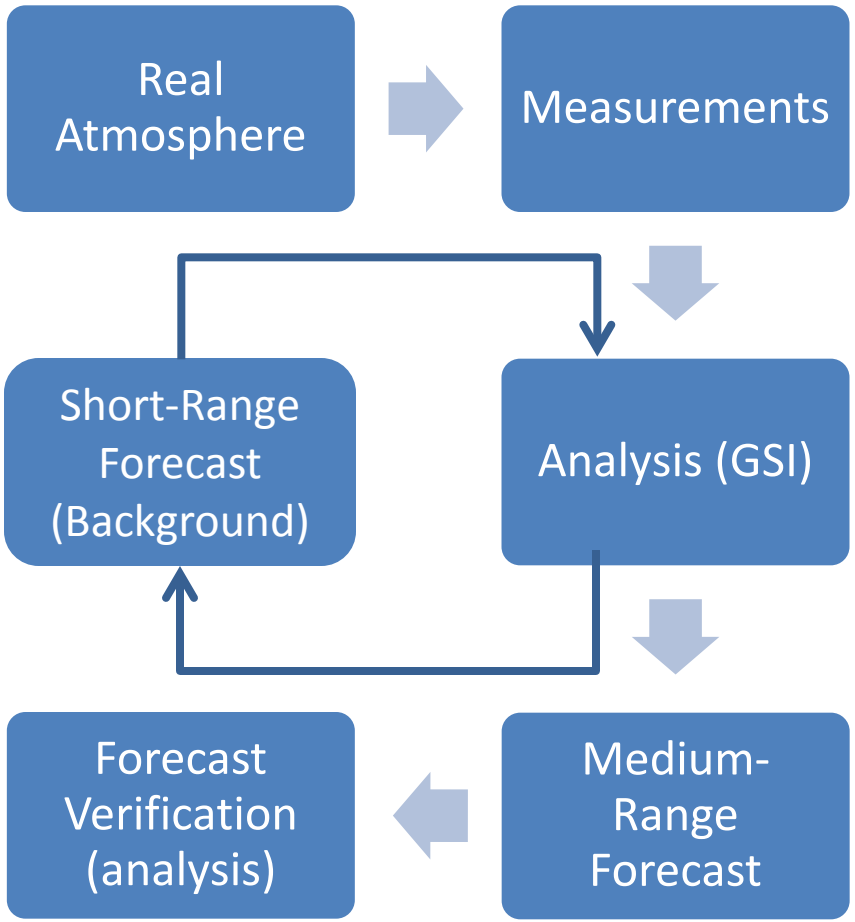
- Motivation/OSSE definition
- 2014: T382-Hybrid Geostationary Hyperspectral Infrared Study (Geo-Hyper IR)
  - T382-Hybrid study description
  - Comparison to planned 2015 Study
  - Summarized preliminary results, VSDB v. 16
- Improvements for 2015 experiments being worked on by JCSDA/CICS-MD OSSE team
  - Simulations from new Nature Runs (NRs)
  - Bias/variance addition to conventional obs
  - Radiance bias addition
  - Upgraded GDAS/GFS system
- Summary

