Temporal and Spatial Variation of Wind Velocity along Gulf of Suez

Nabil N. Saad

National Institute of Oceanography and Fisheries, Egypt
nabilelbatikhy@yahoo.com.

Abstract. The wind data obtained from two stations at Suez and El Tor have been analyzed as an attempt to understand the relation between the wind velocities along the Gulf of Suez. The kinetic energy has low values during the high frequency while it has high values at the low frequency oscillation due to the several depressions pass over the red sea during the cold period. The relation between the wind velocity at Suez and El Tor stations is expressed in terms of the coherence phase difference a function of frequency. The correlation coefficient of the two wind components between the two stations declared high correlate values.

Keywords: Wind, Kinetic Energy, Gulf of Suez.

Introduction

The Gulf of Suez is a large semi enclosed shallow area (about 10,000 km$^2$) bounded by Sinai Peninsula on the east and the eastern desert of Egypt on the west. It extends about 250 km southeast from Port Suez in the north (29°56’N) to Shadwan Island in the south (27°36’N). Its width varies between 20 and 40 km and its depth (throughout its axis) is fairly constant with the mean depth of 45m (El-Sabh and Beltagy, 1983). Geologically, the Gulf of Suez is continuation of down faulted rift valley, which apparently extends from the East African Rift to the southern tip of Sinai Peninsula. The Gulf is bordered by high land, reaching close to the coast at many points. Dead and living coral reefs border mostly the coast of the Gulf. (Rady, 1992). The NNW wind prevails mostly over the Red Sea all the year with Wind speeds are usually less than 10m/sec (Radwan, 2008).
The wind data obtained from the three stations at Suez and El Tor have been analyzed as an attempt to understand the relation between the wind velocities along the Gulf of Suez. The position of two meteorological stations is given in Fig. 1. The distances between Suez and El Tor stations are about 212 km. The recording instruments at the two stations are fixed at about 10 m above mean sea level.

![Fig. 1. Location of the two meteorological stations.](image)

**Data and Method of Analysis**

Three years of three hourly values of wind speed and direction at El Tor station were analyzed in the period from January 1989 to December 1991. At Suez station 3 hourly values of wind speed and direction in the period from January 1989 to December 1990 and 6 hourly intervals in the period from January 1991 to December 1991. From these data, the monthly mean of kinetic energy of wind was calculated using the following equation:

\[
KE = \frac{1}{2}(\sigma u^2 + \sigma v^2) \quad \text{(after Seung 1979)}.
\]

Where, \(\sigma u^2\) and \(\sigma v^2\) are the variance of long shore and normal to the shore components respectively.
The spectral analysis technique was applied on time series of both wind components. The number of points in each time series was 744 corresponding to a record length of 744 hours (three months). The highest frequency is 0.5 cycle/hours, corresponding to 6 hours period. To determine the variance at each frequency, the spectral density was multiplied by the frequency (El Gindy and Hamed, 1986).

To find out the relation between wind velocity at Suez and El Tor stations, the coherence at different frequencies for both components was calculated using the standard spectral method (Bendat and Piersol, 1980).

**Monthly and Annual Variation of Wind Kinetic Energy**

The monthly mean kinetic energy of the different years at Suez and El Tor are shown in Fig. 2. In general, Suez station has lower kinetic energy values if it is compared with the other station, with very little variations during the year and from one year to another. This evidence is due to high elevation of the mountain that bordered Gulf of Suez which shelters the area and accelerates the wind in the southeast direction. At El Tor station and during the three years, the kinetic energy has minimum values (24.3-33.06 knot$^2$/unit mass) during the period extended from June to September, while it has maximum values (67.7-83.6 knot$^2$/unit mass) during February to May. This monthly evolution is obviously related to the cyclonic activity variations. The annual variation between the stations during the three years declared the same feature.

