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Variation of the South Pacific Tropical Water in an Ocean Data Assimilation (MOVE) System and its Relation to ENSO

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1. Introduction

Examination of the variability of the South Pacific Tropical Water in the equatorial Pacific with an ocean data assimilation system (MOVE system) revealed that its change proceeds the change of surface temperature fields and even ocean heat content above 300m. We propose "SPTW oscillator", a new scenario on the cyclic chain mechanism of ENSO from this analysis.

2. MOVE System (MOVE/MRI.COM-G)

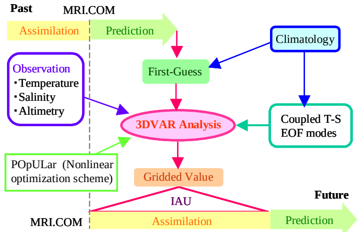


Fig.1. System design of MOVE-3DVAR.

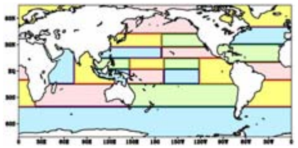


Fig.2. Model region and subregions divided for EOF modes.

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.
- observation data : In situ temperature and salinity measurement (ship, buoy, ARGO float)
  satellite altimetry data (TOPEX/Poseidon, Jason–1, ERS–1/2, ENVISAT)

REANALYSIS PERIODS : 1993 January to 2004 December (12 years)

3. SPTW Index and Warm Water Heat Content (WHC)

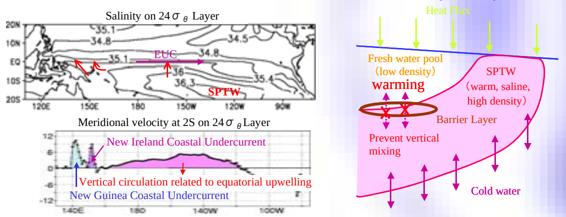


Fig. 3. Schematic figure of the relation between SPTW and ENSO (top) and the origin and passage of SPTW (bottom). SPTW is relatively warm and saline water that makes the salinity maximum in the subsurface layer in the equatorial Pacific. SPTW stabilizes the subsurface layer by forming the barrier layer and plays an important role in keeping the temperature in the warm water pool high. **In order to discuss the influence of the variability of SPTW on ENSO, we define the Warm Water Heat Content (WHC) and SPTW Index (SPTWI).**

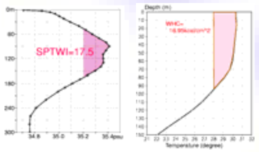


Fig. 4. Examples of WHC and SPTWI. SPTWI is defined as the amount of salinity in the water more than 35.2psu above 300m depths. WHC is defined as the heat content relative to the depth of 28°C.

4. A new scenario of ENSO (SPTW Oscillator)

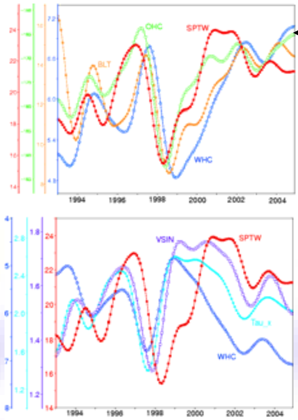
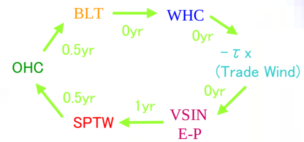


Fig. 5. Time series of Indices averaged in 5S–5N, 125E–120W. High frequency components whose periods are less than 1.5 years are removed.

BLT: Barrier Layer Thickness
(Isothermal Layer Depth – Mixed Layer Depth)
OHC: Ocean heat content (cal cm^{-2}) above 300m
VSIN: Northward velocity on $25\sigma_\theta$ surface across 5S.
$-\tau x$: Zonal wind stress (Strength of the trade wind)



SPTWI is oscillated accompanying with ENSO. The change of SPTW proceeds the change of WHC and even OHC. Change SPTWI is proceeded by the $-\tau x$ because it controls the advection and production of SPTW. Then $-\tau x$ is proceeded by the change of WHC.