Motivation

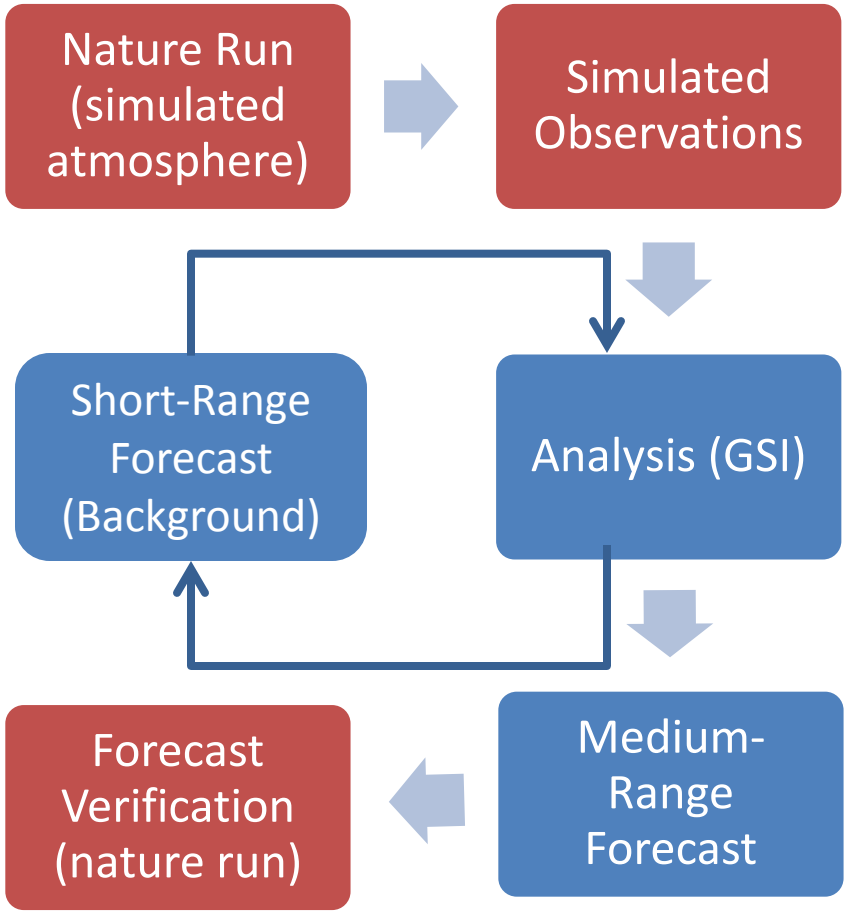
- Disaster Relief Appropriations Act of 2013 (H.R. 152), Title X, Chapter 2, Section 4 included funding "to improve weather forecasting and hurricane intensity forecasting capabilities, to include data assimilation from ocean observing platforms and satellites"
- NOAA OAR awarded a portion of these funds to Robert Atlas (AOML) for a larger Observing System Simulation Experiment (OSSE) investigating prospective new observations, including geostationary hyperspectral IR sounders
- As part of this larger project, CICS-MD scientists at the Joint Center for Satellite Data Assimilation (JCSDA) will be working with the Global Forecast System (GFS) developed by NOAA/NCEP to investigate global impacts of new sensors, as well as providing boundary conditions for regional studies by other project partners and investigate improvements to be made to simulated observation experiments

What is an OSSE?

Real World



Observing System Simulation Experiment



2014 Study Experiments (in preparation for main 2015 study)

- Prs382hna
  - "Parallel-Run, Sean Casey, T382-3D-Hybrid, No AIRS_G13"
  - Control run
    - Simulated observations for July-August 2005 (T511 ECMWF Nature Run) assuming 2012 observation system
    - All instruments (conv, GPS, radiance) operational in July-August 2012, with addition of SSMIS-F16,F17,F18
    - Random-errors added to all radiance observations using modified version of R. Errico's (GMAO) error-addition code
    - Two week spin-up, 47-day experiment period (20050716-20050831)
- Prs382hwa
  - As prs382hna, only "With AIRS_G13" (AIRS instrument in the location of GOES-13, 75°W)
  - Simulated from T511 NR by Z. Li, U. Wisconsin, using SARTA (compared to CRTM for JCSDA-simulated radiances)
  - Random-errors added using expected error distribution for AIRS_AQUA

