Roles of dense in-situ observation network around Japan in the eddy-resolving ocean reanalysis

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Abstract

We have produced high-resolution reanalysis data in Japanese coastal ocean by using the JCOPE2 ocean forecast system as a part of a cooperative study between FRA and JAMSTEC. We found that incorporation of the in-situ temperature/salinity data obtained by Japanese local fishery research agencies into JCOPE2 reanalysis data significantly improved biases for temperature south of the Japanese coast.

Introduction

Coverage of hydrographic surveys around the Japanese coasts is most active and dense observation areas in the world. However, more than half of data on coastal repeated hydrographic observation lines conducted by Japanese prefectural fisheries research agencies (FRA-DATA) have not been reported in near real-time via Global Telecommunication System and then not been utilized in operational ocean forecast systems. Development of a real-time data transfer system for the fishery research agencies has allowed us to incorporate FRA-DATA into a real-time data archive, Global Temperature-Salinity Profile Program (GTSPP), from April 2007 (Komatsu et al., 2007).

However, FRA-DATA obtained from 1994 to 2006 have not archived in both of GTSPP and World Ocean Database (WOD), which are often used for production of the ocean reanalysis data (e.g., JCOPE2 reanalysis data; Miyazawa et al., 2009). By incorporating FRA-DATA into JCOPE2 reanalysis from 1994 to 1999, we investigated sensitivity of FRA-DATA to quality of the reanalysis.

Model and data assimilation

The ocean model is based on the Princeton Ocean Model for generalized coordinate of sigma (Mellor et al., 2002). The model region covers the western North Pacific from 10.5° to 62° N and 118° to 180° E, with horizontal resolution of 1/12° and 46 vertical sigma levels. The model was driven by wind stresses, and heat and salt fluxes. The wind stress and heat flux fields were calculated from the 6-hourly National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data (Kalnay *et al.*, 1996), using bulk formulae. Salinity at the ocean surface is restored to the monthly mean climatology data (Conkright *et al.*, 2002) with a time scale of 30 days.

The data assimilation procedure in our system comprises two steps: the creation of temperature-salinity analysis data on three-dimensional uniform grid by the variational assimilation method (Fujii and Kamachi, 2003), and incremental analysis update (IAU) (Bloom et al., 1996) of the analysis data for smooth initialization. Using the analysis temperature and salinity, we conducted the IAU procedure for data from December 1992 to January 2009 and stored daily mean data, referred to as FRA-JCOPE2 data.

The following observation data were assimilated into the model: along-track sea surface height anomaly (SSHA) obtained from the TOPEX/Poseidon and ERS-1,2 satellites during December 1992 to January 2002 and from the Jason-1,2 and Geosat Follow-On during January 2002 to January 2009; sea surface temperature (SST) obtained from the Advanced Very High Resolution Radiometer / Multi-Channel Sea Surface Temperature (AVHRR/MCSST) products; and in-situ temperature and salinity profiles extracted there different data archives: GTSPP, WOD, and FRA-DATA. Notice that present version of GTSPP and WOD do not involve FRA-DATA for the period from January 1994 to March 2007.

To investigate sensitivity of FRA-DATA and WOD to quality of our ocean reanalysis data, we produced additional reanalysis data (hereafter, 'noFRA') by assimilating only GTSPP for the period from 1993 to 1999. Figure 1 compares mean data density of in-situ temperature and salinity profiles in the model region for only GTSPP (left panels) and GTSPP+WOD+FRA (right panels). Inclusion of FRA-DATA significantly increased data density near the Japanese coasts. Salinity data around the Japanese coasts for this period was not involved in GTSPP.

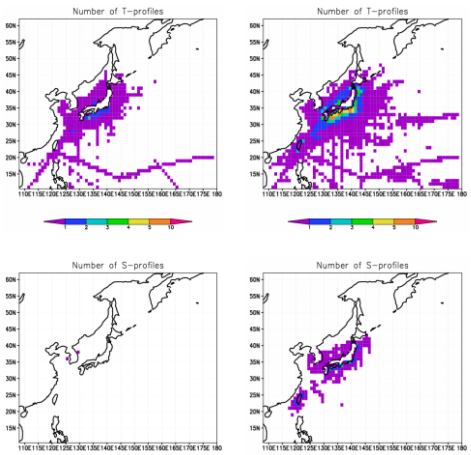

Fig.1: Number of in-situ profiles monthly averaged in 1 deg. X 1 deg. boxes from 1993 to 1999. Left: GTSPP archive. Right: GTSPP+WOD+FRA archives. Upper: temperature. Lower: salinity.

