Towards an understanding of shelf dynamics along the Southern Coast of Turkey

by

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Abstract

Measurements of currents in the Mediterranean off the coast of Erdemli show significant low-frequency oscillations in the long-shore velocity component. These oscillations are found to be highly correlated with the passage of cyclonic disturbances over the ocean.

1. Introduction

Very little is known about the dynamics of the deep and the shallow waters along the southern coast of Turkey. This is especially unfortunate because the region extending from the Bay of Iskenderun in the east to Anamur in the west is heavily industrialized undergoing rapid change.

The meagerness of the knowledge about the aforementioned waters is particularly evident regarding characteristics of currents, including both spatial and temporal variability. In view of the mounting environmental questions concerning the Mediterranean in general and coastal transport of pollutants in particular, the situation is quite dismaying. With regard to the transportation of pollutants in coastal waters, attempts should clearly by made, commencing, perhaps, with investigations directed towards the understanding of shelf dynamics.

As a first step, a measurement programme involving a sequence of observational experiments is being carried out to investigate the characteristics of currents and of the mass field in coastal waters 40 km west of Mersin where M.E.T.U.'s Marine Science Department is situated. Reported herewith is the first of the observational experiments designed for the sole purpose of investigating the temporal variability of the currents over the shelf. This experiment is being carried out in relatively shallow waters and future experiments will involve the successive establishement of current meter mooring stations some distance from shore.

The first observational experiment indicates the presence of significant shore-parallel, low-frequency ($f < 0.02$ cpn) motions which can be attributed to the cyclonic disturbances that frequently pass over the area (TREWARTHA, 1961). Semi-diurnal tidal as well as sea-breeze forced diurnal motions of small energy levels are also found but the attention is focused on the low-frequency motions because of their energy content and the crucial importance they have in shelf dynamics (NEILLER, 1975).

2. The Experiment.

a. *Field Measurements*

Fig. 1 shows the area at large and the various locations referred to below. Fig. 1. b. is a close-up of the region where observations were made. The principal bathymetric features of the near shore region are also shown in Fig. 1. b.

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From March 2 to April 6 1978, a vertical array of two current meters was maintened in about 20 m of water off the Erdemli campus of M.E.T.U. A taut-mooring system was employed, with the current meters being located at 5 and 10 m from the surface. The current meter mooring station is indicated in Fig. 1. b. by a solid square. The current meters are savonious rotor instruments of the type Aanderra RCM-4 ; both instruments were set to record current speed, direction and temperature at 5 minutes intervals.

The wind and atmospheric pressure data for Anamur and Mersin were provided by the Turkish Meteorological Office.

Sea level measurements are made but the data were discarded due to an instrument mal function. It is worth noting however that the sea level measurements at the locality during other periods of the year indicate semi-diurnal tidal fluctuations up to 45 cm.

b. *The Data.*

The bathymetry in the region of the observational experiment is such that the orientation of the depth contours is approximately towards NE45°. On addition, the results indicate that the direction of the low frequency motions with higher energy levels coincides with this orientation. The current meter data were thus transformed into its vector components with essentially a longshore component (: v) toward NE45° and an onshore component (: u) toward NW315°. After this breakdown, the values of the velocity components as well as the temperature in 5 min. intervals were averaged over an hour to convert the time series into one with one-hour intervals. The time series thus constructed is shown in Fig. 2 and 3.

Wind and atmospheric pressure data were provided in one-hour intervals. The wind-stress components (τx, τy) were computed using.

$$\vec{\tau} = 3.2 \times 10^{-2} \times \vec{w} / \vec{w} \text{- dyn-cm}^2$$

wherein $\vec{w}$ is the wind velocity in units of m/sec (NEUMAN and PIERSON, 1966). Fig. 3 shows the components of the vector $\vec{w}/\vec{w}/$ for the observation period.

c. *Data processing*

The digital time-series were frequency broken down by Fast Fourier Transform (FFT) techniques (BRIGHAM, 1974) to obtain the autospectra, cross-spectra, coherency and phase (not presented here) of the various variables under consideration. Prior to FFT computations, the averages were removed and the correlation functions were windowed by the cosine bell window. Smoothed spectral estimates did not differ significantly from the raw estimates. Only the raw spectral estimates are given here. The resolution of the spectral estimates is 3×10^{-2} cph, and the nyquist frequency is 0.5 cph. The standard deviations of the variables are also computed. The cross-spectra have been normalized by the mean-square of each variable correlated.

