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MRI Multivariate Ocean Variational Estimation (MOVE) System

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1. Introduction

MRI Multivariate Ocean Variational Estimation (MOVE) System is an ocean data assimilation system developed for monitoring, analysis and prediction of the ocean state and climate in MRI. Sea surface topography data observed from the TOPEX/Poseidon ERS-1, -2, and Jason-1 satellite is assimilated together with in-situ observation data into an OGCM in MOVE System. We show the system design including how sea surface topography data is assimilated in this poster. The impact of assimilating sea surface topography data is also shown with the result of assimilation.

2. Outline of MOVE System and MRI.COM

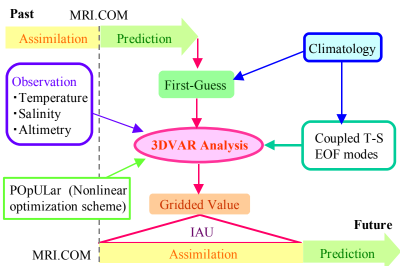


Fig.1. System design of MOVE-3DVAR.

MOVE System uses MRI community ocean model (MRI.COM) and a multivariate 3DVAR scheme with vertical coupled T-S EOF modes. MRI.COM uses the Takano-Ohnishi scheme, which improves diagonally upward advection along the topography, and the generalized Arakawa scheme, with which the enstrophy is conserved. Various schemes (ex. Mellor & Yamada Level 2.5/ KPP/ Noh & Kim for vertical mixing and QUICK/ UTOPIA for tracer advection) are prepared. The model fields are corrected with the analysis result using the Incremental Analysis Updates (IAU) technique.

3. 3DVAR Analysis Scheme

3.1 Cost function and Coupled T-S EOF

The control variables of the cost function are amplitudes of coupled T-S EOF modes which represent the coupled variabilities of T-S (Fig. 3). The coupled variability relates the temperature observation to the salinity field. Therefore, the scheme has ability to estimate the salinity field from temperature observation alone without an OGCM (Fig. 4).

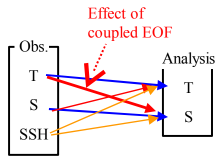
The model area is partitioned into several areas and EOF modes are calculated in each area (Fig. 2). The background covariance matrix B is non-diagonal because it includes the horizontal correlations. On the other hand, the observation constraint, as well as the additional constraint, is nonlinear because of calculation of sea surface dynamic height and variational QC . We use the preconditioned nonlinear optimizing scheme named POpULar in order to handle the non-diagonal matrix and the nonlinearity together.

Background constraint | Observation constraint ($J_o + J_h$) | Additional constraint

$$J = \frac{1}{2}\mathbf{w}^T\mathbf{B}^{-1}\mathbf{w} + \frac{1}{2}(\mathcal{H}(\mathbf{w})-\mathbf{y})^T\mathbf{R}^{-1}(\mathcal{H}(\mathbf{w})-\mathbf{y}) + \alpha$$

Non-diagonal | Nonlinear

Amplitudes of Vertical Coupled T-S EOF



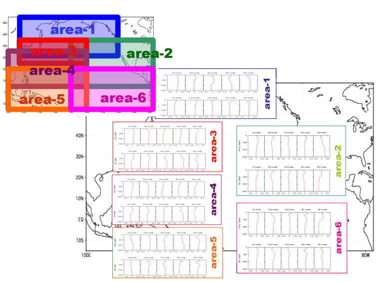


Fig.2. Example of area partition for a North Pacific model and T-S EOFs.

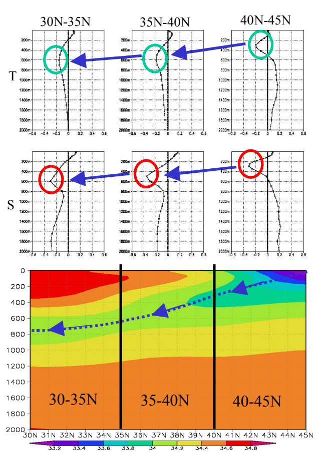


Fig.3. The EOFs including the variability of NPIW low salinity minimum. and the vertical section of salinity along 165E. The EOFs account that the low salinity water is related to cold anomaly.

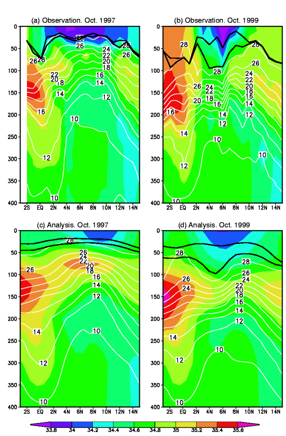


Fig. 4. Comparison of temperature (℃, contour lines), salinity (psu, color shaded) fields, Mixed and Isothermal Layer Depths (MLD and ILD, black lines) in the depth-latitude section at 165E near the equator. (a) Observation fields of October 1997 (El Nino). (b) Observation fields of October 1999 (normal). (c) Estimated fields of October 1997. (d) Estimated fields of October 1999.

