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Effect of weather system on the regime of sea level variations in IzmirBay

İzmirKörfezindeki meteorolojik sistemin su seviyesi değişim rejimine olan etkiler

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Abstract:

On the basis of the daily and monthly mean data for the year 1990 at Menteş in IzmirBay, the effects of both barometric pressure and wind on the fluctuations of sea level have been studied. Barometric pressure is one of the main parameters affecting sea level variations in IzmirBay. The sea level has a significant inverse coherence with the barometric pressure for the frequency band lower than two-day periodicity. The wind is also a significant factor affecting sea level. At Menteş, increases in sea level are caused by westerly winds, while decreases in sea level are mainly caused by southerly and southeasterly winds, especially for higher wind speeds.

Keywords: IzmirBay; Aegean Sea; sea level; air-sea interaction; atmospheric forcing

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Introduction

Sea level characteristics of the Aegean Sea have been partially studied in the past. The very short period oscillations with periodicity between 3.5-4.2 hours were attributed to seiche-like motions in IzmirBay (Figure 1). Tidal amplitudes are small and the most important tidal constituent is semi-diurnal lunar (M_2). The semi-diurnal solar (S_2) tidal input from the sun is typical of the Mediterranean. The range is about 4 cm during neap tides and about 17 cm during springs. Consequently tides are mixed but mainly semi-diurnal in nature (Table 1). A seasonal cycle of monthly mean sea level shows a major minimum in March and a major maximum in July, with an average range of 8 cm [Defant (1961); Yüce (1991); Alpar and Yüce (1996)].

Apart from the short period of oscillations and astronomical tides, the mean sea level varies due to other factors related to the climate, river discharge and oceanic circulation. Rainfall, piling of sea water against the coast and rises in sea water temperature increase the level; whereas evaporation, upwelling of the subsurface denser water and water cooling decrease the level. Such seasonal variations related to meteorological influences, e.g. pressure and wind, are termed meteorological tides. These non-astronomical agents cause greater range of amplitudes.

The low pressure systems in the Aegean Sea are generally west to east in direction (Özsoy, 1981). The cyclones move eastward over the Aegean towards the eastern Levantine basin. The life of cyclones in the area is about 3 to 5 days, although they may last much longer. Occasionally they may slow down or stagnate completely for a period of several days. On the other hand, a well-developed storm may move for short distances at velocities as great as 69 knots (31 ms^{-1}) under usual conditions. On an annual basis, from a 33 year statistical average, IzmirBay is generally exposed to westerly winds (7.9 knots average) from May to October, while the southeasterly winds (11.6 knots average) prevail for the rest of the year. The annual average wind speed is about 9.2 knots.

The distribution of barometric pressure over the Mediterranean and Aegean Seas plays an important role in sea level variation. For the eastern Aegean Sea, the spectral analyses indicate significant sea level variability between 5.6-12 day periods while the barometric pressure spectra display major peaks spotted at 5.6, 7.1 and 14.7-day periods. The correspondence of the energy peaks in the spectra is a consequence of the barometric pressure on the sea surface. The wind stress also indicates some variability lying within the frequency band of 4-12 days (Alpar and Yüce, 1996).

In this study, the effect of both barometric pressure and wind on the variability of sea level in IzmirBay will be examined by performing a quantitative analysis using time series as long as one year.

Material and method

The hourly values (365 days) of sea level, barometric pressure and wind data collected in IzmirBay for the year 1990 were used to perform the analyses. The sea level data have been collected by using an OTT float-type tide gauge in a permanent stilling well at Menteş (Figure 1), hourly sampled and issued by the General Command of Mapping. Comparative hourly meteorological data (barometric pressure, wind speed and direction) were obtained from IzmirMeteorological Station.

