

## The Relation Between Jet Stream Location and Cyclones Over the Western Iran

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**Abstract:** Daily rain data for the selected stations were obtained from the Meteorological Organization of Iran for the 1985-1999 period. The consecutive rain days of length 1 to 5 days and widespread over the study area were extracted. The jet tracks and speed surges were extracted from the daily weather maps of IRIMO for the 54 selected rainy periods. The results showed that the wind speed does not affect the rain intensity. The jet tracks show negative curvature during the non and low rain days but strong positive curvature during the maximum rain day. The establishment of a deep trough during the intensive rain days caused the jet tracks to concentrate close to the study area.

**Key words:** Jet streams, precipitation, Iran, relation between jet streams and rainfall, synoptic systems

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### INTRODUCTION

Jet streams are very important factors in the climate of an area. They develop and steer the pressure systems and hence control the weather and climate. Winds with speeds exceeding 30 m sec<sup>-1</sup> are called jet stream<sup>[1]</sup>. Jet streams exist as concentrated speed surges embedded usually in the westerly currents. The two Polar Front Jet streams (PFJ) and Sub Tropical Jet streams are well known. The PFJ embedded in the mid to upper tropospheric westerlies, 500 to 300 hPa levels. It is very variable in characteristics. It gains its energy from the thermal contrasts of the earth surface and hence forms mostly over Polar Front. The Polar Front Jet stream through the vertical motion controls the development of surface pressure systems and weather or in long run the climate. On the other hand, the Sub Tropical Jet stream located at the tropopause level over the subtropical region. It is developed due to the conservation of the earth's momentum. Due to its higher altitude, its impact on the climate of the earth surface is not as strong as of the PFJ.

Jet streams have long been concerned by the climatologists<sup>[2]</sup>. Harman<sup>[3]</sup> has done a lengthy work about their location in the westerlies. He has defined the jet location according to the monthly frequency of the daily wind maxima during the 1946-1987 period for the four mid season months of January, April, July and October. According to him the polar front jet surge is in its southern most location during the winter months over the Persian Gulf. Greci<sup>[4]</sup> has studied the height, direction and other characteristics of the jet streams.

Ziv and Paldor<sup>[5]</sup> have studied the relation between thermal variables and the location of the jet surges and determined the divergence and convergence locations accordingly. Conaty<sup>[6]</sup> studied the structure and evolution of extra-tropical jet surges, fronts and cyclones in the GEOS general circulation model and thereby described the general circulation. Grover<sup>[7]</sup> correlated the fall precipitation of the Great Lake basin to the upper level flow pattern and indicated the role of upper tropospheric subtropical jet. Yang *et al.*<sup>[8]</sup> studied the relation between the climate of Asia, Pacific Ocean and North America and the jet of the eastern Asia. Cutlip<sup>[9]</sup> tried to establish the relationship between the drought episodes and water availability and the form and location of the jet stream over the Canadian prairies.

O'Driscoll<sup>[10]</sup> investigated the location of jet stream surges during the El Nino and La Nino years over the United States of America. Weisman<sup>[11]</sup> studied the relation of jet stream location and the inverted trough over the United States. Kraus<sup>[12]</sup> studied the jet streams over Britain.

Jet streams alone or in relation with precipitation are not concerned much in Iran. Few works<sup>[13,14,15]</sup> have dealt with jet streams over Iran. On the other hand some works have been carried out regarding the relation between precipitation and pressure systems<sup>[16,17,18,19]</sup>.

Therefore it seems important and necessary to study this very important phenomena over Iran This object is achieved through analyzing the relation of jet maxima with daily precipitation over the western part of Iran.

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**MATERIALS AND METHODS**

In order to achieve the objects of the study, daily rainfall data of seven synoptic stations over the western Iran (Fig. 1) during 1990-1999 period were obtained from Iranian Meteorological Organization (IRIMO) in the quality controlled format. The selected stations are located within the area between 45° and 24' E to 48° 30' E and 32° N to 35° 15' N. The reason for the selection of this area is its location on the windward of the Zagros mountains across the westerlies. Because of this location the area experiences many westerly systems during the colder season. The area receives about 400 to 600 mm annual rainfall.

