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ORIGINAL ARTICLE

Time Synoptic Index of Winter Season in The Southern Beaches of IRAN

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ABSTRACT
Each place according to its geographical, topographic and peripheral environment properties reflects the features of the air mass governing on that region which can create unique meteorological conditions in the station scale. In this research, the Time Synoptic Index (TSI) of winter season and/or in other words, its nativism, the types of superficial weather of stations in the seaboard of Persian Gulf and Oman Sea formed from six stations have been studied. For doing it, by using the principal and clustered components analysis, the identification and separation of different climatic types were done in the station scale based on 9 meteorological variables including the sea level pressure, dew point temperature, minimum and maximum temperature, minimum and maximum deficiency of daily saturation, cloud amount, extent of daily temperature and daily extent of dew point with daily scale during 1961-2004(befor Tsunami of Indonesia). The meteorological features of each weather type were determined by regularizing 40 variables, utilizing and emphasizing on elements like rain, daily temperature, relative humidity, cloud amount, minimum and maximum daily temperatures and also, the number of rainy days. The results of this research showed that the weather types of eastern stations of Hormoz Strait including Jask and Chabahar in terms of the meteorological conditions and rain amount are distinguishable with western stations and if the rain properties aren't considered, in terms of the heat and humidity, a kind of relative homogeneity will be observed between the types of stations which may cause to emerge the fault. Hence, the rain element has the relative prominence in separation of types. In terms of the amount of rain, more rainy types in the western stations of Hormoz Strait have conformed to the moderate and humid type; while, in the eastern stations, they are concordant with the relatively hot and humid type, in the meantime, more rainy types in Bandar Abbas and Bandar Lengeh Stations have the most frequency of presence during the statistical period of station, in the Booshehr and Chabahar Stations, they have been in the middle rank and in Kish and Jask Stations, they have allocated the least frequency of presence to themselves. Therefore, by accounting the number of the rainy days and frequency of presence of weather types, generally, the winter season of Bandar Abbas, Bandar Lengeh, Booshehr, Chabahar, Jask/Kish can be defined in order, relatively rainy, semi-rainy, less rainy, relatively less rainy and much less rainy.

Key words: *Cluster analysis, principal components analysis, weather types, TSI.*

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INTRODUCTION

The weather diversity has been arising from the similarities and differences of its constituent elements in time which is proposed in the frame of weather types. This definition conforms to the concept of time synoptic index. In other words, it has been a set regularized from the main constituent elements of weather in different times which reflect similar features. Repetition of these types of weather expresses the climate of the place which has worthy importance in managerial decisions related to it in terms of the weather behavior cognition in long-term. The air masses at the time of their settlement in a region, with regard to their thermal and humidity homogeneity in the horizon level, according to the lower level features in terms of latitude and longitude, topography, height from the sea level and distance from the humidity sources cause the meteorological variables to gain eigenvalues that different classes of these elements during the time can introduce the weather types. Studying the weather types in terms of the

manner of relation and effect of them on environment, water sources and climatic swings such as drought and even heating and cooling waves and dusty storms is important and lack of cohesive researches in this subject is felt completely. Therefore, identification of the weather types and study about the frequency of occurrence of them for a correct cognition of the place climate has been completely necessary as one of the methodologies so that by doing these works, the reaction of the geographical place in time of governance of different air masses can be explained. Thus, any type of action for clarifying different types of weather in order to understand the climate more really and regulate the managerial decisions is considered very important and the aim of this research is also to calculate the time synoptic index (TSI) or weather types classification in the stations of southern beaches of Iran and compare their humidity and thermal conditions by emphasizing on their rainy days as the most important factor in the hydrological cycle of the region. Numerous researches have been accomplished about it that the related cases are referred.

Berrera [1] did the classification of the weather types in relation with severe rains which generate flood during the small freezing- weather period (1840-1870) in Catalonia. He collected the old useful information of 10 different cities of Europe for studying the floods meteorological relation, has recovered the daily superficial synoptic data with pressure date and in order to study the transformations and time of occurrence of flood incidents, used the daily data series of Barcelona's meteorology during 1870-2002 that in total, 62 meteorological-flood incidents were identified. This researcher succeeded in determining 6 types of weather including southern and northern flows, western circuital revolution, cyclonic, anti-cyclonic and eastern flow and concluded that in four seasons, the southern flow type with 31 flood incidents had allocated the most frequency to itself which can create floods in any scope and season.

