Weather types, their frequency and relation with rainfall in west of Iran

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Abstract: Over time, various places experience different weather; there is even possible and quite tangible some different kinds of weather in a season. In this study, an automated synoptic classification (T S I) with meteorological data of six synoptic stations in the west of Iran has been used, which are exposed to Mediterranean and Sudan systems, in different seasons of the year to categorize each day by its particular category. The used variables include cloudiness (12GMT), maximum and minimum daily temperature, Dew point (12GMT), maximum and minimum daily humidity, dry temperature degree (12GMT), daily rainfall, and u and v components of wind in 1961-2004 periods. After elimination of days lacking data, by creating a P-type matrix, the correlated variables were identified and selected in form of independent components as an objective technique by analyzing principal components, and then a homogeneous collection was extracted from days of record periods in each station under name of weather types by hierarchical cluster analysis (AHC). Afterwards, through evaluating rainfall amount in every weather type and its related days using cluster analysis (CA), isohyets types were identified in west of Iran. Accordingly, 4 isohyets groups were identified in 26 weather types, including high rainfall, very high rainfall, medium rainfall, and very low rainfall. Occurrence time frequency of weather types in stations of the region was studied in terms of presence number of each weather type throughout the each year and as repeated occurrence in each individual day of statistical year (number of presence of each weather type in 1 Jan of all years then 2 Jan and so to 29 Dec) and subsequently their seasonal activity was determined.
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1. Introduction

In fact, Air masses refers primarily to source region but Weather types refers to time formation of those variables or components (days clustering of each station) which play an important role in forming a certain type of its climate. In other words, there is a systematic collection of main elements of weather at different times, and they reflect similar specifications. Repeating these species of weather expresses climate type of a location, and this plays an important role in managerial decisions in long-term behaviorology. By considering the thermal and humidity homogeneity of air masses during their presence in a region in horizontal, it can provide conditions such that meteorological variables reflect special amounts based on their specifications of bottom surface, from geographical latitude and longitude, topography, height from sea level, and distance from humidity sources, at which if different classes of these elements are included in manufacturer climate during time, they can identify weather types. Identification of weather types and studying their frequency of occurrence for identification of climate location is necessary in order to explain reaction of geographical location to air mass duration and there is an appropriate assessment from behavior of surface level. Therefore, any actions consistent with showing different weather types are very important in order to better understand the climate-regulating managerial decisions. The purpose of this study is automated weather type classification in stations in west of Iran, during those days of year when they are exposed to westerly winds and Mediterranean and Sudan systems. Several researches have been carried out in this field, and the related ones will be considered.

Barrera (2002) classified weather types about the flood-generating rainfalls during small frost (1840-1870) in Catalonia. He collected useful information from 10 old cities in Europe and used them in order to study the meteorological floods relation, and then reconstructed synoptic daily surface data with pressure. He used data series of daily meteorological information in Barcelona during 1870-2002 in order to study changes and time of flood events. In total, 62 meteorological events were identified.

The researchers have determined 6 weather types, including southern air flow, northern air flow, western-oriented, cyclonic, anti-cyclonic, and eastern air flow. They found that in the four seasons, southern air flow had assigned the highest abundance with 31 flood events, so it can provide floods in every season and field.

Cheng et al. (2004) executed an automatic synoptic classification method in order to predict snow in Ottawa, Ontario. This study was based on data including temperature, dew point, surface pressure, total overcastting, u and v components of vector wind directions, and snowfall occurrence, as well as 6 hours of upper-atmosphere data in 6 atmospheric levels with network density 2.5˚×2.5˚, including temperature, relative humidity, geopotential height, vertical wind speed, and speed of west-east and south-north winds in all days of winter from 1958 to 1990. Using principal component analysis and cluster analysis based on hierarchical agglomerative style, the input matrix data consisting of 240 variables resulted in synoptic temporal index (TSI), and as a result, 18 principal components were achieved which explained 92% of variance.

In this analysis, thermodynamic variables set aside the most contribution, including temperature and dew point with variance 36%. By clustering factor scores, 13 synoptic groups were obtained with synoptic weather type, which allocated 85% of total days. Finally, these researchers matched these weather types with snowfall days, and then they compared frequency of days with snowfall; meantime they fitted 4 weather types with these conditions by regression model. Afterwards, they used them for predicting conditios in 1991-2001 decade, which showed an appropriate compliance with the initial series of data.

