OBSERVING SYSTEM EVALUATIONS USING THE OCEAN DATA ASSIMILATION AND PREDICTION SYSTEM, MOVE/MRI.COM

Yosuke Fujii [(1)], Masafumi Kamachi [(2)], Norihisa Usui [(3)], Satoshi Matsumoto [(4)], Tamaki Yasuda [(5)], Shiro Ishizaki [(6)]

[(1)]MRI, 1-1 Nagamine, Tsukuba, Ibaraki, 305-0052 (Japan), Email: yfujii@mri-jma.go.jp
[(2)] MRI, 1-1 Nagamine, Tsukuba, Ibaraki, 305-0052 (Japan), Email: mkamachi@mri-jma.go.jp
[(3)] MRI, 1-1 Nagamine, Tsukuba, Ibaraki, 305-0052 (Japan), Email: nusui@mri-jma.go.jp
[(4)] MRI, 1-1 Nagamine, Tsukuba, Ibaraki, 305-0052 (Japan), Email: smatsumo@mri-jma.go.jp
[(5)] MRI, 1-1 Nagamine, Tsukuba, Ibaraki, 305-0052 (Japan), Email: tyasuda@mri-jma.go.jp
[(6)] JMA, 1-3-4 Ohtemachi, Chiyoda, Tokyo, 100-8122 (Japan), Email: s_ishizaki@met.kishou.go.jp

ABSTRACT

we summarize activities to evaluate observing systems using MOVE/MRI.COM, the ocean data assimilation and prediction system developed in the Meteorological Research Institute. The result of a singular vector analysis indicates an effective area of observations for predicting the Kuroshio large meander formation. Impacts of the TAO/TRITON array and Argo floats on ENSO forecasting are confirmed by Observing System Experiments. These provide essential information for sustaining and expanding the ocean observing systems.

1. INTRODUCTION

MOVE/MRI.COM, the ocean data assimilation and prediction system developed in Meteorological Research Institute (MRI) [1], is constituted of the ocean general circulation model, MRI.COM [2, 3], and the 3-dimensional variational (3DVAR) analysis scheme using a vertical coupled temperature-salinity EOF modal decomposition of the background error covariance matrix [4, 5]. MOVE/MRI.COM has been used in Japan Meteorological Agency (JMA) in the operation since March 2008. The global version of MOVE/MRI.COM (MOVE-G) is employed for the ENSO monitoring as well as providing a coupled atmosphere-ocean general circulation model (CGCM) with initial conditions for the ENSO forecast [6]. The western north Pacific version of MOVE/MRI.COM (MOVE-WNP) is used for monitoring and forecasting of the ocean state around Japan, and able to predict the formation of the Kuroshio meandering south of Japan about two month ahead [7].

Evaluating the impact of observation data on the skill of data assimilation and prediction systems is instrumental for sustaining and expanding the observation systems. Some activities to evaluate the impacts of observations are conducted in JMA/MRI using MOVE/MRI.COM. From the activities, we here introduce the two major results, the singular vector analysis of the Kuroshio large meander and the evaluation of the impacts of the TAO/TRITON array and Argo floats on the ENSO forecasting.

2. SINGULAR VECTOR ANALYSIS OF THE KUROSHIO LARGE MEANDER

Singular Vector (SV) analysis is a way to identify the most unstable perturbations that grow up most rapidly in a certain period and affect a following phenomenon most effectively under a linear approximation. If the most unstable perturbations are detected by observations appropriately, it will improve the prediction of the following phenomenon substantially. This technique is, therefore, applicable for identifying an effective area of observations for predicting a certain target phenomenon.

We applied SV analysis to the formation process of the Kuroshio large meander reproduced in MOVE-WNP, and demonstrated that the leading singular vector represents a growing perturbation that leads to a further development of the large meander [8]. Fig. 1a shows the perturbation to vertical velocity and pressure at 820 m depth before the growing. An anticyclonic anomaly is positioned at 133 E and 31 N. This anomaly enhances an anticyclonic eddy traveling from east and contacting with Kuroshio there in the background state. The anomaly induces cold advection across the Kuroshio and downwelling to the north. This results in shrinking of the vortex tube and development of an anticyclonic circulation in the deep layers. This deep-layer anticyclonic eddy generates the cold water core in the downstream side of it, and the core interacts with a small meander of the Kuroshio in the upper layer, resulting in inducing baroclinic instability.

