

Assimilating New Passive Microwave Data in the NOAA GDAS

Erin Jones¹, Kevin Garrett¹, Eric
Maddy¹, Krishna Kumar¹, Sid
Boukabara²

Outline

- New passive microwave data assimilation objectives
- GMI data assimilation:
 - Pre-assimilation quality control and assessment
 - Post-assimilation assessment and analysis impacts
 - Forecast impact assessment
- AMSR2 data assimilation:
 - Pre-assimilation quality control and assessment
- Conclusions and future work

Objective

There is currently no capability to assimilate GMI or AMSR2 brightness temperature data in NOAA's Global Data Assimilation System/Global Forecast System (GDAS/GFS)

Goal:

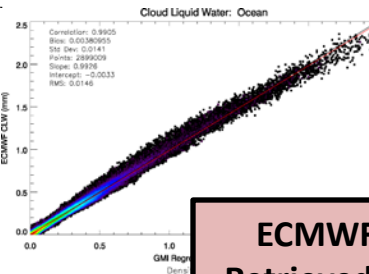
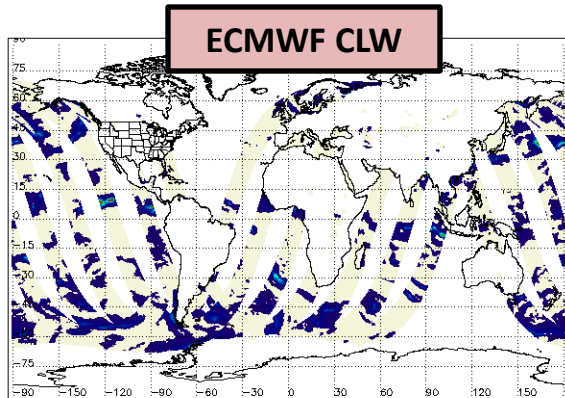
- Extend NOAA's systems to GMI L1C-R and AMSR2 L1B data
- Ingest all channels to be used at once (hence the use of GMI L1C-R data)
- Preliminary focus on clear sky, ocean only

Requirements:

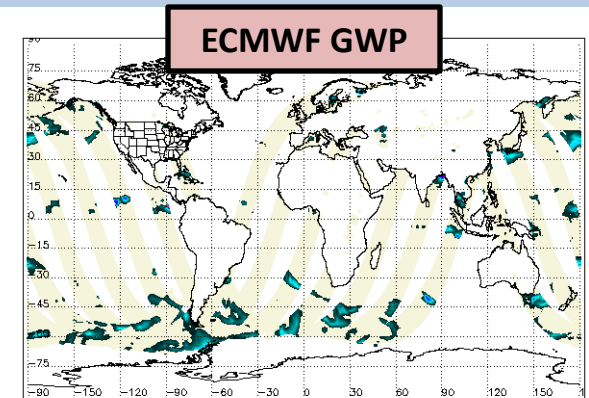
- Data ingest and thinning
- Quality control procedures
- Tuning of biases and obs errors

GMI Radiance Quality Control

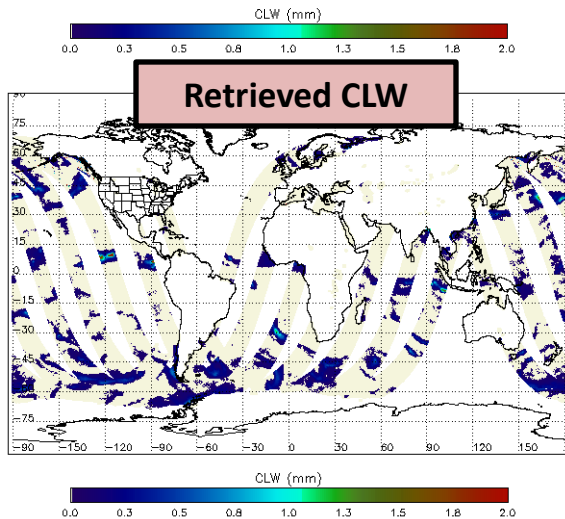
For clear-sky radiance assimilation, algorithms were developed to retrieve cloud and ice (graupel) and filter out cloud/precipitation.



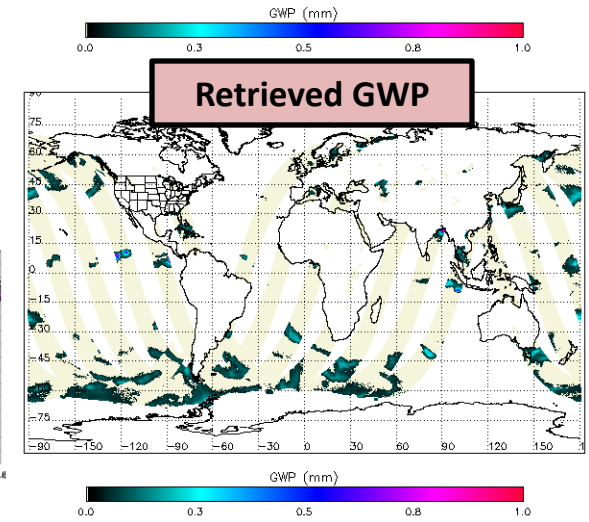
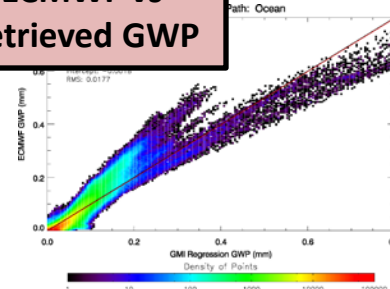
Integrated Graupel Water Path (GWP) algorithm developed to detect/retrieve ice cloud from GMI



Multi-linear regression trained using ECMWF analyses and simulated GMI brightness temperatures from CRTM (channels 1-7, 12, and 13 used).