Christensen and Brayson (1966) tested the ability of principal components analysis in order to classify weather types. In their study, they used 15 meteorological parameters with two times of daily observations including dry temperature, wet temperature, more overcasting, pressure, u and v components, etc. They entered the obtained results into multiple regression analysis by analyzing principal components with Varimax rotation, and determined weather types by selecting correlation threshold as 0.7.

The studied data had a four-year duration (1955 -1958) for January, and five year duration (1954 -1958) for July. Each type of features was studied according to mean and quarter of each variable, and finally the synoptic situation of the classified days for each season was compared. Then, 107 out of 124 evaluated days for January were grouped in 25 types or classes, and 17 days were also identified as days of transition. Subsequently, they carried out this process for July.

Davis and Kalkstein (1990) divided days of 1984 into same groups based on six meteorological elements. They studied synoptic index and called the obtained calendar and time classification as climate periods, and then they expanded the above-mentioned index to place of synoptic index. The selected ingressive of 90 types was classified, and after that they reduced them to 10 principal weather types as the results of their research.

Kerschner (2005) studied weather type's rainfall climatology in eastern Alps Mountain, in order to test the feasibility of weather type classification and regional analysis of rainfall synoptic climatology.

He used surface air flow 500 hPa and anomaly quarters of daily mean on a network with 25km cell distance as principal data and for classification. The classiufication includes 24 directional classes and 5 classes for weak or mixed airflow patterns. Then, he extracted daily rainfall data of the network from internet and analyzed the possibilities greater than 1mm daily rainfall in weather types. He found that anti-cyclonic weather types usually have too many negative anomalies in all seasons, and cyclonic types with too many positive anomalies are specified in core of certain regions such as northern Alps margin.

Littmann (2000) presented an experimental classification of weather types in Mediterranean basin, and subsequently studied internal relationship of the types with rainfall. He identified major and essential elements of synoptic large-scale patterns on synoptic maps during 1992-1996 for 1338 days as pressure cells.

He organized pressure centers data according to their presence as binary, 1 or 0. Then, he carried out cluster hybridization by analyzing hierarchical cluster and Euclidean distance square technique and Ward algorithm, and finally separated 20 clusters with ability to explain 69% of variance. He identified rainfall area in a 1º×1º network consisting of monthly total rainfall, by using PCA analysis, in order to study weather type's relationship with Mediterranean rainfall, which resulted to detection of 10 components with explanation of variance 92%.

He proofed a significant internal communication by using Chi-square test ($\chi 2$), and noted that rainfall patterns in Mediterranean regions core (components 1 and 2) have been well explained by synoptic types.

Mc Gregor and Bamzelis (1995) studied synoptic typing and its application to air pollution in Birmingham, England. They used 11 variables in their research, including overcasting, wet and dry temperature, dew point, vapor pressure, atmospheric pressure, relative humidity, visibility, total radiation, and u and v components, as well as related data to pollution consisting of sulfur dioxide, nitrogen dioxide, ozone, nitric oxide, carbon monoxide, and particles smaller than 10 microns (PM10).

Afterwards, they achieved four components with variance 81.2% by analyzing principal components with P matrix configuration and Varimax rotation, which were determined to include hygrothermal, fog, westerly, and cloud. The researchers determined 6 weather types by hierarchical cluster analysis, and then interpreted synoptic charts with center of each type. They also studied contamination by using representative days of each weather type.

From mean concentration of O3, NO2 and PM10, they found that weather mass 5 was important. They also found that fourth weather mass (number 4) was important from PM10, NO2 and NO. Furthermore, the most frequent of events with severe pollution has typically anti-cyclone nature, which has a poor ventilation system. Also, western cyclone streams have a better air quality, altuough there has been increased O3 levels due to vertical transmission from upper troposphere.

Muller (1977) achieved 8 types for New Orleans, by assessing daily surface weather map sets in the United States. Next, weather types were changed to 3 environmental indexes in order to analyze the relationship between climate and environmental reactions:

1) Shower index with wet, cloudy, and windy air;
2) Continental polar index with cooler air and lower dew point; and
3) Tropical marine index with warmer and very desirable weather.

This technique was used to periodically study local-effect Gold quest region.

