Status and Progress of Observation Usages in the GMAO GEOS Atmospheric Data Assimilation System

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Abstract

The Global Modeling and Assimilation Office (GMAO) continuously works to enhance the use of observations in the Goddard Earth Observing System – Forward Processing (GEOS-FP) model and analysis system. Updates to GEOS-FP in March 2022 and February 2023 focused on the analysis component, adding new capabilities to ingest radiances and other new observing systems, such as SPIRE GNSS-RO data. Concurrent activities enhance aspects of the radiance assimilation, such as the use of hyperspectral radiances in the stratosphere and lower troposphere, the introduction of microwave radiances over land, and a revised treatment of GMI observations. Furthermore, GMAO has been contributing to the Joint Effort for Data assimilation Integration (JEDI), including development and testing of various components of the observing system and GEOS-specific background error covariances that will allow migration of GEOS-FP from a GSI- to a JEDI-based analysis system. A number of examples are shown.

1. Recent upgrades of GEOS-FP

GEOS configuration

- FV3 dycore + GEOS physics suite
- GSI hybrid 4D EnVar, 4D Incremental analysis update
- Aerosol assimilation

Key updates since last ITSC

- CRTM update to CRTM v2.3.0
- Revised treatment of GEOS-16 AMVs (thinning and observation error) to address the issue found in Zhu et al 2022
- Modifications to observation operator for RO data
- Correction for high-latitude buoy observations handling
- Updates to the input observing system:
  - IASI Metop-C radiances
  - Radio occultations from KOMPSAT and Paz
  - Commercial radio occultations from SPIRE
- Assimilated radio occultation data top lowered from 60 km to 55 km
- Incorporation of version v1.12.3 of the forecast model
- Orbital parameters updated in the radiation scheme
- Revised Henry's Law constant for NH_3
- Updated scavenging coefficients for gaseous constituent species CO, CO_2, CH_4 and NH_3

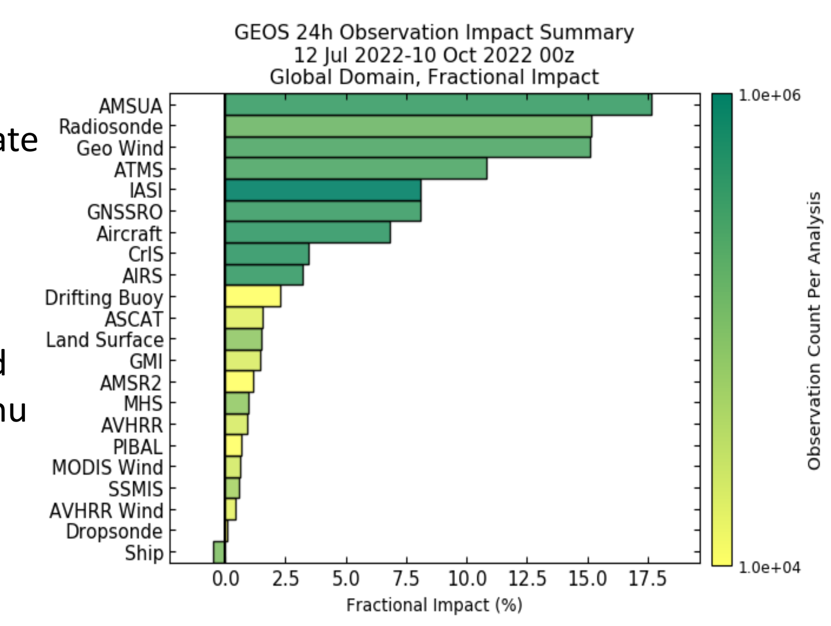

Figure 1: FSOI results for GEOS-FP system.

