Updates on Clear-Sky Radiance Assimilation from Geostationary Satellites at NCEP

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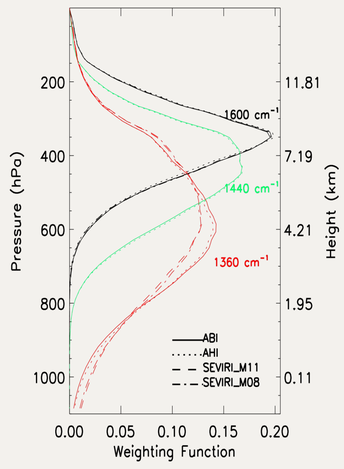
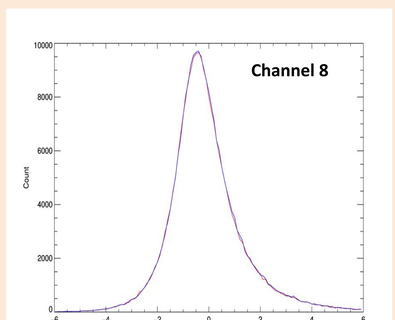
Background: The Clear-Sky Radiance (CSR) product is generated by averaging the brightness temperatures (BTs) for the infrared channels from the clear-sky pixels identified by a cloud mask in a processing segment. The percentage of the clear pixels and the standard deviation of the BTs from the clear pixels within the processing box are reported in the CSR product as well. National Centers for Environmental Prediction (NCEP) has been actively assimilating the CSR data in the global data assimilation system (GDAS) from the water vapor (WV) channels on several geostationary satellites, such as the ABI-GOES16 operated by the National Oceanic and Atmospheric Administration (NOAA), AHI-Himawari operated by Japan Meteorological Agency (JMA), and SEVIRI on Meteosat Second Generation (MSG) operated by EUMETSAT. The figure on the right shows the peaking functions of the WV channels from the ABI, AHI and SEVIRI instruments. We have previously demonstrated that assimilating these WV channels from the CSR products improves the humidify field in NCEP's operational Global Forecast System (GFS).

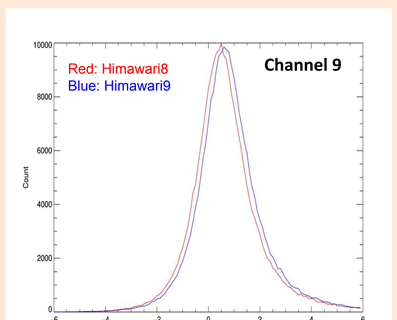


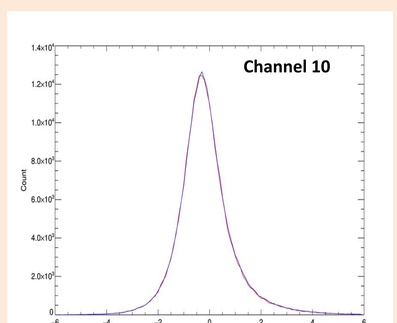
Since late 2022, there have been changes to the existing CSR products. Firstly, the SEVIRI CSR has been decommissioned since October 5, 2022. Secondly, on December 13, 2022, the Himawari-9 replaced the Himawari-8, becoming the JMA primary geostationary satellite and providing the AHI CSR product. Thirdly, GOES-18 (G18) is the third of the GOES-R series of geostationary weather satellites and its CSR data has become available in real-time since January 4, 2023. To prepare for a data upgrade implementation scheduled for this summer and to support the continued operational assimilation of the radiance observations from the geostationary satellites, we evaluate the quality of AHI_himawari9 and ABI_G18 through studying the statistical characteristics of these CSR products compared with their simulated model equivalences (OmFs). The GFSv16 6-hr forecast is used as the background and the Community Radiative Transfer Model (CRTM) version 2.4.0 is used as the radiance forward operator. Additionally, the ABI_G18 and AHI_Himawari9 CSR assimilation experiments are carried out and their data impact on global forecast skills is assessed. In order to use the SEVIRI All-Sky Radiance (ASR) product, GDAS code must be modified. As a result, SEVIRI ASR integration will be planned for the next model upgrade.

AHI OmF Himawari9 vs Himawari8

JMA distributed Himawari9 CSR experimental product for NWP users to evaluate prior to the switch between Himawari8 and Himawari9 satellites. The first guess departure (FG Depar or OmF) histogram plots for 3 WV channels comparing Himawari9 and Himawari8 AHI CSR products are shown below. The data samples are collected in 30 cycles from October 10 to 17, in 2022. The OmF bias from the Himawari9 increases by about 0.2K when compared to the OmF bias from the Himawari8 for the middle peaking WV channel 9. The other two WV channels' OmFs are comparable between the Himawari9 and Himawari8 CSR products.

