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*Supplement of*

# Improvements to the Met Office's global ocean–sea ice forecasting system including model and data assimilation changes

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## S1. Differences between EOS80 and TEOS10

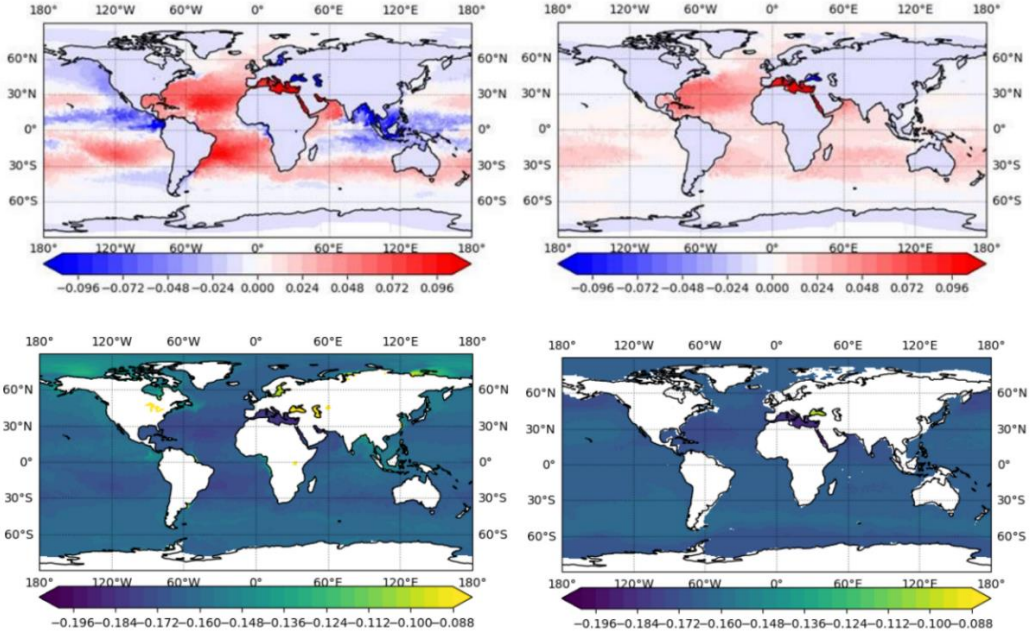


**Figure S1. The top plots show the difference in Potential Temperature and Conservative Temperature (PT minus CT) at the surface (left) and 300 m (right). The bottom plots show the difference in Practical Salinity and Absolute Salinity (PS minus AS) at the surface (left) and 300 m (right). All plots are valid on 1 February 2015.**

## S2. Impacts of updating the SST observation errors

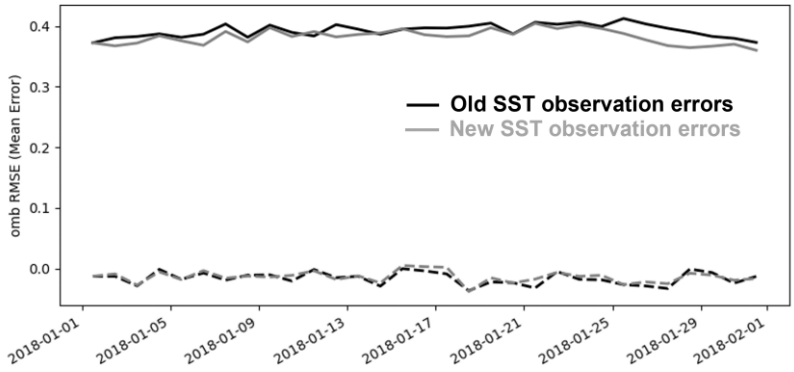


**Figure S2. Global SST observation-minus-background statistics (°C) for ORCA025 when the SST assimilation uses new (grey) and old (black) observation error estimates for January 2018. The solid lines correspond to the RMSD and the dashed lines correspond to the mean differences with respect to SST drifter observations.**

