Seasonal Modulations in the Eddy Field of the South Pacific Ocean

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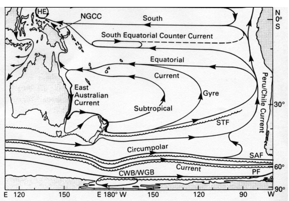
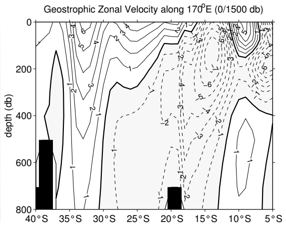
1. Introduction

Two high eddy kinetic energy (EKE) bands with well-defined annual cycles in the South Pacific are revealed in the decade-long satellite altimeter data. One is along the South Equatorial Countercurrent (SECC) centered $\sim 9°$S, and another is along the the South Tropical Countercurrent (STCC) in 21°–29°S. Although the STCC is less well recognized (lower left panel, Tomczak and Godfrey 1994), its existence as a *mean* eastward current can be seen in the Levitus climotology (lower right panel). Although both the SECC and STCC flow eastward and override the broad westward-flowing South Equatorial Current (SEC), we show that the seasonal EKE modulations in the SECC and STCC are caused by different mechanisms.

Schematic surface currents in the South Pacific



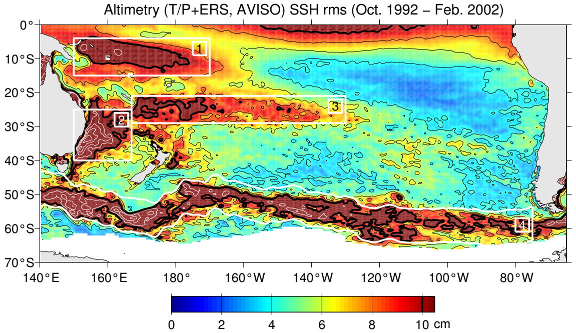
Geostrophic Zonal Velocity along 170°E (0/1500 db)

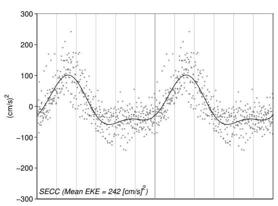


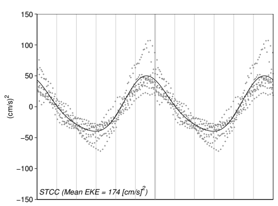
2. Altimetric Observations

Among the four high eddy variability bands in the South Pacific, the EKE signals have well-defined annual cycles in the SECC and STCC bands. While the EKE in the SECC peaks in March/April, the EKE in the STCC has a maximum in November/December.

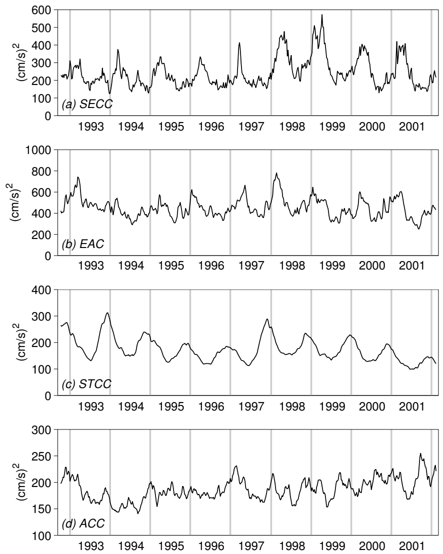
Altimetry (T/P+ERS, AVISO) SSH rms (Oct. 1992 – Feb. 2002)







EKE seasonal variations in **SECC**, EAC, **STCC** and ACC bands



3. STCC: Baroclinic Instabilty

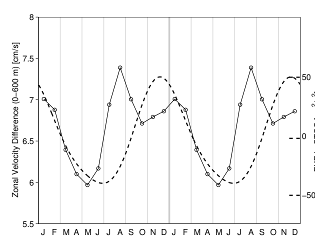
Following Qiu (1999), we consider the $2^1/_2$-layer QG model:

