ON THE VARIABILITY OF CURRENTS IN THE NORTHEASTERN LEVANTINE SEA

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Abstract

Current data obtained during a five month period on the Turkish continental shelf adjoining the Cilician Basin are analyzed to study the variability in the northeastern part of the Levantine Sea. Low frequency currents with periods of 16 days or more are found to be due to topographic Rossby waves in the canal-like Cilician Basin region. Motions with periods of up to 10 days are attributed to internal Kelvin waves. Superimposed on these low frequency motions, a net current flows in a westerly direction. In the high frequency range, surface currents are generated by the highly energetic sea-breeze system during summer months. Inertial motions are detected during winter, when cyclonic disturbances are increased.

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Introduction

Although current systems are known to play important roles in climate, biological activity, and sediment transport, very little information is available on the current systems and the circulation regime of the eastern Mediterranean, and especially of the northeastern Levantine Sea.

A net cyclonic circulation in the eastern Mediterranean has been well known (LACOMBE and TCHERNIA, 1972). In accordance with this general circulation, a westerly mean current can be expected in the southeastern coastal waters of Turkey. On the other hand, intermittent shipboard measurements show that the current regime in the Cilician Basin, located between Turkey and Cyprus, is highly variable and complex (Mediterranean Pilot, 1976, The Mediterranean, 1975). Even these limited observations indicate the need to determine the time scales and temporal variability of coastal and offshore currents. Therefore an observational experiment with long duration has been carried out to examine these aspects.

The measurements have been done offshore of Erdemli-İçel and have covered a period of five months. The experiment site is selected due to the narrow and steep continental shelf geometry, which facilitates the detection on the continental shelf of the time scales of the motions at large. The experiment is also designed to guide the meso-scale oceanographic studies on the Turkish continental shelf.