## S3. Issues with the projection of the SLA data assimilation signal onto model temperatures at depth

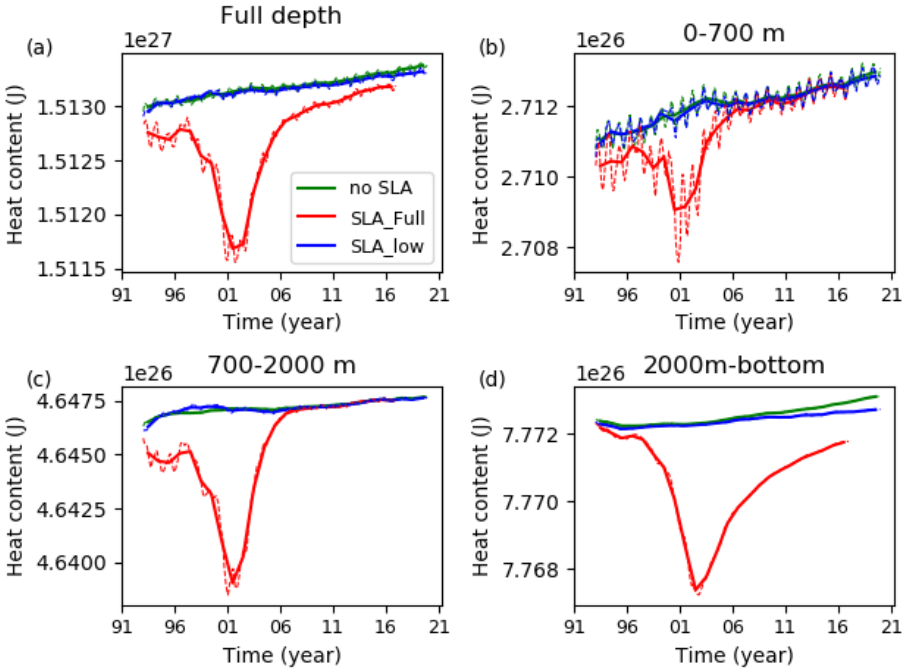


**Figure S3. Annual-mean (solid lines) and monthly-mean (dotted lines) ocean heat content in the 1993-2020 FOAM reanalysis, averaged globally over varying depths. The green line corresponds to a run without SLA assimilation, the red line corresponds to a run assimilating SLA observations, and the blue line corresponds to a run giving low weights to SLA observations in the assimilation.**

