New Ocean Data Assimilation System for monitoring ENSO at Japan Meteorological Agency

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INTRODUCTION

Japan Meteorological Agency (JMA) has been monitoring El Niño/Southern Oscillation (ENSO) using an ocean data assimilation system since 1995. Products of this system have also been used as initial conditions for ENSO forecast. Since 2000, a new version of the ocean data assimilation system has been developed at JMA and Meteorological Research Institute (MRI), and will replace the current JMA operational system in March 2008.

MOVE/MRI.COM-G: Ocean Data Assimilation System in JMA

The new system consists of an ocean general circulation model and a data assimilation system. The former is the MRI Community Ocean Model (MRI.COM; Ishikawa et al., 2005), and the latter is the Multivariate Ocean Variational Estimation (MOVE; Usui et al., 2006) System. In the new system, the horizontal resolution is 1.0º in both longitude and latitude with 50 vertical levels (24 levels in the upper 200 m). To drive the ocean model, data from the Japanese Re-Analysis 25 years (JRA-25; Onogi et al., 2007) and the JMA Climate Data Assimilation System (JCDAS) are used. The MOVE System assimilates observational data including temperature, salinity and sea surface height (altimetry data) to the model, and the analysis method of the MOVE System is a three-dimensional variational (3D-VAR) method with coupled temperature-salinity empirical orthogonal function (EOF) modes (Fujii and Kamachi, 2003).

EXPERIMENTAL DESIGN

To evaluate the performance of the new system, we have run the new system during 1979-2004 with JRA-25 as an atmospheric forcing. Additionally, in order to elucidate characteristics of JRA-25 as an atmospheric forcing of the ocean model, we have carried out another run with the new system driven by ECMWF 40 Year Re-Analysis (ERA-40; Uppala et al., 2005) during 1979-2001. We compared the results with these different driving forces.

We have also run the ocean model without assimilating ocean observations by using two different atmospheric forcings, in order to clarify model errors, which would affect the assimilation results. It is also expected that the differences between runs with different forcings are clearer in the model-only (or free) runs than in the assimilation results.

We firstly checked the difference of the ENSO description, especially the subsurface temperature structure in the tropical Pacific, because the main purpose of this system is monitoring and forecasting ENSO events.

As references, we used subsurface temperature and current data measured by TAO arrays. The differences from current data are good indicators, since current data are not assimilated in this system (Figure 4, 5).

RESULTS

1) Atmospheric Forcing

The most significant difference between two forcings (JRA-25 and ERA-40) is zonal wind stresses in the eastern equatorial Pacific. Easterlies of JRA-25 were stronger than those of ERA-40 for almost all periods through this experiment, except during the intensive El Niños (Figure 1 (a)). The difference of zonal wind stress climatology shows that easterlies of JRA-25 in the east were stronger than those of ERA-40 and seasonal variation in the difference was found in the west (Figure 1 (b)).

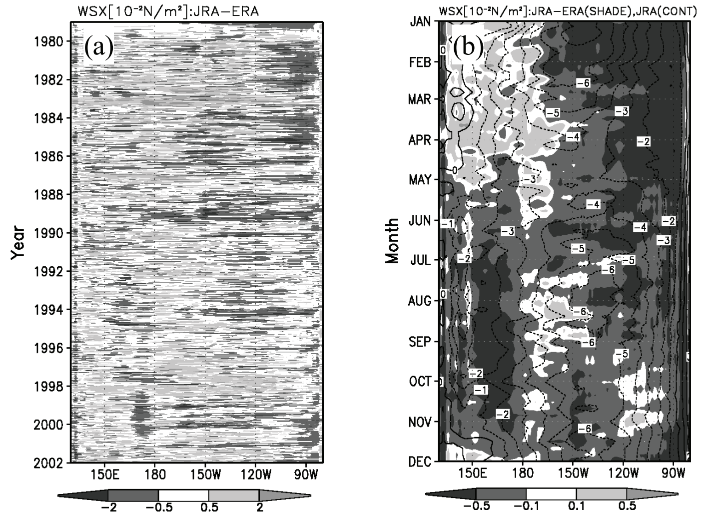

Figure 1 Longitude-time section of zonal wind stress difference in the equatorial Pacific (JRA – ERA, (a): historical series, (b): climatology (climatology is based on 1979-2001 mean)).

