Impact Experiments for Satellite Radiance Data in the GEOS-5 Analysis System

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GESTAR/NASA GMAO

Thanks to Ricardo Todling, Steve Bloom, Will McCarty, Larry Takacs, Santha Akella, Ron Gelaro, and many others in GMAO

Motivation

- There is interest to have multiple sources of information from different types of satellite sensors but it is not easy to examine the performance of each type of observation.

- We have been using the adjoint-based method to estimate observation impacts on forecast errors. But it is still difficult to find the sources of problems in the analysis process especially if the analysis is biased.

Data Currently Assimilated In GEOS-5 System

• Microwave radiance data: AMSU-A (in NOAA 15, 18, 19, Aqua, METOP-A & B AMSU-A), MHS (in NOAA 18, METOP-A & B), ATMS (in Suomi NPP), SSMIS (in DMSP F17, F18)

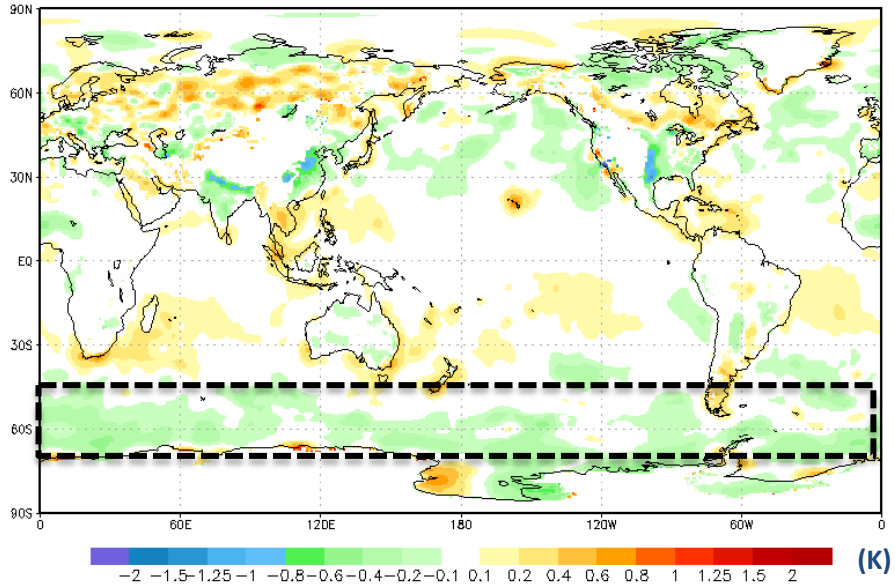
• IR radiance data: AIRS (in Aqua), IASI (in METOP-A & B), HIRS (in METOP-A), CrIS (in Suomi NPP), SEVIRI (in METEOSAT-10), GOES13, GOES15

• Conventional Data : Sonde, Buoy, Ship data, Aircraft data
• GPS Radio Occultation : bending angle
•SatWind retrieved wind vectors

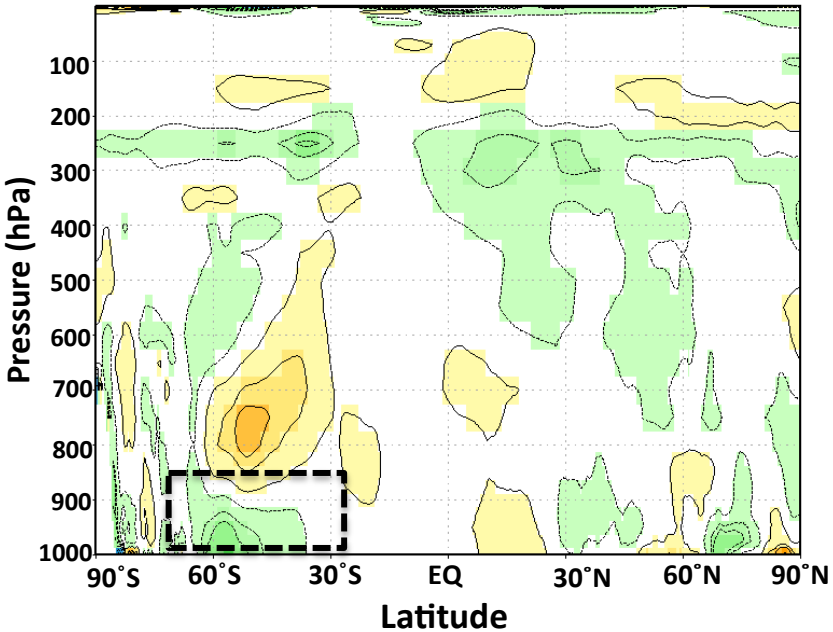
Motivation

JUNE 2014

Monthly Mean T Analysis Increment at 925 hPa



Monthly Zonal Mean T analysis Increment



Are analysis increment contributions from certain radiance data related to the analysis biases?

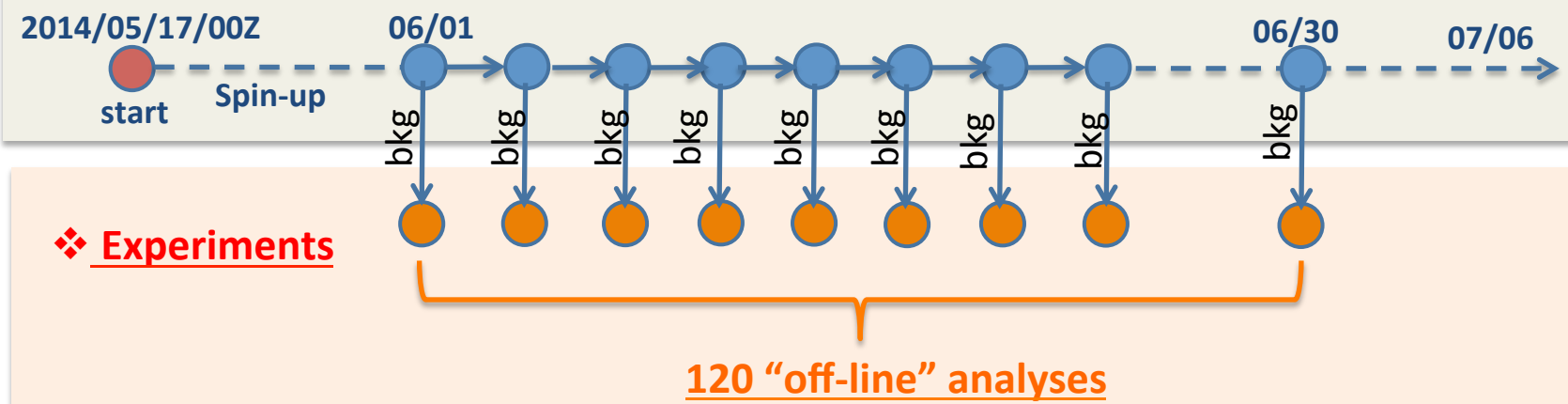
GOAL

1. To introduce an efficient methodology to estimate contributions from different sensors' radiance data to the total analysis increments (Are they consistent? Conflicts? Where?)
2. To determine if the analysis increment contributions from certain radiance data are related to analysis biases we want to fix.
3. To find clues on what to improve in the current use of satellite data

Experimental Methodology

❖ **Control Run**

- 0.5˚ horizontal resolution, 3D-Var
- Assimilated data: Conventional, AMSU-A, MHS, ATMS, AIRS, IASI, HIRS, SBU2, SEVIRI, GPSRO, GOES-Sounder



❖ **Experiments**

- EXP1: Conventional data only
- EXP2: AMSU-A data only
- EXP3: MHS data only
- EXP4: AIRS data only
- EXP5: IASI data only
- EXP6: HIRS data only

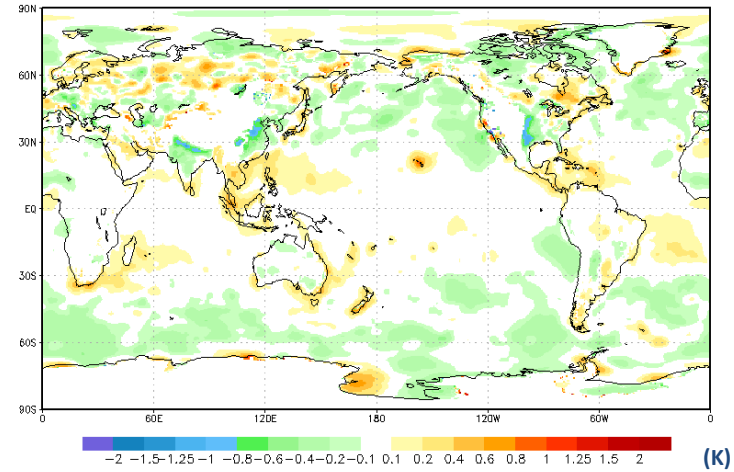
Monthly Mean 925hPa T Analysis Increments

1. Large discrepancy between increments from conventional data and increments from satellite data.

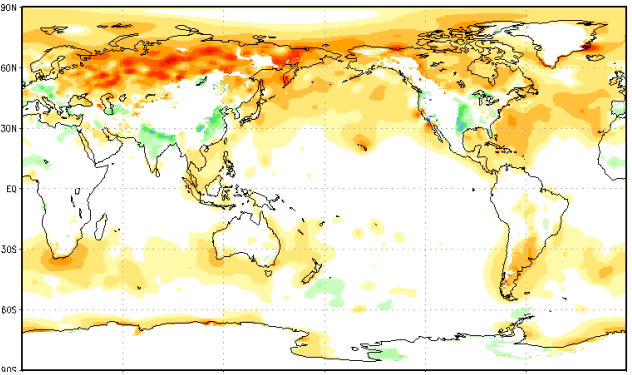
2. Increments from different satellite data have opposite signs in many areas.