Sfetsos et al. (2004) attempted to identify representative days in synoptic climatology studies. They carried out actions in order to identify groups of days with common characteristics using data of two complete years, applied prediction model in Meteorological Institute of Norway (DNMI), analyzed the components based on findings, carried out differential cluster analysis, and observed information plus obtained data from the model. This study was performed in a region with 280,000 square kilometers area between southwest coast of Norway and Shetland Islands.

Stone (1989) developed a similar method to TSI. He used principal components analysis (PCA) for meteorological surface data in Brisbane, Queensland, as well as Varimax rotation and correlation matrix, in order to obtain orthogonal components. Then, he used Ward cluster technique in order to identify large weather types. Finally, he identified 25 hybrid types and 63 sub-types for a 15-year period from 1967 to 1981.

In this article, we have used Temporal Synoptic Index to group the days of six stations in the west part of Iran (Kalkstein and Corrigan 1986). We have applied some weather type to each group of these days, and conducted an experiment regarding the raining amount on these types' grouping. We used multivariate statistical methods to better perceive the weather types temporal conformity and behavior on each other. This process helps us enhance our awareness toward the raining behavior of each weather type and the effect of atmospheric systems in the west part of Iran. Besides, considering the aerology characteristics, the diverse presence of weather types, and their comparisons in our case study make the present ecological conditions on the satiations and areas more manifest.

2. Material and Methods

For this research, 10 meteorological variables were used which describe the heat and moisture properties of the atmosphere including cloudiness (12GMT), maximum and minimum daily temperature, Dew point (12GMT), maximum and minimum daily humidity, dry temperature (12GMT), daily rainfall, and u and v components (12GMT) of wind in six synoptic stations located in west of Iran, including Kermanshah, Sarpolzahab, Ilam, Khorramabad, Sanandaj, and Nozheh in 1961-2004 period. map distribution of the stations is presented in Fig. 1 and their general specifications are presented in Table 1.

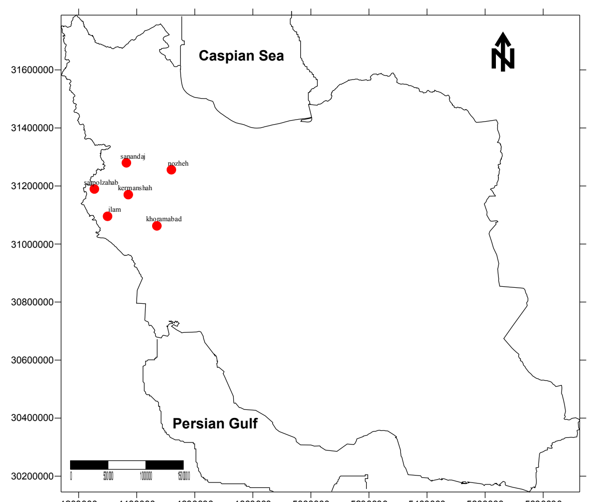

Fig 1- Location of selected stations in Iran

A matrix was formed from the mentioned variables with P mode, after initial preparation of data series and elimination of days without data. Standardization of data was subsequently performed in order to scale data; and then for removing repeated effects of correlated variables, initial variables were reduced to fewer principal components with explanation of most variance percent, by using principal components analysis (PCA) and an eigenvector technique, based on Cattell test.

Table 1- General specifications of the stations

Station	longitude	latitude	Altitude(m)
Kermanshah	47. 15	34. 35	1318. 6
Sarpolzahab	45. 87	34. 45	545
Ilam	46. 43	33. 63	1337
Khoramabad	48. 27	33. 43	1147. 8
Sanandaj	47. 00	35. 33	1373. 4
Nozheh	48. 72	35. 20	1679. 7

In the next stage, we used analysis hierarchical clustering (AHC) with Ward technique on factor scores, in order to separate days with homogeneous meteorological conditions (Green et al 1999). As a result, the station weather types and/or Temporal Synoptic Index (TSI) were identified. Meteorological characteristics of each weather type were studied via calculating mean important variables; then similar weather types of the stations were identified based on mean rainfall by using cluster analysis, and the isohyet groups were determined. For more information about the presence of weather types during year and studying their occurrence in any given day of year in statistical period, the frequency of occurrence of each type was calculated by using a script in Matlab software.

