

- Early results from SOCA DA system experiments show that **SWOT nadir altimetry assimilation has positive impacts especially around western boundary currents**, such as aiding correction of an erroneous Gulf Stream position
- Longer experiments with the current **GEOS-S2S-3** ocean DA system show **tropical impacts concentrated near the thermocline, with large monthly variability**
- These experiments serve as a prelude to assimilation of SWOT KaRIn within GEOS/SOCA at GMAO

S2S Forecasting at GMAO

NASA's Global Modeling and Assimilation Office (GMAO) maintains and develops the Goddard Earth Observing System (GEOS), a suite of coupled earth system models (atmosphere, oceans, land, sea ice, aerosols) for forecasting and reanalysis. For data assimilation (DA), the next-generation subseasonal-to-seasonal (S2S) forecast system at GMAO will transition to the Joint Effort for Data assimilation Integration (JEDI), with marine component Sea ice-Ocean Coupled Assimilation (SOCA). This transition will facilitate adoption and testing of new DA methods as well as assimilation of new observation types such as wide-swath altimetry from the Ka-band Radar Interferometer (KaRIn) on the Surface Water and Ocean Topography (SWOT) satellite.



SWOT Nadir Observing System Experiments

Before assimilating SWOT KaRIn, GMAO is testing the impact of assimilating Absolute Dynamic Topography (ADT) from SWOT's conventional Jason-class nadir altimeter into our current and next-generation S2S forecast systems. To this end, four Observing System Experiments (OSEs) are being run: For both the current (GEOS-S2S-3)¹ and next-generation (SOCA) systems, one run assimilates SWOT nadir ADT (SWOTN) and one run does not (NO-SWOTN). Details of the two experimental setups are shown in Table 1.

	GEOS-S2S-3	SOCA
Run period complete	11/12/23—12/31/24	11/12/23—1/31/24*
Ocean Model	MOM5, 1/4° tripolar, 50 levels	MOM6, 1/4° tripolar, 75 levels
Sea Ice Model	CICE4 1/4°	CICE6 1/4°
Atmosphere Model	GEOS 1/2°, 72 levels, replayed to MERRA-2 reanalysis	No model; JRA55-DO forcing
Marine DA Method	4D LETKF, 20-member offline ensemble changing by month	3D-FGAT
Marine DA Window	5 days, 18-hr IAU	6 hours, 3-hr IAU
Background Frequency	6 hours	3 hours
Ocean Observations	<ul style="list-style-type: none"> SST[†] (L4 OSTIA) SSS (SMOS, SMAPv5) T/S profiles (Argo, TAO, PIRATA, RAMA, XBT, CDT) ADT (CryoSat-2, Jason-3, Saral, Sentinel 3A/3B/6A, SWOTN) 	Same as GEOS-S2S-3
Sea Ice Observations	MERRA-2 sea ice fraction	Same as GEOS-S2S-3 [‡]
Initialization	GiOcean reanalysis	2-yr spin-up from WOA18 using JRA55-DO forcing

Table 1: Observing System Experiment (OSE) setup using current (GEOS-S2S-3) and next-generation (SOCA) subseasonal-to-seasonal GMAO forecast systems.

*The SOCA run is currently stalled due to the end of the JRA55-DO forcing, while a new in-house forcing is being developed.
[†]S2S-3 uses 5-d relaxation to OSTIA SST, plus also assimilation of OSTIA SST from July 2024.
[‡]SOCA sea ice assimilation begins Jan 11, 2024.

Conclusions

Early results from OSEs with the GMAO next-generation DA system for S2S forecasting show SWOT nadir's promise in improving SSH globally, especially in the western boundary currents. These improvements are likely to have a long-term positive impact on T and S as well, which may help to improve coupled forecasts (e.g. for tropical cyclones). Discussions are ongoing for SWOT KaRIn assimilation strategies (e.g. thinning, error assignment), but these results suggest potentially greater positive impacts from SWOT KaRIn.

