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An Observational Study for a Gap Wind: A Study Case in Sepeed-Rood, Iran

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Abstract: The aim of this study was to examine the roles of meteorological and geographical factors which affect the flow in the Sepeed Rood valley. The valley is considered as a narrow passage in Alborz mountain range in which the remarkable air flow causes intensive winds in its route cities such as Rood Bar and Manjil. The results show that there is strong correlation between the pressure difference between the two ends of the gap and the wind velocity. The correlation is more noticeable in the winter. The effects of regional circulations such as Foehn, sea breeze and anabatic wind are noticeable causing intensive gap winds in summer days. We analyzed the gap current under an active synoptic system which passing through the north and center of the country. In this case, the current is completely dependent on the pressure difference of the two ends of the gap and the effect of the heat forcing circulations specially sea breeze and land wind mostly would be negligible under the influence of intensive synoptic pressure gradients.

Key words: Gap wind, air pressure, synoptic patterns, pressure gradient, sea breeze

INTRODUCTION

The interaction between the regional or mesoscale pressure gradient and the environment topography can cause intensive winds in many mountainous areas. Some mountains separate different air masses and in these cases, the strong pressure gradient in the width of mountains accelerates the air masses through the existing gaps creating strong non geostrophic winds known as gap winds. The Sepeed-Rood River valley located in the north of Iran is in the form of a deep gap in the Alborz Mountain range in which the existing pressure gradient of the two mountain sides leads to blowing of strong winds with the velocity of $8-18 \text{ m sec}^{-1}$ and sometimes even up to 30 m sec^{-1} .

The first attempts to describe gap winds are found in Lackmann and Overland (1989), Reed (1931), Tyson and Preston-White (1972), Marvill and Jayaweera (1975), Ryan (1977), Dantels and Schroeder (1978), Ramachandran *et al.* (1980) and Banta and Cotton (1981).

Reed (1931) observed the non geostrophic nature of the gap wind in Juan de Fuca Bay and examined the synoptic conditions which are associated with it. He introduced the gap wind as a flow of somehow homogenous air in a sea surface channel which can be accelerated by the pressure gradient component parallel to the channel axis.

Ramachandran *et al.* (1980) performed an observational study to explain the downwind increase of winds which transiting in a gap in India. Observed data show that there is a fanning out of surface winds which passes through the gap. Gap winds in Howe Sound, British Columbia are described by Jackson and Steyn (1994a, b). Surface and vertical sounding measurements show that gap winds vary along and across the channel, as well as vertically. Mass *et al.* (1995) studied localized windstorm which caused suffering some areas of Northwest Washington State. They described that the arctic air

originated in British Columbia descended into a mesoscale gap in the Coast/Cascade Mountains. They describe this gap acceleration by a three way balance among the pressure gradient force, friction and inertia.

Liu *et al.* (2000) used a Navy's Coupled Ocean-Atmosphere Mesoscale model to study a flow in the Lut Valley, Iran. They explained that the flow is originated as a gap flow in the convergence topography of the Lut valley by the valley parallel pressure gradients produced by the large scale processes and by the pressure of cold air over the valley's sloping terrain.

De Foy *et al.* (2006) analysed surface and upper-air meteorological observations to obtain an index of the strength and timing of the gap wind in Mexico City. They shown that the gap wind is found to occur on most days of the campaign and is the result of a temperature gradient across the southern basin rim which is very similar from day to day.

The low-level seasonal and intraseasonal wind variability over the northeastern tropical Pacific (NETP), its relationship with other variables and the connection with large- and middle-scale atmospheric patterns were analyzed by Romero-Centeno *et al.* (2007). The seasonal and intraseasonal evolution of these wind systems determines the circulation patterns over the NETP, showing predominant easterly winds in winter and early spring and wind direction reversals in summer over the central region of the NETP.

In this research we have analyzed the meteorological observations around the Sepeed-Rood and studied their effect on the gap flow initiated from the north of the valley and passes through the south.

