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Synoptic approach to forecasting and statistical downscaling of climate parameters (Case study: Golestan Province)

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ABSTRACT: The present study attempts to introduce a method of statistical downscaling with a synoptic view. The precipitation data of Golestan Province has been used for the years 1971 to 2010. Employing multivariable regression, this study models the precipitation gauges in the station scale, by making use of 26 predicting components of model HadCM3, on the basis of two A2 and B2 scenarios. However, the minimum predicting components for precipitation in station scale included 26 components for one grid to 390 atmosphere circulation components for the 15 suggested grids. Nevertheless, results indicate minimum error, related to the precipitation models, based on projecting components of the studies of 15 grids. By applying this selected method, the precipitation gauges for 2020 to 2040 has been simulated. General results of the precipitation changes for the yearly decennial average of Golestan Province indicates additive stream of this component, based on both A2 and B2 scenarios. Yet this yearly decennial addition of precipitation go with seasonal and annual changes, i.e. getting drier in summer as well as its subsequent increase in draught issue on one hand, and increased centralization of precipitations in the winter and lack of its proper distribution during year on the other. As a result, changes in local patterns of precipitations throughout the province is promising for maximum increase of precipitation for the farthest southwest area of Golestan, greatly potential for decreasing precipitation of sub eastern area.

Keywords: climate change, modeling, statistical downscaling, synoptic procedure, validation.

INTRODUCTION

To survey the rates of climatology components and also get access to an obvious image of potential changes of the future climatology in different parts of the earth, the big outcome of general circulation models of atmosphere are downscaled (Ghanghermeh et al., 2013). Before making any scenario for future climatic, it is of high account to know how to have a proper project for a local climatology. In order to come to an end, it is quite necessary to assess the outcome of general circulation models of atmosphere, the outcome of methods used for downscaling, and the outcome of general circulation models for preparing local data. In order to achieve this goal, it is very important to have an adequate knowledge of different models of downscaling in daily data generation, since application of improper methods or wrong use of models can cause uncertainty (Farajzadeh et al., 2015).

Statistical downscaling techniques tend to set statistical relations between local

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observations and large scale variables, thus filling the gap between what the present climatology methods are capable of and what is required to evaluate the effects of climate change (Dibike & Coulibaly, 2006; Wilby & Dawson, 2012). While these procedures are able to correct the outcomes of systematic errors of general circulation models of atmosphere, such as gradient in average, etc., they increase the precision of the outcome of general circulation models of atmosphere up to station dimension. As various studies have been conducted in the field of downscaling across the globe, the following surveys have been inferred in terms of their importance approximately in most mono downscaling resources, they are engaged in. Among the most important systematic and comprehensive comparisons in this field, we can refer to the studies, conducted by Wilby et al. (2002) as well as Wood et al. (2002). They investigated empirical function, weather generators and grouping plans of weather via simulation of climatic changes along with observed data in a geographical area. Their studies yielded fruitful results, yet since they were looking for skills and deficits of different methods instead of offering a given method towards others, there still remained a need to assess more concisely. Neural networks, of high value in downscaling, are used in all phenomena too, especially in non-linear cases at present. The accumulation of conditioned estimation network, kept stable on the basis of multi-layer network has been used in various studies to downscale the extreme rates of temperature and precipitation. Cannon (2012) applied this algorithm, employing a sample case around the freezer river in British Colombia, which led to the development of Kidness software package in the so-called 'R' software environment that provides a suitable condition for hazardous downscaling of climatology rates.

Random weather generators are one of the practical methods to produce daily temporal series, one of the most interesting procedures of which is Generalized Linear Model (GMLS) (Furrer & Katz, 2007). Quintile matching procedure has been known for a long time; its developed procedures, used in different studies. One of these procedures is the statistical scaling method, called cumulative distribution function conversion, developed by applying large scale predictors in order to produce cumulative distribution function of climate variables of the earth level (Michelangeli et al., 2009). One of the fundamental works in the field of downscaling is the work of Frost et al. (2011), who compared six statistical scaling methods in order to downscale daily precipitation in 30 rain gauge stations of southeastern, Australia. Under investigation methods which have an important role on hydrologic studies in reproducing some wide spectrum of data, such as in-year changeability and local connection, by using NCEP / NCAR, and the outcome of general circulation models were experimented. Another study, conducted by the Canadian environment specialist (2012) (Farajzadeh et al., 2015), applied five statistical downscaling methods of mono and multi stations, namely statistical downscaling automatic regression, bias correction of local separation, quantile regression neural networks, trigon, and expanded downscaling in order to downscale the extreme rates of the region with mountainous- complex topology, on plain and coastal of western Canada (Bürger et al., 2012). In Iran, too, there have been several investigations in this field, some examples of which are as follows: Soltani et al. (2000) applied WGEN for different parameters of weather like maximum and minimum temperatures, while simulating Tabriz station. Moradi and Nosrati (2002) applied CLIMGEN to simulate maximum and minimum temperatures as well as sunshine in some stations of Iran. Also, in another study, by using weather generator, CLIMGEN was applied for random simulation of maximum and minimum temperatures of ten weather stations of Iran with different climate conditions; after evaluating statistical results, it was clear that the simulated data was in proper agreement with the observed ones. Nosrati et al. (2007) in a study, called Random Simulation of Minimum and Maximum Temperatures, used a weather generator known as CLIMGEN to generate temperature data. Azaranfar et al. (2007), in order to evaluate the effects of climate change on precipitation and temperature in Zayanderood River basin, statistically downscaled the outcome of these models by making use of general circulation models. Ashofteh and Massah Bovani (2007) downscaled temperature rates and precipitation of atmosphere-ocean models through proportional, temporal, and local methods of causing change in order to survey the effect of climate change on maximum discharges. Roshan et al. (2013a) in a study used the statistical downscaling method Lars-WG, to evaluate the role of global warming on severity and abundance of precipitation curve in northwest of Iran. Also in another study, in order to simulate the effect of global warming on demanding energy in the northwest of Iran, they used the LARS-WG downscaling statistical procedure (Roshan et al., 2013b).

The present research tries to first project and then downscale the rate of precipitation of meteorology stations of Golestan province, by using a different procedure in the bed of possible climate changes, resulting in human activities in the next century. As a result, the attempt is to present a clear picture of future climate changes for the studied region, as much as possible.