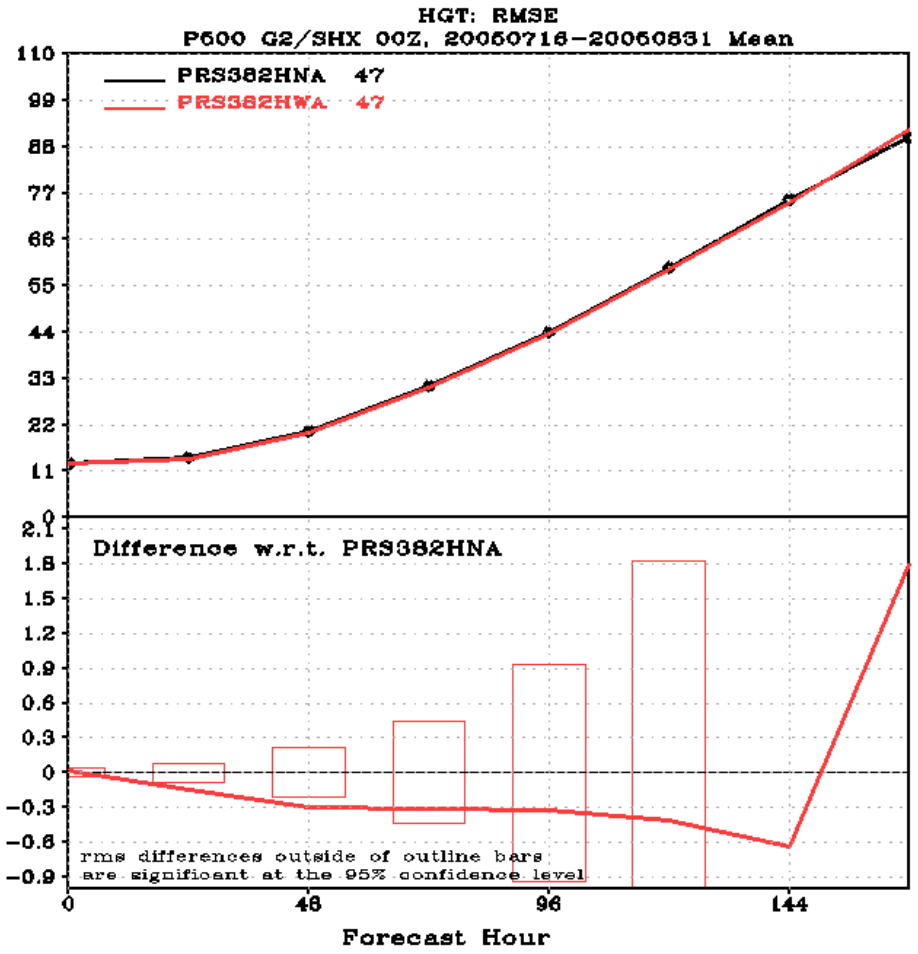
Geo-Hyper Experiments, 2014 vs. (planned) 2015

- Ten areas of concern for 2014 study with plans to remedy these by the start of 2015 study (May)
- Cover each aspect of OSSE process:
  - Nature Run (1)
  - Simulation (6)
  - Analysis (2)
  - Forecast (1)
  - Verification (1)
- Because of these issues, the following results should be considered <u>preliminary</u> (i.e., not suitable for programmatic conclusions)

System Tool	2014 study	Planned 2015 study
Nature Run (NR)	ECMWF T511	GMAO 7-km or ECMWF T1279
Conventional obs errors	None	Assigned bias/random errors as appropriate
GPSRO obs type	Refractivity	Bending-angle
GPSRO obs errors	None	Assigned bias/random errors as appropriate
CRTM version	2.0.5 (control obs only)	2.1.3
Radiance obs errors	Added random errors	Assigned bias/random errors as appropriate
Test obs simulation	SARTA (U. Wisconsin)	CRTM (JCSDA)
GDAS/GFS resolution	T382 analysis, forecast; T190 3D-hybrid ensemble	T1534 forecast; T574 analysis, 3D-hybrid ensemble
Radiance bias correction	Two-factor (one internal to GSI assimilation, one external)	One-factor (internal in GSI assimilation)
VSDB	Version 16	Version 17

Preliminary VSDB Results

- Right: RMSE for SH 500 hPa geopotential height (forecast hour on horizontal axis)
- Lower figure: difference between mean RMSE, prs382hwa-prs382hna
- Red boxes: 95% confidence interval; counts outside these bounds are considered statistically significant
- Comparisons done with respect to T511 NR
- Here, the experiment with AIRS_G13 shows significant reduction in RMSE for days 1, 2
- Full results can be viewed on JCSDA website: http://www.jcsda.noaa.gov/vsdb/users/scasey/prs382hwa/vsdb.php
- VSDB Version 17 (planned for 2015) includes a "scorecard" summary plot which includes multiple metrics/regions in one easy-to-read image
- I created a "rough scorecard" based on the Version 16 results (next slide)



