Semi-daily fluctuations in geopotential off the Washington coast

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ABSTRACT

Fluctuations in geopotential anomaly at eight 12-hr time-series stations off Washington appeared to result from semi-daily internal tides propagating seaward from the shelf break. Comparison of the observations with computations suggests the existence of a first mode wave. The oscillations did not appreciably decay offshore, perhaps as a result of bathymetric focusing.

In September 1973 a survey was conducted from the NOAA ship *Oceanographer* in the waters off Washington during which eight 12-hr STD (salinity/temperature/depth) time series (Fig. 1) were obtained. Casts were taken at 1.5-hr intervals except for stations 49-55, which were taken at 2-hr intervals. The main purpose of these stations was to estimate the effects of temporal variations on the geopotential topography and thus the confidence with which one may use the data from individual casts to determine geostrophic flow (see Reed and Halpern, 1976, for discussion). The data reveal other interesting features not previously discussed, however.

Plots of the time-series data (see Figure 2 for an example) exhibit a fairly regular rise and fall of isolines of temperature and salinity with a time difference of about 6 hr between high and low positions and amplitudes in the pycnocline of about 6-8 m. Maximum and minimum values of geopotential anomaly, referred to 1000 db, occur near the times of lowest and highest positions (respectively) of property isolines, and the patterns at the various levels were quite similar. Thus the data suggest that semi-daily internal tides were present in the area.

As a reasonably objective estimate of differences in amplitude, we have computed the standard deviation from the mean geopotential anomalies for various levels at the eight time-series stations (Table 1). A reduction in amplitude toward the deeper levels is shown. Although the first three time-series stations (Table 1) suggest a trend, there is no overall, consistent pattern of reduced amplitude with distance from the shelf break (100-fathom isobath) as might be expected.

Internal tides exist as one or more vertical modes which can be computed from vertical profiles of density and sound speed (see for example, Mofjeld and Rattray,

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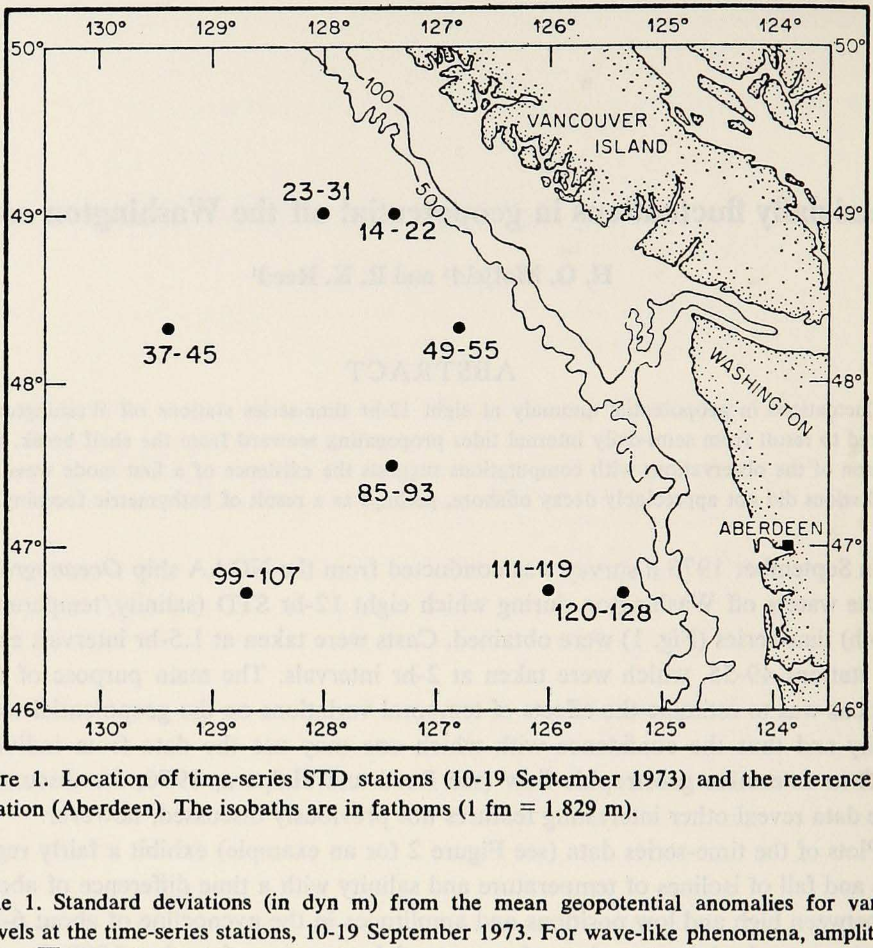

Figure 1. Location of time-series STD stations (10-19 September 1973) and the reference tide station (Aberdeen). The isobaths are in fathoms (1 fm = 1.829 m).