2) SST

Associated with stronger easterlies of JRA-25 in the eastern equatorial Pacific, SSTs in the assimilation and free run with JRA-25 were lower than those with ERA-40 in this area (Figure 2 (a) – (d)), except during the intensive El Niños (Figure 2 (a), (b)). Both SSTs with JRA-25 and ERA-40 get close to the value of COBE-SST (Ishii et al., 2005) by assimilation, but the negative bias of JRA-25 still remains in this area (Figure 2 (a), (b)).

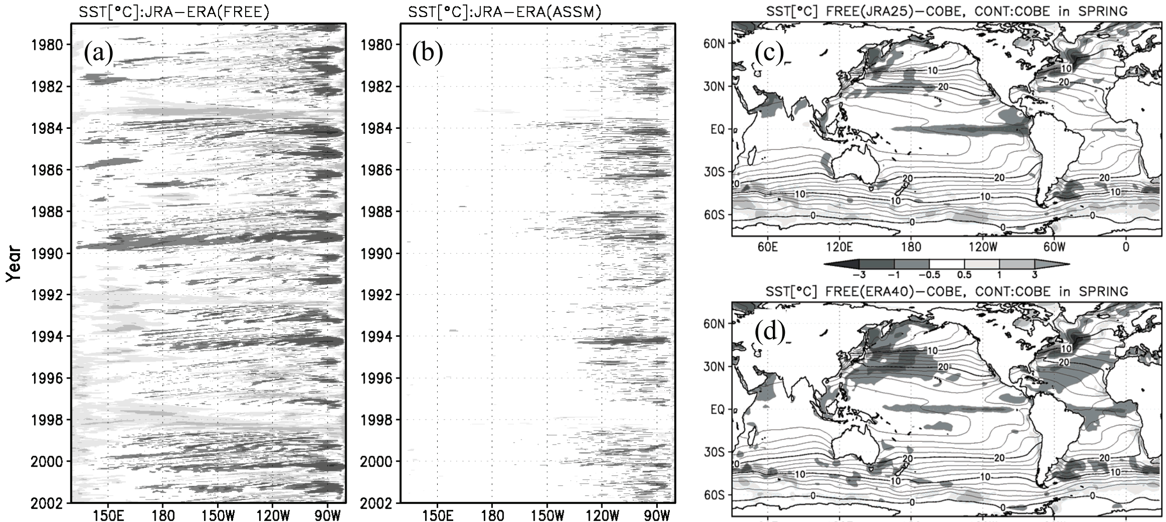

Figure 2 Longitude-time section of SST difference in the equatorial Pacific (JRA – ERA, (a): free run, (b): assimilation). SST climatology difference with COBE-SST in Spring (climatology is based on 1979-2001 mean. (c): free run with JRA, (d) free run with ERA)

3) Subsurface Temperature and Current in the Equatorial Pacific

In the equatorial Pacific, Ocean Heat Contents (OHC; defined as vertically averaged temperature from surface to the depth of 300 m) in the free run with JRA-25 were higher than those with ERA-40 for almost all periods of this experiment, except near the eastern end (Figure 3 (a), (b)). The difference was reduced by assimilation (Figure 3 (a), (b)). According to the longitude-depth section of temperature in the equatorial Pacific, the thermocline in the free run was deeper than that in the assimilation with both JRA-25 and ERA-40, and the difference between the assimilation and free run was larger with JRA-25 than that with ERA-40 (Figure 3 (c), (d)). In the western and central equatorial Pacific, the differences of temperature and zonal current between assimilations and free runs were little (Figure 4 (a), (b), Figure 5 (a), (b)), but the differences in the eastern equatorial Pacific were great (Figure 4 (c), (d), Figure 5 (c), (d)). As to temperature, assimilated data reproduced the observation well in both JRA-25 and ERA-40, but the thermocline in the free run was deeper with less temperature drop, especially with JRA-25 (Figure 4 (c), (d)). Associated with this difference in stratifications in the eastern equatorial Pacific, the vertical structure of the Equatorial Undercurrent (EUC) was different, especially in the free run, with different forcings (Figure 5 (c), (d)).