MATERIALS AND METHODS

In order to project climatic, the present research has used general circulation model predictors of the atmosphere HadCM3 with two A2 and B2 scenarios, the components of which are available via http://www.cccsn.ec.gc.ca (CCDS, 2013). It is necessary to say that general circulation model predictors of the atmosphere are to be calculated here. These have been provided by daily scale for the entire globe, which has a guage with a separation power 2.5×3.75, and is employed for past and future decades, based on regression relation of some variables of the predicted components, known as precipitation. It should be added that HadCM3 model is based on physical delivery, material, and energy (Shamsipour, 2013), using 26 fold predictors that include the average of sea level pressure, weather flow power, circuit and wind hour circle speed, vorticity, wind direction, divergence, pressure level altitude, proportional wetness, special damp, and two meters altitude from the earth level, considered for three levels; sea level pressure, altitude of 850, and 500 hectopascal (Table 1). It should be mentioned that the next steps of the following 26 components have been used as predictors.

Table 1. The 26 output of HadCM3 model for three SLP level, 850 altitude, and 500 hectopascal

Row	Circulation component	Row	Circulation component
1	Mean sea level pressure	14	500 hPa geopotential height
2	500 hPa airflow strength	15	850 hPa geopotential height
3	500 hPa zonal velocity	16	Surface airflow strength
4	500 hPa meridional velocity	17	Surface zonal velocity
5	500 hPa vorticity	18	Surface meridional velocity
6	500 hPa wind direction	19	Surface vorticity
7	500 hPa divergence	20	Surface wind direction
8	850 hPa airflow strength	21	Surface divergence
9	850 hPa zonal velocity	22	Relative humidity at 500 hPa
10	850 hPa meridional velocity	23	Relative humidity at 850 hPa
11	850 hPa vorticity	24	Near surface relative humidity
12	850 hPa wind direction	25	Surface specific humidity
13	850 hPa divergence	26	Mean temperature at 2m

According to Figure 1, it can be seen that all HadCM3 model predictors are dynamic and continuous components of atmosphere; therefore, possibility prediction and/or downscaling consistent parameters of atmosphere would act efficiently. On the other hand, for determining the precipitation of that location, the 26 fold components in a 2×3.75 gauge cannot be a suitable index of prediction and downscaling of precipitation. However, although dynamic downscaling methods on effective geographical area for generation of weather data of a given point can enjoy a larger grid, in most statistical downscaling methods, like LAR-WG and/or SDSM, the existing procedures for predicting and downscaling atmosphere data of a station only rely on one-grid predictors components, in which the location of the intended station is placed. But from a synoptic look, vorticity in location cannot be the precipitation factor in that location. In other words, the dynamic conditions for producing clouds and its seeding and consequently precipitation act on a wider scope. To illustrate it with an example, if the least distance to supply precipitation water resources of Golestan Province is considered as Caspian Sea arena from the center of the province to the center of southern Caspian Sea, at least a distance of 850 kilometers should be taken into account; therefore, things, derived only from a space of 2.5×3.75 gauge, cannot give a proper outcome, at least for precipitation.

To downscale out of precipitation, the present research has applied data of 82 pluviometer stations of Golestan Province, yet before using this data, in order to inform the lost data, the regression method was used, and at the next step, the quality management of the data was conducted through run-test and K-S. This study carried out some constant tests to determine the best predictors' scope for downscaling of precipitation component of Golestan Province stations. Thus the base of the work, founded upon this method, is first to make use of 26 components of atmosphere circulation pertinent to grid 1, located over Golestan province. Later, the rate of precipitation for 82 study stations is predicted and downscaled. In this manner, in the next step, grids are doubled, increasing the number of predictors to 52 atmosphere circulation indices. Then the number of grids increases to 3, 5, 9, and finally 15. In the latter case, the number of predicting components reaches 390 indexes. So, up to this stage, precipitation has been projected and downscaled on the basis of 1, 2, 3, 9, and 15 grids. It is taken for granted that if the number of grids is increased on proper efficiency, predictions will be based on the fact that by influencing span latitude on the precipitation of a spot, the patterns and circulation systems can show their effects more perfectly. However, to investigate the effectiveness of each of grid in downscaling the rate of performance and errors, have been evaluated in different statistical methods, e.g. Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Bias Method (MBE), Correlation of Determination (CD), Scatter Index (SI), rate of R-Square, F-Statistic, Simulation Efficiency Method (EF), and Durbin-Watson (DW) test, which will be briefly mentioned in the test (Table 2).

Table 2. Statistical relations used in evaluation of simulated results, according to different grids

MAE	**RMSE**	**MBE**	**CD**
$MAE=\frac{1}{N}\sum \lvert P_i-O_i \rvert$	$RMSE=\left[\frac{1}{N}\sum\left(P_i-O_i\right)^2\right]^{0.5}$	$MAE=\frac{1}{N}\sum P_i-O_i$	$CD=\frac{\sum_i^n\left(P_i-O_i\right)^2}{\sum_i^n\left(O_i-\bar{O}\right)^2}$
SI	R-square	F statistic	EF
$SI=\left(\frac{sd\ of\ error}{O_i}\right)\times 100$	$R^2=\frac{\left[\sum_{i=1}^n(O_i-\bar{O})(P_i-\bar{P})\right]^2}{\sum_{i=1}^n\left((O_i-\bar{O})\right)^2\sum_{i=1}^n\left((P_i-\bar{P})\right)^2}$	$f=\frac{\sigma_O^2}{\sigma_P^2}$	$EF=\frac{\sum_{i=1}^n\left(O_i-\bar{O}\right)^2-\sum_{i=1}^n\left(P_i-O_i\right)^2}{\sum_{i=1}^n\left(O_i-\bar{O}\right)^2}$

In these Pi equations, the simulated rates, Oi, rates are the number of the statistical years under study. The least rate of RMSE and CD is zero and the highest rate of EF equals 1. EF can have negative rates. It compares simulated deals with the observed average. Negative rates of EF indicate appropriate or inappropriate performance. The great deals of MAE would be an indicator of the worst status of similar action, while the RMSE indicates how much maximum and minimum the estimation is, compared to the observed data. The CD index shows the dispersion proportion between simulated and observed deals. In the best status of the numeric rate, RMSE and EF would be close to zero and the CD rate is close to 1. MBE indicates how different the estimated and the observed rates are. If the rate equals zero, it indicates the deals are good examples of simulation, but in most cases the difference is in a way that the further it is from zero, the weaker simulation becomes. The F statistic, in a way, shows a comparison of estimated and/or observed data changeability proportion ratio, with correlating two variances demonstrates that if this data reaches to 1, it would indicate the inner changeability of data, similar to each other and the more they are far from 1, the weaker the simulation would be. R-Square is in fact the so-called determination index, which indicates the correlation ratio of the two variables, and if multiplied by 100, it can show the impact ratio percent. The SI distribution index, in a way, shows SD (standard deviation of error) ratio with the average of observations and the closer the ratio of this index is to zero, the greater the simulation match would be with the observations.