3. Results

A cursory examination of the time-series for the velocity component, (Fig 2) shows that, both at 5 and 10 m depths, the order of magnitude of the longshore velocity (u) is larger than that of the onshore velocity (v). The time series for the longshore velocities at two different depths are essentially the same and, more significantly, shows low frequency oscillations with time scales greater than 2 days. No such oscillations are evident in the onshore component which shows irregular oscillations with periods of up to 50 hrs.

These higher frequency oscillations are also evident in the longshore velocity. It can be seen in Fig. 2 that no net motion occurs in the off-shore directions, while the longshore velocities have a mean component directed towards south-east. These observations are quantified in the following table and Fig. 4 where the spectra of the velocity components are shown.

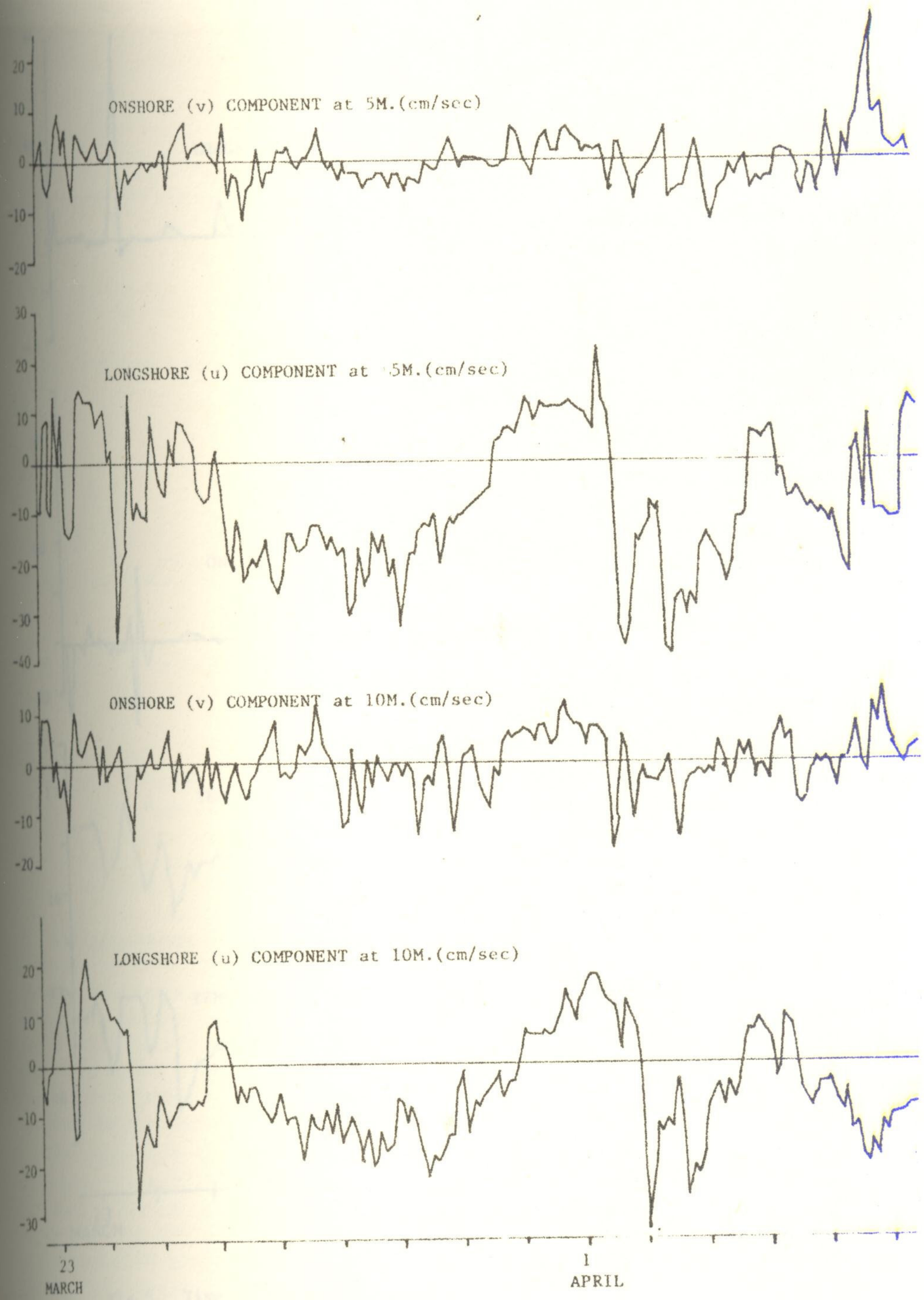

Fig.2. Time history of current components

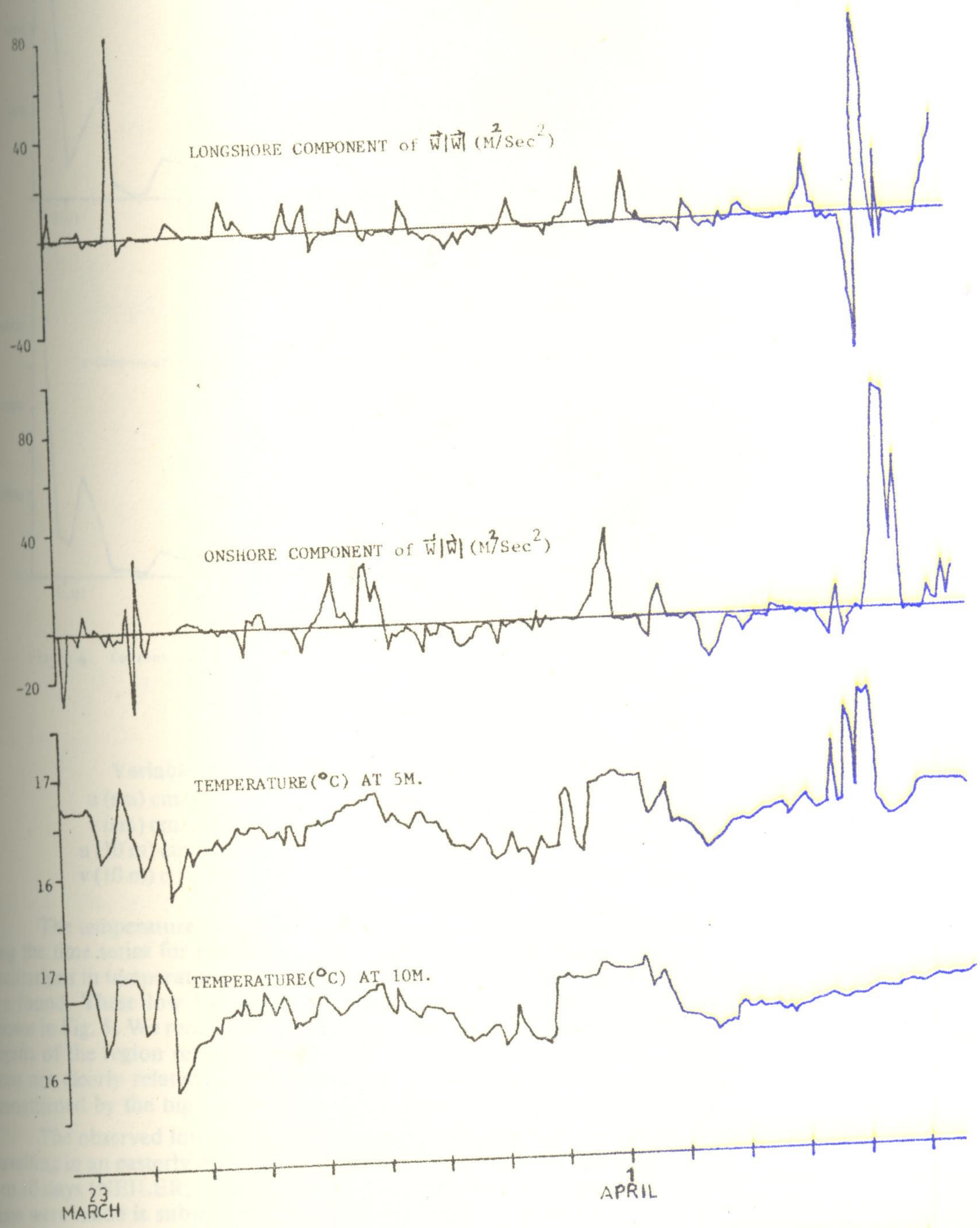

Fig.3. Time history of wind-stress and temperature. When multiplied by 3×10^{-2} the upper two curves gives wind stress in dyne/cm^2.