MATERIALS AND METHODS

Study Area and Measurements

Sepeed-Rood gap is a narrow break in the Alborz mountain range with the length of 55 km, width of 7 km and the depth of 1800 m (Fig. 1). In this study the meteorological data including air temperature, air pressure and wind velocity include another variables from four stations in the north of valley (Ramsar, Rasht, Anzali and Manjil) and three stations in the south of valley (Tehran, Qazvin and Zanjān) were analyzed for the period of four years from 1996 to 1999. Geographical and climatic attribute of the stations are reported in Table 1. The stations located in the north of Alborz chain have very humid and rainy climate through the year but the southern stations have rainy winter and dry summer generally with semi-arid climate conditions.

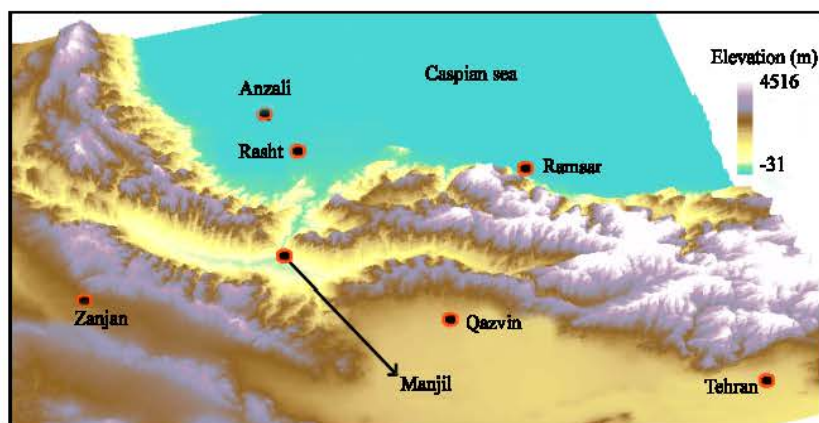


Fig. 1: 3D view of the study area. Manjil station is located in the valley

Table 1: Geographical and climatic attributes of the studied stations

Station	Latitude (°N)	Longitude (°E)	Elevation (m)	Tmax (°C)	Tmin (°C)	Rain (mm)	Win speed (Knot)	RH (%)
Ramsar	36.90	50.67	-20.0	19.4	12.6	1218.0	3.2	83
Rasht	37.25	49.60	-6.9	20.6	11.3	1359.0	2.5	82
Anzali	37.47	49.47	-26.2	19.2	13.2	1854.0	3.9	84
Manjil	36.73	49.40	333.0	22.4	12.7	209.3	12.1	59
Tehran	35.68	51.32	1190.8	22.6	11.8	231.0	5.2	40
Qazvin	36.25	50.05	1279.2	21.2	6.9	316.0	3.9	51
Zanjan	36.68	48.48	1663.0	18.0	4.0	313.0	3.7	54

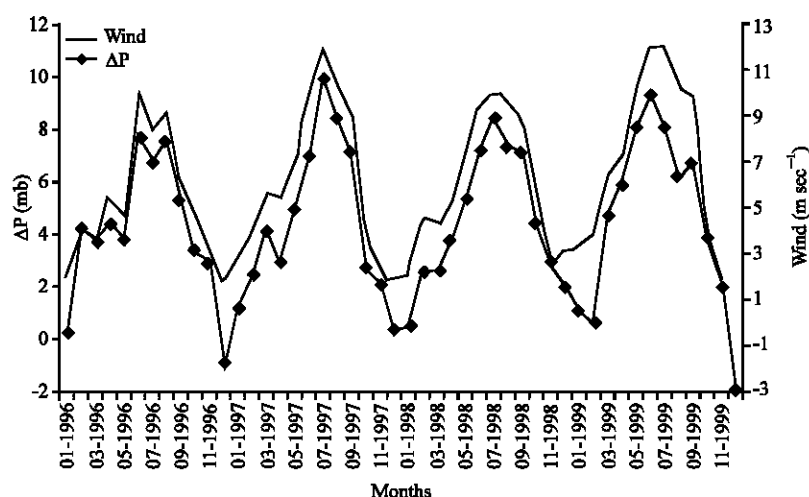


Fig. 2: Monthly averages of the wind velocity versus the pressure difference in the two ends of the gap, during the years 1996 to 1999

