

## Synoptic Analysis of Storms and Severe Storms of Zahedan City with an Emphasis on Predicting the Probability of Their Incidence

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**Abstract:** Hurricane is one of the climate risks that are always led to life and financial losses. The purpose of this study is to predict the incidence of hurricanes at Zahedan city based on statistical analysis and synoptic analyses of this phenomenon. For this reason, the data related to wind survey of synoptic stations of Zahedan in 1983-2011 were collected. First, the accuracy and homogeneity of data were conducted using Run Test. Then, the hurricanes that their average annual incidence was between 3-5 times per year were selected based on partial series analysis model and the basic wind speed was determined 22 m/sec. After creating data matrix in Mat lab, the number of severe winds identified during the statistical period was 79 storms which their frequency has been increased in recent years. Results have shown that the storms with a speed of more than 26.4 m/s in 2-year period with a 50% probability and the storms with a speed of more than 36.52 m/s in a hundred-year return period can be occurred. Although the strongest winds occur in spring, January is the most incidence of occurring storms. Also the cyclone shows 80% of hurricanes northward. For example, the synoptic pattern of the storms occurred in 4 April 2002 and 2 April 2002 using maps of mean daily pressure, temperature, Zonal and Meridional winds at two sea levels and 850 hPa. The patterns indicate establishing low-pressure nuclear and locating 1000 hPa tabs on the region. Creating two high pressures, one on Zagros and the other Asian high pressure makes possible the conditions to intensify pressure gradient, making steep and severe pressures in the region, conditions are occurred by the winds exceeds more than 40 m/s. in this condition, Zahedan region is the maximum temperature of the surrounding in which severe temperature conflicts predominated on the region.

**Keywords:** High pressure, natural hazards, synoptic storm, zahedan

### INTRODUCTION

Natural hazards that appear consistently across the universe put at risk human lives and properties. Extreme climate phenomena currently focused the attention of researchers, for the risk of increased frequency; duration and increased sensitivity of climatic thresholds have been increased (Houghton *et al.*, 1996:572). Storms, one of the most hazardous natural disasters, are considered in the group of weather hazards (Ghaemi and Adl, 1992: 7). The studies show that nearly 90% of the world's natural disasters have climatic origins and floods after storms (35%) consecrates more than 30% of these risks (Meteorological Organization, 2006).

Wind is one of the most important variables for understanding atmospheric phenomena (Alizadeh *et al.*, 2002). Storms, which occurs by severe atmospheric turbulence and severe weather disruption is a very severe flow of weather that cause falling trees, collapsing buildings and breaking glass etc. and smashes vast areas

(Razjouyan, 2007). Storms sometimes reach to hundred km per h (Lin, 2005).

Occurrence of the storms with the speed of more than 100 km/s is not also expected in Iran. The storms events in August 9, 2006 at Zabol city, 27 April, 2008 at Dehloran, December 7 2009 at Ardebil, February 22, 2010 at Golpaygan, March 15, 2010 at Mahabad, March 29, 2010 at Makouh, Naghadeh and Piranshahr cities, March 17, 2010 at Mahabad, March 29, 2010 at Zanjan and Ardebil provinces, May 10, 2010 at Ardebil (Tavoisi and Raispour, 2010), especially the storm occurred at April 1, 2010 at Zahedan city with an approximately 130 km/h (Meteorological station data, Zahedan). The storms cause financial losses to facilities, networks and residential areas and also the death and injuring people, including Zahedan city.

Storm, as one of the climatic phenomena plays a main role in human lives and his/her present and future plans and is also one of the study bases of environmental planning (Kaviani and Alijani, 2007).

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Dust storms are the most serious problems of environment in specific regions of the world and its occurrence in arid and semiarid regions has a higher prevalence (Arimoto, 2000). Therefore, identifying storms that play main roles in the ecosystem and are one of the natural hazards of systemic effects in the environment seems necessary. The figures indicate the great importance of the issue. Although natural disasters have essentially complex nature and many of them seem beyond human control in the present condition, the amount of vulnerability is the result of human factors performance and as has been said, preventing the event is better than reaction against the incident. Therefore, increasing public awareness and knowledge is an important factor in reducing the effects of storms.

True understanding of storms leads to the prediction, prevention and its logical confrontation. In other words, minimizing the risks associated with storm incidence will be possible by choosing effective strategies. Therefore, studying and identifying stormy and strong winds occurred at Zahedan city as well as predicting the probability of their occurrence in a long period of time seems necessary. Determining the vulnerability of these structures in rural and urban areas, designing stable structures in the future and reducing its damages and its management can be satisfactory by identifying this phenomenon. Generally, this study aims to cope with this weather phenomenon by predicting the events of local hurricanes in various periods of return and reduce the damages caused by it as much as possible.

## LITERATURE REVIEW

The main reason for the wind is the pressure gradient between high-pressure and low-pressure cores (Kaviani and Alijani, 2007: 147). When the wind speed increases from a certain threshold, its damaging activities are started (Hangen, 1976, 107).

To determine the contribution of the strong and windy storms, understanding the wind characteristics of the region (speed and direction) throughout the day are required and so wind speed frequency distribution in each region is important (Stewart & Essenwanger, 1987, 1633), for the wind forces over the year, even in the time of day, are changed dramatically (Zobeck, 1991, 112). In their study, Goligera and Retiefb (2007) discussed and reviewed the phenomenon of strong winds and the damages resulted from in South Africa (Goligera and Retiefb, 2007). Simeonov and Georgiev (2003) extracted severe storms and winds associated with hailstone in the years 1999-2001 in Bulgaria and analyzed them synoptically (Simeonov and Georgiev, 2003).

Many studies have been conducted to identify the characteristics of storms in Iran. For Example, the analysis of strong and stormy winds in Yazd showed

that more than 77% of the region's storms blow from 250 to 300° with a speed of 15-29 m/s.