As the base for suggested method is downscaling on the basis of multivariable regression, it is important to use Durbin-Watson in order to estimate the effectiveness of the above-mentioned method so that the sovereignty of resting can be determined. One of the data, regarded in regression, is error independence (the difference between real rates and predicted ones via regression equation) from one another. In case error independence is rejected and errors correlate with observations, there will be no possible space for regression. To survey the error independence from one another, the Durbin-Watson test has been used which is demonstrated as below.

$$d = 2\left(1 - r\left(u_t,\, u_{t-1}\right)\right) \tag{1}$$

where U_t is the simulation as well as the observations difference, resulting in regression model. It should be pointed out that the numeric amount of the data 'd' varies from zero to four. Also, in this equation ‘r’ is the correlation of remaining itself, in a way that if 'd' equals 2, the correlation is positive, and if it is greater than 2, the correlation is negative. Generally speaking, if this data is smaller than 1, or bigger than 3, there will be some caution for lack of independence data; however, if this data is closer to two, it indicates that the regression model enjoys a high significance. It is noteworthy that the second part of the present research concentrates on predicting the precipitation component changes for future decades. In this way, after conducting statistical tests and selecting the most proper number of grids to predict precipitation in station scale, the rates of this component will be predicted based on two A2 and B2 scenarios for the years 2020 to 2040, and the results related to the precipitation fluctuation will be investigated, while relying on temporal and local changes across Golestan Province.

RESULTS AND DISCUSSION

The current research used the Durbin-Watson test in each assessment, conducted according to the remaining data independence, resulting in observation differences and evaluation, so that it can be observed that with regards to 'd' data, the multiple regression variables can be used as a suitable tool of downscaling in the study. Regarding this point, it is remarkable that to evaluate the entire results, outcomes of eight stations were used, which were instances of different areas of the province. As it was mentioned earlier, these evaluations were based on the data of two A2 and B2 scenarios from 1971 to 2010. Therefore, according to the results of chart 3, presented through the test, it can be concluded that making use of regression method is a proper and efficient instrument for downscaling the precipitation data. What confirmed this fact was the 'd' data rates, in accordance to Durbin-Watson's Figure. It has been specified that these data are quite significant, based on the working space 1 to 15 grids for both A2 and B2 scenarios.

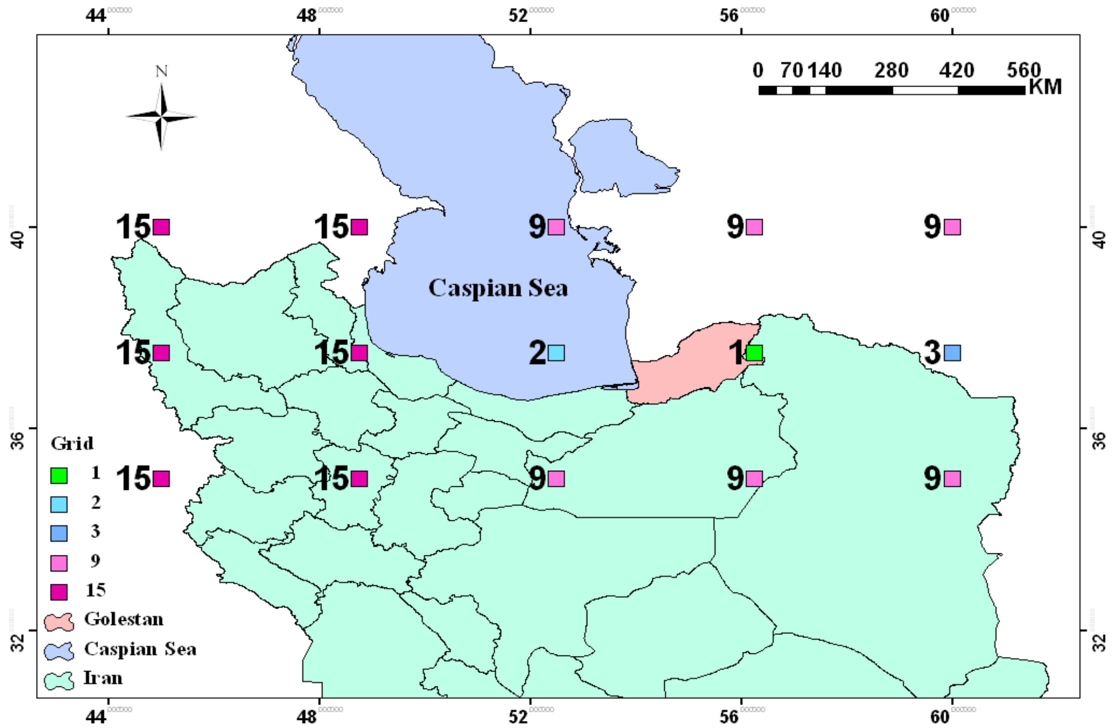

Fig. 1. The situation of 15 suggested grids for 26 predictors' component to predict and downscale the precipitation components of Golestan province

Table 3. The results of Durbin- Watson test for different grids and scenarios

Station	A2_grid01	A2_grid02	A2_grid03	A2_grid09	A2_grid15	B2_grid01	B2_grid02	B_grid03	B2_grid09	B2_grid15
Torshakli	2.09	2.14	1.97	2.04	2.00	2.12	2.01	1.97	2.01	1.98
Hotan	2.05	2.09	2.05	1.98	2.00	2.17	2.10	2.05	2.03	2.02
Robat Gharabil	1.94	1.95	1.72	1.70	1.71	2.11	1.86	1.72	1.77	1.79
Bidak	1.76	2.11	2.05	2.12	2.11	2.04	2.05	2.05	2.00	2.07
Golidagh	1.97	1.94	1.74	1.72	1.69	2.01	1.96	1.74	1.76	1.65
Hagh Alkhajeh	1.83	2.03	1.78	1.81	1.79	2.04	2.00	1.78	1.79	1.83
Gorgan	1.99	2.02	1.92	1.96	1.94	2.09	1.80	1.92	1.95	1.96
Minoodasht	2.05	2.20	2.05	2.09	2.04	1.96	2.01	2.05	2.04	2.05