3. Cold bias in Southern Hemisphere is exacerbated by negative temperature increments contributed by satellite data.

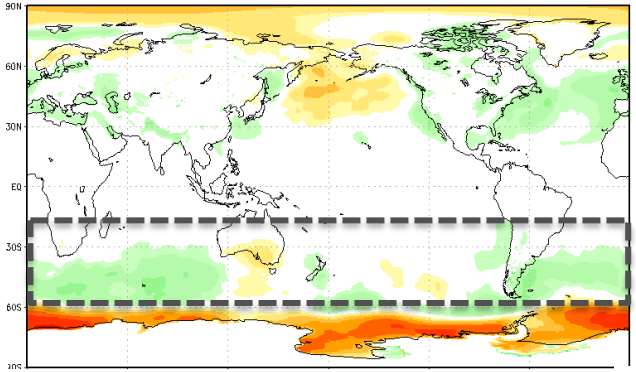
All observations (Control)



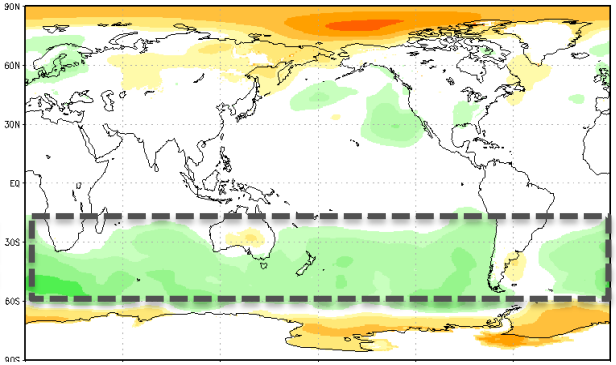
Conventional data



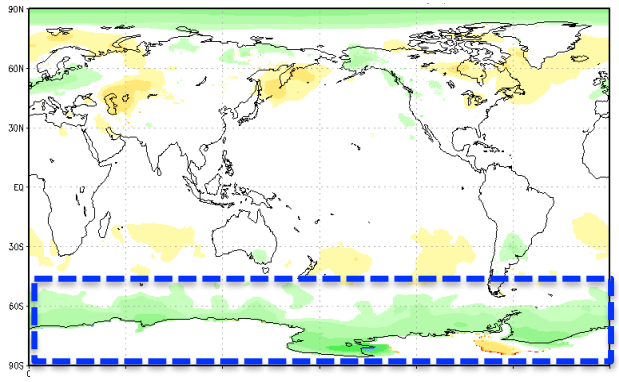
AMSU-A



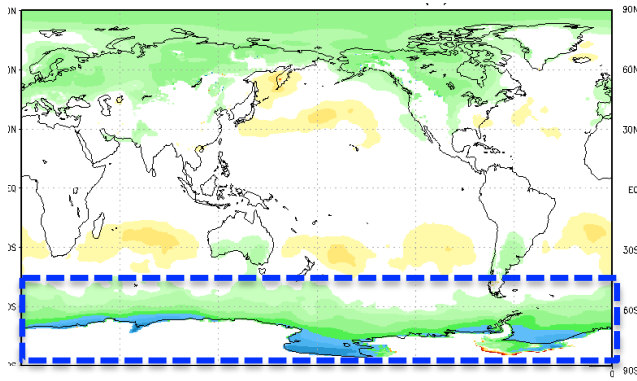
MHS



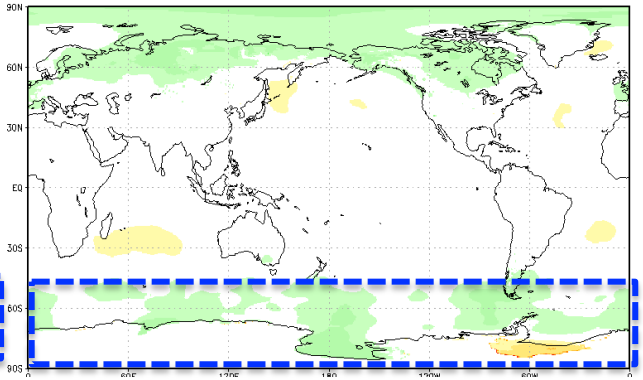
AIRS



IASI



HIRS



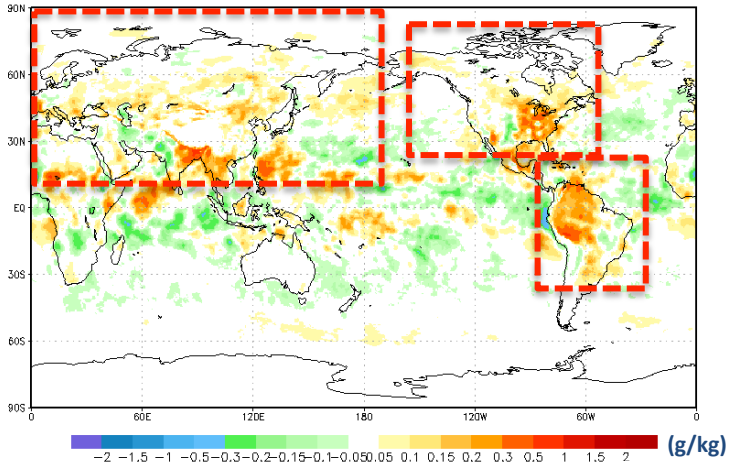
Monthly Mean 700hPa q Analysis Increments

1. Infrared data from AIRS and IASI are the major contributors to total humidity increments over land.

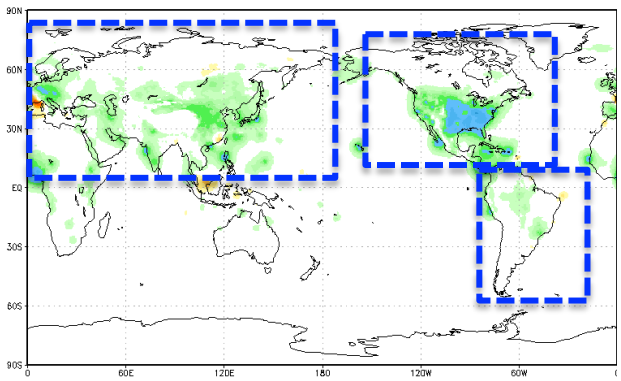
2. They are opposite in sign to increments from conventional data.