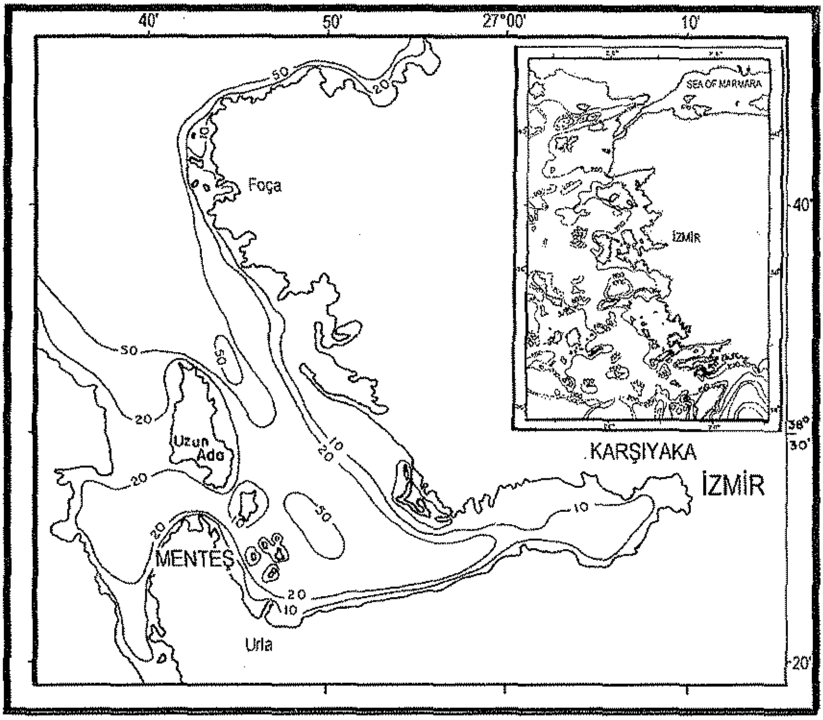

Figure 1. Location and bathymetric map of İzmir Bay

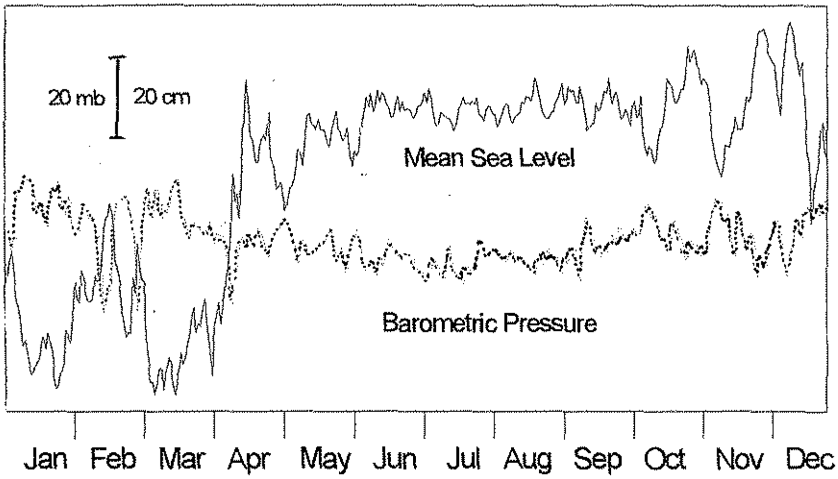

Figure 2. The daily mean sea level and the daily barometric pressure in İzmir Bay for the year 1990.

Table 1. Harmonic constants in IzmirBay. The amplitudes and phases were calculated by applying nodal corrections to the outputs from the linear least squares tidal analysis. Amplitudes are in cm and the phases are relative to the local reference time origin (030°E) at 00:00, 1 January 1976 (after Alpar and Yüce, 1996).

Station	M_2	S_2	K_1	O_1	Mean Spring Range	Mean Neap Range	Form Factor
Karşıyaka	5.1	3.7	2.5	1.3	17.4	2.8	0.441
	113	130	365	329			
Menteş	5.2	3.3	2.4	1.3	17.0	3.8	0.431
	118	142	359	334			

All barometric pressure data are expressed in millibars and corrected for the sea level and 0 °C temperature. Wind stress components were computed from usual quadratic stress formulation using a constant drag coefficient of $2.5*10^{-3}$. This computation provides a relative measure for wind stress which quantifies the effect of the wind forcing.

The daily averages were calculated from hourly sea-level data by using the 119-point tide-killing filter (Caldwell, 1991) to eliminate diurnal and semi-diurnal oscillations. Monthly averages were calculated by taking the simple arithmetical mean of daily averages. Histograms of the frequency distribution of wind direction and their associated surges were calculated by elementary statistical procedures.

Result and Discussion

In IzmirBay, sea level fluctuations are dominated by long-period energy inputs (70-80%), while the secondary contribution comes from the tidal band (11-24%) dominated by semi-diurnal (6-16%) energy input. Since the sea level has a coherence with atmospheric forcing for periods longer than two days (Alpar and Yüce, 1996), tidal inputs can be eliminated from sea level records. In order to eliminate tidal energy from the records and to obtain the subtidal inputs, hourly sampled data were subjected to the 119-point tide-killing filter and re-sampled on a daily basis.