Preliminary AIRS_G13 impacts (00Z runs)

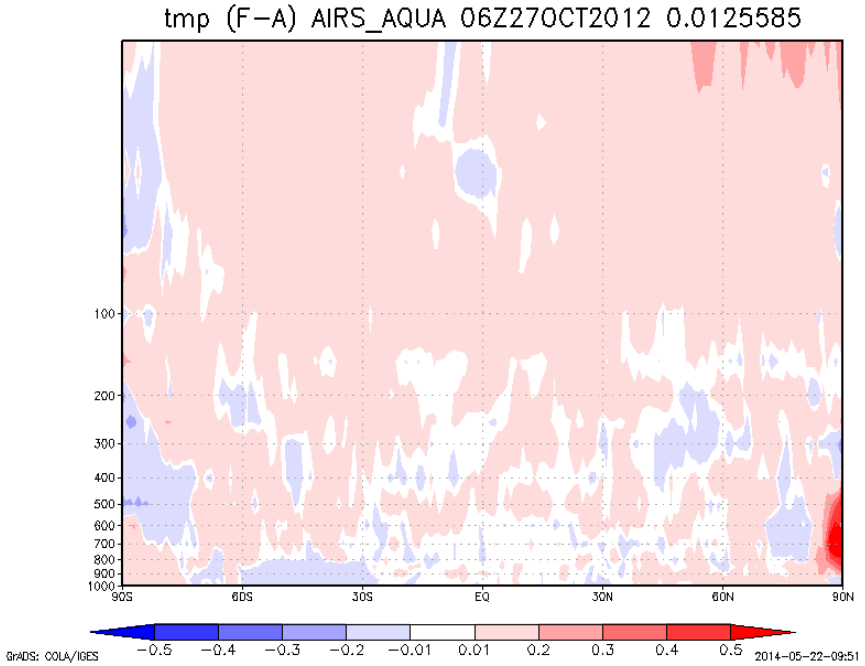
Domain	Parameter	Level	Anomaly Correlation Forecast Day 1	2	3	4	5	6	7	RMS Error Forecast Day 1	2	3	4	5	6	7
PNA	Temperature	250/200 hPa														
		500 hPa														
		850 hPa														
	Wind	250/200 hPa														
		850 hPa														
	Geopotential	250/200 hPa														
		500 hPa														
		700 hPa														
		1000 hPa														
NH	Temperature	250/200 hPa														
		500 hPa														
		850 hPa														
	Wind	250/200 hPa														
		850 hPa														
	Geopotential	250/200 hPa														
		500 hPa														
		700 hPa														
		1000 hPa														

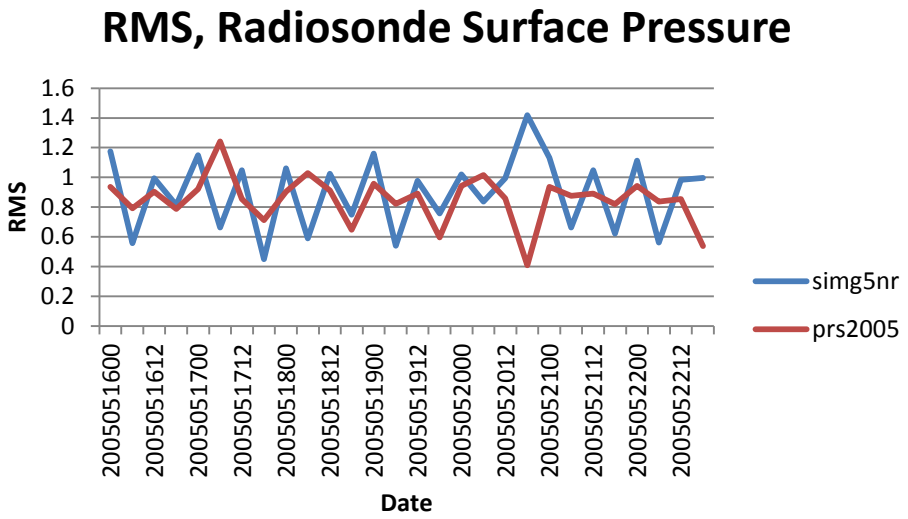
Domain	Parameter	Level	Anomaly Correlation Forecast Day 1	2	3	4	5	6	7	RMS Error Forecast Day 1	2	3	4	5	6	7
SH	Temperature	250/200 hPa														
		500 hPa														
		850 hPa														
	Wind	250/200 hPa														
		850 hPa														
	Geopotential	250/200 hPa														
		500 hPa														
		700 hPa														
		1000 hPa														
Tropics	Temperature	250/200 hPa														
		500 hPa														
		850 hPa														
	Wind	250/200 hPa														
		850 hPa														

