Operational 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. The products of this system have also been used as initial conditions for ENSO forecast (Fig.1). A new version of ENSO forecasting system including an ocean data assimilation system (MOVE/MRI.COM-G) and a coupled model (JMA/MRI-CGCM) was developed at JMA and Meteorological Research Institute (MRI), and replaced the previous system in March 2008.

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

The Ocean Data Assimilation System in JMA, MOVE/MRI.COM-G consists of an ocean general circulation model and an objective analysis. The former is the MRI Community Ocean Model (MRI.COM[1]), and the latter is the Multivariate Ocean Variational Estimation (MOVE[2]) System. This system covers the global ocean (indicated by -G) and its horizontal resolution is 1.0º in both longitude and latitude with 50 vertical levels (24 levels in the upper 200m, Table.1 and Fig.2). To drive the ocean model, the Japanese Re-Analysis 25 years (JRA-25[3]) 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 MOVE is a three-dimensional variational (3D-VAR) method with coupled temperature-salinity empirical orthogonal function (T/S-EOF) modes[4]. Furthermore, MOVE/MRI.COM-G provides the initial conditions for the coupled model (JMA/MRI-CGCM), which is used as the system of ENSO forecasting.

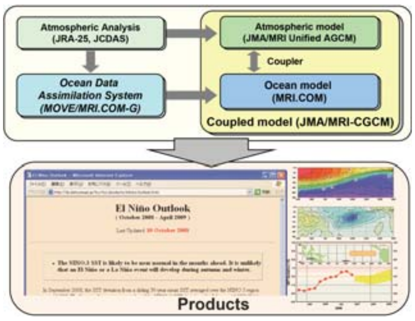


Fig. 1 Schematic diagram of ENSO monitoring and forecasting system at JMA.

System Name	• MOVE/MRI.COM-G & JMA/MRI-CGCM
OGCM	
Horizontal resolution	• 1.0 deg (0 – 360E) / 0.3 – 1.0 deg (75S – 75N)
Vertical levels	• 50 (1 – 4,500m)
Vertical mixing scheme	• Noh and Kim (1999)
Atmospheric forcing	• JRA-25 (1979 – 2004) / JCDAS (2005 – present) • Wind stress, Precipitation and Heat flux (Bulk)
Ocean Data Assimilation	
Data Analysis	• 3D-VAR (T/S-EOF)
Assimilation method	• IAU (10-day)
Quality check	• Fujii et al. (2005)[5]
Maximum analyzed depth	• 1,500m
Assimilated data	• T/S profiles (mainly GTS and WOD01) • SST (COBE-SST[6]) • Altimetry (mainly T/P, Jason-1, and Envisat)
Interval	• Every 5-day
Operation	• Mar 2008 – present
CGCM	
Resolution of Atmospheric model	• TL95L40 (~200km)
Coupling interval	• 1-hour
Flux adjustment	• Adjusted (heat and momentum flux)
Forecast ensembles	• 12 member LAF (1mem/5day x 2month)
Operation	• Mar 2008 – present

Table. 1 System configurations of ENSO monitoring and forecasting system at JMA.

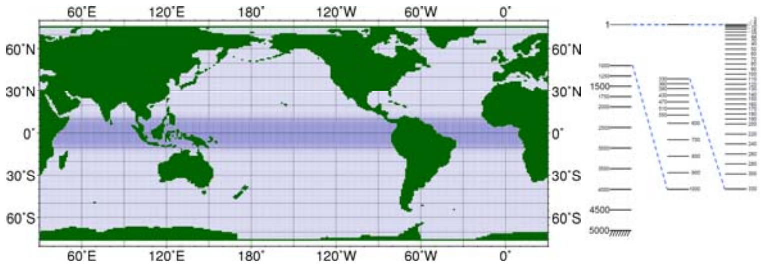


Fig. 2 Horizontal map (left) and vertical levels [m] (right) of MOVE/MRI.COM-G.