ECMWF vs Retrieved GWP



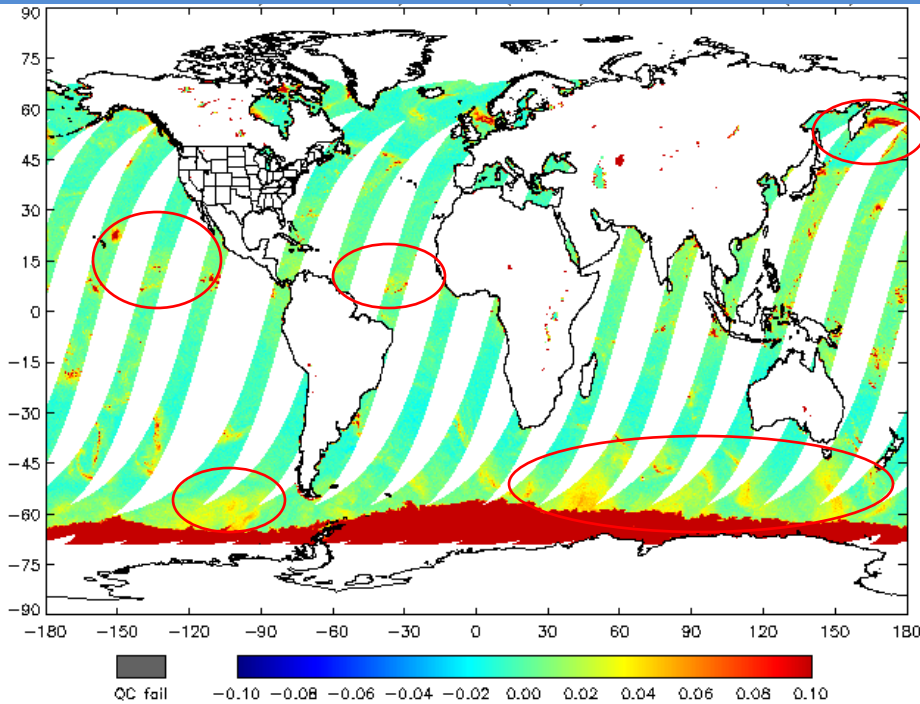
Integrated Cloud Liquid Water (CLW) algorithm developed to detect/retrieve liquid cloud from GMI

GMI Radiance Quality Control

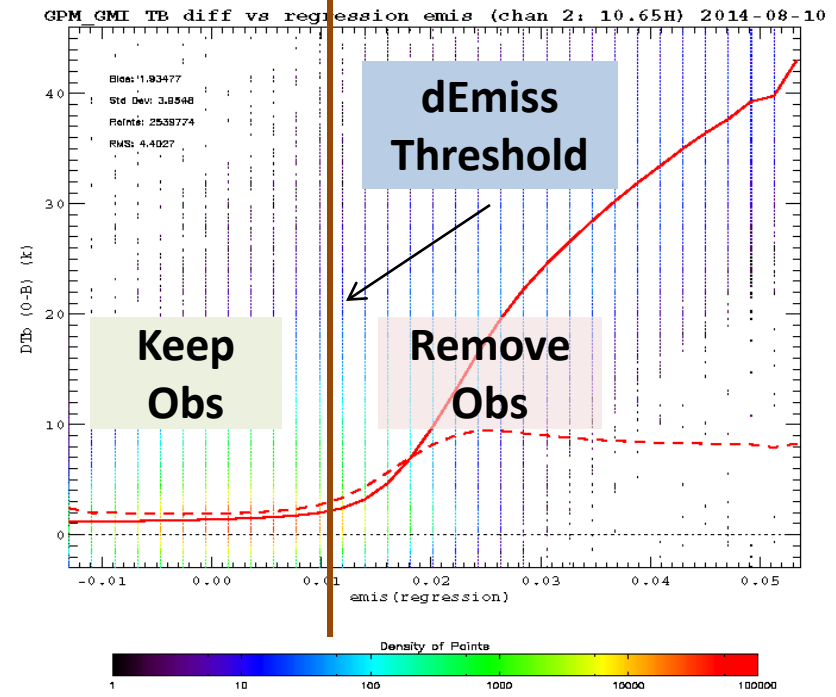
Additional algorithms were developed to retrieve emissivity, and filter out observations still contaminated by cloud or coast.

- Multi-channel emissivity retrievals (all channels used) and single channel emissivity retrievals using a T-skin predictor for channels 2, 4, and 7 (10.65GHz H, 18.7GHz H, and 36.5GHz H)

10.65GHz H Surface Emissivity Difference



10.65GHz H O-A vs Emissivity Difference

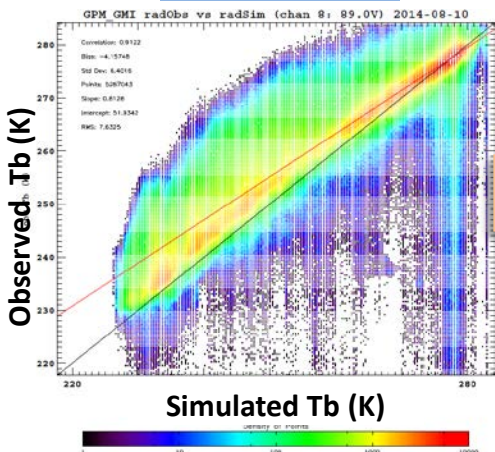


Large values of emissivity differences (dEmiss) correlate with large differences between observed and simulated brightness temperatures. Thresholds of dEmiss can be used to filter out points not modeled well in forward simulation.

GMI Radiance Quality Assessment

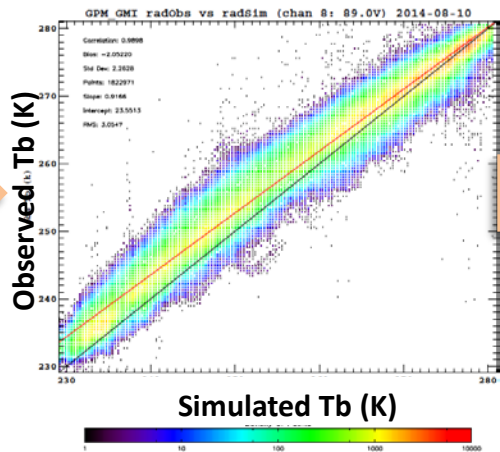
Pre-Assimilation Assessment with respect to TBs simulated in CRTM from collocated ECMWF analysis fields.