- prs382hwa significantly better than prs382hna
- prs382hwa better than prs382hna, nonsignificant
- no discernible difference
- prs382hwa worse than prs382hna, nonsignificant
- prs382hwa significantly worse than prs382hna

- Bright Green, Red = statistically significant
- Visual interpretation, erred on side of caution (i.e., calling results “significant” only if clear without a doubt)
- Separation will be quantitative in Version 17 scorecard

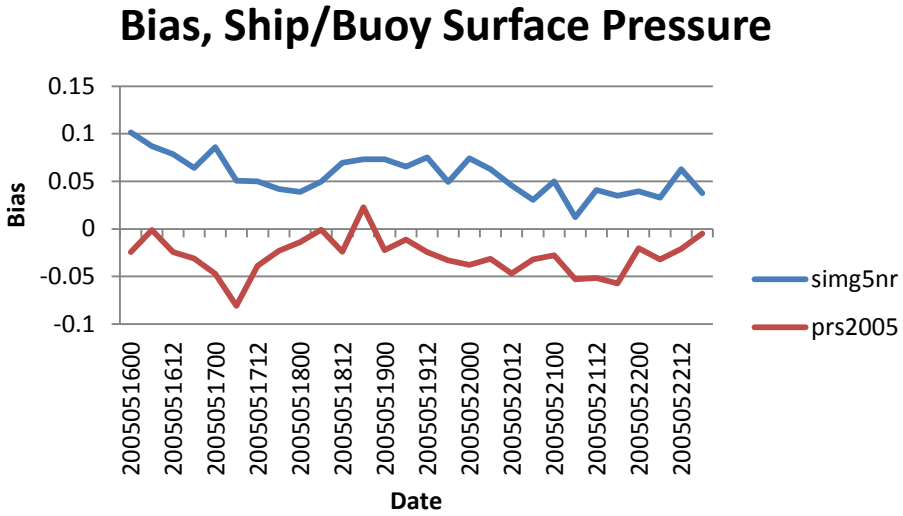
Improvements for 2015: simulations from new NRs

