Improvement in JMA's Ocean Data Assimilation and Prediction System for the Seas Around Japan (JPN system)

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1. Introduction

Since October 2020, JMA has operated an ocean data assimilation and prediction system (known as the JPN system) for the seas around Japan to support analysis and prediction of major currents (such as the Kuroshio), mesoscale eddies, high tides caused by oceanic conditions, rapid coastal currents, and sea ice conditions (Sakamoto et al. 2019; Hirose et al. 2019). The JPN system consists of an analysis part and a prediction part. The analysis part incorporates an eddy-resolving North Pacific model with reduced grid configuration (NPR) nested in a coarse global ocean model (GLB), and four-dimensional variational ocean data assimilation (NPR-4DVAR; Usui et al., 2015) is carried out for the NPR model. The prediction part comprises a fine-resolution (approx. 2 km) ocean model for the area around Japan (JPN) nested in an eddy-resolving North Pacific model (NP) with regular grid spacing that is also two-way nested in the GLB. NPR-4DVAR analysis provides water temperature and salinity data for initialization of the NP and JPN models.

Bias reduction in assimilation of satellite altimetry data and version updating of the forecast models (Sakamoto et al. 2023) were applied to the operational system in February 2023. The bias reduction is reported here.

2. Improvement in satellite altimetry data assimilation

Sea level anomaly (SLA) data derived from satellite altimeters (η_{obs}) incorporate surface dynamic height anomaly (η_{dyn}), barotropic response to surface wind forcing (η_{bt}), changes in total sea water mass over the entire model domain (η_{mass}), and measurement errors. In the JPN system, the η_{dyn} value obtained by subtracting non-steric components (η_{bt} and η_{mass}) from η_{obs} is used for assimilation to determine precise water temperature and salinity. Previously, both η_{bt} and η_{mass} were prescribed as monthly constants based on extrapolation from an ocean reanalysis experiment. To enhance accuracy, the monthly mean non-steric SLA averaged over the model domain is now estimated every day using the latest SLA and in-situ observation data, which is expected to allow more precise analysis of water temperature and salinity. To evaluate this, an experiment employing the updated SLA assimilation scheme (TEST) was conducted, and the results were compared with those from the previous control (CNTL) experiment.

3. Results

The estimated non-steric SLA averaged over GLB largely follows the extrapolated time series, while estimated values for NPR diverge downward from the extrapolation (Figure 1). This implies non-steric SLA overestimation and η_{dyn} underestimation for NPR-4DVAR in CNTL, leading to negative biases in water temperature.

Water temperature biases against in-situ observation in NP subsurface layers at initial states are depicted in Figure 2. The negative biases in CNTL decrease in TEST as expected. Reduced root mean square errors (RMSEs) are also seen in TEST (not shown). Figure 3 compares the biases and RMSEs of CNTL (blue) and TEST (red) averaged over the JPN model domain at initial states. The biases of CNTL are negative for most layers, and the negative biases of TEST are smaller than those of CNTL (Figure 3, top). TEST RMSEs are also smaller than those of CNTL almost everywhere (bottom). Error reduction associated with the smaller bias in the subsurface layer is seen for 10-day forecasts of the NP and JPN models (not shown).

In summary, the improved SLA data assimilation reduces cold biases in subsurface layers for NPR-4DVAR and prediction errors in the NP and JPN models.

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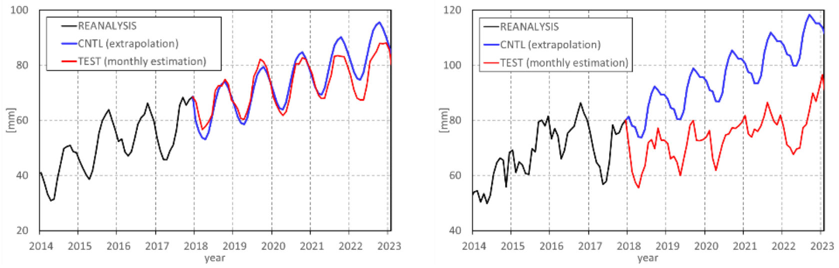

Figure 1 Monthly non-steric SLA averaged over the entire model domain (left: GLB; right: NPR). Black and red lines: monthly estimation; blue lines: extrapolation from black lines.