Unfiltered



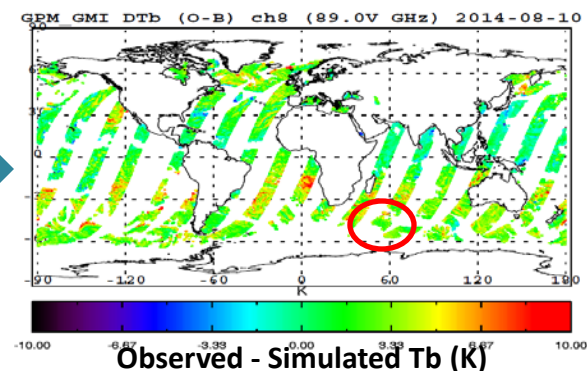
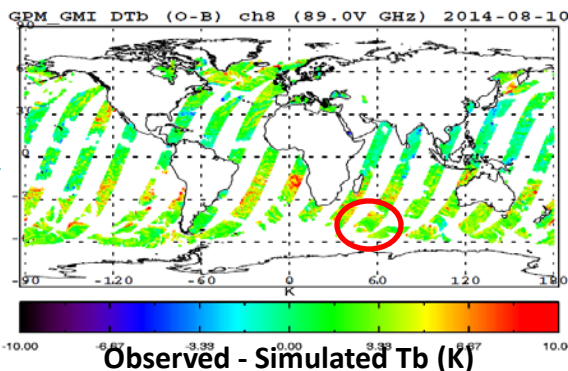
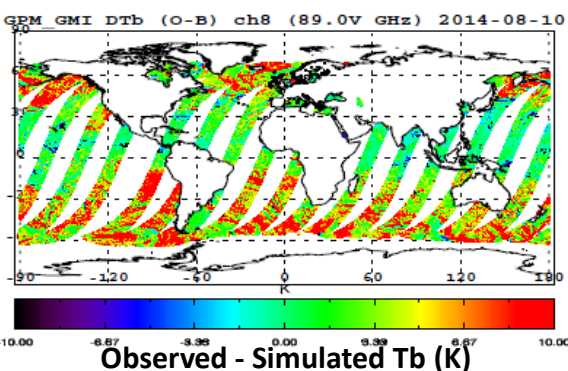
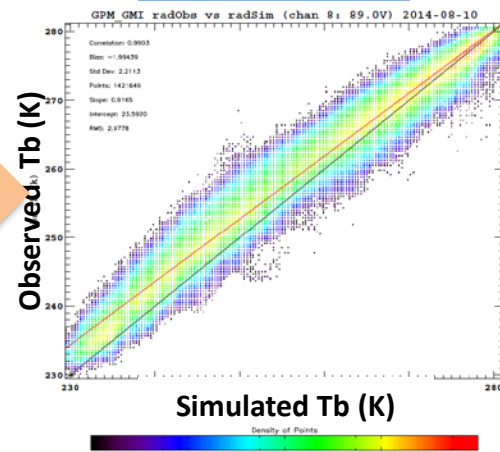
CLW, GWP
Filter

Ch 8 – 89V GHz



dEmiss
Filter

All Filtering



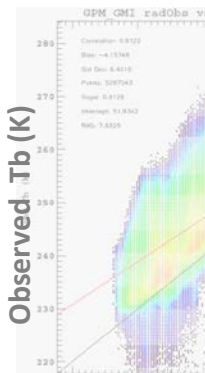
- Retrieve CLW and GWP
- Remove obs where retrieved CLW or retrieved GWP > 0.05 kg/m²

- Retrieve dEmiss for Ch 2, 4, 7
- Remove obs where retrieved dEmiss exceeds threshold for any channel

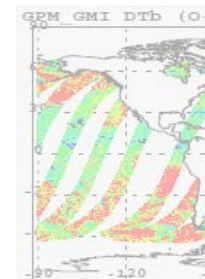
Points with high values of O-B filtered out of the observation pool.

GMI Radiance Quality Assessment

Freq	All-Sky			Clear-Sky (all filters)		
	Count	Bias	Stdv	Count	Bias	Stdv
10v	4198292	5.27	3.29	1421649	3.87	1.06
10h	4185488	2.90	4.38	1421649	0.94	1.33
18v	4151550	7.80	3.91	1421647	5.75	1.47
18h	4105726	5.59	5.81	1421649	2.80	2.50
23v	4187954	5.81	4.51	1421649	3.89	2.28
36v	4071842	5.03	4.79	1421649	2.19	1.50
36h	4201564	7.44	13.67	1421649	0.16	2.83
89v	4201564	4.16	6.40	1421649	1.99	2.21
89h	4201564	8.41	12.41	1421649	1.82	4.52
166v	4201564	-5.18	7.78	1421649	-4.03	1.54
166h	4201564	-3.76	9.86	1421649	-3.30	2.55
183v	4201564	-1.42	3.95	1421649	-0.96	1.77
183h	4201564	-4.93	5.95	1421649	-4.00	1.61



Simulated Tb (K)



Observed Tb (K)

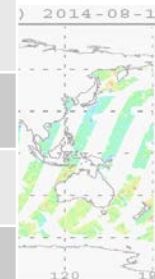
- Retr...
 - Rem...
- CLW of retrieved CLW > 0.05 kg/m²

CLW exceeds threshold for any channel

out of the observation pool.



Observed Tb (K)



Observed Tb (K)

CLW of retrieved CLW > 0.05 kg/m²

Implementing GMI DA in the GDAS

GMI data ingest in the NOAA GDAS:

- GMI L1C-R BUFR data
 - All 13 GMI channels in 1 BUFR file; only use points where there are observations for all channels (i.e. not at swath edges)
- Non-ocean points filtered by read routine (read routine provided by NASA GMAO)
- Data are thinned to a 45km thinning grid
- Observation errors/weights are based off of previous pre-assimilation assessments and GDAS results

GMI quality control in the NOAA GDAS:

- CLW, GWP, and dEmiss retrievals performed on GMI TBs over ocean
- All points where retrieved CLW or GWP $> 0.05 \text{ kg/m}^2$, or where dEmiss exceeds thresholds set for channel 2, 4, or 7, are flagged and removed
- Gross check of 5K performed on remaining points for all channels

Experiment setup:

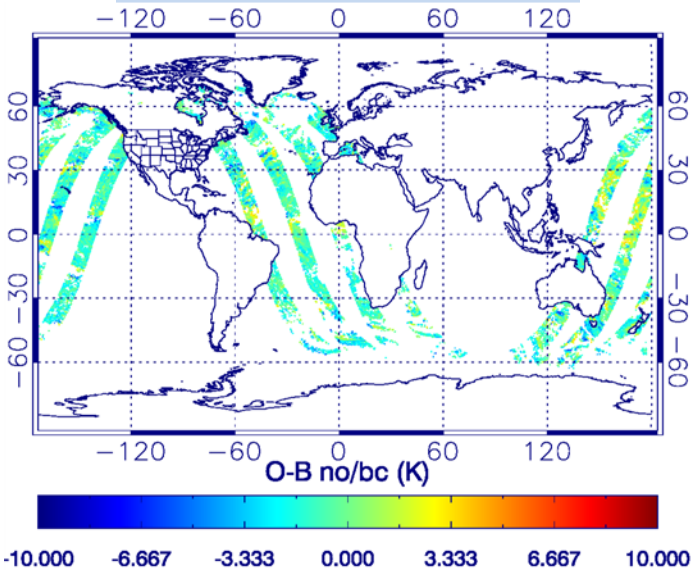
- Analysis (GDAS) run at T254, Forecast (GFS) run at T670
- Control run with all current satellite and conventional data, experiment is control plus GMI
- Experiment run from 20140801 00Z to 20140909 00Z with pre-spun up GMI bias

