The impacts of flood warnings on flood damages in Iran

There are some reports related to flood monitoring and it's effect Particularly important has been surveys of those to whom flood warnings have issued, designed to determine the actions that they were able to take, the damage that was thereby averted, and the factors that affects this (including flood warning lead time, the availability of assistance with moving vulnerable household goods, etc.).

The following equation has been developed (Parker, 1991)

$$FDA=PFA\times R\times PRA\times PHR\times PHE \quad (1)$$

Where

FDA: estimated actual flood damage avoided owing to the flood warning;
PFA: potential flood damages avoided (property plus road-vehicle damages avoided);
R: the reliability of the flood warning process;
PRA: the proportion of residents available to respond to a warning;
PHR: the proportion of residents able to respond to a warning;
PHE: the proportion of households who respond effectively.

Reflecting the perceptive analyses of disaster research pioneers such as Williams (1957), three conclusions may be summarized that document why flood warnings must be viewed as networks of social processes:

1. Even though several persons may listen to the same warning message, there may be considerable variation in what they hear and believe.
2. People respond to warnings on the basis of how and what they hear stimulates them to behave.
3. People are stimulated differently depending on who they are with, are who they are with, and who and what they see (Mileti, 1975)

Four sub processes were identified; each of these is made up of four additional sequential actions (adapted from Rogers, 1989):

1. Hazard detection
    - Initial detection of hazard
    - Released hazard information
    - Public alert and notification
    - Return to normality
2. Hazard assessment

- Initial assessment
- Peer assessment
- Non-peer assessment
- Public assessment

3. Communication

- Initial communication
- First responder
- Response organizations
- Confirmation

4. Behavior selection

- Immediate response options
- Protective action decision – making
- Response selection
- Public response[9]

National Flood Early Warning System in Iran

Flood hazard and disaster in the I. R. of Iran is one of the most frequent and damaging types of natural disasters. They have been the most common type of geophysical disaster in the latter half of the twentieth century in Iran, generating an estimated more than 20 percent of all disasters from 1950 to 2003. One of the hazardous floods of Iran occurred in Golestan and north of Khorasan provinces, located in north-east of the country, on August 2001 and 2002. The floods were worst in 200 years. The damages caused by this disaster have been reported that about US$ 80 Million and more than 300 people have been died, for 2001 flood. The damages for 2002 flood are recorded about US$ 10 million and 30 people have been died. In this regard, according to the responsibility of I. R. of Iran Meteorological Organization (IRIMO) on the flood forecasting, the early warning issue of the mentioned flood, issued within 48 hour's in advance. Studies show that not only frequency but also intensity of floods have been increased during recent years. Even more important was the fact that the flood of August 2001 exceeded the estimated Possible Maximum Flood (PMF) by more than 20%. This is while when a good cover turns into a poor one; its absorption decreases by 7 times and its potential for producing runoffs and floods increases up to 30 times.
Flood risk mitigation measures aim at modifying either the flood producing processes, or the flood hazards, or exposure and vulnerability to flooding. The analysis and response to flood risk needs to be integrated in a systemic manner: that is to say, in a manner that recognizes all the factors present in natural hazard systems and their interactions. A guideline for integrated flood risk management was established, in our country. It is covered land-use regulation; the integration of structural and nonstructural measures; the integration of flood risk management plans with related plans; and recommendations on inter-provincial cooperation on flood risk management.
Based on the above-mentioned components, the National Flood Early Warning System in I. R. of Iran (NFEWSI) has been designed and introduced to the government, and it is on operation in the country from 2000. Flowchart of the NFEWSI has been shown on Figure 13, where the NFEWSI consists from three main parts: 1. Observation, 2. Forecast and Warning Issue, and 3. Response. First of all, the daily Meteorological and Hydrological Observation data of National Networks (IRIMO and Water Resource Investigation (WRI)), as well as the data of Global Observing System (GOS), are collected at Automatic Switching System (ASS) of IRIMO. Next, the National Forecasting Center (NFC) of IRIMO issues the daily Forecasts and Warning, using the data of ASS, and also the data of National Climatic Data Center (IRIMO-NCDC). Then, the flood early warning issue is distributed quickly to Media, NCNDR, and Regional Departments of IRIMO. The mentioned system, NFEWSI, is based on
mitigation and preparedness of all society's sectors, in advances[1].