The study of synoptic pattern of widespread dust storms in central Iran indicates the favorable conditions for the formation and development of superficial instabilities in the earth at the level of 500 m bar (Omidvar, 2008). The analysis of Tehran windstorms also indicates low-pressure Mediterranean low-pressure and Black Sea (Hejazizadeh *et al.*, 2004). In another study, it has been indicated that closed cyclones on Iraq and northern Arabia is the cause of creating dust storms in the west (Heydari, 2008), for the establishment of a low-pressure system on Mediterranean region make possible the condition to transfer the cyclones to the west of Iran by strengthening the unstable conditions in the desert levels and also the coordinated effect of a dynamic low-pressure wave on the region's atmosphere (Zolfaghari *et al.*, 2010). Synoptic analysis of dust storm phenomenon at Khouzestan also showed that northern winds products in cold seasons and pressure systems at the earth's level, especially low-pressure of Persian Gulf in the warm years are the main causes of dust storms in the South West of Iran (Raispour *et al.*, 2008).

The statistical analysis of the occurrence of severe storms in Sistan indicates thunderstorms with a speed of approximately 144 km/h in the area (Tavousi and Raispour, 2010). Some of these storms known as 120-day wind of Sistan occur exactly when the positive cyclone area of western winds is located adjacent to subsidiary low-pressure monsoon winds (Khosravi and Salighe, 2005). Results achieved from data analysis of winds indicate the most probability of erosive winds of Zabol city in July and August with the north-northwest direction, respectively (Gandomkar *et al.*, 2007). Determining the numerical model of severe winds in Iran indicates that the highest amount of wind was in Zabol meteorological station and the lowest amount was in Semnan meteorological station (Delalian: 2003).

## MATERIALS AND METHODS

Daily data of Zahedan meteorological station with 1369.9 m height above the sea at the statistical period of 1983-2011 was used for a statistical analysis of hurricanes and dust storms. First, accuracy survey and homogeneity test of daily data of wind using Run Test was conducted.

Having been mentioned this reasoning, it is found that several hurricanes occurs throughout the year in which their speed is higher than the highest storm rate in other years which should be taken into account in terms of preventing their damages and the safety of structures. Therefore, to predict the probability of occurrence of the greatest storms, Partial Test analysis method was used. For this reason, the maximum data of diurnal wind in Mat-lab environment has been placed in one matrix and then was ordered from large to small without regarding the date of the event. The condition for the accuracy of this model is that the average

Table 1: Classification of wind speed in meters per second based on beau fort scale

Description	Wind speed	Beaufort number	Description	Wind speed	Beaufort number
Calm	0.5	0	Moderate gale	14-16.5	7
Light air	0.5 -1.5	1	Fresh gale	17-20	8
Light breeze	2-3.5	2	Strong gale	20.5-23.5	9
Gentle breeze	3.5 -5	3	Whole gale	24-27.5	10
Moderate breeze	5.5-8	4	Storm	28-31.5	11
Fresh breeze	8.5-10.5	5	Hurricane	32<000	12-17
Strong breeze	11-13.5	6	(Alizadeh <i>et al.</i> , 2002)		

frequency of occurrence of such as  $\lambda(f)$  windy days should be between 3-5 cases in a specific return period (which the annual unit has been selected in this study). In other words, the statistical likelihood of selected windstorms with Partial Series method is subject the Eq. (1) (Mahdavi, 2006 a, b):

$$3 < \lambda(f) < 5 \tag{1}$$

$\lambda(f)$ : Here, mean stormy day's occurrence in the statistical period

The base speed ( $W_0$ ) of selected cyclones for each location should be consistent with the Beaufort scale; that is to say, the base cyclone should be selected in such a way that Eq. (1) is observed and is also considered in the group of Beaufort storms and hurricanes (Table 1).

After determining the basic wind speed, the days that maximum wind speed equals to basic wind speed or more than it should be first extracted as the stormy day. The mean speed of hurricanes in the area ( $\bar{W}$ ) in the statistical period under study can be calculated using the occurrences of the days that the days with a speed of more than basic wind speed specified as ( $W_i$ ):

$$\lambda(f) = \frac{M}{N} \tag{2}$$

$$\beta = \sum_{i=1}^M (W_i - W_0) / M \tag{3}$$

$$\bar{W} = (W_0 + (\beta \times \ln \lambda)) + (0.5772 \times \beta) \tag{4}$$

Here:

- M = Frequency of stormy days with wind speed of equal or more than basic wind speed
- N = Statistical period according to each year
- $\lambda(f)$  = Average annual number of days with stormy wind speeds equal to or more than the basic wind speed
- $W_i$  = Monitored storm speed in meters per second in each of stormy days under study
- $W_0$  = Hurricane base speed in meters per second
- $\beta$  = Coefficient that depends on the deviation from the basic number
- $(\beta \times \ln T)$  = Rotation factor 0.5772 = (Euler constant)
- $\bar{W}$  = Average wind speeds more than basic wind speed

The probability of wind speed occurrence for different return periods was predicted using this model (Tavousi and Raispour, 2010).

$$W_T = (W_0 + (\beta \times \ln \lambda)) + (\beta \times \ln T) \tag{5}$$

Here:

- T = Return period in year
- $W_T$  = Probability of storms speed occurrence in the specific return period in m per sec

Since the aim of synoptic studies is to elucidate key interactions between the atmosphere and surface environment as well as exploring the relationship between atmospheric circulation patterns with environmental events (Parnal, 2006: 10).

Therefore, the environmental approach to circulation one was used. For this reason, the maps related to stormy days of the annual data parameters of Sea Level Pressures (SLP), air temperature, Zonal Flow (U wind) and Meridional wind (V wind) in the two ground levels and 850 hPa level of the internet site [www.esrl.noaa.gov](http://www.esrl.noaa.gov) was prepared. With respect to the fact that the data related to geo-potential height and air temperature in 17 atmospheric levels is unavailable in this site and has the location distinction of 2.5\*2.5 spatial resolution as a network, it was possible to draw the maps of atmospheric levels in Grads atmosphere to study the patterns of air flow direction. Maps of 850 hPa were chosen for the coordination of the flows of this level with the behavior of ground level air mass behavior. The used maps involve 15 to 50° of north latitude and 45 to 90° of east longitude based on daily atmospheric conditions and spatial coverage. Selecting this locational range was for the fact that it can involve the region's hurricanes from its initiation to the end in its own network and cover all synoptic structures making Zahedan cyclones.