RESULTS

Wind Velocity Versus Pressure Difference

The wind velocity changes in Manjil and the pressure difference between the two ends of the gap from 1996 to 1999 are shown in Fig. 2. It is obvious that, there is a strong correlation between the pressure gradient along the gap and the wind velocity in the gap. So on the whole the pressure gradient along the gap is considered as one of the most important forcing for the wind in a gap which is not the only one. As seen, this correlation is more noticeable in winter. Also there are cases in which the correlation is not strong which may be due to other factors that are considered in the followings. Special mesoscale conditions or even the temporary large scale ones can create such situations. But altogether the general trend for the pressure difference between the two ends of the gap and the velocity along the gap reveals an overall correlation.

In summer the pressure gradient is always positive and most of the times, the foehn effect and local circulations such as sea breeze and anabatic winds play important roles. The observations show the average velocity in summer days is 12 m sec^{-1} . At night because of some factors such as nocturnal cooling and lack of sea breeze which is one of the effective marginal factors and on the other hand creation of a marginal preventing current called land breeze the average velocity of a current in a gap comes to 6.4 m sec^{-1} which is remarkably decreased in comparison with the daily winds. The

maximum observed velocity in this season is about 25 m sec^{-1} . Actually, this pressure difference is related to the three northern stations (Ramsar, Rasht, Anzali) and of three stations in the south (Tehran, Qazvin and Zanjan).

It seems that in winter the effect of thermal circulations and Foehn wind are small. The average wind velocity is 2.5 m sec^{-1} in a day and at night. In this season, many synoptical systems passing over north and center of the country and causing instant and intensive pressure gradients between the two ends of the gap that leads to the intensive winds with the velocity more than 25 m sec^{-1} . Sometimes very dry southerly wind could occur by decreasing or negative pressure difference. So in the next session the effect of an active synoptic system will be analyzed.

The Gap Wind under an Active Synoptic System

In this part we will examine the gap current in a case that a synoptic system is entering north and center of Iran. Our aim for studying this case of gap flow is examining its forecasting strength which is similar to the one done by Vidmer for the occurrence of shallow southerly Foehn winds. Nonetheless the previous surveys reveals the strong relation between Sepeed-Rood gap wind velocity and its two ends pressure gradient in case of precipitation on the gap.

In this situation the currents completely become dependant of the pressure difference of the two ends of the gap. However the effect of Foehn phenomenon and down slope currents must not be neglected. The heat forcing circulations specially Sea breeze and Land wind mostly would be negligible under the influence of intensive synoptic pressure gradients.

So in this part, firstly the significance of the relation between the gap wind velocity and the pressure difference of the two ends of the gap will be examined. Secondly the trend of its both sides pressure gradient in case of the existence of a synoptic system crossing over Iran will be analyzed.

As example, we will examine a system which entered Iran at the initial hours of Feb. 1st, 1996. This system initially entered south of Iran on 00:00 GMT Feb 1st, 1996 and within the next 6 h captures south west and west regions of Iran (Fig. 3a). In this case the gap pressure gradient immediately becomes negative that leads to the blowing of southerly dry winds. Simultaneously the upper level maps show a deep trough in west of Iran which hasn't affected the west and northern parts of it yet. The approaching of this trough is accompanied with the creation of a low pressure center on the Caspian Sea that will be reinforced as a result of the approach ness of a deep trough on the upper levels.

That's why the gap pressure gradient suddenly changes its mark and the current becomes southerly. The pressure falling is more than 5 mb in some coastal areas after 6 h.

Proportional to the reinforcing of this low pressure, a high pressure is going to be created in center of Iran. As it is clear in the surface maps, this High pressure tends to move to the east (Fig. 3b, c).