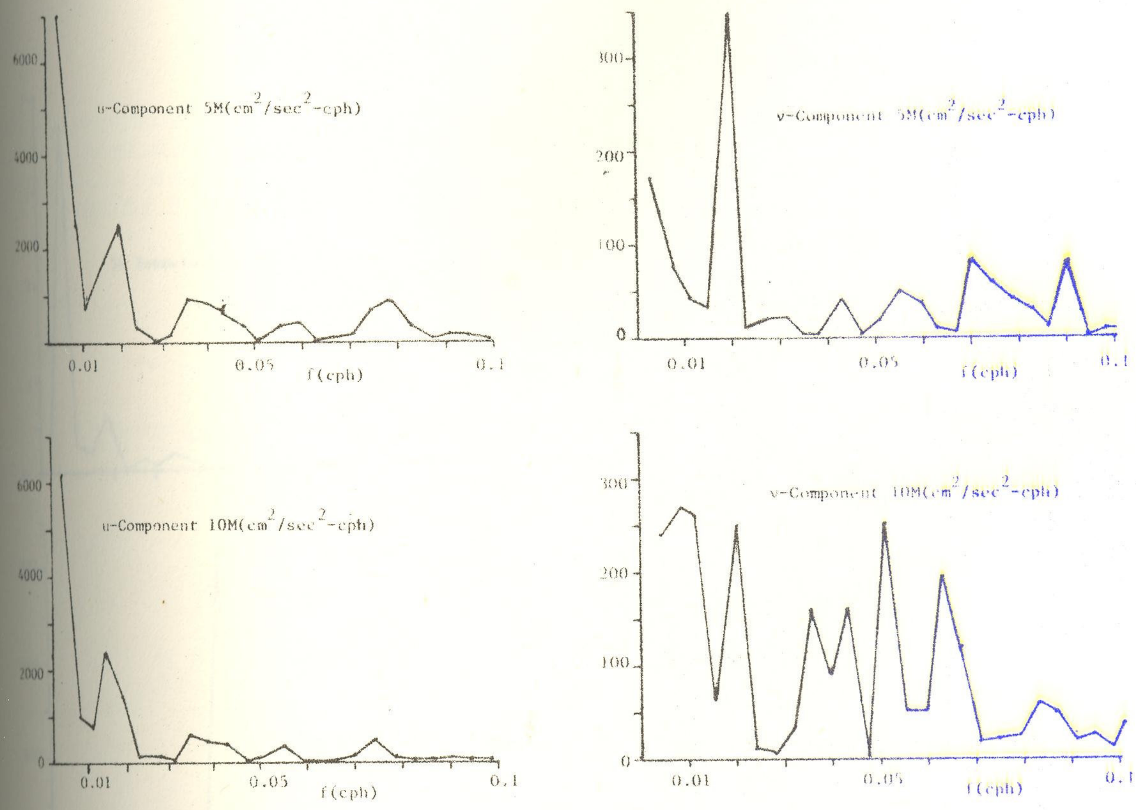

Figure 4. Current Spectra

Variable	Mean	Standard Deviation
u (sm) cm/sec	-8.3	12.9
v (sm) cm/sec	0.25	5.6
u (10 m) cm/sec	-4.6	10.75
v (10 m) cm/sec	0.17	5.5

The temperature time series (Fig. 3) shows fluctuations up to 1.5°C in magnitude. Upon comparing the time series for long shore velocities with that for the temperatures, low frequency (< 0.02 cph) oscillations in temperature, which are remarkably similar to those observed in the current component u. are found. These low frequency fluctuations are also quite apparent in the temperature autospectra shown in Fig. 5. We remark that the wintertime observations of salinity and temperature in the shallower depths of the region reveal a well-mixed water column, so that the low frequency temperature fluctuations are clearly related to those observed in the longshore component of the current. This is further strengthened by the high correlation found between the two variables for f <0.02 cph (Fig. 6).