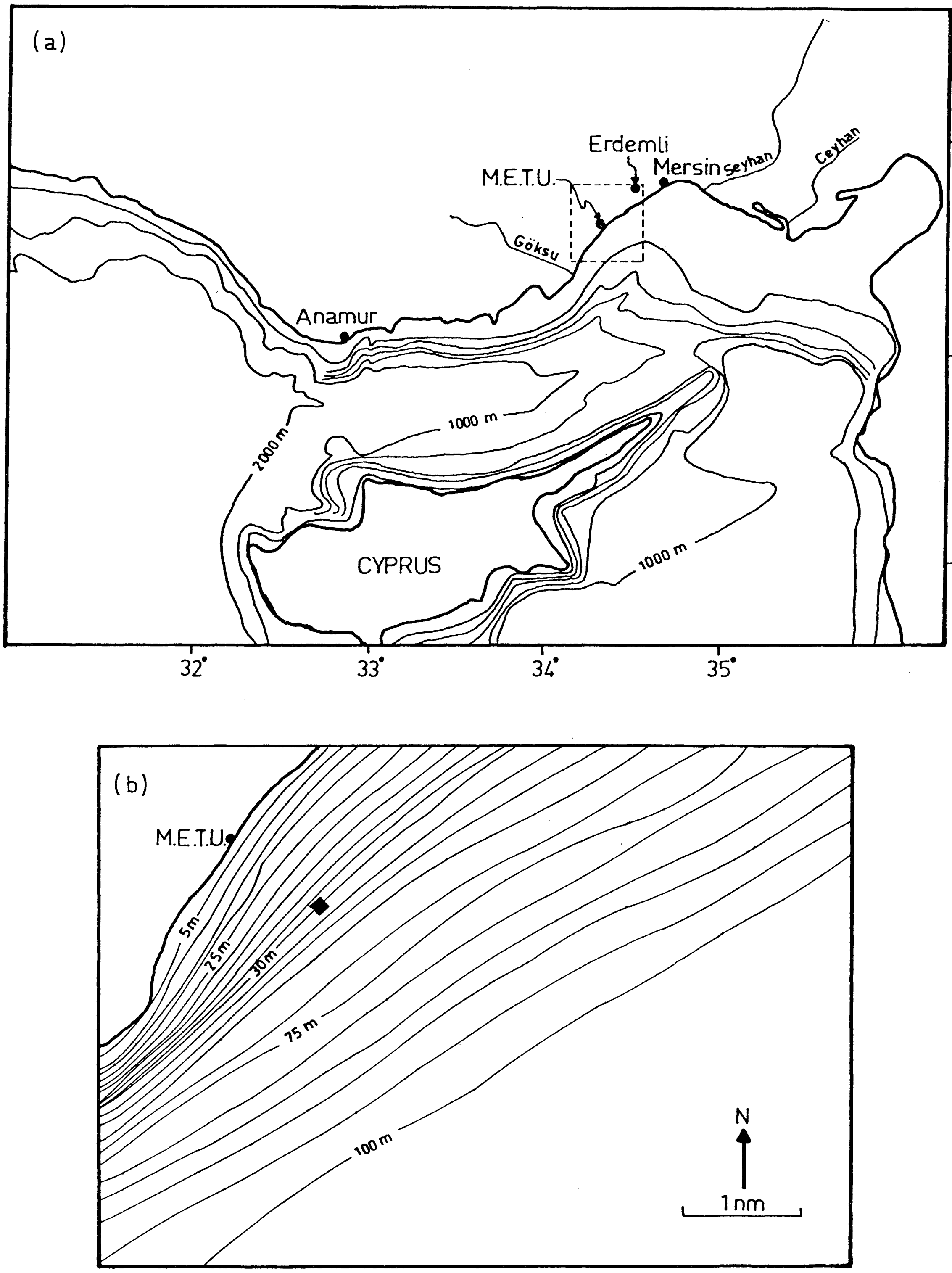

Fig. 1: Site Location. (a) General Region. (b) Area Within Dotted Lines

Data Collection and Analysis

a. Measurements. The current measurements are obtained offshore of Erdemli during the period 28 August 1978 - 30 January 1979 on a continuous basis. The experiment location and the general bathymetry of the region is shown in Fig.1

- An Aanderaa RCM-4 sav-onious rotor current meter has been deployed at a depth of 20 m., and at a location 2 km offshore, where the total depth is 30 m. The sampling interval is set to 10 minutes and the current meter tape is replaced at approximately 30 day intervals.

During the same period, hourly wind and tide measurements have been made at the coast near Erdemli. Water temperature measurements were also obtained by the current meter. But, with the exception of winds, these data will not be analyzed in the present paper.

b. Data Analyses. Due to vorticity conservation, continental shelf currents are steered by topography. Therefore, the horizontal current information sampled at 10 min intervals are first decomposed into components parallel (: u) and perpendicular (: v) to the coastline. Then the 10 min. vector time series is converted to hourly time series by forming hourly averages. The hourly time series is then high and low-pass filtered. Low frequency (period $>$ 1 day) currents are filtered by applying a 30 h. moving average on the data. The high frequency (period $<$ 1 day) currents are filtered by subtracting 24 hr. moving averages from the original time series.

The hourly wind vector time series $\vec{W}$ is used to calculate the time series for the vector $\vec{\tau} = \vec{W}\,|\vec{W}|$ which is proportional to the surface wind stress.The actual wind stress can be calculated as $3.2 \times 10^{-2}\,\vec{\tau}$ dyne/cm^2 when the wind speed units are in m/sec. The constant coefficient has been omitted in the present calculations, and the vector is defined as wind stress.

The time series of the wind stress have also been filtered .After the filtering operation, the energy and rotary spectra (CALMAN, 1978) of the time series have been calculated using the F.F.T and M.E.M. (Maximum entropy) techniques (DENHAM, 1975).

In the spectral computations of high frequency oscillations, the time series have been divided into 128 hr. ($\sim$5.33 day) segments and the spectra for each segment have been calculated separately. The monthly average (smoothed) spectra for each month is calculated as an average of the spectra for the segments. For each segment of time series, the Nyquist frequency is 0.5 cph and the resolution is 0.008 cph.

In the spectrum calculations of low-frequency currents, no segments are formed and the total data length is taken as 159 days. The digitization interval of the low-passed time series is 0.25 day (6 hrs), the Nyquist frequency of the spectra is 4 cpd, and the resolution is 0.006 cpd.

