Impacts of the Transition from DMSP SSMIS to WSF-M MWI on IMERG

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Executive Summary

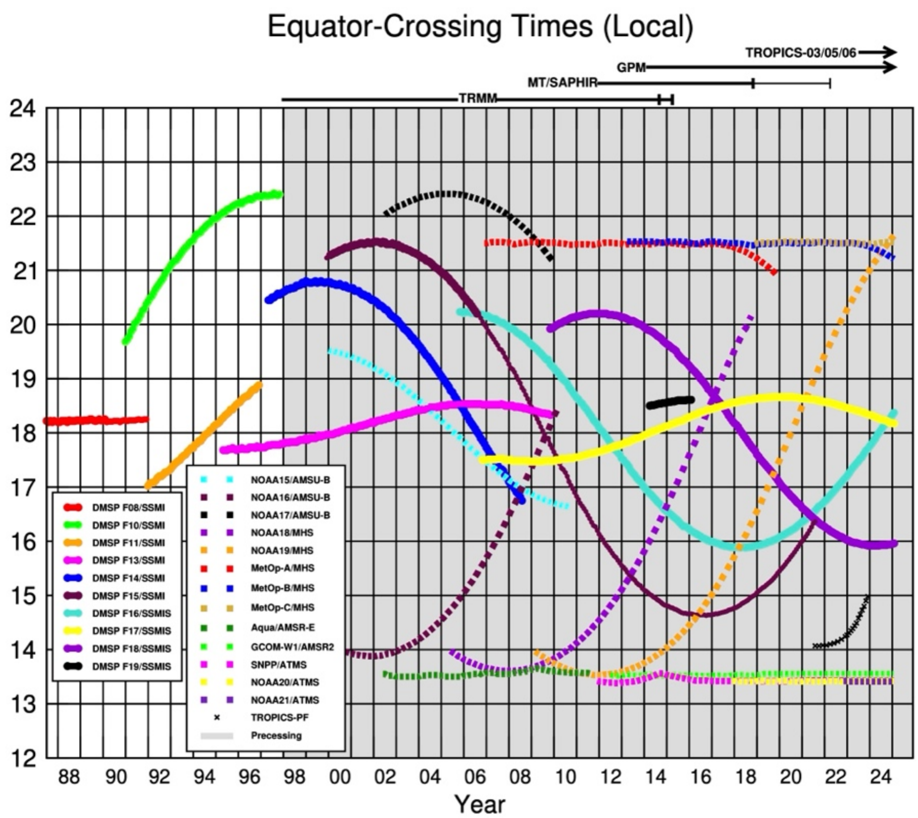
The Integrated Multi-satellitE Retrievals for the Global Precipitation Measurement (GPM) mission (IMERG) combines precipitation retrievals from all available low-orbit passive microwave (PMW) data, together with geosynchronous infrared (GEO-IR) providing baseline retrievals to compute merged global precipitation every half hour. The IMERG Early Run includes forward propagation of PMW data, while the Late Run also uses backward propagation. IMERG includes the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager/Sounder (SSMIS) constellation operated by the U.S. Department of Defense (DoD). DMSP satellites F16, F17, and F18 are currently operational, but the entire program is scheduled to be retired in September 2026. At the same time, the DoD's new Weather System Follow-on – Microwave satellite 1 (WSF-M1) is being operationalized (currently planned for late September 2025), providing MicroWave Imager (MWI) data. Using December 2023 as a test case, this study examines the impact of eliminating the SSMIS constellation, and then using the F17 SSMIS to simulate the addition of MWI since F17 and WSF-M1 occupy nearly the same orbital slot.

SSMIS provides roughly 25% of the available PMW data in IMERG, and critically is the only PMW data source available every day for a wide span of orbit times centered on 06/18 local time (LT). Loss of SSMIS would force IMERG to rely more heavily on the lower quality GEO-IR retrievals, which typically have correlation scores of around 0.2 compared to GMI, versus correlation scores of 0.7 or higher for SSMIS overpasses. The data denial experiment revealed that the GEO-IR data's average weight for a (representative) sample map increases from 22.2% to 39.6% for IMERG Early Run and from 9.9% to 22.9% for Late Run, driven by the broad timespans around 06/18 LT where the low-quality GEO-IR data are the sole input when SSMIS is removed. Re-introducing the F17 SSMIS as a stand-in that approximates the spatial coverage and overpass time of the WSF-M MWI, we find that the PMW coverage is about 10% lower than for full SSMIS coverage, and the GEO-IR average weighting increases to 30.5% for Early Run and 15.1% for Late Run. An evaluation against the Ground Validation Multi-Radar Multi-Sensor (an independent ground reference) reveals that the reduction in SSMIS sampling leads to lower skill, with the complete loss of SSMIS resulting in a drop in skill roughly equivalent to the loss of backward propagation. The relatively large impact of the single (simulated) WSF-M data stream arises because its orbital time slot around 06/18 LT is close to the middle of an 8-hour gap between the major agency PMW observation times.