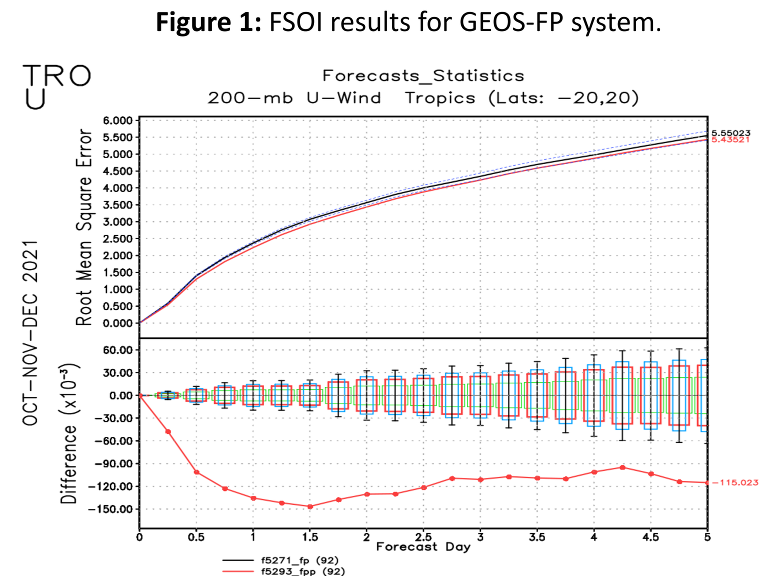

Figure 2: Revised handling of GEOS-16 AMVs significantly improved forecast RMSE

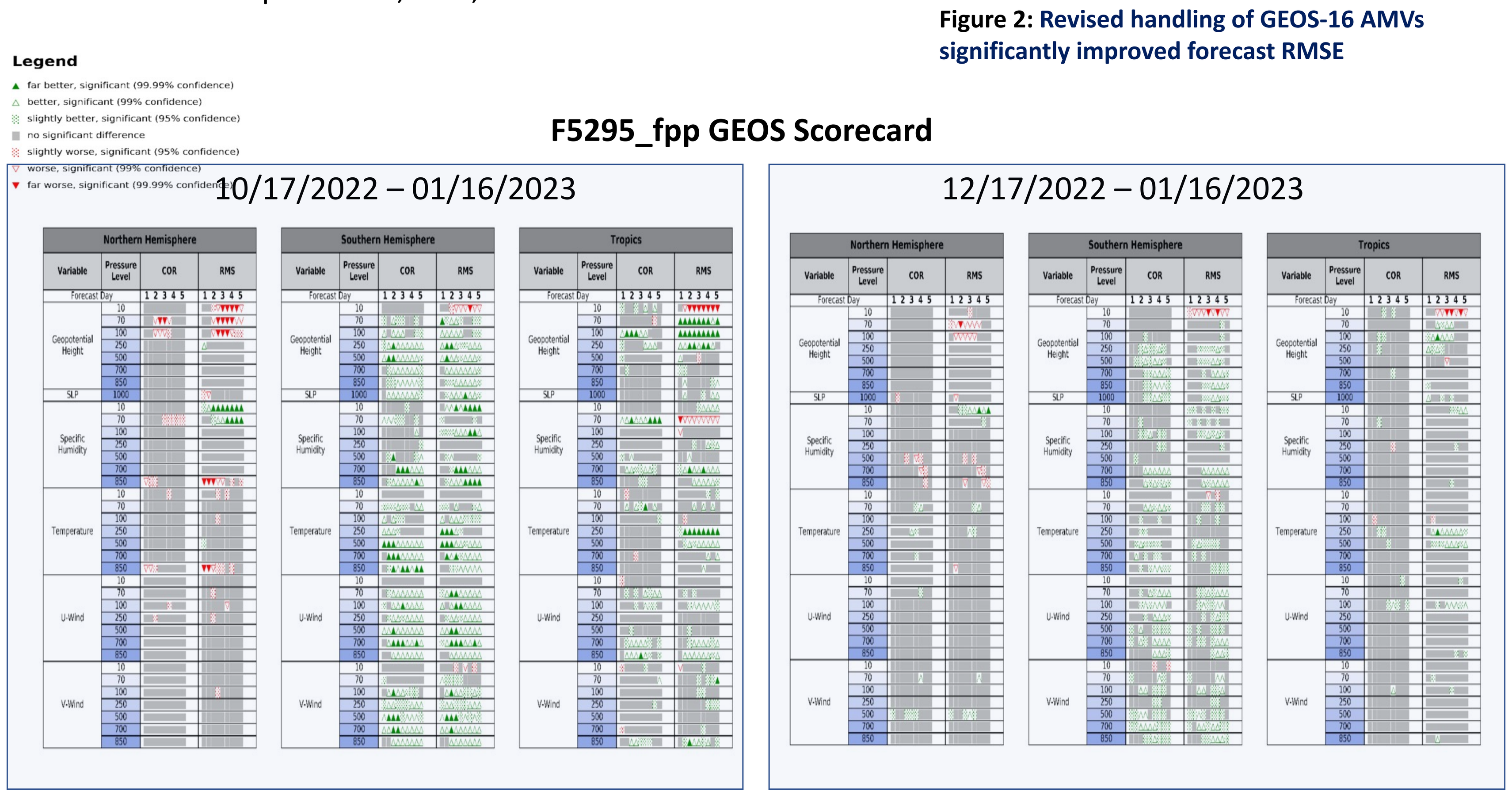

Figure 3: Comparison of scores for f5294_fp (Control) and f5295_fpp experiments: **Added Spire RO data has slightly positive impact on forecast skill in Fall/Winter (Left) but neutral impact in Spring (Right)**

2. Improving the use of MW and IR data in GEOS

- **Evaluation of using CRTM v2.4.0 in the GEOS**
- **Revisit of the handling of GMI data to address the issue of small data sample used for GMI bias correction**
- **Assimilation of surface-sensitive MW radiances from AMSU-A/ATMS over land**
- **Use of additional IR channels in upper stratosphere + turn on AMSU-A ch14/ATMS ch15 bias correction**