Cheng and *et al* [7] executed an automatic method of synoptic types classification in order to anticipate the icy rains in Ottawa of Ontario, in this study, the superficial meteorological data such as temperature, dew point, pressure of ground level, total of cloud amounts, elements u and v of wind, occurrence of icy rains and also, 6-hour data of upper atmosphere related to 6 levels of atmosphere with reticulated congestion of 2.5°×2.5° including temperature, relative humidity, geo-potential height, vertical speed of wind and speed of western-eastern and southern-northern wind for all days of winter season were considered as the base of action since 1958 till 1990. The data input matrix formed from 240 variables by using the base component analysis and then, clustered analysis by cumulative hierarchic method led to generate the Time Synoptic Index (TSI) that consequently, 18 main components with variance explanation power of 92% were gained. In this analysis, the thermodynamic variables including temperature and dew point with variance of 36% allocated the most share in the first component to themselves. By clustering the factor scores, 13 synoptic groups with synoptic weather type were gained that allocated 85% of total days to themselves. These researchers, finally, adjusted the weather types with the ice rain days and compared the frequency of the days embracing ice rain.

Christensen and Brayson [8] tested the ability to analyze the principal components for studying and classifying the weather types. In this research, 15 parameters of meteorology have been used by twice daily observations including dry temperature, humid temperature, cloud amount, pressure, elements u and v, And by executing the principal components analysis with varimax rotation, they inserted the gained results in multiple regression analysis and by selecting the correlation coefficient threshold of 0.7, they specified the weather types. The data studied for January and July have been in order, a four-year period of 1955-1958 and a five-year period of 1954-1958. The specificity of each type has been studied according to the mean and quarterly range of each variable and eventually, for each season, the synoptic situation has been compared with each classified day and from 124 days studied for January, 107 days were classified into 25 classes or types and 17 days were also placed as the passage days. Then, these stages were also done for July.

Davis and Kalkstein [9] according to six elements of meteorology divided the days of year 1984 into similar time groups and studied the Time Synoptic Index (TSI). They named the gained calendar and time classes as the climatic periods and then, expanded the mentioned index to the Spatial Synoptic Index (SSI). The introvert selection of 90 types and then, reduction of them to 10 main weather types are accounted from the results of these researchers.

Kerschner [10] studied the climatology of the rain weather types in eastern Alp with the aim of testing the capability of applying the weather types classification and in order to do the regional analysis of the rain synoptic climatology. He has used the air flow level of 500kPa and anomaly quarters related to the daily mean as the main data on a lattice with cellular distance of 25km and succeeded in classifying 24 directional groups (N, NE,..) and 5 groups with weak or mixed flow models. Then, he extracted the daily rain data related to the lattice from the internet and analyzed the probability of rain larger than 1mm in day in the weather types. The mentioned researcher found out that the anti-cyclonic weather types