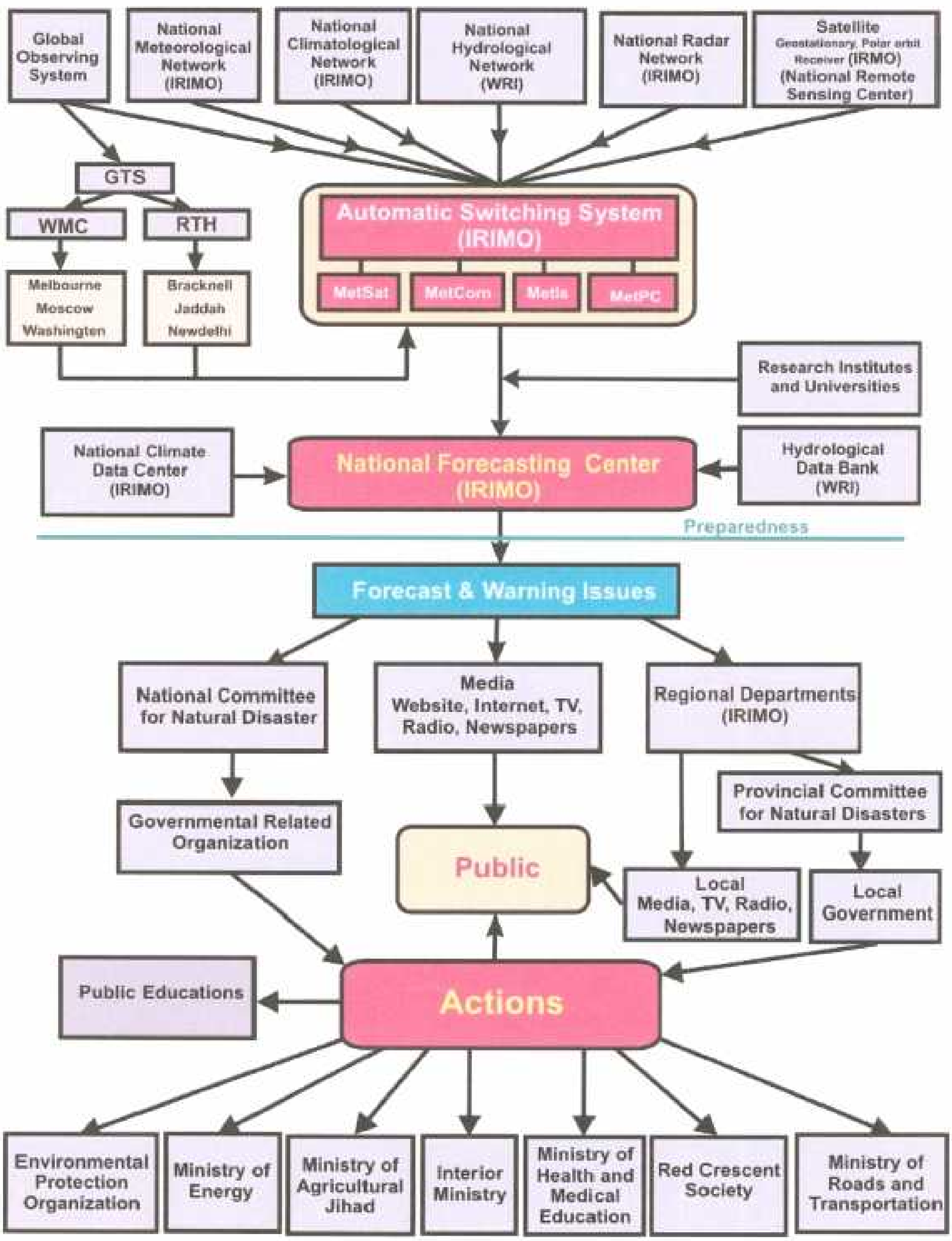


Figure 13: National Flood Early Warning System in I R. of Iran (NFEWSI), Source: IRIMO (2001) and CRI, (2002)[1].

All collected meteorological observation data from IRIMO networks, where the data are quality controlled, will be included to the IRIMO computerized data base. IRIMO database contains more than 27,000,000 data records since 1920, providing requested information for different end users, and support research projects in national and global level. In addition to weekly, monthly and seasonal publications, precipitation analysis are issued in this center and provided to applicants. Besides, hydrological observation, included of surface water and groundwater resources in the country, having interrelated their monitoring and assessment activities have been combined and placed within the WRI under the Ministry of Energy. The hydrological observation network consists of observing water levels stations (Class A, B and C), ordinary rain gage, and storage rain gage.

The NFEWSI has been applied during the already mentioned two heavy floods, where have been occurred in the north of Khorasan and Golestan provinces during August 2001 and 2002. Heavy summer rainfall in the northern belt of Iran begins from early July to August. During the summer, due to the northward displacement of Inter-Tropical Convergence Zone (ITCZ), the seasonal low pressures can develop over Iran. In the normal conditions the seasonal low pressure increases the maximum temperature and injects humidity to the northern mountains of Iran. The source of humidity is the Oman Sea, Persian Gulf and Indian Ocean, if a high pressure exists over the Caspian Sea. During a strong low pressure on the central of Iran, the air flow becomes northerly, so the humidity of Caspian sea moves toward the Alborz mountain. According to the recent researches, heavy summer rainfall and flood in Iran are produced by interaction between maximum heating level (it is around 700 hpa and the level that latent heat can be released) and baroclinicity of the surface level.

Based on the synoptic pattern of flood events on August 2001, there was a seasonal low pressure over south side of Alborz, and a high pressure over northern side of Alborz Mountain. At the same time, over Pakistan and Saudi Arabia, there are two heats low. The existence of low pressure over south of Alborz mountain and high pressure over north of it, can produce a heavy frontal zone over the east of Alborz, including Golestan province and north of Khorasan. The effect of mountain on the heavy rainfall is very important, because the humid air can slide over the mountain and rapidly reaches to the Lifting Condensation Level (LCL) and then produces a large amount of latent heat, and after a few minutes convective clouds cover whole of the area. On the 500 hpa pressure chart, there was a weak trough over the north-eastern of Caspian sea. The mentioned trough can bring the northerly cold flows to the north-eastern of Iran, and then it produces condensation process very rapidly. The amount of precipitation during the August 2001 event is reported by climatologically network, and in some of them the precipitation was more than 200 mm.

On the other hand, the synoptic pattern of flood on August 2002 is also very similar to the same pattern of August 2001. A humid warm air comes from south (Indian Ocean, Persian Gulf and Oman sea) and a northerly cold air comes from north of Caspian sea. The interactions of these two different air mass cause a frontal zone on the north of Iran.

Based on the report of the NCNDR (2001 and 2002), the estimated social and economic damages during the mentioned flood disasters could be very more than reported value, if there was no operational NFEWSI. For example, the number of died people for 2001 flood was estimated around 7000 people, if there was no early warning issues of IRIMO. In the respect of the successful experience of the NFEWSI, it is going to be an operational system for all parts of the country[1].

Hydrological Observation

Systematic monitoring of the surface water resources of Iran began in 1945, although measurement of flow in the Karun River began in 1982. Fairly accurate data were also collected for the Karkheh and the region around Tehran. A surface water department was set up in 1945 within the independent irrigation corporation. Hydrological data collected by it were used in various development projects, such as construction of 14 storage dams and 34 flow diversion and regulation dams. Surface water and groundwater resources in Iran having interrelated their monitoring and assessment activities have been combined and placed within the Water Resources Investigation (WRI) under the Ministry of Energy.
WRI is responsible for the planning and supervising of water resources data, surface water, groundwater and meteorological data necessary for water resources assessment. 14 Water (and Power) authorities are responsible for the execution of the programmes of the Ministry. The largest water authority is situated in Khuzestan.
WRI is divided into three departments:

- Surface Water Department;
- Groundwater Department; and
- Data Analysis and Coordination Department; 5 Branches (Mathematical modelling, Hydrological and hydro geological atlases, Experimental and representative basins, Hydrological forecasting and warning stations, Artificial recharge of groundwater)[9].

Objective

Flood survey and forecasting

The only forecasting activity at the Ministry of Energy is for irrigation planning during the crop season. The basic for this type of forecasting is snow surveys in the upper parts of the catchments performed during the winter; typical rainfall patterns selected from historical records (wet, dry and average years) and estimated water demand for different purposes in the inhabited and cultivated parts of the river basins. The influence of snowmelt is estimated from typical temperature variations and degree-day type of snowmelt models. Reservoir operations are simulated with models like HEC-3 and the final results are forecasts of shortages in the water supply during the crop season. All hydrological modelling make use of purchased software packages and no model development and programming activities in this field is performed. In addition to the already mentioned use of HEC-3 for reservoir simulations, hydro geological modelling is also represented. This modelling is based on finite difference methods and is used to forecast the changes in groundwater aquifers caused by human activities (groundwater retrieval, etc.) and climate variations.
Protection Service to other levels like communities, districts and other administrative bodies in accordance with flood planning and under a supervision of flood authorities (see Figure14).