GMI Post-Assimilation Observation Assessment

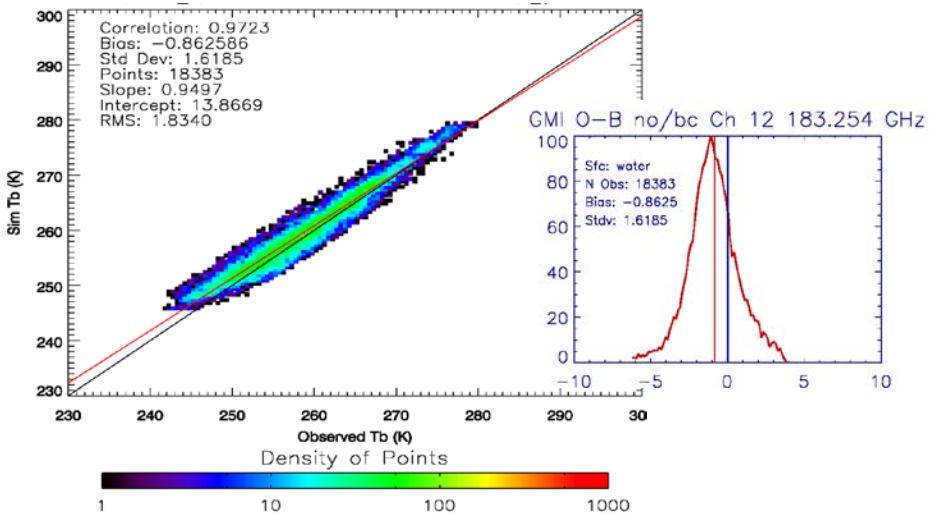
1 Cycle

Ch 12 -183.31±3V GHz

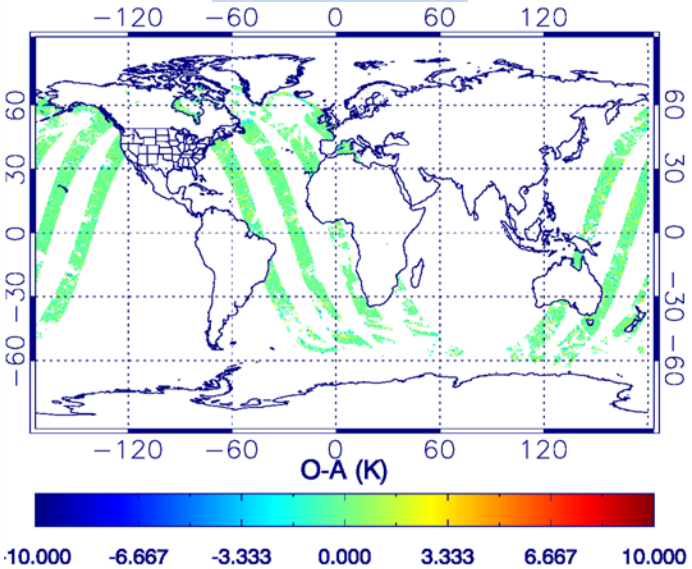
O-B filtered, no bias corr.



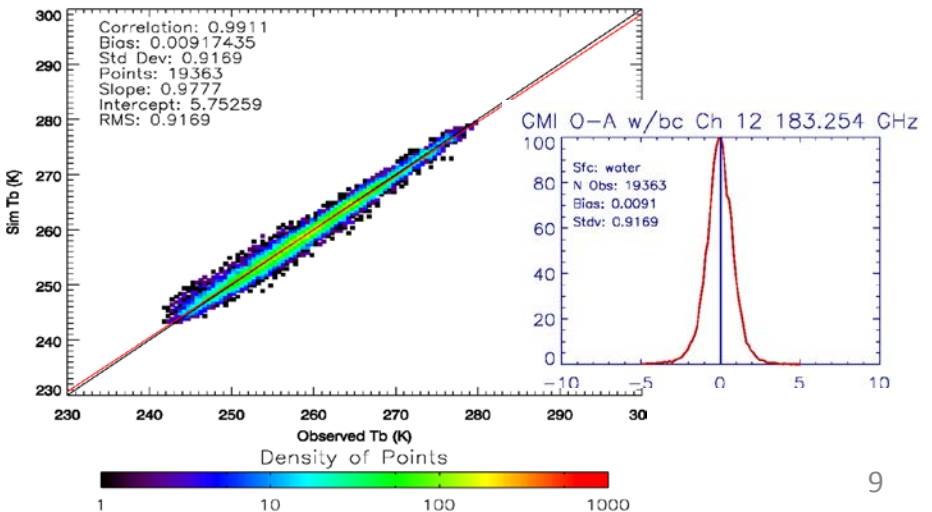
O vs B filtered, no bias corr.



O-A, bias corr.



O vs A, bias corr.



GMI Post-Assimilation Observation Assessment

Freq	O-B without Bias Corr			O-A with Bias Corr			Obs Error Used
	Count	Bias	Stdv	Count	Bias	Stdv	
10v	18903	1.41	1.03	19393	-0.02	0.84	1.60
10h	18854	1.68	1.08	19362	0.01	0.75	1.70
18v	18877	3.29	1.26	19384	-0.01	0.83	1.40
18h	18486	2.70	1.88	19341	0.01	1.08	2.00
23v	18647	1.39	1.75	19378	-0.03	0.96	1.50
36v	18899	-0.25	1.26	19397	0.00	0.71	1.10
36h	18425	-0.82	2.24	19339	0.02	1.14	2.00
89v	18838	0.36	1.59	19385	0.00	0.95	3.00
89h	16681	0.17	2.65	18723	0.02	1.83	5.00
166v	18541	-3.84	1.28	19113	-0.01	0.97	1.80
166h	18211	-3.58	1.50	18948	0.00	1.19	3.40
183v	18383	-0.86	1.62	19363	0.01	0.92	1.20
183h	18528	-2.04	1.40	19240	0.01	0.85	1.10

1 Cycle

Ch 12 -183.31±3V GHz

O-B Stdv similar to pre-assimilation assessment
 O-A Stdv reduced to below prescribed observation error



10

Assimilating GMI: Assessment of Analysis

Analysis comparison versus ECMWF – 32 day average, starting 20140805 00Z

Variable	Without GMI		With GMI		Change with GMI	
	<u>RMSE</u>	<u>Stdv</u>	<u>RMSE</u>	<u>Stdv</u>	<u>RMSE</u>	<u>Stdv</u>
HGT 500hPa	2.96	2.52	2.81	2.48	5.33%	1.61%
TMP 1000hPa	1.36	1.34	1.35	1.33	0.74%	0.75%
U 1000hPa	0.62	0.62	0.65	0.65	4.84%	4.84%
V 1000hPa	0.59	0.59	0.59	0.60	0.00%	1.69%
RH 1000hPa	7.52	5.20	7.51	5.18	0.13%	0.39%
RH 850hPa	6.27	6.22	6.20	6.17	1.13%	0.81%
RH 500hPa	3.57	3.21	3.42	3.18	4.39%	0.94%

Green = Improvement, Red = Degradation

Preliminary results show a mostly neutral/slightly positive on the GDAS analysis (verified against ECMWF) when GMI is added, excepting 1000hPa U and V wind.

