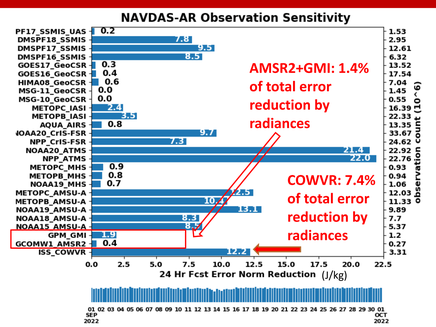
Improve the Use of Microwave Conical Sensors in U.S. Navy's Global Weather Prediction System

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Background and Motivation



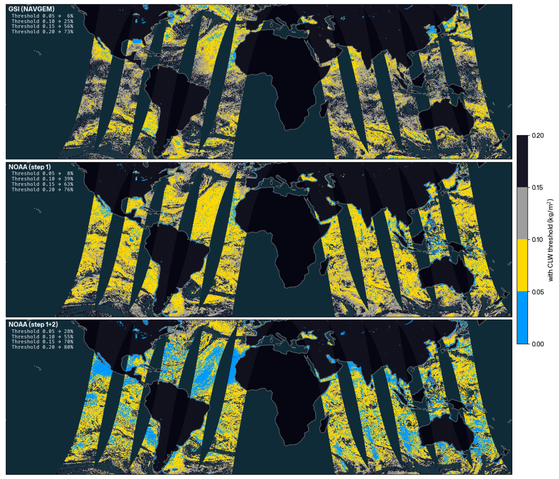
Percentage of the 24-h total forecast error norm reduction (J/kg, larger is better) by all radiances assimilated in the NAVGEM data assimilation system for September 2022. Sensor is labeled along with corresponding satellite platform. Adopted from Christophersen et al. (2024).

NAVy Global Environmental Model (NAVGEM)
Advanced Microwave Scanning Radiometer 2 (AMSR2)
Global Precipitation Measurement (GPM) Microwave Imager (GMI)
Special Sensor Microwave Imager/Sounder (SSMIS)
Advanced Microwave Sounding Unit (AMSU-A)
Advanced Technology Microwave Sounder (ATMS)

- AMSR2/GMI contributes less than 2% of total 24-hour forecast error reduction by all the radiances in the NAVGEM data assimilation system, which is very small compared to other microwave sensors (e.g. SSMIS, AMSU-A, ATMS).
- Radiances from the AMSR2 at 23 GHz and GMI at 23 GHz and 183 GHz are actively assimilated in the system
- Recent study on the Compact Ocean Wind Vector Radiometer (COWVR) has shown significant positive impacts on model forecasts in the Southern Hemisphere through the assimilation of COWVR radiances at 18 GHz, 23 GHz, and 34 GHz (Christophersen et al. 2024). COWVR also contributes to ~7.4% of total forecast error reduction.

This study aims to enhance the use of AMSR2 and GMI radiances in the DA system by assimilating channels at 18GHz and 36 GHz, as well as improving the quality control and data superobbing for these two sensors. These efforts will yield insights on the use of Weather Satellite Follow-on-Microwave (WSF-M) microwave imager (MWI) in NAVGEM.

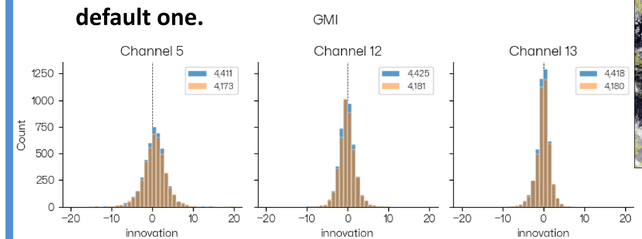
Quality Control and Thinning



NAVGEM estimated CLW compared to NOAA (Chang et al. 2015) retrieved CLW on April 1 2023 0600 UTC. The NOAA step 1 consists of a regression-based estimate of CLW based on 9 different frequencies and polarizations, while step 2 is a correction to the step 1 estimates with localized regression-based estimates in 40 different bins of CLW values at every 0.01 kg/m².