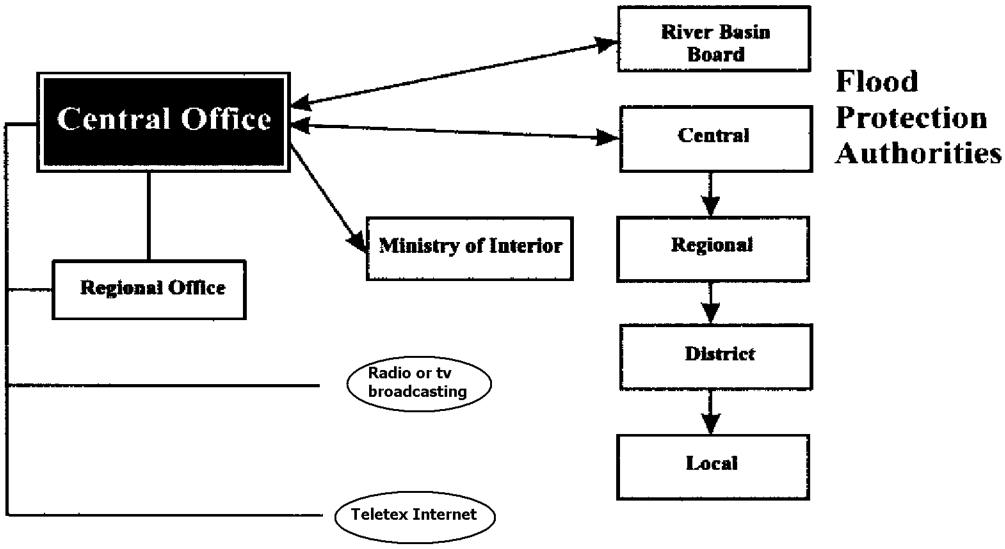


Figure 14: flood Forecasting and Warning System in the I. R. of Iran
Source: NCNDR, 2002

Central Flood Authority operated by the Ministry of Environment is always warned directly from IHMI. It can be seen that the system ensures delivery of warning up to local levels where a newly built Integrated Rescue System (IRS) will be used with an advantage.

The main purpose of the flood warning a forecasting system is forecasting of flood activity at various levels of flood danger with a sufficient lead-time.

Forecasts and warnings are used for timely information of flood authorities, River Board dispatchers, and property owners and also for warning of population and institutions responsible for people safety. However, in the urgent cases of flood danger and necessary to warn population in regions very quickly warnings from IHMI can be passed directly to people by means of public radio, television, Internet and other media. This possibility has been included in agreements between IHMI and above-mentioned media. Organization of flood forecasting and warning service is shown in Figure 15.

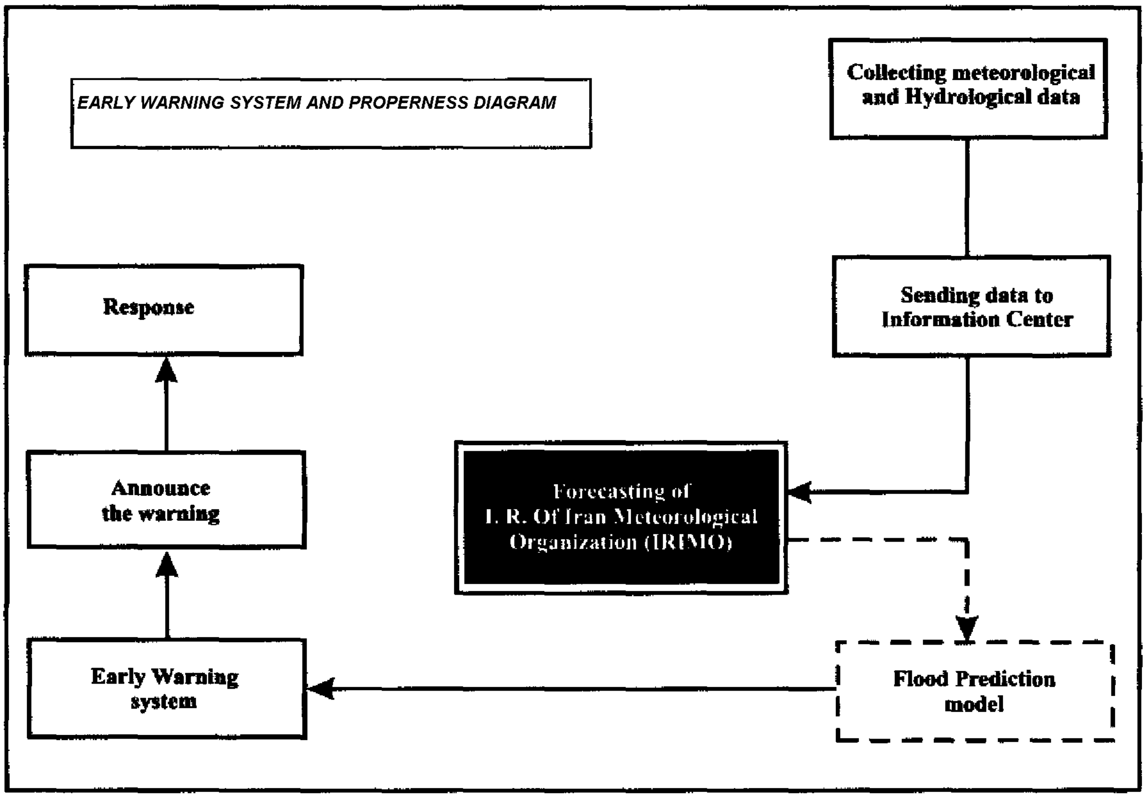


Figure 15: Early Warning System and Preparedness Diagram Source: NCNDR, 2002

This integrated Flood Forecasting and Warning System operated by IHMI (National hydro meteorological service) is based on a multi-sensor observation input (precipitation, river flow etc.) containing modern observational instruments like weather radars and satellites. Moreover, the system will use routinely numerical weather models to be able to forecast heavy precipitation and consequent floods with longer lead-time. Very important is also hydrological part utilizing hydrological models and potentially GIS images in the last stage. Development of hydro meteorological part of the system has been coordinated with activities of rivers and also in a co-operation with specialists from other countries.

The new system has been under stepwise development and will be finished within 2 years and will involve or changes and amendments in control and compete ncies connected with forthcoming new law for crisis management and IRS.