## S4. Impacts of applying the SSH balance throughout the whole water column

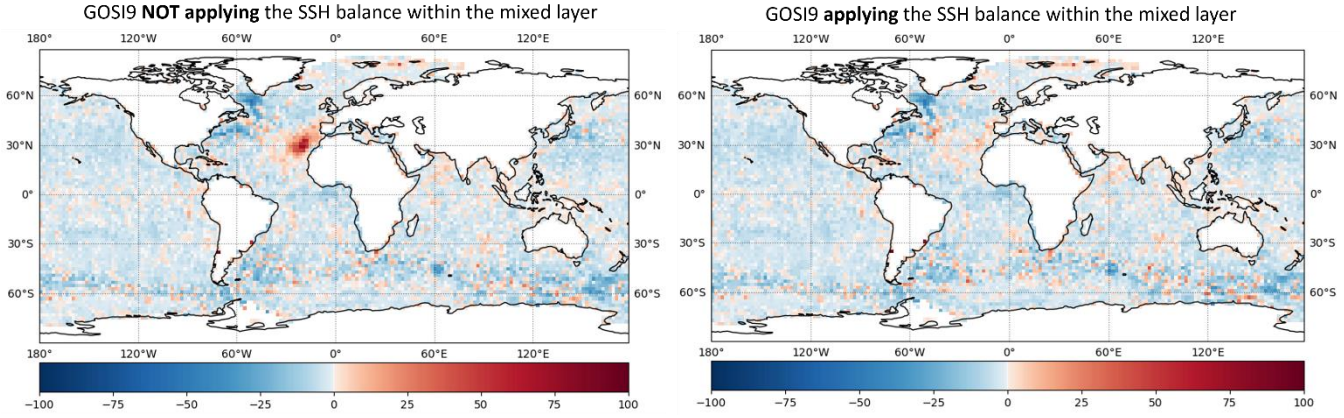


**Figure S4. SLA observation-minus-background RMSD percentage improvement (blue) and degradation (red) of ORCA12 GOSI9 not applying (left) and applying (right) the SSH balance within the mixed layer relative to ORCA12 GO6. The statistics are calculated from January to March 2019.**