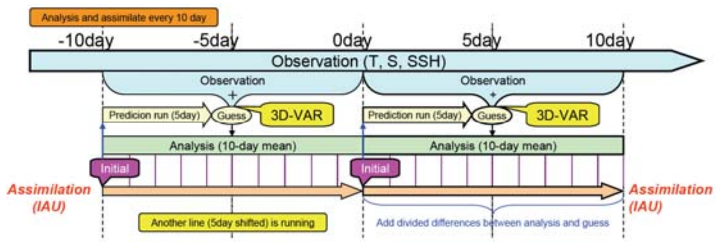


Fig. 3 Schematic diagram of the Ocean Data Assimilation Procedures of the MOVE/MRI.COM-G.

Previous ODAS

Differences of MOVE/MRI.COM-G from the previous system (ODAS) are as follows:

• In the ocean model (MRI.COM), both higher spatial resolution and adoption of some new techniques[1] (Table.1) enabled us to represent physical processes better, especially variations of thermoclines and propagations of the equatorial ocean waves.

• By using JRA-25/JCDAS as the atmospheric forcing (ODAS used GANAL; JMA's operational global atmospheric analysis), the analyzed fields have more consistent quality through the analysis period (from 1979).

• In assimilation, an introduction of T/S-EOF modes enabled us to analyze a salinity field more precisely[4], and adopting variational QC enabled us to represent ENSO phenomena more effectively[5].

• In assimilation, setting 10-day window (ODAS; 1-day) as an analysis period and using all data just in the period enabled us to represent the analyzed fields more realistic.

Future Plan

1) Introduction of Ensemble Forecast

We are going to introduce a new method to generate the initial conditions for ENSO forecast using perturbed wind stresses of atmospheric BGM[8]. The products from JMA/MRI-CGCM, which has enhanced ensemble members by this method, will be used for not only ENSO forecast but seasonal forecast.

2) Monitoring Indian Ocean

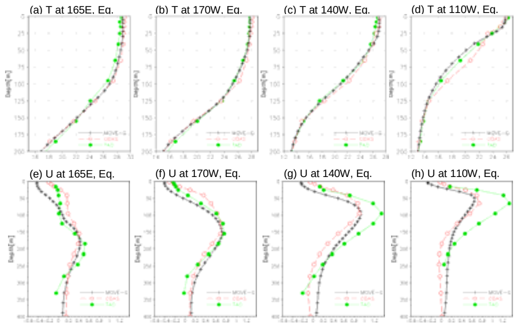
Monitoring Indian Ocean becomes more important recently. Following increased observations by ARGO and performances of the system, we are going to offer the information of monitoring Indian Ocean in 2009.

Performance of MOVE/MRI.COM-G

1) Climatology: Subsurface Temperature and Zonal current on the Equator

To show the performance of the new system, we compared time-averaged values (climatology) of subsurface temperature and zonal current on the Equator of the present system with those of the previous system. We used observations of TAO arrays as the reference of subsurface temperature and zonal current on the Equator. In Fig.4 (a) – (d), subsurface temperatures of MOVE/MRI.COM-G were closer to the observations, and this was remarkable at 110W. In Fig.4 (e) – (h), subsurface zonal currents of MOVE/MRI.COM-G were not closer to observations necessarily, but depths of the local minimum and maximum were closer to observations in the central and western equatorial Pacific.

Fig. 4 Climatology in April (averaged from 1988 to 2004).
(a) – (d): Temperature [deg C] on the Equator (165E, 170W, 140W, and 110W).
(e) – (h): Zonal current [m/s] on the Equator (165E, 170W, 140W, and 110W).
In each figures, the values of MOVE-G, previous ODAS, and TAO arrays are plotted.
The values of TAO in (a) – (h) are linearly interpolated to the vertical levels of ODAS.



2) Time-series: Subsurface Temperature in the Equatorial Pacific

In Fig.5, time series of vertical temperature gradients (dT/dz) and depths of 20C (D20) at 110W, Eq. are shown. In this area, the depths of 20C (D20s) nearly correspond to thermoclines, minima of vertical temperature gradients (dark shaded). D20s correspond well to minima of dT/dz in MOVE/MRI.COM-G and TAO (Fig.5 (a), (b)), but not in ODAS (Fig.5 (c)).