## DISCUSSION

**Statistical analysis:** In this study, the total daily data of wind speed is over 2667 days which is monitored in the 1983-2011 statistical period. With respect to the condition of Partial Series model Eq. (1), 90 maximum wind speed data was selected from large to small without respect to the occurrence year. Accordingly, the average stormy days of the 3.41 stormy days per year and the basic speed of Zahedan's hurricanes were determined 22 m/s. In other words, a total of 99 days of the storms with the speed of higher than 22 m/s blew in Zahedan city in a 29-year period. Throughout these

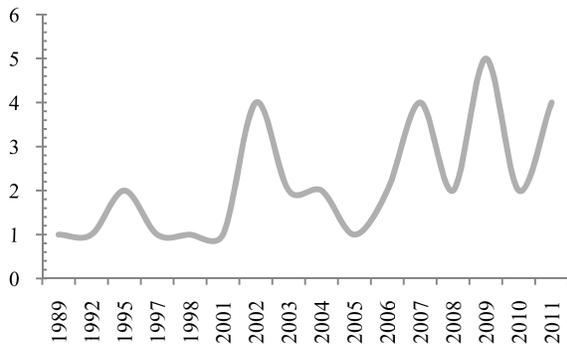


Fig. 1: The annual process of severe annual storms of Zahedan station, 1984-2011

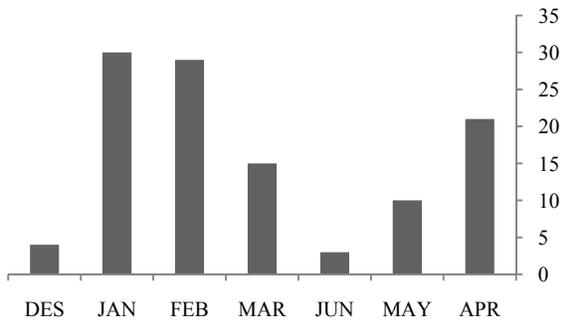


Fig. 2: Monthly frequency of occurrence of storms in Zahedan

years, the year 2009 has been the stormiest day by having 5 stormy days. Generally, the occurrence of hurricanes and storms in the last years of the study had a higher frequency and in the years of 2006-2011, the frequency of occurring stormy days has been dramatically increased. The highest recorded wind speed has been occurred in the Zahedan station with 40 m/s in April 4, 2002. Studying the monthly occurrence of the winds showed that January was the most hazardous month and February and March are in the second and third grades (Fig. 1 and 2).

To study wind survey data, Wind rose software was used to draw wind rose. To show the direction and speed of the winds of more than 22 m/s, wind rose of these winds was drawn. 80% of severe and gusty winds are blowing from the north and northeast towards Zahedan. Therefore, Zahedan's storms mainly blow from the north. The next prevailing direction is southwest (Fig. 7). Wind roses for various seasons are given in Fig. 3 to 7. Winter wind rose shows that 62% of stormy days are mainly from the north (N), 24% are mainly from Southeast and East (SE,E) and 14% are mainly from the South and Southwest (S,SW) and the strongest winds are blown from the north (Fig. 3). As shown in Figure 4, 25% of wind rose is from the West (W), 65% are from the Southwest and South (SW, S) and 5% are from the north (N) and 5% are from the south and southeast in the wind rose. The wind rose in the fall (Fig. 5) constitutes 80% of storms from the Southwest and West (SW, W) in that the strongest

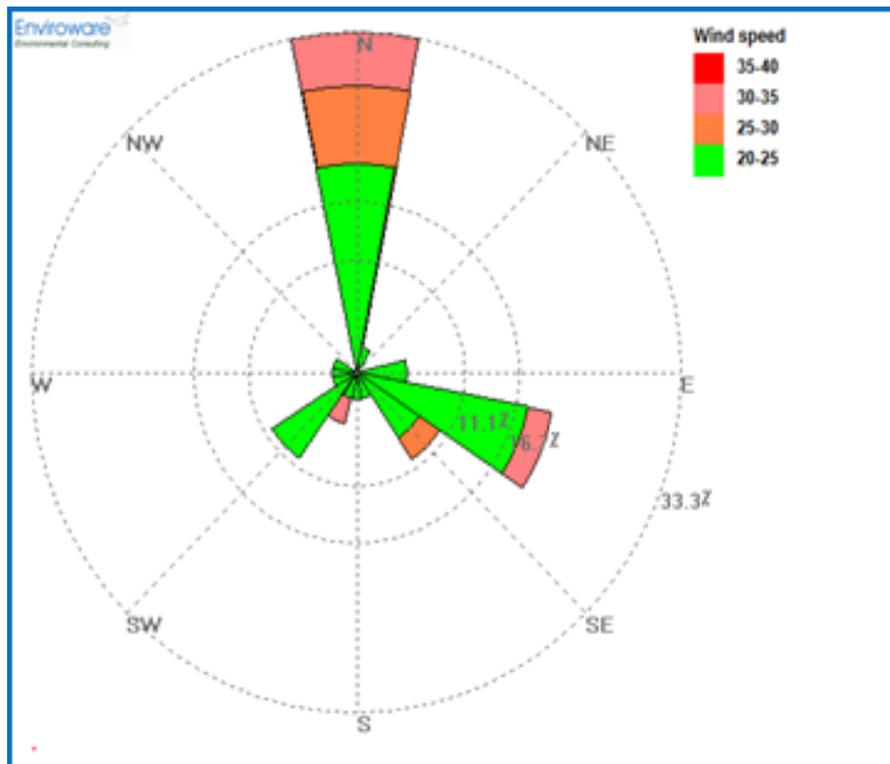


Fig. 3: Wind Rose in winter (1982-2012)

