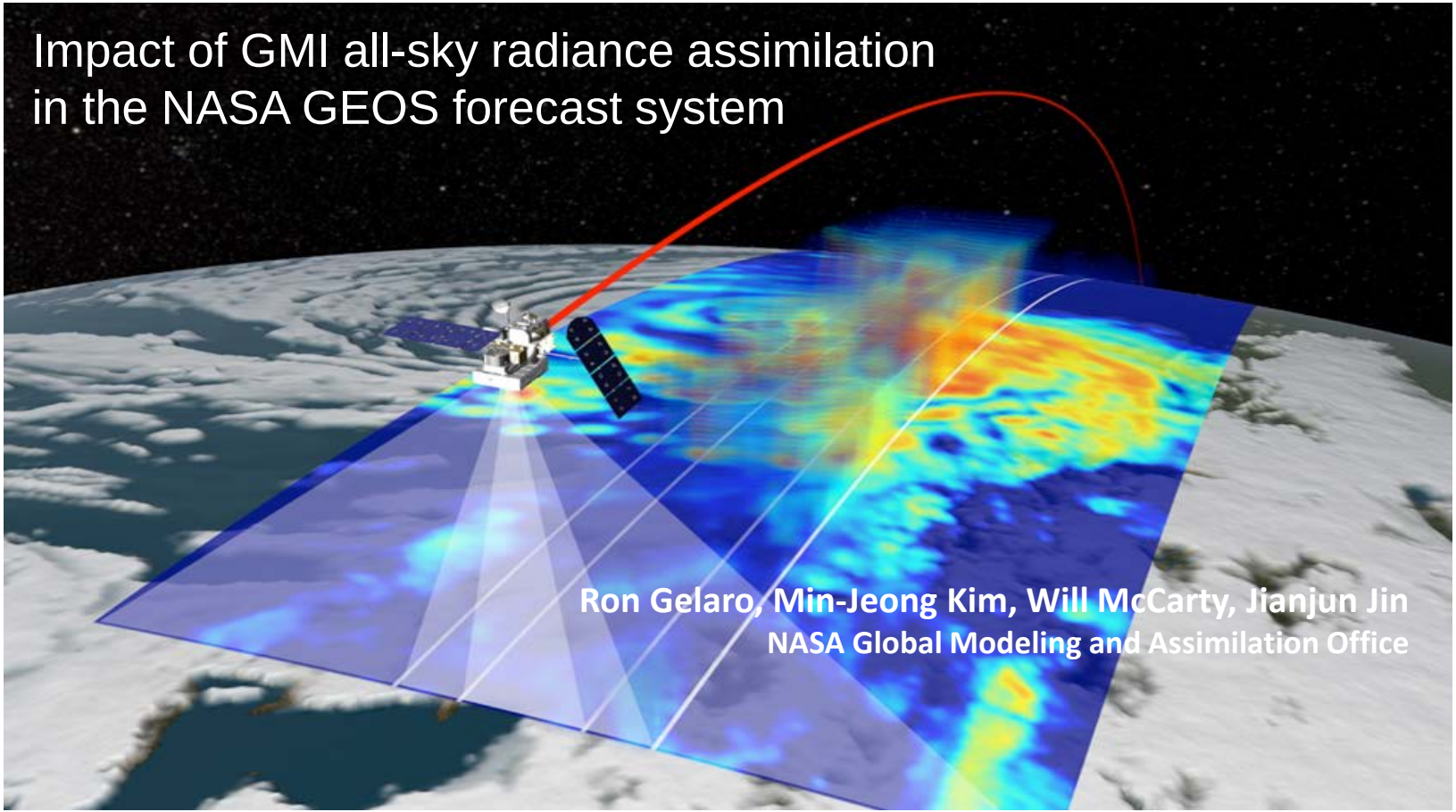
Impact of GMI all-sky radiance assimilation in the NASA GEOS forecast system



Ron Gelaro, Min-Jeong Kim, Will McCarty, Jianjun Jin
NASA Global Modeling and Assimilation Office

Seventh AMS Symposium on the Joint Center for Satellite Data Assimilation; 99th AMS Annual Meeting, Phoenix, Arizona, 6-10 January, 2019

GMI all-sky radiance assimilation in GEOS

All-sky assimilation of GPM Microwave Imager (GMI) radiances implemented in GEOS real-time production system on 11 July 2018

