Upper-ocean heat budget inferred from ECCO2 ocean data assimilation

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1. Introduction

The MIT Ocean General Circulation Model and its adjoint are used to assimilate data so as to estimate the four-dimensional state of the ocean. Validation of the assimilation and analysis of upper-ocean heat budget associated with various climate phenomena based on the assimilation product are presented. Please see [1]-[3] for more description of the assimilation and related efforts.

Model: domain: 75S-75N; resolution: 1x0.3 in tropics, 1x1 in extra-tropics, 46 vertical levels, 10-m thickness above 150 m.

Adjoint: constructed using an automatic differentiation software TAF; computes sensitivity of cost function to control variables.

Cost function:
J = Deviation of model sea level anomaly from TOPEX/Poseidon data + Deviation of estimated surface fluxes from priors (NCEP reanalysis) + Deviation of model mean T and S from climatology (Levitus'97).

Control variables:
X = Initial T and S, wind stress, surface heat and freshwater fluxes.

Optimization:
Adjoint sensitivity $\partial J/\partial X$ is used to minimize J by adjusting X, subject to constraints by nonlinear model dynamics. Optimization period: 1997-2001.

2. Validation

Skill in fitting sea level data

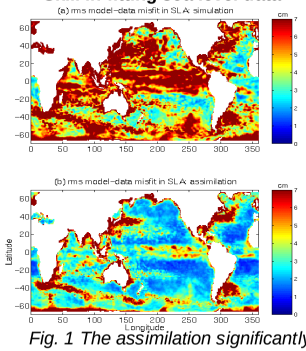

Fig. 1 The assimilation significantly reduces model-data misfit in sea level, especially in the tropics.

Comparison with independent data

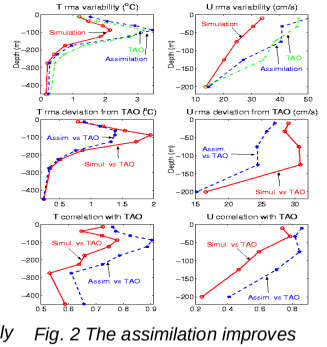

Fig. 2 The assimilation improves comparison with temperature and velocity measurements (TOGA-TAO).

3. Analysis of mixed-layer heat budget

Processes controlling interannual evolution of mixed-layer temperature in several areas (Fig. 3) are examined. The variability in these areas are associated with various climate variations: El Nino-Southern oscillation (Nino boxes), Indian-Ocean Dipole (Iw), & Pacific Decadal Oscillation (PDOn). Tendencies of mixed-layer temperature averaged over each area are computed. The averaged seasonal cycle is removed. They are then integrated in time from January 1997.

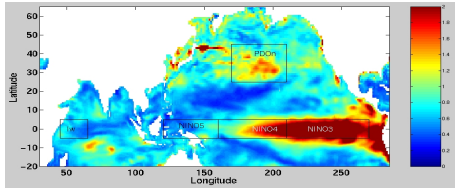

Fig. 3 Interannual variability of SST and regions associated with different climate variations (ENSO, Dipole, and PDO).

3.1 Comparison for different parts of equatorial Pacific

Relative role of advection, diffusion, and surface heat flux

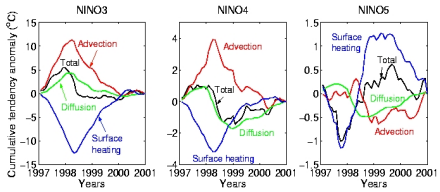

Fig. 4 Nino3 & 4: advection & diffusion cause warming & cooling, surface heat flux damps changes. The opposite is true for Nino5.

Relative role of zonal, meridional, and vertical advection

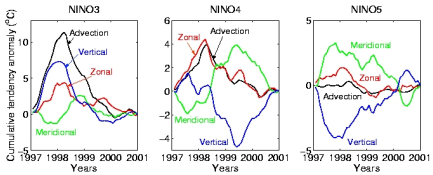

Fig. 5 Despite similarity of heat balance in Nino3 & 4, contribution by different components of advection is different. Zonal advection is most important in Nino4 where zonal temperature gradient is the largest. Vertical advection is most important in Nino3 where stratification is the strongest.

3.2 Comparison for different climate variations

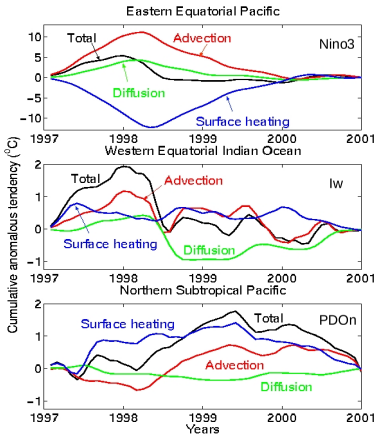

Fig.6 Mixed-layer heat budget in three areas associated with ENSO, Indian-Ocean Dipole, and PDO, respectively.

The effect of advection is similar for all three areas because it (red curve) is well correlated with temperature change (black curve), especially during the warming phase in 1997 for Nino3 and Iw and 1999 warming phase for PDOn. However, that of the surface heat flux is not: it damps temperature change in Nino3 but partially assist temperature change in Iw and PDOn. Therefore, while **the role of ocean circulation is similar for the three climate variations, the interaction of the ocean with the atmosphere is different.**

4. References

[1] Fukumori, I., T. Lee., D. Menemenlis, L.-L. Fu, and the ECCO Consortium. A prototype GODAE routine global ocean data assimilation system: ECCO-2. "En route to GODAE".
[2] Menemenlis, D., I. Fukumori, T. Lee, and L.-L. Fu. Calibrating the ECCO ocean general circulation model using model's green's function. "En route to GODAE".
[3] Stammer, D., C. Wunsch, and the ECCO Consortium. Variations in the large-scale ocean circulation estimated by combining satellite and WOCE data with a numerical model. "En route to GODAE".

Acknowledgement

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