How lateral mixing affects the amplitude of El Nino

Anand Gnanadesikan¹, Alexandria Russell¹, Marie-Aude Pradal¹ and Ryan Abernathey²

¹: Johns Hopkins University  ²: Columbia University

1. Motivation

Lateral mixing coefficient in ocean is very uncertain (Figure Aa) based on theories developed for vertical E-P flux-low values on equator.

Some theories relate coefficient strongly to baroclinicity (Figure Aa) based on theories developed for vertical E-P flux-low values on equator.

Recent estimates based on satellite altimetry (Fig. 1C) show very different distribution. (Abernathey and Marshall, J. Geophys. Res-Oceans., 2013)

Zonal average of this distribution (Fig. 1d) has very high values in mid-latitudes.

What are the implications of this uncertainty for simulating El Nino?

2. Approach

Take GFDL CM2.1 model.

Do 4 runs with spatially constant coefficient (400, 800, 1200 and 2400 m²/s denoted by AREDI400, AREDI800, AREDI1200 and AREDI2400)

2D-coefficient from Fig. 1C above (ABER2D)

Zonally averaged version from Fig. 1D above (ABERZONAL).

Perform term balance regression following von Oldenborgh et al. (Ocean Sciences, 2005) in which

$$\frac{\partial T^*}{\partial T} = \alpha z_{20}^* + \beta T_x' - \gamma T^*$$

Where T', z_{20}' and T_x' are the anomalous temperatures, pycnocline depth and wind stress respectively.

Increases in α, β and 1/γ mean that the ocean is more responsive to the atmosphere.

Regression can be done using total tendencies or just  using tendencies due to particular processes.

$$\frac{\partial T^*}{\partial T} = \left(\frac{\partial T^*}{\partial T}\right)_{\text{advect}} + \left(\frac{\partial T^*}{\partial T}\right)_{\text{contact}} + \left(\frac{\partial T^*}{\partial T}\right)_{\text{eddy}}$$

Drivers of mean change

Mean state

Figure 1

Good overall agreement.

Increasing mixing warms SS' (Fig. 2A), reduces cross Pacific temperature contrast (Fig. 3B) shallow pycnocline slightly (Fig. 2C) and weakens zonal stress slightly (Fig. 2D)

Drivers of mean change

Mean state

Figure 2

Isopycnals (Fig. 3A, contours) cross isotherms (Fig. 3A, colors) near equator.

Isopycnal mixing moves heat up in water column (Fig. 3B).

Changing isopycnal mixing (ABERZONAL-AREDI400) moves more heat up in water column (colors Fig. 3C) but this is compensated by vertical mixing (contours Fig. 3C)

Same compensation is seen in section along the equator (Fig. 3D).

Increase in vertical mixing is due to higher mixing increasing stratification (mixing coefficients actually drop).

Regression of temperature tendency terms over top 100m vs. SST

Moving from left to right, as mixing increases

Ocean heat balance terms give stronger damping.

Eddy mixing exerts stronger damping.

Total vertical heat transport exerts weaker damping.

Advection becomes a stronger driver.

Surface forcing damping provides slightly stronger damping.

Vertical diffusion of heat from below interruption of mixing of cold water at surface warms becomes stronger driver.

3. Conclusions

Increasing isopycnal mixing does damp anomalies all else being equal...

but all else is not equal.

Warming east Pacific makes atmosphere more sensitive to SST perturbations (as in previous work by Anderson, Gnanadesikan and Wittenberg, Ocean Sciences, 2009; Russell and Gnanadesikan, J. Clim. 2014).

Increasing stratification produces compensating changes in vertical diffusion.

Careful attention must be paid to interaction between vertical and lateral diffusion.

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