The present findings have been offered with the aim of statistical analysis of each of the suggested grids' performance in simulation of the precipitation between the years 1971 and 2010. Based on Fig. 4, it can be seen that eight various tests have been taken to assess the values of the modeled outcomes. For the sake of ease, these can be divided into two general groups: one in relation with four methods, namely MAE, RSME, SI, and CD, wherein the smaller the rate of these data, the more favorable is the modelling, having fewer errors; and the other associated with other four methods, i.e. MBE, EF, R2, and F, wherein higher rates indicate more capability of the model in simulation. Based on the first group test, it is viewed that in all study stations, by increasing the number of grids, the error rate would decrease, in a way that the maximum error related to modeling is based on one grid while the minimum belongs to 15 grid. As an example, for Bidak Station, the maximum rate of MAE for A2 and B2 scenarios include 19.76 and 19.41 respectively, which belongs to the modeling, based on one grid, whereas minimum rate of MAE for A2 and B2 scenarios is devoted to modeling of 15 grids at the rate of 3.52 3.85 respectively. For RMSE, too, we can refer to the results of Torshakli Station. In this station, considering A2 scenario, the maximum and minimum rates of RMSE relate to the 1 and 15 grid modeling at the gauge of 15.92 and 6.82 respectively. Also the results of the test SI for Hotan Station indicates that in case of increasing the number of grids, the numeric rate of SI data would decrease, hence confirming the decrease of errors in modeling. The evidence for this claim is the rate of SI data for mono grid modeling of A2 scenario at the rate of 74.29 as well as its value of 30.36 for modeling of 15 grid. Consequently, results of CD index, too, like three previous data show that by increasing the grids, the rate of data decreases, in other words, this means the decrease of error in modeling would happen. In this direction, we can refer to the results of Robat Gharabil that after modeling with B2 scenario, the minimum of CD of 0.10 related to 15 grids and the maximum CD data of 0.75 belonged to mono grid (Fig. 4).

The results of second group of statistical tests, however, demonstrate that the most favorable temporal modeling was done when the number of grids got bigger. For instance, based on the outcomes of A2 scenario, the minimum and maximum of MBE data for Gorgan Station include 0.87 and 0.25. Also, for Hagh Alkhajeh, maximum R2 data is 0.86 and its minimum, 0.20.

Finally, as an example, we can point out the F test outcome for Minoodasht, where minimum and maximum data include 0.48 and 0.91, respectively. Thus, in all of these tests, the minimum data relates to the time when only one grid is used for modeling, and as the numbers of grids increase the rate of data will increase too, its maximum gauge for modeling obtained on the basis of 15 grids. It is worth noting that in order to downscale some tests in working space, more than 15 grids have been used, though the outcomes show that the minimum error is related to 15 grids, and by expanding the grids, the results of modeling have accompanied more errors. On the other hand, considering the limited space of the paper, the researcher has not brought the results of modeling more than 15 grids.

The aim of analyzing data sensitivity is to identify the impact rate of the data for each parameter that enter the outcome data by determining their index. If this index is low, the data relating to the entering parameter has less impact on the resultant outcome Considering the definition of sensitivity analysis in regression models, it is specified that out of the great number of effective components, some of them have neutral effects, while the impact of others are positive and some are even negative. In this model of downscaling, to estimate the precipitation parameter, the rate of influencing 26 circulation components has been investigated for modeling, based on one to 15 suggested grids and the results have been presented in the form of Figure 2. Of the points understood from Figure 2, the changeability of positive and negative patterns of sensitivity analysis can be mentioned. The aim of negative and positive indices is to direct effectiveness and inhibitive effect of atmosphere circulation components on the rate of precipitation of the studied stations. As it has been observed, in most stations, the challenge of these indices follow an approximately equal pattern, e.g. in mono grid modeling, the sensitivity analysis index is positive for two atmosphere circulation components: 500 hPa vorticity and 500 hPa wind direction of most stations, or in 15 grid modeling, the sensitivity analysis indices for 850 hPa vorticity components of most stations are negative and also the numeric rate of the sensitivity analysis index of 850 hPa geo-potential high component in most stations are close to zero.

Table 4. Results of different statistical tests for valuating the conducted simulations, based on different grids

Grid	Station	MAE	RMSE	MBE	SI	CD	EF	R^2	F
A2_grid01	Torshakli	11.76	15.92	0.02	85.05	0.76	0.24	0.24	4.28
A2_grid02	Torshakli	11.25	15.34	0.04	81.93	0.71	0.29	0.29	3.50
A2_grid03	Torshakli	10.75	14.49	0.14	77.43	0.63	0.37	0.37	2.91
A2_grid09	Torshakli	8.11	10.70	0.46	57.11	0.35	0.65	0.66	1.74
A2_grid15	Torshakli	5.20	6.85	0.39	36.53	0.14	0.86	0.86	1.26
B2_grid01	Torshakli	11.80	15.90	0.00	84.97	0.76	0.24	0.24	4.22
B2_grid02	Torshakli	11.38	15.30	0.04	81.73	0.71	0.29	0.29	3.47
B2_grid03	Torshakli	10.75	14.49	0.14	77.43	0.63	0.37	0.37	2.91
B2_grid09	Torshakli	8.78	11.52	0.43	61.51	0.40	0.60	0.60	1.91
B2_grid15	Torshakli	4.92	6.54	0.43	34.87	0.13	0.87	0.87	1.25
A2_grid01	Hotan	12.18	16.93	-0.02	74.29	0.66	0.34	0.34	2.92
A2_grid02	Hotan	11.87	16.50	0.00	72.40	0.63	0.37	0.37	2.68
A2_grid03	Hotan	11.54	15.73	0.13	69.03	0.57	0.43	0.43	2.42
A2_grid09	Hotan	8.97	11.58	0.44	50.79	0.31	0.69	0.69	1.60
A2_grid15	Hotan	5.32	6.93	0.42	30.36	0.11	0.89	0.89	1.21
B2_grid01	Hotan	12.18	17.02	0.03	74.69	0.67	0.33	0.33	3.03
B2_grid02	Hotan	11.77	16.28	0.07	71.44	0.61	0.39	0.39	2.64
B2_grid03	Hotan	11.54	15.73	0.13	69.03	0.57	0.43	0.43	2.42
B2_grid09	Hotan	9.29	12.25	0.45	53.70	0.34	0.66	0.66	1.71
B2_grid15	Hotan	5.37	7.04	0.50	30.81	0.11	0.89	0.89	1.23
A_grid01	Robat Gharabil	12.69	18.24	-0.09	95.24	0.77	0.23	0.23	4.14
A_grid02	Robat Gharabil	12.12	17.45	0.00	91.11	0.70	0.30	0.30	3.37
A_grid03	Robat Gharabil	11.82	16.82	0.11	87.81	0.65	0.35	0.35	3.02
A_grid09	Robat Gharabil	9.14	12.40	0.51	64.72	0.35	0.65	0.65	1.75
A_grid15	Robat Gharabil	6.03	7.83	0.51	40.80	0.14	0.86	0.86	1.26
B2_grid01	Robat Gharabil	12.41	18.09	-0.02	94.47	0.75	0.25	0.25	4.04
B2_grid02	Robat Gharabil	12.06	17.58	0.02	91.82	0.71	0.29	0.29	3.52
B2_grid03	Robat Gharabil	11.82	16.82	0.11	87.81	0.65	0.35	0.35	3.02
B2_grid09	Robat Gharabil	9.12	12.61	0.57	65.79	0.37	0.63	0.64	1.81
B2_grid15	Robat Gharabil	5.04	6.73	0.57	35.04	0.10	0.90	0.90	1.22
A2_grid01	Bidak	19.76	27.11	-0.14	75.78	0.76	0.24	0.24	3.95
A2_grid02	Bidak	19.14	26.36	-0.09	73.69	0.72	0.28	0.28	3.46

