



# Assessing the Accuracy of Cloudy Sky Infrared and Microwave Brightness Temperatures in the GFS

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## Purpose

Document the biases of computed brightness temperatures (Tb) for cloudy scenes using the Community Radiative Transfer Model (CRTM) within the Global Forecast System (GFS) for the observations and the GFS background state. Determining criteria for matching cloudy sky conditions of the GFS background state with the observations has begun which will allow analysis to categorize bias for various cloud conditions. For microwave observations, a cloud liquid water retrieval can provide an estimate of cloud conditions (Weng et al 1997). For infrared instruments, the Minimum Residual Method of Eyre and Menzel (1998) is used to estimate cloud fraction and cloud top pressure. Currently, the GFS includes one cloud species. For this research, the cloud water was partitioned to ice and liquid amounts based on temperature to specify all liquid at 0C, all ice at -20C and a linear ramp between those two temperatures. Results are shown below for 0Z & 6Z 4 April 2014 analysis cycles for the Cross-Track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) onboard Suomi-NPP. Data has been collected from the T670 NCEP GFS for April-May, 2014 using CRTM version 2.2.1. This work is supported by the Joint Center for Satellite Data Assimilation.

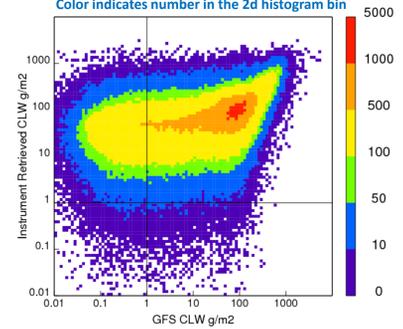
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## Criteria for Matching Cloudy Sky Conditions

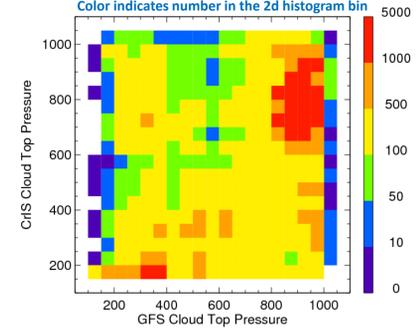
Comparing the GSI estimate of cloud liquid water (CLW) for ATMS to the GFS background CLW (below) for the month of April 2014 indicates some agreement for GFS values larger than 40 g/m<sup>2</sup>. Cloudy sky observations are defined as CLW values between 40 and 400 g/m<sup>2</sup>. ATMS Channel 1-3 Tb observation-GFS background statistics (OMB) for ice-free, ocean points are shown in the table for all sky, clear sky CLW < 5 g/m<sup>2</sup>, and cloudy sky conditions (below left). Statistics for the Tb OMB are shown before the GSI variational bias correction. CrIS cloud top pressure (CTP) is compared to the GFS background CTP for observations with a cloud fraction > 80% and a background cloud amount > 1 g/m<sup>2</sup> (below right). The two maximums in density plot show agreement about the low and high clouds but also reveal a tendency for the estimate of CrIS CTP to be lower values or higher altitudes than the background state.

Tb Departure Statistics	Mean [K]	RMSE [K]	Count
<b>ATMS April 2014</b>			
1 (23.8GHz) All Sky	1.16	5	6.48E6
ATMS Clear & GFS Clear	0.17	2.05	64,308
ATMS Cloudy & GFS Cloudy	-0.14	3.97	144,728
<b>2 (31.4 GHz) All Sky</b>			
ATMS Clear & GFS Clear	-0.63	1.50	64,308
ATMS Cloudy & GFS Cloudy	-0.77	5.35	144,728
<b>3 (50.3 GHz) All Sky</b>			
ATMS Clear & GFS Clear	0.21	1.18	64,308
ATMS Cloudy & GFS Cloudy	-1.70	4.00	144,728

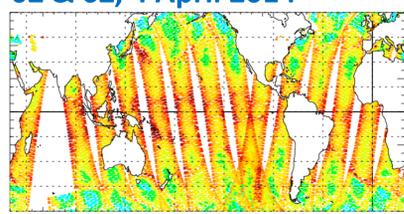
GFS vs ATMS Cloud Liquid Water, April 2014.