1. Introduction

The international constellation of satellites carrying passive microwave (PMW) sensors has grown over time, starting with a single Defense Meteorological Program (DMSP) F08 carrying a Special Sensor Microwave/Imager (SSMI) in 1987, and typically comprising almost a dozen satellites for the past decade (Fig. 1). The possibility arose in Summer 2025 that all three operational Special Sensor Microwave Imager/Sounder (SSMIS) data streams might be terminated, and at the same time the new Weather System Follow-on – Microwave satellite 1 (WSF-M1) was being moved toward operational status, providing MicroWave Imager (MWI) data. This study examined a data denial scenario in which all three SSMIS datastreams were terminated, and then a follow-on scenario in which the SSMIS's were no longer available, but the MWI was. Since MWI was not available at the time of the study, and because the DMSP F17 and WSF-M1 occupy very similar Sun-synchronous orbits, the DMSP F17 SSMIS swath was used to simulate the MWI.

2. Input datasets



Ascending passes (F08, TROPICS-PF descending); satellites depicted above graph precess throughout the day.
Image by Eric Nelkin (SSAI), 7 March 2025, NASA/Goddard Space Flight Center, Greenbelt, MD.
https://gpm.nasa.gov/resources/images/gpm-constellation-overpass-times

Figure 1. History of ascending Equator-crossing times (Local Time) for all PMW satellites starting with DMSP F08. Note that the current times for F16, F17, and F18 (cyan, yellow, purple) provide the only coverage between the two clusters of agency satellites at 13:30 and 21:30 LT, an 8-hour gap.

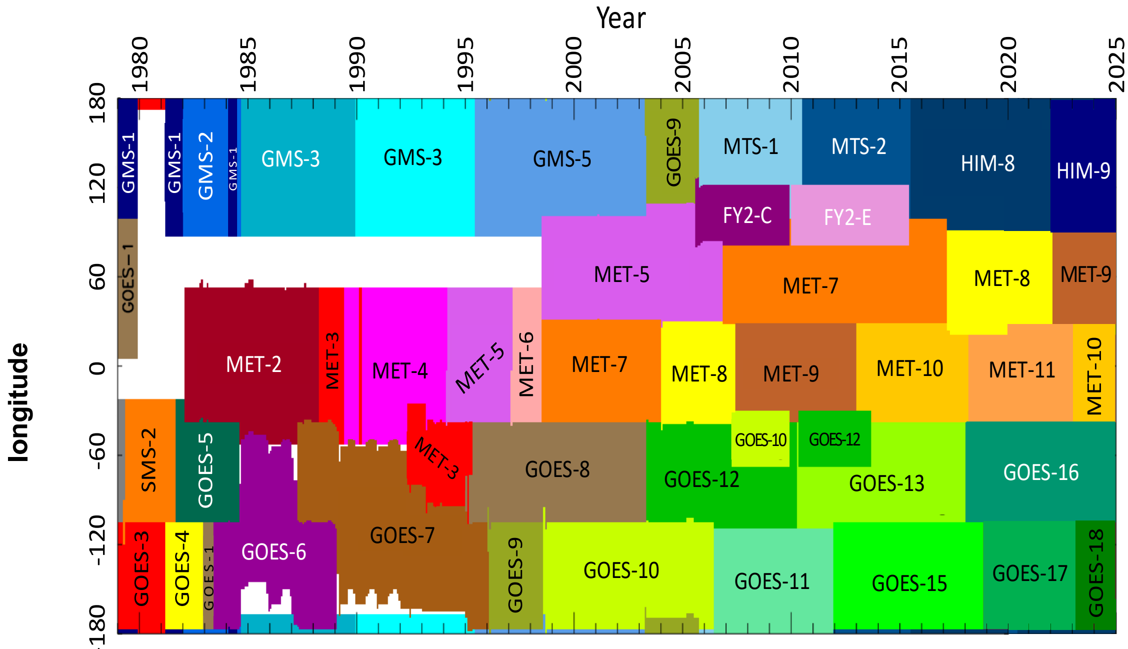


Figure 2. History of subsatellite longitude for the GEO-IR satellite constellation. Coverage is complete except for transient satellite/sensor/processing problems.