3. Results

After constructing the databases and their standardization, based on Eigen vectors, variables of each station were reduced to variables with the highest explanatory variance, by principal components analysis (PCA). Results of Eigen vectors are presented in Tables 2-7, and decision was made about number of retained components. Figs. 2-7 show the importance and power of principal variables based on their rate variability.

Table 2- Eigenvalues of Kermanshah station

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Eigenvalue	4.781	1.650	1.115	0.851	0.697	0.492	0.223	0.129	0.058	0.005
Variability %)	47.810	16.501	11.147	8.511	6.966	4.922	2.227	1.288	0.582	0.047
Cumulative %	47.810	64.310	75.457	83.968	90.934	95.856	98.083	99.371	99.953	100.000

Table 3- Eigenvalues of Sarpolzahab station

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Eigenvalue	4.931	1.619	1.081	0.839	0.730	0.496	0.170	0.084	0.045	0.005
Variability (%)	49.307	16.193	10.810	8.394	7.297	4.963	1.702	0.842	0.445	0.046
Cumulative %	49.307	65.500	76.311	84.705	92.002	96.965	98.667	99.509	99.954	100.000

Table 4- Eigenvalues of Ilam station

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Eigenvalue	5.23	1.58	0.99	0.78	0.71	0.47	0.12	0.09	0.03	0.00
Variability (%)	52.25	15.78	9.88	7.85	7.08	4.69	1.22	0.90	0.32	0.04
Cumulative %	52.25	68.03	77.91	85.76	92.84	97.53	98.75	99.65	99.96	100.00

5- Eigenvalues of Khoramabad station

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Eigenvalue	4.82	1.69	1.01	0.94	0.66	0.51	0.21	0.11	0.05	0.00
Variability %)	48.19	16.86	10.13	9.44	6.59	5.09	2.09	1.05	0.51	0.05
Cumulative %	48.19	65.05	75.19	84.63	91.22	96.30	98.39	99.44	99.95	100.00

6- Eigenvalues of Sanadaj station

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Eigenvalue	4.68	1.65	1.13	0.89	0.71	0.48	0.26	0.12	0.07	0.00
Variability (%)	46.83	16.54	11.31	8.87	7.06	4.85	2.64	1.18	0.68	0.04
Cumulative %	46.83	63.37	74.68	83.55	90.61	95.46	98.10	99.28	99.96	100.00

7- Eigenvalues of Nozheh station

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Eigenvalue	4.59	1.69	1.10	0.91	0.71	0.53	0.29	0.12	0.06	0.00
Variability (%)	45.92	16.88	11.04	9.06	7.13	5.27	2.85	1.23	0.59	0.04
Cumulative %	45.92	62.79	73.83	82.89	90.02	95.29	98.14	99.37	99.96	100.00