→ **Conventional data are working to reduce the wet bias over land while satellite data are making the analysis wetter.**

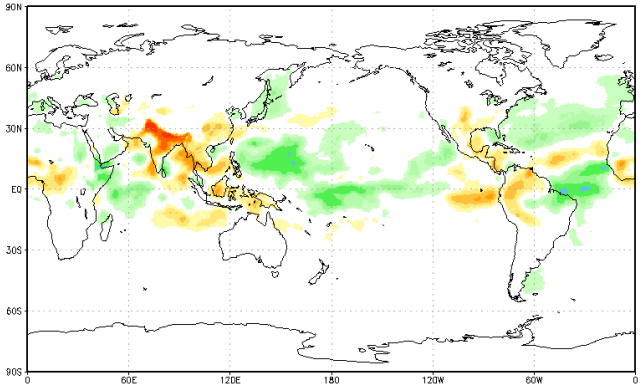
All observations (Control)



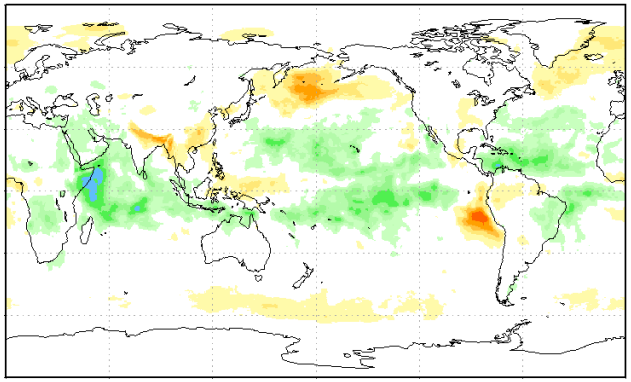
Conventional data



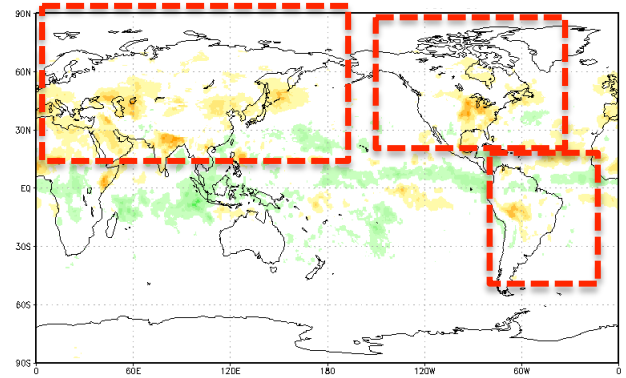
AMSU-A data



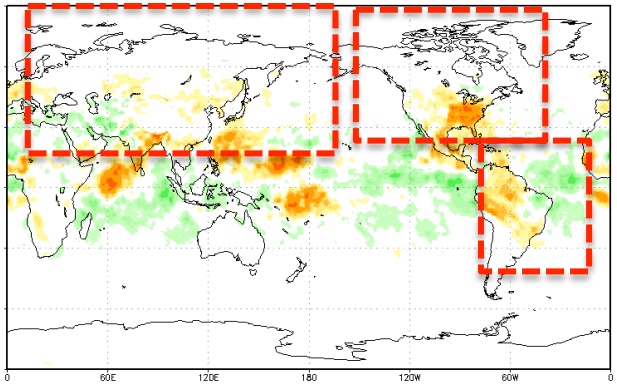
MHS data



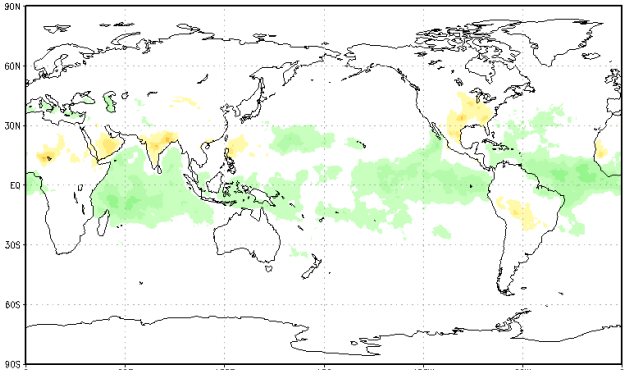
AIRS data



IASI data



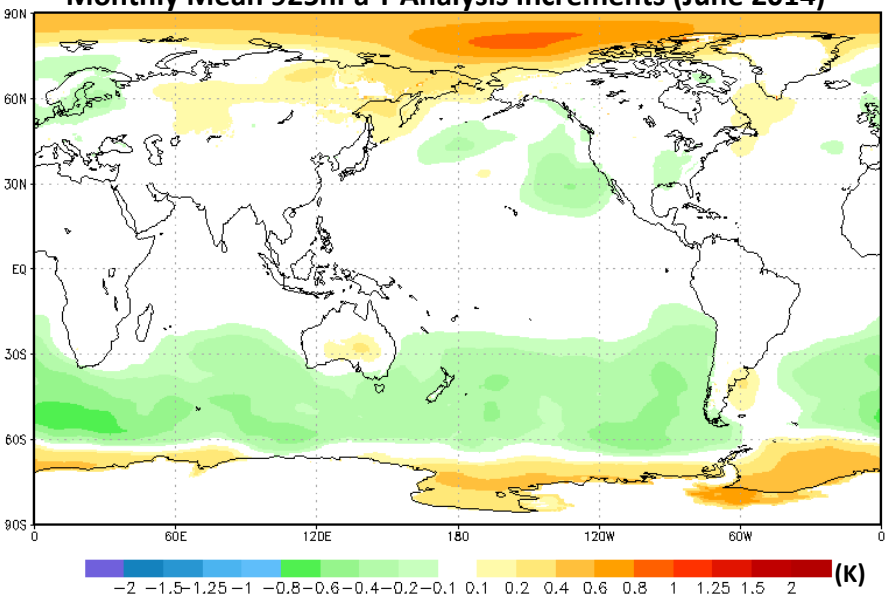
HIRS data



What was going on..

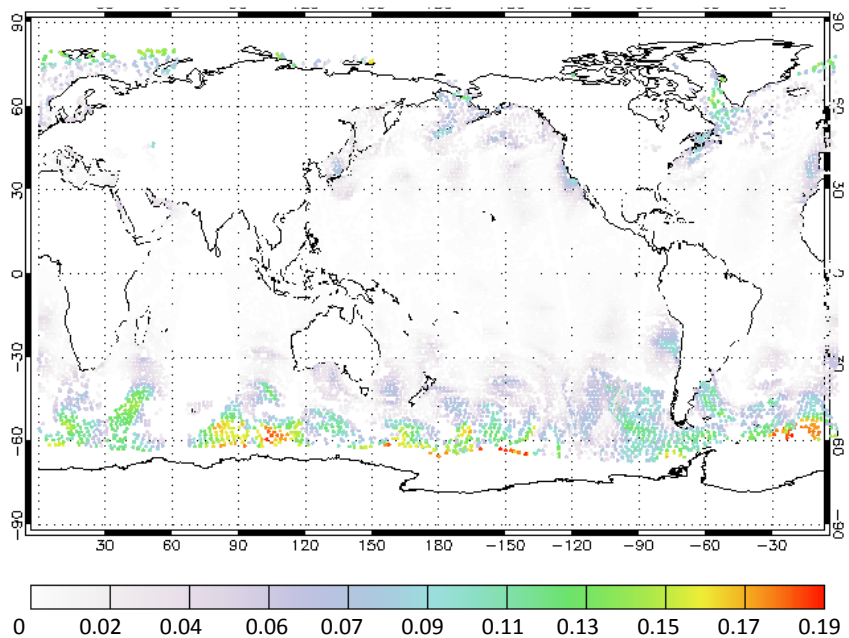
MHS Only Experiment

Monthly Mean 925hPa T Analysis Increments (June 2014)



d(Tb)/d(Tsfc) computed by CRTM using background field

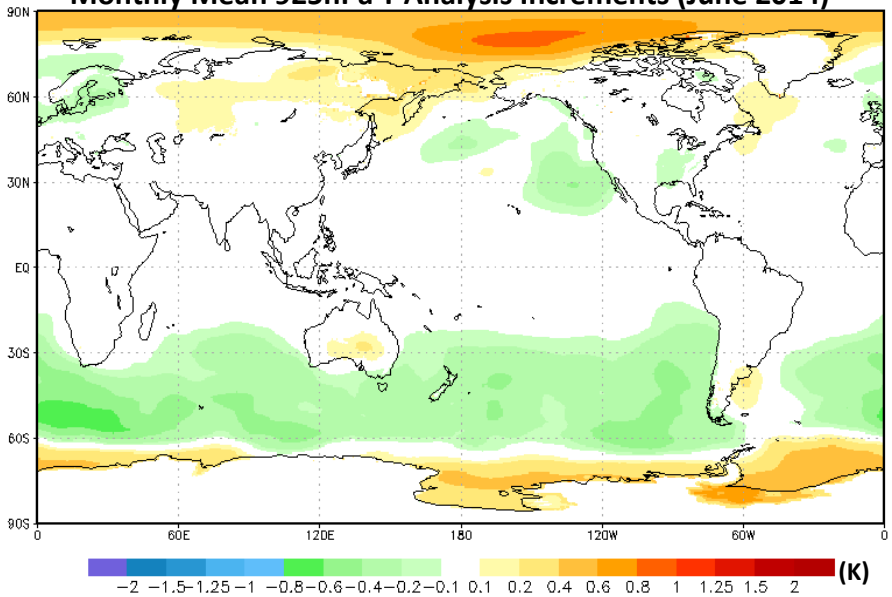
MHS CH5 (06/01/2014 00z-06z)



- Observations of MHS water vapor channels 3-5 over the Ocean have relatively large weight compared to MHS surface sensitive channels.
- Lower peaking water vapor channels are still sensitive to surface near the polar region.

