Assimilating GPM GMI Data in the NCEP GDAS: Progress and Plans

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1. Introduction

The National Oceanic and Atmospheric Administration (NOAA) Center for Satellite Applications and Research (STAR), in support of the Joint Center for Satellite Data Assimilation (JCSDA), and in conjunction with the National Aeronautic and Space Administration (NASA) Global Modeling and Assimilation Office (GMAO), has extended the Gridpoint Statistical Interpolation (GSI) data assimilation system used in the National Centers for Environmental Prediction (NCEP) Global Data Assimilation System (GDAS) to assimilate GMI clear-sky ocean-only L1C-R brightness temperature (TB) data into the Global Forecast System (GFS).

Extending the GDAS to assimilate GMI brightness temperatures has been a multi-step process: the GMI data were converted to BUFR format and assessed for errors and biases, quality control (QC) procedures tailored to GMI were developed and implemented, and the impacts on the resulting GDAS analyses and GFS forecasts are being assessed. The use of the Community Observation Assessment Tool (COAT) and the Multi-Instrument Inversion and Data Assimilation Preprocessing System (MIIDAPS) has been integral to assessment and QC procedures, and will allow for the optimization of the assimilation of GMI observations. These tools could ultimately assist in efforts to assimilate radiance observations over non-ocean surface types, and in cloudy conditions.

2. GMI Data Used

GMI data have been converted from the original hdf5 format into the BUFR file format, which is required in order for the data to be ingested into the GSI. The JCSDA has the ability to convert L1B and L1C GMI products from hdf5 to BUFR. To take advantage of co-registered data, L1C-R GMI products have been BUFRized as well.

Co-registered data allows us to use the most information over a given terrestrial footprint, and is preferred. Additionally, using co-registered data has allowed us to put all GMI channels into a single BUFR file, instead of having to creating separate BUFR files for the GMI channels 1-9 (first swath) and channels 10-13 (second swath). For these reasons, GMI L1C-R brightness temperatures have been used in the assessments and experiments presented here. For simplicity, differences in the incidence angles of the first and second swaths (52.821 and 49.495 degrees, respectively) were ignored. The angle difference can be considered a systematic bias, and removed during bias correction.

STAR, in support of the JCSDA, has been in coordination with the Office of Satellite Products and Operations (OSPO) to have GMI L1C-R BUFR data produced in near-real-time be available to NCEP for use in operational data assimilation and forecasting. It is anticipated that these data will be included in the data stream and available to the operational community some time in the latter half of 2015.

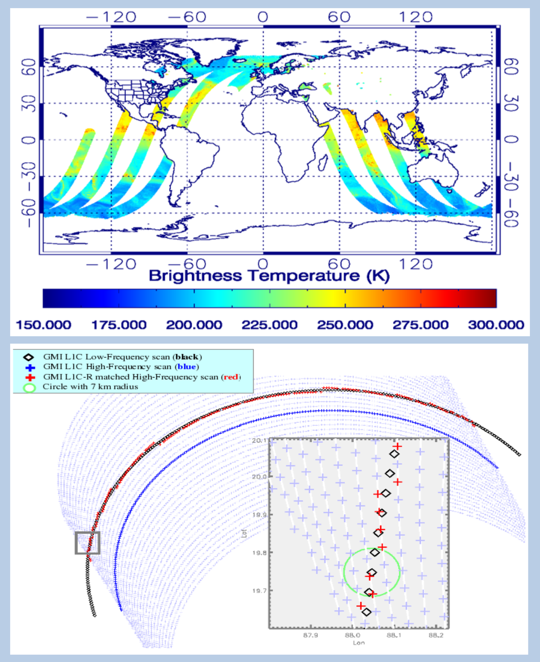


Figure 1. Sample 6-hour block of GMI coverage (channel 5 shown, top), and schematic of L1C-R GMI data (bottom, image from GMI L1C_ATBD document[1]).