Similar Early Warning System has also been applied to other hydro meteorological risk (severe storms, frosts and other weather extremes) and also in the case of predictions and warnings for smog situation. The I. R Iran has also built a special warning system used in the case of nuclear accident –in this case the state office for nuclear safety has been the highest component authority. The system utilizes results of a continuous measurement radioactivity network together with predictions of trajectories and contamination dispersion. Results of radioactivity measurement and also warnings have been continuously disseminated to neighboring countries.

Finally, it is necessary to mention another important factor- training of population to react properly under emergency situations like floods. According to experience from the last flood in 1997 year the lack of training and poor knowledge of people about proper behavior and response under flood conditions had a strong influence on number of victims during this event.

About the Golestan Province

Golestan gained provincial status and were declared the twenty-eighth province of Iran after the 1996 parliamentary elections.
The province of Golestan is among the fertile regions of the country, with vast potentialities in terms of waters resources, soil and agricultural products.
Situated on the southeastern the Caspian Sea (the largest land locked body of water in the world), Golestan province covers an area of 20891 sq kms. This province is bounded on the northwest by the Caspian Sea, on the east by Khorasan province, on the west by Mazanderan province, on the south by Semnan province and on the north by Turkmenistan.
The high Alborz Mountains, sealing off the narrow Caspian strip, trap humidity and create a mild humid region with luxuriant forests and swamps. Golestan Province is one of the most humid regions in Iran.
The rivers are numerous; most of them originate in the Elborz Mountains. Gorgan Rude and Atrak, are among the largest reveres in Golestan province, originate in the eastern Alborz mountain range, flowing into the "Dashte Gorgan & Gonbad" Steppe Block and then to the Caspian Sea. The " Dashte Gorgan & Gonbad" Steppe Block is quite flat and open, broken up by hills and river valleys. Other important rivers are the Siah ab (Qaresu), Madar ab and Sepid band.

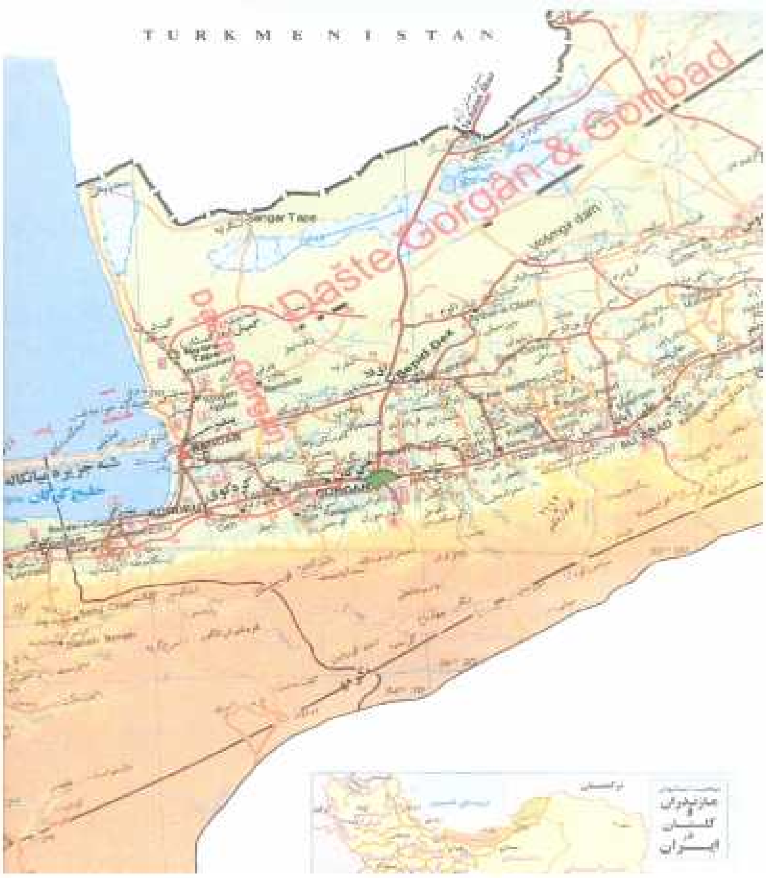
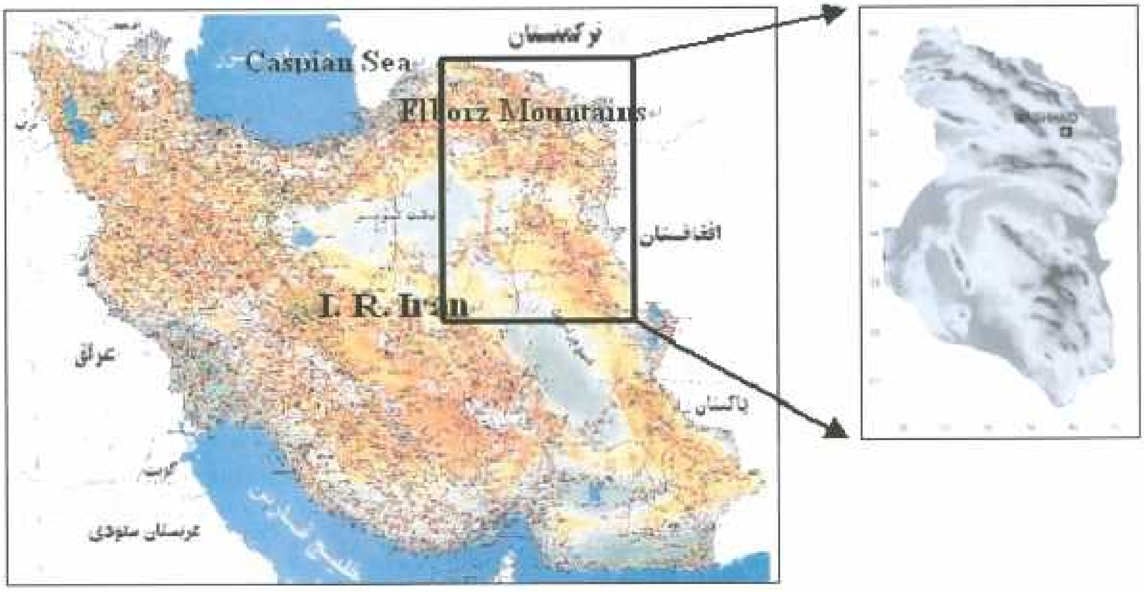


Figure 16: Golestan Province of Iran

Summer time rainfall mechanism of Golestan province

During the summer season, warm and humid air of the Oman Sea and Indian Ocean influence the southern barrier of Elborz Mountains. In the same time, strong northerly cold currents flows to the northern barrier of Elborz Mountains and into north-south channel of Dasht area, located between Khorasan and Golestan provinces. Mentioned condition cause a convective instability in accompany with heavy rainfall. Three type of synoptic patterns have been introduced for development of heavy rainfall of the northern parts of Khorasan province and eastern area of Golestan province, located on the north east of Iran: upper level trough, twin surface pressure systems and composed jet-streams [3].