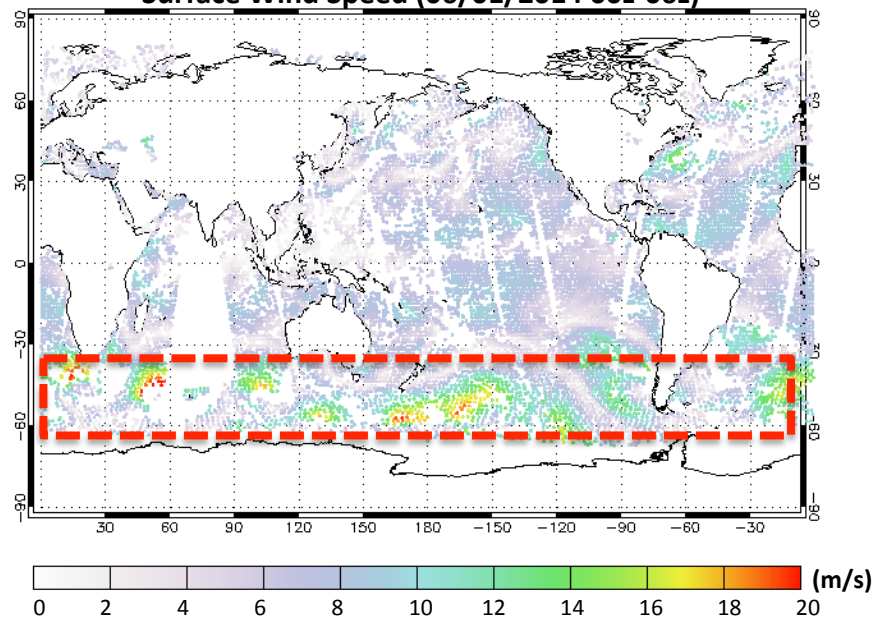
MHS Only Experiment

Monthly Mean 925hPa T Analysis Increments (June 2014)



GEOS-5 Background

Surface Wind Speed (06/01/2014 00z-06z)



Cold SST & Ocean foam caused by strong wind in background fields

↓

Increase CRTM calculated background surface emissivity in MHS channels.

↓

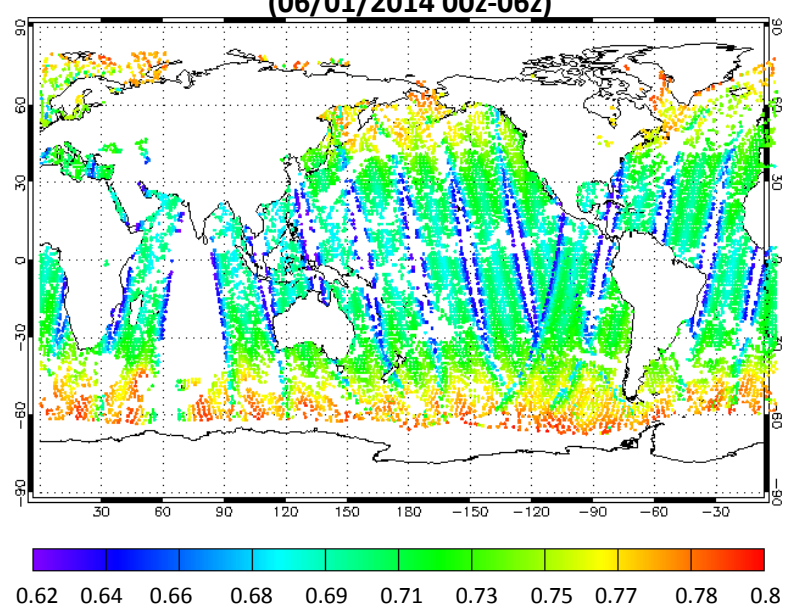
high background TB

↓

TB_{obs}-TB_{bkg}< 0

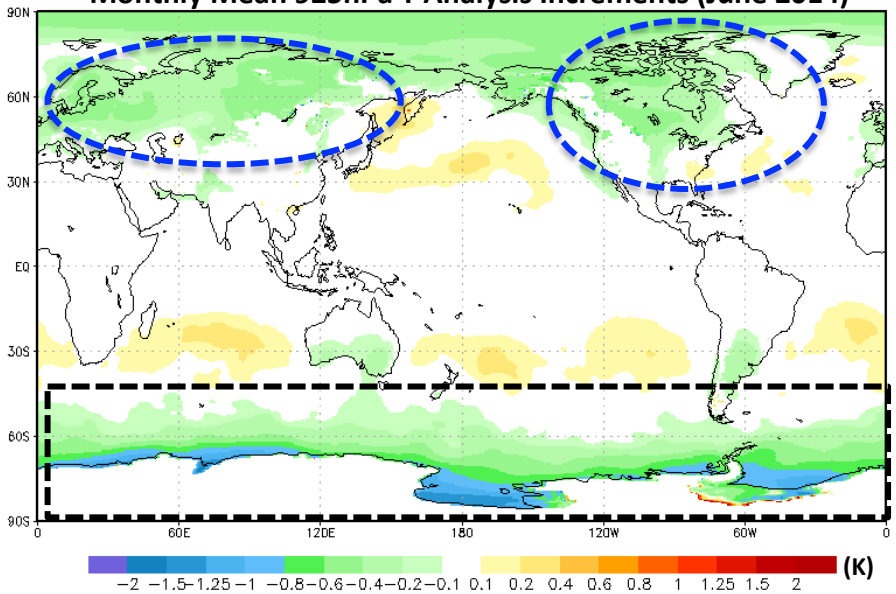
CRTM Computed Surface Emissivity for MHS CH5

(06/01/2014 00z-06z)



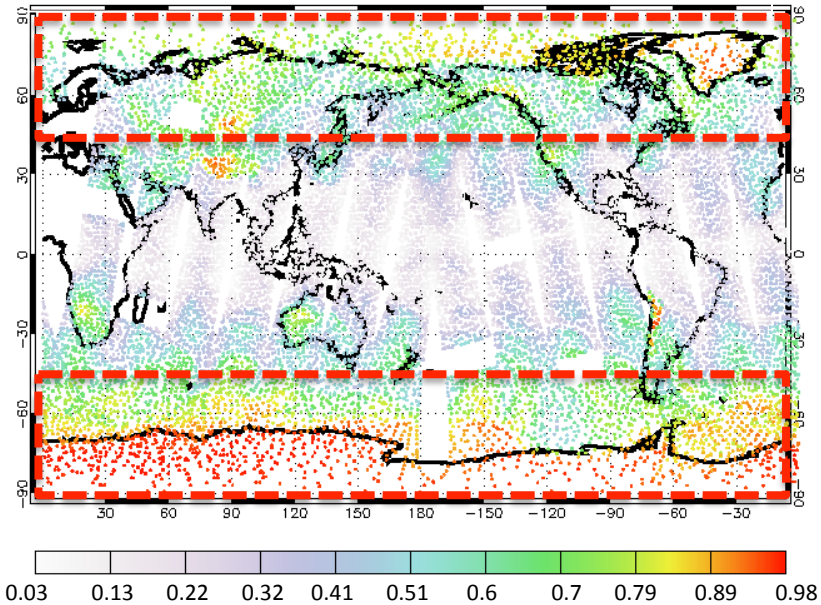
IASI Only Experiment

Monthly Mean 925hPa T Analysis Increments (June 2014)



METOP-A IASI 10.8μm

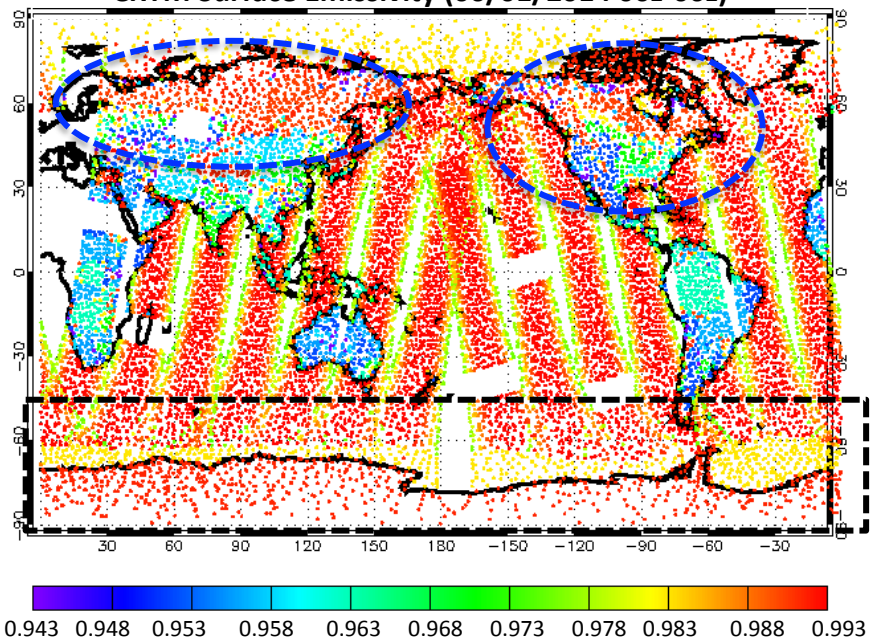
CRTM d(Tb)/d(Ts) (06/01/2014 00z-06z)