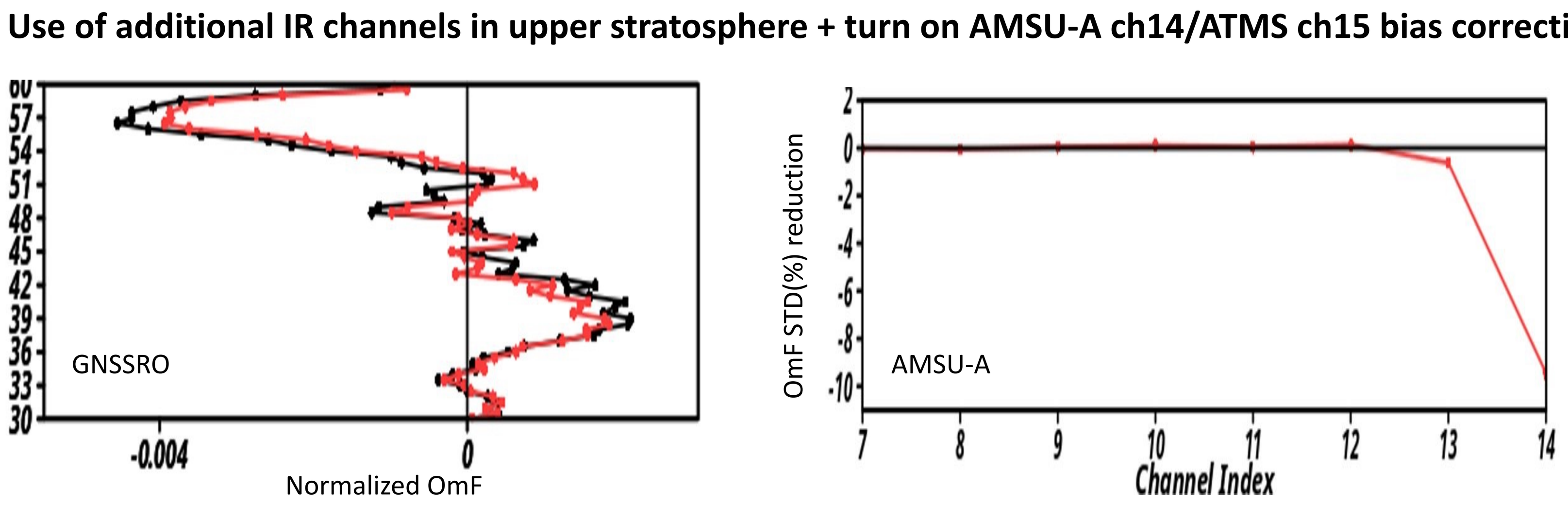

Figure 4: Adding IASI ch92, ch93 and ch95 in upper stratosphere and turning on bias correction for AMSU-A ch14/ATMS ch15 improve OmFs of RO bending angle (Left) and AMSU-A Metop-b (Right).

- **Modifications to treatment of IR assimilation to address unrealistic bias of surface-sensitive channels and negative data impacts due to poor cloud detection** (see B. Karpowicz 15p.08)
  - Change channels used for cloud detection and adjust correlated observation error
  - Tighten gross error check to remove problematic cloud

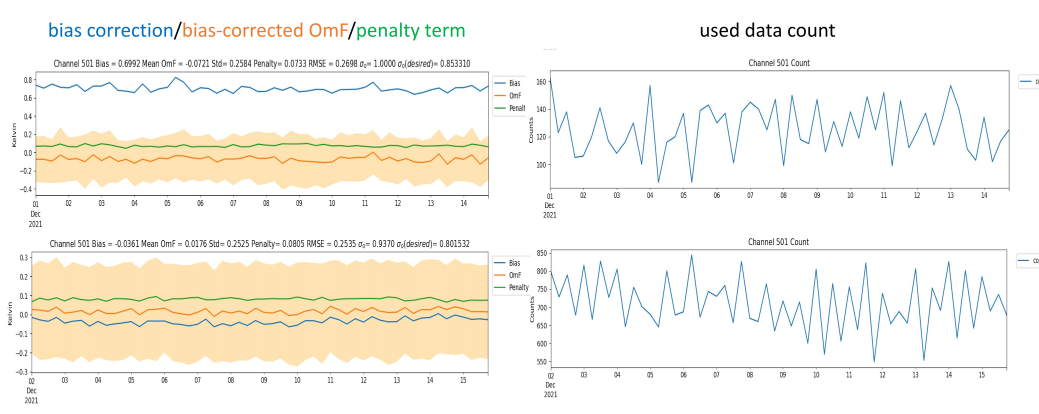