Grid	Station	MAE	RMSE	MBE	SI	CD	EF	R^2	F
A2_grid03	Bidak	18.25	24.76	0.06	69.22	0.63	0.37	0.37	2.84
A2_grid09	Bidak	13.26	17.41	0.34	48.67	0.31	0.69	0.69	1.43
A2_grid15	Bidak	3.52	4.41	0.12	12.32	0.02	0.98	0.98	0.25
B2_grid01	Bidak	19.41	26.84	-0.08	75.04	0.74	0.26	0.26	3.78
B2_grid02	Bidak	18.82	25.89	-0.01	72.38	0.69	0.31	0.31	3.15
B2_grid03	Bidak	18.25	24.76	0.06	69.22	0.63	0.37	0.37	2.84
B2_grid09	Bidak	13.55	17.52	0.48	48.96	0.32	0.68	0.69	1.50
B2_grid15	Bidak	3.58	4.53	0.14	12.67	0.02	0.98	0.98	0.40
A2_grid01	Golidagh	25.18	34.92	-0.03	71.93	0.75	0.25	0.25	3.91
A2_grid02	Golidagh	24.68	33.74	0.00	69.51	0.70	0.30	0.30	3.31
A2_grid03	Golidagh	23.72	32.49	0.13	66.94	0.65	0.35	0.35	2.92
A2_grid09	Golidagh	18.94	24.27	0.32	49.99	0.36	0.64	0.64	1.64
A2_grid15	Golidagh	11.89	14.62	0.37	30.12	0.13	0.87	0.87	1.17
B2_grid01	Golidagh	25.32	35.06	-0.02	72.24	0.75	0.25	0.25	4.03
B2_grid02	Golidagh	24.50	33.80	-0.02	69.63	0.70	0.30	0.30	3.31
B2_grid03	Golidagh	23.72	32.49	0.13	66.94	0.65	0.35	0.35	2.92
B2_grid09	Golidagh	19.34	25.72	0.30	52.99	0.40	0.60	0.60	1.75
B2_grid15	Golidagh	10.88	13.74	0.45	28.30	0.12	0.88	0.89	1.17
A2_grid01	Hagh Alkhajeh	16.03	22.45	-0.13	92.64	0.80	0.20	0.20	4.73
A2_grid02	Hagh Alkhajeh	15.50	21.83	-0.03	90.06	0.75	0.25	0.25	4.05
A2_grid03	Hagh Alkhajeh	14.89	20.85	0.09	86.01	0.69	0.31	0.31	3.34
A2_grid09	Hagh Alkhajeh	11.38	15.80	0.47	65.15	0.40	0.60	0.61	1.83
A2_grid15	Hagh Alkhajeh	6.98	9.34	0.56	38.48	0.14	0.86	0.86	1.26
B2_grid01	Hagh Alkhajeh	15.38	21.86	-0.05	90.20	0.76	0.24	0.24	4.07
B2_grid02	Hagh Alkhajeh	14.88	21.22	0.06	87.54	0.71	0.29	0.29	3.61
B2_grid03	Hagh Alkhajeh	14.89	20.85	0.09	86.01	0.69	0.31	0.31	3.34
B2_grid09	Hagh Alkhajeh	11.62	15.95	0.63	65.74	0.40	0.60	0.60	1.93
B2_grid15	Hagh Alkhajeh	6.79	8.94	0.63	36.81	0.13	0.87	0.88	1.25
A2_grid01	Gorgan	22.57	29.51	-0.15	60.40	0.77	0.23	0.23	4.17
A2_grid02	Gorgan	21.83	28.50	-0.09	58.33	0.72	0.28	0.28	3.49
A2_grid03	Gorgan	21.46	27.54	0.02	56.37	0.67	0.33	0.33	3.10
A2_grid09	Gorgan	16.39	20.73	0.20	42.43	0.38	0.62	0.62	1.69
A2_grid15	Gorgan	10.01	12.95	0.15	26.50	0.15	0.85	0.85	1.20
B2_grid01	Gorgan	22.51	29.40	-0.25	60.17	0.77	0.23	0.23	3.93
B2_grid02	Gorgan	21.36	28.23	-0.16	57.79	0.71	0.29	0.29	3.28
B2_grid03	Gorgan	21.46	27.54	0.02	56.37	0.67	0.33	0.33	3.10
B2_grid09	Gorgan	16.93	21.66	0.13	44.33	0.42	0.58	0.58	1.77
B2_grid15	Gorgan	10.14	12.76	0.28	26.12	0.14	0.86	0.86	1.21
A2_grid01	Minoodasht	30.71	41.04	-0.17	66.73	0.78	0.22	0.22	4.41
A2_grid02	Minoodasht	29.38	39.25	-0.09	63.81	0.72	0.28	0.28	3.46
A2_grid03	Minoodasht	28.66	38.08	-0.03	61.92	0.67	0.33	0.33	3.06
A2_grid09	Minoodasht	22.61	29.03	0.15	47.19	0.39	0.61	0.61	1.68
A2_grid15	Minoodasht	13.23	17.01	0.36	27.65	0.13	0.87	0.87	1.20
B2_grid01	Minoodasht	31.08	41.27	-0.26	67.09	0.79	0.21	0.21	4.48
B2_grid02	Minoodasht	30.26	40.01	-0.18	65.06	0.74	0.26	0.26	3.76
B2_grid03	Minoodasht	28.66	38.08	-0.03	61.92	0.67	0.33	0.33	3.06
B2_grid09	Minoodasht	23.60	30.28	0.21	49.22	0.43	0.57	0.57	1.80
B2_grid15	Minoodasht	12.54	15.97	0.34	25.96	0.12	0.88	0.88	1.17