- **Larger sensitivity Tb to sfc near polar regions**
- **Negative T increments near 60S are caused by sea ice and its boundaries with water and snow.**
- **Regions with negative T increments over snow covered land are consistent with regions where surface emissivity is high.**

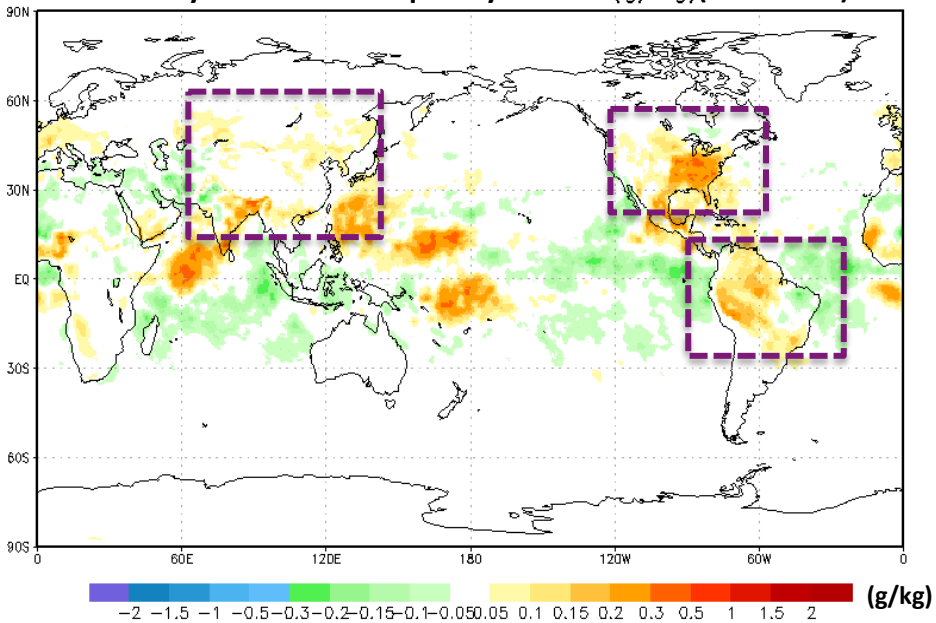
METOP-A IASI 10.8μm

CRTM Surface Emissivity (06/01/2014 00z-06z)



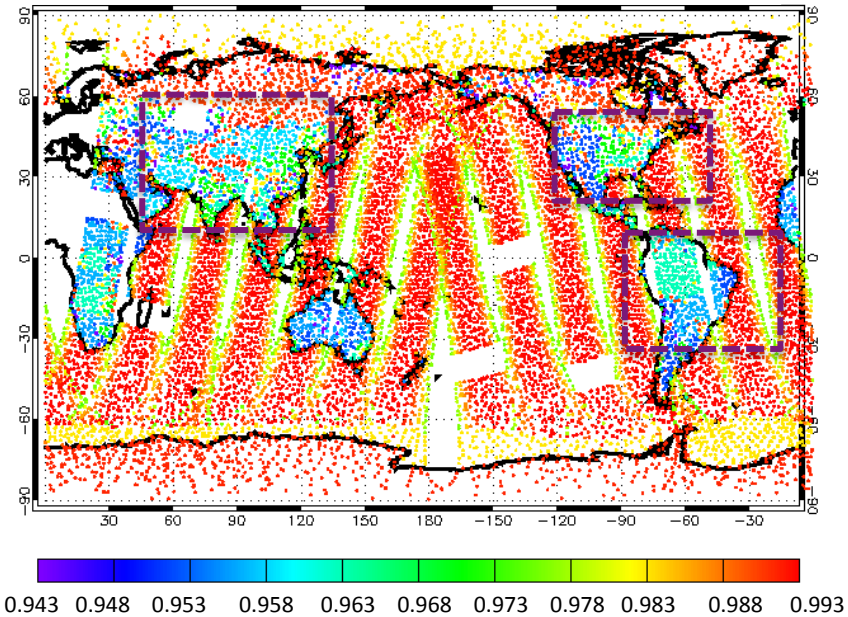
IASI Only Experiment

Monthly Mean 700hPa q Analysis Increments (June 2014)



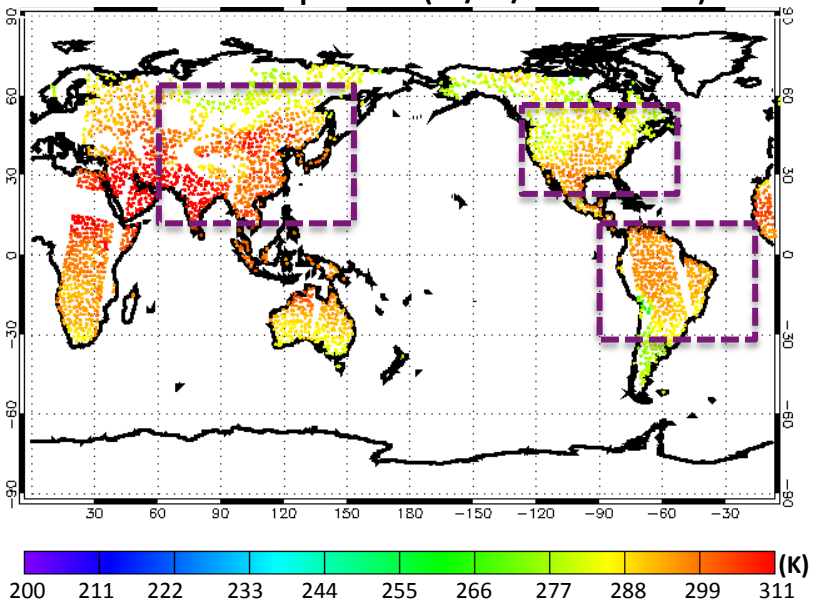
METOP-A IASI 10.8μm

CRTM Surface Emissivity (06/01/2014 00z-06z)



GEOS-5 Background

Land Skin Temperature (06/01/2014 00z-06z)



- **Regions with positive humidity increments over America and Eastern Asia are consistent with regions with relatively high land surface emissivity and high land skin temperature**

Modified Data Quality Controls (QC)

- ***Over land***: Make all analysis increments more similar to increments from conventional-only experiments.

- ***Over ocean***: Make analysis increments from all other sensors more consistent in terms of cold, warm, wet, or dry.. and preferably in the direction reducing the known biases.

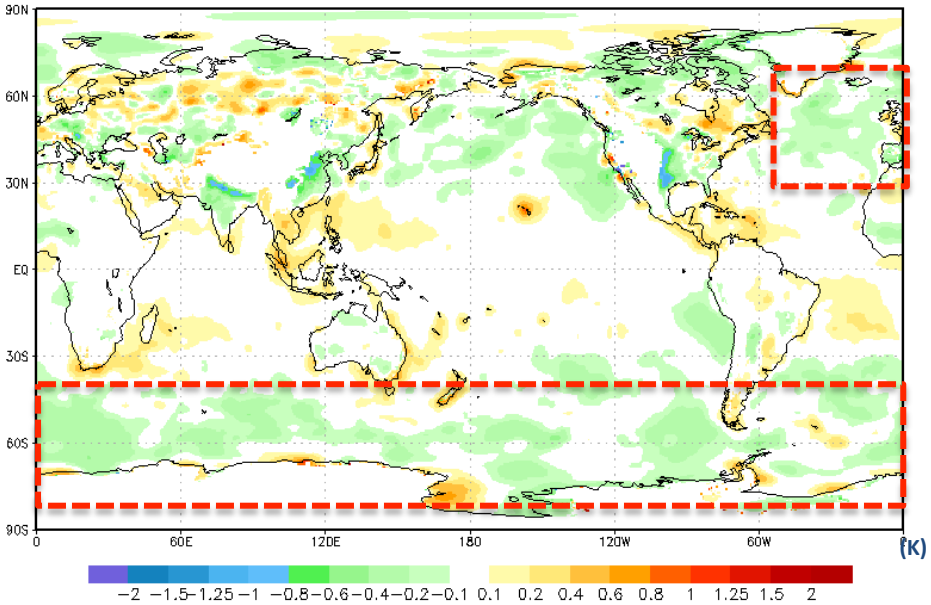
	Changes made in Quality Controls	
MHS	Do not use surface sensitive channels over land, snow, and ice surface types. ∵ Large uncertainty in surface emissivity over non-oceanic region	Do not use surface-sensitive MHS channels over the ocean if SST is low and wind speed is high. ∵ Low SST and ocean foam caused by high wind speed tend to increase microwave surface emissivity and generate cold temperature increments.
AIRS		
IASI		
HIRS		
AMSU-A	Most important satellite data and will be challenged next.	