Sensitivity of FRA-DATA to the reanalysis data

To detect effects of FRA-DATA on quality of the reanalysis data, we compared mean error (bias) of temperature and salinity profiles from 1993 to 1999 of both the FRA-JCOPE2 and noFRA data for the observed profiles included in GTSPP+WOD+FRA archives. The noFRA data showed negative bias of -1 to -2 ° C for the temperature at the depth from 100m to 400m near the southern coast of Japan but no significant bias for the salinity (not shown). The negative bias of FRA-JCOPE2 profiles there was decreased to -0.5 to -1 ° C owing to assimilation of FRA-DATA. Comparison of skills of the Kuroshio path latitude between FRA-JCOPE2 and noFRA data using the observation data of the Kuroshio path position obtained from the surface velocity data (Ambe et al., 2004) showed no significant difference, suggesting that the assimilation of sea surface height anomaly and sea surface temperature was effective for the reproduction of the realistic Kuroshio path (i.e. Yoshinari et al., 2008).

Figure 2 illustrates a typical example showing the sensitivity of FRA-DATA to the quality of the reanalysis data south of Japan. Both of noFRA (upper panel) and FRA-JCOPE2 (upper middle panel) reproduced the similar Kuroshio path as observed (lower middle panel). However, in coastal region north of the Kuroshio front, temperature of noFRA at 200m depth is relatively low compared with FRA-JCOPE2, which well reproduced warm water of 14 ° C intrusion along the eastern coast of the Kii Peninsula, around 34 ° N and 136.5 ° E. Lower panel of Fig.2 indicates that negative bias for the temperature profiles of noFRA data in the coastal region (34 ° -35 ° N and 136 ° -139 ° E) was considerably reduced for those of FRA-JCOPE2 data.

The assimilation of FRA-DATA clarified that the temperature profiles of JCOPE2 reanalysis had the negative bias in the near shore region along the southern coasts of Japan. We found that the negative bias was caused by the low quality of climatological temperature data near the coast. The United States Navy's Generalized Digital Environmental Model (GDEM) monthly climatological temperature and salinity data were used to create the first guess of the assimilation (Miyazawa et al., 2009). If no in-situ data are assimilated into the JCOPE2 system near the coast, the analysis temperature equals to the first guess there. The quality of JCOPE2 data without the assimilation of FRA-DATA is governed largely by that of the climatology data used as the first guess.

Summary

Incorporation of FRA-DATA into the JCOPE2 reanalysis resulted in the improvements of the reproduction skill of temperature and salinity distribution near the coast of Japan. In particular, the assimilation of FRA-DATA was effective to correct the positive bias of temperature profiles in the coastal region south of Japanese coasts. To reproduce more realistic temperature and salinity distributions near around Japanese coasts, using FRA-DATA, we are revising the climatology data of temperature and salinity there that are used as the first guess of the data assimilation.

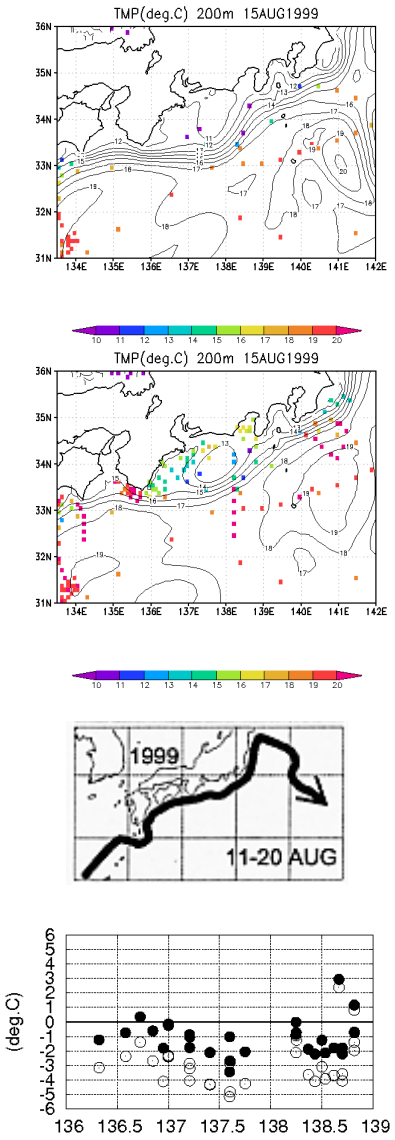

Fig.2: Upper: Contours (colored squares) denote reanalysis (observed) temperature of 200m depth. Upper: noFRA with GTSPP. Upper middle: FRA-JCOPE2 with GTSPP+WOD+FRA. Lower middle: Observed Kuroshio path from 11 to 20 August 1999 reported by Japan Meteorological Agency. Lower : Biases of temperature profiles in 34 ° -35 ° N, 136 ° -139 ° E for FRA-DATA. 'FRA' denotes FRA-JCOPE2.