The observed low frequency oscillations may be due to cyclonic disturbances of the global winds, travelling in an easterly direction and having a significant effect on the oceans with a periodic of between 3 to 10 days (NEILER, 1975). Indeed, in wintertime the region of the Mediterranean where the observations were made is subjected to cyclonic disturbances with a periodicy greater than or equal to 2 days. This is supported by analysis of synoptic maps of the region, and by data given in TREWARTHA (1961), which shows that the western basin of the Mediterranean has relatively the highest frequency of occurrence of cyclones. These disturbances typically follow an easterly path along the longitudinal axis of the Mediterranean passing through the region of observation.

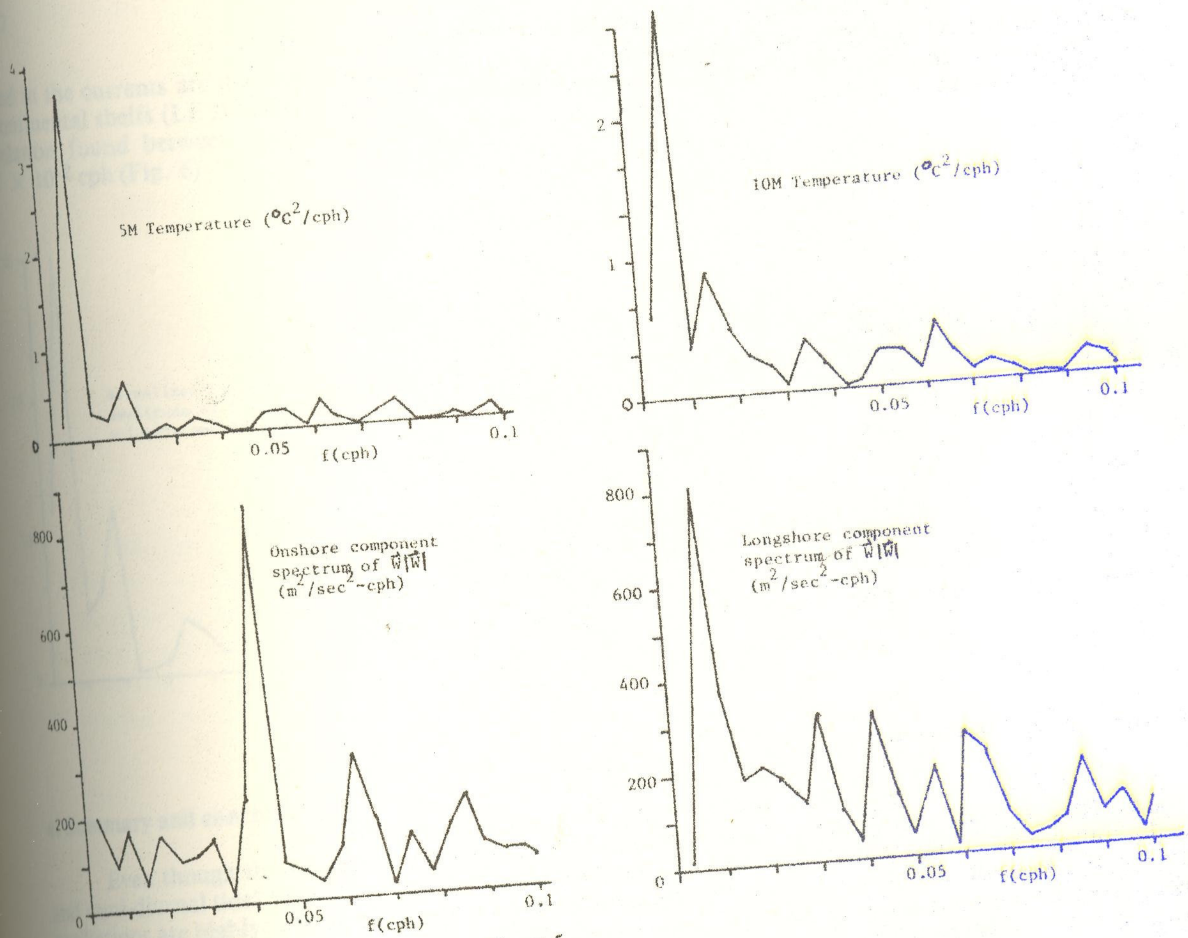

Figure 5.