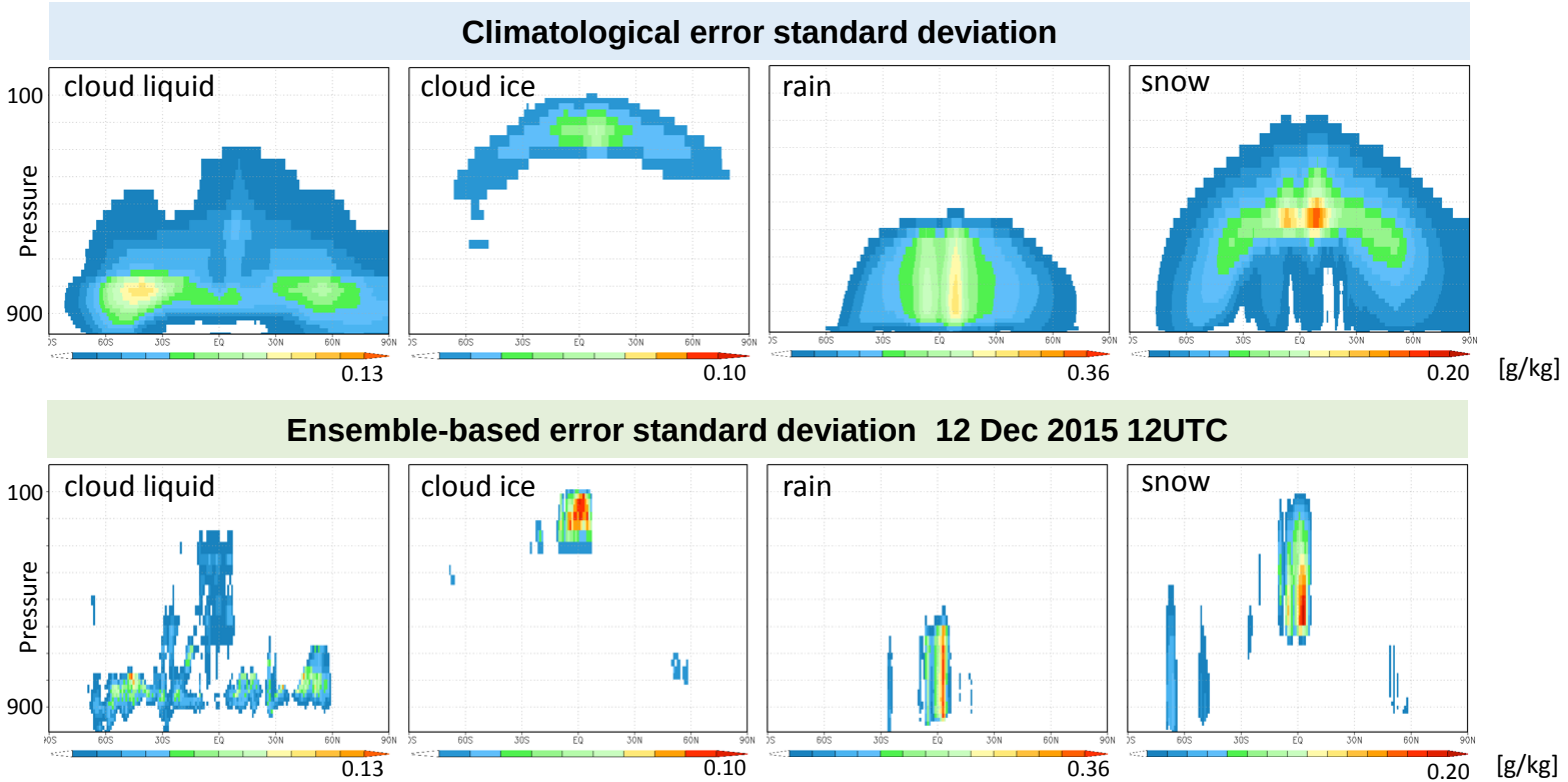
- **GMI data selection**
  - Six (of 13) GMI channels assimilated
  - Low-frequency: **5**(23.8 GHz V), **6**(36.5 GHz V), **7**(36.5 GHz H)
  - High-frequency: **10**(166 GHz V), **12**(183.3 ±3 GHz V), **13**(183.3 ±7 GHz V)
  - Observations over ocean surfaces only

- **Upgrades to assimilation infrastructure**
  - New control variables for hydrometeors: **cloud liquid**, **cloud ice**, **rain**, **snow**
  - Improved radiative transfer (3-bullet DDA, CRTM)
  - New background error (hybrid) and observation error (symmetric, Geer and Bauer 2011) models
  - Modified QC and bias correction

Details in Kim et al. (2019)

