Interannual Variation of Mixed-Layer Heat Balance:
Contrasting Different Climate Phenomena and the Roles of Linear vs. Nonlinear Effects

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ABSTRACT

An ECCO assimilation product is used to investigate interannual variation of mixed-layer heat budget in several regions in the Pacific and Indian Oceans during 1997-2000 associated with ENSO, Indian Ocean Dipole (IOD), and the phase switch of Pacific Decadal Oscillation (PDO). The similarities and differences in ML heat balance for these climate events are discussed, focusing on the roles of oceanic advection and diffusion, air-sea heat flux, and relative contribution of linear & nonlinear effects.

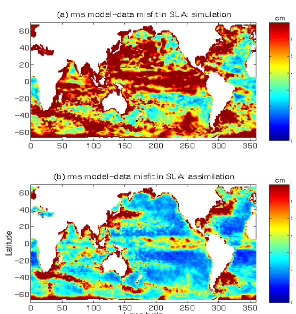
Model and assimilation

Model: MIT OGCM; 75S-75N; 1x0.3 in tropics, 1x1 in extra-tropics, 46 levels, 10-m thickness above 150 m. KPP & GM mixing.

Assimilation: The adjoint model is used to adjust surface forcings & initial state to minimize cost function J =
Deviation of model SSH anomaly from TOPEX/Poseidon data +
Deviation of estimated surface fluxes from NCEP reanalysis +
Deviation of model mean T and S from Levitus climatology.
See [1] for more info on ECCO assimilation.

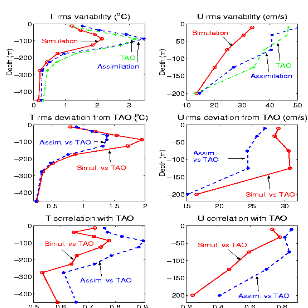
Validation

Skill in fitting sea level data



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

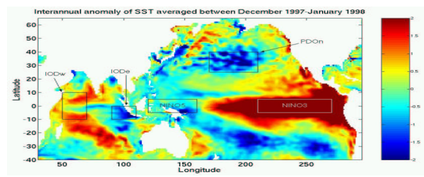
Comparison with independent data



The assimilation improves comparison with temperature and velocity data (TOGA-TAO).

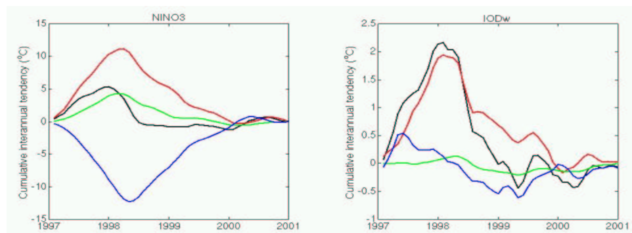
MIXED-LAYER HEAT BUDGET

Averaged mixed-layer temperature (MLT) balance in the marked regions are examined. Averaged seasonal cycles in MLT tendency are removed. They are then integrated in time from January 1997.



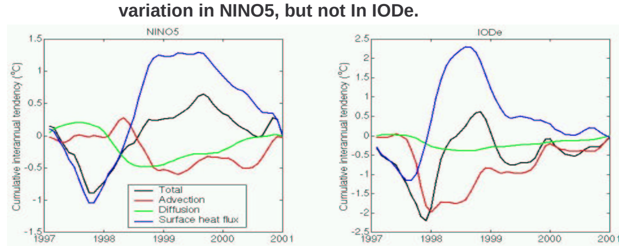
ENSO & IOD: NINO3 vs. IODw

Similarity: Advection is the main cause of MLT variation.
Difference: Advection in NINO3 piles up much more heat than the ocean stores, resulting in large surface heat flux. That in IODw is comparable to MLT variation; air-sea interaction is less active.



ENSO & IOD: NINO5 vs. IODe

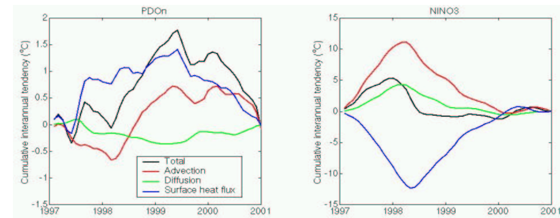
Similarity: Heat flux is the main cause for MLT variation.
Difference: Advection & diffusion are anti-correlated to heat flux & MLT variation in NINO5, but not In IODe.



Effect of diffusion: more important to ENSO than to IOD.

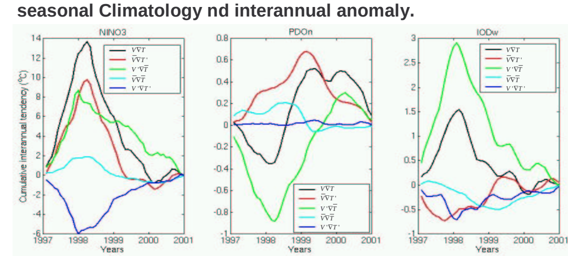
PDO & ENSO: NINO3 vs. PDOn

Similarity: Advection assists the change of MLT.
Difference: Roles of surface heat flux are opposite; the same is true for diffusion.



How important is nonlinear effect?

Advective tendency is decomposed into linear and nonlinear terms based on $V = \bar{V} + V'$ and $T = \bar{T} + T'$, where $\bar{}$ and $'$ denote seasonal Climatology nd interannual anomaly.



$\bar{V}\cdot\nabla\bar{T}$ is non-zero because of interannual variation in ML depth.

Nonlinear tendency due to V'T' is **important to ENSO** because it's comparable to the magnitudes of and counteracts linear terms. It is **less important to PDO & unimportant to IOD** (for 1997-2000).

CONCLUSIONS

Mixed-layer heat budgets associated with ENSO, IOD, & PDO events during 1997-2000 are similar in the role of advection, but different in the roles of surface heat flux (except near tropical warm pool) and diffusion. Nonlinear advective tendency is important to ENSO.

Reference

[1] Fukumori et al., Seasonal-to-interannual variability of the ocean during WOCE, …. This symposium.

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