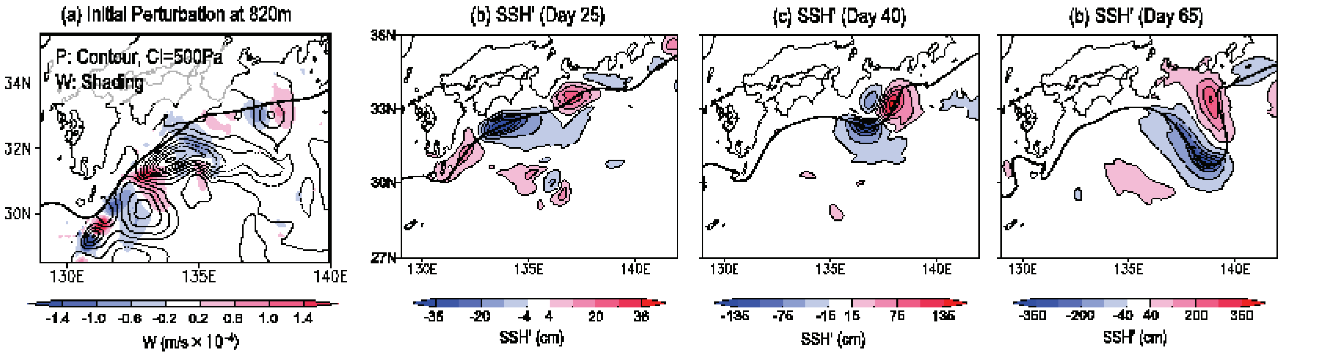

Figure 1. Perturbation represented by the leading SV affecting the formation of the Kuroshio large meander. (a) Perturbation fields for pressure (contour; dotted lines are negative) and vertical velocity (shading; positive is downward) at 820 m depth. (b-d) SSH anomalies (scales are different for each panel) that result from the perturbations represented in panel (a). Thick lines show the axis of Kuroshio Current in the background state; adapted from [8].

Time-evolution of SSH anomalies that represents the development of the perturbation is summarized in Fig. 1b-d. As illustrated in these figures, the perturbation shown in Fig. 1a induces the further development of the large meander about 2 months later. Although SV analysis is performed under a linear approximation, we also confirm that the large meander developed further when the perturbation is added to the background and that it does not appear when the perturbation is subtracted from the background in the original nonlinear model.

This result indicates that, in order to predict the Kuroshio large meander effectively, a data assimilation system must reproduce the structure of anticyclonic eddies approaching Kuroshio from east precisely, and is consistent with a conventional sensitivity study [9]. This implies that observations around 133 E and 31 N are likely to benefit the forecast of the variability of the Kuroshio path south of Japan. In addition, the analysis shows the importance of the observation at depths of 1000 to 1500 m around there.

3. IMPACTS OF OBSERVATIONS FOR THE ENSO FORECASTING

Observing System Experiment (OSE) is a method to assess the degradation in quality of a model forecast or analysis when a certain observation type is withdrawn deliberately in the data assimilation process. It should be emphasized that OSE is an only way which can confirm the impacts of real observations directly and precisely.

Effects of assimilating TAO/TRITON array and Argo float data in MOVE-G and its impact on the ENSO forecasting using the CGCM in JMA has been evaluated by OSEs. These OSEs are performed mainly for discussing necessity of sustaining TAO/TRITON array under the situation of nowadays where a number of temperature and salinity profiles are observed by Argo floats. Three assimilation runs (ALL, NTT, NAF) were performed in the period of 2000-2007 first. All available observation data is assimilated in ALL. Data from the TAO/TRITON array is excluded in NTT. Data from Argo is excluded in NAF. The difference of the ocean heat content in the equatorial Pacific between ALL and NTT demonstrates that the impact of TAO/TRITON array is degraded in the data assimilation system after 2004, while the impacts of the Argo floats increases with the number of the floats.