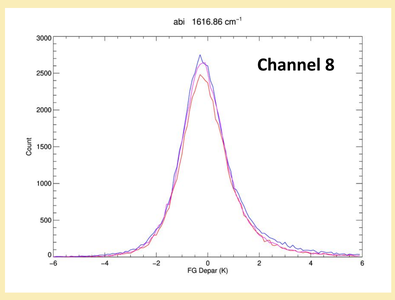


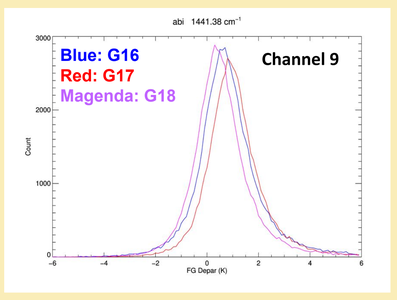


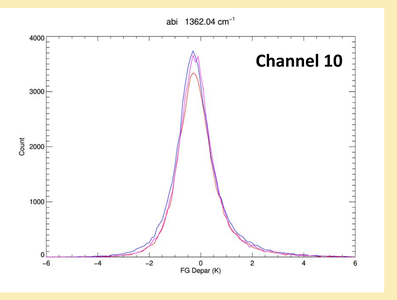


ABI OmF GOES-16 vs GOES-17 vs GOES-18

GOES-18 replaces GOES-17 as GOES West, covering the Pacific Ocean and the western U.S. (see the map in the upper right of the poster). In order to evaluate the ABI_G18 CSR product, we collect data samples in 22 cycles from November 12-17, 2022 when the ABI CSR products are available from all three GOES satellites. Below are the OmF histograms for the 3 WV channels from the ABI_G16, ABI_G17 and ABI_G18. Because of the loop heat pipe issue, the GOES-17 ABI instrument has the smallest data count. The GOES-16 and GOES-18 counts are comparable. The OmF biases for the low and high peaking WV channels are comparable across all three satellites while the OmF biases for the middle peaking WV channel 9 show significant differences.

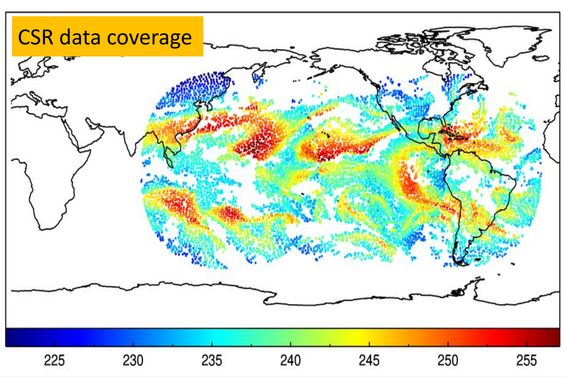






CSR Assimilation Experiment Configuration

A set of parallel experiments were carried out to assess the impact of assimilating the ABI_G18 and AHI_Himawari9 CSR data into the NCEP GFSv16 system. The data coverage of the ABIG_16, ABI_G18 and AHI_Himawari9 CSRs is displayed in the horizontal map here. The data assimilation system is hybrid 4DEnVar. The GFS model uses finite-volume cubed-sphere (FV3) dynamical core. Both deterministic and ensemble horizontal resolutions are cut in half from the operational resolution, with the deterministic model horizontal resolution being about 25km (C384) and the ensemble being about 50km (C192). The GFSv16 has 128 vertical levels extending up to 0.01 hPa (80km). The control (v16.3.5_ctl) assimilates all the operational observations. The parallel experiment v163_g18csra2 assimilates all the operational observations as well as the three WV channels from ABI_G18 and AHI_Himawari9 CSRs. The ABI G18 coefficient files are included in CRTM v2.4.0 and are used in the parallel experiment. The experiments are initialized at forecast step on January 5, 2023 18Z cycle and run until the February 23, 2023 18z cycle.