usually in all seasons have had so much negative amount of anomaly and the cyclonic types with much positive amounts of anomaly ere specified in the core of determined regions like northern margin of Alp.
Littmann [11] presented an experimental classification of weather types in the Mediterranean domain and then, studied the internal relation of types with rain. The mentioned researcher identified the principal and fundamental components of large scale synoptic models which are pressure cells on synoptic maps and in the period of 1992-1996 and for 1338 days. He regularized the pressure centers data according to their presence in binary form of (0,1); then, by doing the hierarchic clustered analysis and technique of Euclidean square distance and Ward algorithm accomplished the clusters grafting that finally, separated 20 clusters with variance explanation ability of 69%. To study the relation of weather types and Mediterranean rain, he identified the rain zones in a lattice of 1°×1°from total monthly rain and with help of PCA (Principal Components Analysis) which led to introduce 10 components with variance explanation power of 92%. He has proved the significant internal relation by applying K^2 test for observations of study period and acknowledged that the rain models in the core of Mediterranean regions (components1, 2) have been explained well by synoptic types.
McGregor and Bamzelis [13]studied the synoptic types classification and its application in relation with air pollution in England's Birmingham. They used 11 superficial variables including cloud amounts, dry and humid temperature, dew point, vapor pressure, atmosphere pressure, relative humidity, visibility, general radiation and components u and v and also data related to the pollution formed from sulfur dioxide, nitrogen dioxide, ozone, nitric oxide, carbon monoxide and particles smaller than 10μ(PM10) in their researches. Then, by doing the principal components analysis with matrix array P and Varimax rotation, they gained four components with variance of 81.2% that were specified with the names of hydrothermal, fog, westerly and cloud. These researchers, then, by doing the hierarchic clustered analysis, determined 6 weather types, interpreted the synoptic quarters with centers of each type and also studied the amount of pollution with the representative days of each weather type.
Muller [14] by studying the set of daily superficial air maps of United States, gained eight types for New Orleans and in order to analyze the relation between climate and environmental reactions converted the weather types into 3 environmental indexes: 1)Shower index with humid, cloudy and windy weather, 2)continental polar index with colder weather and lower dew point and 3)equatorial marine index with hotter and very humid weather. This technique alternatively and for studying the local effects in Gold Quest Region was used.
Sfetsos and *et al* [15] identified the representative days in the synoptic climatology studies. By using the data of 2 complete years and applying the applicable anticipation model of Norway's Meteorology Institute (DNMI) and rotated component analysis and then, differential clustered analysis, observed information surplus information gained from the model, they identified the mentioned weather type and those groups of days which had common properties. This study had been done in a region with an area of 280000 km^2 between the south-western beach of Norway and Shetland Islands.
Stone [16] developed a method similar with TSI and used the principal components analysis (PCA) for superficial data of meteorology in Brisbane of Queensland with correlation matrix and Varimax rotation in order to gain the perpendicular components. Then, he applied the clustered technique of Ward on factor scores and for identifying the large types of weather. Eventually, he succeeded in identifying 25 hybrid types and 63 sub-types for a 15-year period since 1967 till 1981.
Mohammadi and Masoudian [12] studied the relation between the synoptic types in Sanandaj Station by rotatory models of the level of 500 HectoPa. By using seven climatic variables of rain, proportional humidity, sunny hours, mean, minimum and maximum temperatures and level pressure of station in the statistical period of 1965-1995, by doing the base component analysis and then, executing the clustered analysis, they identified eleven synoptic weather types. Then, by similar analysis on geo-potential height data of the level of 500HectoPa, during the period of 1974-2004, they introduced eight rotatory models and by using the cross table, they studied the frequency of weather types in the time of each one of the rotatory models. The mentioned researchers in the meantime of expressing the seasonal behavior of these models, have concluded the coincidence of some types of weather with them.
Beedel [3-5] gained the rainy weather types with annual scale for Kermanshah. And then, in a research, he studied the weather types of Birjand, and their relations as the stressful environmental conditions. And, in another research, he studied the climate change in Kermanshah by frequency of annual presence of weather types.
Beedel [6] studied the weather types, frequency and their relation with rain in west of Iran and after selecting six synoptic stations and applying the statistical methods of the principal and clustered components analysis, he diagnosed 26 weather types and then, in terms of the rain amount, classified them.

MATERIAL AND METHODS

After selecting six synoptic stations in the southern beaches including Booshehr, Kish, Bandar Lengeh, Bandar Abbas, Jask and Chabahar, the initial studies were done on daily data of winter season and then, a matrix with dimensions of 3960×9 was regularized with array P for winter season of each station formed from ennead elements of the sea level pressure, dew point temperature, minimum and maximum temperatures, minimum and maximum deficiency of daily saturation, cloud amount, extent of daily temperature and daily extent of dew point. Those days in which even, an element didn't have statistics, were eliminated and no type of statistical recovery was also accomplished. Due to the internal dependency of some elements on each other and in order to prevent from the repetition of their effects in calculations, by using the principal components analysis, the variables with specified criteria were converted to the perpendicular components which had the most share in variance explanation. By grouping these components and utilizing the hierarchic clustered analysis and technique of Ward grafting, those classes of days which expressed the special conditions of meteorology in each station, were gained. Study on these groups by reporting from properties of 40 elements of meteorology and emphasizing on variables like rain, daily average temperature, maximum and minimum temperatures, relative humidity, cloud amount and deficiency of saturation led to clarify the features of weather types, nominate and study their frequency. In this field, study of the number of rainy days of weather types of each station was also used for better adjustment of similar types. The map No.1 is the situation of the stations used in Iran's realm and table1 also reflects their geographical specifications.

