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Global temperature and salinity reanalysis experiment using 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, and has been developed for monitoring, analysis and prediction of the ocean state and climate in MRI. Using MOVE system for global ocean (MOVE-G), reanalysis experiments are implemented, and their products are examined to evaluate the performance of MOVE system. We also attempt to correct the zonal wind stress forcing along the equator using analyzed temperature and salinity fields.

2. Outline of MOVE-G and reanalysis experiment

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

- region : 75°S-75°N, global model
- resolution : 1°(lon.)x0.3°(lat.) within 6°S-6°N,
  1°(lon.)x1°(lat.) poleward of 15°N and 15°S
  50 vertical levels (23 levels in the upper 200m)
- vertical mixing scheme : Mellor & Yamada Level 2.5
- isopycnal diffusion scheme : Gent McWilliams (1990)
- wind stress, and short and long wave fluxes :
  NCEP/NCAR reanalysis (Kalnay et al., 1996)
- latent and sensible flux :
  bulk formula of Kara et al. (2000) with model SST

ANALYSIS : multivariate 3DVAR scheme
with vertical coupled T-S EOF modes.
(Fujii and Kamachi, 2003)

- Analysis is implemented once a month.
- Incremental Analysis Updates (IAU) technique is used to correct the model fields with the analysis result.
- observation data : in situ temperature and salinity measurement
  (ship, buoy, ARGO float)
  TOPEX/Poseidon altimetry data

REANALYSIS PERIODS : 1993 January to 2001 December (9years)

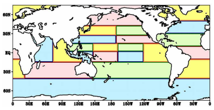


Fig.1. Model region and subregions divided for EOF modes.

Table 1. Reanalysis run of this experiment.

	Observation			correct
	T	S	T/P	
TSH	○	○	○	T, S
TS	○	○	×	T, S
TH	○	×	○	T, S
NOS	○	×	○	T

3. Climatological fields in TSH run

Temperature and salinity fields are reasonably well reproduced in climatological mean field (Fig. 2). But there are some inconsistencies compared to observation; e.g. too warm in the eastern equatorial Pacific, and, much fresh in subarctic Pacific, Indian Ocean and Antarctic circumpolar region.

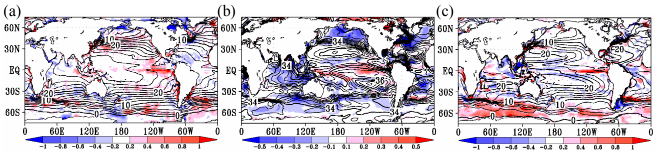


Fig. 2. Mean filed of (a) SST, (b) SSS and (c) vertical averaged temperature (0-300m) averaged from 1993 to 2001 in TSH run. Shaded areas indicate differences to observed climatology (averaged from result of the analysis without model).

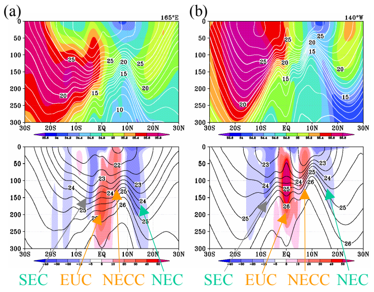


Fig.3. Mean vertical section of (top) temperature and salinity, (bottom) zonal velocity and potential density at (a) 165°E and (b) 140°W.

Saline water masses (NPTW and SPTW) are subducted at subtropical regions of both hemispheres and advected into the equatorial Pacific. NPTW is a little fresh and SPTW is saline compared to observation. One of the reason seems to be due to model own biases.

Current system around the equator is captured successfully. The EUC, NEC, SEC, NECC, SECC, and so on can be seen and are well separated.

4. Influence of correcting salinity field

In TSH run, it is clear that saline water (SPTW) is advected into the equator at western part and is carried eastward by EUC. Subsurface saline area along the EUC in TH run is similar to that of TSH run. On the other hand, subsurface water along the EUC in NOS run is, however, much fresher than in TSH run. Moreover, in NOS run, vertical salinity change is less than in TSH, and thermocline is more broad. It suggests that density instability would be occurred in NOS run, in which salinity field is not corrected (cf. Troccoli et al., 2002). The density instability affects density field and, hence, velocity field. It could result in the reduction and upward shift of the EUC in NOS run (Fig.4(b)).

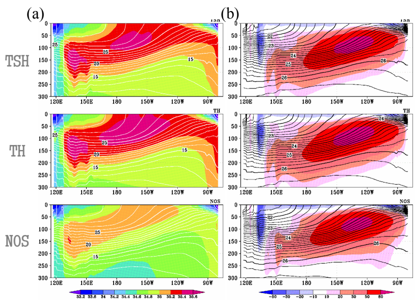


Fig.4. Mean vertical section of (a) temperature and salinity, and (b) zonal velocity [cm/sec] and potential density at the equator from three experiment.