3. GMI Data Assessment and Quality Control

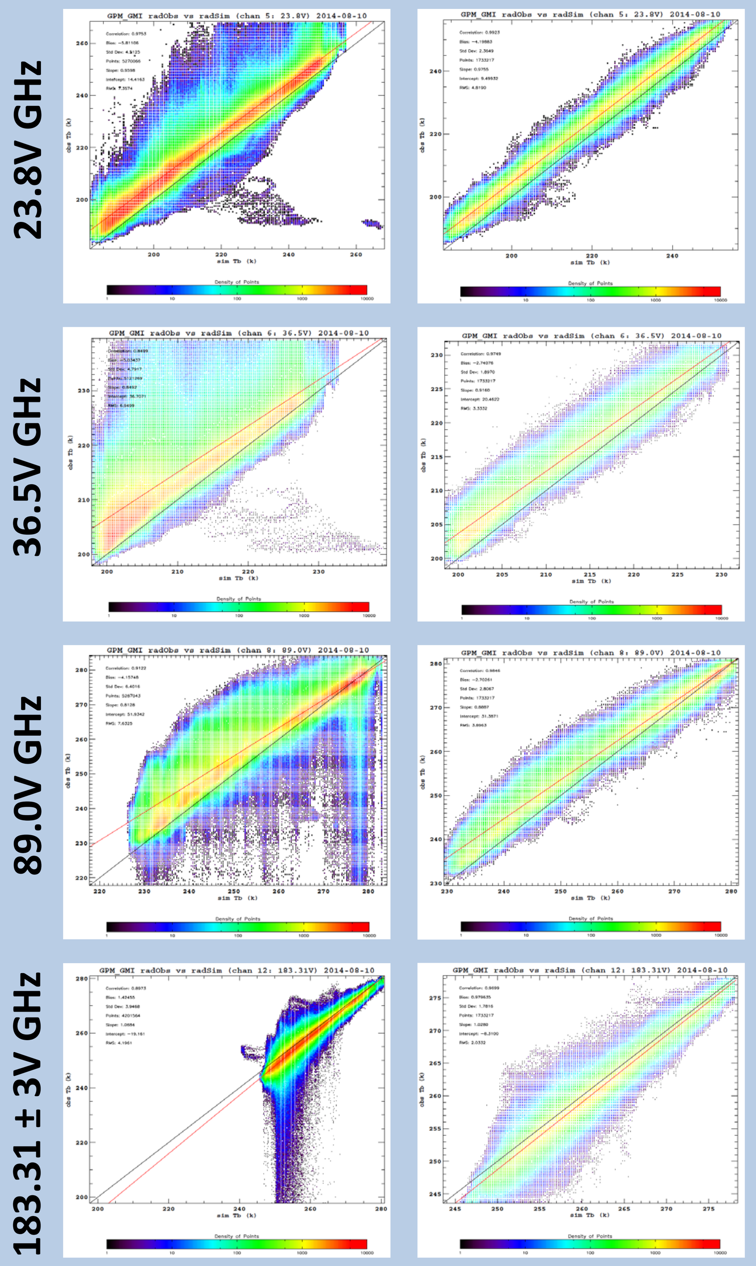


Figure 2. Scatterplots of observed versus simulated TBs for GMI channels 5, 6, 8, and 12 over ocean, before filtering for cloud, ice, and dEmissivity (left) and after filtering (right). TBs were simulated from ECMWF backgrounds.

The COAT is a utility independent of any data assimilation system that is used for evaluating satellite data quality. It uses the Community Radiative Transfer Model (CRTM) for its forward operators, and provides a channel-by-channel assessment of satellite-observed brightness temperatures with respect to co-located simulated brightness temperatures from NWP backgrounds (GFS or European Center for Medium-range Weather Forecasting (ECMWF)) in all sky conditions, over all surface types. Because of these capabilities, the COAT is used as a testbed to evaluate QC / filtering procedures for brightness temperature data before these procedures are implemented within an assimilation system.

At present, only the assimilation of clear-sky GMI observations over ocean is being tested. Algorithms tested in the COAT to retrieve and filter cloud liquid water (CLW) and graupel water path (GWP) were derived from multi-linear regressions that were trained on GMI brightness temperatures simulated with the CRTM from ECMWF backgrounds. Since high frequency channels were used for retrievals, only points with data for all channels are considered. For the purposes of this work, CLW or GWP thresholds were set at 0.05 kg/m^2 to remove any points where observations were likely affected by cloud or precipitation.