Figure (1): The stations of southern beaches of Iran

Table (1): The geographical specifications of studied stations

name of station	Longitude	Latitude	Height from sea level, m
Bandar Abbas	56 22	27 13	9.8
Bandar Lengeh	54 50	26 32	22.7
Booshehr	50 50	28 59	19.6
Kish	60 37	25 17	8
Jask	57 46	25 38	5.2
Chabahar	53 59	26 30	30

RESULTS

In the process of calculating the principal components analysis, by using the Cattle's method and drawing the Screen Plot, according to the breakage of gained gradient and also eigenvalues less than 1, the

components with the most power of variance explanation were selected. Table (2) shows the eigenvalues and figure (2) shows the Scree Plot of Bandar Abbas Station as the sample.

Table (2): The eigenvalues- partial and cumulative variance of principal components of Bandar Abbas Station

	First component	Second component	Third component	Fourth component	Fifth component	Sixth component	Seventh component	Eighth component
Eigenvalue	4.066	1.729	1.1	0.740	0.559	0.436	0.321	0.050
Variance (%)	45.182	19.209	12.224	8.217	6.211	4.839	3.562	0.557
Cumulative variance (%)	45.182	64.391	76.615	84.832	91.042	95.881	99.443	100

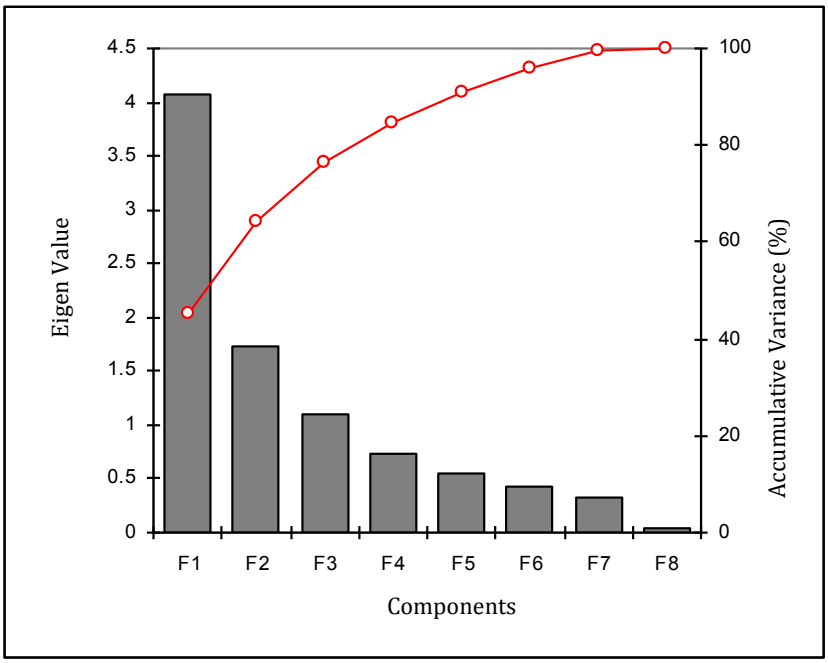

Figure (2): The Scree Plot of eigenvalues-cumulative variance of components

Based on the factor loads matrix of each station, the first and second components of all stations, in order, reflect the humidity and then, thermal features that the priority of explainer component of meteorological properties has coordination with climatic conditions of the region, adjacency with water zones and existence of pressure systems.The hierarchic clustered analysis led to separate the classes formed from days with similar features in each station that for deciding about the shear points of the related tree diagrams, $R^2$and RMSSTD statistics and program SAS were used. After shearing the tree diagrams, for Kish Station and other stations, in order, four and three distinguishable weather types were diagnosed. Then, calculations were continued for extracting the features of each weather type that for this purpose, 40 variables and elements of meteorology were considered as the base of initial study of weather types properties that among them, the rain, cloud amount, mean of daily temperature, maximum and minimum temperatures, relative humidity and dew point temperature were emphasized more. In the meantime, the weather types of stations can be nominated in terms of the mean of thermal and humidity features and considering their rainy days. The results of regularization and calculations of this stage have been presented in the table (3).