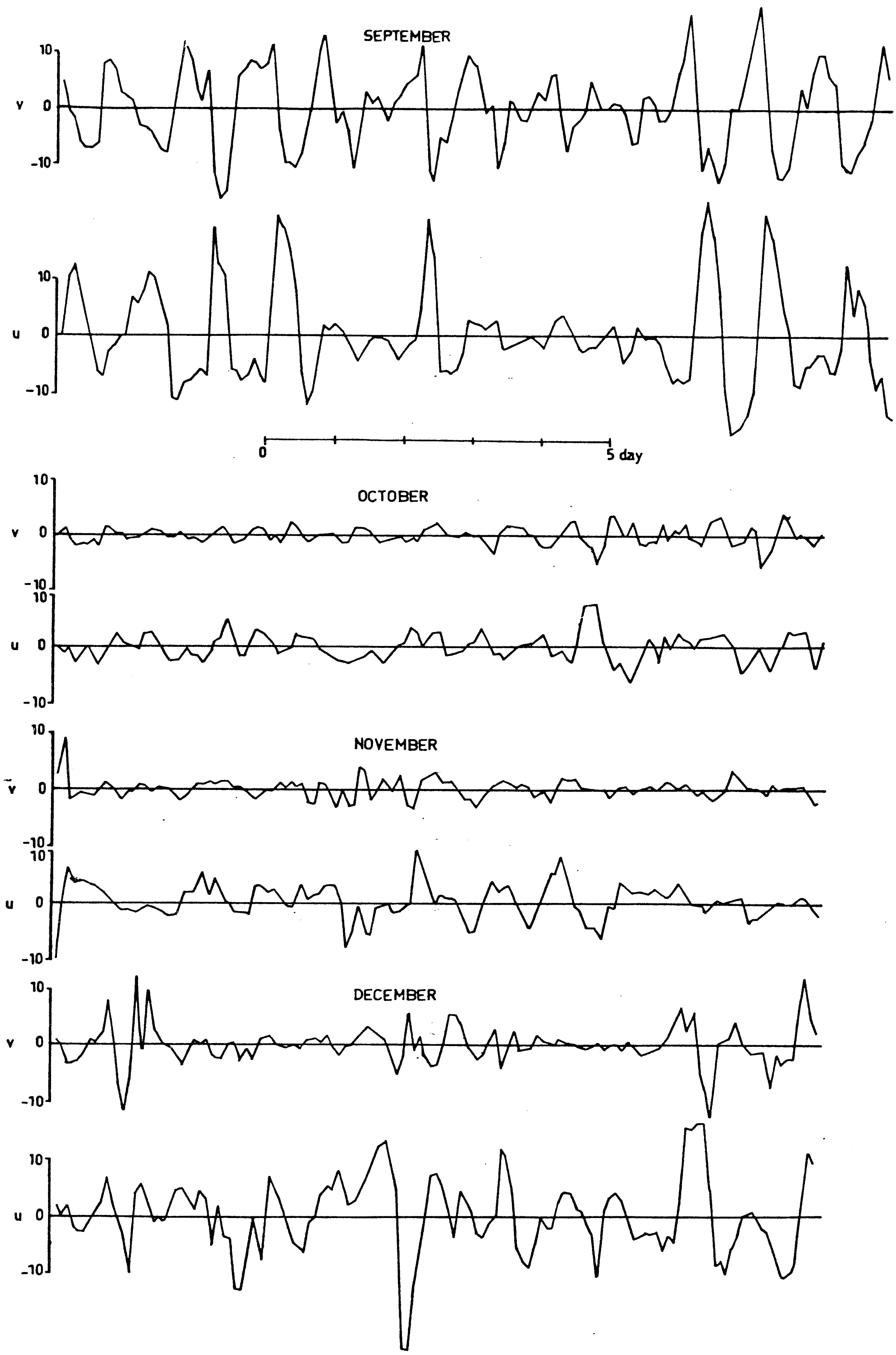

Fig. 2 : Monthly Samples of High-Passed Currents.

Results

a. High-Passed Oscillations: 10 day samples of high-passed time series of currents are shown in Fig.2 for different months within the measurement period. The positive values of the u component are in the NW direction (parallel to the coast). whereas the positive values of the v component are in the NE direction (perpendicular to the coast). The monthly variations of mean spectra for high-passed currents are shown in Fig.3.

The high-passed currents during August-September (Fig.2) show strong oscillations with 24 hr. period (0.04 cph), and amplitudes on the order of 20cm/sec. The energy spectra for the same period (Fig.3) show significant peaks around a frequency of 0.04 cph.

On the other hand, the wind stress spectra for August-September also shows a primary peak at diurnal frequency, indicating the effects of sea-breeze forcing which starts to be effective in the area from summer months till late September with a typical magnitude of 15 m/sec from the SW direction. The effectiveness of these winds in generating diurnal surface currents is observed clearly in the spectra. The currents corresponding to the 12 hr. and 8 hr. secondary peaks in the wind stress spectra are relatively weaker. The 24 hr. oscillations are much stronger due to the closeness of the diurnal periods to the local inertial period of 20.4 hr. ($\sim$0.05 cph.), and the possible near-resonant excitation of these currents under continuous wind stress forcing. On the other hand, the frequency band of the peak around 0.04 cph in the energy spectra of currents also covers the band of inertial oscillations. Two seperate peaks located respectively at $\sim$0.04 cph and $\sim$0.05 cph can not be observed due to insufficient spectral resolution.