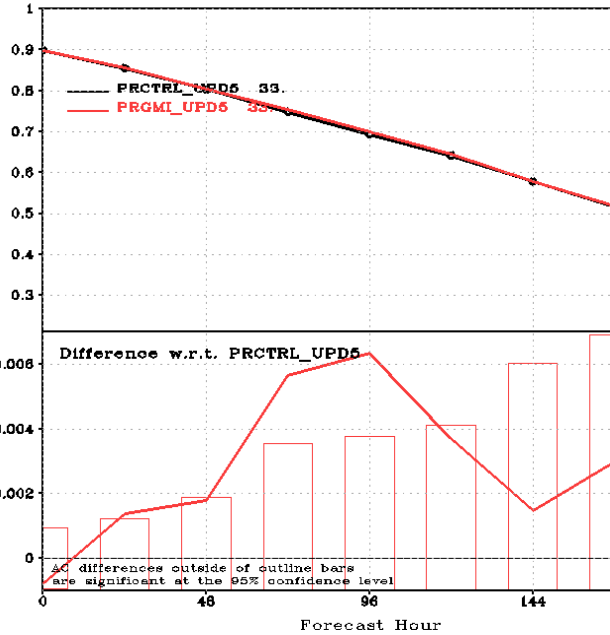
Assimilating GMI: Preliminary Forecast Impacts

Forecast comparison versus ECMWF – 20140805 to 20140909 00Z cycles

Anomaly Correlation

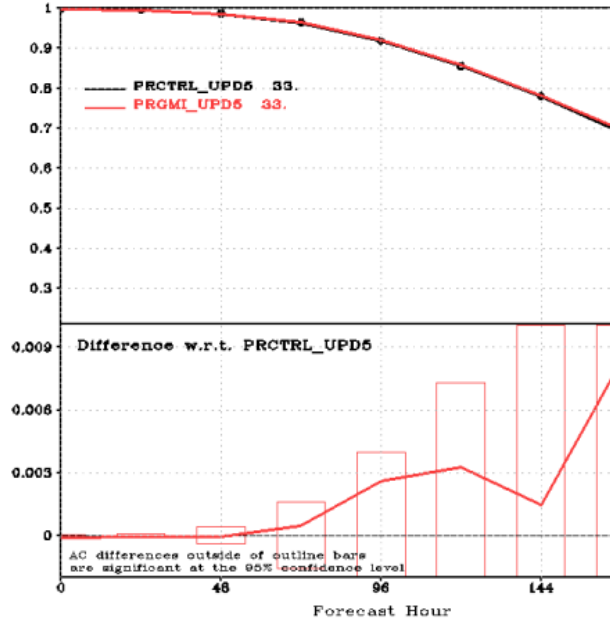
Wind: 850 hPa Tropics

AC: WIND P850 G2/TRO 00Z, 20140805-20140909



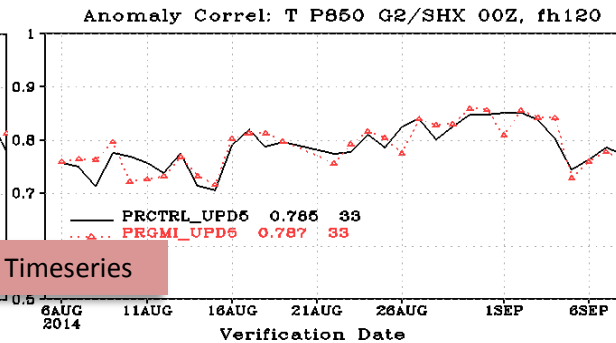
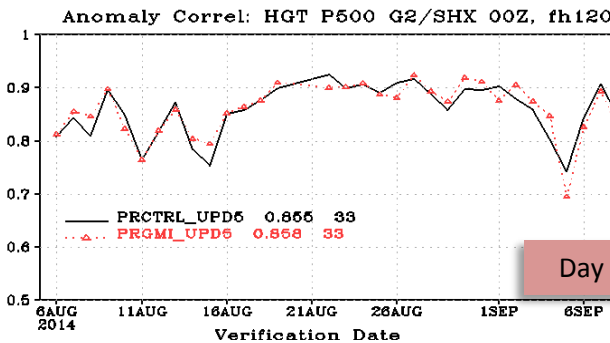
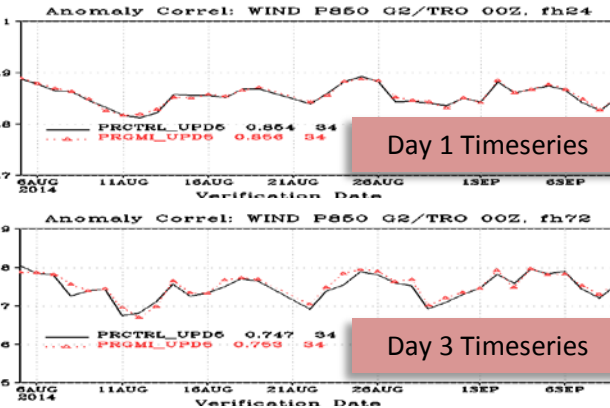
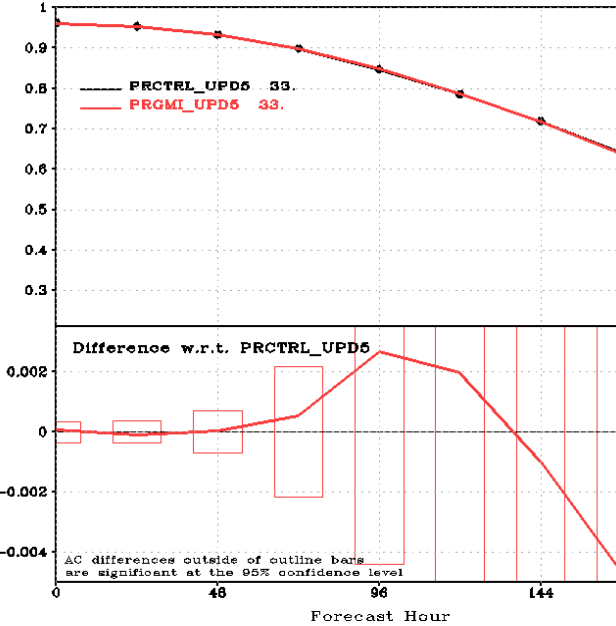
Height: 500 hPa SH