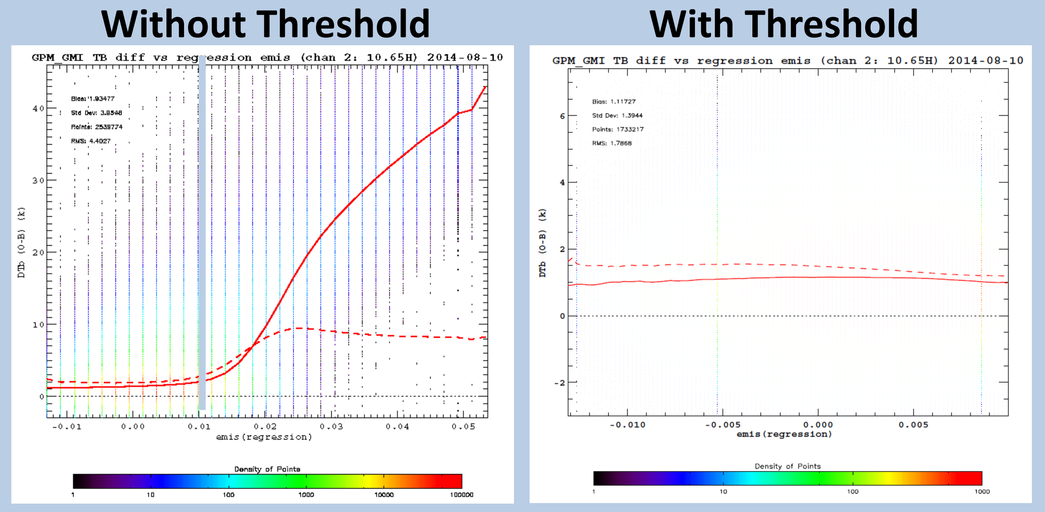


Figure 3. The difference in multi-channel and single-channel emissivity for GMI channel 2 with no threshold (left) and with a threshold of 0.01 (right).

		Unfiltered		Filtered	
Channel	Freq. (GHz)	Bias (K)	Std. Dev. (K)	Bias (K)	Std. Dev. (K)
1	10.65 V	5.27	3.29	4.00	1.11
2	10.65 H	2.90	4.38	1.12	1.39
3	18.7 V	7.80	3.91	6.01	1.57
4	18.7 H	5.59	5.81	3.23	2.65
5	23.8 V	5.81	4.51	4.20	2.36
6	36.5 V	5.03	4.79	2.74	1.90
7	36.5 H	7.44	13.67	1.24	3.61
8	89.0 V	4.16	6.40	2.70	2.81
9	89.0 H	8.41	12.41	3.56	6.04
10	165.5 V	-5.18	7.87	-3.95	1.63
11	165.5 H	-3.76	9.86	-2.89	3.05
12	183.31 ± 3 V	-1.42	3.95	-0.98	1.78
13	183.31 ± 7 H	-4.93	5.95	-4.03	1.60

Table 1. Bias and standard deviation (rounded to two decimal places) from the COAT for TBs over ocean from all GMI channels on 10 August 2014 for unfiltered and filtered cases, with an ECMWF background as reference.

To remove any observations missed by CLW and GWP checks, or contaminated by non-ocean surfaces, an additional emissivity retrieval and check was developed in the COAT. A single-channel emissivity retrieval using a skin temperature predictor was performed for channels 2 (10.65H GHz), 4 (18.7H GHz), and 7 (36.5H GHz), and subtracted from a multi-channel emissivity retrieval done for these channels to obtain the dEmissivity. The results were thresholded at 0.01, 0.035, and 0.05, respectively.