Observations are made by Ryofu-Maru , an observation vessel of JMA. Here, the estimations are conducted with *in-situ* temperature and TOPEX/Poseidon altimetry. It should be noted that observed salinity data or any OGCM is not adopted in the estimation.

The variabilities of near surface salinity, MLD, ILD, South Pacific Tropical Water (the depth and influence in the northern hemisphere) and the influence of the North Pacific Intermediate Water are adequately estimated.

3.2 Method of sea surface topography data assimilation (Nonlinear effect)

$$J_h = \frac{1}{2\sigma_h^2}\sum_j \{h_j(\mathbf{Gw}) - h_j^o\}^2 \quad\longrightarrow\quad h = -\frac{1}{\rho_S}\int_0^{z_m}\rho'(T,S,p)dz$$

Sea surface Dynamic Height (SDH) is calculated in order to assimilate sea surface topography data. MOVE System uses the nonlinear function of T and S for the calculation of SDH. The result of the analysis without an OGCM in 30-45N, 140-160E is shown in Figs 5 and 6. Figure 5 shows the analysis below 500m is improved by using the nonlinear function. The T anomaly of the warm eddy in the 144E section is overestimated with the linearized SDH function in Fig. 6. The overestimation is improved with the nonlinear SDH function. Thus, considering the nonlinearity is important for improving analysis.

	ARGO float	h
NL	used	nonlinear
L	used	linear
NF	no	nonlinear

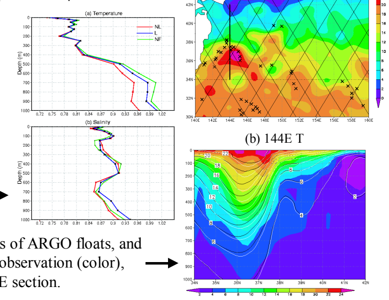


Fig. 5. Profiles of RMSE normalized by RMSE of the climatology. A low value means that the analysis result is accurate.

Fig. 6. (a) 100m T in NL. T/P paths, positions of ARGO floats, and the 144E line are superimposed. (b) T of the observation (color), NL (black line), and L (white line) in the 144E section.

4. Impact of Sea Surface Topography Data on the Rossby Waves

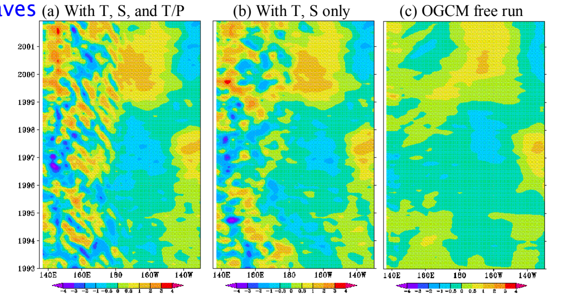


Fig. 7. Longitude-time sections of the heat content (0-300m) anomaly (degree) at 35N. (a) Assimilated field with T, S, and T/P data. (b) Assimilated field with T, S (without T/P). (c) Field of OGCM free run. The model resolution is 1x1 degrees.

The Rossby wave activity west of the date line in the mid-latitude is well reproduced in the assimilation field with T, S and T/P data. On the other hand, the eddies are not well reproduced in the assimilation field without T/P data, and cannot be seen in the OGCM free run, although the both fields expresses the interannual variability. Thus, T/P data has a great impact on the expression of the eddy activities in MOVE System.

5. Validation with Satellite Altimetry Data

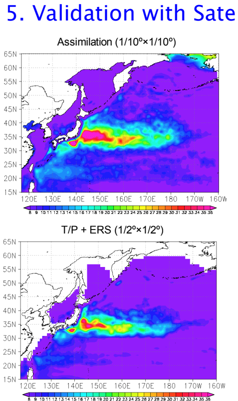


Fig. 8. Root mean square of SSHA.

The root mean square of Sea Surface Height Anomaly (SSHA) in a result of MOVE System has a good agreement with the objective analysis with T/P and ERS (Fig. 8). The power spectrum also agrees well with T/P (Fig. 9). The energy spectrum obeys the –5/3 law in the energy inertial subrange and the –3 law in the enstrophy inertial subrange (Fig. 10). The length scale of the energy input is O(100km).

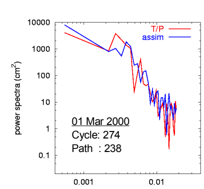


Fig. 9. Power spectrum of SSHA along a T/P path in 25º-40ºN.

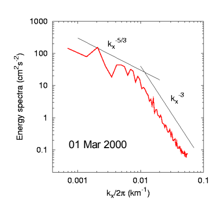


Fig. 10. Zonal energy spectrum in 142º-158ºE averaged in 32º-38ºN.

6. Summary

MOVE System is constituted by the OGCM of MRI, MRI.COM, and the multivariate 3DVAR scheme with vertical coupled T-S EOF modes. The 3DVAR scheme can estimate the salinity variability from temperature observation alone without OGCM. Using the nonlinear function of SDH improves the accuracy of th analysis in MOVE System. Assimilating T/P data has a great impact on the expression of the mid-latitude Rossby waves. The property of the eddy activity has a good agreement with the objective analysis from T/P and ERS data.

7. Reference

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