Hybrid background errors for hydrometeors

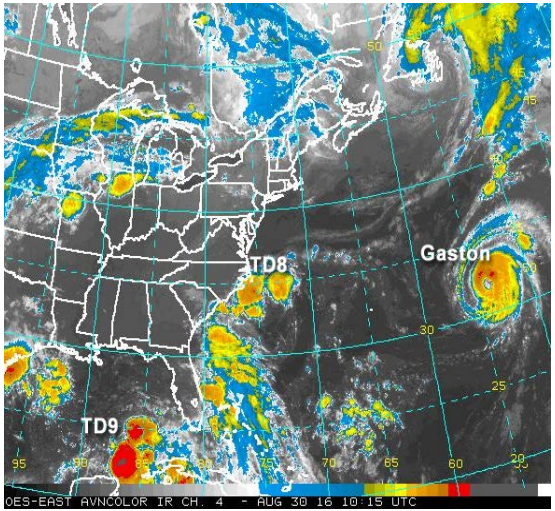
Longitudinal slice along 150°E



Dynamic adjustments in precipitating regions

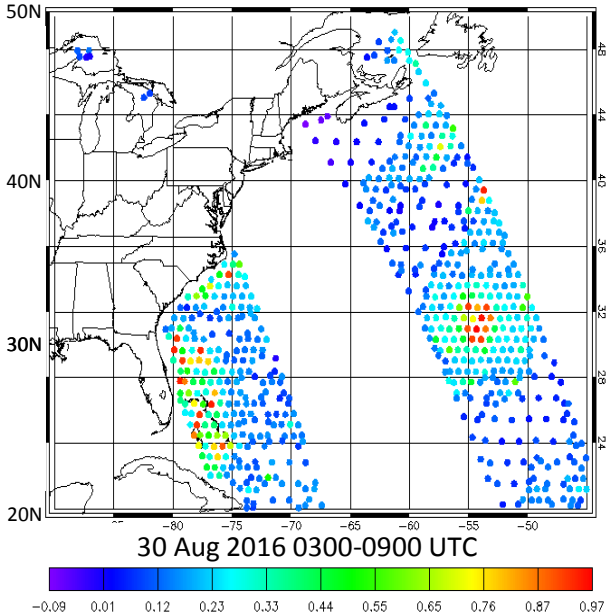
Hurricane Gaston case study

GOES East IR Imagery



30 Aug 2016 1015 UTC

GMI 37-GHz Tb Polarization Difference



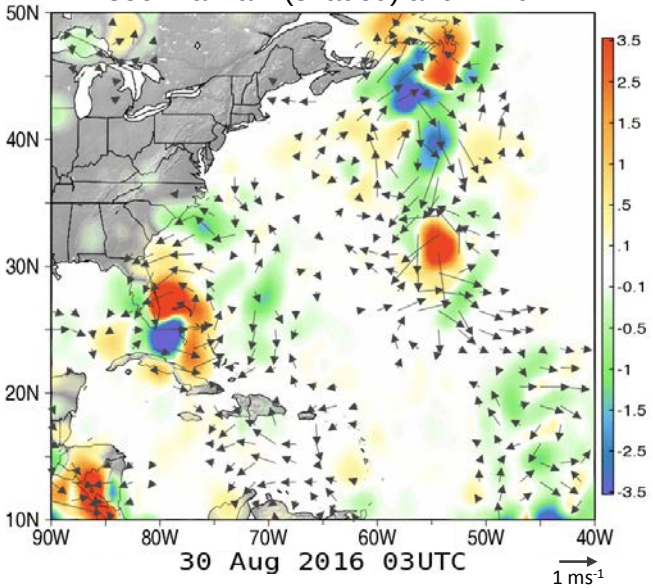
30 Aug 2016 0300-0900 UTC

Dynamic impact of GMI all-sky radiances on GEOS analyses is demonstrated in a case study of Hurricane Gaston in which **GMI data only** (right) are assimilated

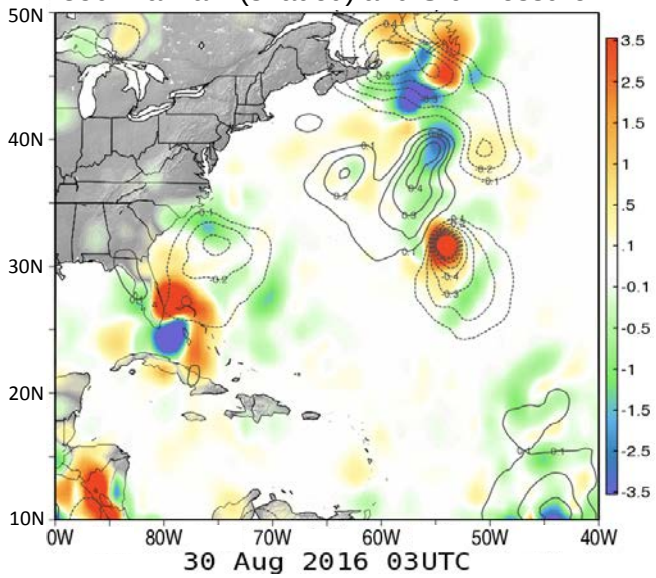
Dynamic adjustments in precipitating regions