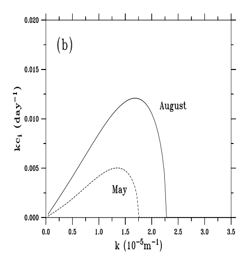
$$\left(\frac{\partial}{\partial t}+U_n\frac{\partial}{\partial x}\right)q_n+\frac{\partial \Pi_n}{\partial y}\frac{\partial \phi_n}{\partial x}=0, \quad n=1,2$$

where $\Pi_1=\beta+\frac{f_0^2}{g'H_1}(U_1-U_2)$ and $\Pi_2=\beta-\frac{f_0^2}{g'H_1}(U_1-U_2-\frac{\rho_2-\rho_1}{\rho_3-\rho_2}U_2)$. For the vertically-sheared STCC-SEC system, $\Pi_{1y}>0$, and the necessary and sufficient condition for the baroclinic instability

$$\Pi_{2y}<0, \quad \text{or} \quad U_1-U_2>\frac{\beta g' H_1}{f_0^2}+\frac{\rho_2-\rho_1}{\rho_3-\rho_2}U_2$$

is satisfied. In austral winter, the STCC/SEC system is baroclinically more unstable than in other seasons due to the large vertical shear (solid line in the lower left panel) and weak stratification. This seasonal variation in the intensity of baroclinic instability is responsible for the seasonal modulation of the STCC's EKE field with a November/December maximum and a June/July minimum (lower right panel contrasting the growth rates in the two seasons).





4. SECC: Barotropic Instabilty

The large deformation radius in the low-latitude SECC region prevents the vertically-sheared SECC-SEC system from becoming baroclinically unstable. Here, we adopt the $1^1/_2$-layer reduced-gravity model:

$$\left(\frac{\partial}{\partial t}+U\frac{\partial}{\partial x}\right)q+v\frac{\partial \Pi}{\partial y}=0,$$

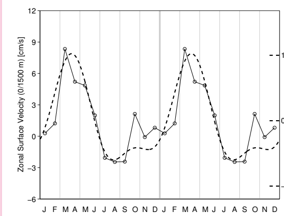
where $\Pi=\frac{f-U_y}{H}$. The necessary condition for the barotropic instability is the change of sign in Π_y. Since

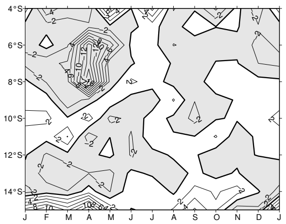
$$\Pi_y \propto \beta - U_{yy} + U\lambda^{-2},$$

we find the presence of the background westward flow (i.e., the SEC) can significantly lower the threshold for barotropic instability (see Philander 1976). The seasonal EKE signal along the SECC results from the barotropic instability which modulates seasonably due to the strength of the horizontal shear in the SECC-SEC system (lower left panel; solid line). Analysis of the barotropic conversion rate (BCR):

$$\text{BCR}=\overline{u'u'}U_x+\overline{u'v'}\left(U_y+V_x\right)+\overline{v'v'}V_y.$$

inferred from the altimetric data (lower right panel) supports this notion.





5. Conclusions

A. Seasonal EKE modulation in the STCC is due to the seasonal variation of the intensity of the **baroclinic instability** of the vertically-sheared STCC-SEC system. In austral winter, the STCC/SEC system is baroclinically more unstable than in other seasons due to the large vertical shear and weak stratification.

B. Seasonal EKE modulation in the SECC is due to the seasonal variation of the intensity of the **barotropic instability** of the horizontally-sheared SECC-SEC system. Energetics analysis shows that the energy transfer from the mean to the EKE peaks approximately one month before the EKE reaches maximum.

C. Despite being a weak, surface-trapped eastward current in the center of the wind-driven subtropical gyre, the STCC provides a strong EKE source.

References and Acknowledgment

Philander, S. G. H., 1976. JGR, 81, 3725–3735.

Qiu, B., 1999. JPO, 29: 2471–2486.

Tomczak, M. and J. S. Godfrey, 1994. Regional Oceanography: An Introduction. Pergamon, 422 pp.

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