Status and Ongoing Developments of In-situ and Satellite Data Assimilation in the NASA GMAO's GEOS System

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Abstract

The Goddard Earth Observing System (GEOS) developed at NASA Global Modeling and Assimilation Office (GMAO) produces operational-quality products to support NASA's Earth Science missions and diverse user communities, by combining advanced GEOS atmospheric model with a wide range of observations from various observing systems. While progress has been made in increasing model resolution and improved physics, the GMAO continuously enhances observation usage and develops new methods to advance the GEOS capabilities and performance. The GEOS Forward Processing (FP) system for real-time NWP is routinely upgraded, and efforts are also underway to assimilate new observations and prepare for future observing systems. The latest advancements in observation usage have also been incorporated into the GMAO's newly implemented MERRA-21C. Meanwhile, GMAO has completed the transition, testing and validation of all operational observations used in the GEOS-FP to the JEDI. A cycled JEDI-based GEOS version is expected to be released this year.

1. Recent and upcoming upgrades of GEOS-FP

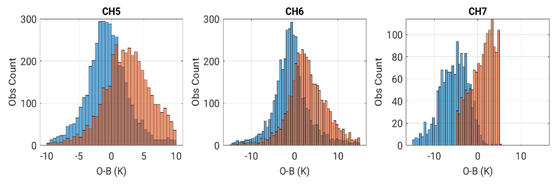
GEOS configuration

- FV3 dycore + GEOS physics suite, 12.5 km with 72 levels
- GSI hybrid 4D EnVar, 4D Incremental analysis update
- Aerosol assimilation

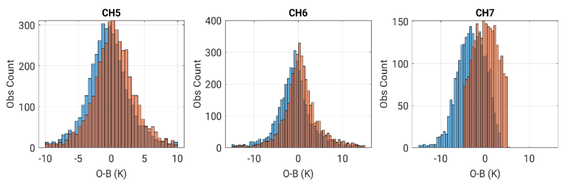
Key updates since last ITSC

- Improvement of all-sky GMI radiance assimilation
- Assimilation of ATMS NOAA21
- Assimilation of RO data from PlanetIQ
- Assimilation of OMPS-LP NOAA21 ozone observations
- Update to account for erroneous reports of observed surface pressure from some ships

GMI OmF before modifications (Before BC/After BC)



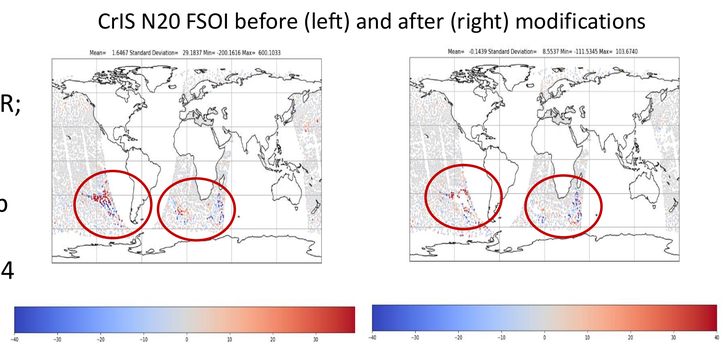
GMI OmF after modifications



Changes included for the upcoming upgrade

- CRTM v2.4.1
- Assimilation of AVHRR Metop-C
- Revised channel selection for CrIS-FSR; tightened gross error check for IASI, AIRS, CrIS
- Assimilation of AMSU-A and ATMS Tb instead of Ta
- Bias correction of AMSU-A channel 14 and ATMS channel 15

CrIS N20 FSOI before (left) and after (right) modifications



2. Ongoing development of observation usage in the GEOS-FP

As NOAA will end delivery of all data from the POES constellation in June 2025, we have been preparing for these and any other potential losses of data since later last year for the GEOS-FP with the following efforts to minimize the impacts of any potential data loss:

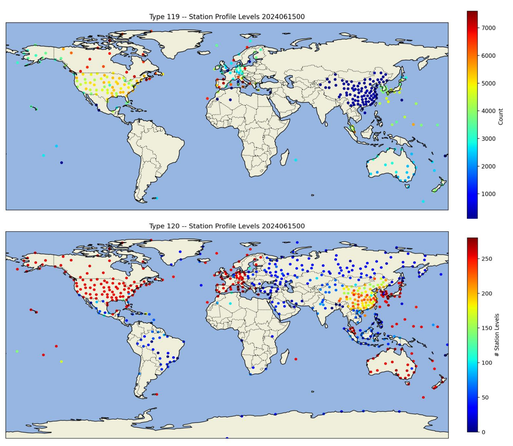
- The testing of clear-sky ATMS N21 was finished and included in GEOS-FP;
- The testing of AVHRR Metop-C was finished;
- The following assimilation experiments are underway
- VIIRS JPSS
- All-sky ATMS
- CrIS N21

Assimilation experiments with high-res radiosonde, GOES-16/18 (also 19), all-sky IR, TROPICS, radar, reconstructed radiances are also ongoing, with more details shown below.