CSR Bias Correction

- The variational bias correction (VarBC) is used in the GDAS to estimate the radiance observation biases.
- The bias correction coefficients begin at zero for all CSR data in the experiment.
- The bias correction terms are spun up after a few cycles (see Fig. 1 for ABI G18 total bias correction).
- The bias correction performs well for all 3 instruments and all 3 three WV channels (Fig. 2).
- The globally averaged Ges (simulated model equivalences)-Obs after bias correction and quality control is about 0.15-0.2K for all 3 WV channels (see Fig. 3a for channel 9 AHI_Himawari9 as an example). The WV sensitive channels from other instruments also show such biases after bias correction (Fig. 3b)
- The standard deviation of Ges-Obs is smaller in the experiment than that in the control for AHI_Himawari9 three WV channels (Fig. 3c for channel 9 as an example)

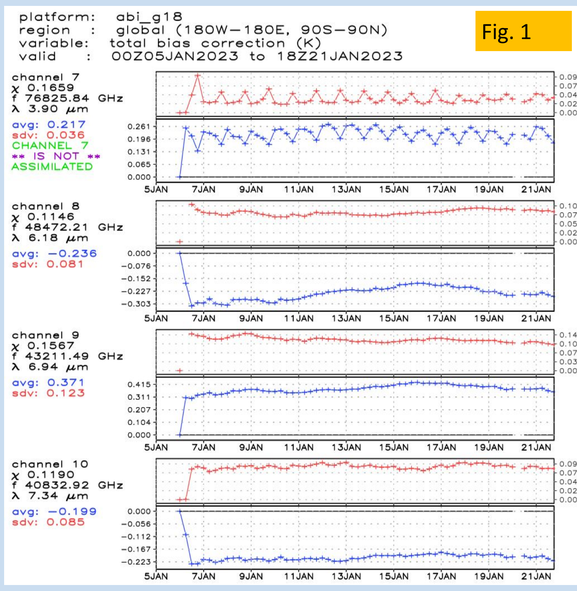
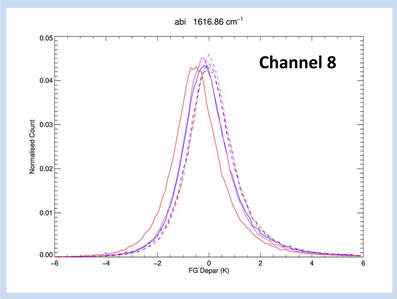
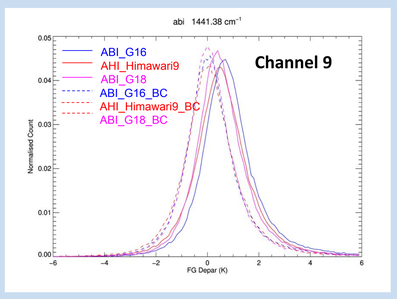


Fig. 1





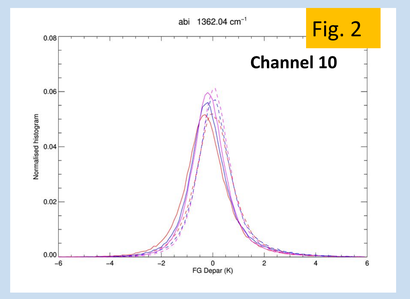


Fig. 2

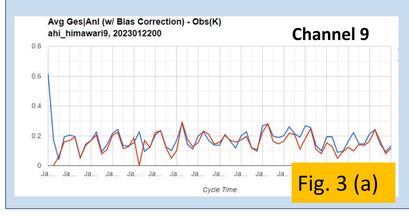


Fig. 3 (a)

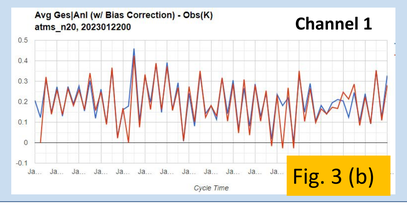


Fig. 3 (b)

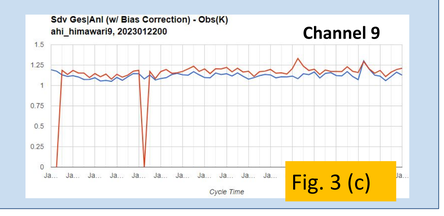
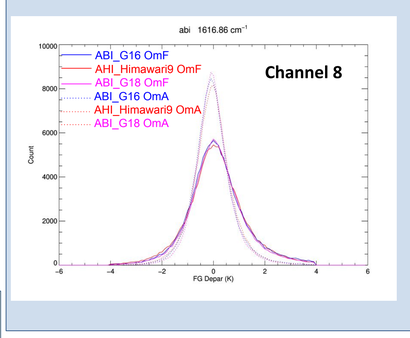
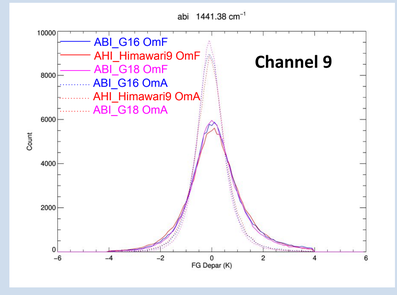