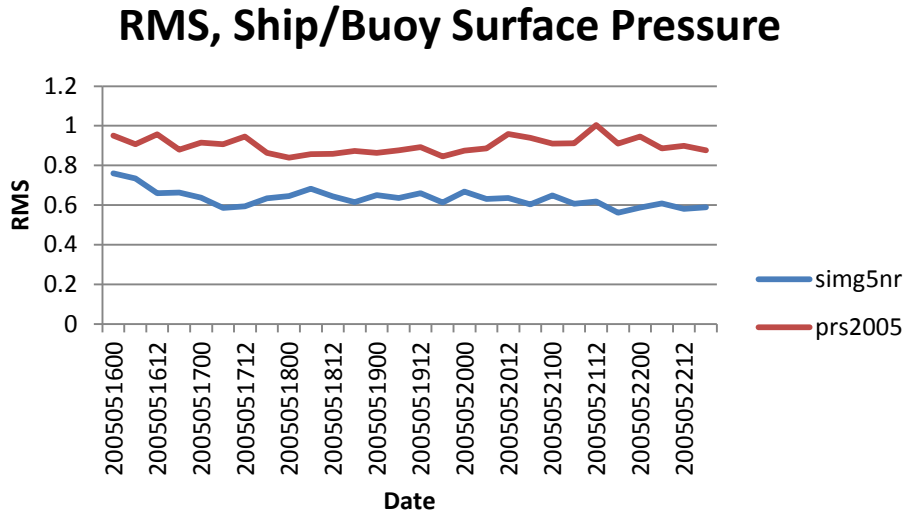




- Left: Impact of assimilating simulated AIRS_AQUA data from ECMWF T1279 sample period (2012102706); red=analysis closer to sample data
- Right: model-identified O-A RMS error for radiosonde surface pressure, 2005051600-2005052218, assimilating only conv obs
  - Red: real observations
  - Blue: simulated observations from GMAO G5NR (7-km resolution)

Adding biases/random errors to conventional observations

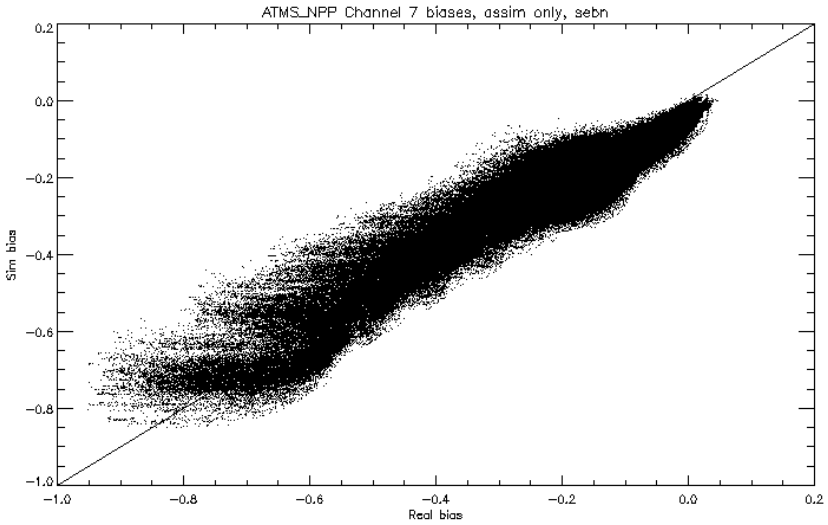


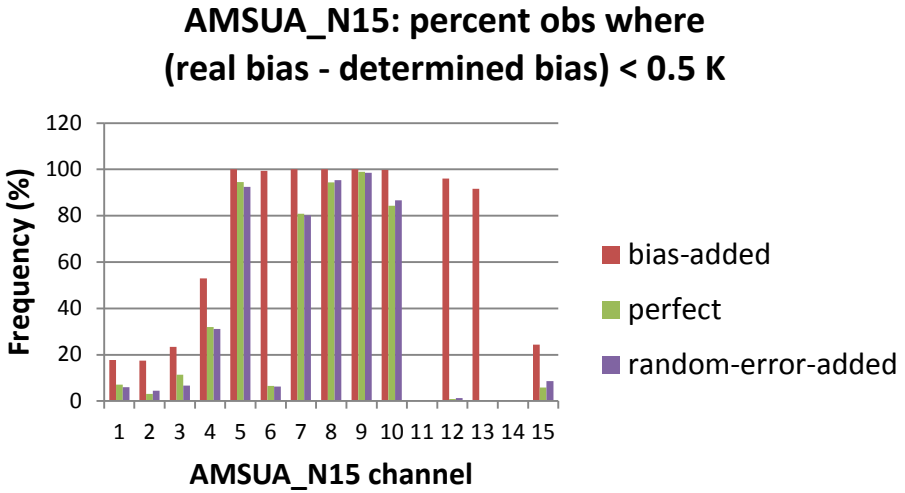


- Assimilation package identifies bias, RMSE (O-A) for each observation type
- Most conventional obs (surface pressure, wind, temperature, moisture) show significant differences in bias, RMSE for real (red), simulated obs (G5NR, blue)
- Significance tested by 2-sample Z-test (2σ threshold)
- Different error characteristics for simulated data could impact feasibility of results
- Investigating methods of adding bias, variance until statistics match real data for first week of NR (when real, simulated obs differ minimally)
  - Should account for adding bias, variance for new observations as well
  - May be applicable for GPSRO, radiance assessment at a later date