❑ Assimilating high-resolution radiosonde data

- High frequency measurements up to 1 sec^{-1} of T, q, uv, new *uprair* bufr files disseminated by NCEP
- Five new observation types, including two for descending radiosondes

KX	Description
118	Descent data (mass)
119	Ascent data (mass)
217	Descent data (wind)
218	Ascent data (wind) *no pressure
219	Ascent data (wind)



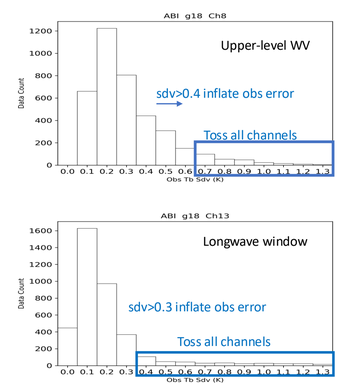
Approaches tested

- NCEP approach with high-resolution radiosonde
- Thinning: assimilate only observations closest to model gridpoint vertical center
- Superobbing: combine all observations in level
- Smoothing: apply binomial filter to profile with desired time kernel width

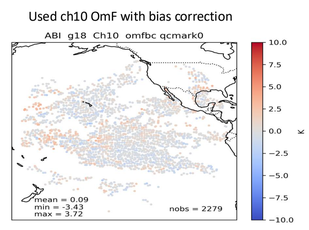
- Assimilating high-res radiosonde observations produces modest forecast improvements at upper levels

- Lack of prepBUFR QC still presents a challenge that must be addressed, along with implementation in JEDI

❑ Use of GOES-16 and 18 radiances



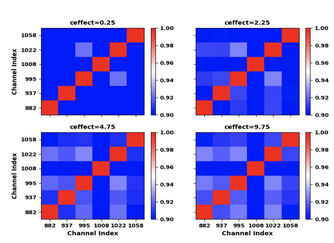
- Testing of ABI CSR product from GOES-16, 18 is underway
- Observations from water vapor channels are being assimilated: 6.2, 6.9, 7.3 μm



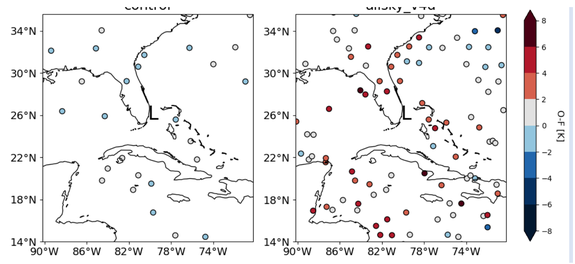
- Tightened existing quality controls, based on clear-sky ratio and inhomogeneity of FOR, split window channels being used to remove opaque clouds for lowest water-vapor and surface channels
- Slightly positive impact on model forecast

❑ All-sky CrIS radiance assimilation

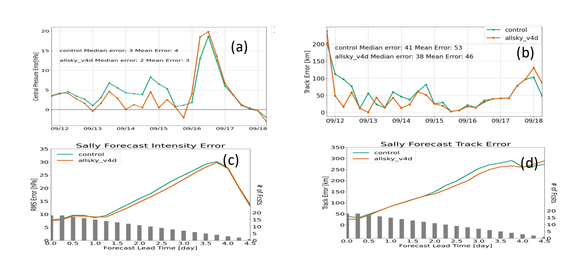
Our initial focus is on 6 water-vapor channels, with the lowest peaking channel (882, 7.605μm) around 695hPa and the highest peaking channel (1008, 7.175μm) around 382hPa.



All-sky IR observation error model is cloud-amount dependent and interchannel correlated



OMF of used radiances from channel 882 around Hurricane Sally. (a) clear-sky (b) all-sky.

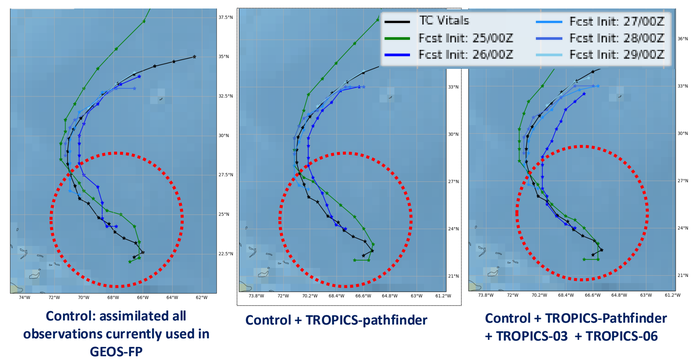


The assimilation of cloud-affected observations has a positive impact on the analysis (a,b) and forecast (c,d)of Hurricane Sally.