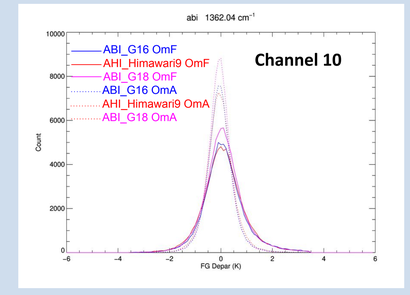
Fig. 3 (c)

OmF vs OmA from ABI_G16, ABI_G18 & AHI_Himawari9

- Three WV channels 8-10 are assimilated
- Data are sampled over the period of January 10-17, 2023 after thinning, bias correction and quality control







CSR Data Impact Verification

- The forecasts are verified against their own analyses
- The first week of results is considered as a spin up period, so it is excluded from verification
- The forecast scores from the experiment (v163_g18csra2) and the control (v16.3.5_ctl) are compared.
- The anomaly correlation coefficients show that CSR data has a neutral impact on temperature fields at standard pressure levels of 250, 500 and 850 hPa for almost all forecast hours (Fig.4).
- It is expected to have a more direct impact on the humidity field by assimilating the WV channels of the CSR data. The GFS model 6 hour forecast fits to the rawinsonde data is shown in Fig. 5. The relative humidity biases in the upper troposphere become smaller when additional CSR WV channels are assimilated.
- The RMSE of the humidity analysis bias is smaller in the lower troposphere, as shown in Fig. 6.
- More MHS channel 2 data pass quality control when additional CSR data is assimilated, as shown in Fig. 7. The MHS other channels show similar results, indicating that the humidity field in the model is improved.

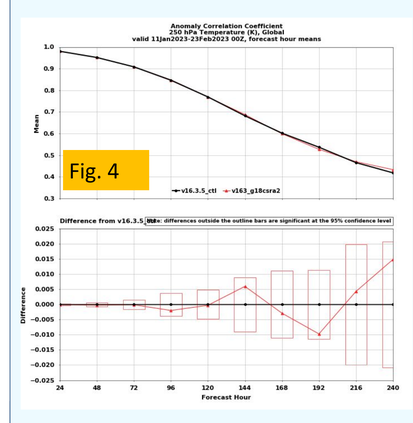


Fig. 4

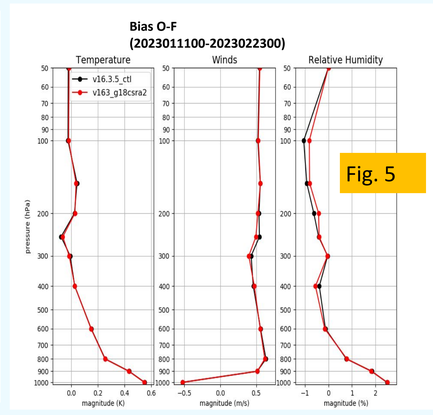


Fig. 5

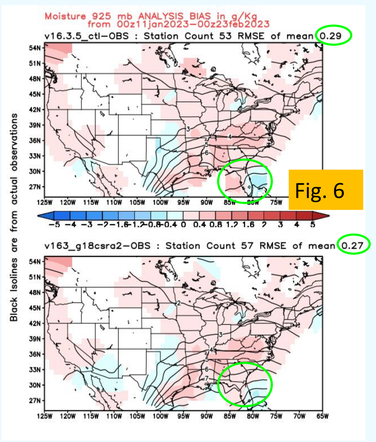


Fig. 6

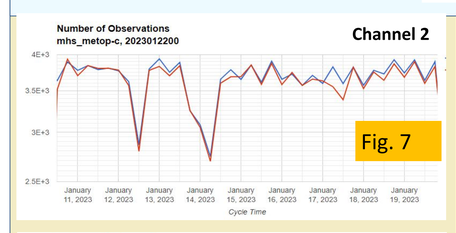
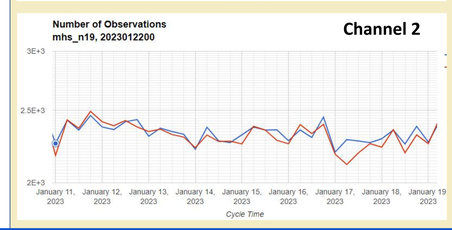


Fig. 7



Future Plan: SEVIRI ASR Assimilation

SEVIRI All-Sky Radiance (ASR) reports the clear-sky radiance information. The clear-sky percentage reported in ASR is not channel dependent, unlike the percentage reported in CSR. When switching to using the clear-sky radiances reported in the SEVIRI ASR product, the modifications are required for data quality control and thinning. This work is ongoing and will be included in the next NCEP GFS upgrade.