Oceanic fields generated in these assimilation runs were employed in sets of 11-ensemble forecasts started from January 31st, April 26th, July 30th, and October 28th in 2004-2007 (16 cases). Here, the ensemble members were generated by adding perturbation to the gridded SST data in the last 10-day data assimilation cycle. Fig. 2 shows the impacts of data from TAO/TRITON arrays and Argo floats on the 1-7 month forecasts of SST. The impact of TAO/TRITON array is remarkable in a most part of the central and eastern tropical Pacific. Actually, TAO/TRITON array improves the SST forecasts in NINO3, NINO34, and NINO4 regions with a significance level over 90%. Data from TAO/TRITON array is thus essential for the ENSO forecasting even with a number of observations by Argo floats. In contrast, the impact is not clear in the western tropical North Pacific and the Indian Ocean.

Argo floats have impacts in the most part of the central and eastern tropical Pacific, although it is smaller than that of TAO/TRITON array. This result shows that the information of TAO/TRITON array and Argo floats complimentarily contributes to the improvement of the ENSO forecast. Furthermore, the impact of Argo floats can be seen in the western tropical North Pacific and the western Tropical Indian Ocean. Actually, the impact can be seen in the whole tropical Indian Ocean for the longer lead-time forecasts. Globally homogeneous data from Argo floats is thus effective to improve the

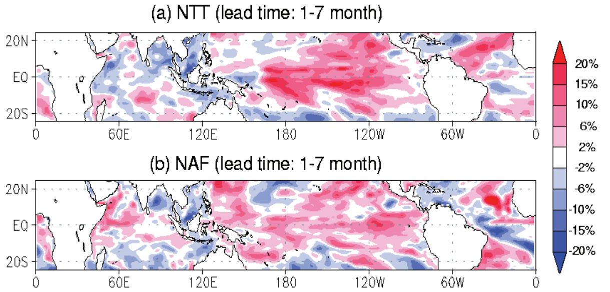

Figure 2. Horizontal distribution of the ratios of RMSE reductions for 1-7 month SST forecasts in (a) NTT, and (b) NAF. The ratio is calculated as the difference of the Root Mean Square Error (RMSE) between NTT or NAF and ALL normalized by the RMSE of ALL. Positive values denote improvements in ALL over NTT or NAF. Here, the forecast bias is estimated for each initial month, each lead time, and each experiment, and removed before calculating RMSEs.

forecasts in an extensive area, and for long-range forecasts.

4. SUMMARY

In this contribution, we summarize activities to evaluate impacts of observing systems using MOVE/MRI.COM. We effectively identified the area sensitive to the formation process of the Kuroshio large meander using a singular vector analysis. This means that observations in the area are likely to be beneficial. The singular vector analysis is, thus, a powerful tool for designing future observation systems or arrangement of target observations.

Impacts of the TAO/TRITON array and Argo floats on ENSO forecasting are confirmed by Observing System Experiments (OSEs). Similar OSEs demonstrated the robust impacts of the TAO/TRITON array on the ENSO forecasting in the system of ECMWF [10]. These results give the society a definite message that it is essential to sustain the TAO/TRITON array and Argo floats in order to keep the good skill of ENSO forecasting. Results of OSEs, however, depend on the forecasting model, assimilation scheme, the period of experiments, etc. It should be also noted that OSE is the only strategy that directly demonstrates the impacts of observations in a system with strong nonlinearity, or chaotic nature, such as a seasonal forecast system. It is, therefore, important to perform OSEs using various assimilation and forecast systems. In addition, we need to sustain the current combination of the observing system including the TAO/TRITON array and Argo floats as longer as we can in order to evaluate the impact of them properly.

We discuss the importance of ocean observations for the ENSO forecast above, while they may be also effective to reproduce the precipitation in the monthly time-scale in the tropical region. The study in [11] demonstrated that a coupled model whose ocean part is constrained by ocean observations (Quasi Coupled Assimilation System) improves the summer precipitation fields in the tropical region, particularly in the Philippine Sea, over an uncoupled atmosphere model with observation-based SST data as boundary condition (i.e., AMIP-type run). We thus need to evaluate the potential of ocean observations to improve monthly forecasts of precipitation in the tropical region.

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