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A new strategy with a time-spreading correction technique in the 4DVAR version of MRI Multivariate Ocean Variational Estimation System (MOVE-4DVAR)

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1. Introduction

MRI Multivariate Ocean Variational Estimation (MOVE) System is an ocean data assimilation system developed in JMA/MRI. The 4DVAR version of MOVE system (MOVE-4DVAR) adopts, as the control variables (i.e., the values optimized by the 4DVAR technique), a time-spreading correction term instead of the initial value. This poster shows the impact of using time-spreading correction as well as the other strong points of MOVE system, that is, considering horizontal correlation of the control variables and employing vertical coupled T-S EOF modes.

2. MOVE System (MOVE/MRI.COM)

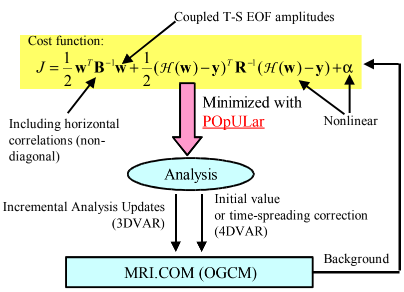


Fig.1. Schematic figure of MOVE System

Corrections to temperature and salinity fields are represented by the linear combination of T-S EOFs in MOVE System. Model integration is included in $\mathcal{H}(\mathbf{w})$.The model used in MOVE system is MRI.COM (Ishikawa et al. 2005). The amplitude of the EOFs are estimated by minimizing the cost function *J*. Vertical correlation and correlation between T and S is represented by T-S EOFs. Horizontal correlation is represented by the off-diagonal elements of **B**. Although calculating the inverse of **B** is difficult, Preconditioned Optimizing Utility for Large-Dimensional Analysis (POpULar) makes it possible to minimize the cost function without calculating it (Fujii and Kamachi 2003b; Fujii 2005) .

3. Time-spreading correction

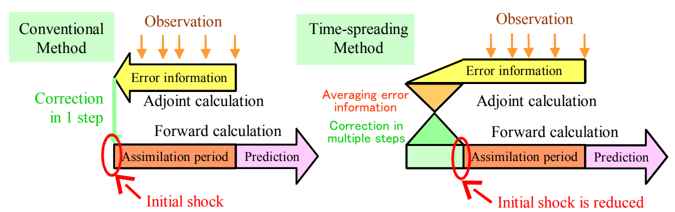


Fig.2. Schematic figure of Time spreading correction

Initial values of an assimilation period are supposed to be corrected in "one step" in conventional 4DVAR method. The assimilation fields, however, suffers from severe initial shock even though model equation is adopted as constraints. It is possible to reduce the initial shock by supposing that model fields are corrected constantly in "multiple steps" right before the assimilation period. High frequency error information propagated by adjoint calculation is filtered out by time-averaging calculation which is the adjoint code of the forward constant correction. The slow correction of the model fields moreover prevents initial shock by reducing high frequency noise like Incremental Analysis Update (IAU). The time-spreading method improves an assimilation result because it cuts the high frequency components of correction which severely suffers from nonlinearity.

4. Identical-twin experiments

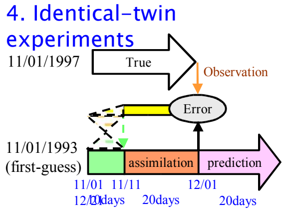


Fig.3. Schematic figure of Experiments

Table 1: Conditions of Experiments

	time-spreading	horizontal correlation	T-S EOF
CNTL	○	○	○
NTSPRD	×	○	○
NHCORR	○	×	○
NTSEOF	○	○	×

Model　A North Pacific model (15°S-65°N)

resolution:　0.5°×0.5°,　54 Levels

Observations:　T, S profiles (0-1500m) → 11/30 (only last day),　every 3°

SST → 11/30 (only last day),　all grids

Gaussian-distributed errors are added to the true values.

5. Convergence

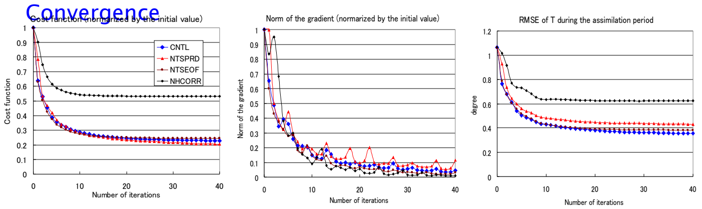


Fig.4. Changes of the values of cost functions, norms of gradients, and RMSEs of T in the assimilation period in each iteration.

Values of cost functions are monotonically reduced in all experiments. Norms of the gradients and RMSEs of the assimilation results are also effectively reduced. The constant values of cost functions and RMSEs after 30 iterations imply that the solution is well converged in 40 iterations. Hereafter, we show the assimilation result after 40 iterations were performed.