GEOS analysis increments

850hPa Rain (shaded) and Wind



850hPa Rain (shaded) and Sfc Pressure



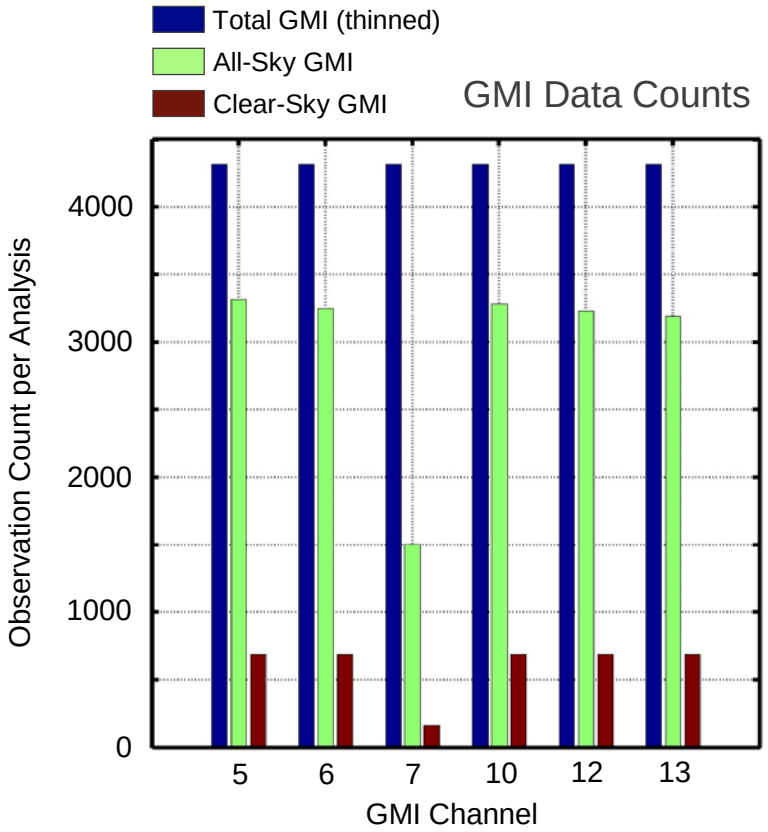
Assimilation of GMI all-sky radiances in **hybrid 4D-EnVar** adjusts not only hydrometeors but also dynamic variables such as wind and pressure

Pre-production experimentation

- **Science testing**
  - GEOS hybrid 4D-EnVar
  - 25-km GCM, 25-km GSI, 32 x 100-km EnKF
  - Control with full observing system
  - Experiments add GMI all-sky (or clear-sky) radiances only
  - Winter and summer 2016

- **High-resolution parallel production**
  - GEOS hybrid 4D-EnVar
  - **12.5-km** GCM, 25-km GSI, 32 x **50-km** EnKF
  - Full observing system plus GMI all-sky radiances
  - **Model physics updates**
  - Winter-Spring 2017/18