As it is clear in Fig. 4a by approaching the synoptic system from the west, the cold air falling happens on back of the penetrated cold front. The low pressure would be weakened. After its deliberation on the Caspian Sea, it will be moved to the east of Iran. The increase beginning of the pressure difference of the two ends of the gap is accompanied with the blowing of northerly winds in it. It is interesting to know that the increasing of the pressure gradient during the 12 h is approaching 25 mb. The temperature and wind velocity show great changes in accordance with the gap both sides pressure gradient. The 500 mb map at 12:00 GMT Feb. 1st (Fig. 4a) shows that the upper level trough has been somehow become nearer and its curvature on the lower latitudes existing over Iran is increasing which reveals vorticity and instability decreasing in south of Iran. The surface maps of 12:00 (Fig. 4b) and 18:00 GMT (Fig. 4c) shows the southerly synoptic system has been shifted to upper latitudes causing low pressure. So the low pressure as a result of the establishment of southern front over center of Iran will be reinforced and deepened explained by the approach ness of an upper level

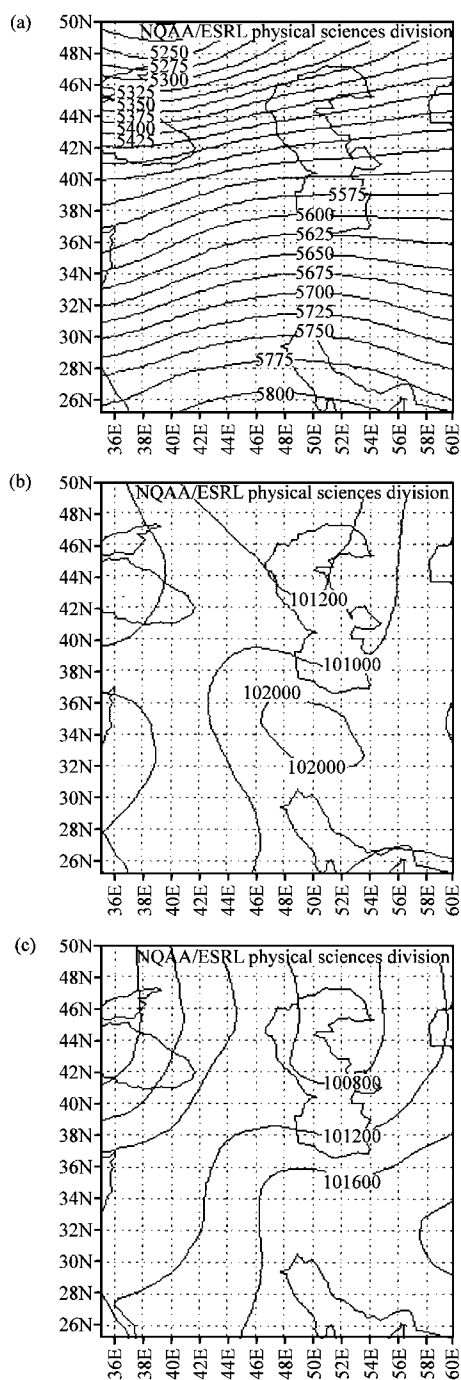


Fig. 3: The synoptic maps of the region on Feb. 1st 1996. (a) 500 mb level map for 00:00 GMT shows a deep trough in west of Iran which has not affected the west and northern parts of it yet. (b) the sea level map for 00:00 GMT and (c) the sea level map for 06:00 GMT