The Effect of Barometric Pressure on Sea Level

In order to investigate the barometric response on sea level in IzmirBay for the daily scale, the temporal changes of the daily mean barometric pressure and daily mean sea level for the year 1990 have been plotted together (Figure 2). The long-term oscillations in sea level records are due to long-term tidal constituents and meteorological influences. These long-term oscillations with a periodicity of several days are meteorologically induced, and their frequency is related to large-scale cyclic atmospheric patterns in the region. The inverted relation between barometric pressure and sea level is evident and lasts through the year. This means that the direct effect of pressure on sea level is confirmed. The subtidal sea level has a significant coherence (about 0.8) with barometric pressure for the low frequency band with more than two-day periodicity. The oscillations are almost persistent with periods from 4 to about 12 days, modulating sea-level variations of longer periods. They are generally associated with the natural periods of occurrence of cyclones in the mid-latitudes.

The scatter diagram between the daily barometric pressure and sea level for the year 1990 can be seen in Figure 3. The best linear fit, which is superimposed on the diagram, again makes clear the inverted relationship between pressure and mean sea level (with a correlation coefficient of 0.369) in IzmirBay. In order to investigate the barometric effect on sea level in IzmirBay for the monthly scale, monthly variations in mean sea level (in cm), mean barometric pressure (in mb) and the corrected sea level (in cm) in IzmirBay for the year 1990 have been plotted (Figure 4). It is seen that the mean monthly barometric pressure is highest during January and lowest during July, with a range of approximately 16 mb. The inverted relation between barometric pressure and sea level is quite remarkable. The corrected sea level curve is slightly modified from that of sea level and there is a decrease in the displacements from the annual mean. This means that the barometric pressure is one of the factors affecting sea level fluctuations in IzmirBay and the sea level response to barometric pressure is nonisostatic.

The Effect of Wind on Sea Level

To show the effect of wind on sea level in IzmirBay, the daily average of N-S and E-W wind stress components were plotted with the mean sea level (Figure 5 a, b). The positive values of wind components in the graph indicate westerly and southerly winds for each series while the negative values represent easterly and northerly winds. This confirms that the mean sea level is affected by wind stress.

Short-term sea-level variations in IzmirBay mainly depend on the E-W wind component, which shows changes due to diurnal sea breezes. However, the sea-level response to the E-W wind component is insignificant in the low frequency band (more than 5 days). The westerly winds mainly cause an increase in sea level (positive surge), while the southeasterly and southerly winds cause a decrease (negative surge). On the other hand, the sea level displays coherency with the N-S wind component over periods longer than 8 days. These findings indicate that the sea level response to wind forcing is non-linear in IzmirBay. This relation is clearly evident in the summer months when the prevailing wind is a steady westerly. This fact can also be seen on the graph of the monthly means (Figure 6) where the positive values for wind components indicate westerly and southerly winds.

Figure 7 (a, b, c) shows the frequency distribution of wind and the associated positive and negative surges. The wind direction symbols under each graph

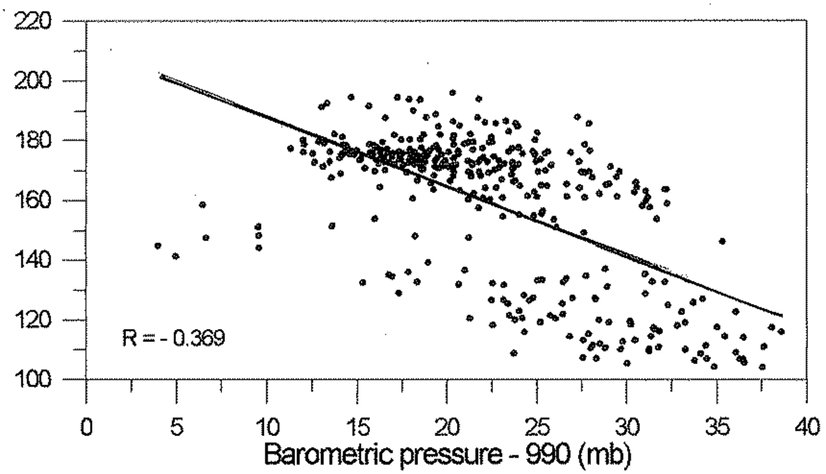

Figure3. Scatter diagram between daily barometric pressure and mean sea level in İzmir Bay for the year 1990. "R" stands for the correlation coefficient.