5. Variability in TSH run

5.1 Changes in the EUC

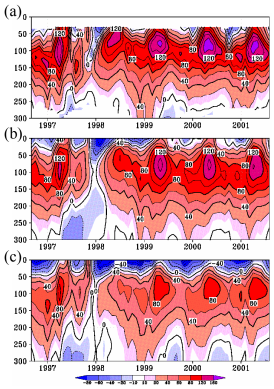


Fig.5. Time series of zonal velocity at 140°W, equator. (a) Observation (ADCP measurement), (b) TSH run (c) model run (not assimilated).

Compared with observation (Fig. 5(a)), TSH run (Fig. 5(b)) reasonably corrects the EUC, while EUC is too weak in model run (Fig. 5(c)). On the other hand, TSH run, however, does underestimate surface westward flow (a part of northern branch of SEC). One of the reason seems to be that the easterly wind at the equator is not sufficiently strong.

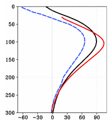


Fig.6. Mean vertical profiles of zonal velocity at 140°W, equator. Averaged from TSH run (solid black), model run (dashed blue), and ADCP measurement (solid red).

5.2 Changes during 1997/98 El Nino event

At the onset of 1997/98 El Nino event, warm water pool in the western equatorial Pacific extended eastward. The salinity front which lies at the eastern edge of fresh water region in the western Pacific moves eastward together with extension of warm water pool (Fig. 7(a), circle). It in turn shifts eastward during La Nina (Fig. 7(b), circle). Zonal velocity and volume transports are changed significantly during 1997/98 El Nino event and even current reversal may have occurred (Figs. 7 and 8). Estimated changes in the zonal volume transport are in good agreement with observation results (e.g. Johnson et al., 2000).

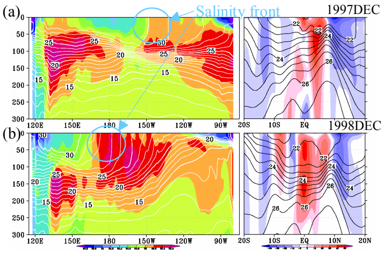


Fig. 7. (right) Vertical section of temperature and salinity along the equator. (left) Vertical section of Zonal velocity and potential density at 165°E. (a) 1997 December. (b) 1998 December.

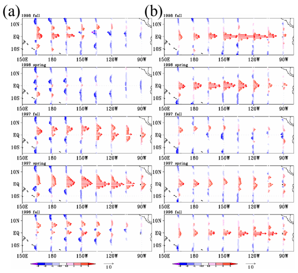
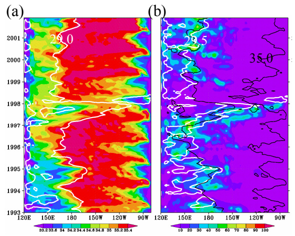


Fig.8. Zonal volume transport (Sv) for (a) the layer with $\sigma_\theta < 24.3$(kg/m^3) and (b) the layer with $24.4 < \sigma_\theta < 26.5$(kg/m^3)

5.3 Changes in barrier layer thickness

Fig. 9. Time series of (a) surface salinity and (b) barrier layer thickness (unit : m) along the equator. White contours indicate isotherm. Black contour indicates isohaline of 35.0.



Barrier layer (estimated as a difference of the surface isopycnal depth and the surface isothermal depth) is important for equatorial phenomena (e.g. fresh water jet) and variabilities of upper ocean heat content. Deep barrier layer tends to appear in the western region together with anomalous warm water area.

6. Attempt to correct zonal wind stress along the equator

As seen in other assimilation systems, there is spurious vertical circulation along the equator mainly due to imbalance between prescribed zonal wind stress (atmospheric reanalysis) and zonal pressure gradient calculated from assimilated temperature and salinity fields. The zonal wind stress is too weak as far as NCEP reanalysis is concerned.We compare zonal wind stress to zonal pressure gradient estimated from analyzed temperature and salinity fields. We then multiply zonal wind stress from NCEP reanalysis by 1.4 along the equator and apply it to MOVE-G with a main balance of zonal wind stress and pressure gradient. Consequently, the simple balance correction of the wind stress reduces spurious vertical circulation well.

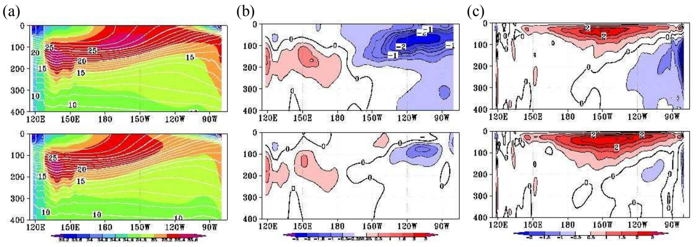


Fig. 10. Mean vertical section of (a) temperature and salinity, (b) analysis increment of temperature and (c) vertical velocity [m/day] at the equator from TSH run (top) and corrected run (bottom).

7. Summary

We found that correcting salinity field prevents from occurring density instability, and MOVE-G captured intra- to interannual variability in the Pacific Ocean. We also showed importance of salinity correction with multivariate analysis scheme and a simplified balance correction of wind stress. These application to the El Nino prediction is the next step.