3. Results

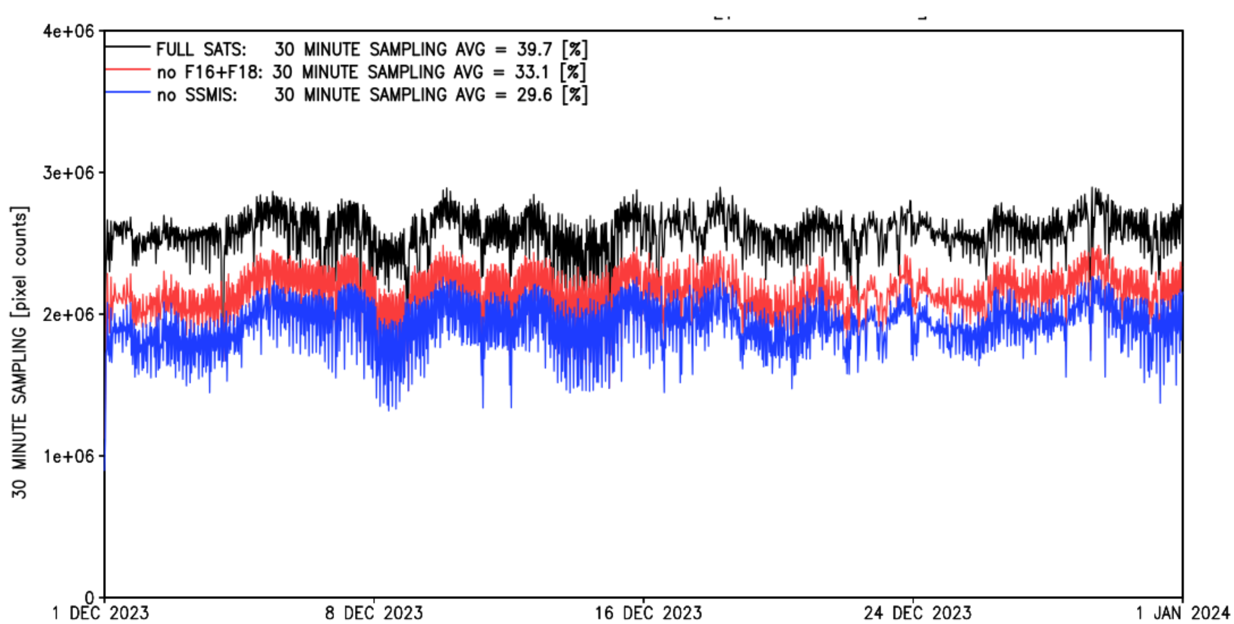
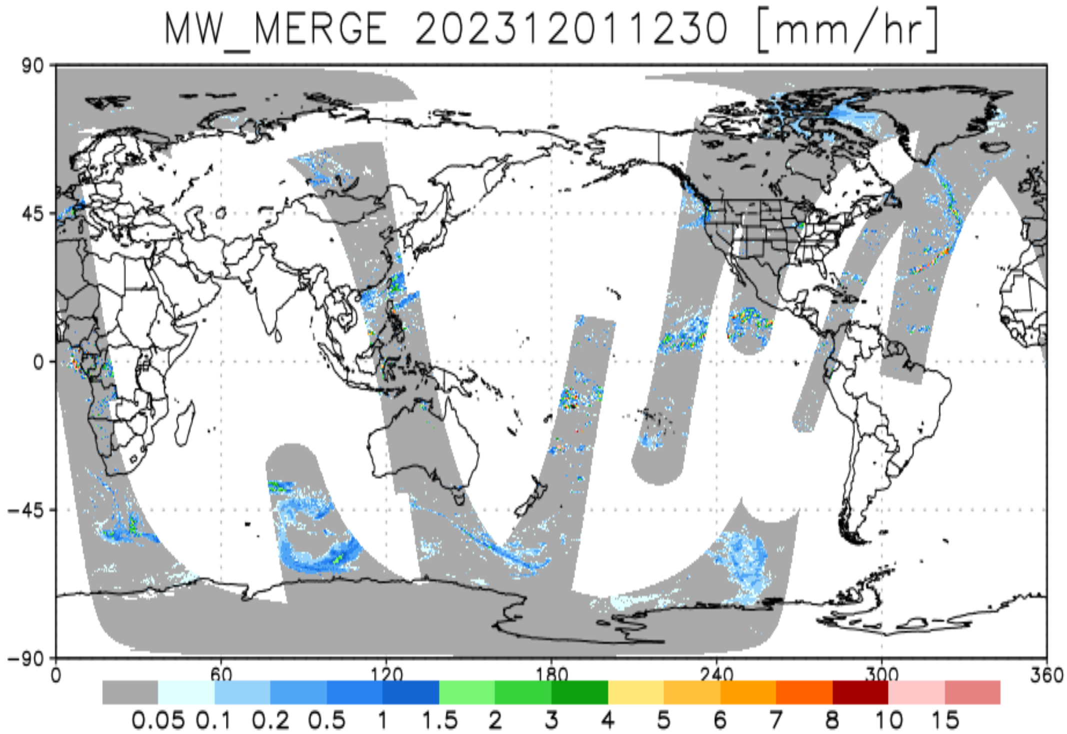


Figure 3. Counts of 0.1° grid boxes with full PMW data (black), PMW data with F17 alone (red), and no-SSMIS PMW data (blue) for each half-hour map during December 2023. The fluctuations across days are likely due in large part to the GMI swath going in and out of synch with the swaths of the other PMW sensors.