References

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Results

Early comparison of SOCA SWOTN and NO-SWOTN runs shows a clear positive impact from SWOTN assimilation, as indicated by a 1–2 mm reduction in 60°S–60°N SSH RMSE, relative to a C3S Level-4 daily product² (Fig. 1a). These improvements are particularly prominent in the western boundary currents (Fig. 2, top), especially the Gulf Stream, where a 3–4 mm reduction in RMSE is seen (Fig. 1b), likely related to its initially position lying too far to the north. SWOTN also aids here in correcting the associated SST and SSS fields on a longer time scale (Fig. 2, bottom).

GEOS-S2S-3 results are more mixed, likely because the ADT data does not affect model SSH directly, but rather through the 3D potential temperature (T) and salinity (S) increments. In the tropics, the SWOTN impact is focused largely around the thermocline (Fig. 3), showing substantial monthly variability despite some consistent biases with respect to ORAS5⁵. This variability is likely related to the changing of the background ensemble used for the DA every month.

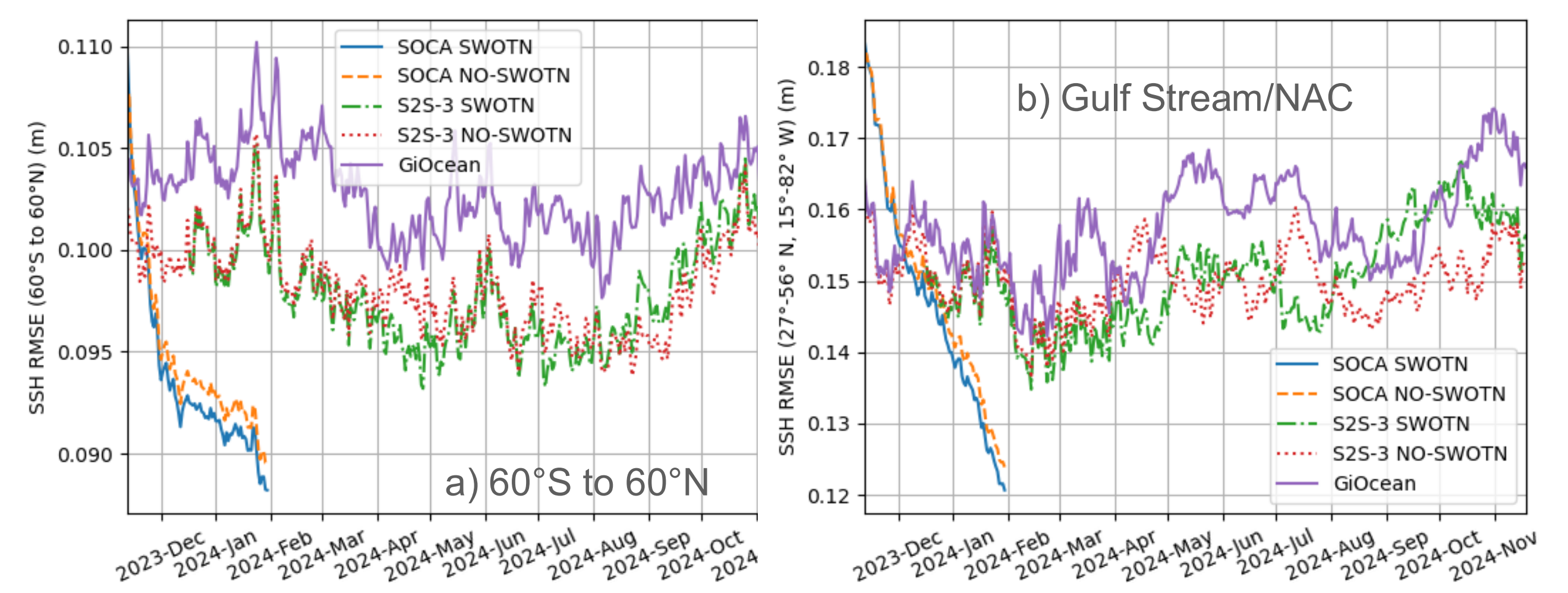


Figure 1: Root-mean-square error (RMSE) in sea surface height (SSH) between 60°S and 60°N (left) and in the Gulf Stream/North Atlantic Current region (right), relative to daily C3S Level-4 SSH². Runs with and without SWOT nadir ADT assimilation (SWOTN and NO-SWOTN, respectively) are shown for both the current (S2S-3) and next-generation (SOCA) S2S forecast systems at GMAO, along with our current flagship ocean reanalysis (GiOcean). At each time, errors were calculated only after subtracting the mean difference between the fields.