We think these results can be attributed mostly to stronger easterlies of JRA-25 in the eastern equatorial Pacific. Stronger easterlies intensify the upwelling, which cools shallower waters near the eastern end of the equatorial Pacific. It is supposed that deepening of the thermocline in the central and eastern equatorial Pacific is due to increased meridional advection of warm waters into the equatorial region, associated with the intensified meridional circulations and increased subductions driven by stronger wind stress curls in the both sides of the equator.

To improve the results of MOVE/MRI.COM-G, improvement of the atmospheric forcing is supposed to be important. A technique of adjusting wind stresses by balancing the observed zonal gradient of the ocean thermocline is proposed (Ishizaki et al., 2006).

ACKNOWLEDGMENTS

We thank I. Yoshikawa, Y. Takaya and staff of the El Niño Monitoring and Prediction Group of JMA for helpful comments.

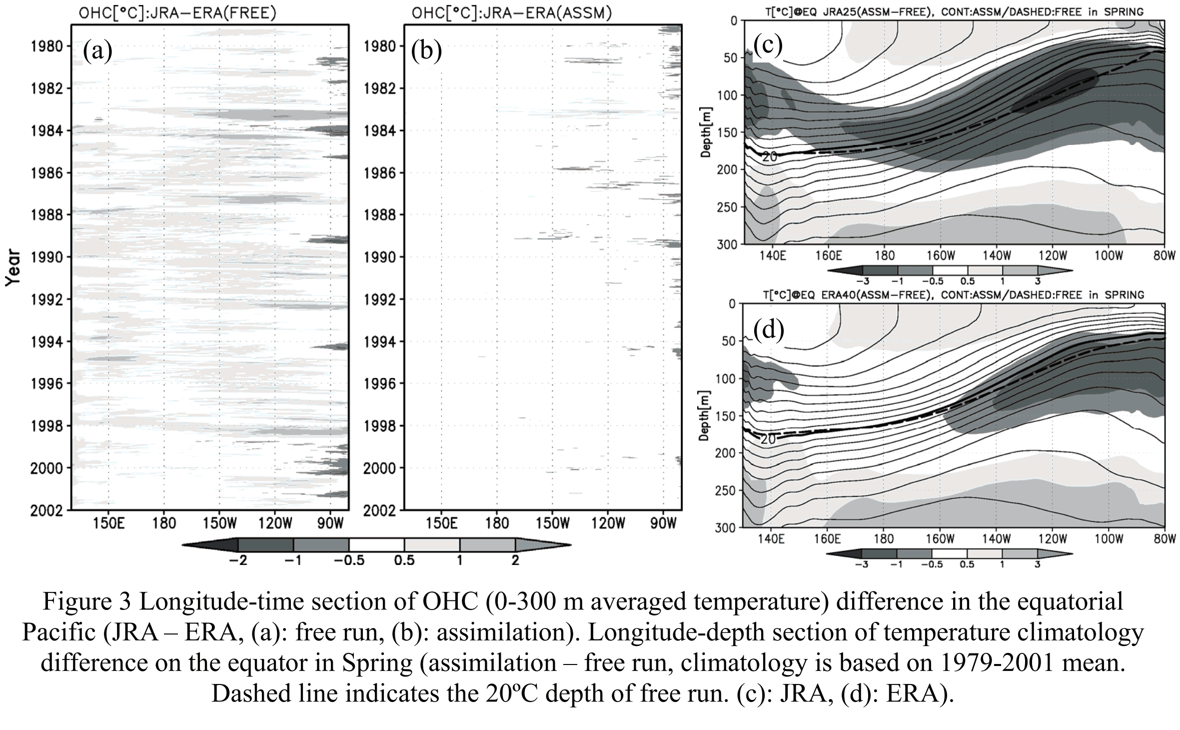

Figure 3 Longitude-time section of OHC (0-300 m averaged temperature) difference in the equatorial Pacific (JRA – ERA, (a): free run, (b): assimilation). Longitude-depth section of temperature climatology difference on the equator in Spring (assimilation – free run, climatology is based on 1979-2001 mean. Dashed line indicates the 20ºC depth of free run. (c): JRA, (d): ERA).