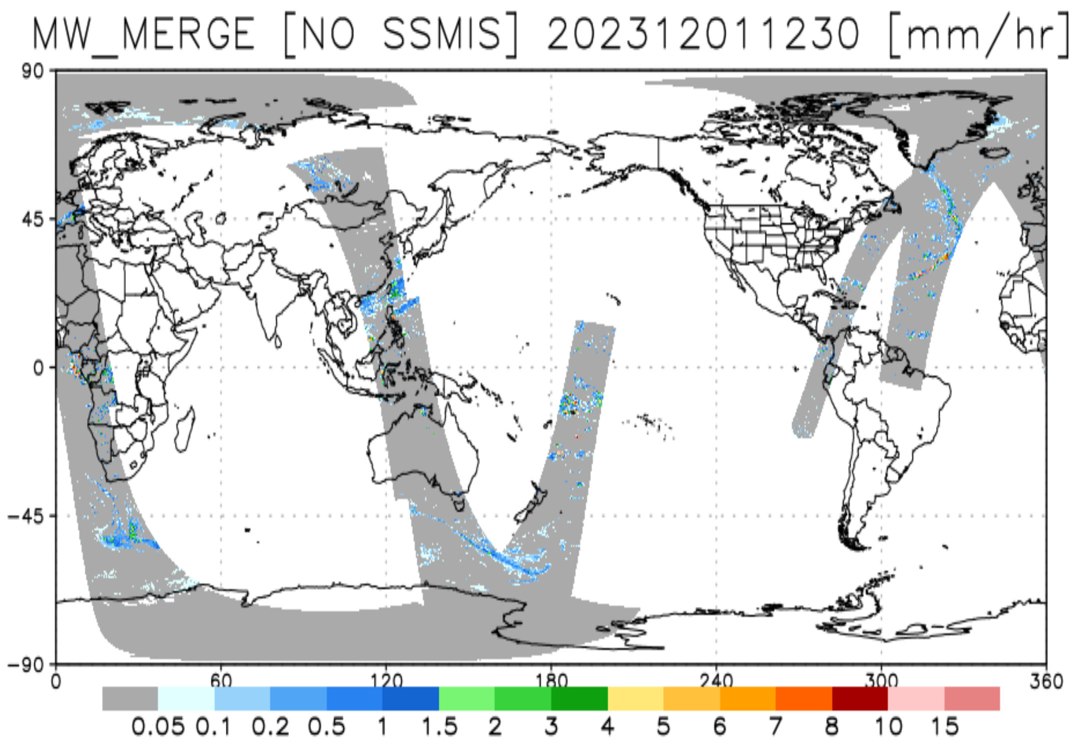


Figure 4. Sample map of PMW retrievals (mm/hr) used in IMERG for all PMW data (top) and no-SSMIS PMW data (bottom). This snapshot is for 12:30-13:00 UTC on 1 December 2023. Note the gaps due to the lack of coverage in this half hour over/south of CONUS and in the Southern Ocean.