As it has been mentioned in the table, type (1) of Booshehr, type (2) of Chabahar, type (3) of Chabahar, type (4) of Kish and type (2) of Booshehr are accounted as the coldest, warmest, driest, most humid and most rainy ones respectively. And, in other words, Booshehr Station has the coldest and most rainy types of weather and Chabahar Station has the warmest and driest types of weather. Study of rainy days of weather types with other properties was also done for better definition of features and nomination; because, some types despite of thermal and humidity similarity and also alike name, have thinkable

differences in terms of the number of rainy days that regard to them can help in distinguishing between the weather types worthily. Study of the frequency of weather types of stations also shows that presence of some of them during the statistical period of station has been colorful and vice versa, there are some types which have had less presence and sometimes, have had reverse ratio with the number of rain days too. The related statistical information has been presented in the table (4).

Table (3): The meteorology features and names corresponding to the weather types

Features / Weather types	The mean of daily	Maximum temperatu re	Minimum temperatu re	Relative humidity %	Mean of rain mm	Cloud amount octaze	The number of	The name of type
Bandar Abbas (1)	20.6	25.1	15.8	73.4	10.5	3.2	493	**Moderate and humid**
Bandar Abbas (2)	17.1	22.8	10.6	63.2	1.8	1.5	24	**Moderate and relatively humid**
Bandar Abbas (3)	18.3	25.4	11.1	45.9	1.2	1.2	8	**Moderate and semi-humid**
Bandar Lengeh (1)	18.9	22.7	12.4	61.9	4	1.5	47	**Moderate and relatively humid**
Bandar Lengeh (2)	21.1	24.2	16.3	73	9.7	3.6	339	**Moderate and humid**
Bandar Lengeh (3)	20.4	24.3	14.2	45.5	5.8	1.5	28	**Moderate and semi-humid**
Booshehr (1)	14	18.4	9.5	73.8	4	1.9	152	**Relatively cold and humid**
Booshehr (2)	17.2	20.9	14.3	77.1	9.5	5.1	571	**Moderate and humid**
Booshehr (3)	18.5	24.5	12.6	61.8	1.6	3.4	98	**Moderate and relatively humid**
Chabahar (1)	22.1	25.1	18.5	77.4	9.1	3.1	221	**Relatively hot and humid**
Chabahar (2)	21.5	25.7	15.9	63.9	6.4	1.2	48	**Relatively (hot and humid)**
Chabahar (3)	19.6	24.1	13.6	34.5	0.7	1	3	**Moderate and semi-dry**
Jask (1)	22	23.7	19.7	78.8	14.2	5.8	146	**Relatively hot and humid**
Jask (2)	20.1	23.1	14.7	43.1	7.5	1.5	15	**Moderate and semi-dry**
Jask (3)	22.5	25.1	18.3	64.3	7.5	2.1	97	**Relatively (hot and humid)**
Kish (1)	19.4	23.6	14.9	72.5	6.6	1.8	65	**Moderate and humid**
Kish (2)	17.8	21.7	14	54.7	5.9	1.4	23	**Moderate and semi-humid**
Kish (3)	21.4	25.4	17.9	62.8	3.6	2.7	61	**Relatively (hot and humid)**
Kish (4)	**20.5**	**23.5**	**17.9**	**80.1**	**12.5**	**5.2**	**179**	**Moderate and humid**