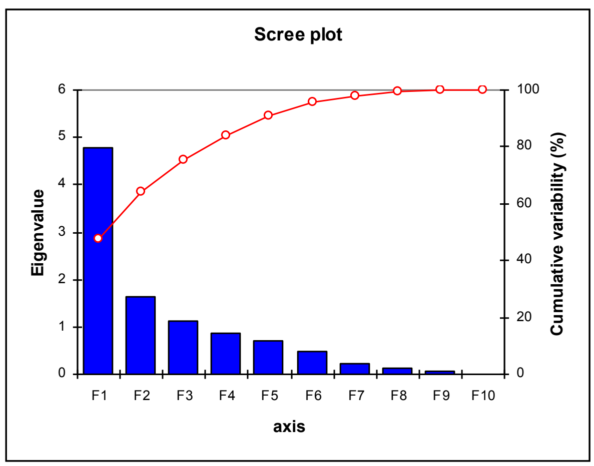

Fig 2- Screeplot of Kermanshah station

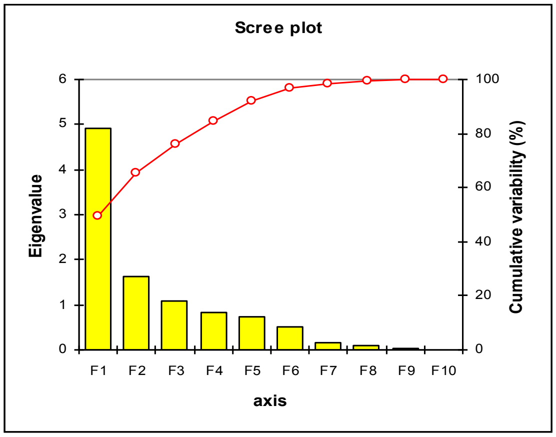

Fig 3- Screeplot of Sarpolzahab station

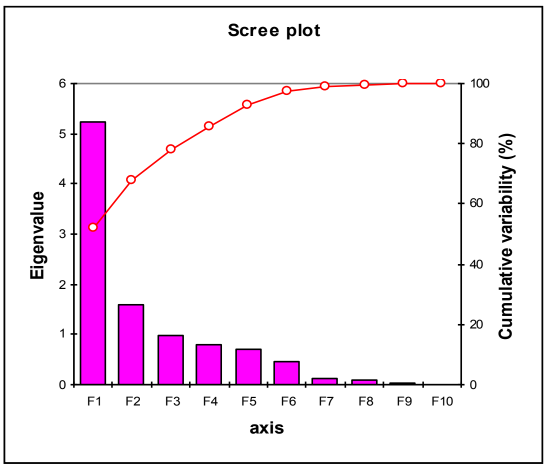

Fig 4- Screeplot of Ilam station

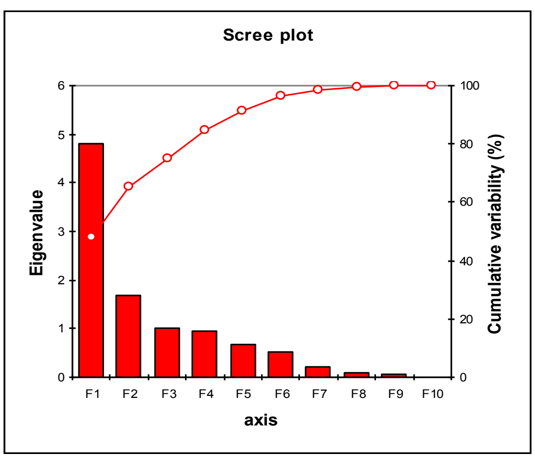

Fig 5- Screeplot of Khoramabad station

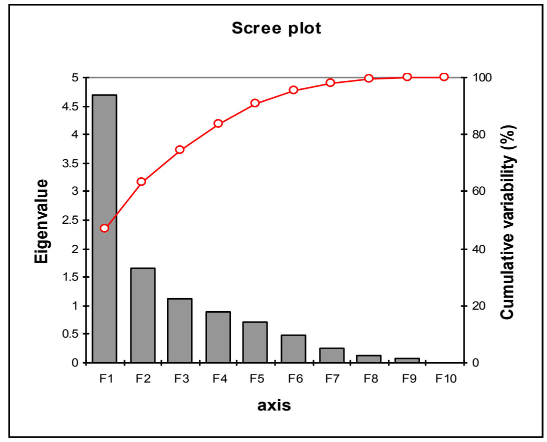

Fig 6- Screeplot of Sanandaj station

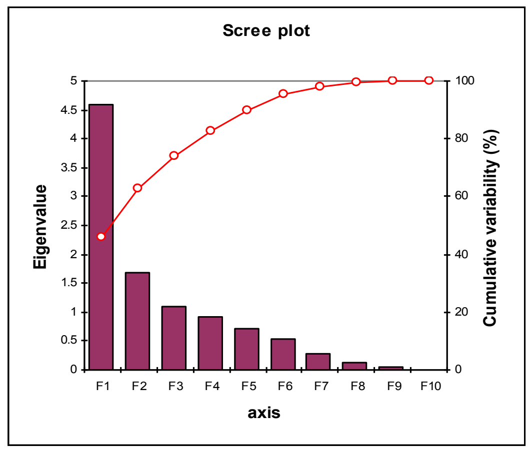

Fig 7- Screeplot of Nozheh station

In all stations, there is homogeneity in occurance of the components characteristics, through selecting the first three principal components, which explain approximately 80% of the variance. In this case, the first, second, and third components reflect thermal, humidity, and windy characteristics, respectively.