6. Variation of RMSEs in time

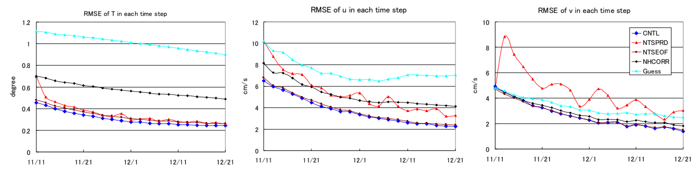
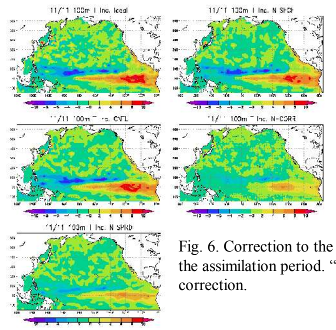


Fig. 5. RMSEs of T, u, v in each step.

The RMSEs are well reduced from the first-guess (light blue line) in the both periods of assimilation and prediction in CNTL. Velocity fields has large errors because of "shocks" in NTSPRD. The large difference between CNTL and NHCORR implies that considering horizontal correlation is important. Using EOFs also reduced errors (compare CNTL with NTSEOF.)

7. Map of Correction



Resemblance between "Ideal" and CNTL means the assimilation works well in CNTL, especially, the warming of temperature at the eastern Equatorial Pacific and the cooling at the western Equatorial Pacific. The NTSEOF shows almost same performance here. The correction is small in NTSPRD because the high frequency noise hides the true signals in adjoint variables. The correction is not satisfactory in NHCORR, either. The correction field in NHCORR is small and noisy.

Fig. 6. Correction to the first-guess field of 100m T (℃)at the beginning of the assimilation period. "Ideal" means (true) – (first-guess), i,e., the ideal correction.

8. Time tendency

If there is too large time-variation (tendency) of the model fields, it means that the fields are severely violated by the shocks due to the correction. The shocks will degrade the prediction skill. Large tendencies of T and u are seen especially around the equator even at the end of the assimilation period in NTSPRD in Fig 7. On the other hand, large tendencies are not seen in CNTL because the time-spreading correction suppress the shocks due to the correction. Thus, the shocks due to the correction is the serious problem even for 4DVAR systems and the time-spreading correction is a easy but promising solutions.

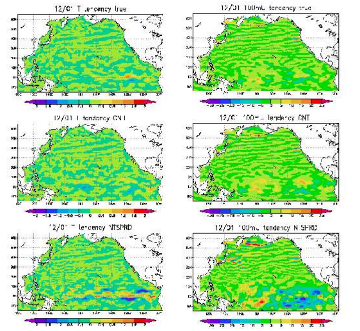


Fig. 7. Time tendency of 100m T(℃/day) and u (cm/s day) at the beginning of the assimilation period.

9. Effect of using vertical TS-EOF

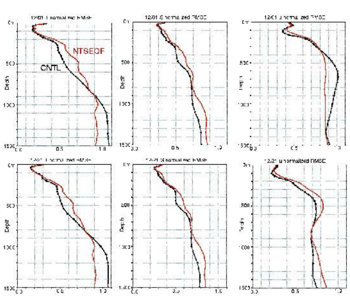


Figure 8 shows using T-S EOFs improves the assimilation and prediction fields. For example, the T and S fields are better above 1000m depth and in all layers, respectively. The zonal velocity at the mid-depth layer is better in NTSEOF at the end (beginning) of the assimilation (prediction). The zonal velocity field in CNTL is, however, better at the end of prediction because the model fields in CNTL is better balanced than in NTSEOF. Thus, using T-S EOF modes successfully improves the accuracy of assimilation fields and skill of prediction.

Fig. 8. RMSE of T , S and u in each layer normalized by the RMSE of the first-guess at the end of the assimilation (top) and prediction (periods) .

10. Summary and discussion

Time-spreading correction effectively suppresses the shocks due to the correction and improves the accuracy of assimilation and prediction. This technique may be good for the long-term assimilation because it attempts to correct the low frequency components alone without making spurious high frequency correction.

Identical-twin experiments also shows that considering horizontal correlations and using T-S coupled EOF effectively reduce the errors in the assimilation and prediction fields.

11. Reference for MOVE System

Fujii, Y., 2005: Preconditioned Optimizing Utility for Large-dimensional analyses (POpULar). *J. Oceanogr.*, **61**, 167-181.

Fujii, Y., and M. Kamachi, 2003a: Three-dimensional analysis of temperature and salinity in the equatorial Pacific using a variational method with vertical coupled temperature-salinity empirical orthogonal function modes. *J. Geophys. Res.*, **108**(C9), 3217, doi:10.1029/2002JC001745.

Fujii, Y., and M. Kamachi, 2003b: A nonlinear preconditioned quasi-Newton method without inversion of a first-guess covariance matrix in variational analyses. *Tellus*, **55A**, 450-454.