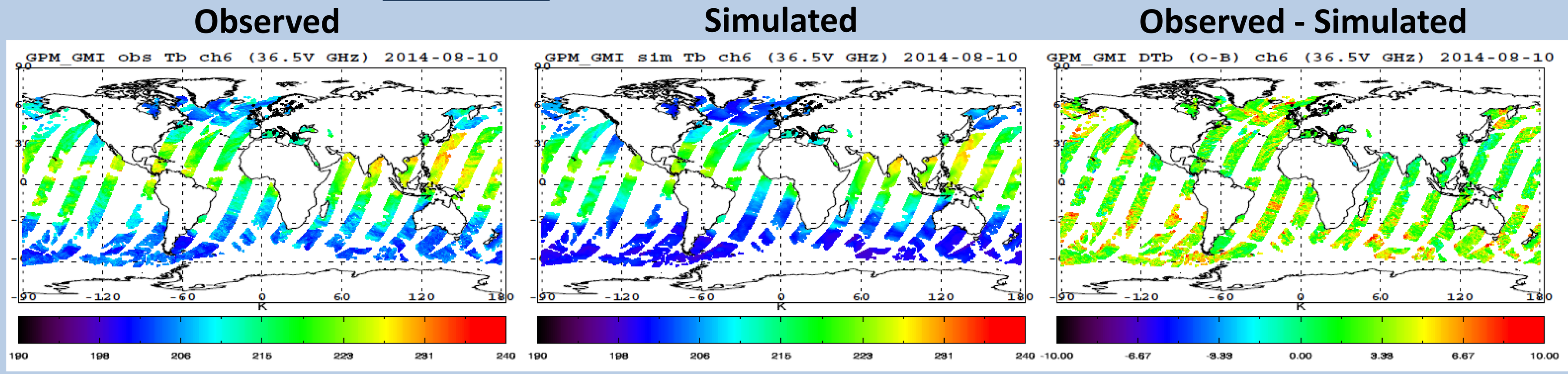


Figure 4. Maps for the ascending node of GMI channel 6 (36.5V GHz) for observed (left), simulated (center), and observed – simulated (right) TBs after filtering for CLW, GWP, and dEmissivity. Simulated TBs were derived from ECMWF NWP backgrounds.

4. Analysis and Forecast Impacts

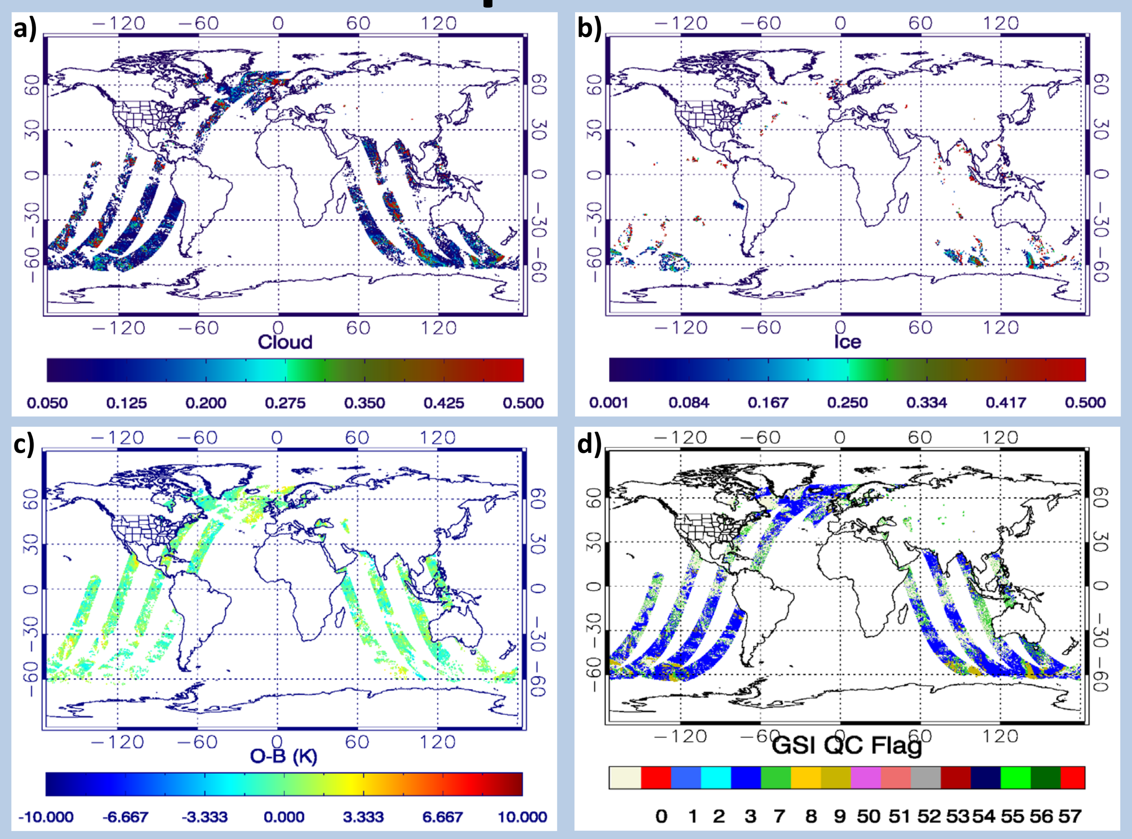
A reader to ingest GMI L1C-R BUFR data into the GSI was provided by NASA GMAO, and modified to include filters for points with non-ocean surface classifications and points with radio frequency interference (RFI) contamination. QC procedures were implemented in the GSI based on results from the COAT assessment of GMI TBs.

In results shown here, CLW and GWP were thresholded at 0.05 kg/m^2, as in the COAT. Since the CLW and GWP retrievals were trained on simulated GMI TBs, the GMI data were bias corrected with COAT biases when used for the retrievals. dEmissivity was calculated and thresholded as previously described. Like in the COAT, data were only used at points where the low and high frequency channels could be co-registered. Unlike in the COAT, a gross check of 5K was applied to all GMI TBs, and data were not used where they failed this gross check. Data have been thinned to 45km in results shown.