**Monthly Variation of Variance Between Suez and El Tor Stations**

At different frequencies, the variance can be represented as a function of the frequency (cycle/3 hours), the variance axis with a linear scale, and the frequency with a logarithmic scale. The monthly variation of variance of wind components that are parallel to the coast at Suez, Fig. 3, showed constant values at low frequency during all months. At the frequency greater than 0.101 one peak starts to appear at all months, while during September and October two peaks were detected at frequency greater than 0.101 and 0.201. During these two months the variance contained in the 0.101 frequencies is more dominated than that in the 0.201 frequencies. Generally, during May, June, July and August, the variance has more clearly dominated with a well defined peak than the other months.
The monthly variation of wind component normal to the coast of the Gulf of Suez at Suez, Fig. 4 shows a little difference (especially during July and October) from the long shore one. During July another peak can be observed at frequency greater than 0.2 while during October the value of variance ranged between 0.0 and 0.5 knot$^2$ during the whole frequency.

The monthly variations of wind component along the coast of Gulf of Suez at El Tor, Fig. 5 show two peaks which appeared during all months (except June) at frequency greater than 0.1005 and 0.2005, the first peak at 0.1005 is more important than the other i.e. more dominated frequency.

The monthly variations of wind component normal to the coast of Gulf of Suez at El Tor. Fig. 6 shows the same pattern at the long shore, except at April where the variance is approximately constant, it has values that ranged between 0.0 and 0.5 knot$^2$ during the whole frequencies.
Fig. 3. Monthly variation of variance of wind component parallel to the coast of the Gulf of Suez at Suez.
Fig. 4. Monthly variation of variance of wind component normal to the coast of the Gulf of Suez at Suez.
Fig. 5. Monthly variation of variance of wind component parallel to the coast of the Gulf of Suez at El Tor.
Fig. 6. Monthly variation of variance of wind component normal to the coast of the Gulf of Suez at El Tor.
The discussion above indicates that the low frequency oscillations are dominant at the two stations. This may be due to the several depression passing over the whole area nearly during the whole year. The variance at the two stations has almost the same values.

**Coherence and Phase of Wind Between Suez and El Tor**

The relation between the wind velocity at Suez and El Tor stations is most conveniently expressed in terms of the coherence phase difference as function of frequency. The coherence between two time series at any frequency tend to zero, if the component of the two series are not related at this frequency, and tends to unity if they are fully related irrespective of the phase difference. The coherence and phase lag between the long shore components and the normal to shore components of wind velocity at El Tor and Suez during 1998 and 1990 are shown in Fig. 7.

In all cases the coherence seems to depend on frequency, and is relatively high (greater than 0.5), this result may be related to the pattern of pressure over the gulf and the geomorphology of the area under consideration and mountain chain surrounding it.

![Fig. 7. The coherence and phase lag between the long shore components and the normal to shore components of wind velocity at El Tor and Suez during 1998 and 1990.](image-url)
The phase between long shore component and normal to the shore at
the two stations during 1989 and 1990 varies slightly with frequency.
This indicates that variation between the components of wind velocity is
very small and therefore has small effect on each other.

**The Correlation Between the Wind Components at Suez and El Tor**

Table 1. Declared relationship between the two components of wind between the two
stations and the monthly correlated values. These equations may be benefit to
calculate the wind speed at El Tor station from El Suez wind data.