From all of the rain days only days having rainfall at all stations were selected. These rainy periods counted up to 60 periods. The availability of weather maps at the IRIMO limited the study only for 54 periods. These 54 periods consisted of 177 rain days. The 12 GMT daily weather maps were analyzed at the 500, 300 and 200 levels. The jet stream tracks are drawn on the maps and jet speed was estimated from station wind speeds. The jet surge was defined as the wind speed exceeding 30 m sec<sup>-1</sup>. The jet track was extracted from the weather maps and drawn on a separate sheet. On the days with two tracks over the map only the one closer to the study area was extracted.

To proceed the work faster and make it more precise the maps were digitized using ARC/INFO and R2V soft-wares and GIS techniques.

The maps were analyzed from 2 days before rain until the end of the rainy period.

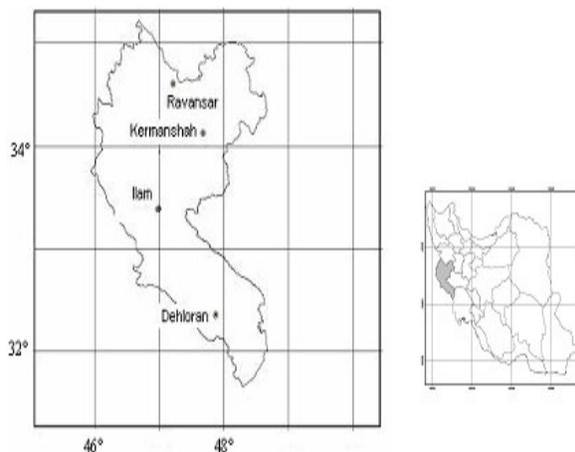


Fig. 1: The location of study area associated with studied synoptic stations

**RESULTS AND DISCUSSION**

**Rainy periods:** The monthly frequency of rainy periods are shown in Table 1. According to this table the winter months experienced the most rainy periods while summer had the least numbers. More interesting is the highest precipitation during the transitional months of March and November. This indicates that during the colder winter months the relatively cold air masses crossing the area contain less moisture. The length of the rainy periods is shown in Table 2. The 2 and 5 days periods are frequent while one day periods are very rare. That is, most of the systems coming to the area are medium to long lasting synoptic systems that can cover vast areas. The short systems rarely produce rain over vast areas.

**Jet location:** Analysis of the maps showed that the jet surges are well shown at the 300 level than the 500 hPa level. Therefore here we present the 300 and 200 levels. Jet tracks were analyzed for rain day runs separately. The mean speed and meridional curvature of jet tracks are shown in Table 3. The wind speed does not show any specific pattern during the rainy period. The correlation between rain amount and wind speed was drawn in Fig. 2. There is no significant correlation between these two variables. But the track curvature shows good indications. During the non rainy days and low rain days it is usually negative but during the maximum rainy day it is completely positive. That is during the low and non rainy days the jet curves anticyclonically but during the intensive rain days it

Table 1: Selected synoptic system in the different months

Months	No. of systems	Precipitation total (mm)
Jan.	6	1990.2
Feb.	8	1953.6
Mar.	8	2546.5
Apr.	6	1296.9
May	3	694.6
June	2	39.9
July	1	54
Aug.	0	0
Sep.	0	0
Oct.	3	688.1
Nov.	8	2864.8
Dec.	8	1431.4

Table 2: Selected synoptic system based on No. of precipitation days

Precipitation periods	No. of systems	(%)
1 days	4	7.55
2 days	15	28.30
3 days	8	15.10
4 days	11	20.75
5 days	15	28.30

Table 3: Statistical characteristics of studied systems based on precipitation periods