Weather typing was performed in each station by objective method and factor scores of components, hierarchical cluster analysis, as well as using Akaic information criteria (AIC) for cutting dendrograms. Except Sarpolzahab and Khoramabad stations with 5 weather types, other stations had 4 weather types. The means of some types of meteorological characteristics are presented in Table 8.

Table 8- Meteorological characteristics of weather types in the stations

variables / Weather types	Mean daily cloudiness	Mean daily temp (C°)	Mean daily dew (C°)	Mean daily precipitation (mm)	Max daily precipitation (mm)	Min daily Precipitation (mm)	Total precipitation (mm)	Number of rainy days	Mean daily humidity (%)
Type1 kermanshah	0.8	24.2	0.8	0	7	0	80.7	977	24.8
Type2 kermanshah	3.6	3.3	-2.5	1.2	24	0	4749.3	1190	69.2
Type3 kermanshah	3.7	11.7	1.1	0.8	25	0	3846	1256	53.4
Type4 kermanshah	6.9	8	4.9	16.9	108	0	11323	669	81.5
Type 1 sarpolzahab	2.3	19.5	6.8	0.1	7	0	119.6	99	48.6
Type 2 sarpolzahab	0.5	30.2	6.7	0	4	0	19.4	16	26.5
Type3 sarpolzahab	2.6	9.6	2.5	3.3	9	0	5975	1371	65.4
Type 4 sarpolzahab	4.9	19.3	6.5	2.4	33	0	1289.8	249	50.4
Type 5 sarpolzahab	6	13	8.7	9.8	102	0	6536	554	77.2
Type1 ilam	3.5	9.2	0.1	1.3	31	0	3038.3	713	56.4
Type2 ilam	1	26.5	0.5	0	8.1	0	111.1	91	20.5
Type3 ilam	6.6	5.6	2.4	15.5	103	0	8263	505	81.4
Type4 ilam	1.1	12.7	-5.6	0	6	0	10.8	9	31.4
Type1 khoramabad	0.6	27.4	4.2	0	26	0	88	59	25.3
Type2 khoramabad	2.7	5.6	-1.7	3.4	8	0	9154	2043	62.9
Type3 khoramabad	1.8	16.5	2.6	0.1	13	0	348	209	43.8
Type4 khoramabad	4	13	3.7	1.4	28	0	4053	1087	57
Type5 khoramabad	6.7	8.1	5.1	12.2	71	0	16463.8	1295	82.4
Type1 Sanandaj	0.9	24.4	1.3	0	7	0	144.2	701	26.7
Type2 sanandaj	3.3	3.9	-4.3	0.4	19	0	1908.8	863	60.4
Type3 sanandaj	3.3	15.9	2.7	0.4	18	0	940.6	432	46.7
Type4 sanandaj	6.4	7.5	2.9	8.4	73	0	15548.4	1632	74.3
Type1 nozheh	5.9	2.8	-0.9	6.6	9	0	19516	2959	78.6
Type2 nozheh	1.1	22.4	1.8	1.8	9	0	9029	3093	30.2
Type3 nozheh	2.7	-2.5	-8.4	3.1	9	0	9046	2282	68.1
Type4 nozheh	3.3	12.2	-0.2	4.4	9	0	20552	4275	48.1

Considering the information in Table 8 obtained based upon calculations on data series of any type of weather, isohyet groups were separated by performing analysis hierarchical cluster and by aplying Ward technique to all weather types in the stations. Results of this classification are presented in Fig. 8 as dendrogram, and types of classes of isohyet weather types are shown in Table 9.