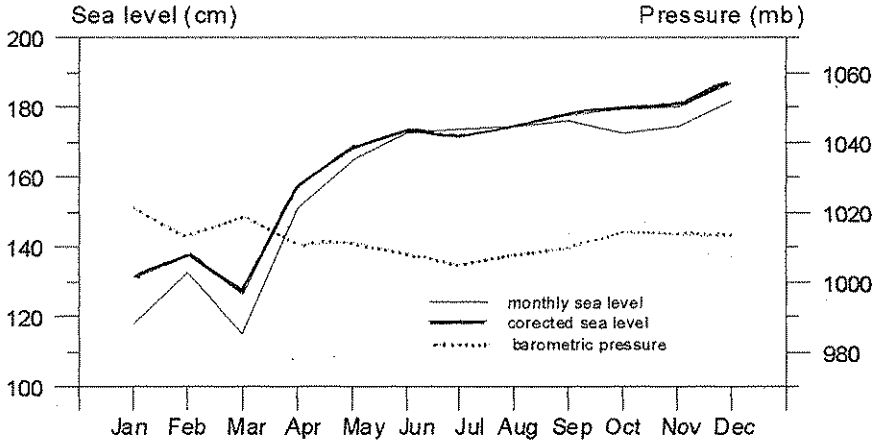

Figure 4.Monthly mean sea level, barometric pressure and corrected sea level in İzmir Bay for the year 1990.

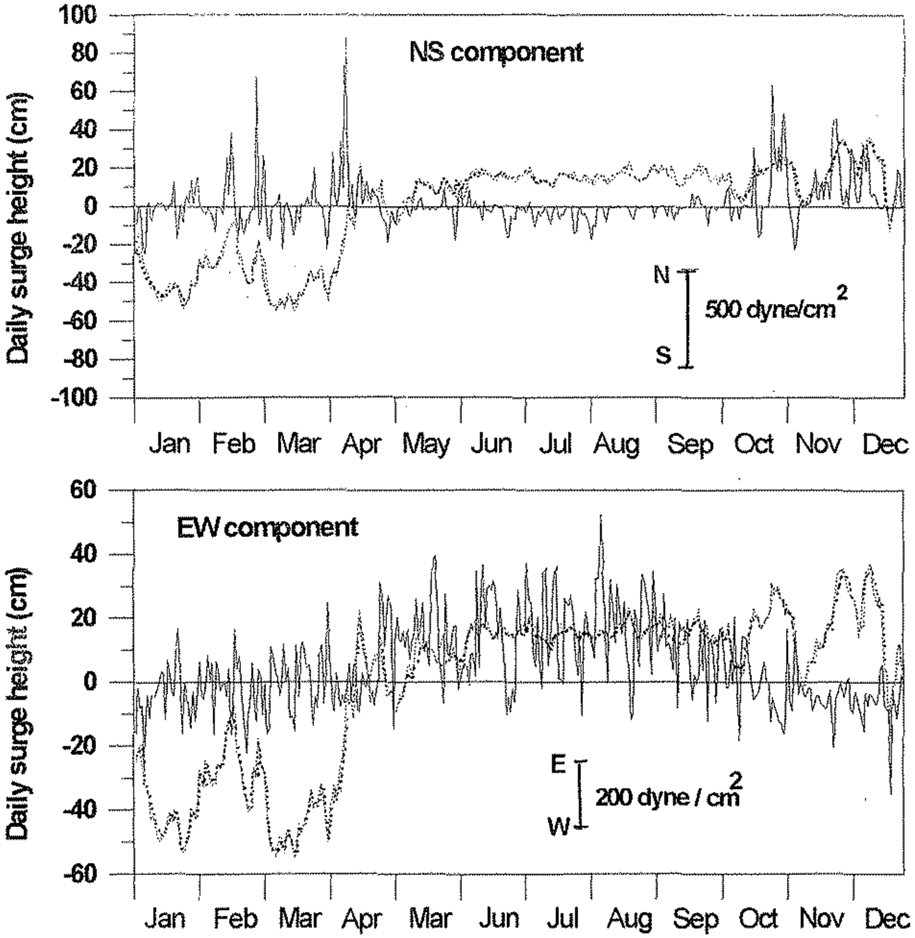

Figure 5. The daily average of NS and EW components of wind stress and mean sea level in İzmir Bay for the year 1990.