Data thinning for AMSR2/GMI

- Supperobbing using either Gaussian or boxcar averaging is currently enabled for AMSR2/GMI.
- **No noticeable difference on the innovation distribution between the two methods aside from the data counts. Gaussian averaging remains the default one.**



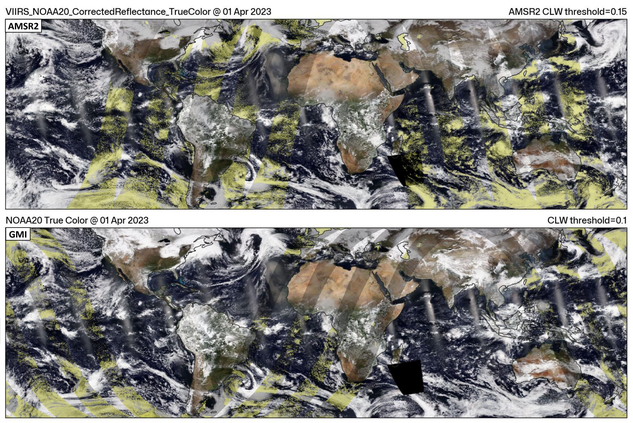
Histogram of innovations with gaussian (blue) or boxcar (orange) averaging for 0600 UTC 1 April 1 2023

QC Cloudy scenes for AMSR2/GMI

- **NAVGEM assimilates MW clear-sky only scenes.** To estimate scenes possibly contaminated by heavy clouds and precipitation, it uses either regression-based cloud liquid water (CLW) or normalized polarization difference (Petty 1994)
- Existing QC screening uses the same CLW regression method used by the NOAA/EMC GSI system. We further evaluated a CLW algorithm provided by Chang et al. (2015), hereafter referred to the NOAA algorithm.

❖ **CLW estimates from the NAVGEM/GSI and NOAA step 1 *look* similar. With 2nd step, the NOAA's CLW is a bit lower. It is interesting that NOAA's estimate has sun glint artifacts, but NAVGEM/GSI does not.**

❖ **0.05 kg/m² is the current threshold to filter out "cloudy" scenes for AMSR2. This threshold is perhaps too strict. We chose 0.15 and 0.10 kg/m² as the new threshold for AMSR2 and GMI, respectively.**



VIIRS N20 overlaid AMSR2 (GMI) data points that are associated with the CLW exceeding 0.15 (0.1) kg/m²

Impact of updated AMSR2 and GMI processing

New changes

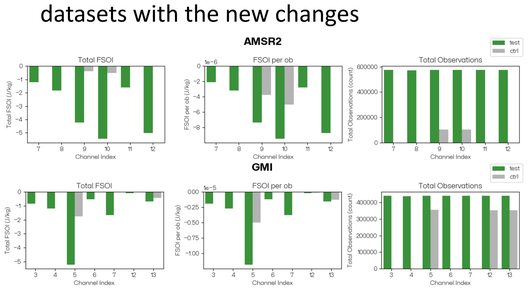
1. Assimilated additional AMSR2 and GMI channels
2. Reduced observation error
3. Lowered CLW threshold in QC step

Experiment setup

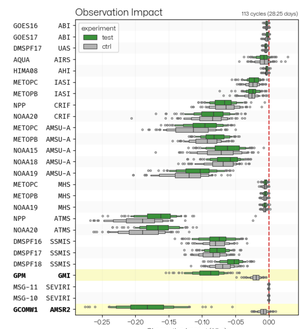
- Period: July 2022
- "Control" uses ops assimilated datasets, while "test" uses the same datasets with the new changes

Assimilated AMSR2/GMI Channels

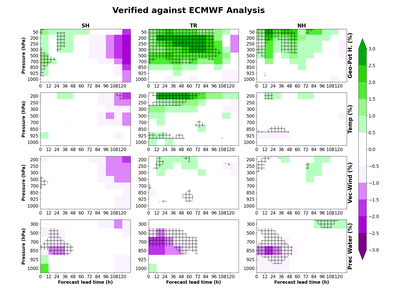
		AMSR2		GMI	
	Freqency	channel #	ob error (K)	channel #	ob error (K)
control	23 V	9	7.5	5	6.5
	23 H	10	12.5		
	183.3+/-3.0			12	3.5
	183.3+/-7.0			13	3
test	**18 V**	**7**	**4**	**3**	**4.5**
	18 H	**8**	**5.75**	**4**	**6.25**
	23 V	9	**3.75**	5	**3.25**
	23 H	10	**6.25**		
	36 V	**11**	**4.25**	**6**	**6.25**
	36 H	**12**	**4.5**	**7**	**6.25**
	183.3+/-3.0			12	3.5
	183.3+/-7.0			13	3