Science testing data assimilation feedback



Background Fit to Satwinds 60N-60S

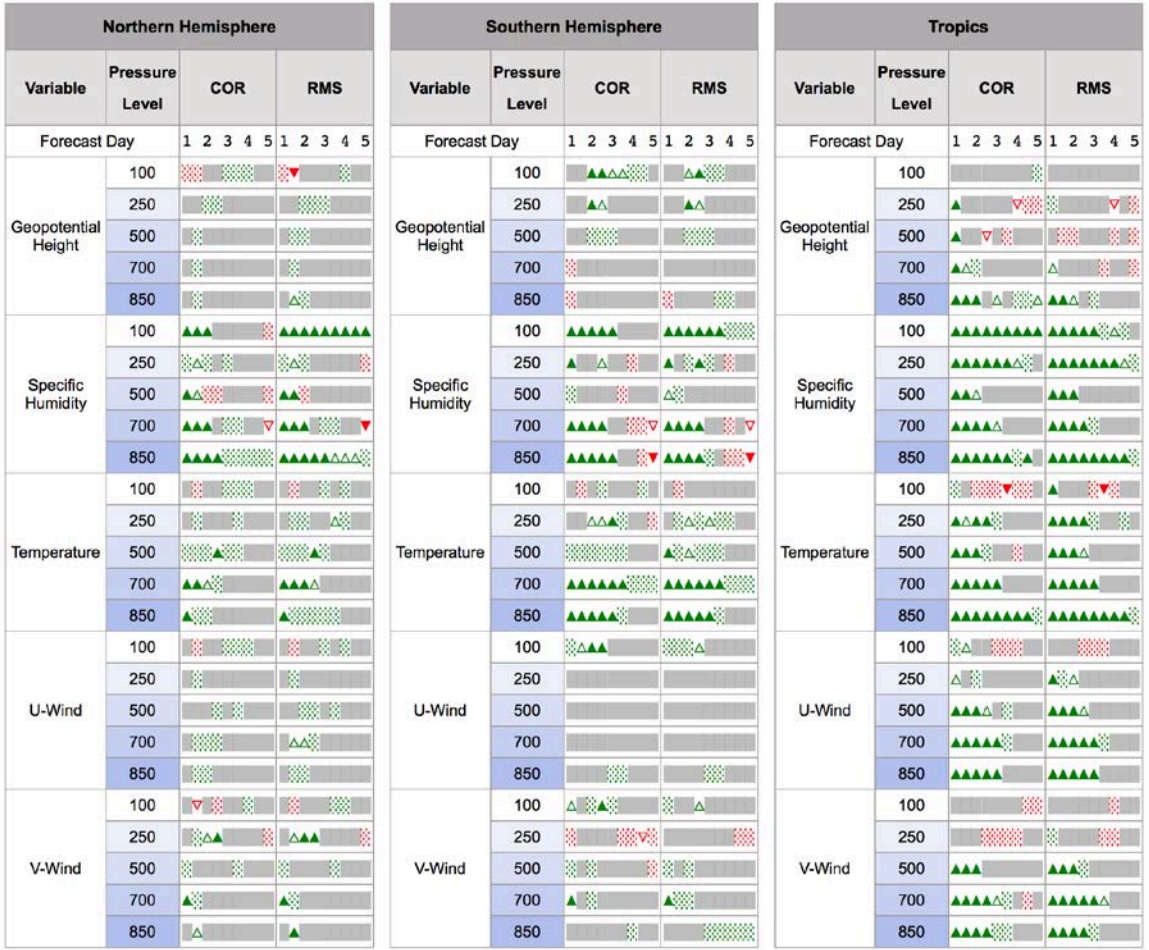
		U-wind			V-wind	
		Mean	STD		Mean	STD
All Levels	No GMI	-0.050	2.74		-0.079	2.76
	All-sky GMI	-0.042	2.75		-0.075	2.78
		-16%	+0.3%		-5%	+0.7%
Low Levels (below 600hPa)	No GMI	-0.17	1.50		-0.017	1.47
	All-sky GMI	-0.17	1.51		0.003	1.48
		0%	+0.7%		-82%	+0.7%
Mid Levels (400-600hPa)	No GMI	-0.25	2.89		-0.25	2.83
	All-sky GMI	-0.24	2.89		-0.25	284
		-4%	0%		0%	+0.4%
Upper Levels (above 400hPa)	No GMI	0.019	3.03		0.18	3.03
	All-sky GMI	0.025	3.04		0.19	3.05
		+32%	+0.3%		+5%	+0.7%

Science testing forecast scorecard

Control v. GMI all-sky
Dec 2016

Legend

- ▲ far better, significant (95% confidence)
- △ better, significant (90% confidence)
- ▒ slightly better, significant (68% confidence)
- ▒ not really any difference
- ▒ slightly worse, significant (68% confidence)
- ▽ worse, significant (90% confidence)
- ▼ far worse, significant (95% confidence)