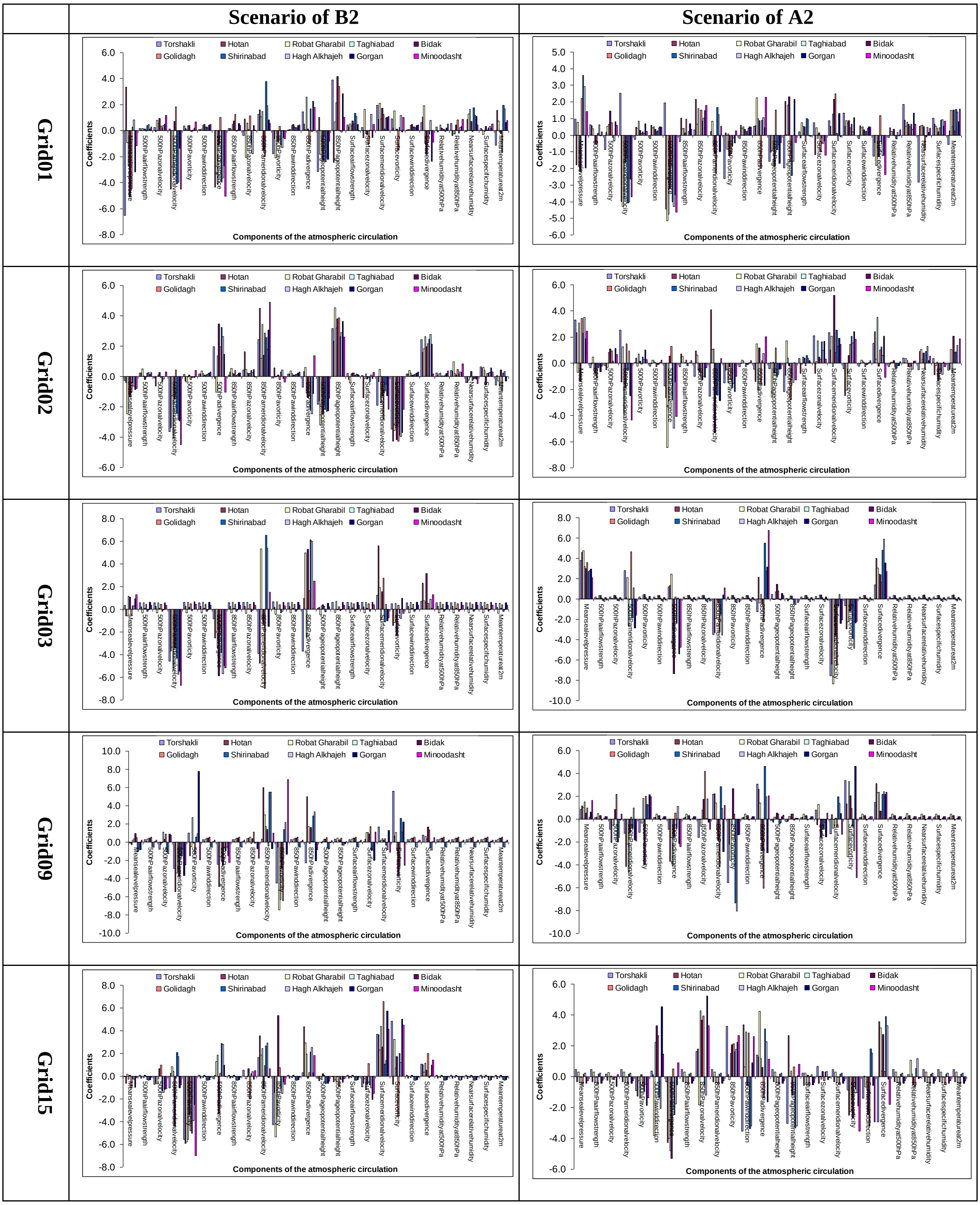

Fig. 2. Calculating indices, pertaining to sensitivity analysis based on regression indices of multi-variables for mono grid with 26 circulation components to 15 grid with 390 circulation component, directing to two A2 and B2 scenarios

Another contemplating issue is that, by detecting the outcomes, it will be clear that by changing the number of study grids, the effectiveness rate of the circulation indices changes (Fig. 2). To properly understand this matter and make comparison more clearly, we can hint the average of indices, related to the sensitivity analysis of 26 circulating components of 10 selected stations for two 1 and 15 grid methods. If we pay attention to Fig. 3, we can see that in mono-grid modeling, seven atmosphere circulation components bear negative indices, having inhibitive effect on precipitation. The maximum inhibitive effect belongs to components like 500 hPa Divergence, 500hPa Meridional Velocity, and Surface Divergence. In contrast, in 15-grid modeling, 18 circulation components have negative indices, among which 500 hPa Divergence, 500 hPa Meridional Velocity, and Surface Divergence have maximum inhibitive effect on the rate of precipitation in study stations. Of the atmosphere circulation components with direct effect on boosting precipitation event, we can mention three components 850hPa zonal velocity, mean temperature at 2 m, and Surface Meridional velocity in mono grid modeling. But in precipitation modeling, based on 15 grids, two components with sea level pressure, Surface Divergence enjoy the lion's share in precipitation event. Therefore, the synoptic reason behind the use of several grids, matching with Figure 1, is that in one grid in 2.5 arenas in 3.75 usually the general circulation dynamic components of atmosphere are averaged, while the neighboring grids are supposed to be considered changeable to some extent. This component, more transparent in local scale, is extended in the direction of atmosphere systems of the studied regions. The role of effective atmosphere index in the intended region's climate will be raised. Here, the special experience of the climatologist will be more determining. To this end, we may have a synoptic look at analysis of future condition. What is crucial in this section is that it rarely happens that the circulation component have any neutral effect. On the other hand, even those components with minimum effect in modeling precipitation, have been used in regression relation. Since, based on a synoptic view, the effect of any component, even a subtle, cannot be removed.