The rotary spectra of currents in the period August-September (not shown here) indicate that the ellipse drawn by the 24 hr. component of the current velocity vector has a major axis in the E-W direction, rotates in the clockwise direction and has an aspect ratio (ratio of minor to major axis) of about 0.8 . The wind stress vector ellipse at 24 hr. is aligned in the 200° SW-20° NE direction, which is roughly perpendicular to the current ellipse. It can be shown that these observed characteristics are in agreement with time dependent Ekman boundary layer flows.

Beginning with late September, the intensity of the high frequency currents are reduced considerably; then towards December, energetic levels are reached once more as observed in Fig.3. In addition, the spectral peak formerly observed at 0.04 cph. shifts towards the inertial frequency (0.05 cph). In order to explain this evolution, the variation in the energy densities of 24 hr. and 20.4 hr. oscillations of current and wind stress is shown in Fig.4.

In this figure, it is seen that the 24 hr. period wind stress input also enters an evolution after October and therefore the constancy of the monthly mean spectra for wind stress in Fig.3 is actually deceptive. The evolution of the 24 hr. wind stress oscillations can be explained as follows:

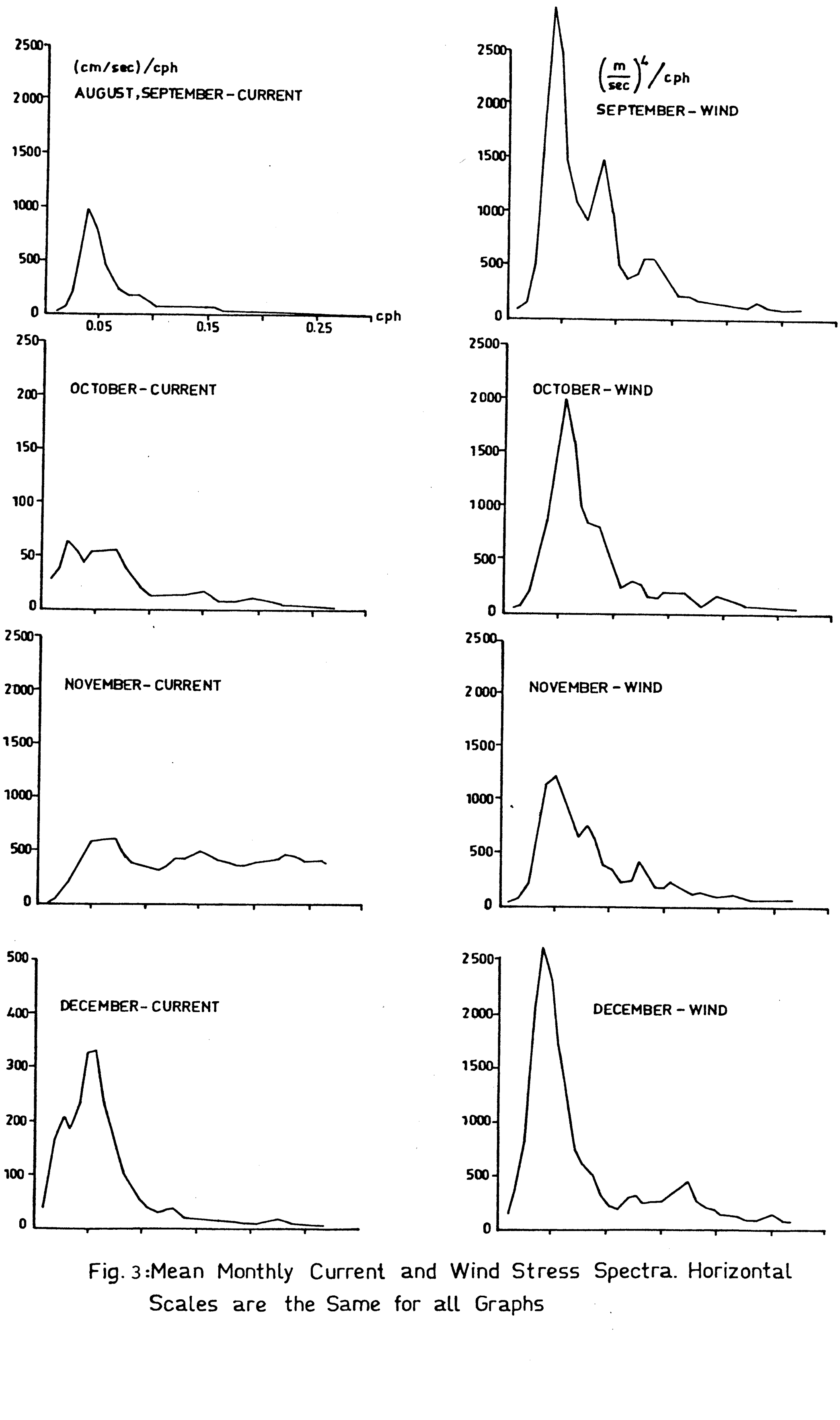

Fig. 3: Mean Monthly Current and Wind Stress Spectra. Horizontal Scales are the Same for all Graphs

As a result of the reduction in the land-sea temperature difference after October, the intensity of the sea-breeze effective in summer is reduced and the region starts to be influenced by winter cyclones. These atmospheric perturbations which pass at five to twenty day intervals typically leave the area, or are locally dissipated, within a single day (PALMEN and NEWTON, 1969, ATAKTÜRK, 1980, KAREIN, 1979). Therefore, the atmospheric inputs due to cyclones also imply 24 hr. period oscillations. The passage of cyclones during the months of October, November and December or during periods of increased wind stress energy (Fig. 4) has been confirmed from synoptic weather maps.