AC: HGT P500 G2/SHX 00Z, 20140805-20140909



Temp: 850 hPa SH

AC: T P850 G2/SHX 00Z, 20140805-20140909



Assimilating GMI: Preliminary Forecast Impacts

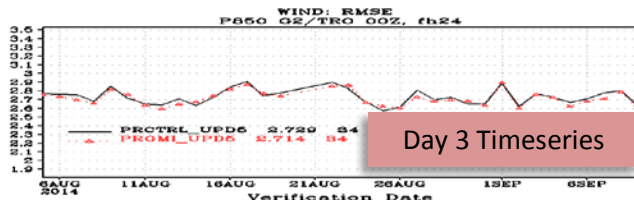
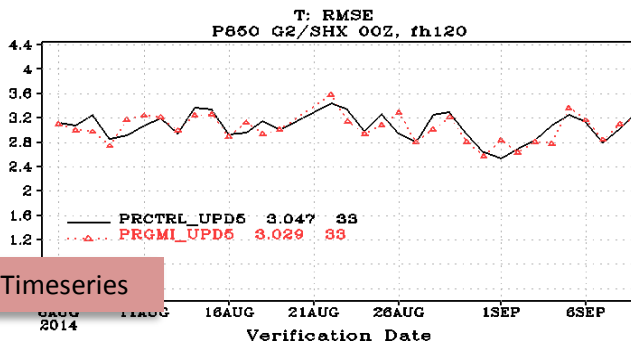
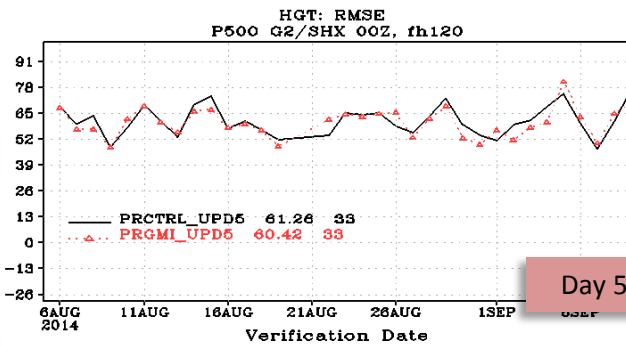
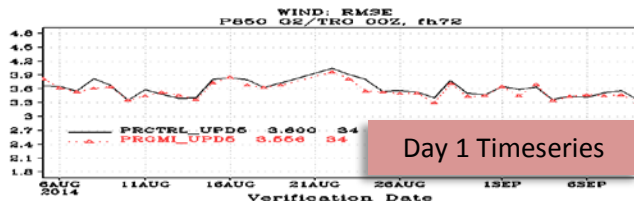
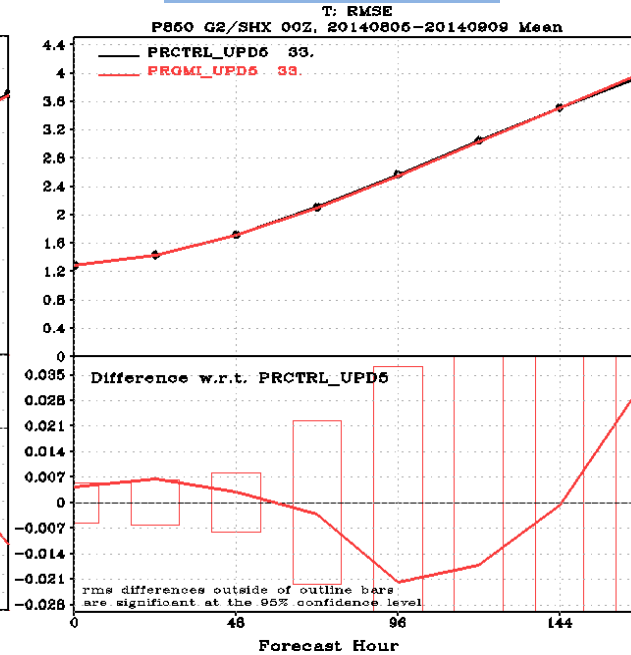
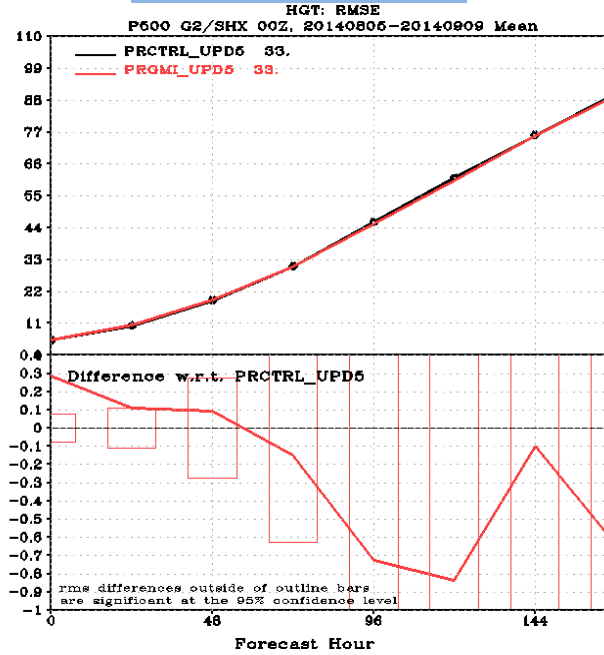
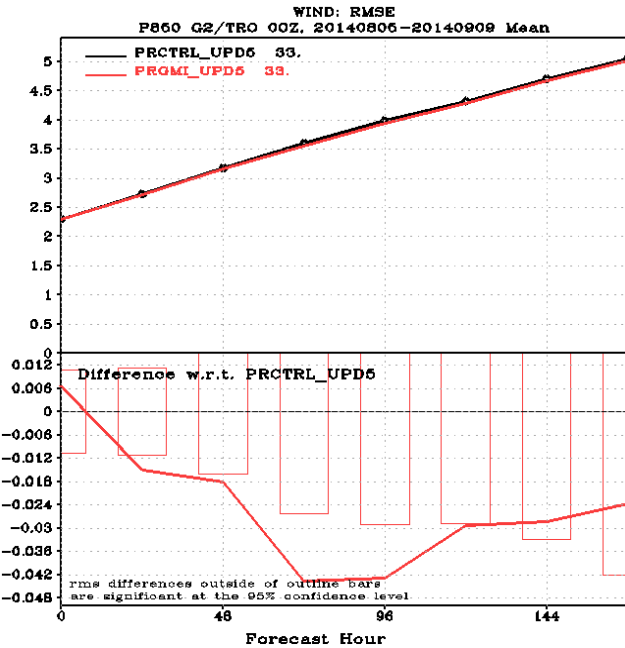
Forecast comparison versus ECMWF – 20140805 to 20140909 00Z cycles