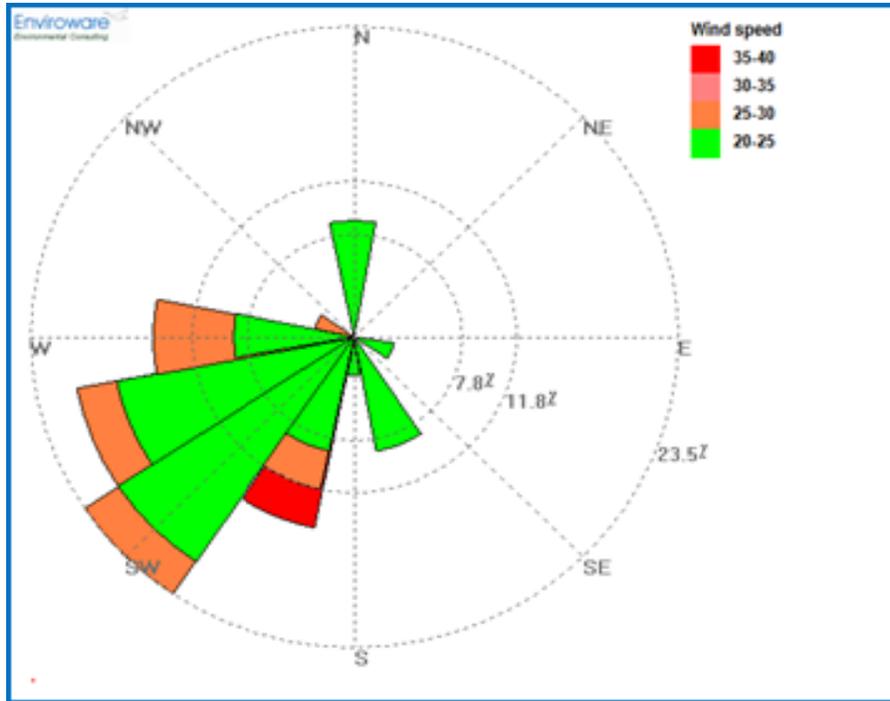


Fig. 4: Wind rose in spring (1982-2012)

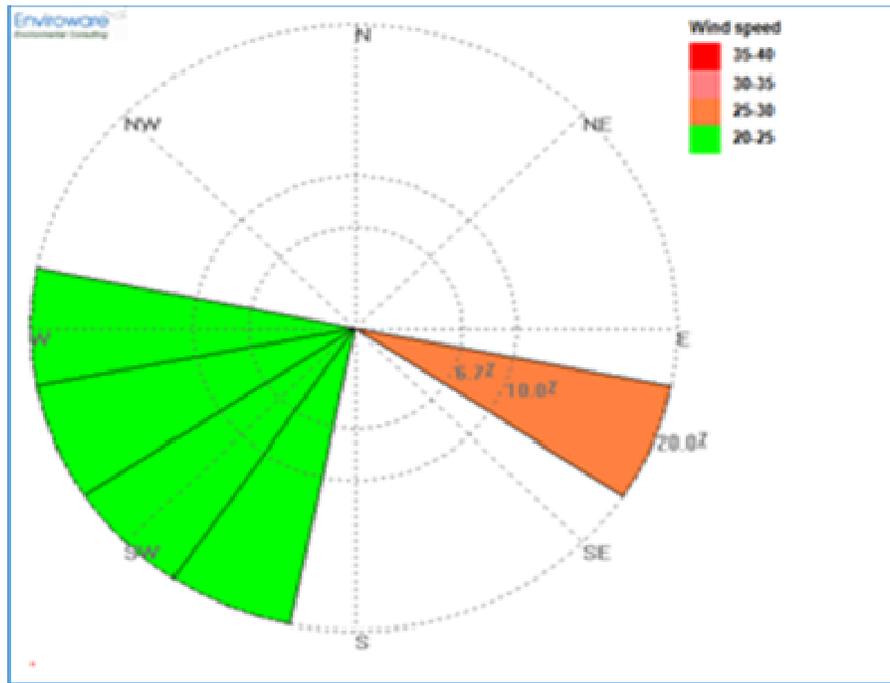


Fig. 5: Wind Rose in fall (1982-2012)

storms have been blown from the Southeast (SE). The wind rose of summer season with the lowest frequency (Fig. 6) shows that all of them are from the West (W). Generally, the total survey resulted from annual wind rose of Zahedan stations during the statistical period (1983-2011) shows that the direction of blowing severe storms

with the speed of more than 30 m/s and more than it are from the north (Fig. 8).

Partial series model shows that the annual mean of the storm speed equal to or more than the basic speed in Zahedan was 25/73 m/s. Predicting the probability of occurring storms with a speed equal to or more than basic