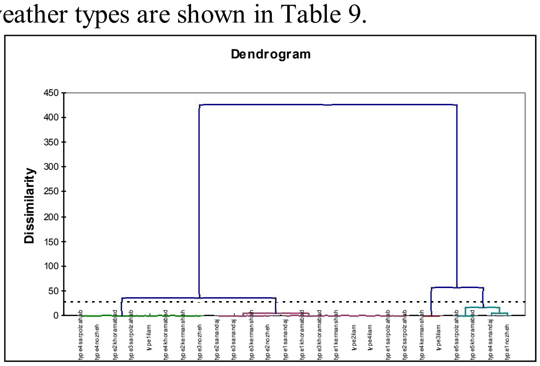

Fig 8- Clustering dendrogram of weather types

Table 9- Isohyet groups of weather types

	Rainy Groups (Classes)			
	Low	Medium	High	Very high
Weather types	Type (1) kermanshah			
	Type (1) sarpolzahab			
	Type (2) sarpolzahab	ype(2)kermanshah		
	Type (4) sarpolzahab	ype(3)kermanshah	Type(4)kermanshah	
	Type (2) ilam	ype(3)sarpolzahab	Type(3) ilam	Type (5)khoramabad
	Type (4) ilam	ype(5)sarpolzahab	Type (2)khoramabad	Type (4) sanandaj
	Type (1) khoramabad	Type(1) ilam	Type (2) nozheh	Type (1) nozheh
	Type (3) khoramabad	pe (4)khoramabad	Type (3) nozheh	Type (4) nozheh
	Type (1) sanandaj			
	Type (2) sanandaj			
	Type (3) sanandaj			

After regulating relevant matrix, the occurrence of the repeatition of weather types was studied in every day of year and in the record period using a script (m-file) in Matlab software, in order to determine activity period of each weather type during year, or in other words, to identify their seasonal belonging, as well as their rise and disappearance. Expertized charts of each station are presented in Figs. 9-14.