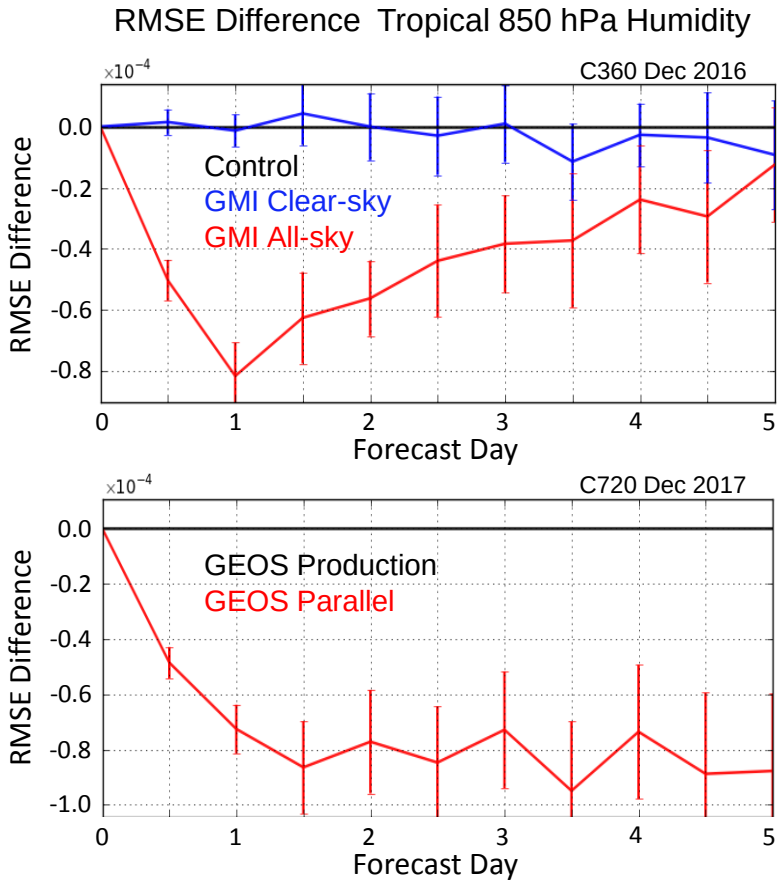
Tropical lower-tropospheric humidity forecasts

Science testing

Adding GMI all-sky radiances improves the initial state and leads to reduced error, especially in the Tropics. Largest impact is at day-1, with diminishing impact thereafter.

High-resolution parallel production

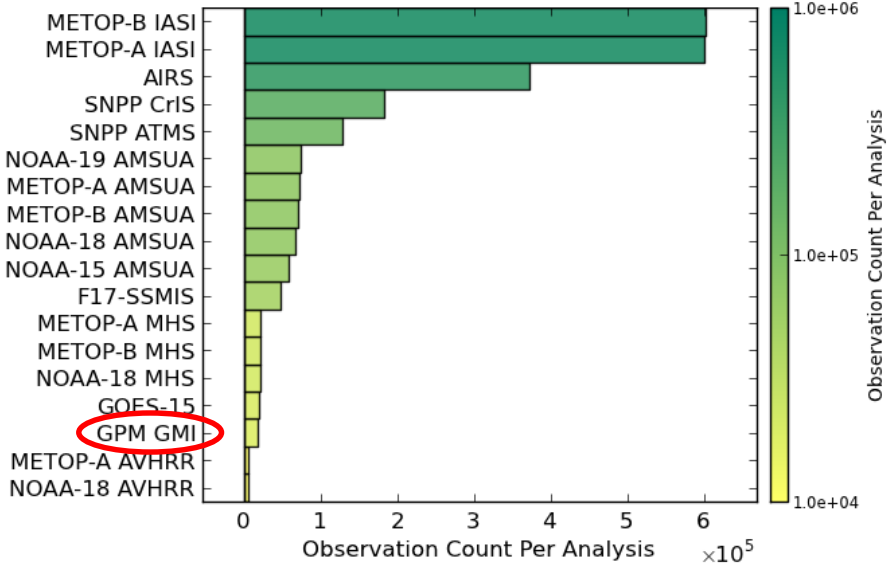
Combining GMI assimilation with retuned model physics extends the beneficial impacts into the medium range. The retuning modifies the effective radii and fall-rate of ice crystals.



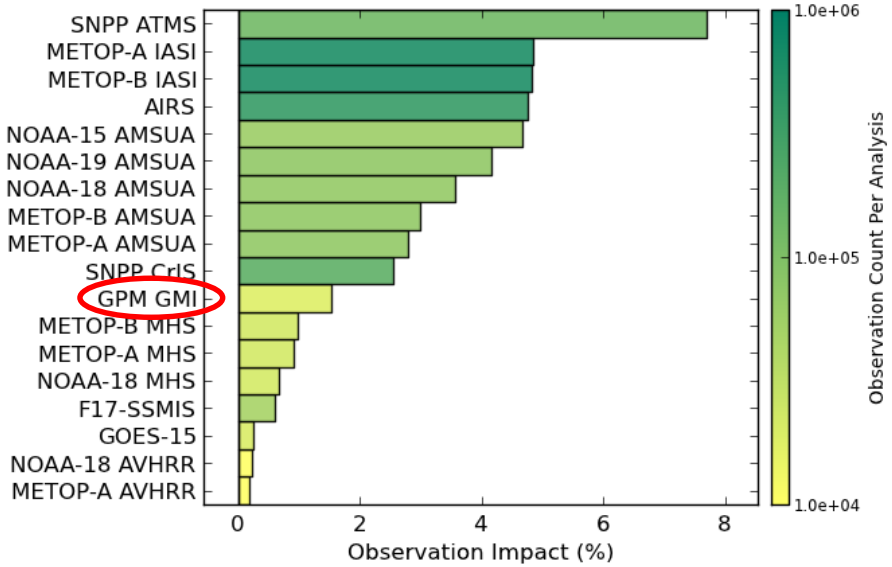
Current GEOS production observation impacts

