A Preliminary Comparison of GEO-GSI with GEOS-JEDI Using the Complete GEOS Observing System

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GMAO

Global Modeling & Assimilation Office

Poster number?

Transitioning the NASA GMAO GEOS data assimilation capabilities to JEDI involves replacing the GEOS Gridpoint Statistical Interpolation (GSI) with a JEDI-based analysis. Performing fair comparisons between the corresponding GEOS-JEDI system and the present GEOS-GSI has involved downgrading the latter's capabilities to compensate for missing capabilities in the former. As the capabilities in JEDI mature and start matching those of GSI's, experimentation has evolved from simple 3DVAR using only radiosondes, to adding satellite observations without VarBC, to now having GEOS-JEDI use hybrid 4DEnVar and full observing system, VarBC and most of the knobs typically used in the present operational (and experimental) version of GEOS-GSI. This presentation provides a discussion of the process and pathway taken to replace GSI with JEDI in GEOS at GMAO. The presentation also shows latest results of testing in the still relatively simply context of 3D-FGAT, but now having JEDI use the whole of the typical observing system used in GEOS. Results are encouraging but preliminary, with various caveats having been identified during the attempt to cycle JEDI analyses. Solutions to most of the identified problems have been worked out, but a few pending issues are still being worked out.

Experimental Settings for Comparing JEDI and GSI in GEOS

The current GMAO hybrid 4DEnVar Atmospheric Data Assimilation System supports variations applications:

- ❑ The 12.5 km GEOS-FP (near-real-time, quasi op).
- ❑ A 25 km GMAO OSSE.
- ❑ A 25 km MERRA-21C (about to).

The ADAS Workflow also supports other Var flavors, in particular, traditional 3DVar which is used for multiple purposes, from research to Instrument Teams deliverables.

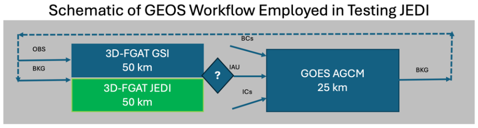
GMAO is transitioning to JEDI in a phased approach:

I. a) Add deterministic JEDI analysis (Hyb 4DEnVar).
   b) Replace deterministic GSI with JEDI (H4DEnVar).
II. Replace ensemble analysis (EnSRF to LETKF or EDA).
III. Replace workflow.

	ca. Winter 2023-24
Algorithm & BEC	Hyb4DEnVar-GSIBEC
Ana Resolution	c180 & c90
Outer/Inner Loops	2/50x25
VarBC	Yes
Correlated IR Rad Channels	Yes
CTL experiment	GSI no Constraints
Date	00Z 12 Dec 2021
Aircraft	YES
AIRS Aqua	YES
AMSR2 GCOM W1	YES
AMSU-A Metop-B	YES
AMSU-A Metop-C	YES
AMSU-A N15	YES
AMSU-A N18	YES
AMSU-A N19	YES
ATMS N20	YES
ATMS NPP	YES
AVHRR Metop-B	YES
AVHRR N18	YES
AVHRR N19	YES
CrIS-FSR N20	YES
CrIS-FSR NPP	YES
GNSS RO	YES
GMI GPM	YES
IASI Metop-B	YES
IASI Metop-C	YES
MHS N19	YES
MLS55 Aura	YES
OMI Aura	YES
OMPNM NPP	YES
Pibal	NO
Sat Wind	YES
Land Obs	YES
Marine Obs	YES
Radiosondes	YES
SSMIS F17	YES

Table 1: Observing systems used in comparison experiments discussed on the right.

Schematic of GEOS Workflow Employed in Testing JEDI



The main test experiments discussed here use 3D-FGAT to compare GSI and JEDI. The GSI configuration is downgraded from its full capabilities to match JEDI as close as possible and adjust to inexistent features in the latter, namely, GSI uses:

- ❑ No Background Error Flow Dependence
- ❑ No TLNMC
- ❑ No Dry-Mass constraint
- ❑ Single middle loop
- ❑ Constant CO2 prescription for CRTM purposes
- ❑ No cycled aircraft bias correction

Two experiments are conducted in parallel using the Workflow in the schematic above:.