One of the most important parts of this research belongs to the simulation of precipitation component on the basis of two A2 and B2 scenarios, related to global warming for future decades. To this purpose, one basic term was picked out during 1971 to 1990 to analyze precipitation changes for the years 2020 to 2040 in this area, though most studies of climate change from 1961 to 1990, concerning the studied stations, lacked data from 1961 to 1990. While in studies of climate change most of the time, 1961 to 1990 is considered a basic era, many studies lacked data for the decades from 1961 to 1970, which restricted the basic era, making 1971 the starting point of this period. Yet it should be confessed that in order to equally compare the changes of precipitation pattern in each month, four study index thresholds have been selected. The first includes those areas, where declining precipitation changes would experience 50 to 100 mm. The second index involves arenas with precipitation decrease between 0 and 50. The third and fourth indices include increase of precipitation, from 0 to 50 and 50 to 100, respectively. The findings for this study section indicate that in the winter, much more precipitation changes are additive. However, comparison between the results of A2 and B2 scenarios are a bit different, i.e. although both scenarios of January has devoted declining precipitation of 23% to 24% to that area of the province, in A2 scenario, a region of the province with an expanse of 20.15% shows a precipitation decrease at the rate of 50 to 0 mm for February, whereas in B2 this precipitation decrease covers less than 1% latitude of the province (Fig. 5). Results from local distribution of the precipitation changes of the province shows that half of eastern part of the province demonstrates a high potential for precipitation decrease pattern and of the regions accompanied by maximum precipitation includes an expanse in the farthest south western of the province.

In the spring, most precipitation changes are additive also. However, based on A2 scenario for June, decrease in precipitation at the gauge of 11.83% indicates the area of province, but this breadth for B2 scenario is only 1.09% (Fig. 5). On the other hand, for April, based on both scenarios, no precipitation decrease is observed. In this season, most of precipitation changes is based on third threshold and/or the in case of precipitation increase between 0 to 50 mm the maximum of precipitation additive changes has developed in the form of a ring from northeast to southwest of the province (Figs. 4 and 5).

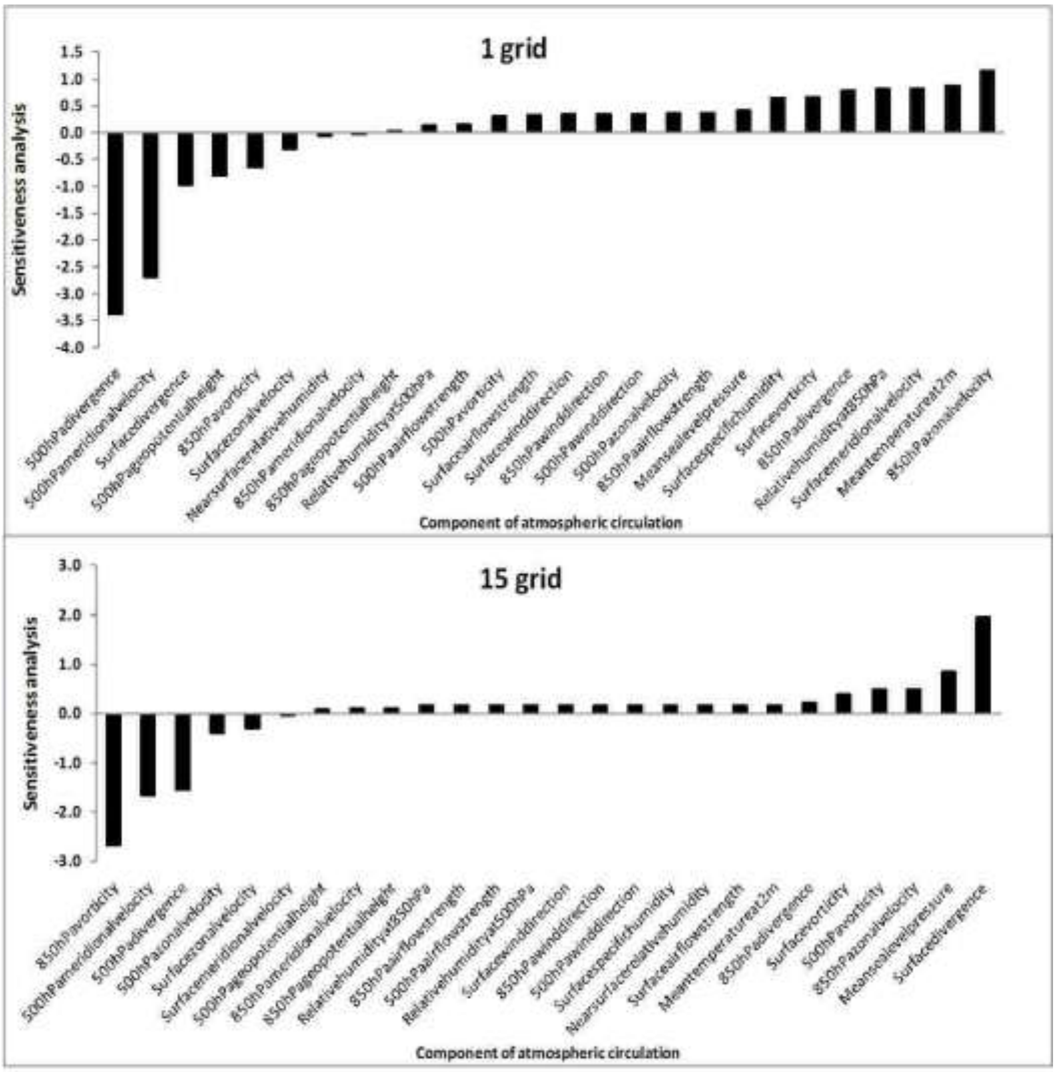

Fig. 3. The average of indices, pertaining to sensitivity analysis of ten studied stations for one or 15 grids, based on A2 scenario data