Figute 11

Synoptic features

Synoptic features of the 16 HV/FF events have been categorized in three groups: twin surface pressure systems, upper level trough and combined PFJ (Polar Front Jet stream) and STJ (Subtropical Jet stream) jet streams. We didn't find any specific pattern for two remaining events. So we ignored them as heavy rainfall events.

Twin surface pressure systems: There were 8 HV/FF events in this group, about 44% of total events [3].

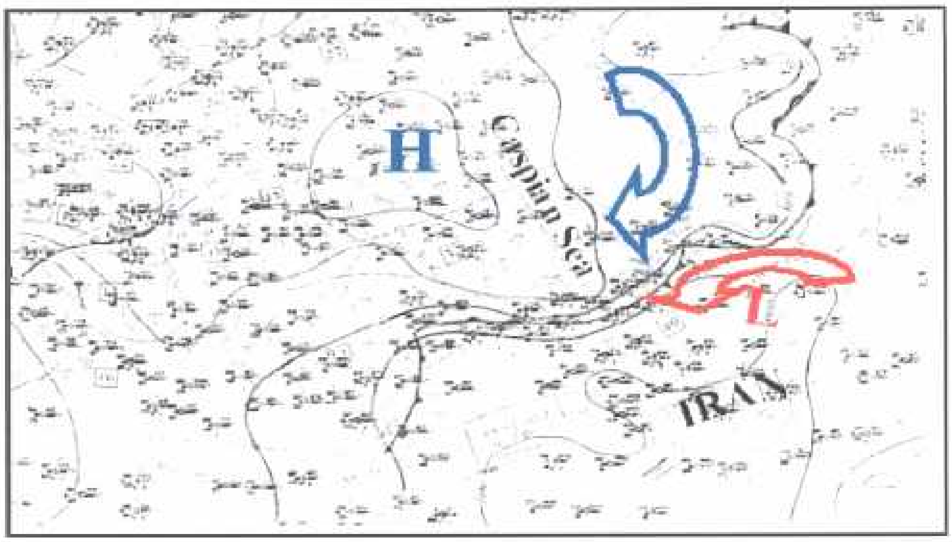


Fig12 Mean sea level pressure pattern in a twin surface pressure system [3].

Twin surface pressure system can be defined as a feature with a high pressure that extends from Caspian Sea upto northern part of Khorasan through northern barrier of Elborz Mountains and a thermal low pressure originating from Oman Sea and Indian Ocean during a strong Indian Monsoon. This regional thermal low covers all of the central desert of Iran, called Kevir desert. High temperature gradient produces during the settlement of a cold air on the north and warm and humid air on the south of Elborz Mountain. Temperature gradient causes baroclinic instability in this region. Convective cells form during the frontal zone because of large amount of released latent heat. Fig.12 shows a typical pattern of twin surface pressure systems

Upper level trough: The second frequent pattern is upper level trough. Five cases of the 18 are categorized in this group, about 28% of total events. It can be defined as existence of an upper trough over north east of Iran. This pattern usually occurs during late spring and early spring, but sometimes it can be occurred on the summertime. In this case a weak northerly surface current over Caspian Sea is necessary for development of heavy rainfall. Fig. 13 shows typical pattern of upper level at 500hpa associated with a heavy rainfall event in summer [3].

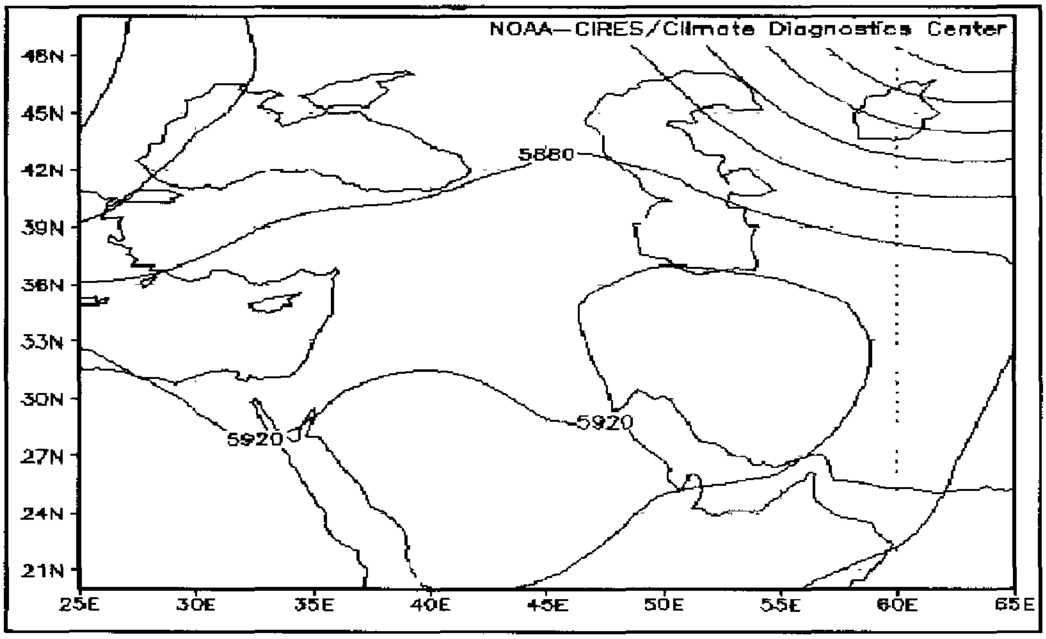


Fig.13 500hpa pattern of an upper level trough during a heavy rainfall in summer [3]

Combined PFJ and STJ jet stream: Defined as combination of a polar front jet stream and subtropical jet stream over the east of Caspian Sea and east of Turkmenistan. 3 events were associated with this pattern, about 17% of total events. In this case polar front jet stream will penetrate to lower latitudes, near 38o of north. Fig.4 shows an example of combined PFJ and STJ pattern associated with heavy rainfall.

Due to high temperature gradient between the cores of PFJ and STJ in the upper level, a frontal zone develops over northeast of Iran. Heavy hail occurs in this case and causes enormous agricultural losses [3].