## S5. Impacts of increasing the number of NEMOVAR inner loop iterations

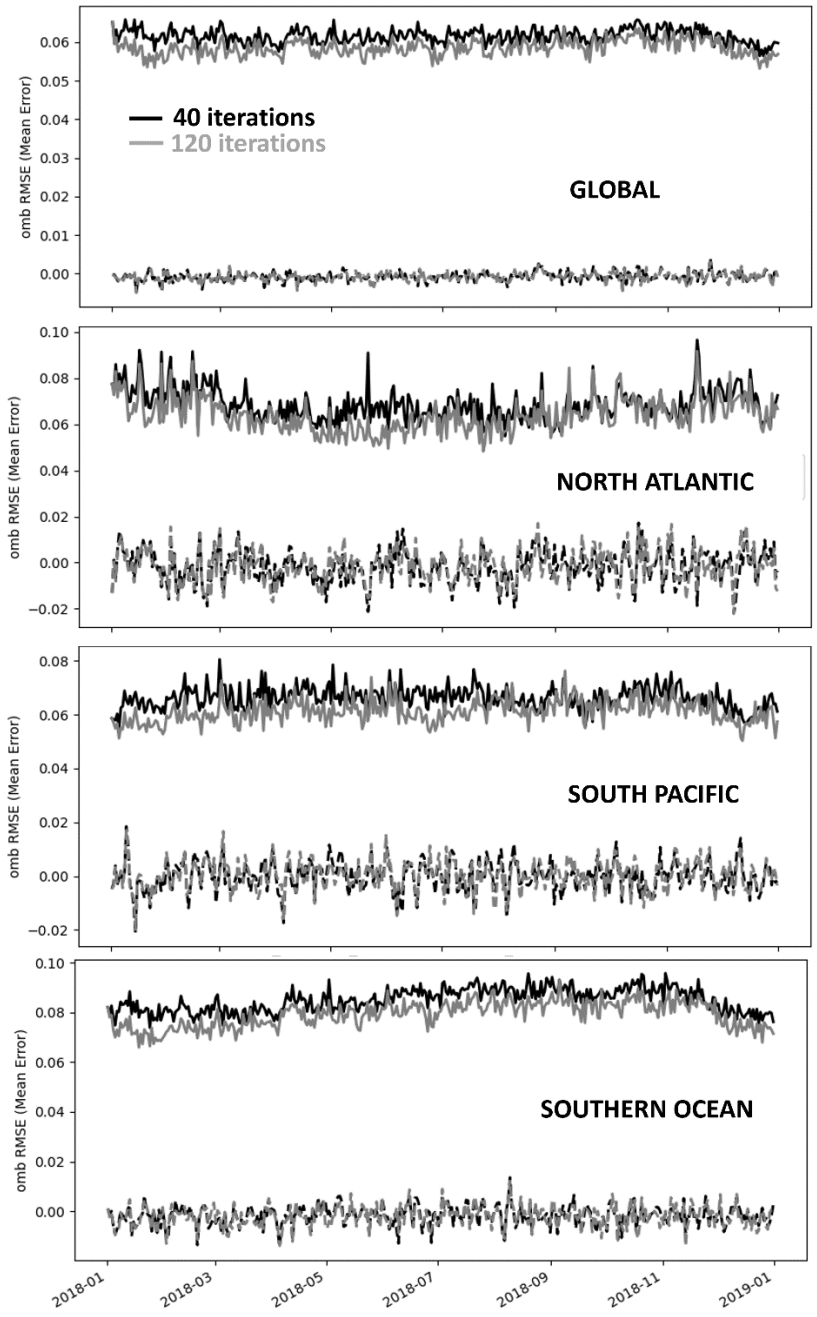


**Figure S5. Observation-minus-background statistics for SLA (m) of ORCA025 runs using 40 (black) and 120 (grey) DA iterations. The solid lines correspond to the RMSD and the dashed lines correspond to the mean differences with respect to along-track data from all available altimeters in 2018.**

## S6. Impacts of applying Brunt-Väisälä checks on T/S increments

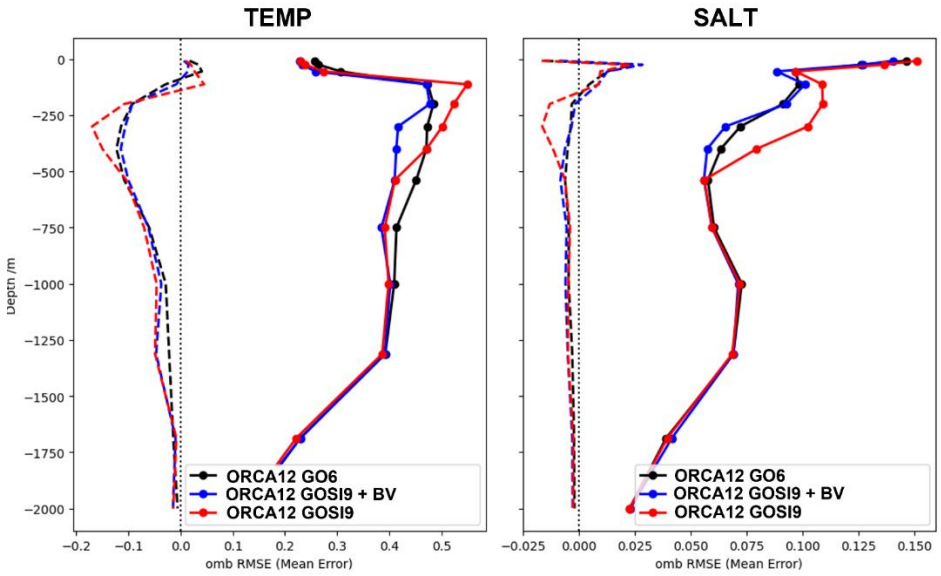


**Figure S6. Observation-minus-background statistics for temperature (left) and salinity (right) in the Mediterranean Outflow region, considering ORCA12 GO6 (black), ORCA12 GOSI9 (red) and ORCA12 GOSI9 applying the Brunt-Väisälä checks on T/S increments (blue). The solid lines correspond to the RMSD and the dashed lines correspond to the mean differences with respect to T/S profile observations in January-April 2019.**

## S7-S9. Breakdown of the impacts between model and assimilation changes on FOAM GOSI9

It is important to highlight that the impacts of the model and DA changes on FOAM GOSI9 were evaluated in ORCA025 only, as the ORCA12 configuration is quite expensive to run for one year. However, since both configurations show very similar impacts on the observation-minus-background (OmB) statistics when comparing FOAM GOSI9 against FOAM GO6 (see Section 4 in the paper), the results below should represent a valid evaluation of the model and DA update contributions to FOAM GOSI9 improvements.