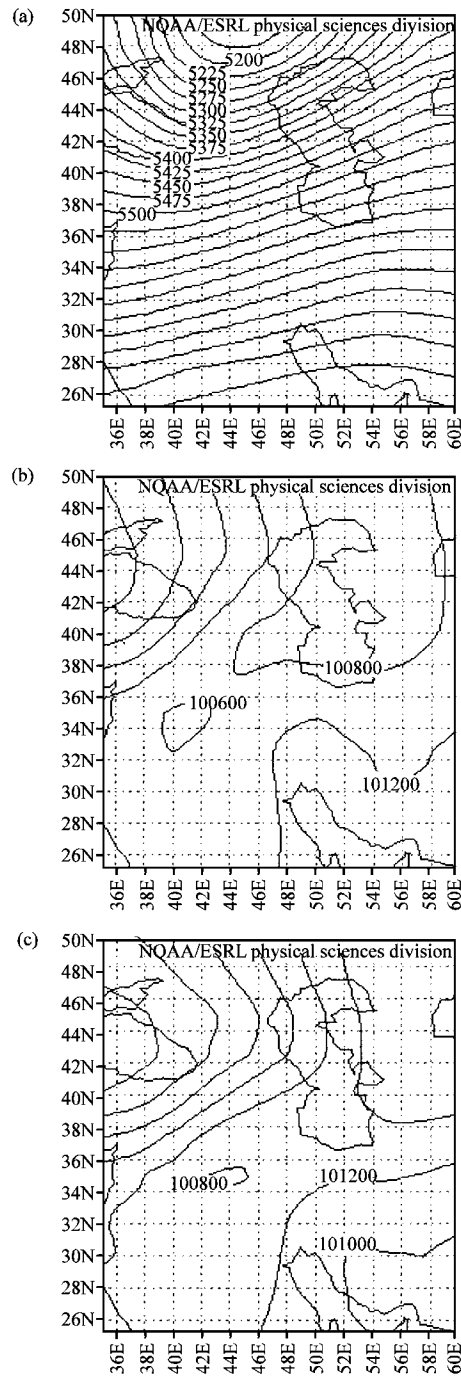


Fig. 4: Same as Fig. 3. But (a) the 500 mb level map at 12:00 GMT for Feb. 1st. (b) the sea level map for 12:00 GMT and (c) the sea level map for 18:00 GMT

deep trough. So it is appropriate to utter that the intensive increasing of the pressure difference of the two ends of the gap is as a result of intensive falling of the northern low pressure and reinforcing of

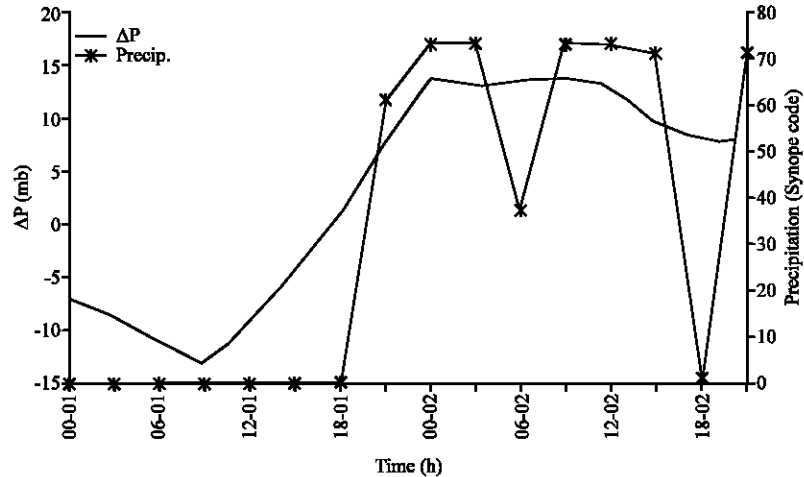


Fig. 5: The precipitation occurrence versus the pressure difference at the two ends of the gap at 00:00 GMT Feb. 1st to 24: 00 GMT Feb. 2nd. The snowfall is seen during the first hours of Feb. 2nd after the exit of the northern low pressure from the Caspian Sea and the intensive falling of the cold air following it

central low pressure. The first precipitation as rainfall will be started within the gap 9 h after the beginning of increasing trend of the pressure difference of the two ends of the gap. Actually since then the trend of pressure increasing will be continued up to the time that the precipitation changes into rainfall.