<table>
<thead>
<tr>
<th>Month</th>
<th>U</th>
<th>R²</th>
<th>V²</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>Y = 0.5234 X + 9.2429</td>
<td>0.1485</td>
<td>Y = – 0.3491 X – 2.0174</td>
<td>0.0329</td>
</tr>
<tr>
<td>Feb</td>
<td>Y = 0.6455 X + 10.174</td>
<td>0.2821</td>
<td>Y = – 0.5985 X – 3.0783</td>
<td>0.0741</td>
</tr>
<tr>
<td>Mar</td>
<td>Y = 0.681 X + 6.6513</td>
<td>0.3091</td>
<td>Y = – 0.3239 X – 5.217</td>
<td>0.0597</td>
</tr>
<tr>
<td>Apr</td>
<td>Y = 0.9142 X + 1.5797</td>
<td>0.3255</td>
<td>Y = – 0.5495 X – 5.1959</td>
<td>0.133</td>
</tr>
<tr>
<td>May</td>
<td>Y = 0.3708 X + 15.345</td>
<td>0.0436</td>
<td>Y = – 0.5365 X – 7.9827</td>
<td>0.0925</td>
</tr>
<tr>
<td>Jun</td>
<td>Y = – 0.4177 X + 17.127</td>
<td>0.1003</td>
<td>Y = – 0.5144 X – 8.4116</td>
<td>0.0728</td>
</tr>
<tr>
<td>Jul</td>
<td>Y = – 0.1388 X – 15.576</td>
<td>0.0125</td>
<td>Y = – 0.4403 X – 6.3912</td>
<td>0.0975</td>
</tr>
<tr>
<td>Aug</td>
<td>Y = – 0.3536 X + 20.218</td>
<td>0.0484</td>
<td>Y = – 0.367 X – 6.4563</td>
<td>0.0604</td>
</tr>
<tr>
<td>Sep</td>
<td>Y = – 0.2093 X + 18.051</td>
<td>0.0199</td>
<td>Y = – 0.5201 X – 4.886</td>
<td>0.0902</td>
</tr>
<tr>
<td>Oct</td>
<td>Y = 0.4227 X + 9.4427</td>
<td>0.0893</td>
<td>Y = – 0.7035 X – 4.8617</td>
<td>0.1108</td>
</tr>
<tr>
<td>Nov</td>
<td>Y = 0.4315 X + 8.0235</td>
<td>0.0893</td>
<td>Y = – 0.5517 X – 0.3453</td>
<td>0.0369</td>
</tr>
<tr>
<td>Dec</td>
<td>Y = 0.3124 X + 8.2341</td>
<td>0.2471</td>
<td>Y = 0.237 X – 0.2485</td>
<td>0.0472</td>
</tr>
</tbody>
</table>

**Summary and Conclusion**

The wind data obtained from Suez and El Tor during 89, 90 and
1991 are analyzed to illustrate the relation between the wind velocities
along the Gulf of Suez. The kinetic energy shows lowest values at Suez
in comparison to the other two stations while it has minimum values
during the warm period and maximum values during the cold period at
Suez and El Tor. In general, the kinetic energy is low during the high
frequency, while it is high at the low frequency oscillation due to the
several depressions passing over the Red Sea during the cold period. The
relation between the wind velocity at Suez and El Tor stations is
expressed in terms of the coherence phase difference as function of frequency. The monthly variation of variance of wind components that parallel to the coast at Suez, have about the same values at the low frequency. During all the year except September and October, one peak appears at frequency greater than 0.101 while another small peak starts to appear at frequency greater than 0.201 at the two months. The main important frequency affected during the two months is around 0.101, because it is more dominated frequency. At El Tor the monthly variations of wind component along the coast of Gulf of Suez show two peaks appeared during all months (except June) at frequency greater than 0.1005 and 0.2005, the first peak at 0.1005 is more important than the other \textit{i.e.} more dominated frequency. The phase between long shore component and normal to the shore at the two stations during 1989 and 1990 varies slightly with frequency. This indicates that, the variations between the components of wind velocity are very small and therefore have small effect on each other. The relation between the wind velocity at Suez and El Tor stations is expressed in terms of the coherence appears, in all cases the coherence seems to depend on frequency and is relatively high (greater than 0.5). The correlation coefficient of the two wind components between the two stations appears a high correlated value.

References


التغير الزمني والمكاني في سرعة الرياح على امتداد خليج السويس

نبيل نصر الدين سعد
المعهد القومي لعلوم البحار والمصابيح، الإسكندرية
جمهورية مصر العربية

المتخلص. تم تحليل بيانات الرياح لكل من محطة السويس والطور، لإظهار العلاقة بين سرعة الرياح على امتداد خليج السويس. وتبين من الدراسة وجود قيم صغيرة لطاقة الرياح في السويس، بالمقارنة بمنطقة الطور. وعلى العموم، فإن طاقة الرياح تكون ذات قيمة منخفضة خلال الشهور الدافئة، ومرتفعة القيم خلال الشهور الباردة. وحساب العلاقة لمركبتين الرياح بين المحطتين، تحقق وجود علاقة معنوية قوية.