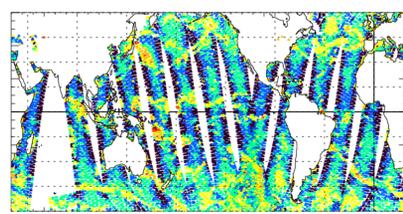
GFS vs CrIS Cloud Top Pressure, April 2014.



## ATMS 50.3 GHz 0Z & 6Z, 4 April 2014

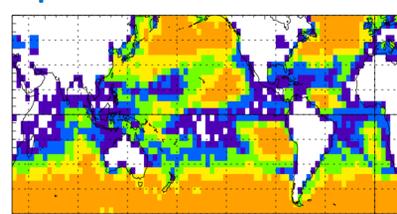


ATMS Brightness Temperature (K)

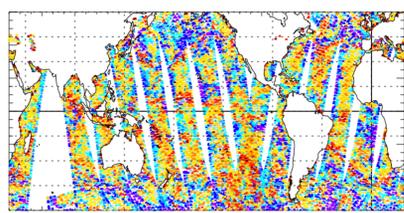


ATMS retrieved Cloud Liquid Water (g/m<sup>2</sup>)

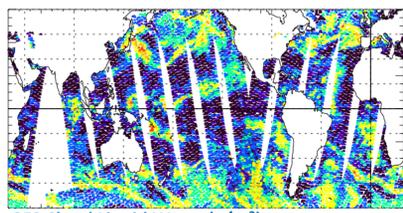
## April 2014



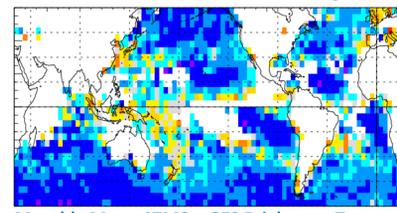
Number of data in the 4° lat/lon bin meeting the cloud matching criteria:  
ATMS & GFS CLW between 40 and 400 g/m<sup>2</sup>



ATMS - GFS Brightness Temperature (K)



GFS Cloud Liquid Water (g/m<sup>2</sup>)

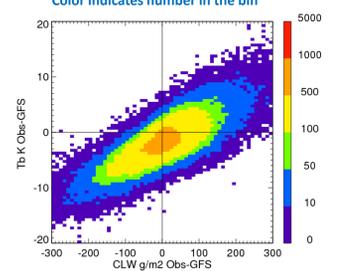


Monthly Mean ATMS - GFS Brightness Temperature for cloud matched data (K)

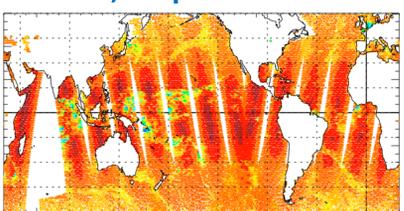
## Tb Departure as a function of Cloud Conditions

Analysis has begun for the data which satisfies the cloud matching criteria for the background and the observation. Planned work includes examining the brightness temperature departure statistics as a function of cloud regimes and cloud conditions such as cloud liquid water departure for ATMS (below).

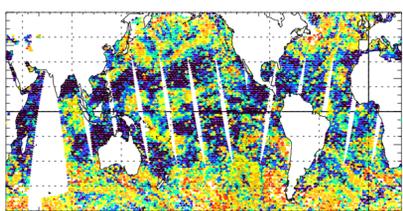
Ch 3 Tb ATMS - GFS as a function of CLW ATMS-GFS Departure for April 2014.



## CrIS 13.96 μm 0Z & 6Z, 4 April 2014

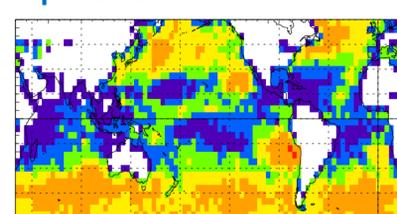


CrIS Brightness Temperature (K)

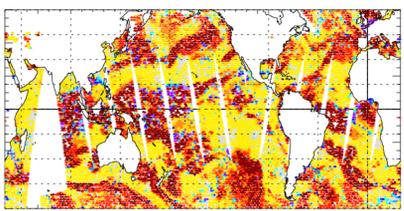


CrIS estimate of Cloud Fraction (%)