		No Bias Corr.		With Bias Corr.	
Channel	Freq. (GHz)	Bias (K)	Std. Dev. (K)	Bias (K)	Std. Dev. (K)
1	10.65 V	1.65	1.18	-0.09	1.08
2	10.65 H	1.57	1.24	0.10	1.21
3	18.7 V	3.42	1.35	-0.16	1.30
4	18.7 H	2.42	1.93	-0.01	1.90
5	23.8 V	1.41	1.74	-0.26	1.70
6	36.5 V	-0.14	1.36	-0.06	1.17
7	36.5 H	-1.05	2.38	0.13	2.05
8	89.0 V	0.42	1.68	-0.17	1.44
9	89.0 H	-0.07	2.73	0.00	2.39
10	165.5 V	-3.85	1.33	-0.01	1.31
11	165.5 H	-3.68	1.60	0.04	1.57
12	183.31 ± 3 V	-0.94	1.60	0.31	1.60
13	183.31 ± 7 H	-2.09	1.40	0.28	1.40

Table 2. Bias and standard deviation (rounded to two decimal places) from the GSI for TBs over ocean from all GMI channels for the 20180810 00Z cycle before and after GSI variational bias correction, with a GFS background as reference.

Figure 5. Results from the GSI for one cycle for 20140810 00Z assimilating GMI. **a)** Retrieved cloud over 0.05 kg/m^2. **b)** Retrieved GWP over 0.01 kg/m^2. **c)** Observed minus simulated (background) TBs after bias correction in the GSI for channel 6 (36.5V GHz) for good points in this cycle. **d)** QC flags used in the GSI for channel 6. Blue points are flagged for cloud (exceed CLW threshold), gold points are flagged for precipitation (exceed GWP threshold), green points are flagged for exceeding dEmissivity thresholds, and light blue points are flagged in the gross check.



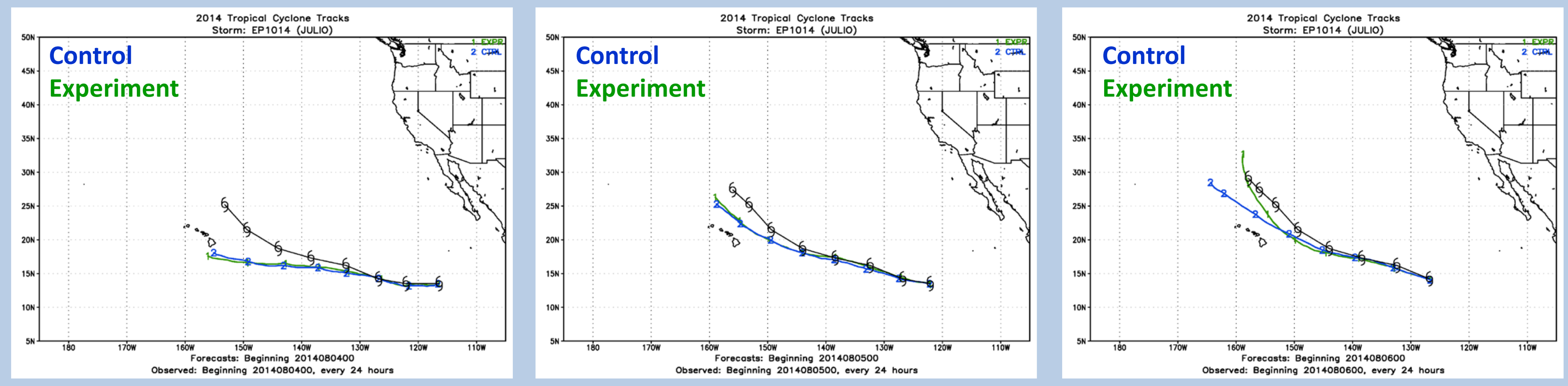


Figure 6. Evolution of 168-hour GFS Hurricane Julio tracks for a control (blue line) and experiment with GMI data assimilated (green) with the hurricane best track (black) for 20140804 00Z (left), 20140805 00Z (center), and 20140806 00Z (right).

Initial results indicate that including clear-sky GMI observations over ocean in the GDAS has impacts on model analyses and forecasts, including features like tropical cyclone tracks. The precise nature of these impacts is currently being assessed, as a larger sample of forecasts is being produced and analyzed.