Figure 5: OmF statistics and used data count for CrIS channel 501 before (Upper) and after (Lower) the fixes.

- **Improving the assimilation of IASI and CrIS radiances over land** (see N. Boukachaba, 10.01)
  - LST is retrieved from IASI channel 1194 and CrIS channel 501 (both 962.5cm^{-1}) and used for radiance simulation
  - Bias correction/quality control are adjusted
  - The use of retrieved LST increases the number of assimilated surface-sensitive radiances

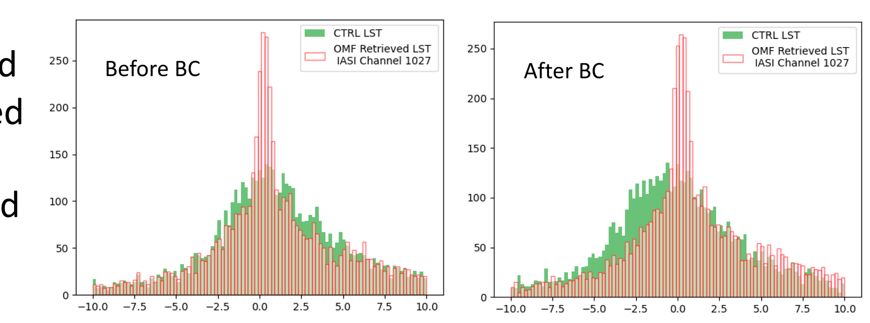

Figure 6: IASI channel 1027 OmF Histograms of radiances over land in CTL (green) and using retrieved LST (red).

