# The Transition of Satellite Observations Assimilated in GEOS to JEDI

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## Introduction

In order to incorporate the Joint Effort for Data assimilation Integration (JEDI) in the Goddard Earth Observing System (GEOS), which is used for weather, climate, and air quality forecasts and producing reanalysis datasets, it is necessary to validate the observing system in JEDI. NASA's Global Modeling and Assimilation Office (GMAO), with the Joint Center for Satellite Data Assimilation (JCSDA), is developing the Unified Forward Operator (UFO) and adding all the necessary features to replicate existing capability. Various satellite and conventional observations are assimilated by the Gridpoint Statistical Interpolation (GSI)–based GEOS atmospheric data assimilations system. GMAO has been adding, validating, and updating procedures including the GEOS all-sky microwave radiance assimilation framework to assimilate those observation in UFO. Robust tests are conducted to ensure correct configurations of observational data bias correction (BC), quality control (QC), and observation error in UFO and good agreements between UFO and GSI results. Our work on satellite observations is reported in this presentation.

## 1 Configuration of observation error and data quality control

GPM-GMI Level 1 Co-Registered (L1C-R) radiance data are assimilated by the GEOS atmospheric data assimilation system within an all-sky microwave radiance assimilation framework. A unique feature of this framework is that observational errors are functions of mean ($x$) cloud amount estimated from observation (ObsValue) and from the forward operator (Hof(X)):

$$
\begin{aligned}
error &= err_0, && \text{for } x < x_0;\\
error &= err_0 + (err_1 - err_0) * (x - x_0)/(x_1 - x_0), && \text{for } x_o \le x \le x_1;\\
error &= err_1 + (err_2 - err_1) * (x - x_1)/(x_2 - x_1), && \text{for } x_1 \le x \le x_2;\\
error &= err_2, && \text{for } x > x_2
\end{aligned}
$$

where $err_0$ is the error in clear-sky conditions and $err_1$ *and* $err_2$ are parameters tuned in cloudy-sky conditions. Figure 1 shows the configuration of the observational error assignment functions in a YAML file that control the UFO operator after the cloud retrieval function *CLWRetSymetricMW* for GMI is added. A good agreement between those effective errors calculated in UFO and the final observational errors estimated in GSI confirms that these cloud retrieval and error assignment functions are added correctly in UFO (Figure 2).


Figure 1, Configuration of GMI observational errors in UFO.

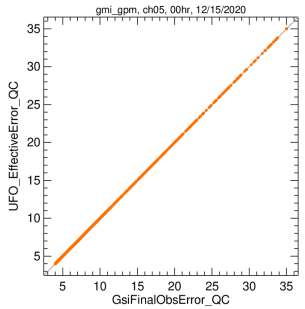


Figure 2, A comparison between UFO effective errors and GSI final observation errors for GMI channel 5 data.

Various GEOS GSI-based data quality control procedures are added for GMI, AMSUA, AIRS and many other satellite data. Those procedures include "domain checks" and "bounds checks" of locations, surface types, sea surface temperature, observational values, cloud retrieval values, surface emissivity values, etc. Bias correction is conducted with cloud amounts, scan angles or positions, atmospheric temperature lapse rates and mean biases. Initial observation errors are assigned as constants or functions of cloud amounts as shown above. For some observations such as AMSUA brightness temperature, observational errors are inflated using relationships to topography, transmittance and surface Jacobian values. Finally, observations are rejected if departures (observation – Hof(X)) are larger than so-called gross error ranges.