RMSE

Wind: 850 hPa Tropics

Height: 500 hPa SH

Temp: 850 hPa SH



Assimilating GMI: Preliminary Forecast Impacts

Forecast comparison versus ECMWF – 20140805 to 20140909 00Z cycles

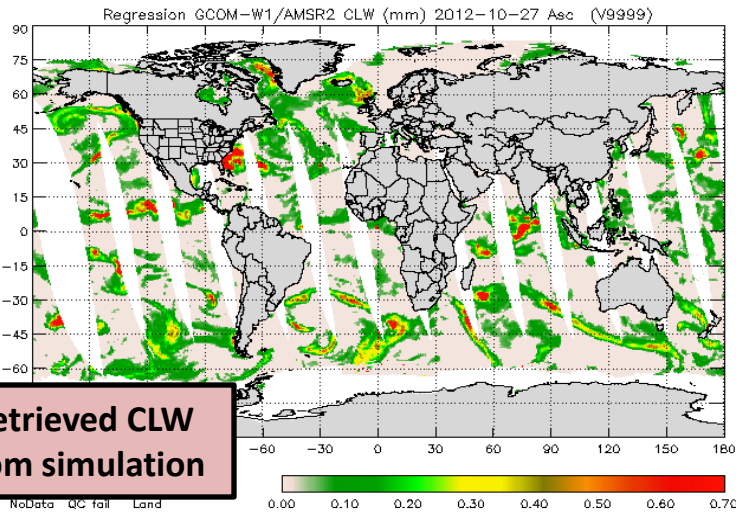
Variable	Without GMI		With GMI		Change with GMI	
	<u>RMSE</u>	<u>AC</u>	<u>RMSE</u>	<u>AC</u>	<u>RMSE</u>	<u>AC</u>
HGT 500hPa, d5	41.25	0.86	41.01	0.86	0.59%	0.00%
TMP 850hPa, d5	2.41	0.76	2.41	0.76	0.00%	0.00%
Tro WIND 850hPa, d1	2.73	0.85	2.71	0.86	0.74%	1.18%
Tro WIND 850hPa, d3	3.60	0.75	3.56	0.75	1.12%	0.00%
Tro WIND 200/250hPa, d1	5.00	0.90	4.99	0.90	0.20%	0.00%
Tro WIND 200/250hPa, d3	7.49	0.78	7.38	0.78	1.49%	0.00%
SH WIND 850hPa, d1	3.13	0.96	3.14	0.96	0.32%	0.00%
SH WIND 850hPa, d3	5.73	0.86	5.70	0.86	0.53%	0.00%

Green = Improvement, Red= Degradation

The addition of GMI data to appears to have a neutral impact with respect to ECMWF, with indications of some positive significant impact in low level Tropical Winds at Day3-4.

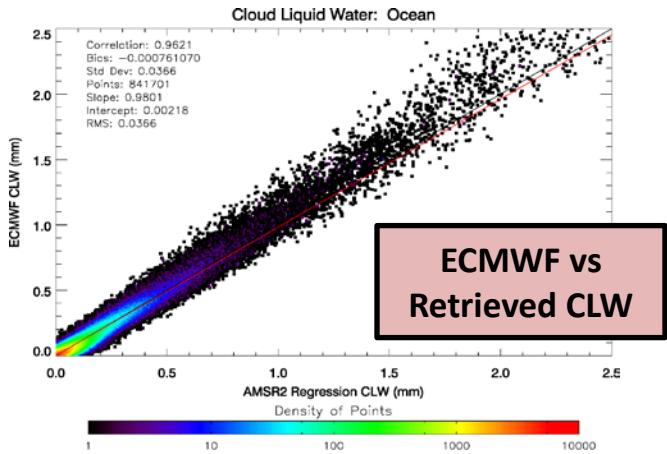
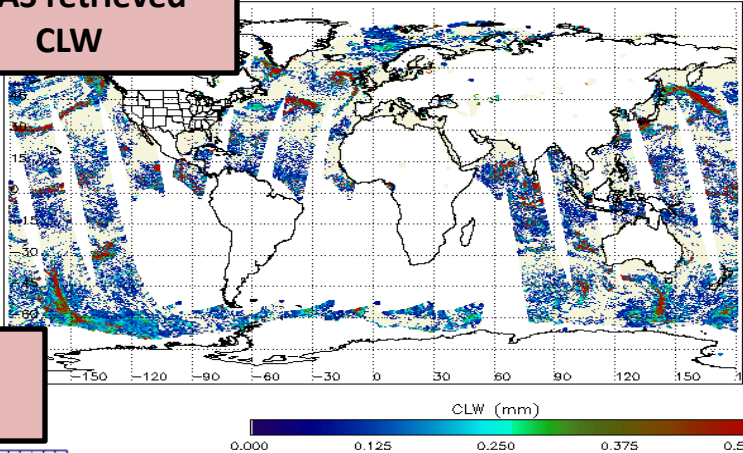
AMSR2 Radiance Quality Control

For clear-sky radiance assimilation, algorithms were developed to retrieve and filter out cloud.

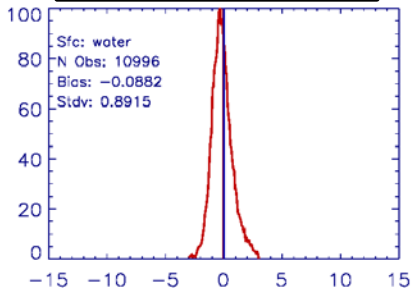


Multi-linear regression trained using ECMWF analyses and simulated AMSR2 brightness temperatures from CRTM (best results using Ch 12). Additional algorithms developed to retrieve dEmiss from AMSR2 observations (not shown)

GDAS retrieved CLW



Ch11 O-A with Bias corr.



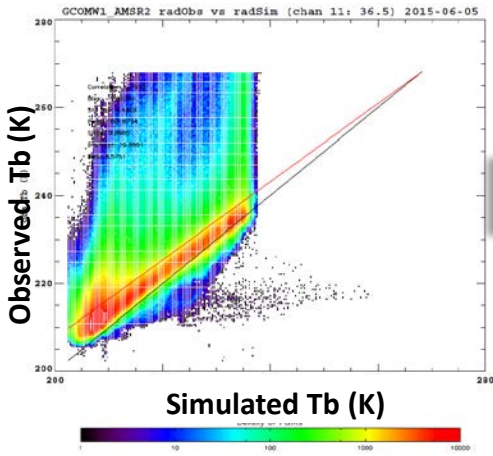
Retrievals and QC filters implemented in the GDAS and tested

Integrated CLW algorithm developed to detect/retrieve liquid cloud from AMSR2 observations

AMSR2 Radiance Quality Assessment

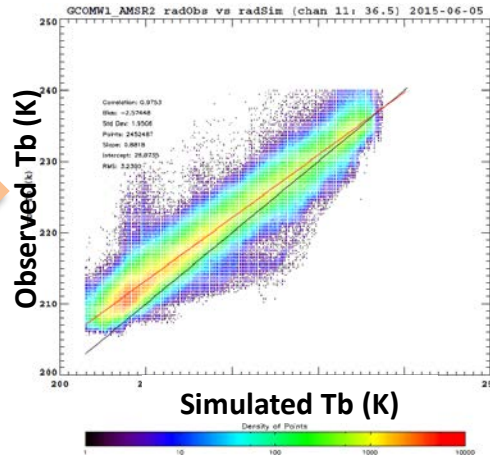
Pre-Assimilation Assessment with respect to TBs simulated in CRTM from collocated ECMWF analysis fields.