Global Moist Energy Norm Aug – Nov 2018 00UTC

Observation Count



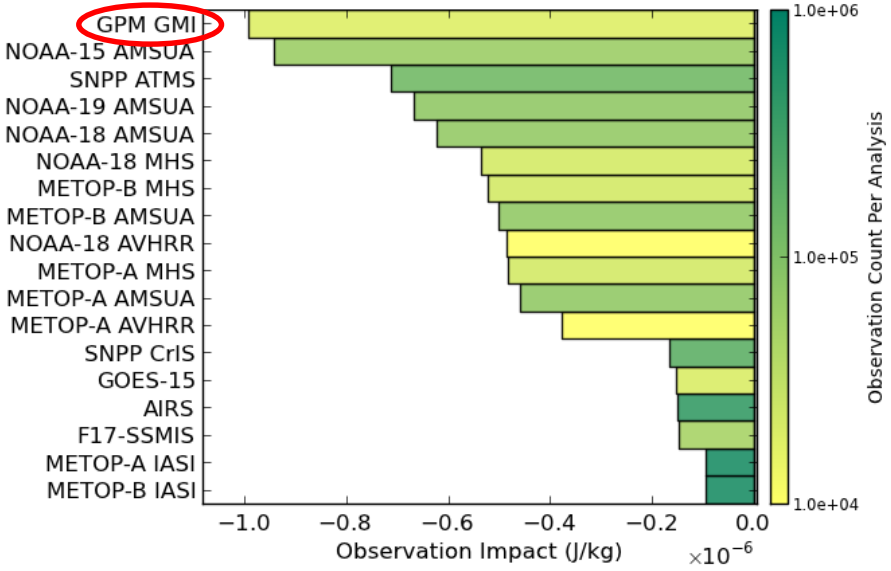
Total Impact



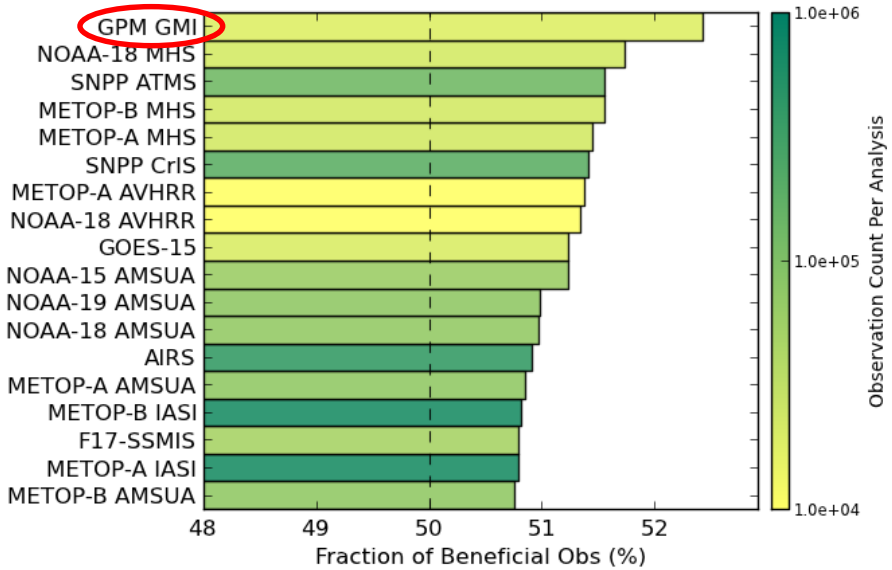
Current GEOS production observation impacts