Cycled Experiments with QC Changes

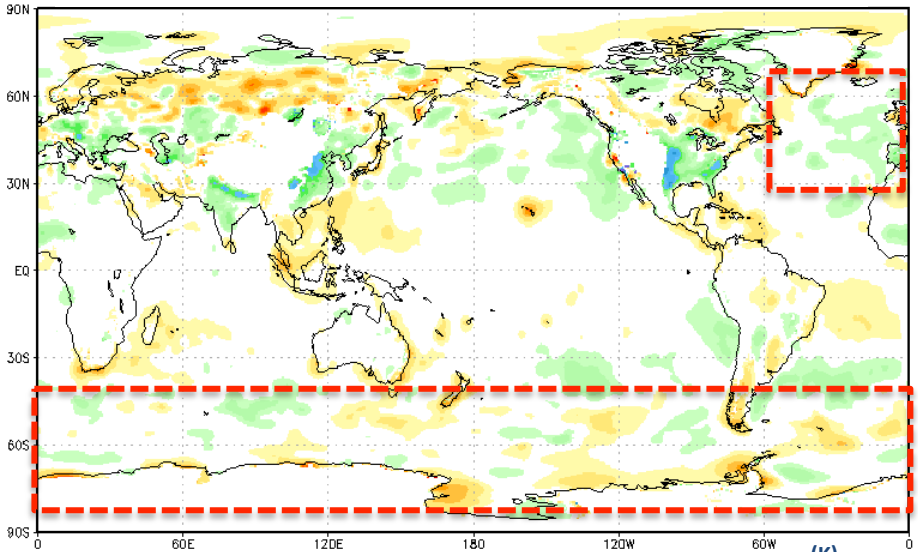
Cycled Experiments = Control run + QC changes

Monthly Mean 925hPa T Analysis Increments

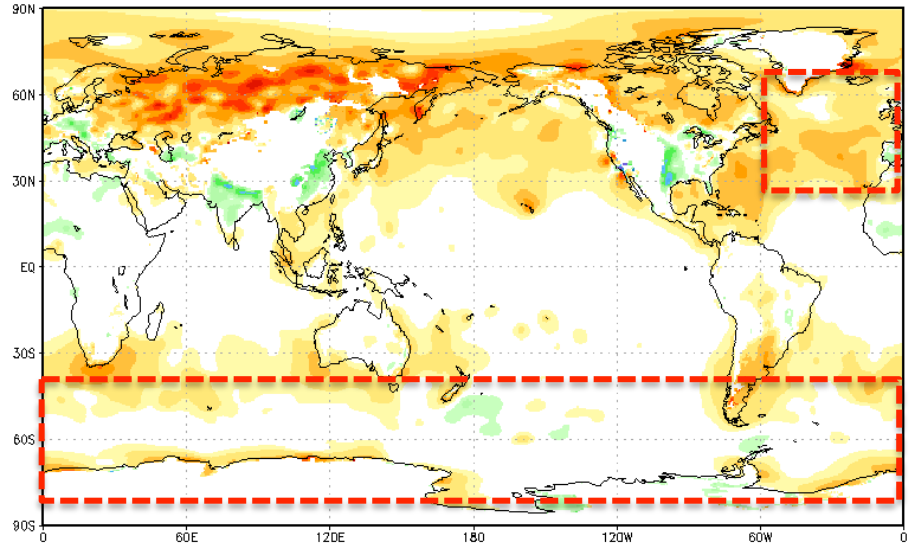
All observations (Control)



All observations (NEW QC)



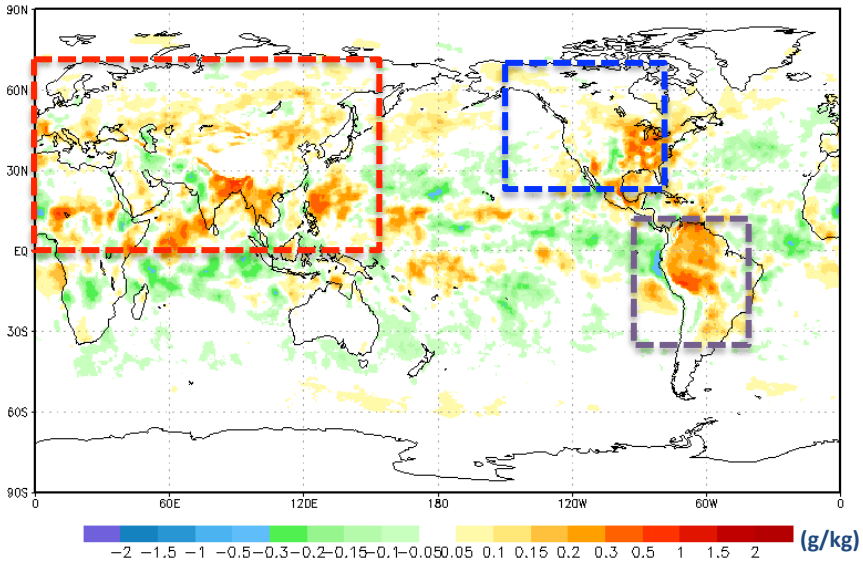
Conventional data



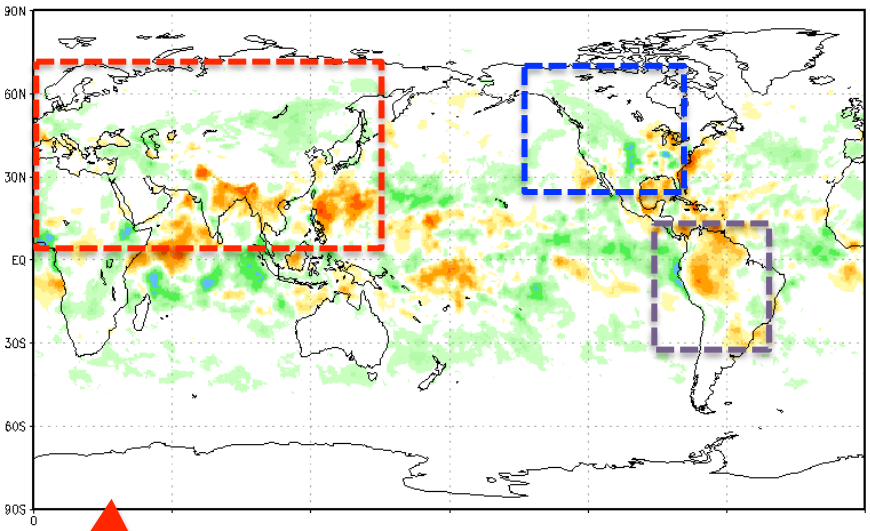
QC changes reduced negative temperature increments from satellite observations over cold ocean surfaces.

Month Mean 700hPa q Analysis Increment

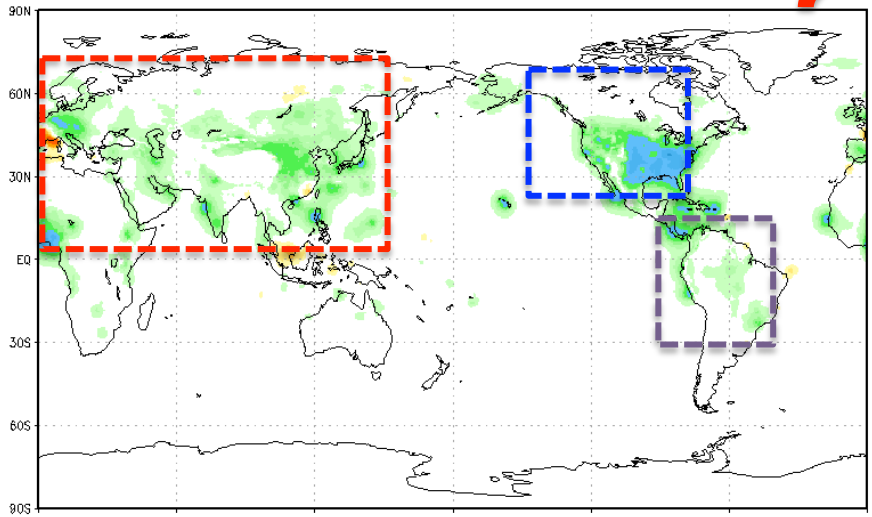
All observations (Control)