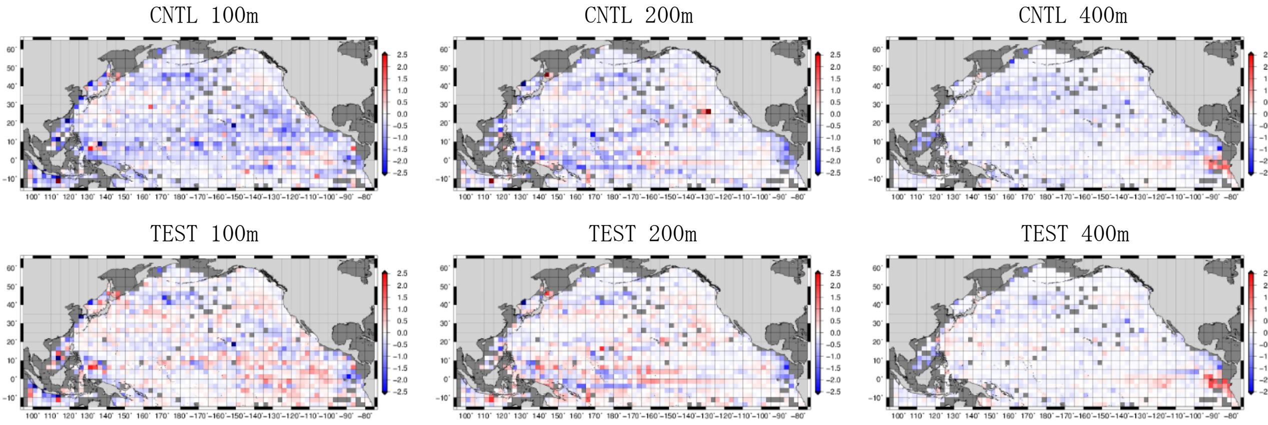

Figure 2 Water temperature biases (model variable minus in-situ observation) at 100 m (left), 200 m (center) and 400 m (right) at NP initial states. Daily observation data are compared with the nearest model grid point value, and biases are averaged within every $2.5^{\circ} \times 2.5^{\circ}$ mesh. The verification period is July 2021 – May 2022. The top and bottom panels depict the biases of CNTL and TEST, respectively.

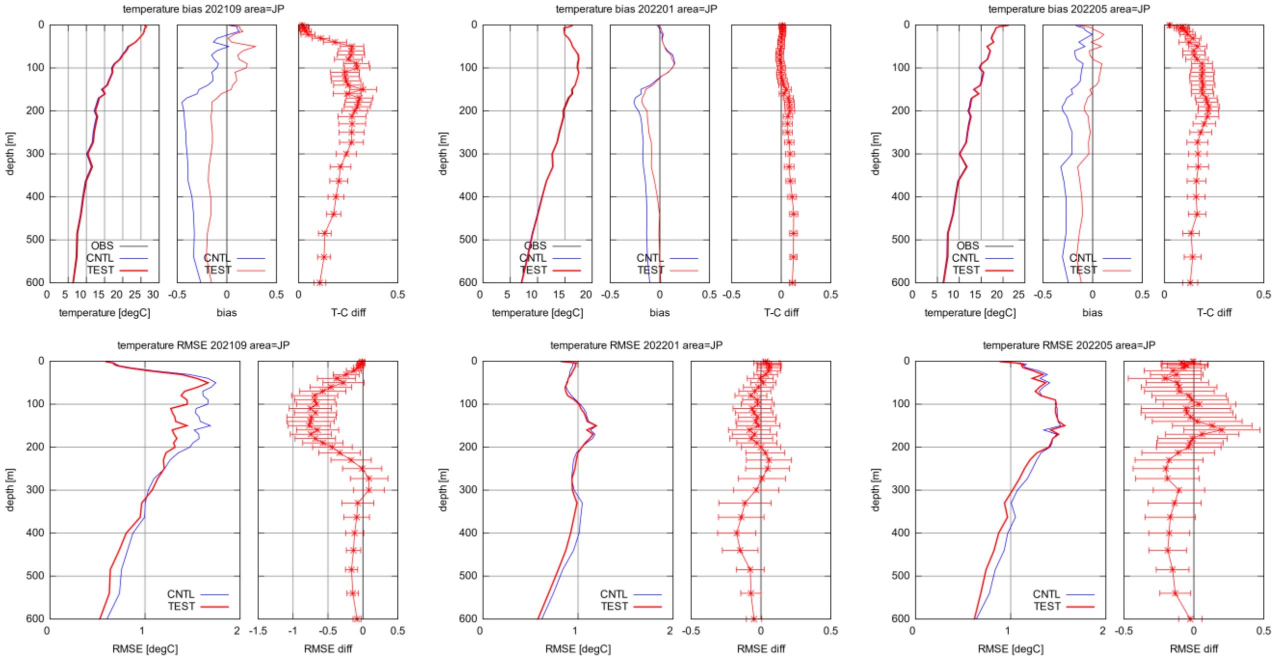

Figure 3 Vertical profiles of bias (top) and RMSE (bottom) for water temperature over the JPN model domain $(117-160^{\circ}\mathrm{E}, 20-52^{\circ}\mathrm{N})$ at initial states for September 2021, January 2022 and May 2022. Top left: in-situ observation (black), CNTL (blue) and TEST (red); top center: CNTL and TEST biases; right: TEST – CNTL. Bottom left: CNTL and TEST RMSEs; right: TEST – CNTL. TEST – CNTL error bars denote a confidence level of 95%.