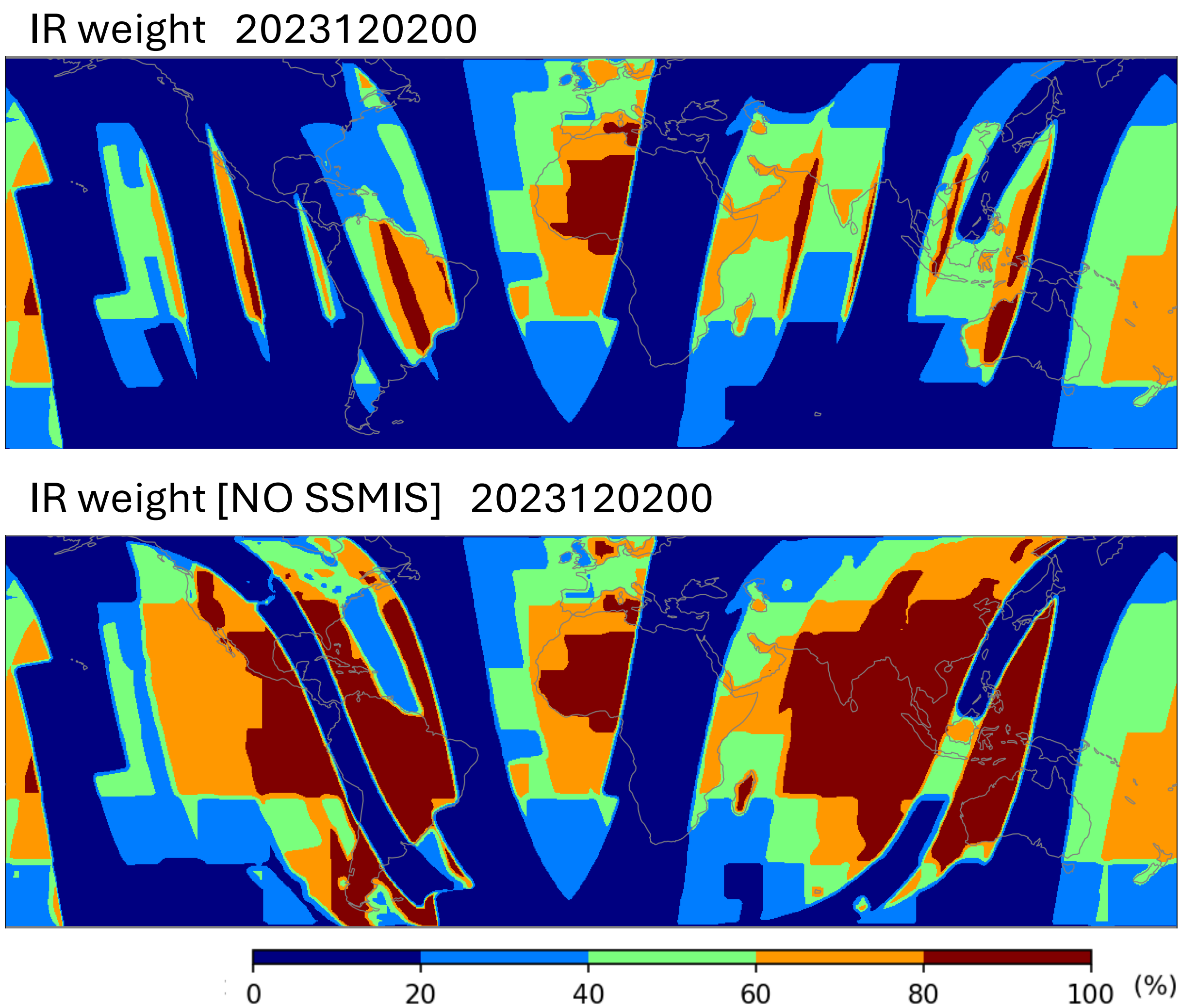


Figure 5. Weighting of GEO-IR data (in %) in IMERG Early Run for 00:00-00:30 UTC on 02 December 2023 for all PMW data (top) and no-SSMIS PMW data (bottom). The loss of SSMIS causes large areas to be dominated by the low-quality GEO-IR. The swath of low GEO-IR weighting (mostly deep blue) across East Asia, the Indian Ocean, and the Americas is from GMI (flying on the GPM Core Observatory [CO]). Because GMI precesses, this area would be entirely based on GEO-IR data (the reddish-brown color), at other times in the GPM CO's precession.

