Reanalysis experiment using MRI Multivariate Ocean Variational Estimation (MOVE) System in the western North Pacific

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Abstract

A data assimilation system (MOVE-system: MRI Multivariate Ocean Variational Estimation System) in the western North Pacific has been developed for the next generation of ocean assimilation and prediction system in Japan Meteorological Agency. Three-Dimensional Variational (3DVAR) method with vertical coupled temperature-salinity Empirical Orthogonal Function (EOF) modal decomposition is used in MOVE-System. The reanalysis experiment from 1993 to 2004 is conducted. The in-situ (ship and ARGO float) temperature and salinity data and satellite altimetry data (TOPEX/Poseidon, Jason-1, ERS-1/2, ENVISAT) are assimilated. The results of reanalysis show a good agreement with observation. Model flow field is successfully improved. The transports of current system around Japan are also reproduced well. By using the results of the reanalysis as the initial conditions, 140 cases of 90-day prediction experiments of the Kuroshio path variability are conducted. The large meandering event in August 2004 is successfully predicted from two months before. The fast eastward progression speed of the meander is the common feature in many failure cases. The initial shock caused by dynamically unbalanced initial condition induces the eastward progression of the meander. The initial shock can be weakened by the changing the ratio of background and observation errors (not shown in this poster). The predictive limit of our prediction system is roughly 40-60 day, which is much longer than the persistency.

1. Outline of the reanalysis experiment

Dynamical Model

MRI.COM: MRI community ocean model (Ishikawa et al., 2005)

- −15ºN~65ºN, 117ºE~200ºE, 1/10º×1/10º,L54
- −Biharmonic Smagorinsky viscosity + harmonic background viscosity
- −Noh and Kim (1999) mixed layer model
- −Boundary conditions from the North Pacific model (one-way nesting)

Analysis Method

MOVE-system: MRI Multivariate Ocean Variational Estimation system

- −3DVAR with vertical coupled T-S EOF modes (Fujii & Kamachi, 2003)
- −Incremental Analysis Updates (Bloom et al., 1996)

Cost function:

$$J(\mathbf{y}) = \overbrace{\frac{1}{2}\sum_m\sum_l \mathbf{y}_{m,l}{}^T \mathbf{B}_l^{-1}\mathbf{y}_{m,l}}^{\text{Background}} + \overbrace{\frac{1}{2}\left[\mathbf{Hx}(\mathbf{y})-\mathbf{x}^0\right]^T\mathbf{R}^{-1}\left[\mathbf{Hx}(\mathbf{y})-\mathbf{x}^0\right]}^{\text{Observation (Temp \& Sal)}} + \underbrace{\frac{1}{2r_h^2}\left[h(\mathbf{x}(\mathbf{y}))-h^0\right]^2}_{\text{Sea Surface Height}} + J_C$$

($\mathbf{y}$: Amplitude of T-S EOF modes)

Experimental Condition

- Period: Jan 1993 – Aug 2004
- Assimilated data:
  - In-situ observation (WOD01,GTSPP; 0-1500m)
  - TOPEX/Poseidon, ERS-1/2, Jason-1, ENVISAT
- Forcing data:
  - NCEP2 (Kanamitsu et al., 2002); Daily wind stress, short/long wave radiation flux
  - Sensible and latent heat flux calculated using Kondo (1975)
- The assimilation results are used as the initial conditions for the 90-day Kuroshio prediction experiments.

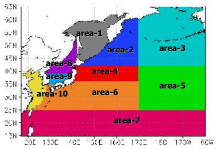
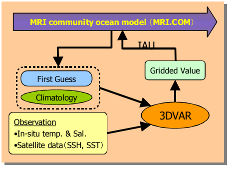


Fig. 1: Model domain and area partition for vertical coupled T-S EOF modes.



MRI community ocean model (MRI.COM)

IAU

First Guess

Climatology

Gridded Value

3DVAR

Observation
- In-situ temp. & Sal.
- Satellite data (SSH, SST)

Fig. 2: Analysis flow in MOVE system.

2. Reanalysis and validation

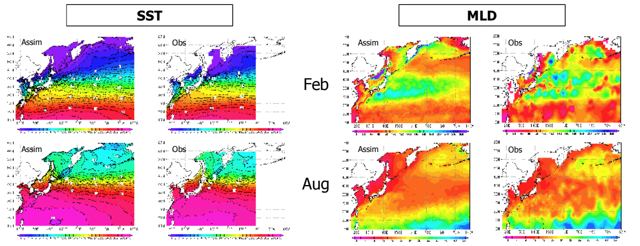


Fig.3: Monthly mean sea surface temperature (SST) and mixed layer depth (MLD) in February and August.

Mesoscale eddy

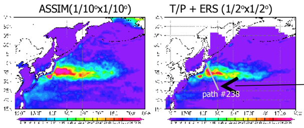


Fig. 4: Sea Surface Height (SSH) variability.