- ❑ One cycles a typical GEOS-GSI, but using 3D-FGAT.
- ❑ Along with this, each cycle also produces an analysis with JEDI using VarBC inputs from GSI; in this, the JEDI analyses do not feedback to the cycle.
- ❑ Another experiment, is setup identically as the first, but has JEDI cycling its own VarBC output. Also, from a certain date onward this cycle switches from having the GEOS GCM use GSI analyses to having JEDI analyses being used instead..

The objective of this setup is to test: (i) VarBC; (ii) the closeness of increments between the two analyses; and (iii) the response of the system when JEDI analyses are used in IAU and passed to GEOS Atmospheric GCM, in place of the GSI analyses.

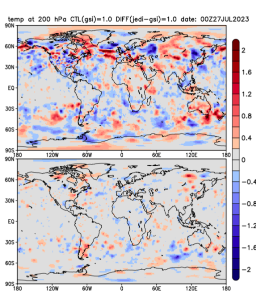


Figure 2: T at 200 hPa after a number of cycles. Top: GSI increment; Bottom: increment difference: JEDI-minus-GSI.

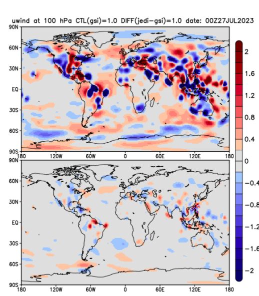


Figure 3: As in Fig. 2, but for Zonal Wind at 100 hPa.

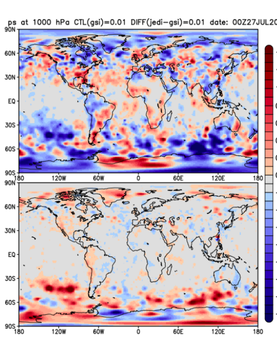


Figure 4: As in Fig. 2, but for surface pressure.

A few cycles into the control CTL a comparison of increments from the cycling GSI analysis with the non-cycling corresponding JEDI analysis shows a combination of favorable and puzzling results: Figs. 2 and 3 (above), compare increments of 200 hPa temperature and 100 hPa zonal winds and show only what appears to be relatively small differences in the increments (bottom panels). A comparison of surface pressure (Fig. 4; left) shows considerably more differences in the increments specially in the Southern Hemisphere.

Closer, and tedious, examination of the results eventually revealed an issue in the JEDI analysis interface that fails to pass 3-dimensional pressure information to the linear observation operators that require such information. One such, and crucial, operator of is that handling the assimilation of GNSSRO observations.

Another similar (known for awhile) issue in JEDI's analysis is in its lack of proper accountability of skin temperature information associated with sensitivity terms in the assimilation of radiance observations. Although the climatological background error covariance used in JEDI (same as that used in GSI) carries a skin temperature term, no skin temperature information has been properly passed to the linear observation operator (CRTM) used in the JEDI interface supporting GEOS applications.

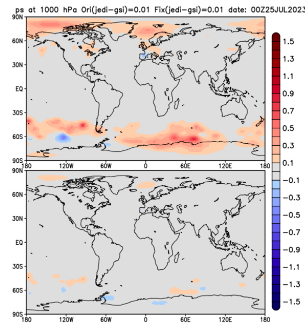


Figure 5: Surface pressure increment differences with GSI when 3d-pressure missing in GNSSRO linear operator (top) and when linear operator has 3d-pressure (bottom).

A correction is in the works to address this issue associated with the handling of 3D pressures required by some observation operators. An illustration of the improvement in the increments obtained when only SPIRE observations are used in the analysis is given in Fig. 5 (left).