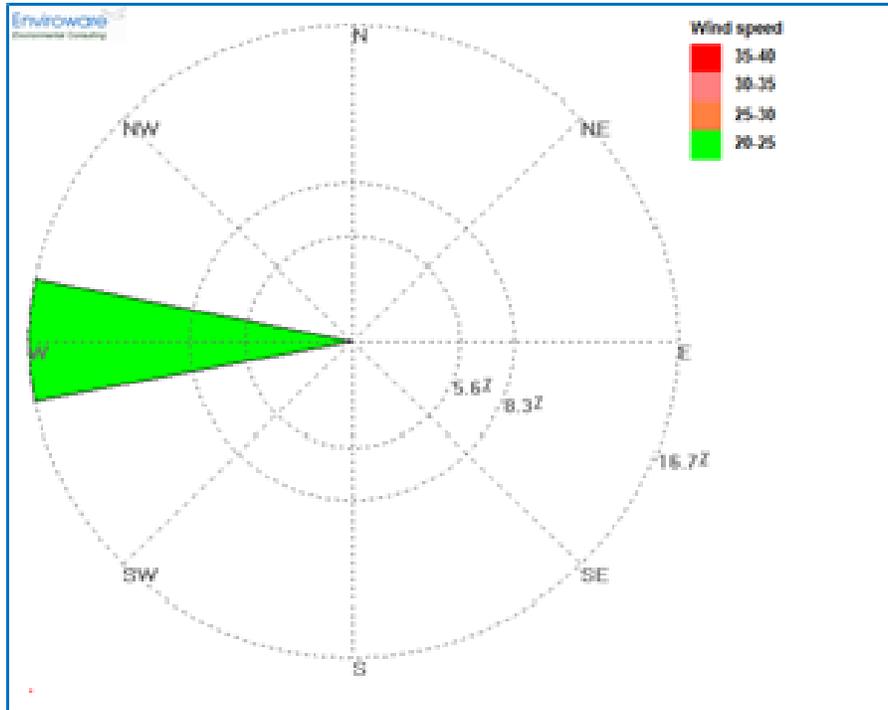


Fig. 6: Wind rose in summer (1982-2012)

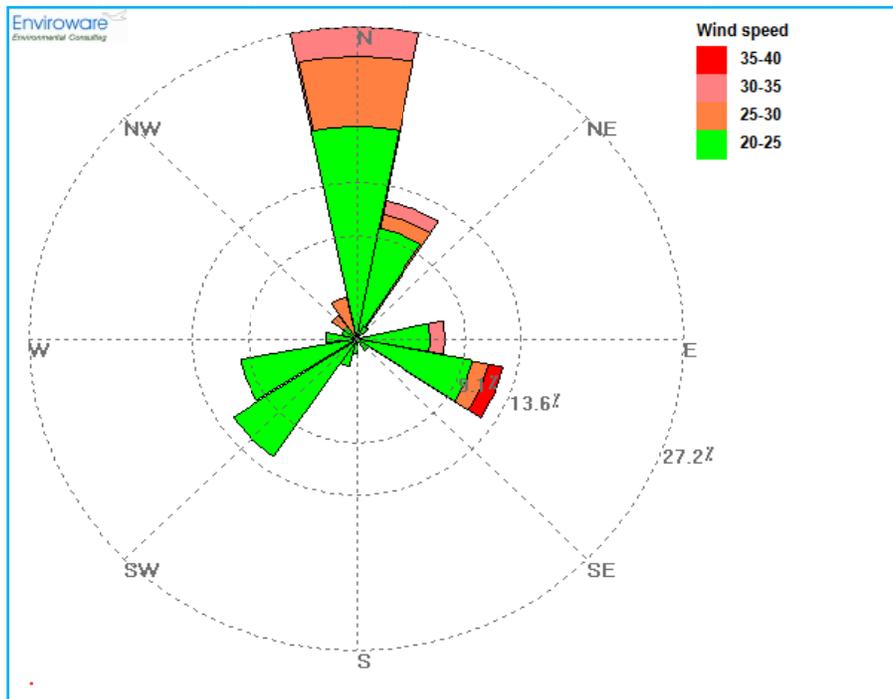


Fig. 7: Annual wind rose strong winds stations in Zahedan

speed (22 m/s) indicates that a storm with 26/4 m/s occurs in a 2-year return period with 50% probability. Predicting the probability of occurring storms for return periods or a longer time range (5-100 years) indicates the probability of occurring the storms with higher speed and this suggests

that there is a direct and linear relationship between them. However, the incidence probability in a longer return period is less likely to occur, so that for 100-year return period, it is predicted that a storm with a speed equal to 36/52 m/s in Zahedan will occur with a probability of 1%,

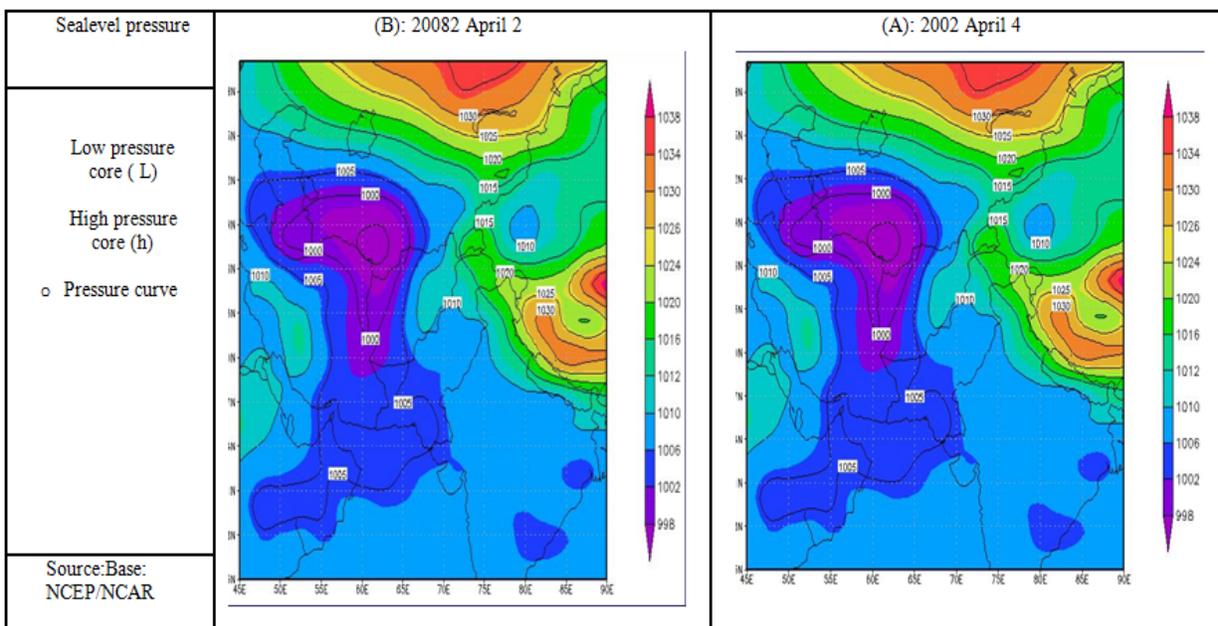


Fig. 8: Air pressure at sea level, A. April 4, 2002 and B. April 2, 2008

Table 2: Mean speed and predicting the probability of occurring the storms with a speed of more than 22 m/s with return period T in Partial Series analysis method