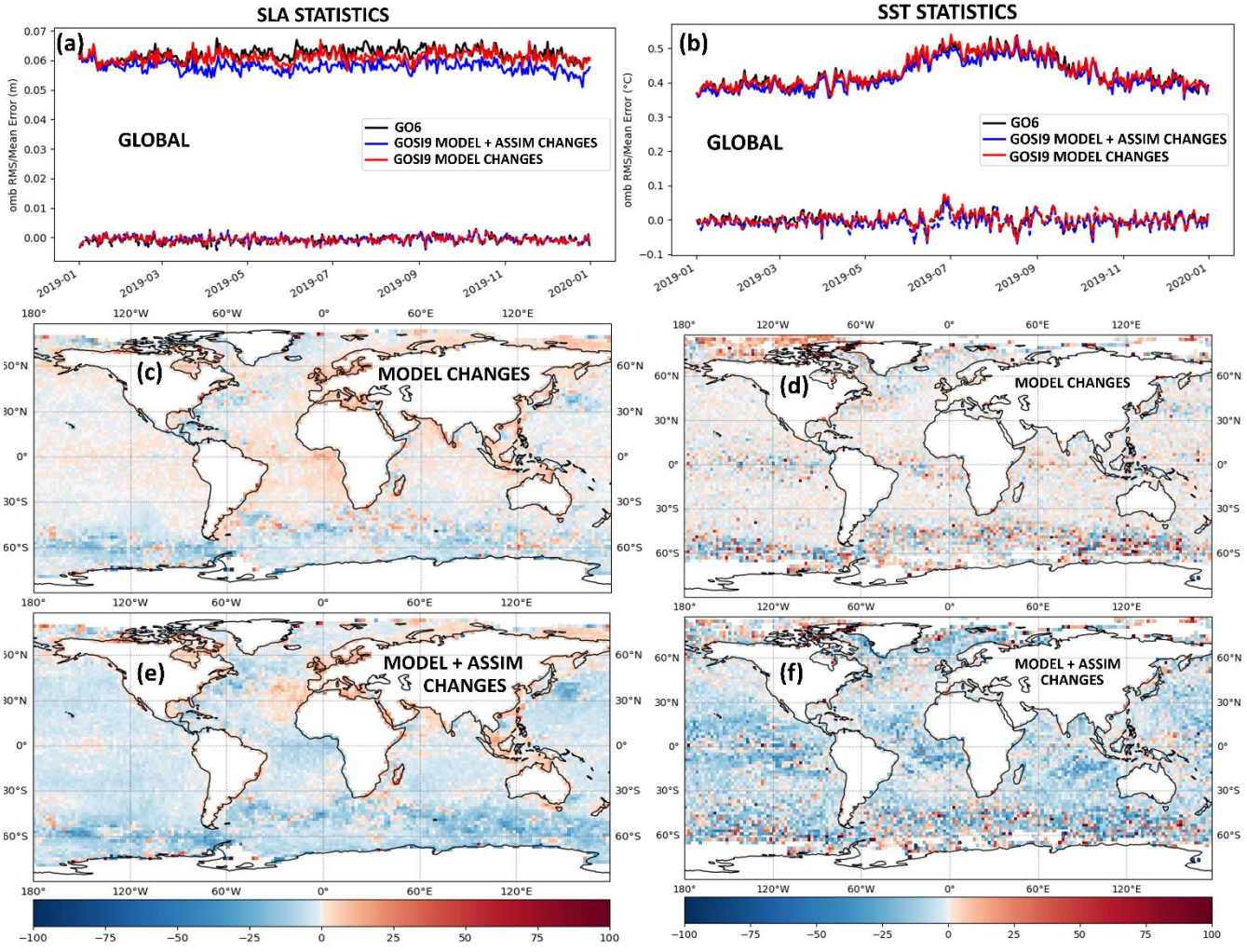


**Figure S7. (a, b) 2019 FOAM ORCA025 OmB statistics for GO6 (black), GOSI9 only considering model updates (red) and GOSI9 considering both model and DA updates (blue), calculated against SLA (m) and SST (°C) observations, respectively. The solid lines correspond to RMSDs, and the dashed lines represent mean differences. 2019 RMSD percentage improvements (blue) and degradations (red) of (c, d) ORCA025 GOSI9 with only model updates and (e, f) ORCA025 GOSI9 with model and DA updates relative to GO6 for SLA and SST, respectively. Observations used for SLA are all the along-track altimeters available, whereas for SST observations used are in situ drifters.**

