Supplements

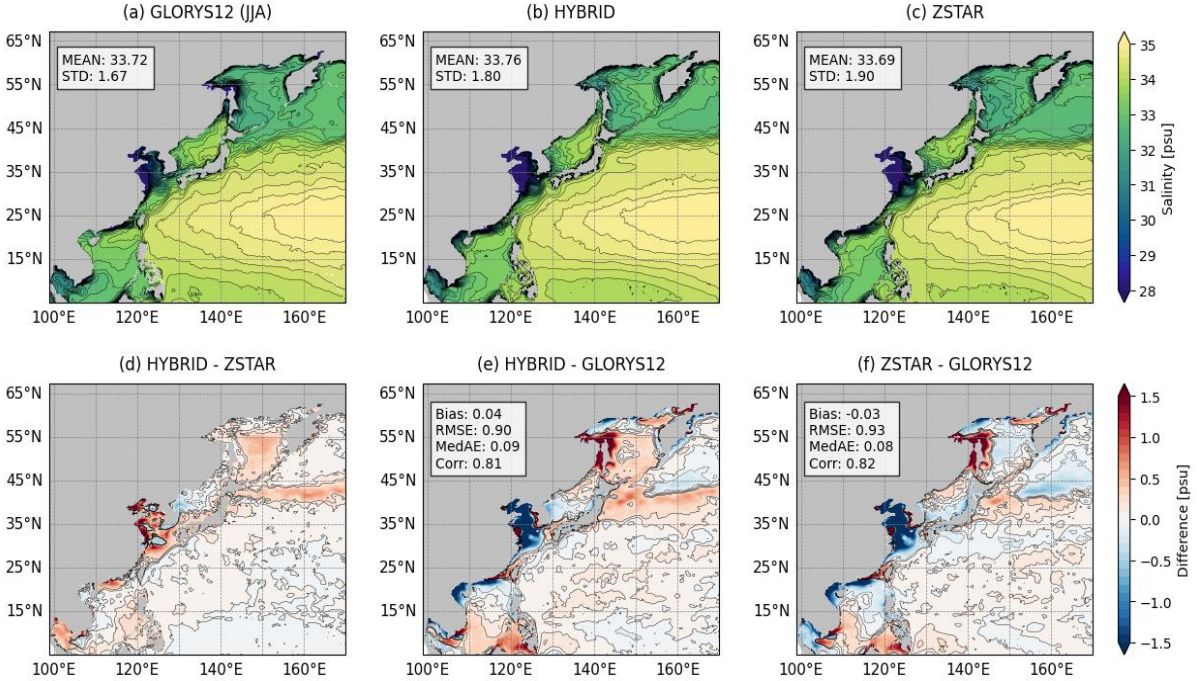

Figure S1. Boreal summer (JJA) mean sea surface salinity (SSS) distributions from GLORYS12 reanalysis and HYBRID and ZSTAR simulations. (a–c) Spatial SSS distributions with corresponding means and standard deviations (STD). (d) Differences between HYBRID and ZSTAR. (e, f) Biases relative to GLORYS12, including mean bias, RMSE, MedAE, and Corr. Contour lines in (d–f) indicate SSS biases ranging from -0.1 to 0.1 psu at 0.1 psu intervals.

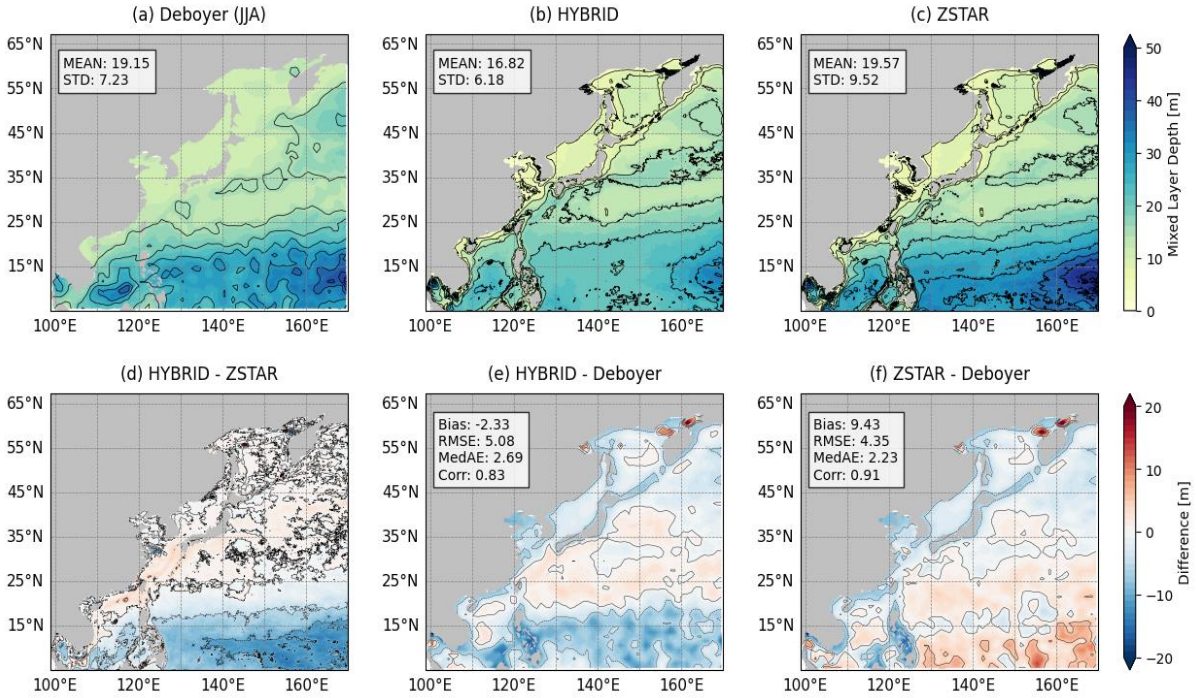

Figure S2. Boreal summer (JJA) mean mixed layer depth (MLD) distributions from de Boyer Montégut and HYBRID and ZSTAR simulations. (a–c) Spatial MLD distributions with corresponding means and standard deviations (STD). (d) Differences between HYBRID and ZSTAR. (e, f) Biases relative to de Boyer Montégut, including mean bias, RMSE, MedAE, and Corr. Contour lines in (d–f) indicate MLD biases ranging from -0.1 to 0.1 m at 0.1 m intervals.