Probability(Percent)	1.000	2.000	5.00	10.00	20.0	50.0
Return periods (Year)	10.00	50.00	20.00	10.00	5.00	2.00
The speed of predicted wind in m/s	36.52	34.66	32.21	30.35	28.48	26.4

$\lambda(f)$ : 3.28;  $\beta$ : 2.68;  $\beta*\ln$ ;  $\lambda$ : 3.18;  $w_0$ : 22 (m/s);  $\bar{w}$ : 25.73(m/s); M: 95; N: 29 Ln  $\lambda$ ; (f): 1.19

although the percentage of occurring the storm with the specified speed is very weak, the probability that a storm with the above-mentioned speed will occur in a 100-year period is not unexpected (Table 2).

**Synoptic analysis:** April 4, 2002 is a representative group of the severest storms of the station that has been occurred in the period under study. The speed of this storm blown from the southwest reached 40 m per sec. The pressure curves at sea level indicates that in this day a low-pressure nuclear with a central pressure of 995 hPa have been emerged in the northeast so that the pressure curve of 1000 hPa of this site has been positioned exactly on Zahedan. This low-pressure wind has been drawn from the southeast of Iran to the Arabian Sea. In the West side of this low-pressure wind, a high-pressure wind with the central pressure of 1100 hPa has been formed on Zagros. Within this condition, a high-pressure wind known to Asian high pressure has been studied in the east side of the area under study that its wind tap has been reached to the west Afghanistan. The central speed of this high-pressure site is 1035 hPa. This condition is led to severe pressure gradient between severe Asian high-pressure system and low-pressure tab of east Iran. The establishment of pressure gradient causes intensifying

wind speed in the region and cyclones in Zahedan city (Fig. 8, a).

April 2, 2008 was a representative group of the storm. This storm was blown with the intensity of 27 m/s in Zahedan and the synoptic pattern of emerging this storm was the same as the previous one, except that the central low-pressure located on the northeast are drawn to the higher latitude (Fig. 8, b).

On this day, high-pressure wind of Zagros is developed further and covered the central part of Iran. Also, the intensity of central pressure of Asian high-pressure has been increased to 1044 hPa. According to this difference, the pressure between the high-pressure eastern system and the temperature low-pressure system of the north intensified emerging severe pressure gradient and dust storms in the area.

The synoptic pattern of 850 hPa at April 4, 2002 shows a pressure core with 1300 geo-potential height near Baikal Lake with the core position of 45 north latitude and 65 east longitudes. The contour of this system with 1410 m geo-potential has been studied in the area. The rotational movement of this site is coordinated with the direction of ground level which intensified the direction of cyclones in the area. Asian anticyclone positioned 33° north latitude and 88° east longitude core with a central pressure of 1550 geo-potential meters is located in West China (Fig. 9, a).

