Reply

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Rotary empirical orthogonal functions (EOFs) are introduced and used to analyze current meter data from the Coastal Upwelling Experiment (CUE-II) in Denbo and Allen, 1984, hereafter referred to as DA. In the rotary EOF analysis of the CUE-II cross-shelf dataset for the 0.25 cycles per day (cpd) frequency band, DA erroneously reported that no change in the relative magnitudes of the first clockwise and anticlockwise EOF amplitude existed in the cross-shelf direction. In fact, such a change does exist at Forsythia (53 km offshore) and thus raises the possibility, as pointed out by Hsieh, that a second dynamical mode may be dominant. However, no time series at Forsythia has more than 40% of the total variance explained by both the mode one clockwise and mode one anticlockwise EOFs. Consequently, the mode-one EOF amplitudes at Forsythia are relatively small, leading to uncertainty in the estimate of rotary coefficients and to questions about the conclusion that a second dynamical mode is dominant.

The use of rotary empirical orthogonal functions is most appropriate for flows that have rotary signals, e.g., near-intertial frequency motions. Denbo and Allen point out that the application of the rotary EOF technique to flows that are nearly rectilinear, such as the low-frequency motions analyzed in Section 8, may not give the optimum description of the signal. In order to explore further the question raised by Hsieh concerning whether a second cross-shelf dynamical mode is dominant, we have made some additional calculations. An alongshore velocity component EOF and a combined alongshore and cross-shelf velocity component EOF were computed using the CUE-II cross-shelf dataset for the 0.25 cpd frequency band. Results from the free wave model described by Hsieh (1982) are compared with the velocity component EOF amplitude and phase functions.

The results of these calculations are summarized in Table 1 and Fig. 1. In Table 1, the mode one dimensional amplitude, phase and percent variance explained for the alongshore velocity component EOF are presented. The EOF amplitude decreases slightly in magnitude from 3 cm s^{-1} at Aster (6 km offshore) to 2.5 cm s^{-1} at Edelwiess (27 km) and then drops to <0.5 cm s^{-1} at Forsythia (53 km). The phase varies less than 90° across the shelf. The cross-shelf variation of the EOF phase is insufficient to correspond to a change in sign of the fluctuating EOF alongshore velocity components. The time series with the lowest percent of total variance explained by the mode one EOF (the velocities at Forsythia) are also responsible for the largest scatter in the phase.

The regression coefficients, residual variance and percent variance explained for the regression of EOF amplitude on each of the first two dynamical modes are presented in Table 2. The residual variance for the regression on the first dynamical mode is less than half the residual for the regression on the second dynamical mode, indicating a better fit with the first mode.

The cross-shelf structure of the first two dynamical modes calculated from the model of Hsieh (1982) for a frequency of 0.25 cpd are presented in Fig. 1. Alongshore and cross-shelf velocity components are denoted by solid and dashed lines, respectively. The first mode

TABLE 1. The dimensional amplitude, phase, and percent variance explained for the alongshore velocity component mode one EOF for the 0.25 cpd frequency band.

Mooring	Distance offshore (km)	Depth (m)	Amplitude (cm s^{-1})	Phase	Percent variance explained
Aster	6	20	3.41	−10	75
		40	2.80	10	84
Carnation	13	20	2.77	14	69
		40	2.87	10	58
		60	3.50	11	83
		80	2.95	18	82
		96	2.35	17	85
Edelweiss	27	20	1.96	8	83
		80	2.36	23	93
		120	2.83	25	88
		180	2.79	22	83
		195	2.50	24	82
Forsythia	53	40	0.28	−37	10
		80	0.32	20	10
		120	0.44	64	58
		180	0.49	70	38

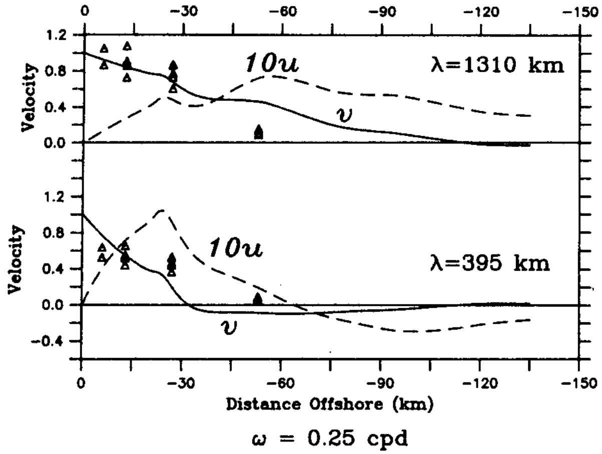

FIG. 1. The cross-shelf structure for the first (top) and second (bottom) dynamical modes at 0.25 cpd are presented together with the normalized amplitudes (triangles) from the first-mode alongshore velocity EOF. The alongshore and cross-shelf nondimensional velocities from the dynamical modes are denoted by solid and dashed lines, respectively. The cross-shelf velocity is multiplied by 10 for display purposes.

EOF amplitudes, denoted by triangles, are displayed with the first dynamical mode (top), wavelength = 1310 km, and the second dynamical mode (bottom), wavelength = 395 km. The EOF amplitudes are normalized by the regression coefficient from the fit with the first and second dynamical mode, respectively. The visual fit between the first EOF mode and the first dynamical mode, Fig. 1, is striking at Aster, Carnation and Edelweiss, where the EOF represents a large fraction of the variance (Table 1). The fit is not as good for the measurements at Forsythia, which are poorly explained by the first-mode EOF. The overall fit by the second mode is poor.

The addition of the cross-shelf velocity component to the matrix for the EOF computations does not qualitatively affect the alongshore velocity component structure. The quantitative differences are also small.

TABLE 2. The regression coefficients, residual variance and percent variance explained from a regression of first mode EOF amplitude on each of the first two dynamical modes.

Dynamical mode	Regression coefficient	Variance (cm s^{-1})	Percent variance explained
1	3.24	6.98	93
2	5.34	16.34	83

The ratios of cross-shelf to alongshore velocity EOF amplitudes (typically 0.2) are up to eight time larger than the free wave model predictions for the first and second dynamical modes. The relatively large magnitude of the cross-shelf velocity component in the EOF is inconsistent with free wave propagation in the first or second dynamical modes. Other processes such as direct wind forcing could be contributing to the cross-shelf velocity field.

In summary, the low frequency (0.25 cpd) velocity fields studied here are nearly rectilinear. The cross-shelf velocity component evidently includes contributions from processes other than low mode free waves. The separation of the nearly rectilinear flow into rotary components is not precise due to the presence of the "noisy" cross-shelf velocity component. The first alongshore velocity component EOF gives no evidence for the presence of coastally trapped free wave modes higher than the first. It should be emphasized that we do not claim, based on this analysis, that the first alongshore velocity EOF corresponds to a first dynamical mode, but rather that there is no evidence that the EOF corresponds to a higher mode.

REFERENCES

Denbo, D. W., and J. S. Allen, 1984: Rotary empirical orthogonal function analysis of currents near the Oregon coast. *J. Phys. Oceanogr.*, **14,** 35–46.

Hsieh, W. W., 1982: Observations of continental shelf waves off Oregon and Washington. *J. Phys. Oceanogr.*, **12,** 887–896.