The snow fall of the initial hours of Feb 2nd is after the complete exiting of northern low pressure from the Caspian Sea and intensive cold weather following it (Fig. 5). The surface maps show the cold weather falling and establishment of high pressure cold air on northern of Iran (Fig. 6b, c). It happens when 15 mb pressure gradient will retain unchangeable during 12 h and the gap wind velocity remains between 10 and 15 m sec⁻¹ in a gusty form with northerly direction. The temperature will reach below zero during the snow fall hours and after the snowfall stopped, the temperature will go above zero instantly. The upper level maps indicate the increase of the trough axis curvature which leads to energy and atmosphere instability. In this map it is seen that a Rosby wave decomposes to two waves with different domains and velocities. The northerly wave with shorter domain and more velocity is separating from the southerly one with longer domain and less velocity. Likely the fronts of center and north of Iran would be converging to the east and northeast that leads to the weakening and destroying of the high pressure of south of Iran.

In Fig. 7a, the upper level map indicates the complete decomposing of Rosby wave to two northerly and southerly waves. The northerly wind is crossing over northwest and north of Iran instantly. While the southerly wind with a very low speed falls behind the northerly one and will affect south of Iran with a less strength than the northerly wind. The 12:00 GMT surface map (Fig. 7b) shows the complete establishment of the cold air high pressure of Eastern Europe over north of Iran. Simultaneously the snow fall will be continued within the gap up to 21:00 GMT of Feb 2nd (Fig. 5). The 18:00 GMT of surface map (Fig. 7c) shows the northerly high pressure will be inclined to east and north east. As a result, the pressure difference of the two ends of the gap will have a decreasing trend and will fall 5 mb during 3 h which causes the velocity decreasing accordingly although keeping its northerly direction.

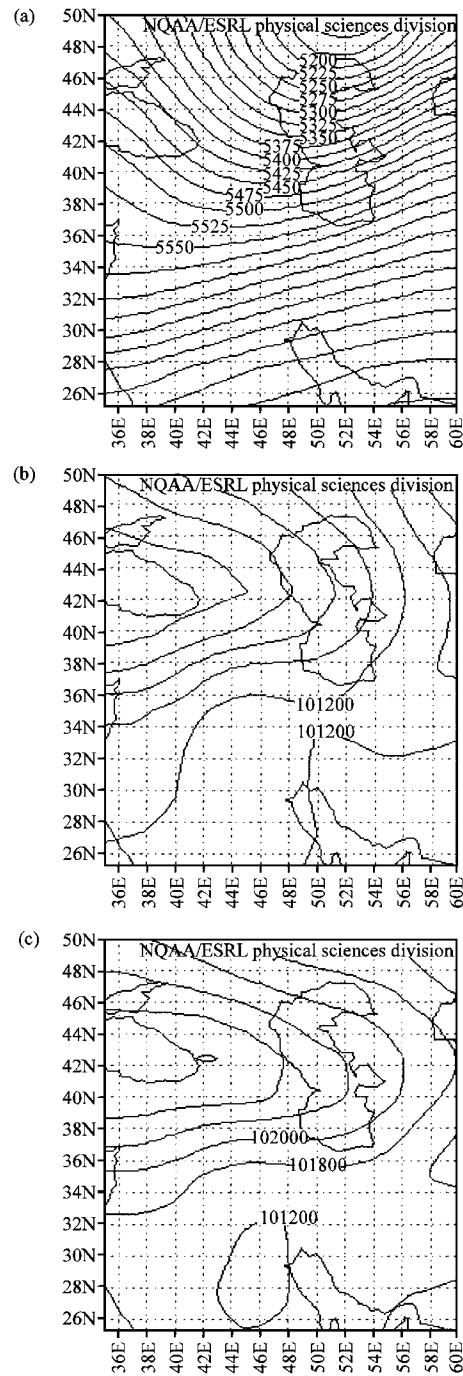


Fig. 6: The synoptic maps of the region on Feb.2st 1996. (a) 500 mb level map for 00:00 GMT, (b) the sea level map for 00:00 GMT and (c) the sea level map for 06:00 GMT. The increase of the trough axis curvature leading to energy and atmosphere instability. In this map it is seen that a Rosby wave decomposes to two waves with different domains and velocities