Unfiltered



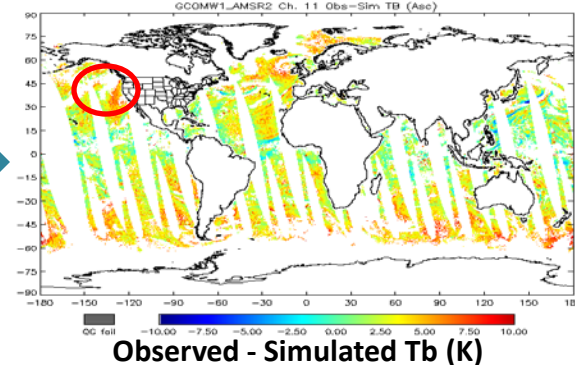
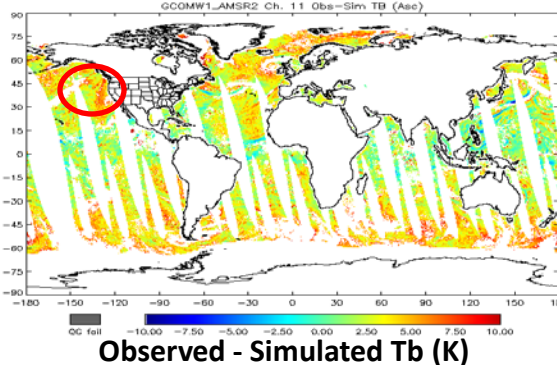
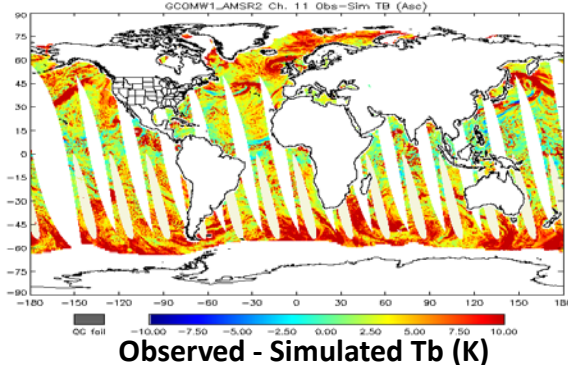
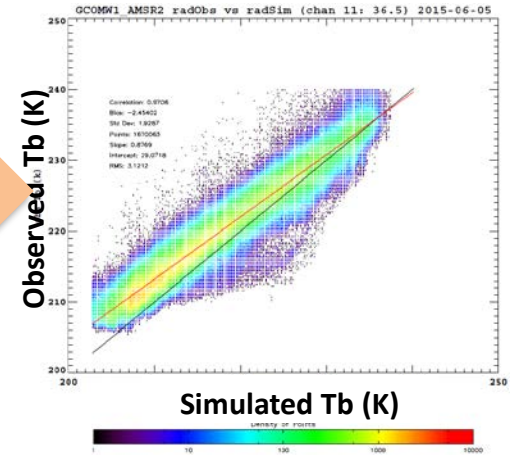
CLW Filter

Ch 11 – 36.5V GHz



dEmiss Filter

All Filtering



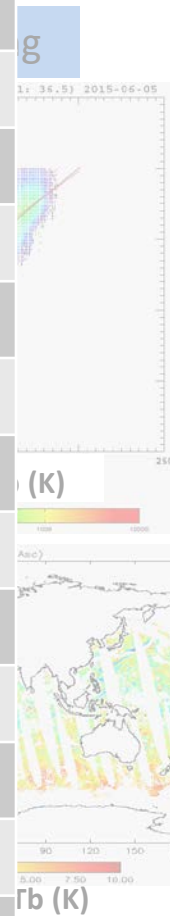
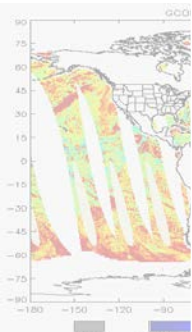
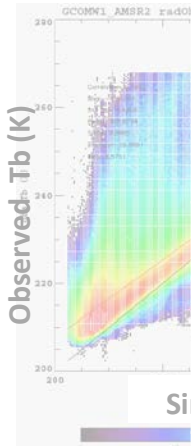
- Retrieve CLW
- Remove obs where retrieved CLW > 0.05 kg/m²

- Retrieve dEmiss for Ch 12, 14
- Remove obs where retrieved dEmiss exceeds threshold for any channel

- Additional check for observations affected by sun glint

AMSR2 Radiance Quality Assessment

Freq	All-Sky			Clear-Sky (all filters)		
	Count	Bias	Stdv	Count	Bias	Stdv
6.9v	5931794	1.51	2.37	1669899	0.67	1.57
6.9h	5931763	3.42	3.30	1669925	2.53	2.02
7.3v	5931696	1.78	2.43	1669875	0.91	1.56
7.3h	5931636	4.01	3.50	1669914	3.15	2.06
10v	5918568	4.81	3.09	1669814	3.56	1.69
10h	5918580	5.64	5.19	1669902	3.85	2.34
18v	5923858	6.62	4.95	1670063	4.41	2.10
18h	5924174	6.22	9.54	1670063	2.48	3.47
23v	5932559	5.91	4.48	1670063	3.95	2.89
23h	3735327	8.11	9.35	1133268	4.61	5.54
36v	5918724	5.68	6.42	1670063	2.45	1.93
36h	5912668	9.87	13.89	1670063	2.70	3.70
89v	5931162	3.30	6.35	1670063	1.75	2.93
89h	5885624	8.26	13.17	1670063	2.42	6.66



- Ret
- Rem
- retr
- kg/m

for
ected by

Channels 15-16 (redundant 89GHz) not used

Summary and Conclusions

The NOAA GDAS has been extended to assimilate GMI L1C-R data and AMSR2 L1B data:

- The capability to read in and thin GMI and AMSR2 data has been added
 - CLW and dEmiss retrievals and filters have been developed for GMI and AMSR2; a GWP filter has been developed for GMI
 - Observation bias and stdv are reduced with filtering (for AMSR2, this is shown in pre-assimilation observation assessment)
 - This capability will be part of the next operational upgrade to the GDAS
- Preliminary results indicate the addition of GMI has an overall neutral impact (globally) on the GDAS/GFS system when verified against ECMWF

Future Work

The assessment of GMI and AMSR2 impacts on the NOAA GDAS/GFS is ongoing.

GMI Plans:

- Perform longer impact experiments (including data denial experiments) using tuned errors
- Optimize clear-sky, ocean only data assimilation
 - Further tune errors and filtering

AMSR2 Plans:

- Perform impact experiments (including data denials) using errors based on COAT results (turning off poor performing channels)
- Optimize clear-sky, ocean only data assimilation
 - Tune errors and filtering

Ultimately:

- Work towards the assimilation of new passive microwave data in all-sky conditions and over land
- Extend the Multi-Instrument Inversion and Data Assimilation pre-Processing System (MIIDAPS) to process new passive microwave data prior to assimilation

Questions?