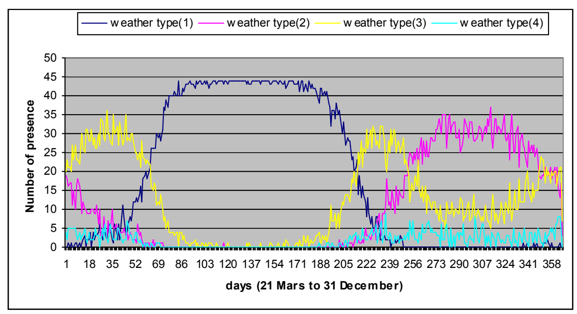

Fig 9- Presence frequency of weather types in Kermanshah station

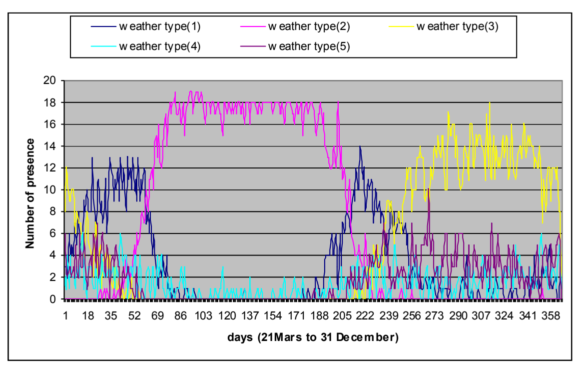

Fig 10- Presence frequency of weather types in Sarpolzahab station

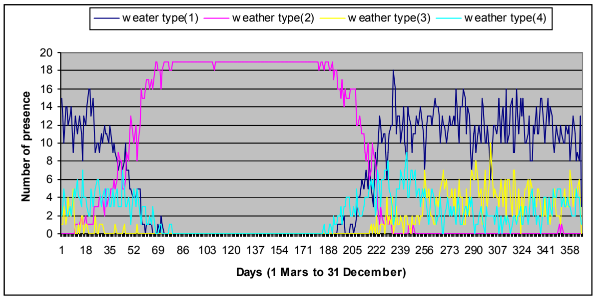

Fig 11- Presence frequency of weather types in Ilam station

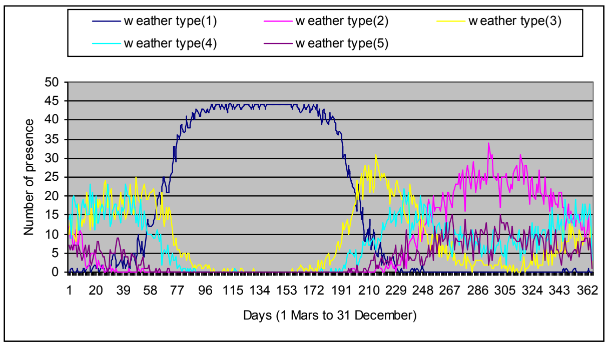

Fig 12- Presence frequency of weather types in Khoramabad station

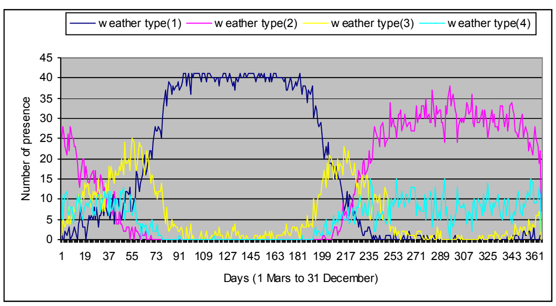

Fig 13- Frequency presence of weather types in Sanandaj station

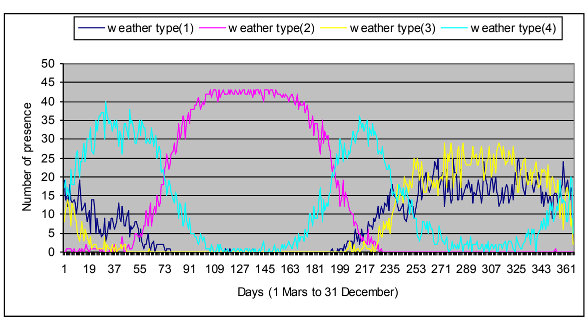

Fig 14- Presence frequency of weather types in Nozheh station

Activity periods of weather types include special seasons of a year.

Regardless of belonging each weather type of the stations to isohyet groups, the presence pattern of weather types can be divided into three categories using related frequency charts (Figs. 9-14):

1) Summer presence pattern: in this pattern, weather types have significant presence frequency in summer, and their presence is very small.

2) Bimodal pattern (spring and autumn): included types in this pattern are appeared in spring and autumn seasons, and their presence in summer and winter is very small.

3) Pattern without summer (three seasons): in this pattern, all stations have two defined weather types, and summer absence is one of charactristics of this pattern which differentiated it from the other patterns. Results of classifying the patterns of presence frequency are presented in Table 10.

Table 10- Classification of presence pattern of weather types in west of Iran

Summer Pattern	Bimodal Pattern (spring & autumn)	Three seasonal Pattern (without summer)
Weather type(1) kermanshah Weather type(2) sarpolzahab Weather type(2) ilam Weather type(1) khoramabad Weather type(1)sanandaj Weather type(2) nozheh	Weather type(3) kermanshah Weather type(1) sarpolzahab Weather type(4) ilam Weather type(3) khoramabad Weather type(4) khoramabad Weather type(3)sanandaj Weather type(4) nozheh	Weather type(2) kermanshah Weather type(4) kermanshah Weather type(4) sarpolzahab Weather type(5) sarpolzahab Weather type(1) ilam Weather type(3) ilam Weather type(2) khoramabad Weather type(5) khoramabad Weather type(2)sanandaj Weather type(4)sanandaj Weather type(1) nozheh Weather type(3) nozheh

Weather typing in west of Iran showed that despite installment of stations in a geographical area (middle Zagros), there are other conditions, too, which cause specific differences in weather types of a station and between stations. These conditions can be studied from several points:

First, studying weather type inside stations and between them showed that they have a specified seasonal behavior; in other words, time factor influences the rise of special weather types because of forming regional synoptic systems including Siberian high-pressure, polar low-pressure, Azores high-pressure, Sudan, Ganges, and Mediterranean low-pressures, and western winds.

Second, by studying weather type in a station with similar absence of the rise characteristics but different meteorological data, the difference can be pointed between synoptic systems, different air masses, and different circulation flow patterns in sea level and 500 hPa levels.

Third, the weather type groups between stations which rise or are absent in similar seasons, in addition to previous reasons, can be added to specific conditions of each geographic location (topography, altitude).

Classification of weather types from amount of rainfall viewpoint revealed four stations with very high rainfall and high rainfall, which have presented specified seasonal behavior, and with high approximation, it means that they are absent in summer and they are present in other seasons.

Low rainfall group study showed that, the related weather types mainly are not activated in winter. Of course there are expectations in this field; meantime, Nozheh station has no low and medium rainfall types. Behavior of medium rainfall type confirms its absence in summer.

Research in recognition of weather types, especially in west of Iran, as one prone area with agriculture and horticulture and annual rainfall, is considered suitable for a more accurate understanding of the regional climate and it can help to manage climate change, especially in drought periods. Studying simultaneous occurrence of weather types and their relationship with circulation patterns with 500 hPa can elucidate the role of these patterns in shaping weather types.

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