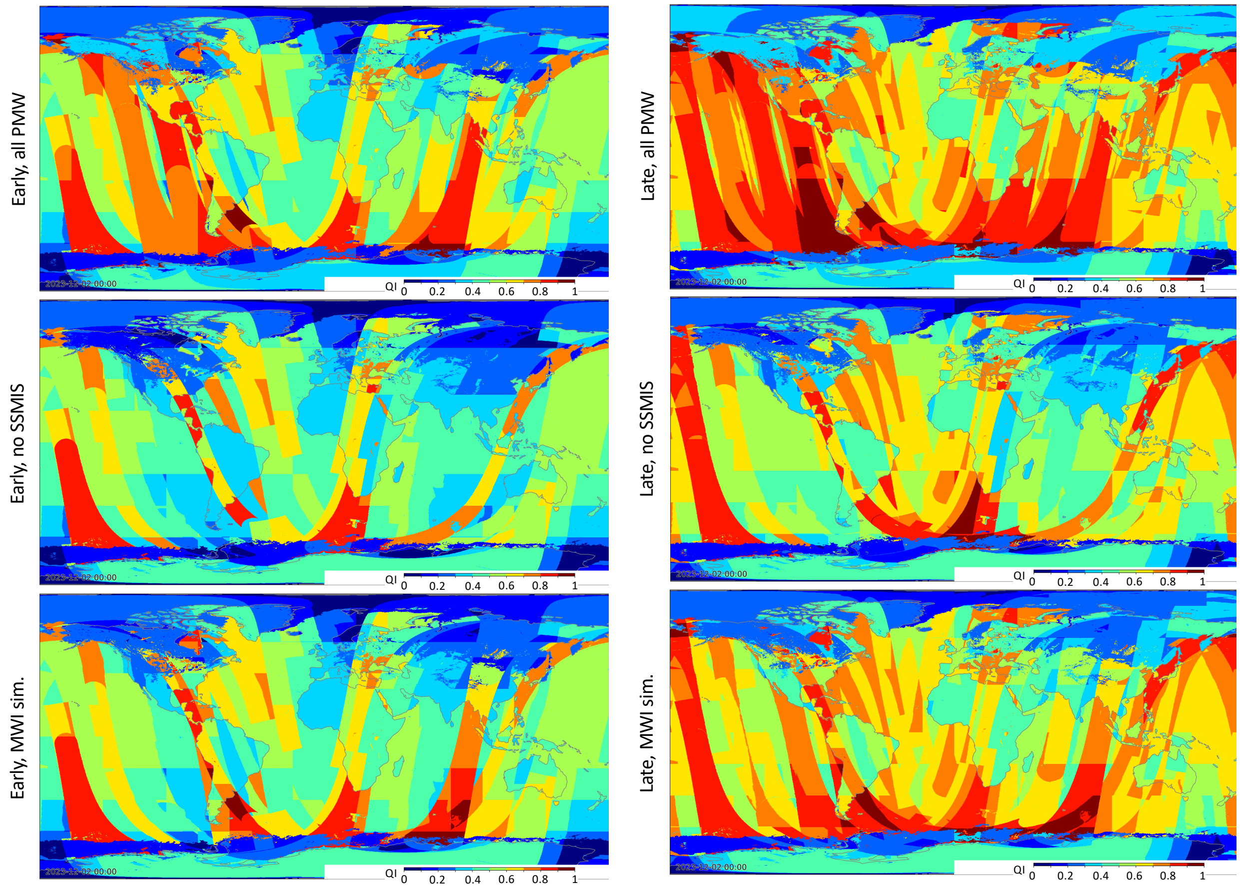


Figure 6. Quality Index (QI) for IMERG Early (left) and Late (right) Runs in the cases of all PMW data (top); no-SSMIS PMW data (middle); and PMW with simulated MWI data (F17 alone; bottom). This snapshot is for 00:00-00:30 UTC on 2 December 2023. The differences in QI over land and ocean are driven by instrument skill differences. Stripes within land and ocean regions reflect the time that has passed since a PMW overpass. Lower values at high latitudes are due to reduced PMW skill over snowy/icy surfaces. Note the importance of the backward propagation in the Late, compared to the Early for maintaining good QI. It is also clear that adding (simulated) MWI helps maintain QI, compared to the no-SSMIS case, but is still not as good as including all of the SSMIS.

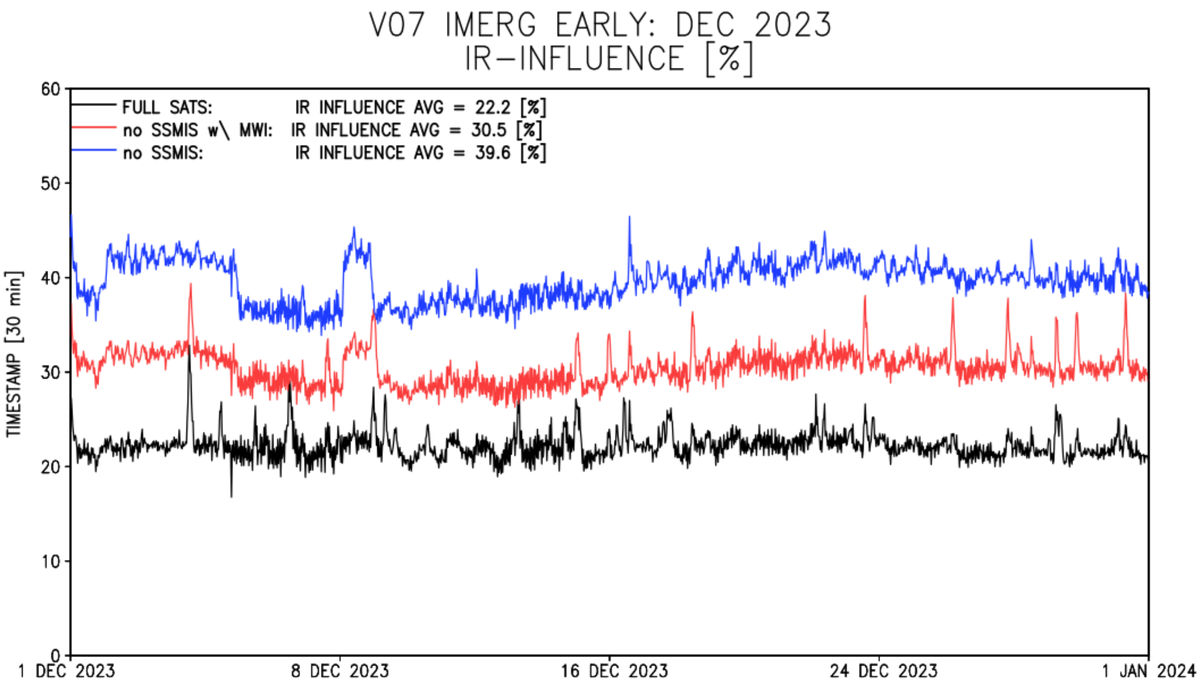


Figure 7. Time-series of the weighting of GEO-IR data (in %) in IMERG Early Run for December 2023 for all PMW data (black), PMW data without SSMIS (blue), and PMW data with F17 SSMIS simulating WSF-M MWI (red). The loss of SSMIS approximately doubles the contribution of GEO-IR, though with (simulated) MWI this loss is nearly halved. Time-average values are shown at the top of the diagram.