- **Evaluation of active-passive microwave land surface database using GEOS** (Karpowicz et al. 2022)

Surface	10.6 GHz V	10.6 GHz H	18.7 GHz V	18.7 GHz H	23 GHz V	37 GHz V	37 GHz H	89 GHz V	89 GHz H	166 GHz V	166 GHz H	183 V +/- 3 GHz	183 V +/- 7 GHz
Land	LandEm	LandEm	LandEm	LandEm	LandEm	LandEm	LandEm	0.95	0.95	0.95	0.95	0.95	0.95
Snow	LandEm	LandEm	LandEm	LandEm	LandEm	LandEm	LandEm	0.9	0.9	0.9	0.9	0.9	0.9
Ice	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92

Table 1: Surface emissivity used in the CRTM for GMI over different surface types.

- All-sky GMI radiances channels 5, 6, 10, 12, 13 are assimilated over ocean only
- Over land, snow, and sea ice, replacing the default CRTM emissivity by a 5-year climatological database for retrieved microwave emissivity from GPM GMI (Munchak et al 2020) can significantly improve simulation of brightness temperatures from GMI over land

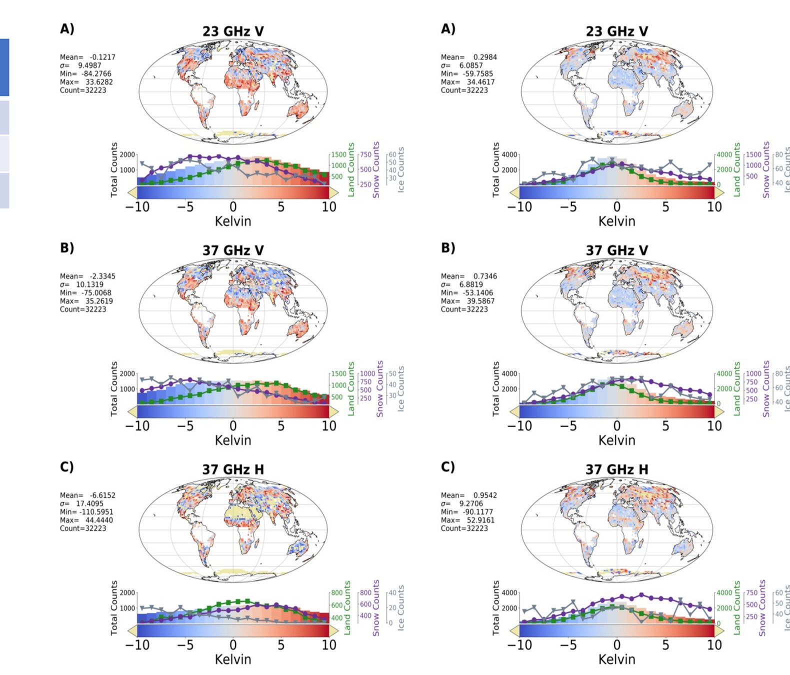

Figure 7: GMI OmF using the default surface emissivity in CRTM (Left) vs. using Munchak et al. 2020 (Right).

3. Development of JEDI-based GEOS

Transition of the GSI-based GEOS atmospheric data assimilation system to JEDI-based GEOS will occur in phases. The planned initial implementation of the JEDI-based GEOS system focuses on background error covariance and observation operator configurations to ensure consistency with GSI data usages.