Table 1. Standard deviations (in dyn m) from the mean geopotential anomalies for various levels at the time-series stations, 10-19 September 1973. For wave-like phenomena, amplitudes are $\sqrt{2}$ times the deviations. The deviations have been normalized, using mean daily tidal amplitudes, for variations over the period in the predicted tide at Aberdeen, Washington.

Stations	Date/Time (GMT)	10/1000 db	150/1000 db	500/1000 db	Distance from Shelf Break (km)
14-22	10/0546-10/1745	0.014	0.008	0.004	40
23-31	10/2112-11/0923	0.012	0.007	0.003	76
37-45	12/0315-12/1516	0.010	0.006	0.002	200
49-55	13/0414-13/1616	0.005	0.005	0.004	55
85-93	15/1530-16/0328	0.010	0.004	0.003	145
99-107	16/2200-17/1000	0.010	0.005	0.003	285
111-119	17/2256-18/1103	0.009	0.006	0.003	90
120-128	18/1402-19/0201	0.009	0.002	0.003	44
	Mean*	0.0099±0.0009	0.0054±0.0007	0.0031±0.0002	

* Error estimates are the standard error of the mean.

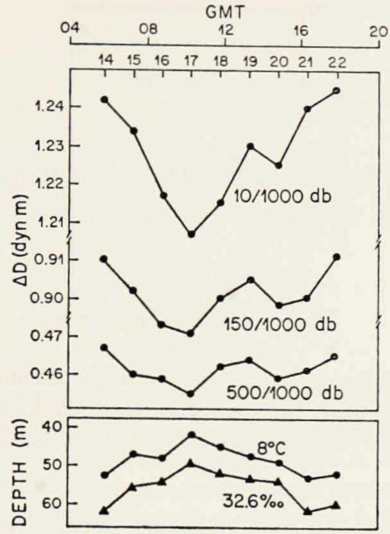

Figure 2. Time-series plot of geopotential anomaly (ΔD) for the 10-, 150, and 500-db surfaces (referred to 1000 db) at stations 14-22, 10 September 1973. Variations in depth of the 8°C and 32.6‰ isolines, which are near the steepest part of the pycnocline, are also shown.

1971). The data at station 86 were used to compute the geopotential anomalies of the first two vertical modes, which were compared to the observed data in Table 1 (see Table 2). Results for the mode 1 wave, which is in phase throughout the water column, are in very close agreement with the observations.

A comparison was also made of the time difference between observed crests in geopotential and predicted high water at Aberdeen, Washington (minus 0.8 hr for the time difference there and on the exposed coast) versus distance from the shelf break (Fig. 3). There is a general trend of increased time differences with distance offshore, which is the behavior one would expect from an internal tide generated near the shelf break and propagating offshore. Furthermore, the computed wavelength (133 km) for a mode 1 wave is in good general agreement with the data in Figure 3.

Table 2. Variations of semi-daily geopotential anomalies with depth (values normalized to 10/1000-db amplitude).

	Observed*	Computed	
		Mode 1	Mode 2
10/1000 db	1.00	1.00	1.00
150/1000 db	0.55±0.09	0.61	−1.76**
500/1000 db	0.31±0.09	0.24	−0.82**

* Average over all stations; error estimates take into account the uncertainty in the 10/1000-db value.
** A negative value indicates anti-phase with respect to the 10/1000-db phase.

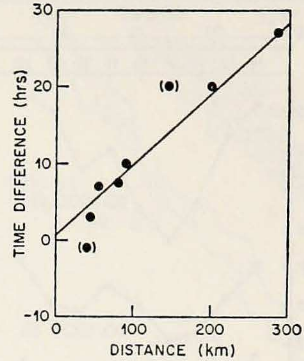

Figure 3. Plot of the time difference between crests in geopotential and predicted high water at Aberdeen versus distance from the continental shelf break (approximated by the 100-fm isobath). The line is a linear regression by the method of least squares, excluding the two data points in parentheses.

Although the time-series data are admittedly of short duration, there is evidence which suggests that internal tides were present throughout the area. Furthermore, in this offshore region they appear to be mode 1 waves, which contrasts with the continental slope-shelf area (see for example, Prinsenberg *et al.*, 1974) where higher modes are more likely. The oscillations did not, however, consistently diminish with distance seaward as would be expected (Wunsch and Hendry, 1972; Barbee *et al.*, 1975). We suspect one reason for this behavior is that the concave (as viewed from the west) shelf may focus seaward propagating waves offshore. Another factor may be the lack of abrupt horizontal changes in the density structure.

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