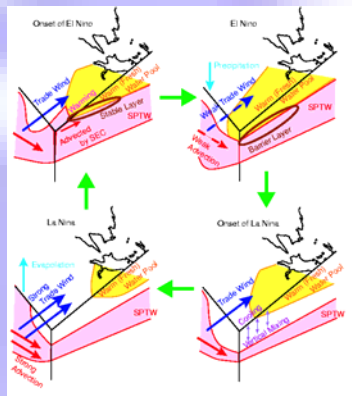


Fig. 6. Schematic figure of the SPTW Oscillator

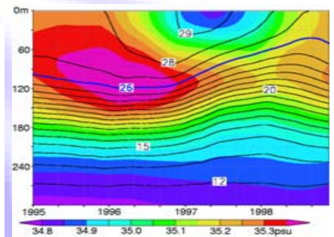


Fig. 7. The variation of area averaged T and S profiles (13 months running mean) in 2S–2N, 160E–150W (NINO4 region) during 1995–1998. SPTW increased in 1995, accompanied by the growth of OHC because SPTW itself is warm. In 1996, the near surface T rose because SPTW stabilizes the subsurface layer, while SPTW and subsurface temperature decrease because the supply of SPTW declined. After 1997, the surface temperature cooled down because subsurface layer is unstable with a little amount of SPTW.

5. Simplified model

$$\frac{d(T-T_b)}{dt}=\alpha(S-S_b)$$
$$\frac{d(S-S_b)}{dt}=-\gamma\Delta U=-\gamma\beta(T-T_b)$$
$$\frac{d^2(T-T_b)}{dt^2}=-\alpha\beta\gamma(T-T_b)$$

T : WHC S : SPTWI T_b, S_b : Background state

ΔU : Zonal wind stress anomaly (positive → westerly)

α, β, γ : propotinal constants (positive)

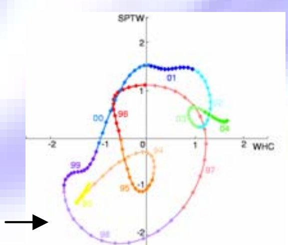


Fig. 8. Plot of the normalized WHC against the normalized SPTWI. They are averaged in 5S–5N, 125E–120W, and high frequency components whose periods are less than 1.5 years are removed. The plot is rotated clockwise as expected from the simple model although a central point and amplitude are different from a different ENSO cycle.

6. Budget Analysis

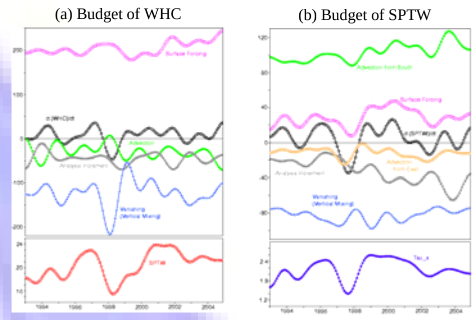


Fig. 9. Result of budget analysis of (a) WHC and (b) SPTW in 5S–5N, 125–240E. High frequency components whose periods are less than 1.5 years are removed. The change of WHC is derived by vanishing (vertical mixing) and the rate of vertical mixing is correlated with SPTW Index. The change of SPTW Index is mainly caused by the variability of the advection rate from south and the surface forcing. They are correlated with the strength of the trade wind. These results support the hypothesis illustrated in Fig. 8.

7. Impact of Assimilating Salinity

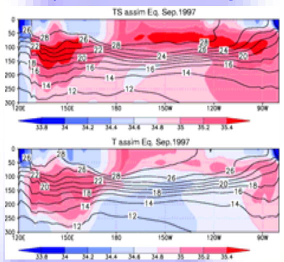


Fig. 10. Temperature (contour) and Salinity (color) fields in the vertical section at the equator in Sep. 1997 analized by MOVE system. Top: Result when assimilating temperature and salinity (Control). Bottom: Result when assimilating Temperature alone (T–alone).

The high salinity related to SPTW is analyzed and the isothermal layer is developed above the high salinity maximum in Control. But the high salinity and the developed isothermal layer are not seen in T–alone.

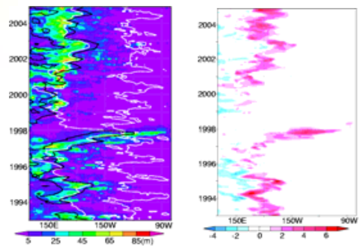


Fig. 11. Longitude–Time section of Barrier Layer Thickness in Control (left) and difference of WHC between Control – T–alone (right). Black and white line in the left are contours of WHC = 10cal/cm^2 and SSS = 35.0 psu.

There is a good correspondence between areas with a thick barrier layer and large WHC. Impact of salinity assimilation is large in areas where barrier layers contribute to develop isothermal layers.

8. Summary

We proposed a new scenario on the mechanism of the oscillatory nature of ENSO (Fig. 6). SPTW (salinity) variability plays an important role there. We should therefore put more attention to salinity variability when we examine the seasonal–interannual variability of climate. In addition, It is shown that assimilating salinity is important for analyzing near–surface temperature fields in the equatorial Pacific properly.

9. Reference

Fujii, Y., and M. Kamachi, 2003: *J. Geophys. Res.*, **108**(C9), 3217, doi:10.1029/2002JC001745.

Usui et al. 2006: *Adv. Spa. Res.*, in press.