All observations (NEW QC)



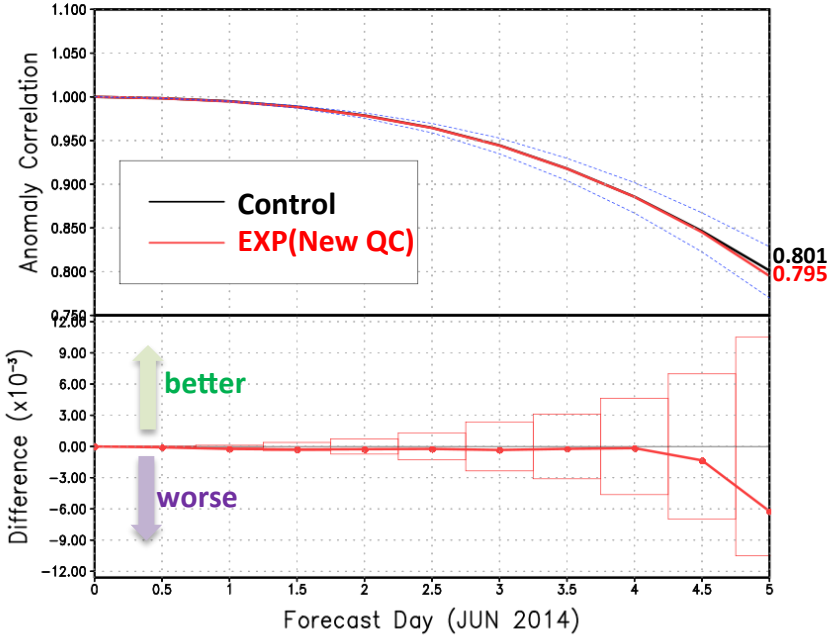
Conventional data



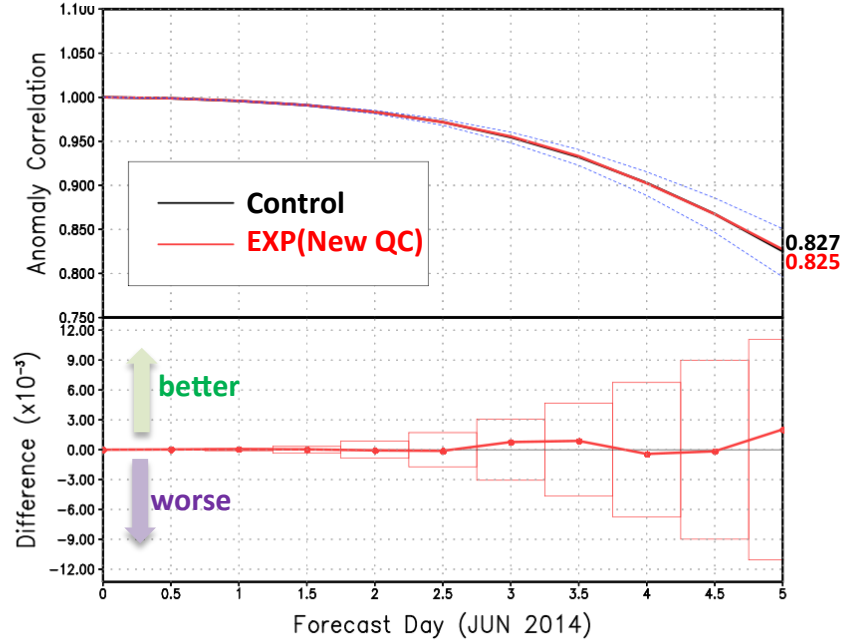
- **Previous large positive humidity increments from AIRS and IASI over land were reduced.**
- **Contributions from conventional data are better able to reduce the wet bias over land.**