❑ TROPICS radiance data assimilation

- 3U cubeSat, cross-track temperature and water vapor microwave sounders
- Received calibrated and validated datasets for TROPICS-03, TROPICS-05, and TROPICS-06 from the calibration team at MIT in August 2024.
- Extended the GEOS all-sky DA system to incorporate radiance data from all four TROPICS satellites.

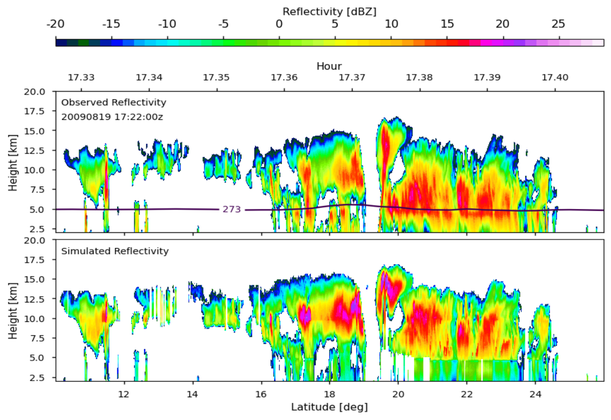
Impacts of single vs. multiple TROPICS satellites on hurricane forecast



Control: assimilated all observations currently used in GEOS-FP

Control + TROPICS-pathfinder

Control + TROPICS-Pathfinder + TROPICS-03 + TROPICS-06



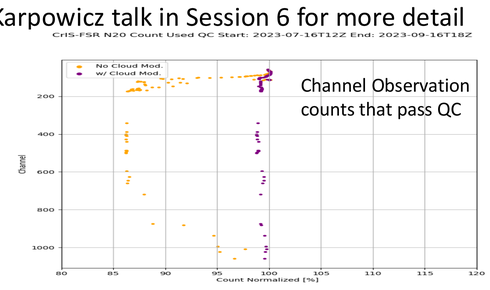
❑ Radar data assimilation

CloudSat Cloud Profiling Radar (CPR) observations vs CRTM simulated reflectivities. CloudSat overpassed Hurricane Bill on August 19, 2009.

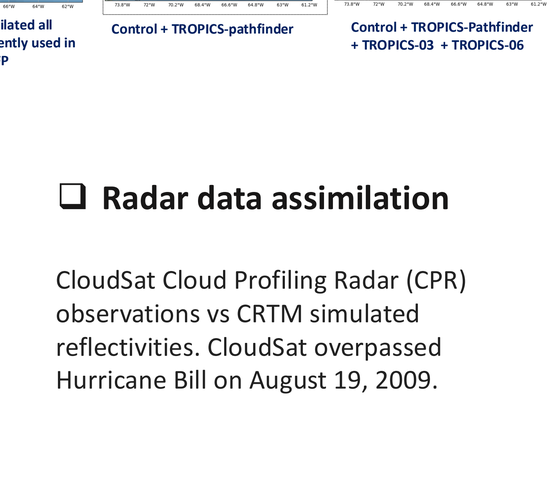
❑ Preparing for future use of reconstructed radiances

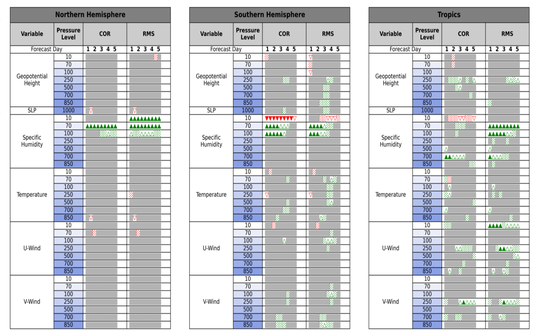
To understand how GEOS responds to using reconstructed radiances in preparation for MTG-IRS and GeoXo which will use PC scores to transmit observations

- Earlier experiments indicated the need to adjust cloud detection to preserve surface sensitive channel counts and some degradation of forecast skill in Q at 850 hPa
- Recent experiments using reconstructed radiances from CrIS PCA RED product from U. of Wisconsin show the need to adjust cloud detection remains, however, the results are neutral to slightly positive in terms of forecast impact
- See Karpowicz talk in Session 6 for more detail



Channel Observation counts that pass QC





Neutral-Positive forecast scorecard using reconstructed radiances from CrIS-PCRED against standard CrIS radiances

3. Looking forward: 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. The release of a cycled JEDI-based GEOS tag is expected soon this year.

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