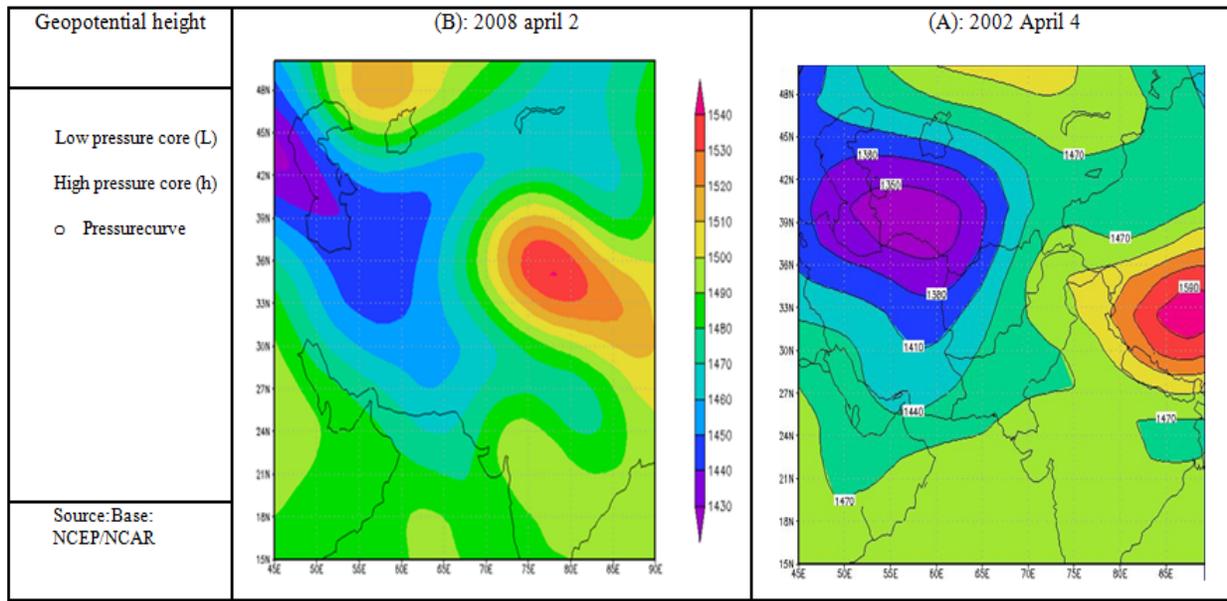


Fig. 9: Geo-potential height at 850 levels, A. April 4, 2002, B. April 2, 2008

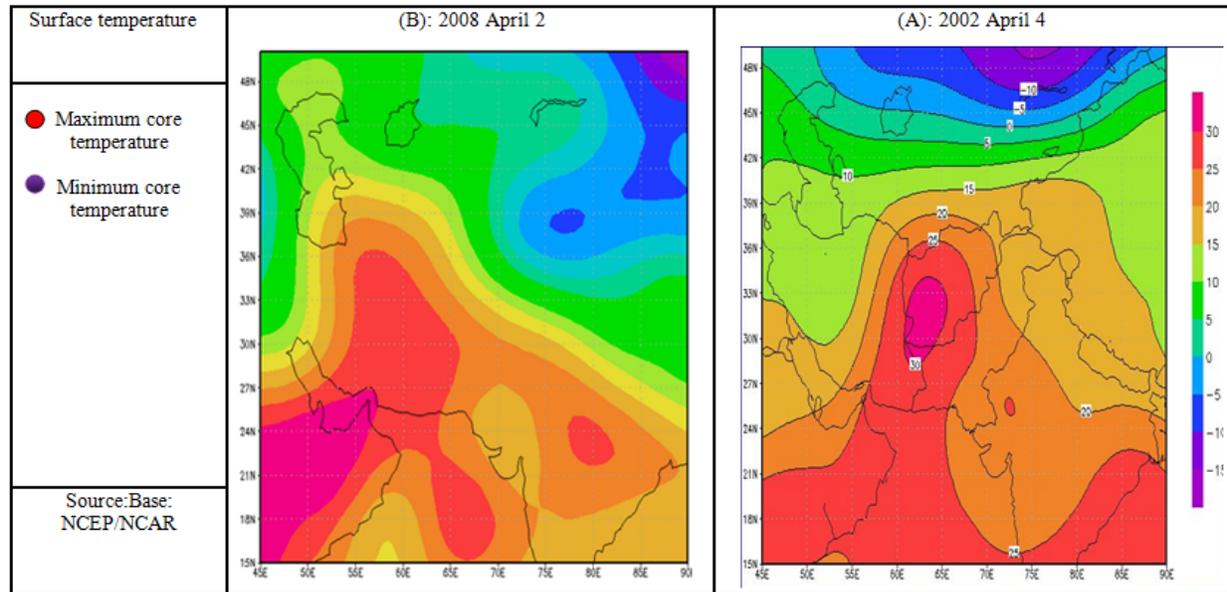


Fig. 10: Surface level temperature, A. April 4, 2002 and B. April 2, 2008

The synoptic pattern of geo-potential pressure map at the 850 hPa levels in 2/4/2008 shows a pressure core with 1540 height geo-potential in central Asia. Asian anticyclone core position of 36° north latitude and 78° east longitude, with a central pressure of 1600 geo-potential m is located on the Mongolia (Fig. 9). It will be deeper with this pressure tabs and 1480 m tab pressure are drawn to Zahedan city. Also a low-pressure with the central pressure of 1430 m geo-potential is located in the west of Caspian Sea. The tabs of this low-pressure wind are drawn to the west Sistan and Baluchestan and Zahedan. According to the

pattern of these models, the pressure difference between the two mentioned systems and also low-pressure western cyclonic movements are the main causes of occurring storms in this time.

Map of surface temperature in April 4, 2002 shows that a temperature core with 30°C has been emerged in the area under study and the maximum temperature is exactly based on the area under study. The pressure difference of this thermal pool and other areas has reached to 40°C. Map of surface temperature in April 4, 2008 shows that a temperature pool more than 200°C temperature has been emerged in

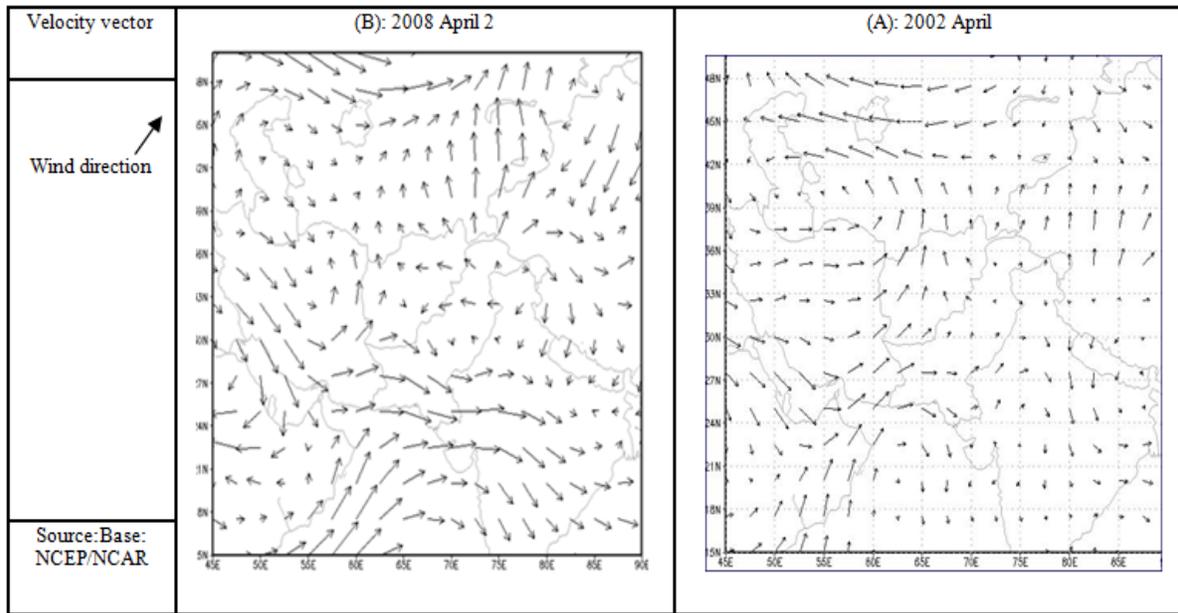


Fig. 11: map of speed vector at 850 h Pa levels, A. April 12, 2002 and B. April 2, 2008