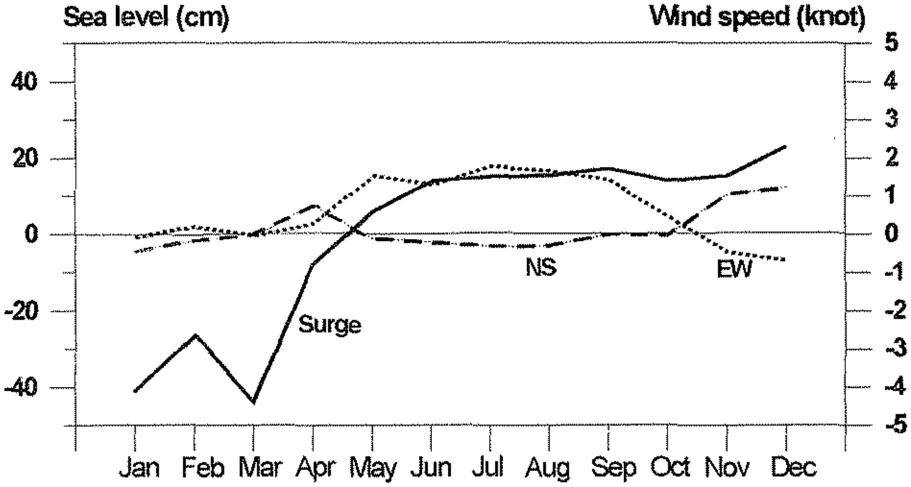

Figure 6. Monthly average of wind speed for NS and EW (dashed) components and the corresponding surge height (thick) in İzmir Bay for the year 1990.