Forecast Skill: Anomaly Correlation 500 hPa Height

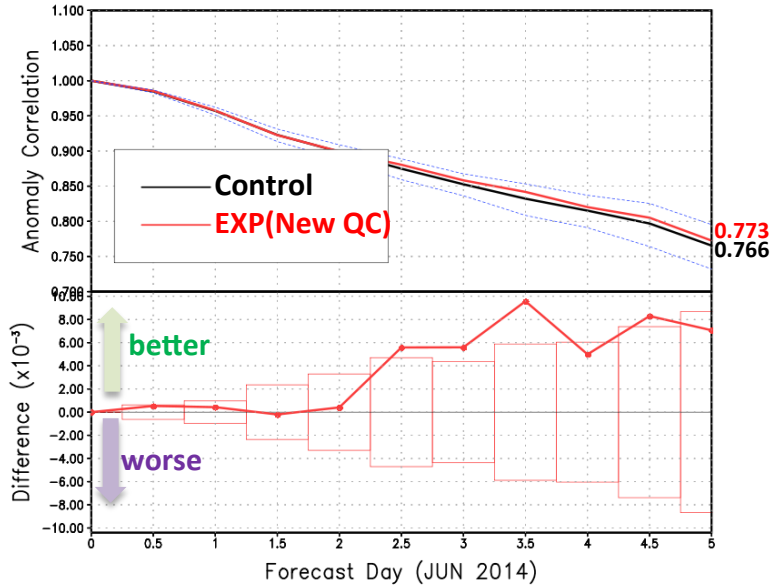
Northern Hemisphere



Southern Hemisphere



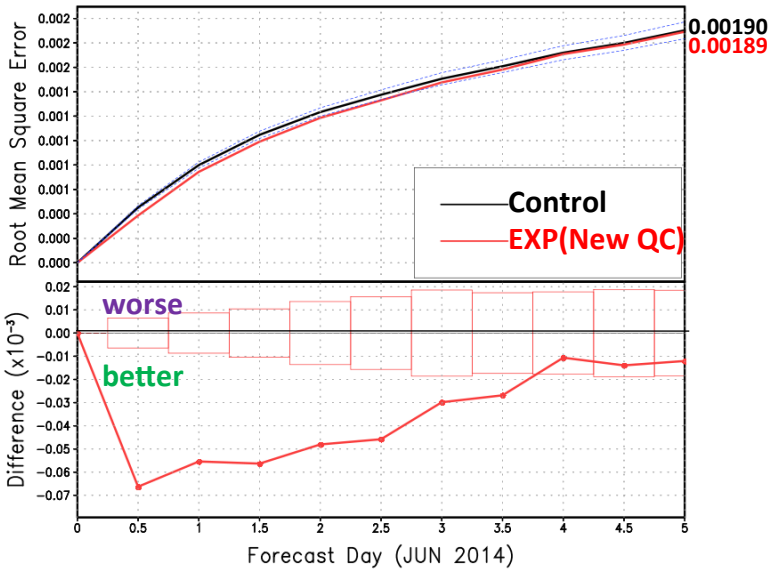
Tropics



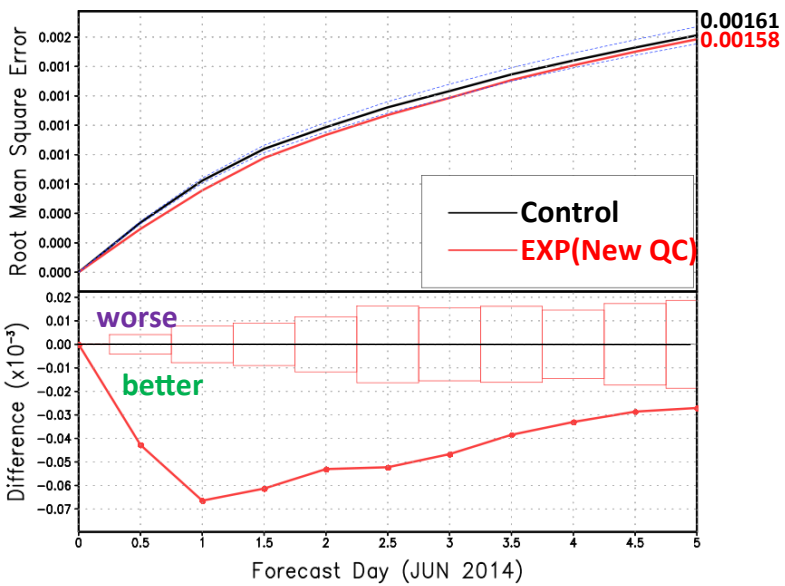
Neutral impact

Forecast Skill: RMSE 850 hPa Humidity

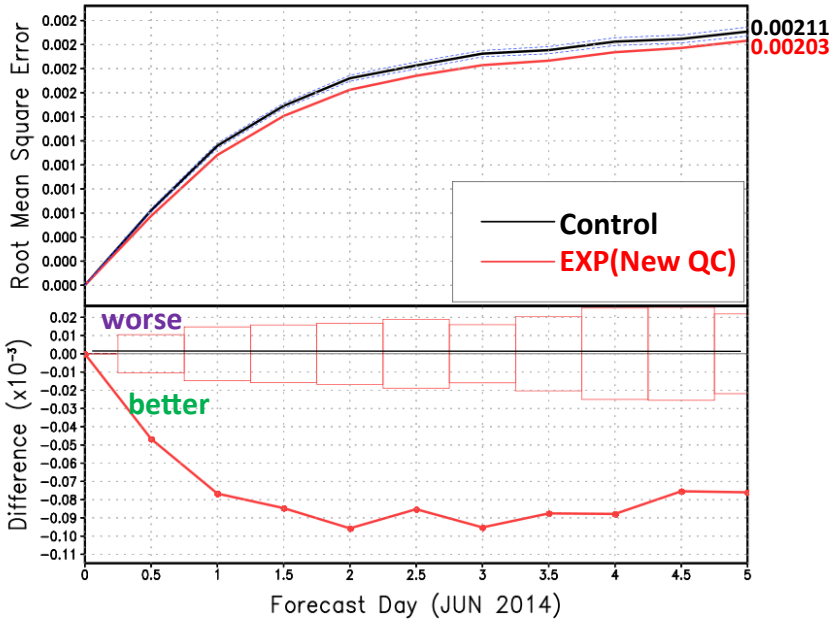
Northern Hemisphere



Southern Hemisphere



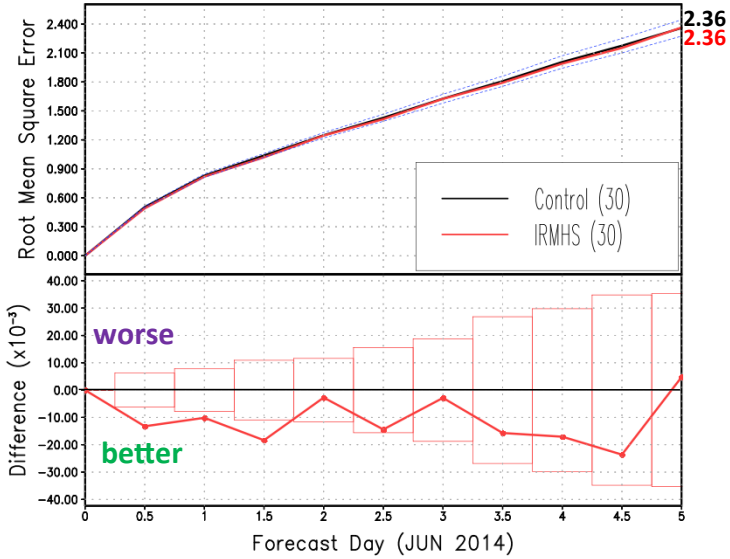
Tropics



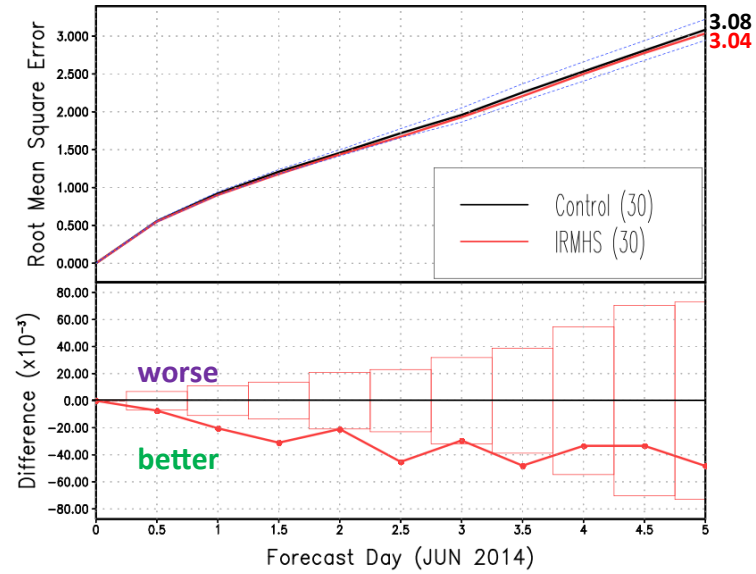
Positive impact

Forecast Skill : RMSE 850 hPa Temperature

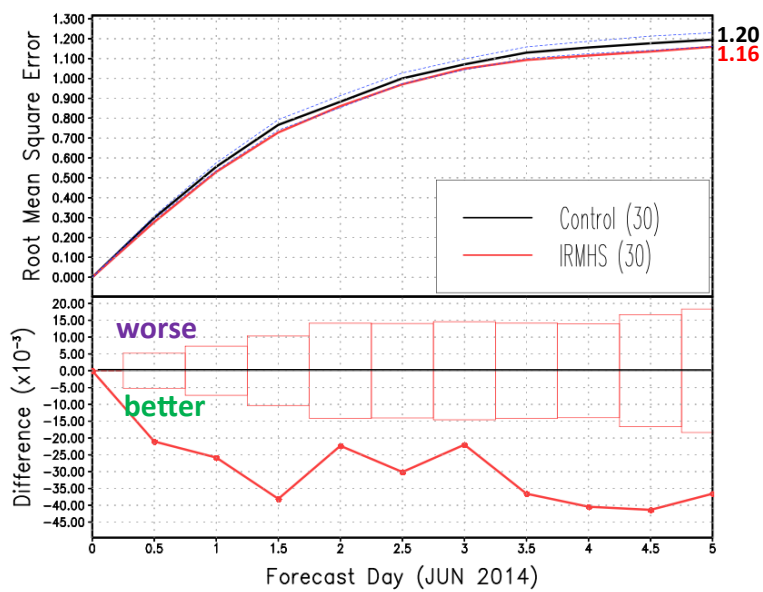
Northern Hemisphere



Southern Hemisphere



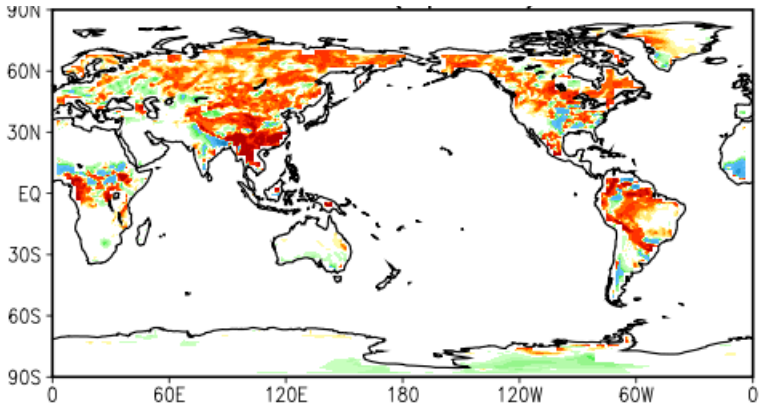
Tropics



Positive impact

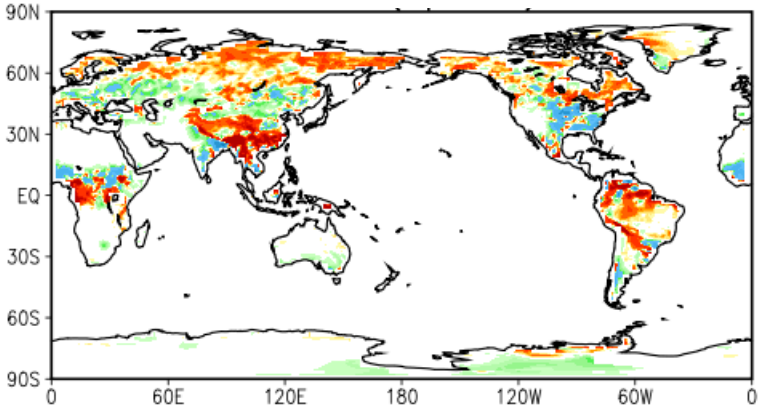
Comparisons with GPCP Preciptation over Land

Control -GPCP

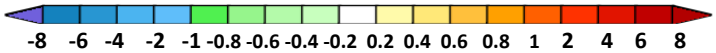


Mean: 0.88
STD: 2.82

EXP -GPCP



Mean: 0.53
STD: 2.78



Future Work

- Improve QC choices for AMSU-A and ATMS data
- Test more QC changes over regions near lakes, mountains, and complex coast lines.
- Revisit codes to define surface types and surface related parameters for CRTM over non-water region in GEOS-5 ADAS
- Compare analysis increments for other variables and for different vertical levels to diagnose inconsistencies between different observation types.