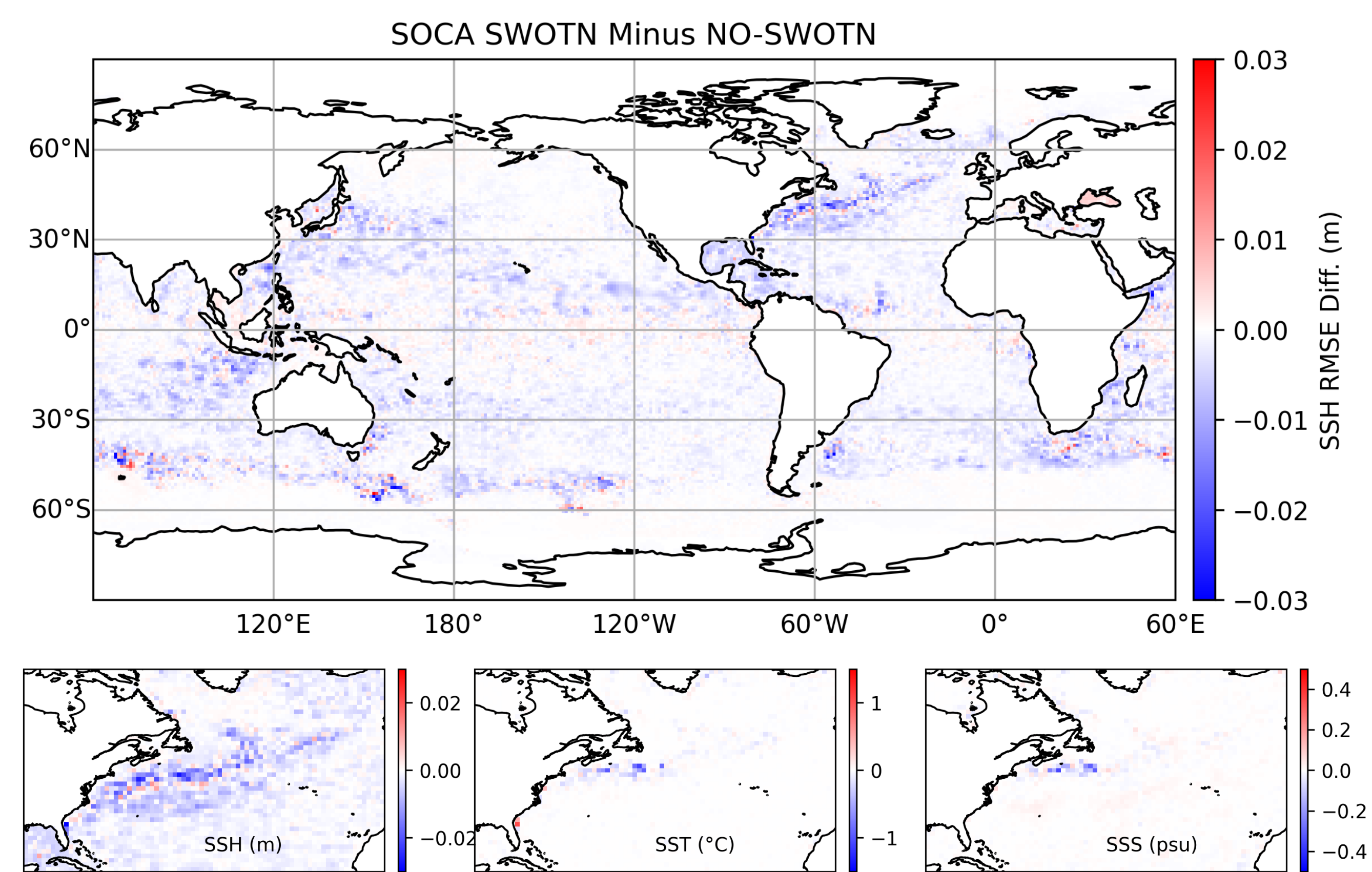


Figure 2: Top: Difference in SSH temporal-RMS error (with respect to daily C3S Level-4 SSH²) between SOCA SWOTN and NO-SWOTN runs during Dec 2023–Jan 2024. Bottom: Close-up on the Gulf Stream region, together with RMSE differences in SST and SSS (relative to OSTIA³ and a CNR product⁴). Blue areas show where RMSE is reduced by assimilation of SWOT nadir ADT.