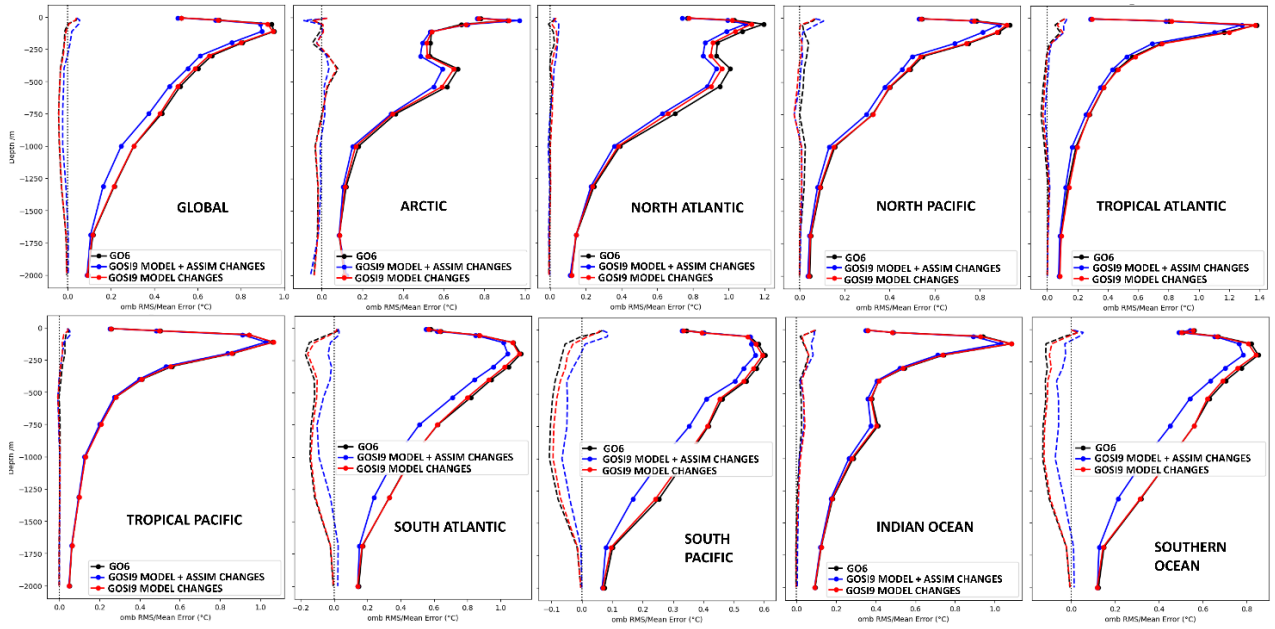


**Figure S8. 2019 FOAM ORCA025 OmB temperature statistics (°C) for GO6 (black), GOSI9 only considering model updates (red) and GOSI9 considering both model and DA updates (blue), calculated against profile observations. The solid lines correspond to RMSDs, and the dashed lines represent mean differences.**