Increased data count, increased impact measured by the forecast sensitivity to observation impact (FSOI) for AMSR2/GMI



Model		
Name	Horz. Res.	Vert. Res.
NAVGEM (Hogan et al. 2014)	T681 (~19km)	L60 (to 0.04hPa)
Data Assimilation system		
Technique	Ensemble	RTM
Hybrid Increm. 4DVar (Xu et al. 2005; Rosmond and Xu, 2006)	Ensemble transform (Bishop and Toth 1999; McLay 2007, 2008)	Community radiative transfer model (CRTM, Johnson et al. 2023)

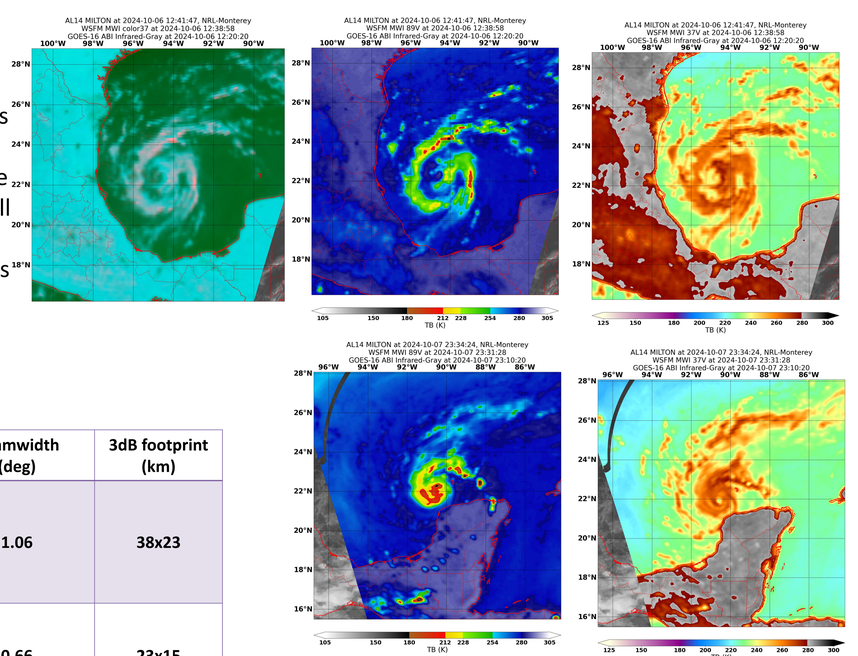


Significant positive impact for geopotential height, temperature and winds forecasts over the tropics and Northern Hemisphere, but degradation for precipitable water forecasts

New conical sensor: WSF-M MWI

Weather Satellite Follow-on-Microwave (WSF-M) MicroWave Imager (MWI)

Launched on April 11, 2024, WSF-M is an operational low Earth orbit (LEO) environmental satellite system for the Department of Defense (DoD) (Newell et al. 2024). It delivers continuous, space-based monitoring of the Earth's environment, currently handled by the Defense Meteorological Satellite Program (DMSP) and following the Coriolis/WindSat heritage.



Channel	Ctrl. Freq. (GHz)	Pol.	Beamwidth (deg)	3dB footprint (km)
1	10.85	V	1.06	38x23
2		H		
3		3rd		
4		4th		
5	18.85	V	0.66	23x15
6		H		
7		3rd		
8		4th		
9	23.8	V	0.58	21x13
10	36.75	V	0.43	15x10
11		H		
12		3rd		
13		4th		
14	37.25	V	0.43	15x10
15		H		
16	89.	V	0.43	15x10
17		H		

- The MWI is a conical scanning polarimetric microwave radiometer with channels from 10 GHz to 89 GHz.
- Primary purpose is to measure ocean surface winds and tropical cyclones.
- Current DA trials with MWI radiances are ongoing. Radiances at channels 18, 23, and 37GHz V/H will be assimilated into the NAVGEM DA system

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