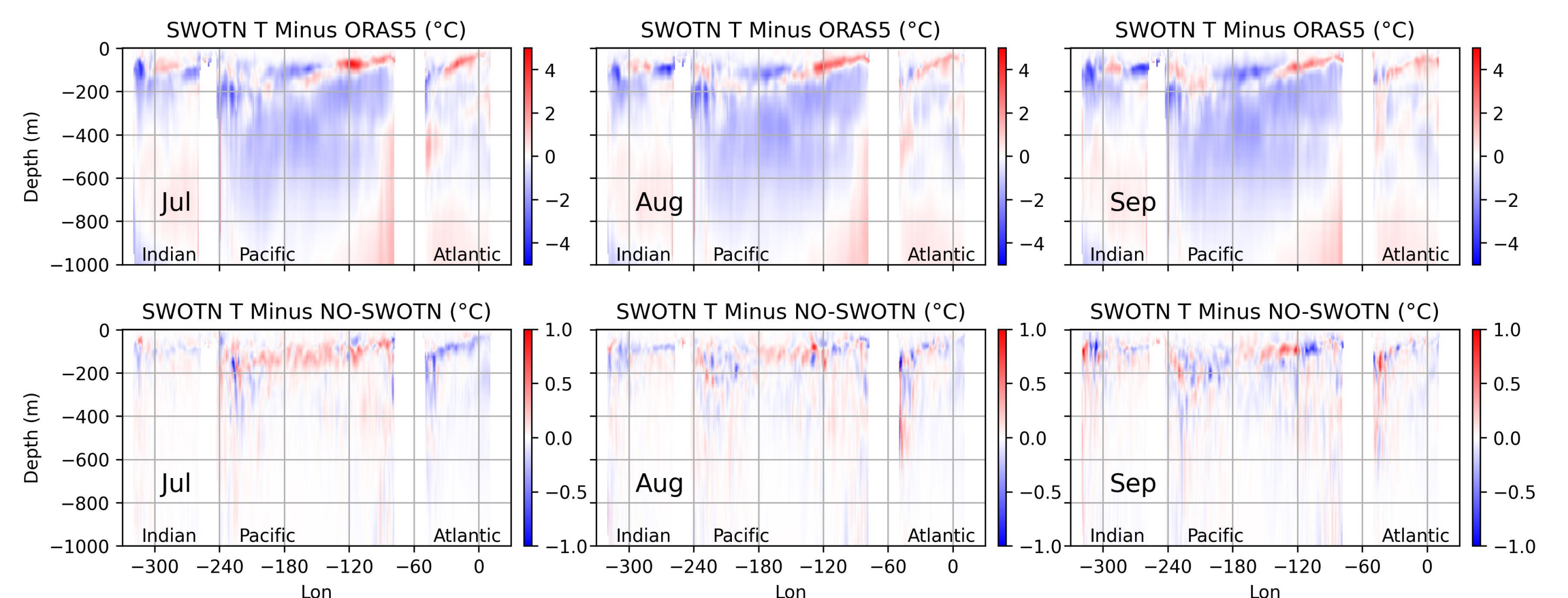


Figure 3: Top: Vertical transect (5°S–5°N mean) of monthly error in potential temperature (T) for S2S-3 SWOTN run with respect to ORAS5. Bottom: Similar transect for S2S-3 SWOTN T minus NO-SWOTN. Differences are concentrated near the thermocline, but exhibit considerable monthly variability, despite some consistent biases with respect to ORAS5.

Acknowledgements

We thank NASA Management for their support.