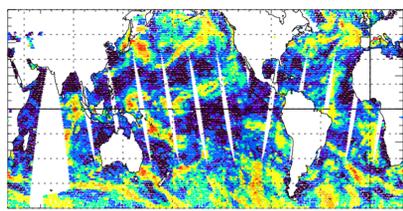
## April 2014



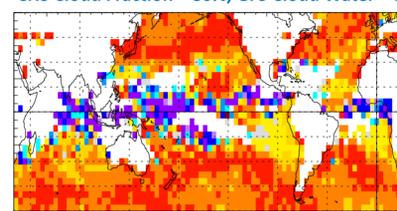
Number of data in the 4° lat/lon bin meeting the cloud matching criteria:  
CrIS Cloud Fraction > 80%, GFS Cloud Water > 1 g/m<sup>2</sup>



All Sky CrIS - GFS Brightness Temperature (K)



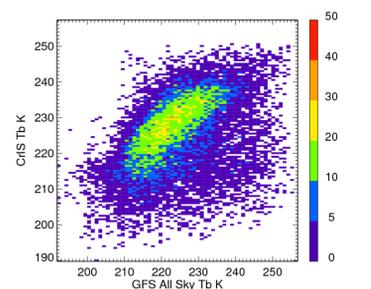
GFS Cloud Total Water (Liquid and Ice g/m<sup>2</sup>)



Monthly Mean CrIS - GFS Brightness Temperature for cloud matched data (K)

For IR observations, cloud top pressure and cloud water amounts will be examined to categorize CRTM bias for various cloud conditions. 13.96 μm Tb for the background GFS vs. CrIS are shown below for cloud matched data with cloud top pressures higher than 500 hPa.

13.96μm Tb GFS vs. CrIS for clouds above 500 hPa for April 2014.

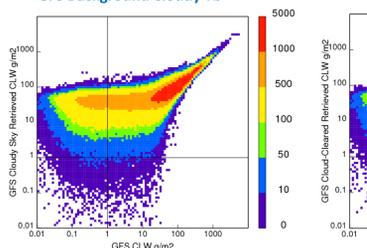


## AMSU-A Cloud Liquid Water Retrieval

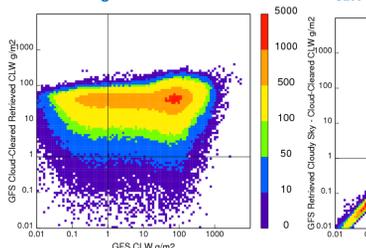
### With GFS Background Brightness Temperatures

Using the GFS background temperatures, water vapor, and cloud amount as inputs to the CRTM Forward Model, the brightness temperature (Tb) has been computed for the GFS cloudy sky first guess fields. Applying the AMSU-A CLW retrieval to the GFS Tb allows the calculation of a retrieved CLW for the GFS background. Plotting the retrieved CLW vs. the input CLW highlights the difficulty for the retrieval to predict the smallest CLW amounts (near right). By setting the cloud amount to zero in the Forward Model to calculate a "cloud-cleared" Tb, the retrieval can still generate small amounts of CLW (middle right). Subtracting the two retrieved amounts, (cloudy sky) - (cloud-cleared) removes the spread in the data (far right) but results in a smaller value than the input CLW.

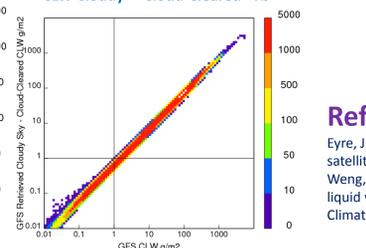
Input CLW vs. Retrieved CLW GFS Background Cloudy Tb



Input CLW vs. Retrieved CLW GFS Background Cloud-Cleared Tb



Input CLW vs. Difference of Retrieved CLW Cloudy - "Cloud-Cleared" Tb



## References:

Eyre, J. R., and Menzel, P. 1989: Retrieval of cloud parameters from satellite sounder data: A simulation study. *J. Appl. Meteor.*, 28, 267-275.  
Weng, F., N.C. Grody, R.R. Ferraro, A. Basist and D. Forsyth, 1997: Cloud liquid water climatology from the special sensor microwave imager. *J. Climate*, 10, 1086-1096.