The wind input is less effective in the winter-time evolution of high frequency currents as compared to summer (Fig.4). The reason for this is the persistence of the wind input during summer. The 24 hour inputs are not persistent during the cold months, and therefore the high frequency components of wind stress can only produce inertial oscillations. In addition, the rotary spectra of 24 hour oscillations in the wind stress display an anticlockwise rotation. Therefore, the wind stress can not contribute to the resonance of water particles which have to selectively rotate in the clockwise direction, in spite of the closeness of the forcing frequency to the local inertial frequency.

Semidiurnal tidal oscillations in the high frequency currents remain at insignificant levels, although a tidal amplitude of around 25 cm has been observed during the measurement period. This suggests that the region may be close to an antinode.

b. Low-Passed Oscillations: The time series of low-passed currents in directions parallel and perpendicular to the coast are shown in Fig.5. The currents parallel to the coast are much larger in magnitude as compared to the components perpendicular to the coast. The low frequency currents are in general parallel to the isobaths due to topographic steering. On the other hand, the low frequency currents are seen to be much more energetic, as compared to the high frequency currents.

The energy spectrum for the low-passed currents is shown in Fig.6 . The Maximum Entropy Method has been used in the spectral calculations in order to obtain a sufficient resolution of the spectral peaks (DENHAM 1975). The largest peak in the spectrum of currents during the periods 28 August 1978-31 January 1979 is observed at 0.0645 cph (~16 days). The second largest peak occurs near a period of 128 days. However, the presence of this peak is slightly suspect due to the closeness of its period to the total length of the time series. The third major peak shows that the 15.5, 39.4 and 128 day oscillations reflect the resonance of wind stress forced topographic Rossby waves in the Cilician Basin, located between Cyprus and Turkey (ÜNLÜATA, 1980).

Small but well defined energy peaks with periods smaller than 15.5 days are also shown in the spectrum. These peaks have been explained by wind forced internal Kelvin waves in the Cilician Basin (ÜNLÜATA and ÖZSOY, 1980).

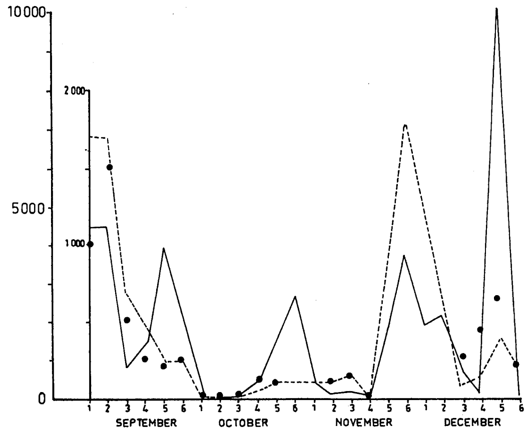

Fig. 4: Evolution of 24 hr. and 20.4 hr. Peaks in the Energy Spectra. —— : Wind Stress, ----: 24 hr. Current, • • •: Inertial Response.