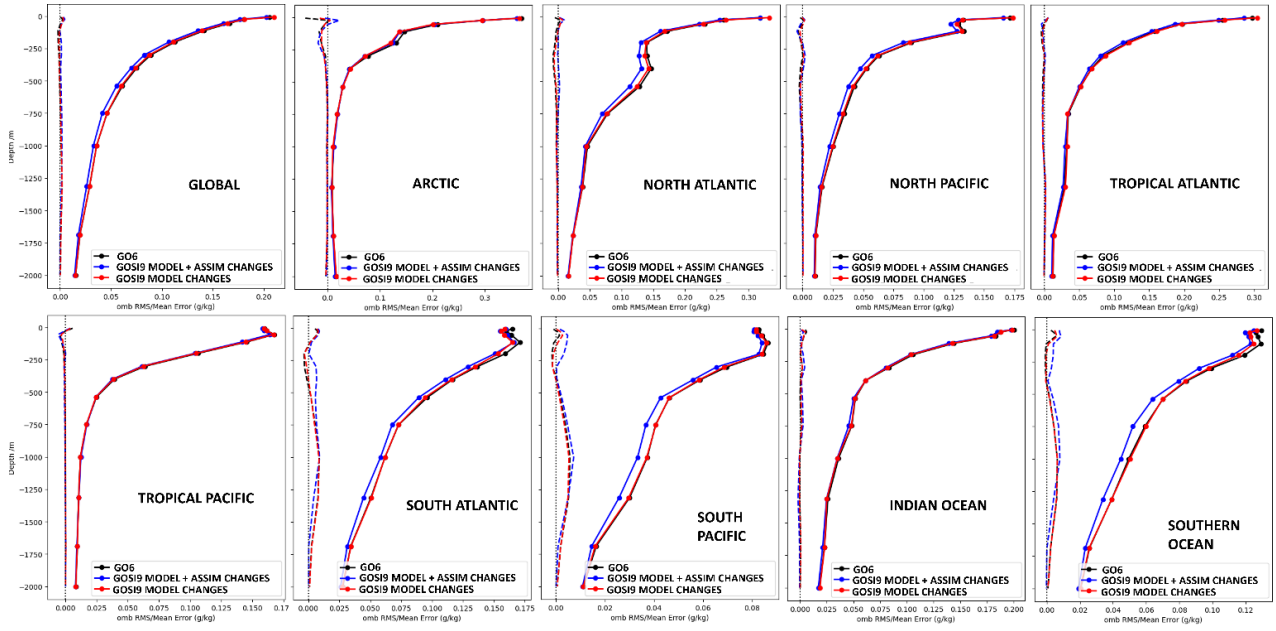


**Figure S9. 2019 ORCA025 OmB salinity statistics for GO6 (black), GOSI9 only considering model updates (red) and GOSI9 considering both model and DA updates (blue), calculated against profile observations. The solid lines correspond to RMSDs, and the dashed lines represent mean differences.**

## S10. Arctic sea ice concentration improvements over summer in ORCA025

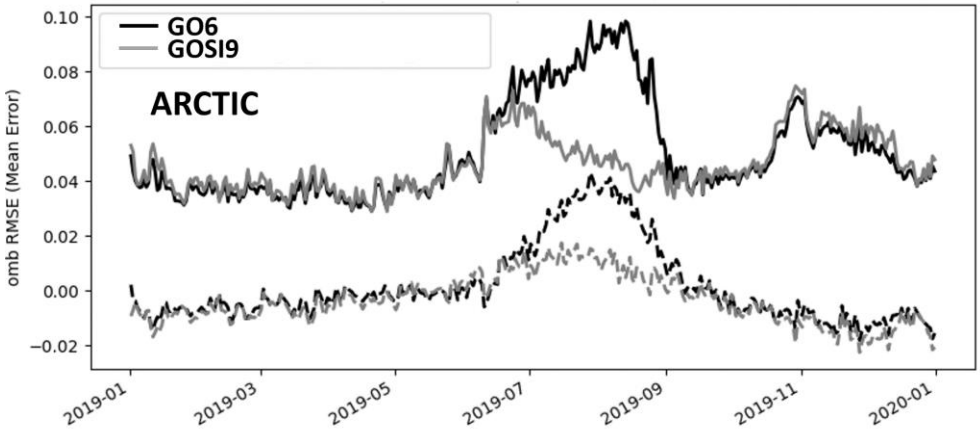


**Figure S10. 2019 FOAM ORCA025 OmB statistics for GO6 (black) and GOSI9 (grey), calculated against SSMIS SIC observations in the Arctic. The solid lines correspond to RMSDs, and the dashed lines represent mean differences.**