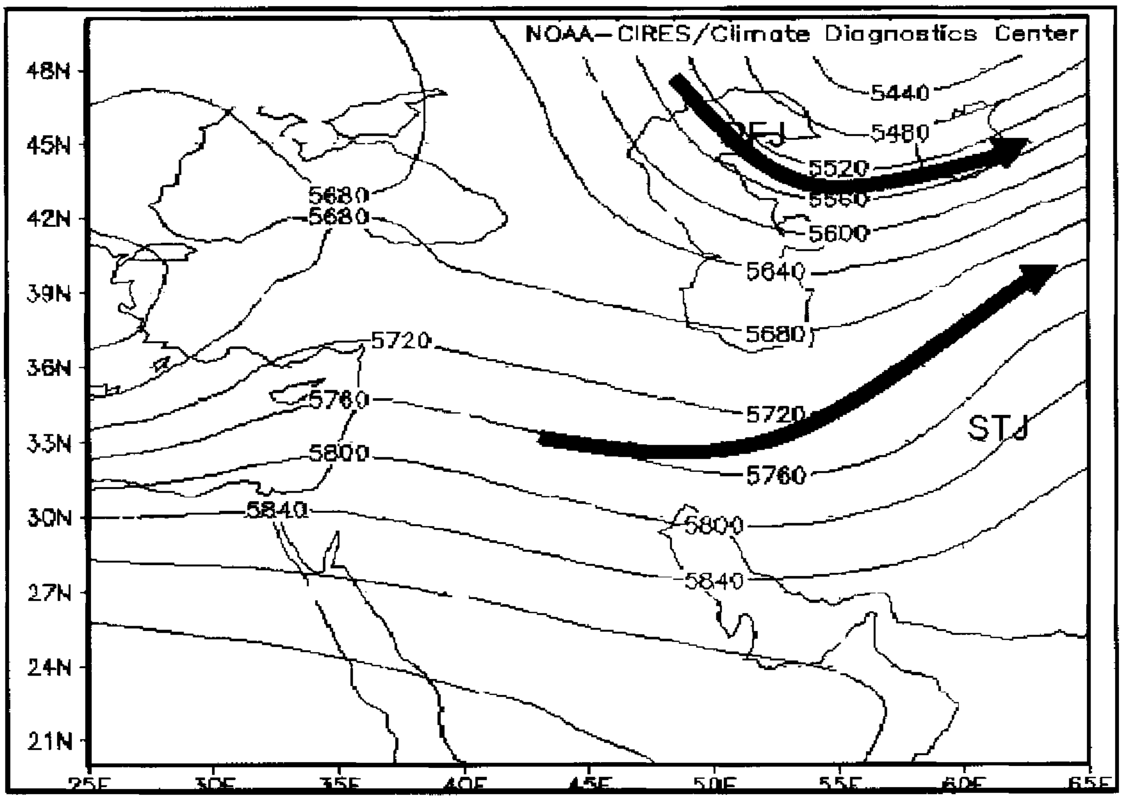


Fig14 Typical feature of 500hpa chart during composed PFJ and STJ [3].

According to the recent researches, heavy summer rainfall and flood in Iran are produced by interaction between maximum heating level (it is around 700 hpa and the level that latent heat can be released) and baroclinicity of the surface level.

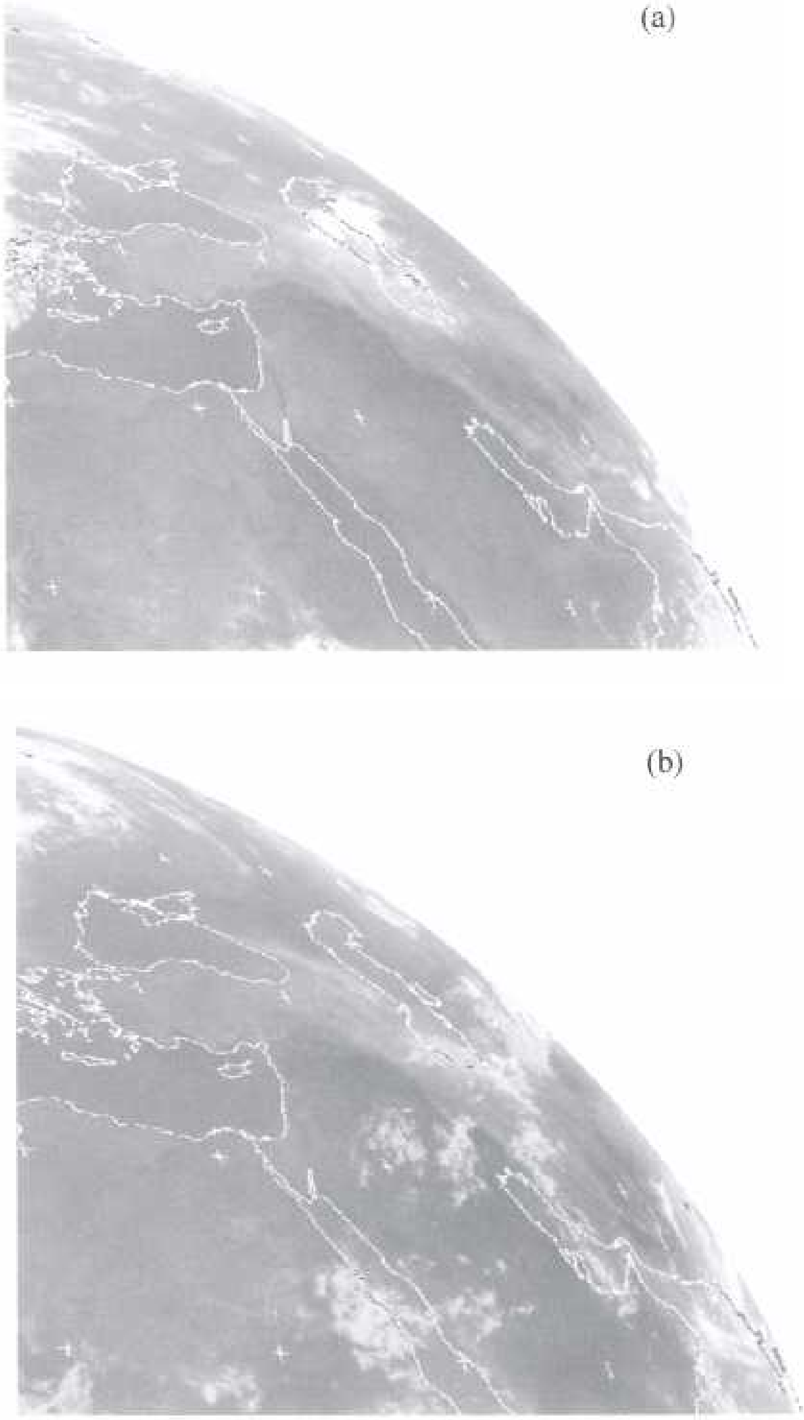


Figure18. Cloudiness of north of Iran during the flood events. a: 11 Aug. 2001, b: A few hours before flood event of Aug. 2002. Source: WWW. Eumetsat.de