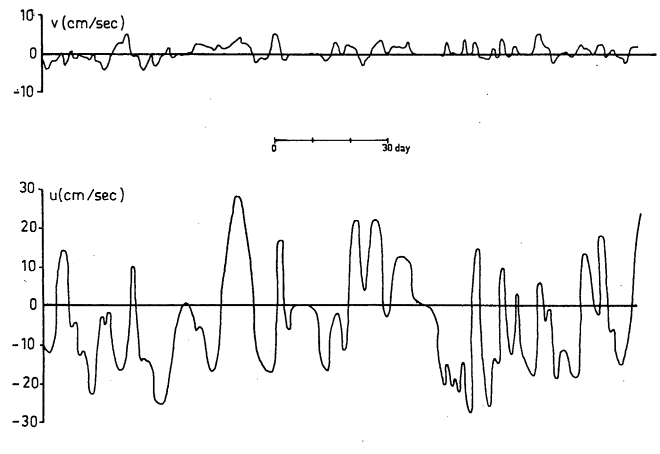

Fig. 5: Low-Passed Currents. u: Parallel to the Coast, v: Perpendicular to the Coast.

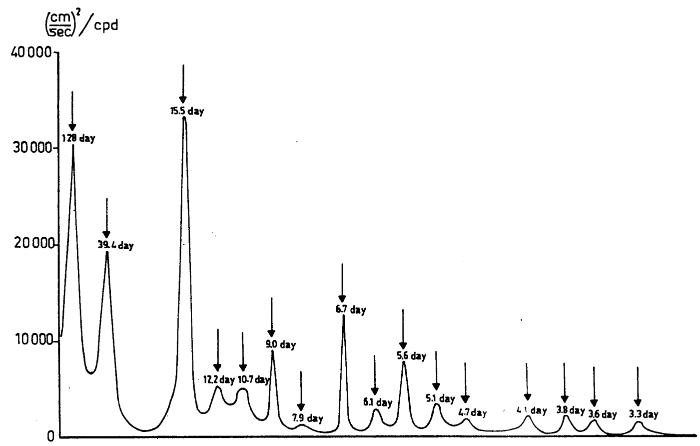

Fig. 6: Kinetic Energy Spectrum of Low-Passed Currents.

Discussions and Summary

Analyses of 5 month long data has shown the temporal variability of currents in the southeastern Turkish coastal waters.

In order to stress these results in a different way, Table 1 has been compiled. The monthly means and standard deviations of currents excluding the month of January has been shown in this table, with $\bar{u}$, $\bar{v}$ denoting mean velocities, and σ_u, σ_v showing the standard deviations respectively in units of cm/sec. The axes of reference are chosen such that the current is towards the coastline for $\bar{v}>0$, and in an easterly direction for $\bar{u}>0$.

Table 1. Means and Standard Deviations of Currents

	September	October	November	December
$\bar{u}$	-9.44	1.81	4.38	-12.60
$\bar{v}$	-1.23	1.64	1.89	0.60
σ_u	13.42	28.70	24.57	15.39
σ_v	7.11	2.93	4.29	4.09

Since the monthly mean currents in this table also include the oscillations with periods above 30 days, the rather large values of the standard deviation indicate the high variability of currents during these months. It is also worth noting that during the 5 month measurement period, the mean currents perpendicular to the coastline are insignificant, whereas the currents parallel to the coastline have an overall mean of 4 cm/sec in a westerly direction. This westerly flow along the Turkish coast is in agreement with the proposed cyclonic circulation of the eastern Mediterranean. Of course, the calculation of this mean current must be based on the assumption that an oscillation with period longer than 5 months does not exist in the area.

The primary time scales observed in the variable current regime include 20.4 hour, 24 hour (in summer months), 6 day, 9 day, 16 day, 40 day and 128 day (?) periods. The magnitudes of the observed currents can reach up to 40 cm/sec and above. These results are in agreement with measurements obtained at another location 80 miles to the west of the observational experiment. The high variability of the observed currents and the relative weakness of their mean values suggest that the periodic motions have much higher significance in studies of coastal transport and that due to the large residence times of the transported materials, the region may indeed act as a sediment trap. In any event, it is worth stressing that studies over periods of several years are needed to determine the meso-scale current regime, and therefore an inventory of data is urgently needed.

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