- Added new filters and functions to UFO to match GEOS data usages

Conventional data:

- Duplicate observation error inflation
- Pressure/Geometric check
- Surface pressure correction height variable option Ambiguity check for scatterometer winds

Radiances:

- Filter to reject IR data over certain surface types
- Bug fixes in AVHRR cloud detection
- GPM GMI, Updated forward operator for AMSR2
- AMSU-A/ATMS thick cloud QC & cloud BC, CRTM bugfix
- Updated MHS cloud index & observation error inflation
- Updated bias correction configurations for AMSR2, GMI

OBS Type	Status
GMI	Done
AMSR2	Done
MHS	Done
AMSU-A	Done
ATMS	Done
CrIS	Done
IASI	Done
AIRS	Done
AVHRR	Done
Ozone	Done
Winds	Satellite AMVs, scat winds, sondes, aircraft
Conventional temperature	Sondes, aircraft
Conventional moisture	Sondes
Conventional surface pressure	Surface, Surface marine, sondes
GNSS RO	In progress

Table 2: Status of observation operator configurations in the JEDI-based GEOS.

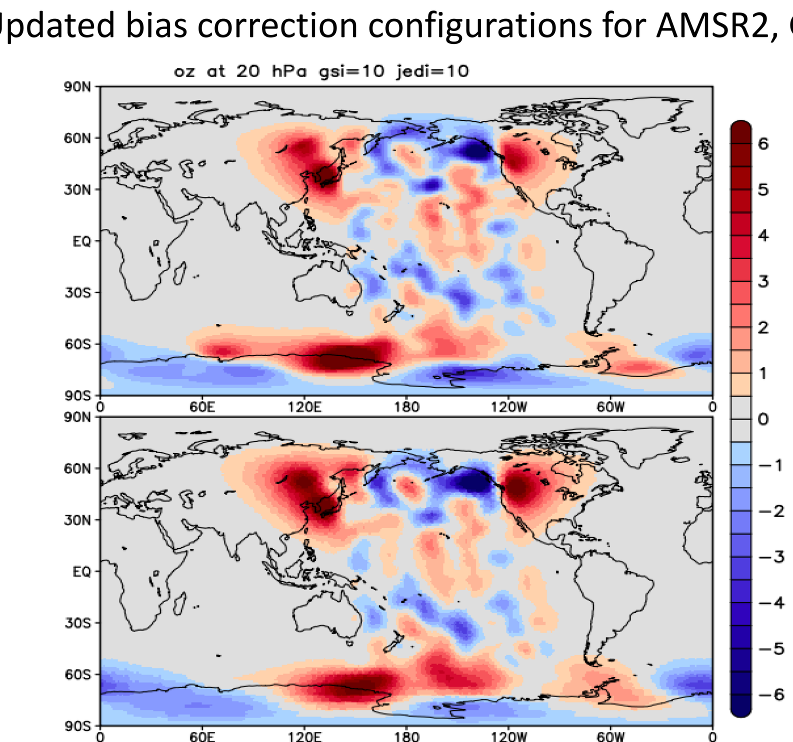

Figure 8: Ozone increment at 20hPa: GSI (Upper), JEDI (Lower).

4. Future plans

- Upgrade from CRTM v2.3.0 to CRTM v2.4.0 in the GEOS
- Assimilate JPSS-2 observations in the GEOS, continue to improve the usages of CrIS radiances
- Continue to improve radiance data usages over land, snow and ice
- Transition from assimilation of AMSU-A/ATMS antenna temperature to brightness temperature
- Expand all-sky radiance assimilation approach to AMSU-A and ATMS
- Further assess commercial GNSS RO data impact in the GEOS
- Finish remaining observation operator configurations for the JEDI-based GEOS, and evaluate observation configurations and impacts in the cycled JEDI-based GEOS

REFERENCES:
Karpowicz,B.M., Y. Zhu, S. J. Munchak, and W. McCarty. 2022. "Assessment of retrieved GMI emissivity over land, snow, and sea ice in the GEOS system." *Journal of Atmospheric and Oceanic Technology, 1433-1443.*
Munchak, Stephen Joseph, Ringerud, S., Brucker, L., You, Y., de Gelis, I., and Prigent, C.: An Active–Passive Microwave Land Surface Database From GPM, IEEE Transactions on Geoscience and Remote Sensing, Vol 58, Number 9 6224–6242 .
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