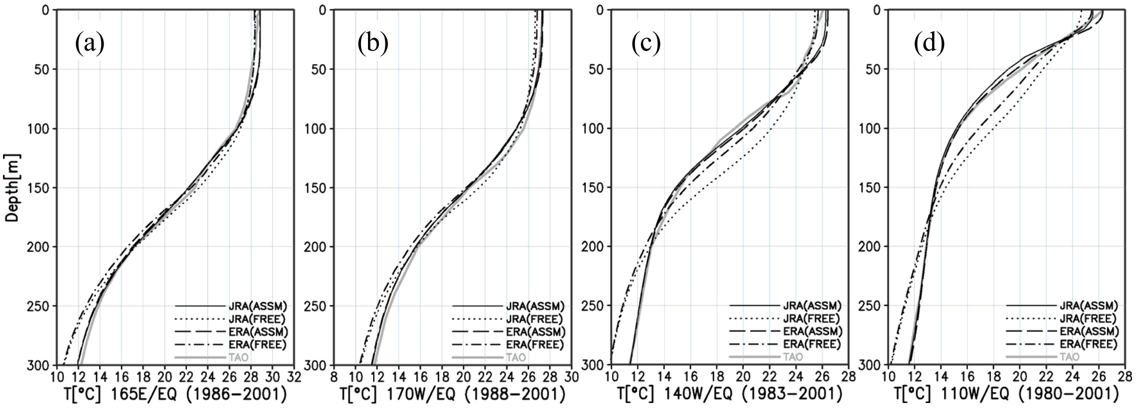

Figure 4 Profiles of mean temperature on the equator in Spring (free run with JRA and ERA, assimilation with JRA and ERA, and observation of TAO array. (a): 165ºE, (b): 170ºW, (c): 140ºW, (d): 110ºW).

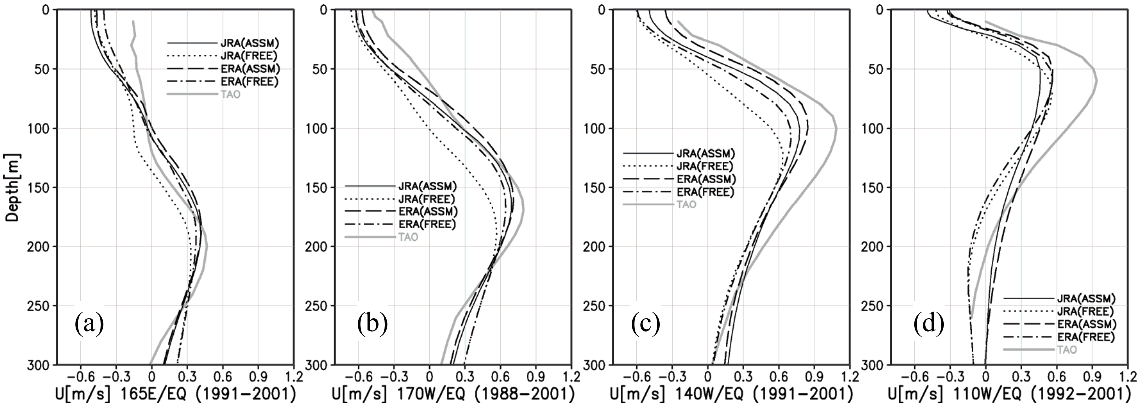

Figure 5 Profiles of mean zonal current on the equator in Spring (free run with JRA and ERA, assimilation with JRA and ERA, and observation of TAO array. (a): 165ºE, (b): 170ºW, (c): 140ºW, (d): 110ºW).

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