Systems	Days	Precipitation (mm)	Meridian movement rate (degree) 200 hPa	Speed average (knot) 200 hPa	Meridian movement rate (degree) 300 hPa	Speed average (knot) 300 hPa
5 days	2 days before	0	-0.15	86	0.95	98
	Start day	5.87	-1.20	99	0.26	91
	Maximum day	26.10	3.40	109	3.7	94
4 days	2 days before	0	0.47	127	0.95	88
	Start day	8.16	0.002	117	0.26	98
	Maximum day	27.50	4.63	118	1	102
3 days	2 days before	0	2.81	105	0.03	86.5
	Start day	2.80	0.17	104	1.3	96.9
	Maximum day	17.70	3.16	116	2.81	90.6
2 days	2 days before	0	0.84	109	1.89	89
	Start day	10.99	2.45	102	4.43	93
	Maximum day	20.10	2.55	115	2.99	90
1 days	2 days before	0	-2.20	104	-1.9	120
	Precipitation day	8.40	2.03	98	0.75	95

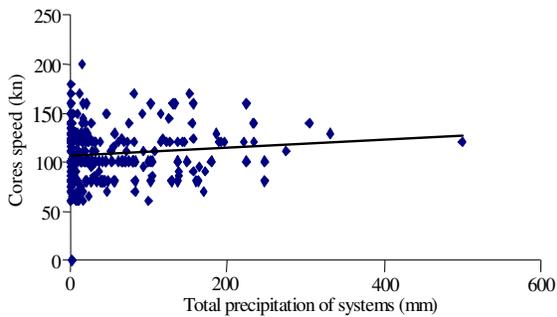


Fig. 2: The relation between cores speeds (knot) and precipitation value (mm) in 200 hPa level

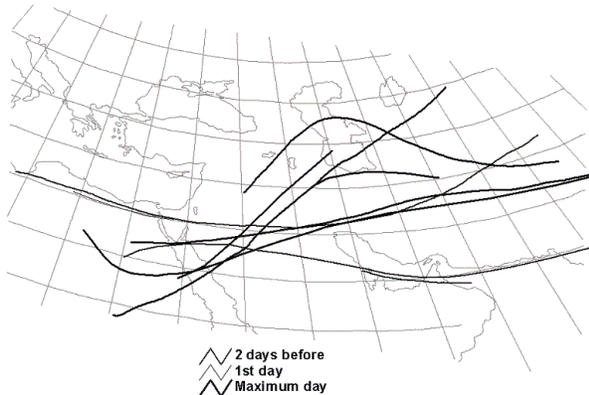


Fig. 3: Typical jet stream tracks of studied systems based on precipitation periods in 200 hPa level

curves cyclonically. These results are well documented with the plots of Fig. 3 and 4. Figure 3 shows the jet tracks at the 200 hPa level. According to this figure during the non and low rain days the tracks show zonal or anticyclonic path over the area. But during the day of

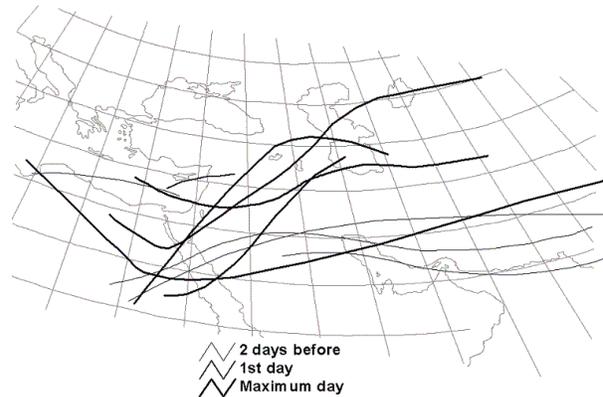


Fig. 4: Typical jet stream tracks of studied systems based on precipitation periods in 300 hPa level

maximum rainfall all tracks indicate a southerly path and cyclonic curvature. The cyclonic curvature is very strong at the 300 hPa level. This level indicates a very deep trough over the eastern coast of the Mediterranean Sea. This is in complete agreement with the findings of Alijani (2002a). Speed surges were plotted in Fig. 5 and 6. In both levels the speed surges are very scattered during the non and low rain days. But they are concentrated in the northeast of Red Sea and south of the Caspian Sea. This means that during the days of maximum rainfall the speed surges and jet tracks are located over and close to the study area. That is during the intensive rain days the positive vorticity is concentrated over the study area.