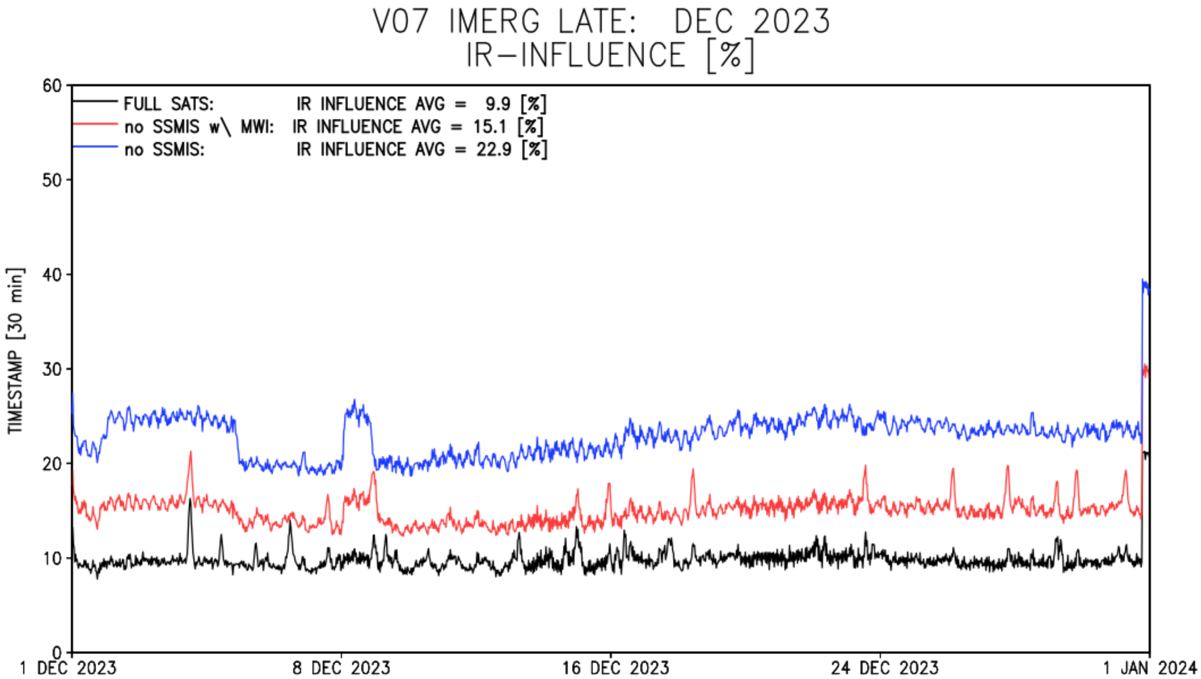


Figure 8. As in Figure 7 but for the Late Run. The contribution of GEO-IR is lower compared to the Early Run because the Late Run includes backward propagation, which extends each PMW swath's influence. However, introducing (simulated) MWI partially mitigates the absence of SSMIS.

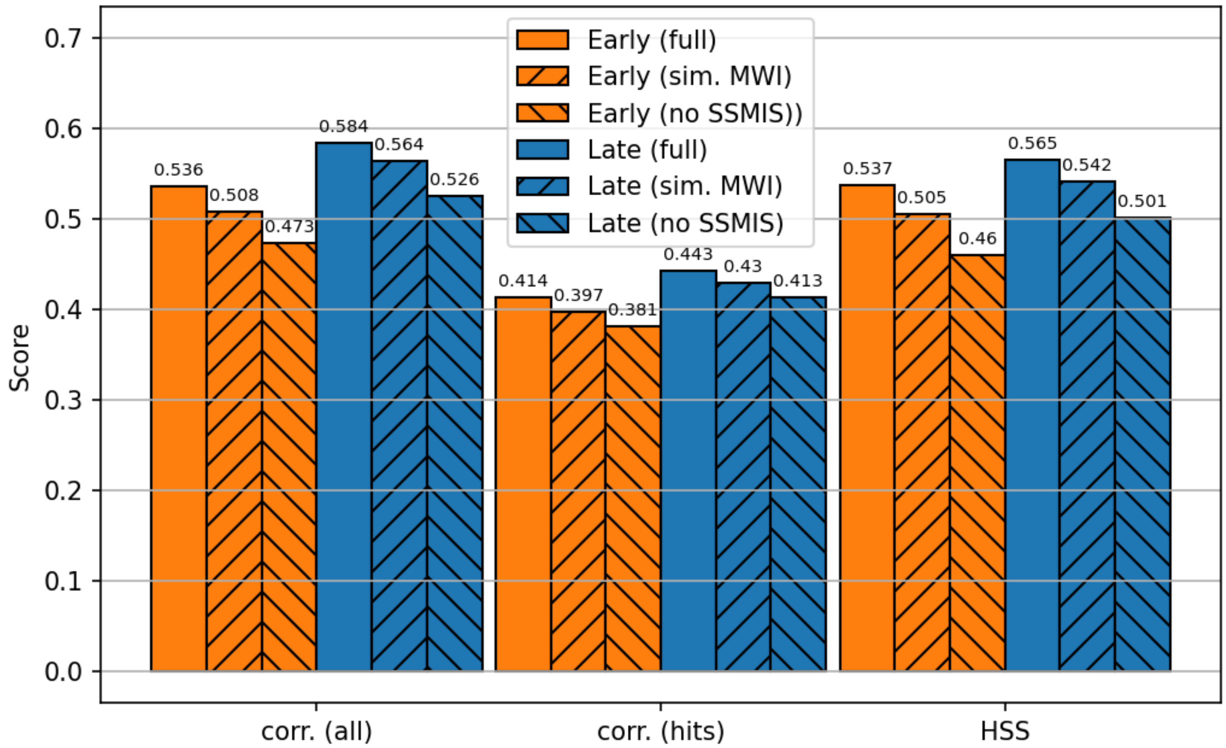


Figure 9. Validation statistics against GV-MRMS data for December 2023 for Early (orange) and Late (blue) Runs computed with all PMW data (solid); PMW with simulated MWI data (F17 alone; left slant hatching); and no-SSMIS PMW data (right slant hatching). The statistics are correlation for all gridboxes, correlation for gridboxes with precipitation detected in both IMERG and Ground Validation Multi-Radar Multi-Sensor (GV-MRMS), and Heidke Skill Score (HSS) for all gridboxes. The loss of SSMIS data leads to an appreciable drop in skill, while adding the simulated MWI recovers some of this loss. Note that the Late Run using no SSMIS has similar skill to the Early Run using all data, which suggests that SSMIS has a comparable impact on the overall skill to backward propagation. This summary obscures the fact that the decrease in skill is focused on times of day centered on 06/18 LT, as earlier figures have demonstrated.