Figure3. Shows the synoptic pattern of flood events on August 2001. On the surface pattern (Figure 8a), there is a seasonal low pressure over south side of Alborz, and a high pressure over northern side of Alborz Mountain. At the same time, over Pakistan and Saudi Arabia, there are two heat low. The existence of low pressure over south of Alborz mountain and high pressure over north of it, can produce a heavy frontal zone over the east of Alborz, including Golestan province and north of Khorasan.
The effect of mountain on the heavy rainfall is very important, Because the humid air can slide over the mountain and rapidly reaches to the Lifting Condensation Level (LCL) and then produces a large amount of latent heat, and after a few minutes convective clouds cover whole of the area.
On the 500-hpa chart (Figure 8-b) there is a weak trough over the northeastern of Caspian Sea. The mentioned trough can bring the northerly cold flows to the northeastern of Iran, and then it produces condensation process very rapidly.

The amount of precipitation during the August 2001 event is shown in the Table 3.

Table 3:Amount of precipitation during the flood event of August 2001 in the North of Khorasan province and Golestan.

Station	**Precipitation (mm)**	**Station**	**Precipitation (mm)**
Jajarm	10.0	Tamr	10
Chamanbid	7	Ghuchmaz	68
Robat gharabil	15	Pishkam	50/3
Eshghabad	25	Soufisheikh	26.8
Gharaghavanlu	23.0	Ramian	120
Garmab	5.0	Azadshahr	120
Dashtshad	191	Nodeh	90
Hagholkhaje	57	Tangrah	153
Galikesh	41	Dasht	150
Dozin	41	cheshmekhan	84

Synoptic pattern of the flood events in north of Iran on 12 August 2002 is shown in Figure19-20.

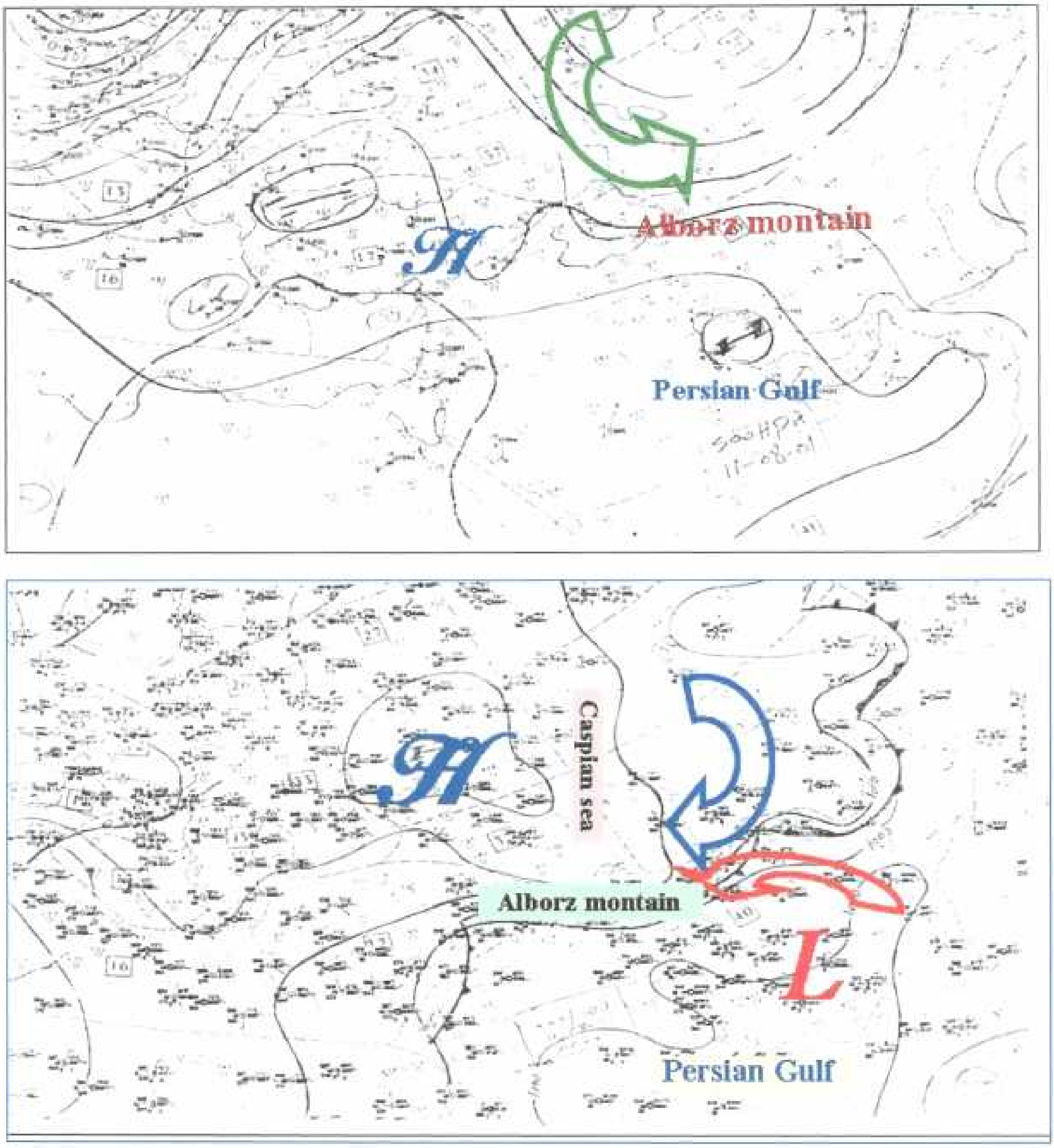
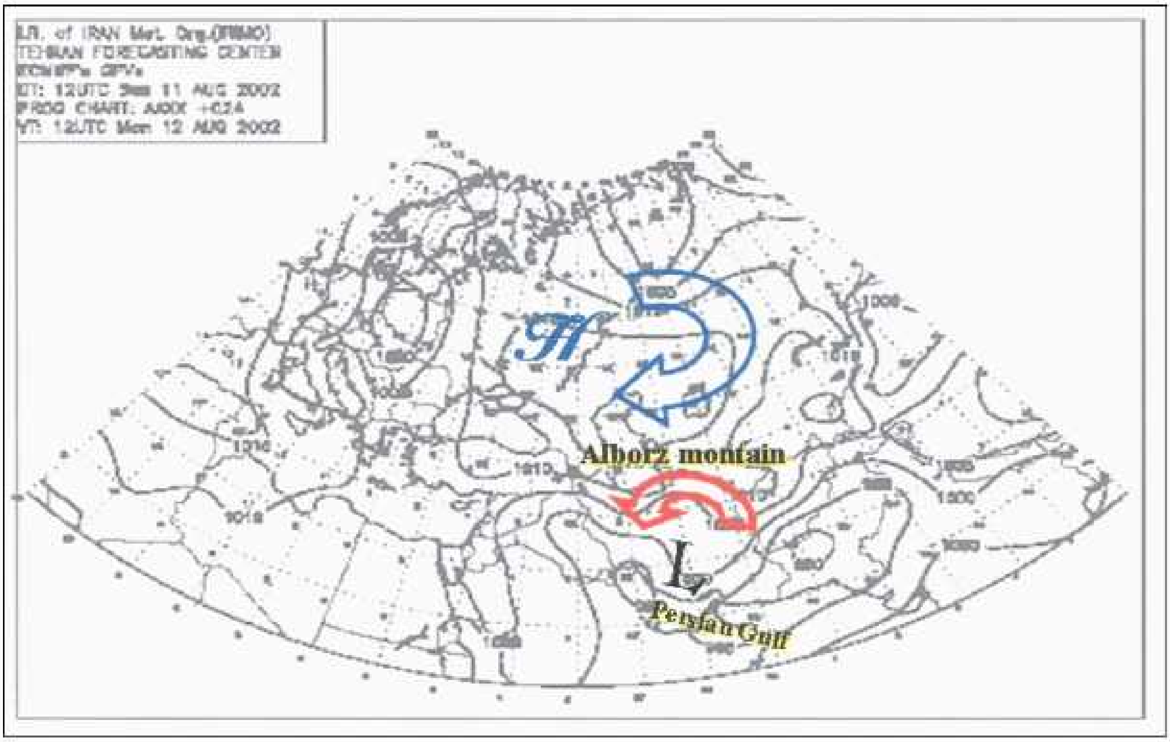