In order to substantiate the results of the study, the rainy periods with higher mean rainfall were analyzed separately. Their mean speed and track curvature are written in Table 4. According to this table the curvature is negative during non rainy days and become very highly cyclonic during the maximum rain days.

Table 4: Statistical states of systems with maximum precipitation

Parameters/ systems	Meridian movement rate (degree) 200 hPa	Speed average (knot) 200 hPa	Average precipitation of systems (mm) 200 hPa	Meridian movement rate (degree) 300 hPa	Speed average (knot) 300 hPa	Average precipitation of systems (mm) 300 hPa
2 days before	-2.11	112	0	-1.48	96	0
Start day	2.52	111	13.93	2.25	106	13.93
Maximum day	5.20	113	27.80	4.16	101	27.80

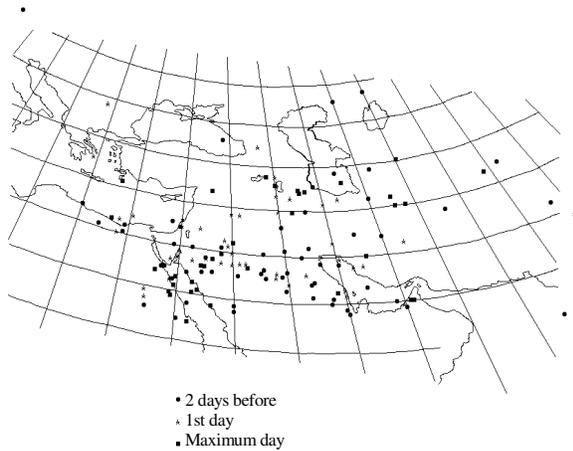


Fig. 5: Jet stream cores of studied systems in 200 hPa level

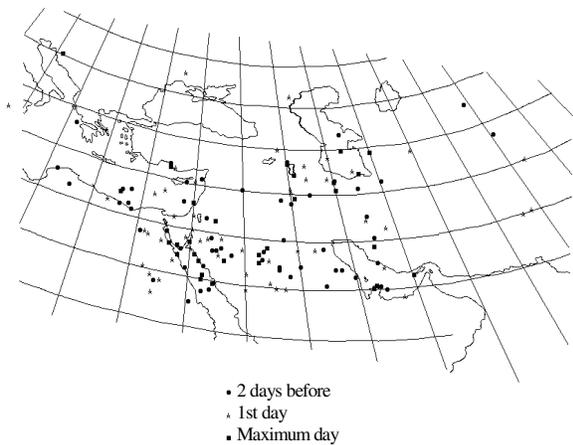


Fig. 6: Jet stream cores of studied systems in 300 hPa level

### CONCLUSION

In order to understand the relation between the jet characteristics and precipitation over western Iran, the daily tracks of jet surges during the rain periods were extracted from the maps of 300 and 200 hPa levels and

mapped for each rainy period. The important findings of the study are:

- Most of the rainy periods were long lasting and widespread. The short periods especially one day were rare. This indicates that widespread and long rains are of synoptic origin. The short ones usually are local
- During non and low rainy days the jet tracks were farther from the area and the jet surges were scattered. But during the intensive rain days the tracks were close to the area and had positive curvature. The upper flow pattern had developed a deep trough on the east coast of the Mediterranean Sea
- The wind speed beyond the jet threshold did not show any significant relation with the precipitation intensity
- The positive curvature of the jet tracks is very important factor in rain producing process over Iran

This study is in fact an introductory work and we hope that it will trigger the detailed work of the subject by utilizing the digitized data and sophisticated computer techniques.

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