Table (4): The rain properties of weather types of stations

Rain features / Weather types	number of weather types days	number of rainy days	percent of rainy days	Total of rain (mm)	mean of humid days rain (mm)	mean of rain for entire days (mm)	percent of days of any type of weather
Bandar Abbas(1)	2413	493	20.4	5157.1	10.5	2.13	61.5
Bandar Abbas(2)	866	24	2.8	42.2	1.8	0.05	22
Bandar Abbas(3)	635	8	1.3	9.3	1.2	0.01	16.5
Bandar Lengeh(1)	1166	47	4	188.2	4	0.16	33.5
Bandar Lengeh(2)	1518	339	22.3	3296	9.7	2.17	43.5
Bandar Lengeh(3)	791	28	3.5	163.5	5.8	0.2	23
Booshehr (1)	1963	152	7.7	604.3	4	0.3	50.5
Booshehr (2)	1149	571	49.7	5428.1	9.5	4.72	29.5
Booshehr (3)	763	98	12.8	155	1.6	0.2	20
Chabahar (1)	1194	221	18.5	2000.2	9.1	1.67	39.5
Chabahar (2)	1507	48	3.2	306.6	6.4	0.2	50
Chabahar (3)	325	3	0.9	2.2	0.7	0	10.5
Jask (1)	424	146	34.4	2079.6	14.2	4.9	16.5
Jask (2)	515	15	2.9	112.7	7.5	0.2	20
Jask (3)	1630	97	6	722.8	7.5	0.44	63.5
Kish (1)	1131	65	5.7	428.7	6.6	0.38	45
Kish (2)	459	23	5	134.7	5.9	0.3	18
Kish (3)	515	61	11.8	220.7	3.6	0.43	20.5
Kish (4)	403	179	44.4	2231.2	12.5	5.5	16.5

DISCUSSION AND CONCLUSION

Study of the superficial data of meteorology stations from the view of identifying the weather types and/or customarily so-called, the time synoptic index, can open a new valve for studying the features and coincidence of distinguished groups of weather. This research showed that the stations adjacent to the southern beaches of the country, in the meantime of being influenced from the alike conditions of these extensive water zones, in combination with other elements like topography and geography, can emerge similar and even, different meteorological features from themselves.

In this field, the difference of western and eastern weather types situation of Hormoz Strait was specified well. For example, Jask and Chabahar Stations (east of Hormoz Strait) have completely different conditions in terms of the mentioned features of weather types, in a manner that only the type (3) of Kish Station which has a relatively warm and humid nature and has been located in west of Hormoz Strait, has similarity with the type of most of them. The stations of west of Hormoz Strait including Bandar Abbas and Bandar Lengeh have completely similar types and Booshehr and Kish Stations also in 75% of cases are similar with them, in the meantime, type (1) of Booshehr has been unique; but, type (3) of Kish which is the base of difference with Bandar Abbas and Bandar Lengeh Stations, is similar with type (3) of Jask and type (2) of Chabahar. In Jask and Chabahar Stations, the weather types of relatively warm and humid have had the most presence in the statistical period of these stations; but, in terms of the number of rain days, this type is in the second rank. In other stations, the conditions are a little different; in Bandar Abbas, Bandar Lengeh and Kish, the moderate and humid types in comparison with other types, have had the most time presence and in Booshehr, the relatively cold and humid type has such a place.

In terms of the limitative amounts, type (1) of Booshehr, type (2) of Chabahar, type (3) of Chabahar, type (4) of Kish and type (2) of Booshehr are accounted as the coldest, warmest, driest, most humid and most rainy ones respectively.

Therefore, according to the thermal and humidity features of weather types of studied stations, we also can distinguish between the western and eastern stations of Hormoz Strait. Nomination of weather types showed that if the rain properties are also considered, especially, using the number of rainy days, the thermal and humidity nature of separated types will be clarified better. For example, the moderate and humid types of western stations of Hormoz Strait, all, have had much rainy situation, except, type (1) of Kish that in spite of this fact that is moderate and humid and has presence in 45% of statistical period days, but, has low rain capacity. Vice versa, in the eastern stations, the relatively warm and humid type has been rainy and the number of days of this type in proportion to their total statistical period has included the last and middle ranks respectively. In other words, they haven't had the maximum presence frequency. If we study the stations by the criterion of the number of rainy days and percent of days of each weather type, we will find out that generally, the winter season of Bandar Abbas, Bandar Lengeh, Booshehr, Chabahar and Jask/Kish Stations is accounted relatively rainy, semi-rainy, a little rainy, relatively little rainy and much little rainy. While, little rainy stations and lower ones have significant rainy types; but, the general conditions of station by considering different weather types have drawn such a specificity.

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