Figure 19. Synoptic pattern of the flood event in the north of Iran on Aug. 2001.A: Surface pattern, b: 500-hpa patterns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TEHRAN FORECASTING CENTER
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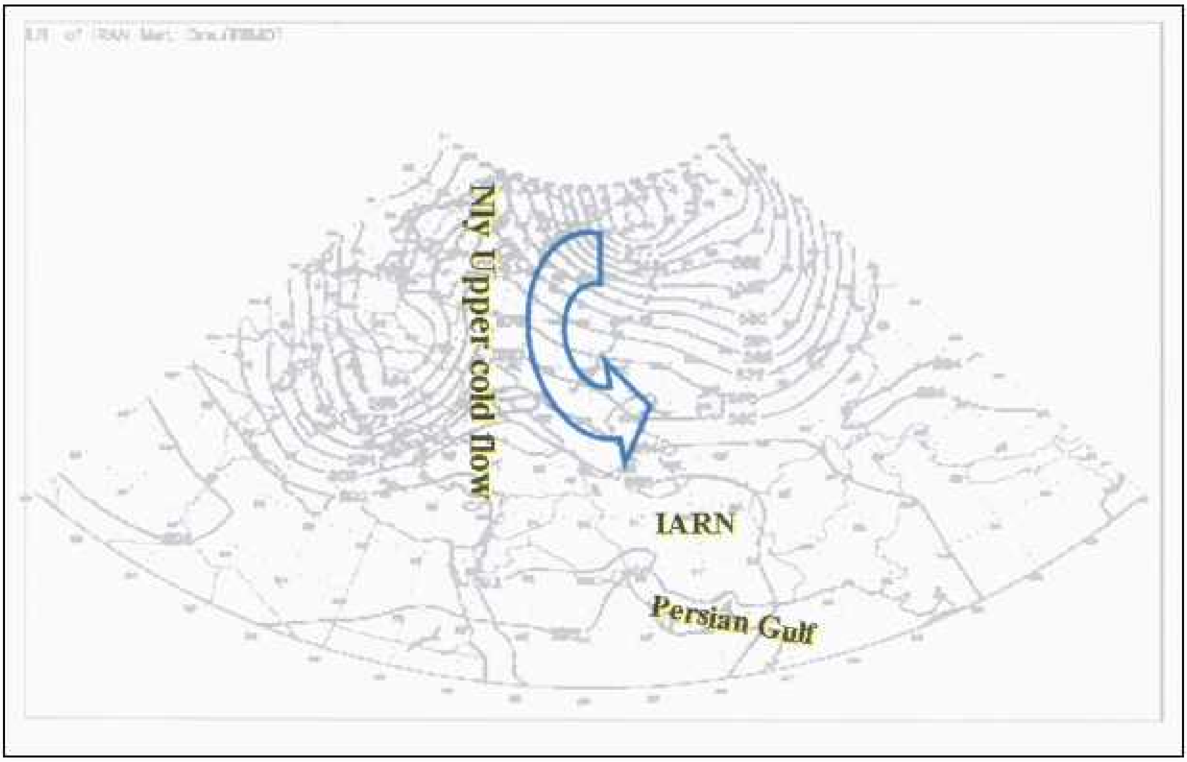
Nly Upper cold flow
IARN
Persian Gulf

Figure 20. Synoptic pattern of the flood event in the north on Iran on Aug 2002. a: 500 hpa pattern of, b. surface pattern.

As it is shown on the Figure 20, synoptic pattern of flood on August 2002 is very similar to the same pattern of August 2001. A humid warm air Comes from south (Indian Ocean, Persian gulf and omman sea) and a northerly clod air comes from north of Caspian Sea. The interaction of these two different air mass causes a frontal zone on the north of Iran.
Amount of precipitation received from selected synoptic and rain gauge station of Golestan province and north of Khorasan are shown in table 4.

Table 4: Amount of precipitation during the flood events of 12 August 2002. in the north of khorasan and Golestan province

Station name	Precipitation
Gharacheshme	67.7
Aliabad	81.5
Masraekatul	77.5
Fazelabad	82.9
Jangalde	89.1
Kiaram	90.2
Galiketsh	132
Malek Aalitappe	66.3
Dasht	60
Cheshmekhan	16