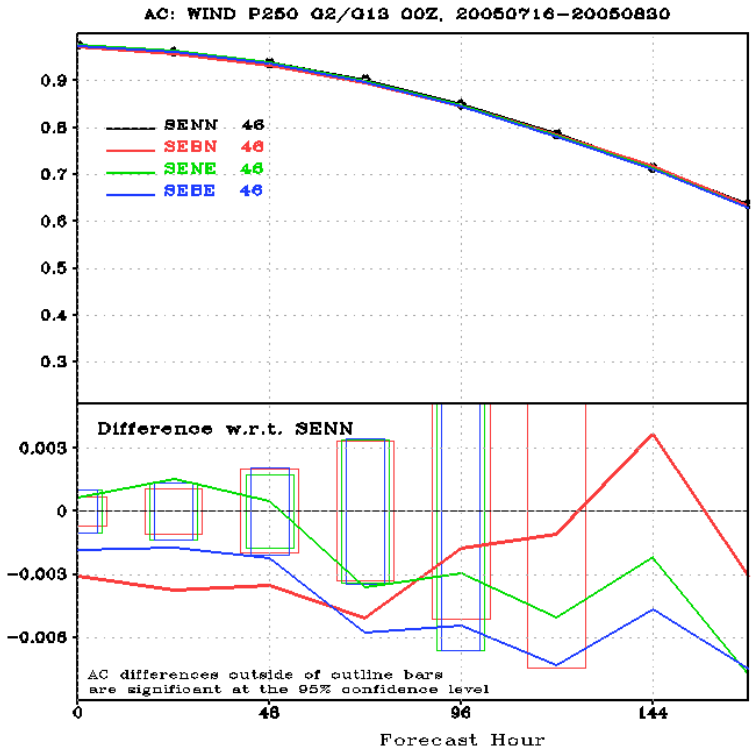
Radiance Bias Addition

- Brute-force method tested, adding model-identified biases from July-August 2012 (courtesy E. Liu, NOAA/NCEP/EMC) to simulated 2005 observations
- Left: Model-identified biases using real data (horizontal), simulated obs + biases (vertical), ATMS 54.4 GHz channel
- Right: Fraction of observations where bias magnitude < 0.5 K, AMSUA_N15
  - Bias-added data (red) better fits data than "perfect" (green) and random-error added (blue) data
  - Free-troposphere, stratospheric channels show near-100% agreement; surface, water vapor channels show poor improvement





Radiance Bias Addition



- Left: 250 hPa wind AC score, GOES-13 region
  - Red: bias-added
  - Green: random-error added
  - Blue: bias and random-error added
  - Bias-added cases show significant degradation compared to perfect data
- What to do for test observations?
  - Bias won't be really known for any new instrument until it is launched
  - Adding bias to control data, but not test data, would overestimate impact
  - If new instrument is same as a current instrument (such as AIRS), we could estimate the expected bias/variance magnitudes based on currently-operational versions of the instrument.

Nwprod_gdas_2014 operational upgrade

- Test-version installed on NCCS JIBB cluster
- Being tested with real observations
- Looking at modifications needed for OSSE setting
- Will allow for:
  - Newer RTM assimilation (CRTM-2.1.3)
  - Higher-resolution (T1534 forecast, T574 analysis/ensemble) given higher-resolution NR
  - Improved radiance bias correction scheme (Zhu et al. 2013, QJRMS), allowing for less spin-up time

Summary

- Preliminary testing for a geo-Hyper IR showed promise, highlighted areas for improvement
- Current work focusing on system improvements
  - Simulations from higher-resolution NRs
  - Bias/variance for conventional obs
  - Uncertainty for radiance obs
  - Upgrade to higher-resolution GDAS/GFS
- Hope to have these, and additional updates, ready by projected start date of main Geo-Hyper IR experiment (May 1, 2015)