Global Moist Energy Norm Aug – Nov 2018 00UTC

Impact Per Observation



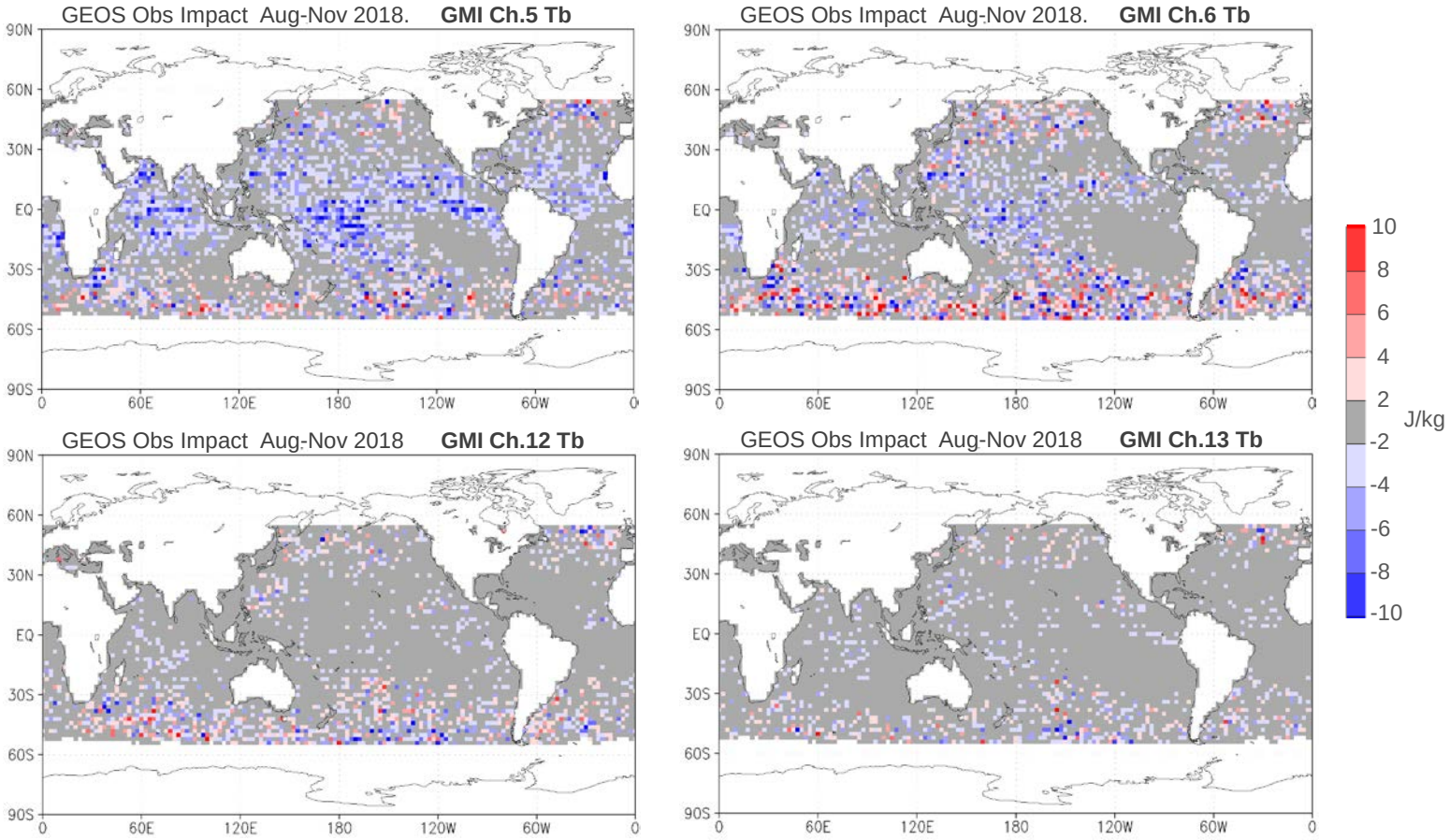
Fraction of Beneficial Obs



Current GEOS production observation impacts

Low Frequency

High Frequency



Concluding remarks

All-sky assimilation of GPM Microwave Imager (GMI) radiances was successfully implemented in the GEOS real-time production system on 11 July 2018.

All-sky GMI radiances have a significant positive impact on GEOS forecasts of tropospheric water vapor, temperature and winds especially in the tropics.

Assimilation of GMI all-sky radiances in hybrid 4D-EnVar adjusts not only hydrometeors but also dynamic variables such as wind and pressure.

GMI all-sky radiances over land surfaces will be included in a near-future implementation of the GEOS production system, as will all-sky radiances for MHS, ATMS, AMSU-A and AMSR-2.

All-sky techniques are being applied to historical microwave instruments such as TRMM/TMI for future GMAO reanalyses.