## 2 UFO configurations of satellite observations assimilated within GEOS GSI

The UFO assimilation procedures for satellite radiance data and GNSSRO observations assimilated within GEOS are validated and updated and new procedures are added. About three million observations, collected from various sources (Table 1), are used within a six-hour time window centered at 2020-12-15T00:00:00Z. The whole data sets are transformed into IODA format along with meteorological fields (GeoVaLs) interpolated by GSI. Meticulous effort is taken to compare UFO and GSI outputs. The metrics considered are Hof(X) values before and after bias correction, data usage after quality control, and the final error assignment. Any disagreements between them are vigorously investigated in order to eliminate them or understand them. Many new UFO functions are added during this process. Overall, the UFO operator can reproduce GSI results for those satellite data as shown, for example, in Figure 3. Table 1 lists all satellite observation configurations which we have investigated in UFO.

| Observation and assimilation types | Satellite data sets | Hof(X), no bias correction | Bias correction (BC) | Quality control (QC) | Hof(X) with BC and QC |
|---|---|---|---|---|---|
| Microwave radiance in clear-sky assimilation | AMSUA - Aqua | ● | ● | ● | ● |
| | AMSUA-Metop-A | ● | ● | ● | ● |
| | AMSUA-Metop-B | ● | ● | ● | ● |
| | AMSUA-Metop-C | ● | ● | ● | ● |
| | AMSUA-N15 | ● | ● | ● | ● |
| | AMSUA-N18 | ● | ● | ● | ● |
| | AMSUA-N19 | ● | ● | ● | ● |
| | ATMS-NPP | ● | ● | ● | ● |
| | ATMS-N20 | ● | ● | ● | ● |
| | SSMIS-F17 | ● | ● | ● | ● |
| Microwave radiance in all-sky assimilation | AMSR2-GCOM-W1 | ● | ● | ● | ● |
| | GMI-GPM | ● | ● | ● | ● |
| | MHS-Metop-B | ● | ● | ● | ● |
| | MHS-Metop-C | ● | ● | ● | ● |
| Infrared radiance | AIRS-Aqua | ● | ● | ● | ● |
| | Cris-N20 | ● | ● | ● | ● |
| | Cris-NPP | ● | ● | ● | ● |
| | IASI-Metop-A | ● | ● | ● | ● |
| | IASI-Metop-B | ● | ● | ● | ● |
| | AVHRR-Metop-A | ● | ● | ● | ● |
| | AVHRR-N18 | ● | ● | ● | ● |
| GNSSRO | GNSSRO | ● | | ● | |

● UFO results are identical or nearly identical to GSI results ● No sea skin temperature assimilation for AVHRR

Table 1, A list of satellite observations for which the UFO operators are validated against GEOS GSI results.

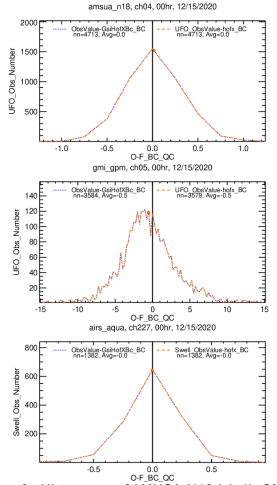


Figure 3, Histograms of AMUSA-N18 (ch 4), GMI-GPM (ch 5), and AIRS-Aqua (ch 227) departures (O-F) after BC and QC in UFO and GEOS GSI output.

## 3 Major contributions in UFO/JEDI developments and summary

In summary, GMAO made various contributions to the UFO system, including:

- Incorporated the GEOS all-sky microwave radiance data assimilation framework in UFO.
- Added new operators for AMSR2 and GMI observations.
- Added cloud retrieval functions for AMUA, AMSR2, GMI, MHS, etc.
- Added and updated various UFO quality control functions for microwave and infrared satellite observations.
- Updated the bias correction operator for radiance observations.
- Various updates in IODA converter to convert GEOS GSI outputs into IODA testing files.

Essentially perfect agreement between the use of satellite data in UFO and GSI is achieved with all the additional features GMAO have added to UFO and when GeoVaLs data interpolated by GSI are used in UFO. A next round of validations is planned, where FV3-JEDI is used to provide the meteorological GeoVaLs. In addition, updated BC coefficients will be investigated to ensure BC is conducted correctly in UFO.

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