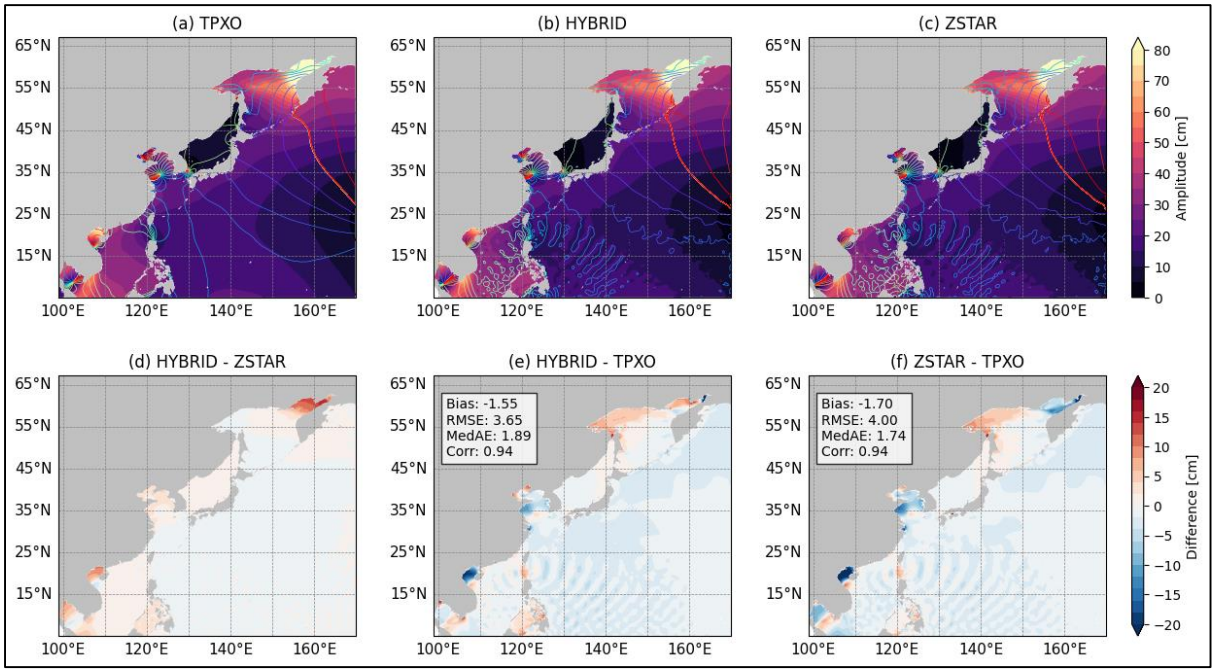

Figure S3. Diurnal K1 tidal amplitude and phase from TPXO data, HYBRID, and ZSTAR simulations. Shaded contours represent tidal amplitude, while overlaid coloured contours show tidal phase for K1 (a–c). Panels below display tidal amplitude differences: (a) HYBRID vs. ZSTAR, (b) HYBRID vs. TPXO, and (c) ZSTAR vs. TPXO. Metrics include mean bias, RMSE, MedAE, and Corr.

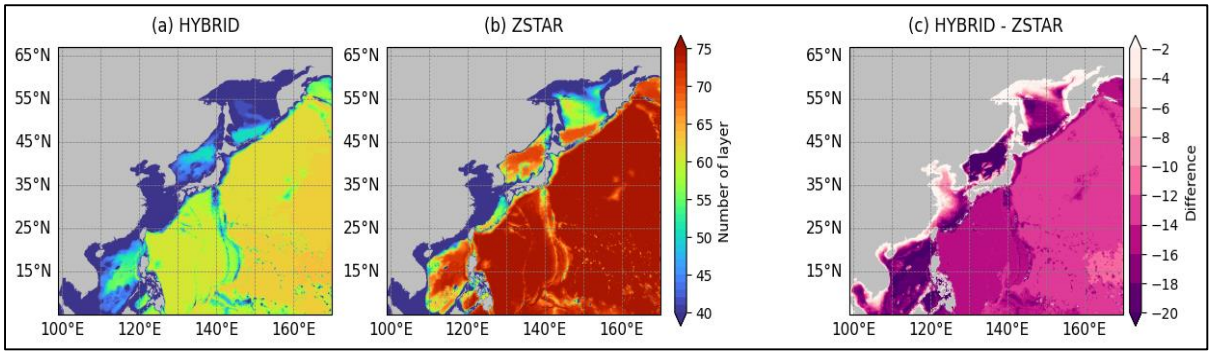

Figure S4. Spatial distribution of active layers in HYBRID and ZSTAR on January 31, 2012. (a, b) Number of active layers in HYBRID and ZSTAR, respectively, where an active layer is defined as having a thickness greater than 0.001 m. (c) Difference (HYBRID - ZSTAR).