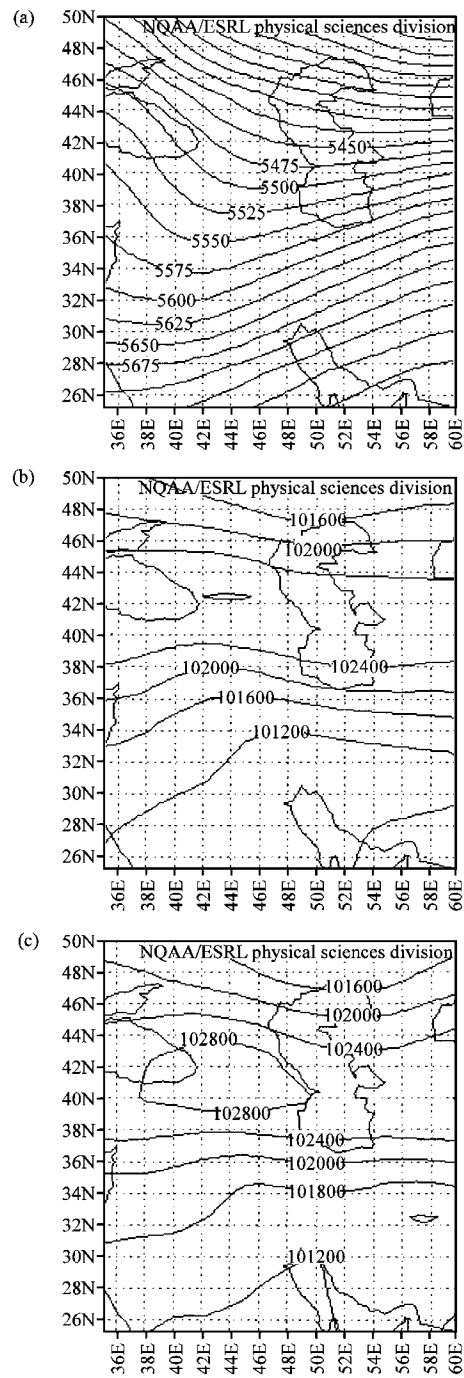


Fig. 7: Same as figure 6. But (a) the 500 mb level map at 12:00 GMT for Feb. 2st. (b) the sea level map for 12:00 GMT and (c) the sea level map for 18:00 GMT

At 18:00 GMT the shifting of a southerly synoptic system shifts to upper latitudes causes a low pressure. The first precipitation as rainfall will be started within the gap 9 h after the beginning of the pressure difference of the two ends of the gap increasing trend.

Actually since then, this trend will be continued up to the time the precipitation changes into rainfall. The snow fall of the initial hours of Feb 2nd is after the complete exiting of northern low pressure from the Caspian Sea. The intensive cold weather will follow it in accordance with the cold weather falling and establishment of high pressure cold air on northern of Iran (Fig. 5).

CONCLUSIONS

The noticeable pressure gradient in the width of Alborz Mountains causes the blowing of intensive winds through Sepeed Rood River valley. The observations show these northerly currents have intensive daily and seasonal changes basically as a result of the both sides of the gap pressure gradient. The existences of considerable velocities in summer days indicate the effects of some factors such as Sea breeze and Anabatic winds. The effects of these factors are less in winter but because of passing meteorological systems in this season the pressure gradient of the both sides of the gap will have instant changes. It sometimes causes the blowing of intensive northerly winds and it occasionally causes the developing of weak southerly winds with the negative ness of the pressure slope. The pressure gradient along the channel as a main factor of creating the flow is made of four components: (1) The large scale pressure gradient, (2) the pressure gradient as a result of slop ness of the channel floor, (3) the pressure gradient as a result the gap current depth changes and (4) the pressure gradient related to sea-land temperature contrast. During the day especially in the afternoons this term makes a strong contribution. Among these four the role of large scale pressure gradient is the most important one.

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