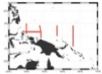


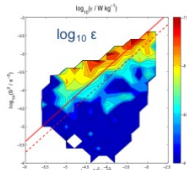
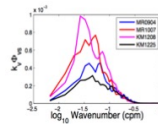
Assessing the importance of mixing in the tropical Pacific

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Observations

Observations of shear and microstructure in the Western Equatorial Pacific show the turbulence to be strongly associated with the shear of relatively small vertical scale flow features, SVSs (order 10m) that are not generally resolved in observations or models.



Writing:

$$\epsilon = \ell_v^2 N^3 f(Ri)$$

we note that $\epsilon \sim N$ for constant Ri (for $N^2 > 10^{-5} s^{-2}$), which implies the vertical length scale

$$\ell_v = \frac{u_t}{N}$$

The vertical diffusivity is then

$$\kappa_v = \frac{\gamma u_t^2 f(Ri)}{N}$$

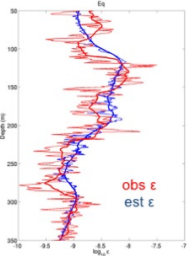
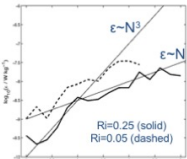
We take the turbulent velocity scale

$$u_t \approx 0.1 \bar{u}$$

where \bar{u} is the amplitude of the SVSs

Comparison of estimated and observed ϵ shows a good correspondence – see example in lower panel. We note there is a tendency for $\bar{u}^2 \sim N$ making κ_v solely a function of Ri

In this example inertial instability is likely playing a major role

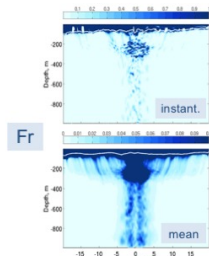


Process Studies

Idealized studies show high vertical shear, small vertical scale, features generated by

- Instabilities (inertial and PSI)
- Wind-generated inertia-gravity waves

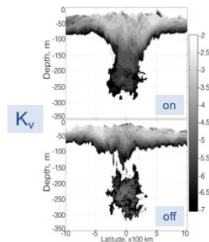
Here we consider wind-generated waves



Wind-forced zonally symmetric model:

Froude number (S^2/N^2) increased close to the equator and in the thermocline (left) through a combination of

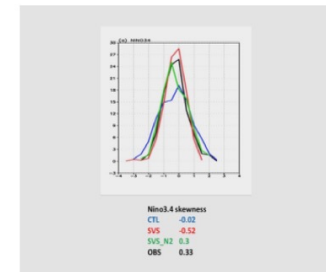
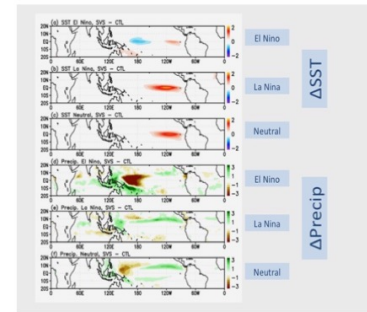
- Increased super-inertial input by the wind
- Amplification of waves as they travel through the thermocline
- Wave-wave interactions (PSI)
- Convergence of wave action at turning latitudes



Increased Froude number leads to **enhanced vertical diffusivity** (with a Ri based parameterization) within the equatorial thermocline (left) regardless of the distribution of the wind forcing. Upper panel on-equatorial winds. Lower panel off-equatorial winds

GCMs

Accounting for the unresolved mixing in a coupled model (SINTEX-F2) reduces biases in the mean state and ENSO variability – a reduced cold tongue bias and improved skewness of ENSO. The response is not unduly sensitive to the details of the enhanced dissipation.



*References:

- Richards K.J., A. Natarov, E. Firing, Y. Kashino, S. M. Soares, M. Ishizu, G. S. Carter, J. H. Lee, K. I. Chang (2015) Shear-generated turbulence in the equatorial Pacific produced by small vertical scale flow features. *J. Geophys. Res.*, **120**, 3777-3791.
- Natarov, A., and K.J. Richards, (2018) Enhanced energy dissipation in the equatorial pycnocline in a simple model of a tropical ocean, *J. Geophys. Res.* (in prep)
- Sasaki, W, K.J. Richards and J.J. Luo (2013) Impact of vertical mixing induced by small vertical scale structures above and within the equatorial thermocline of the tropical Pacific in a CGCM, *Climate Dynamics* DOI 10.1007/s00382-012-1593-8.