In order to check out the possibility of the low frequency oscillations in currents associated with the wintertime cyclones in the area, the atmospheric pressure time series were examined. (We remark that the winds were calm for about 6 days prior to the deployment of the current meters and that about this time a succession of disturbances started). Disturbances with a periodicity of 3 days were evident. The examination of the atmospheric pressure records in Anamur (~ 150 km west of the site) reveals similar disturbances in atmospheric pressure during the winter season in which the measurements were made. These disturbances were also traced from the synoptic charts and were found to travel eastwards after approaching either from the west or north-west. It is worth noting that the low frequency oscillations over the continental shelf areas are attributed to wind rather than to the variations in atmospheric pressure, though the latter is a good indicator of the former (BUCHWALD and ADAMS, 1968 and also CLARKE, 1977).

Thus turning our attention to the winds stress spectra in Fig. 5 it is observed that the onshore windstress show a maxima of about $f = 4.25 \times 10^{-2}$ cph, (± 1 day) and drops sharply on the two sides of this peak. This may be attributed to the strong sea-breeze circulation observed in the area. On the other hand the spectra of the longshore wind-stress component increase rapidly toward the low frequencies for $f < 2 \times 2 \times 10^{-2}$ cph, attaining a maximum at $f = 7 \times 10^{-3}$ cph.

The significant longshore wind-stress for periods greater than 2 days found in the presence of passing cyclonic disturbances indicates that an intimate relation between the two exists. More significantly the low frequency oscillations observed in the currents are directly the low frequency oscillations observed in the currents are directly attributable to the cyclonic disturbances. This is also the case over other continental shelfs (LE BOND & MYSAK, 1977). This possibility is further strengthened by the high correlation found between the longshore wind-stress and longshore velocity for frequencies less than 2×10^{-2} cph (Fig. 6)

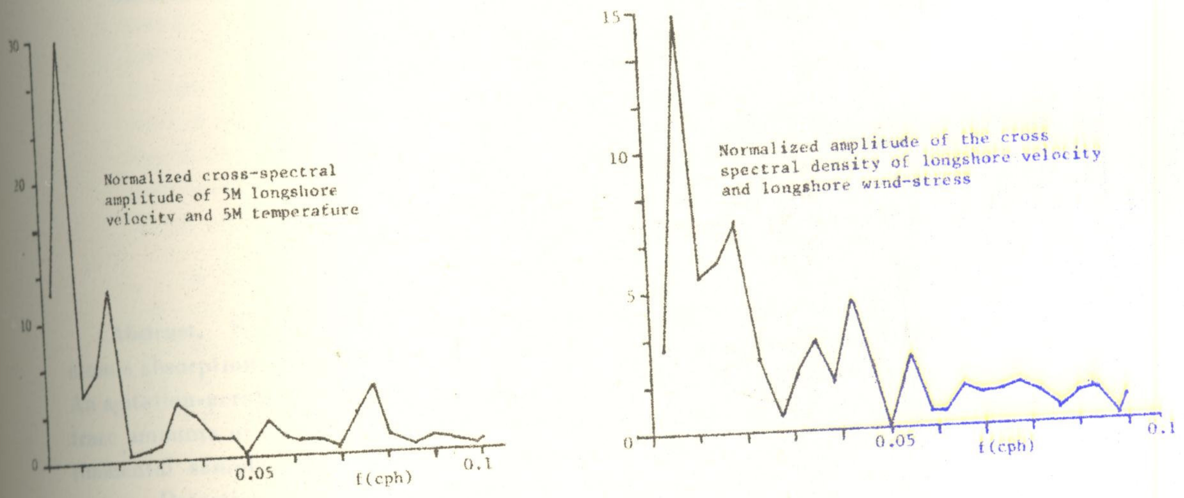

Fig. 6

4. Summary and conclusions

Even though the longshore velocity components contain energy near diurnal (sea-breeze forcing) and semi-diurnal tidal frequency, the significant oscillations occur for periods greater than 2 days. These oscillations are highly correlated with the wind-stress input of the wintertime cyclonic disturbances, indicating a strong evidence for the dominance (during the winter season) of the possibly baratrophic continental shelf wave-like motions in the area. This is also found to be the case in study being conducted 100 km west of the locations where current measurements have been continuing for a year.

Attention is now being paid to the deeper region by establishing progressively off-shore current meter mooring stations. These experiments will be described at a date later. Additional experiments are being designed for the simultaneous monitoring of currents at selected stations along the coast for the detection of low frequency wave motions.

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