A complementary modification in the JEDI interface supporting GEOS applications has also recently been introduced that now allows for the sensitivities of brightness temperature to skin temperature to be properly accounted for. Figure 6 (below) shows increments of skin temperature when only assimilating ATMS-N20 – simply as a test for the added skin temperature.

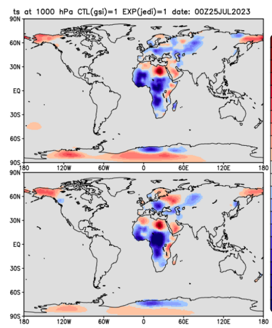


Figure 6: Skin temperature increment from GSI (top) and JEDI (bottom) after implementing correction in JEDI so skin temperature information is properly passed to the linear operators associated with the assimilation of radiances; case study assimilates only ATMS-N20.

Unfortunately, the skin temperature issue is not yet fully solved. The IR instruments (more clearly seen in hyperspectral instruments) show an unphysical skin temperature increment; this is illustrated in Fig. 7 (below) when only IASI from MetOp-B is assimilated.

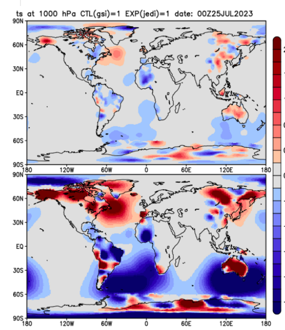


Figure 7 (left): Similar to Fig. 6, but for IASI on MetOp-B.

Back to the brief evaluation of the two experiments, Fig. 8, shows JEDI analyses observation minus background (O-B) residual statistics for ATMS-N20 for a number of cycles until the experiments were stopped. Up to cycle 21, the only difference between the CTL and EXP is that CTL JEDI does not cycle VarBC (it takes it from GSI). Within this period, having JEDI cycle its own VarBC amounts to smaller O-B residuals for the temperature channels of ATMS (results are somewhat mixed for water vapor channels). After cycle 21, EXP has the GCM "listening to" JEDI analyses (as opposed to GSI's); when that happens, the O-B residuals start getting larger (esp. in std-dev).

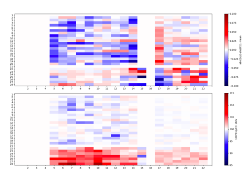


Figure 8: Comparison of ATMS-N20 global JEDI O-B residual statistics between two experiments in studied here. Blue colors indicate EXP has smaller mean and std-dev O-B than CTL.

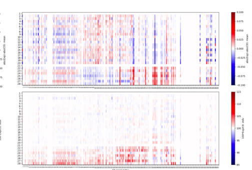


Figure 9: Similar to Fig. 8, but for IASI on MetOp-C.

Figure 9 is similar to Fig. 8, but for IASI on MetOp-C. Before JEDI feedback its results to the GEOS model (cycled 21), the upper tropospheric channels (mid-range indexes) show some worsening in the mean when JEDI cycles its own VarBC, whereas other channels seem to do better with cycled VarBC; the standard deviations are rather neutral in this period. When the model starts getting JEDI analyses the behavior in the mean switches and the standard deviations deteriorate throughout.

Closing Remarks

We have been striving to obtain variational analyses from JEDI that are as close as possible to those obtained with GSI (the analysis system used to derive GMAO's atmospheric assimilation products). We are getting close to achieving our goal but a few issues remain to be tackled:

Target for next cycling exercise:

- ❑ Test with a fully cycling version of the aircraft bias correction.
- ❑ Resolve issue associated with skin temperature sensitivities from IR observations.
- ❑ Complete implementation of 3D-pressures for linear operators.
- ❑ Finalize implementation of background-dependent CO2 for radiance assimilation (not discussed in this poster).
- ❑ Scaled RH as moisture control vector (not discussed in this poster).

Target for cycling after that:

- ❑ Inclusion of TLNMC (initialization procedure)
- ❑ Two middle loops in minimization
- ❑ Full hybrid 4D-EnVar

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