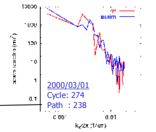


Fig. 5: SSHA power spectrum along the T/P path 238 (25º-40ºN).

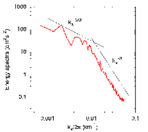


Fig. 6: Energy spectrum from 142º to 158ºE.

Mesoscale eddy is adequately assimilated.

Current system

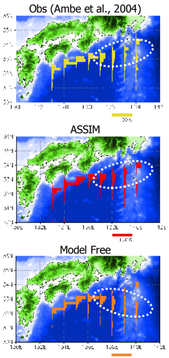


Fig. 7: Histograms of the Kuroshio axis position.

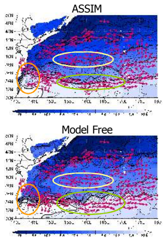


Fig. 8: Comparison of the acceleration potential (contour) and flow field estimated from movements of sub surface floats (arrow; Iwao et al., 2003) on 26.7σ_θ surface.

Model flow field is successfully improved.

Volume Transport

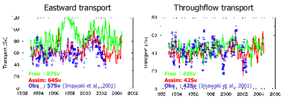


Fig. 9: Time series of the Kuroshio transport crossing ASUKA line.

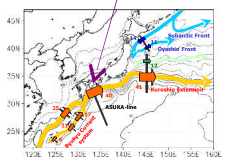


Fig. 10: Mean volume transport (arrow) of current system around Japan (unit is Sv). Mean sea surface height is also shown (solid lines : c.i. is 10 cm). (Usui et al., 2005)

3. Prediction experiments of the Kuroshio path variabilities

Example of success

Initial: July 1st, 2004

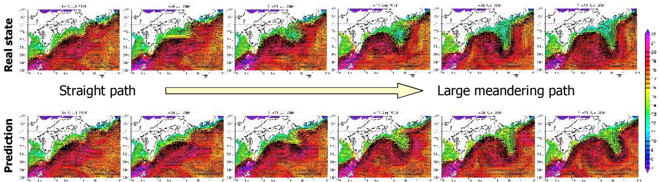


Fig. 11: Horizontal velocity (vector) and temperature (color) at 200m depth.

Example of failure

Initial: April 1st, 1993

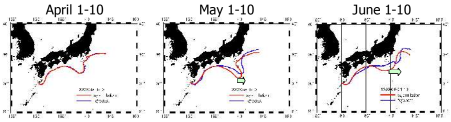


Fig. 12: Time evolution of the Kuroshio axis of assimilation (red) and prediction (blue).

The eastward progression speed of meander is faster than the real state.

Cause of failure

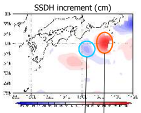


Fig. 13: Sea Surface Dynamic Height (SSDH) difference between first-guess and result of 3DVAR in the assimilation period (Mar 21-31, 1993).

- The tendency of SSH has a signal opposite to SSDH increment.
- The tendency of SSH has a large signal in the early stage of prediction.

→ Initial shock caused by dynamically unbalanced initial condition

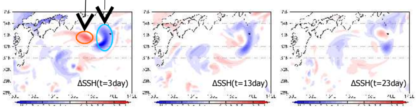


Fig. 14: Tendency of Sea Surface Height (SSH) in prediction initialized on April 1st, 1993.

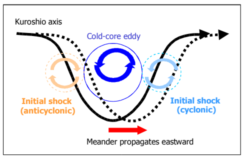


Fig. 15: Schematic diagram of the relation between initial shock and eastward progression of the meander.

- The initial shock induces the eastward progression of the meander.
- The initial shock can be weakened by changing the ratio of background and observation errors. (not shown here)

Predictive limit

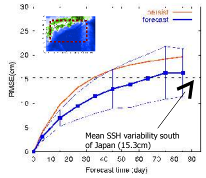


Fig. 16: Time evolution of SSH RMSE south of Japan. Error bar shows the standard deviation of SSH RMSE.

Predictive limit : **40-60** days

4. Summary

Reanalysis experiment

- MOVE-system in the western North Pacific has been developed, and reanalysis experiment from 1993 to 2004 is conducted.
- SST and MLD of reanalysis are in good agreement with observation.
- Mesoscale eddy is adequately assimilated.
- Model flow field is successfully improved.
- The transports of current system around Japan are reproduced well.

Prediction experiment

- The large meandering event in August 2004 is successfully predicted from two months before.
- The fast eastward progression speed of the meander is the common feature in many failure cases.
- The initial shock caused by dynamically unbalanced initial condition induces eastward progression of the meander.
- The initial shock can be weakened by the changing the ratio of background and observation errors.
- The predictive limit of our system is roughly 40-60 days, which is much longer than the persistency.