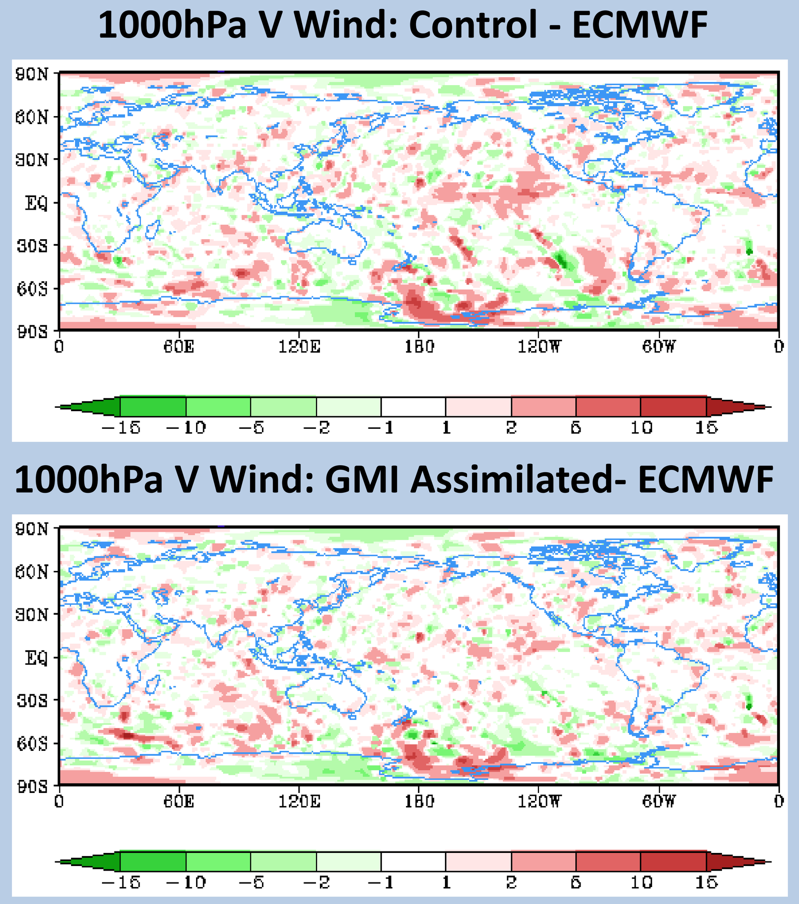


Figure 7. Differences in the 6 hour analysis forecast fields of 1000hPa V wind (m/s) for the 20140807 00Z cycles of GDAS and ECMWF. Control with no satellite data assimilated (top) and experiment with only GMI satellite data used (bottom).

5. Conclusions

An assessment of GPM GMI TBs has been performed in the COAT, and the GSI has been updated to allow for the ingest of these data into the GDAS. An assessment of the impacts of these data on GFS forecasts is ongoing.

- GMI TBs can be used to retrieve cloud and ice fields with realistic features. All channels are used together in retrievals for enhanced cloud and ice detection.
- The addition of emissivity retrievals and a dEmissivity check for GMI data improves filtering of GMI TBs for clear-sky data assimilation.
- Observed GMI TBs show some bias when compared to GMI TBs simulated by the CRTM, but this bias can be accounted for in a data assimilation system. Bias correcting observed GMI TBs with biases found in the COAT prior to the retrieval of cloud and ice within the GDAS allows for more aggressive filtering than when TBs are not bias corrected prior to retrieval (not shown).
- The clear-sky assimilation of GMI TBs over ocean has an impact on model analyses and forecasts. The assimilation of these data influences tropical cyclone tracks and departures from ECMWF forecasts and analyses.

6. Future Work

- Fully assess the impacts that assimilating GMI data has on GFS and HWRF forecasts and analyses.
- Process GMI data in MIIDAPS prior to assimilation.
- Optimize thinning of GMI data in the GSI.
- Optimize GMI representation in the GSI and use of GMI data by continuing to fine-tune error estimates and tailoring QC routines to GMI based on results from the COAT and MIIDAPS.
- Fully extend MIIDAPS pre-processor to the GMI and make modifications to the CRTM to account for the differences in incidence angle between the first and second GMI swaths; eventually use MIIDAPS for dynamically generated emissivities.

[1] GMI L1C_ATBD document is available from NASA PPS at http://pps.gsfc.nasa.gov/Documents/L1C_ATBD.pdf

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