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Note on the significance of a previous Rossby wave fit to internal temperature fluctuations in the Eastern Pacific

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ABSTRACT

This note refers to a paper by Emery and Magaard (1976), where it was shown that low frequency internal temperature fluctuations in parts of the Eastern Pacific can, to a large extent, be interpreted by a baroclinic Rossby wave model.

Fitting a generalized wave model to the same data used by Emery and Magaard shows that the Rossby wave model yields not only a good but, in a certain sense, the best fit, which reinforces the case for the existence of baroclinic Rossby waves in the Eastern Pacific Ocean.

1. Introduction

Emery and Magaard (1976), henceforth referred to as EM, have shown that low frequency (periods of about one to two years) internal temperature fluctuations in the Eastern Pacific between Hawaii and weather station November (30 N, 140 W) can be interpreted, to a large extent, by means of a Rossby wave model. This interpretation was based on a cross-spectral fit of a random field of baroclinic Rossby waves to the observed data (hydrographic and XBT casts taken over a five-year period). Following publication of their paper, the authors heard some critical remarks that a good numerical fit of a Rossby wave model to observations does not prove that Rossby waves are the best explanation for these observations. There remained the possibility that some other model could yield an even better fit.

In this note we respond to such criticism by fitting a more general wave model

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to the same observations. In this general model, the wave number vectors are no longer required to satisfy the dispersion relation of internal Rossby waves. They are now free parameters to be determined by the fit. The wave number vectors that give the best fit in this general model will be compared to those wave number vectors that gave the best fit in the Rossby wave model.

Throughout this note the nomenclature of EM is applied without redefinition.

2. The generalized model

We retain a random field of isotherm fluctuations and vertical mode structure, $\phi\,(\lambda_n, z)$, as described in (5.1) of EM. However, we no longer require these fluctuations to conform to the dispersion relation (4.6). This is equivalent to no longer demanding R_n to be equal to $\left(\frac{\beta^2}{4\omega^2} - f^2\,\lambda^2{}_n\right)^{\frac{1}{2}}$ but assuming R_n to be a free parameter to be determined by the fit. We introduce the notation $R_n{}^{(r)} = \left(\frac{\beta^2}{4\omega^2} - f^2\,\lambda^2{}_n\right)^{\frac{1}{2}}$. Then for $R_n = R_n{}^{(r)}$ our generalized model is identical with the Rossby wave model of EM. In the case of $R_n \neq R_n{}^{(r)}$ our model consists of fluctuations that do not satisfy the dispersion relation of any known wave type.

The cross-spectrum of our model field is (5.6) of EM. This formula is repeated in order to correct misprints in EM:

$$A(\mathbf{r}, z, z', \omega) = \sum_{n=1}^{M} E_n\,\phi_n\,(z)\,\phi_n\,(z')\left[\,\exp\!\left(-\,i\,\frac{\beta}{2\omega}\,r\sin\alpha\right)\right] \times$$

$$\int_0^{2\pi} S_n\,(\phi)\,\exp\,[-i\,R_n\cos\,(\phi - \alpha)]\;d\phi\;\;.$$

3. Fitting the generalized model to observations

We have restricted the application to the "δ-function" fit and to wave periods of 28 and 14 months for which that fit was good. That means that E_1 in (6.11) of EM has to be maximized, which is equivalent to minimizing F in (6.12) of EM. But E_1 and F are no longer functions of only ϕ_1, as in EM, but are now functions of the parameters ϕ_1 and R_1, which have to be determined by maximizing E. Note that this is equivalent to having the wave numbers κ and η as free parameters.

At wave period 28 months we have $R_1{}^{(r)} = 11.81 \times 10^{-5}$ m^{-1}. From our generalized model we find $R_1 = (11.81 \pm 0.16) \times 10^{-5}$ m^{-1} in scheme I and $R_1 = (11.81 \pm 0.05) \times 10^{-5}$ m^{-1} in scheme II and hence ϕ_1 as in EM. And at wave period 14 months we have $R_1{}^{(r)} = 5.63 \times 10^{-5}$ m^{-1}. From our generalized model, we find $R_1 = (5.74 \pm 0.20) \times 10^{-5}$ m^{-1} in scheme I and $R_1 = (5.63 \pm 0.03) \times 10^{-5}$ m^{-1} in scheme II. In scheme I the generalized model gives $\phi_1 = -88.8°$

versus $\phi_1 = -88.0° \pm 1.8°$ in EM; in scheme II we have the same ϕ_1 as in EM. Thus, the results of the generalized model are the same as or only insignificantly different from those in EM for first mode Rossby waves of 14 and 28 month periods.

4. Discussion

In all cases considered, the Rossby wave model gives the best fit. We conclude that baroclinic Rossby waves are not only a useful tool for describing features of oceanic fluctuations but indeed exist in the ocean.

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