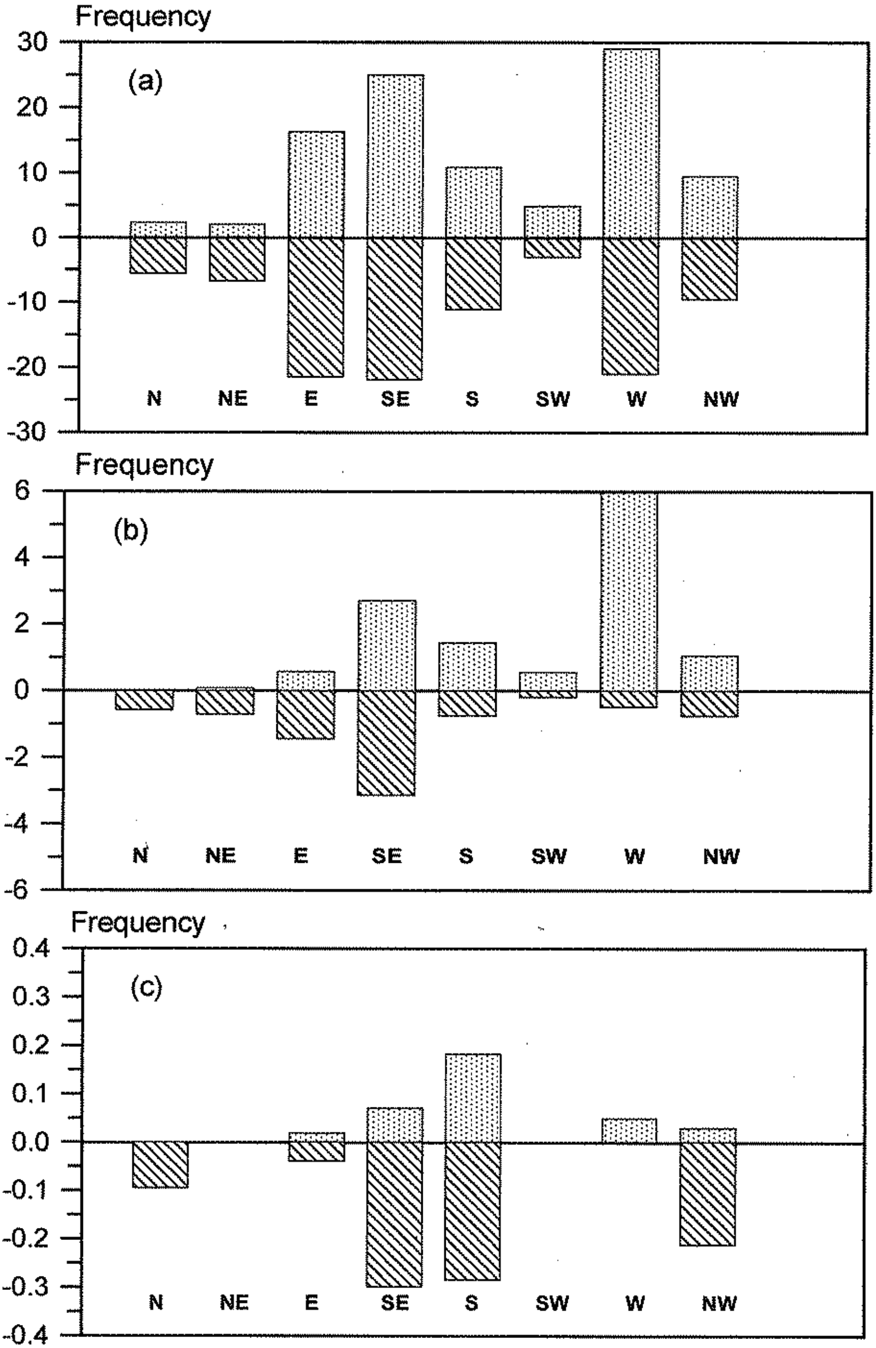

Figure7. The frequency distribution of wind direction and the associated positive and negative surges during year 1990 at İzmir (a) for all readings, (b) for wind speed more than 10 knots and (c) for wind speed more than 15 knots.

represent the wind direction; i.e. "N" for northerly winds. The upward columns indicate the percentage of wind which causes positive surge and the downward columns indicate the percentage of wind which causes negative surge for each direction. Figure 7(a) represents all the data readings of wind speed during the year 1990. However, the figures 7(b) and 7(c) represent the percentage of wind speed over 10 and 15 knots respectively. Considering all of the data readings, it is clear that the prevailing winds blow from the SE-E and from W directions during the year and cause almost equally distributed positive and negative surges (Figure 7a). However, the westerly winds mostly cause positive surges if their speed is more than 10 knots (Figure 7b). The winds coming from the S-SE sector become dominant on sea level and cause negative surges if their speed is higher than 15 knots (Figure 7c).

Conclusion

Based on sea level and meteorological data collected in IzmirBay for the year 1990, the contribution of the meteorological elements on the variability of sea level has been studied. The results reveal that sea level variations in IzmirBay are composed of the superposition of low amplitude short, tidal and subtidal fluctuations.

Barometric pressure is a principal factor affecting sea level in IzmirBay and the sea level response to barometric pressure is nonisostatic. Long-term sea level oscillations are related inversely to barometric pressure, which in turn, is generally associated with large-scale meteorological patterns. Compared to wind, barometric pressure contributions to the regime of sea level variations are relatively small in the frequency band of less than 12 days, whereas variations longer than 12 days in sea level are mainly caused by barometric pressure.

Sea level is also affected by wind in IzmirBay. The low frequency sea level variability of less than 12 days is mainly due to wind forcing. Variations in sea level show a significant coherence with the north winds at very low frequency band, while there is no significant sea-level response to east winds in the low frequency band. Higher frequency sea-level fluctuations are mainly caused by the E-W wind stress variations due to sea breezes. If the wind speed is sufficiently high then the westerly winds cause an increase in sea level (positive surge) while southerly and southeasterly winds cause a decrease in sea level (negative surge).

Özet

İzmir Körfezi'nde Harita Genel Komutanlığı tarafından Menteş'de 1990 yılında kaydedilen saatlik su seviyesi verileri ile Meteoroloji Genel Müdürlüğü'nden temin edilen saatlik meteorolojik veriler kullanılarak, hava basıncı ve rüzgar parametrelerinin su seviyesi değişimleri üzerindeki günlük ve aylık ölçekteki etkileri araştırılmıştır. İzmir Körfezinde hava basıncı su seviyesini etkileyen parametrelerin başında gelmektedir. İki günden daha alçak frekans bandında su seviyesi ile hava basıncı arasında önemli bir ters ve izostatik olmayan bir korelasyon mevcuttur. Keza rüzgar su seviyesini etkileyen önemli bir faktördür. Menteş'teki su seviyesindeki yükselmeler batılı rüzgarların eseridir. Buna karşılık özellikle rüzgar hızının yüksek olduğu dönemlerde güneyli ve güneydoğulu rüzgarlar su seviyesinde azalmaya neden olmaktadırlar.

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