ENERGY DISSIPATION IN THE TROPICAL OCEAN AND ENSO DYNAMICS

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INTRODUCTION

The dynamics of interannual climate variability in the Pacific can be described in terms of an energy budget for the tropical basin. Winds acting on the surface of the ocean generate vertical buoyancy fluxes and alter the slope of the thermocline. The slope of the thermocline stores potential energy, the amount of which fluctuates between El Niño (low) and La Niña (high). The range of these fluctuations depends on the wind work and energy dissipation. Here, we study how the available potential energy is dissipated, and whether the dissipation mechanisms are consistent, within a range of ocean-only and coupled GCMs. We propose that some of the differences between ENSO simulated by coupled GCMs can be accounted for by different dissipative properties of the models.

Main Questions:

How is energy dissipated in the tropical ocean?

How much of the wind work in the tropics goes into changing the slope of the thermocline and how much is dissipated (Calculating dissipation rates)?

Can energy dissipation rates give insight into model differences in simulating interannual variability and the seasonal cycle?

1. **Ocean Model (trying to find a baseline)**
2. **Coupled GCMs (Work in progress)**

Potential Energy

A La Niña (top) has a sloped thermocline and therefore stores potential energy. An El Niño has a flatted thermocline and has low potential energy.

$$E=\frac{g}{2}\iiint\frac{(\rho-\rho^*)^2}{\left|\frac{\partial\rho^*}{\partial z}\right|}dxdydz$$

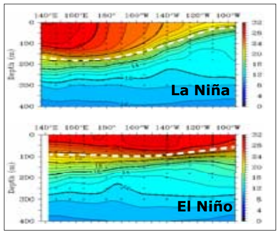


Figure 1: Temperature profile for the equatorial Pacific. Dotted line shows the thermocline.

Wind Work

Wind acts on the ocean to change the thermocline slope.

$$W=\iint U.\tau dxdy$$

We choose the region in the black box (right) to calculate the potential energy and wind work as is captures most of the variance.

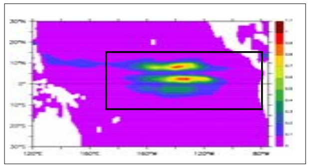


Figure 2: Variance of the wind work over the Pacific Ocean from the MOM4 model.

$$\frac{d(\text{Potential Energy})}{dt}=\text{Wind Work}+\text{Dissipation}$$

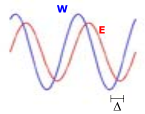
- If there were no dissipation then the wind work and Potential Energy would be exactly 90 degrees out of phase – but they are not. Dissipation means that the lag between the two is reduced (see Figure 3).
- We want to understand the role of dissipation, where it comes from and whether it is the same in all models.
- Dissipation of energy can take many forms including heat fluxes, energy fluxes out of the tropical region, friction, and eddies.

CALCULATING DISSIPATION

Following Fedorov (2007), we take the dissipation to be equal to -2αE and find solutions for each frequency ω

$$\boxed{\frac{\partial E}{\partial t}=W-2\alpha E}$$

α^{-1} is the decay rate of the thermocline anomalies



Solutions: $W=W_0e^{i\omega t}$

$E=E_0e^{i\omega(t-\Delta)}$

ω **Frequency of interest**

Δ **Lag between W and E**

For each ω, what Δ gives you the maximum correlation?

Once we know the Δ for each ω, we can solve for α, the decay rate of the thermocline, shown in Figure 5.

Wind Work (Watts x 10^{11}) and **Available Potential Energy** (Joules x 10^{18})

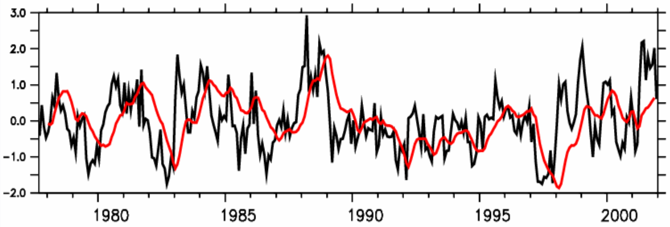
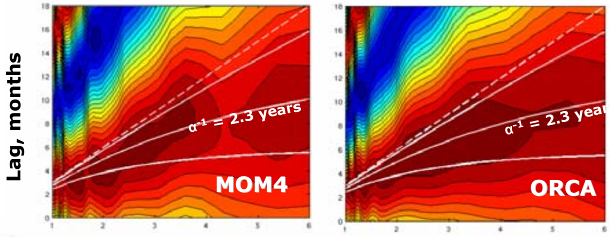


Figure 3: Time series of wind work (black) and potential energy (red) for the MOM4 ocean model. El Niño corresponds to low potential energy.

Ocean GCMs:
Energy Dissipation Rates



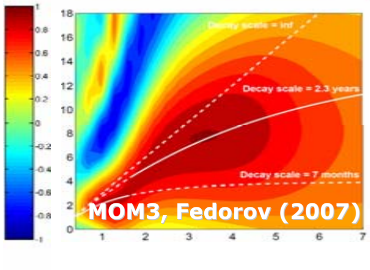


Figure 4: Estimations of the decay rate of the thermocline anomalies in ocean only models. Contours show the correlation between Wind Work (W) and Potential Energy (E) for given frequency on x axis, and lag on y axis. The highest correlation gives the decay rate α^{-1}.

IPCC Coupled GCMs:
Energy Dissipation Rates

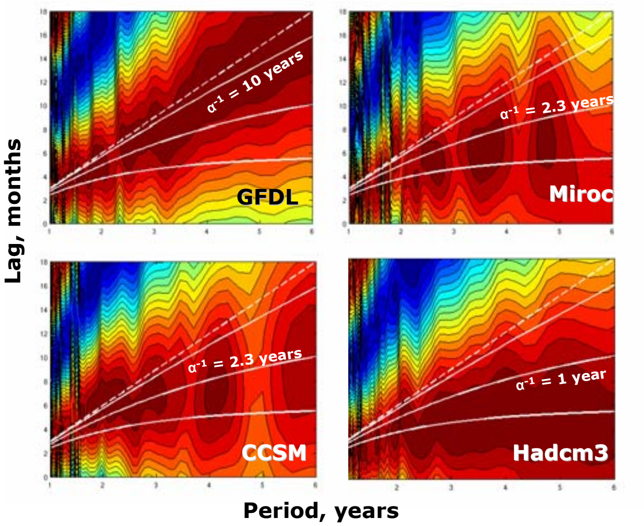


Figure 5: As for Figure 4 but using Coupled Models.

CONCLUSIONS

- The net energy dissipation rates in the tropical ocean are assessed in several ocean GCMs forced by observed surface fluxes and windstress.
- The calculated e-folding timescale for thermocline depth anomalies in ocean models is ~2.3 years.
- Coupled IPCC GCMs exhibit a broad range of dissipation rates (e-folding timescales for thermocline depth anomalies range from roughly 1 to 10 years).

FURTHER QUESTIONS

- Investigate relative contribution of different mechanisms to dissipation in *ocean-only models*.
- Compare energy dissipation in *Data Assimilation* products.
- Look at the energetics of the *seasonal cycle*.
- To investigate what causes the coupled models to produce such different dissipation rates and how these rates affect the simulated El Nino.

References

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