Supplementary Material

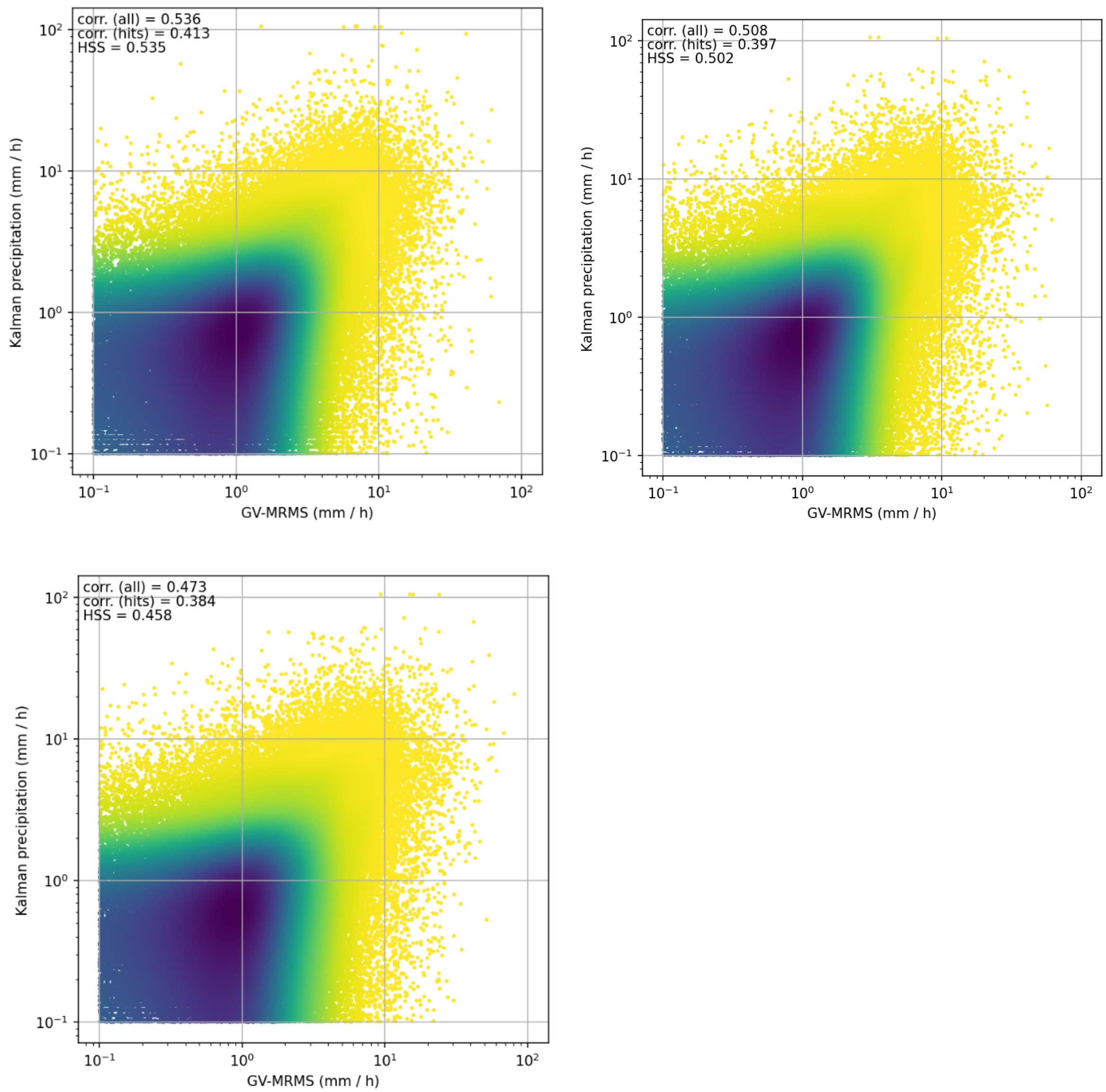


Figure S1. Validation statistics against GV-MRMS data for December 2023 for Early Run IMERG computed with all PMW data (top left); PMW with simulated MWI data (F17 alone; top right); and no-SSMIS PMW data (bottom). The three scatter plots are very similar, which indicates that it is meaningful to compare the summary statistics (at the top of each panel and summarized in Fig. 9). However, it is also true as mentioned for Fig. 9 that the decreases in skill are clustered at particular times of day.