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Title: Assessing the Impact of Satellite Sea Surface Salinity Assimilation on Upper-Ocean Stratification and Thermal Variability in GEOS-S2S v2

Abstract: Upper-ocean stratification depends jointly on temperature and salinity, yet sea surface salinity (SSS) remains comparatively weakly constrained in many coupled data assimilation (DA) systems. Building on prior work demonstrating that satellite SSS assimilation improves MJO propagation across the Maritime Continent in the NASA GEOS-S2S v2 system (Du et al., 2025, J. Climate), we examine how assimilating satellite SSS modifies the upper-ocean thermal state and ocean heat content (OHC) variability on seasonal-to-subseasonal (S2S) timescales in the NASA GEOS S2S-v2 reanalyses.

We compare coupled ocean reanalyses conducted with and without SSS assimilation (SSS vs. CTL) within the GEOS-S2S v2 Atmospheric–Ocean Data Assimilation System (AODAS), under identical SST relaxation constraints . While SST relaxation minimizes surface temperature differences at 5 m, SSS assimilation substantially modifies subsurface temperature-salinity structure, mixed layer depth (MLD), and pycnocline stratification. Time-mean differences reveal basin-scale adjustments to the upper-ocean density structure that project onto stratification and mixed-layer variability. Seasonal diagnostics show that SSS assimilation alters upper-700 m OHC and upper-50 m salinity variability across both hemispheres, with particularly strong signals in the northeast Pacific where atmospheric river precipitation drives seasonal freshening.

Beyond mean-state effects, SSS assimilation modifies detrended, deseasonalized T/S anomalies within the upper 200 m, altering the frequency, depth, and persistence of significant salinity (>0.25 psu) and temperature (>1 °C) differences . These structural changes imply systematic adjustments to vertical mixing, entrainment, and air–sea flux coupling. Together with demonstrated improvements in tropical convection prediction, the results highlight the dynamical importance of satellite salinity constraints for representing coupled upper-ocean processes that regulate intraseasonal variability and regional heat content storage.

These findings underscore that satellite SSS observations do more than improve salinity fields. They reshape upper-ocean density structure and thermal memory, with implications for subseasonal predictability, air–sea exchange, and the representation of precipitation-driven freshening in midlatitude basins.

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