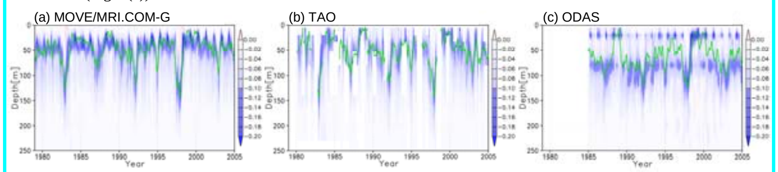


Fig. 5 Time-depth section of vertical temperature gradient (dT/dz; shaded) and depth of 20C (D20; contour) at 110W, Eq. In this region, D20 is thought to correspond with the minimum of dT/dz. (a):MOVE/MRI.COM-G, (b): Observation of TAO, (c): ODAS. The values of (b) are linearly interpolated to the vertical levels of ODAS.

3) ENSO Forecast

The results of MOVE/MRI.COM-G are also used as the initial conditions in forecasting ENSO (Fig.1). And the forecasting skills derived from the coupled model (JMA/MRI-CGCM) are better than those of the previous system (JMA-CGCM02). In the equatorial Pacific, the forecasting skills are better than those of the previous system not only in the eastern part (Fig.6 (a), (c)), but also in the western part (Fig.6 (b), (d)).

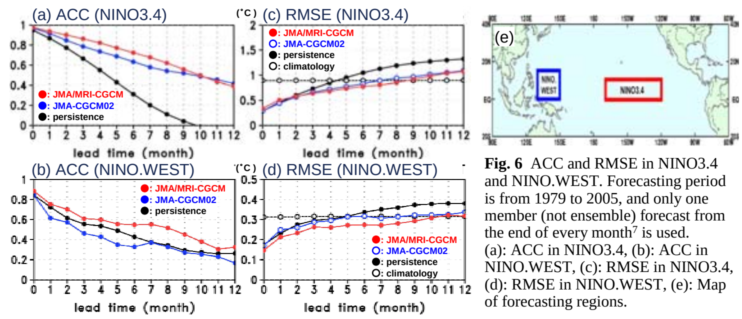


Fig. 6 ACC and RMSE in NINO3.4 and NINO.WEST. Forecasting period is from 1979 to 2005, and only one member (not ensemble) forecast from the end of every month[7] is used.
(a): ACC in NINO3.4, (b): ACC in NINO.WEST, (c): RMSE in NINO3.4, (d): RMSE in NINO.WEST, (e): Map of forecasting regions.

4) Atmospheric Forecast of Coupled Model

JMA/MRI-CGCM is not only used for ENSO forecast, but also intended to be used for seasonal forecast in the future. For present, JMA operates AGCM with two-tier method; prescribed SSTs are given as boundary conditions. According to the hindcast experiment (1984 – 2005), the forecast skills of atmospheric fields are improved by the CGCM compared to the present AGCM[7] (Fig.7). This result shows that SSTs are important boundary conditions for the seasonal forecast and ocean-atmosphere interaction can be treated explicitly by the CGCM. This improvement is remarkable especially in the monsoon region, in which SSTs are not highly correlated with convection.

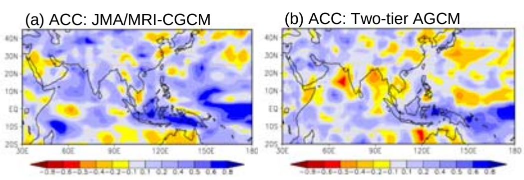


Fig. 7 Forecast skill of precipitation (JJA 4 months lead). 10-member ensemble forecast started from around the end of January. Period of the retrospective forecast is 22 years (1984 – 2005). JJA mean precipitation is verified with CMAP analysis.
(a): Coupled, (b): Two-tier AGCM.

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Presented at the GODAE Final Symposium, Nice France 12-15 November 2008.