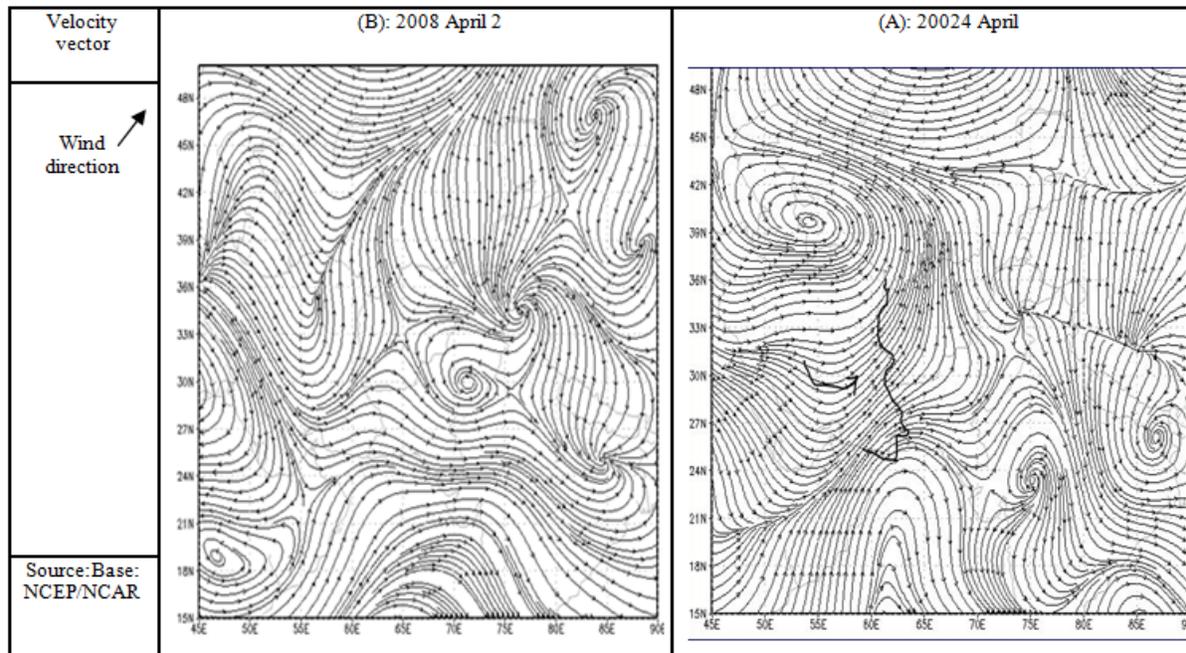


Fig. 12: Map of stream line at 850 hPa level, A. April 4, 2002 and April 2, 2008

the study area which the core of this invasion was the hot air of Arabian Peninsula. The study area is one of the focal points of maximum temperature. The temperature difference of this thermal core and other areas has reached to 20°C. Emerging a thermal conflict between this area and Asian low-pressure in this time indicates the pressure difference in this region and shows that such conditions is led to forming pressure changes gradient from the surrounding area to Zahedan.

The establishment of these conditions causes increasing wind speed and making storm in the area (Fig. 10a and b).

Map of wind vector is shown at the 850 hPa level at 4 April indicating that the wind in Zahedan blows from southwest to northeast. Counterclockwise movement of air in the low pressure located on the North East of Iran is consistent with the direction of the wind. Wind stream in this direction blows first in

"north-south" and then it is deflected while being reached to southeast. The maximum speed is formed at the southeast.

Map of wind vector at the 850 hPa level for April 2, 2008 shows that the wind blows in the south-southwest direction in Zahedan. Counterclockwise movement of air in the low pressure placed on the west Iran is consistent with this wind direction. Wind stream in this movement blows first in "west-east" direction and then is deflected while being reached to southeast (Fig. 11a and b).

Maps of weather stream on April 4, 2002 indicates that counterclockwise air flow in anticyclone located in the northeast and the east part of Caspian Sea is in wave form which is reached to southern latitude and is reached to Zahedan in southwest direction. Simultaneously, clockwise flow in the eastern part of the region (East of Afghanistan) is led to the establishment of anticyclone flow from the center of anticyclone towards the cyclone in the northeast part of the country. In the southern part of the country, anticyclonic movement and counterclockwise flow cause severe wind flows in the area. In both cases of selected storms, airflow at the upper level of atmosphere is consistent with the wind flow at the ground level. The air flow blows from the anticyclone center towards the area and the compression of air stream within the study area indicates a high wind speed in this day.

Maps of air stream for April 2, 2008 shows that clockwise movement of the air in the cyclone located at the northwest of the country is reached in wave form to the southern latitudes and is reached to Zahedan in south and southwest direction (Fig. 12 a and b).

## CONCLUSION

According to the Partial Series analysis model, the average number of storms in the statistical period is reached to 99 days. The results showed that the storms with the speed of more than 26.4 m/s in Zahedan region will be blown with the probability of 50% in each 2 years. The highest gusts of this city that is predicted with the probability of 1% for a 100-year return period can be at least 36/52 m/s. Although the strongest winds occur in spring, January and winter are the most incident month and season. Also wind rose shows 80% of northern hurricanes. For example, the synoptic pattern of April 2, 2002 and April 2, 2008 was studied using map of daily average pressure, temperature, Zonal and Meridional winds at two sea levels and 850 hPa. The patterns indicate the establishment of low-pressure core in the northeast and the establishment of 1000 hPa tabs over the area. simultaneously, forming two high-pressure winds, one on the Zagros and the other on Asian high-pressure makes possible the conditions for intensifying pressure gradient, emerging

steep and a high pressure in the area and condition that emerged the winds with the speed of more than 40 m/s. in such condition, the area was the center of maximum temperature to the surrounding area and a sharp temperature conflict dominated over the area.

Generally, one of the natural and damaging phenomena occurring each year in Zahedan is blowing the winds that can be one of the characteristics of the region. However, identification and knowledge of statistical and synoptic characteristics associated with the occurrence of this phenomenon can be instrumental in the planning related to the occurrence of this natural disaster.

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