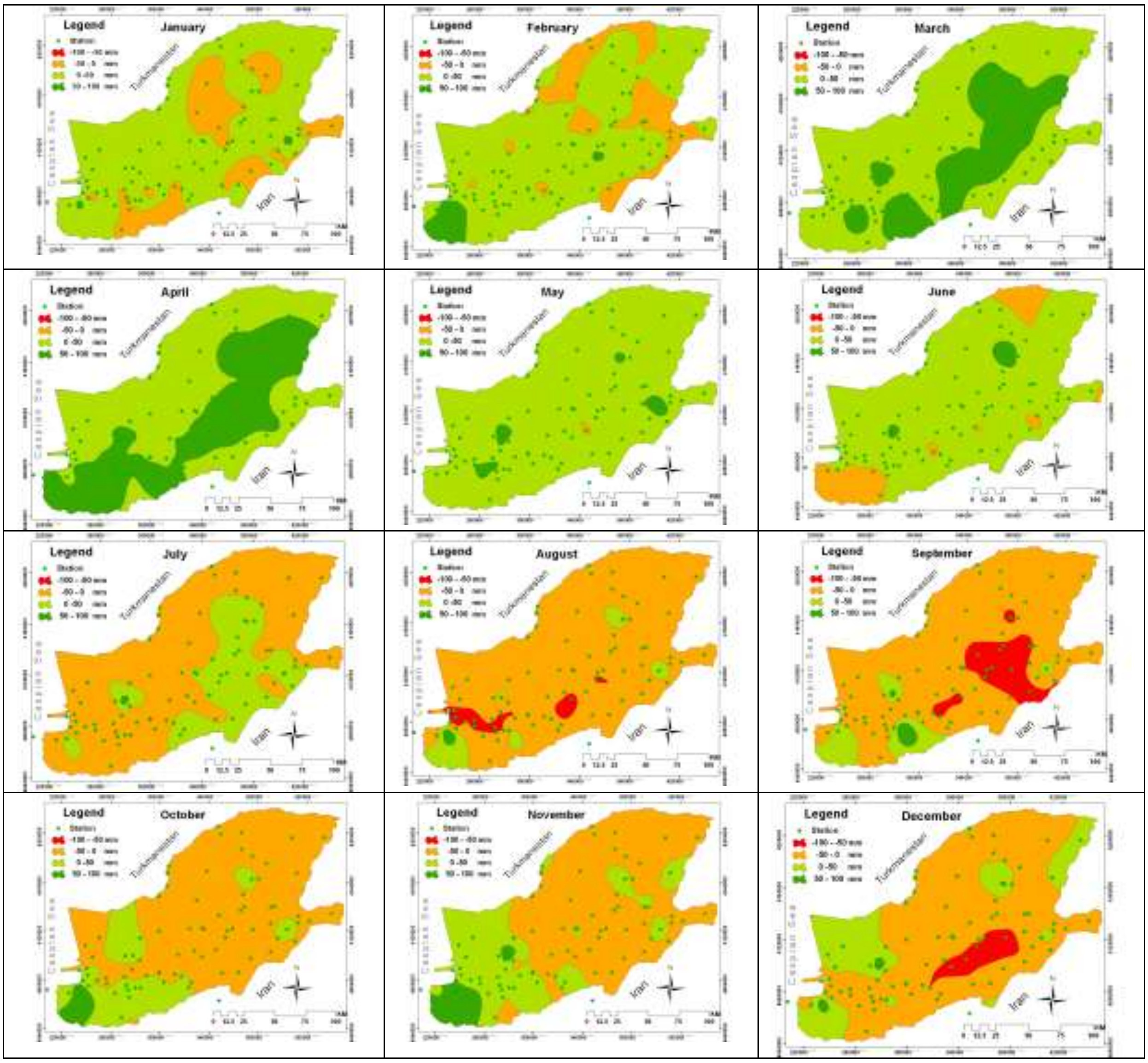

Fig. 4. Spatial-temporal precipitation changes of Golestan Province between 2021 and 2040 A2 scenario in comparison to the basic era from 1971 to 1990

Table 5. The monthly percentage of increasing/decreasing precipitation of A2 and B2 scenario (2021-2040) in comparison to the basic period (1971 to 1990).

	Scenario A2				Scenario B2			
Mont	**(-100)-(-**	**(-50)-**	**(0)-**	**(50)-**	**(-100)-(-**	**(-50)-**	**(0)-**	**(50)-**
Jan	0	23.9	75.79	0.31	0	23.04	72.55	4.41
Feb	0	20.15	75.8	4.05	0	0.39	88.98	10.63
Mar	0	0	70.76	29.24	0	0	62.57	37.43
Apr	0	0	58.91	41.09	0	0	75.2	24.8
May	0	0.24	97.26	2.5	0	0.18	68.4	31.42
Jun	0	11.83	86.39	1.77	0	1.09	78.32	20.59
Jul	0	72.99	26.81	0.21	0	28.88	68.32	2.8
Aug	3.65	90.2	5.73	0.42	0.05	91.99	7.68	0.28
Sep	10.69	79.7	8.47	1.14	1.01	90.29	8.7	0
Oct	0	77.24	20.1	2.66	0	36.11	55.45	8.44
Nov	0	64.96	29.5	5.55	0	65.72	29.77	4.51
Dec	5.2	73.02	21.21	0.57	0	34.43	57.82	7.76

Summer is the season in which the highest monthly change confirms decrease of precipitation for future decades toward the basic era. In spite of this, in both study scenarios a remarkable area of precipitation addition is seen for July and these areas in B2 scenario go through a greater addition, compared to precipitation decrease. However, the additive monthly area is 71.10% in A2 scenario and 27% in B2 scenario. The most additive changes of precipitation, regardless of January, is located in sub eastern part of the province. In this season, for the first time, the two months of August and September experience a decrease of precipitation, belonging to 50 to 100 millimeter threshold and the gauge of this area is more for A2 scenario than B2. As an example, for September, the expanse of this area on the basis of A2 scenario is 10.7, which with regards to B2 scenario, this expanse is around 1% for the province (Fig. 5). For the autumn, the simulations show the dominance of precipitation decrease in comparison to the basic area. This condition is seen for both scenarios, though for A2 scenario the intensity of precipitation decrease is more severe than B2. Even in a way, based on A2 scenario, in December 5% of the area of the province has experienced precipitation decrease, accounting to 50 to 100 millimeter. One of the interesting outcomes is that in November both A2 and B2 scenarios modeling show changes in local patterns of precipitation, which are nearly similar to one another. Such a phenomenon is rarely viewed in other months; however, both scenarios of sub eastern and center of the province indicate maximum precipitation decrease with the focus of precipitation addition still observed in the farthest southwestern area of the province (Figs. 4 and 5).

Finally, due to the importance of learning about decennial changes of precipitation component for the province, the general average of the province has been evaluated from 1971 to 2040. It should be explained that as the statistical era monitors, this time series include the observing and project period (Fig. 6). So this issue is justifiable that there must be no difference among precipitation curve, based on both A2 and B2 scenarios, at the end of the observation era and then we can see the difference and changes between the two scenarios. Yet, in the beginning as is observed from Fig. 6, the process of decennial average of precipitation has been additive for the entire study era and the maximum precipitation is seen for the simulated era. In addition to these results, Figure 5 indicates that in the observed period, the precipitation changes follow three patterns: First in the first decade, the average has decreased, followed by an increase in the second period, and then in the third period it declined once more. Based on conducted modeling, following B2 scenario from the end of the observed era to the end of simulated period, the precipitation process is completely additive and ascending. Evidence for this matter is the decennial average of precipitation for 2010s at a rate of 659 mm, for 2020s at a rate of 688 mm, and finally for 2030s at a rate of 729 mm. Although the decennial process of precipitation, too, is based on A2 additive scenario, the precipitation average in 2020s indicates a 39 millimeter decrease, compared to 2010s (Fig. 6). Therefore, although the decennial average of yearly precipitation of Golestan Province heightens, changes of monthly pattern are not so promising for an ideal condition of this precipitation increase.

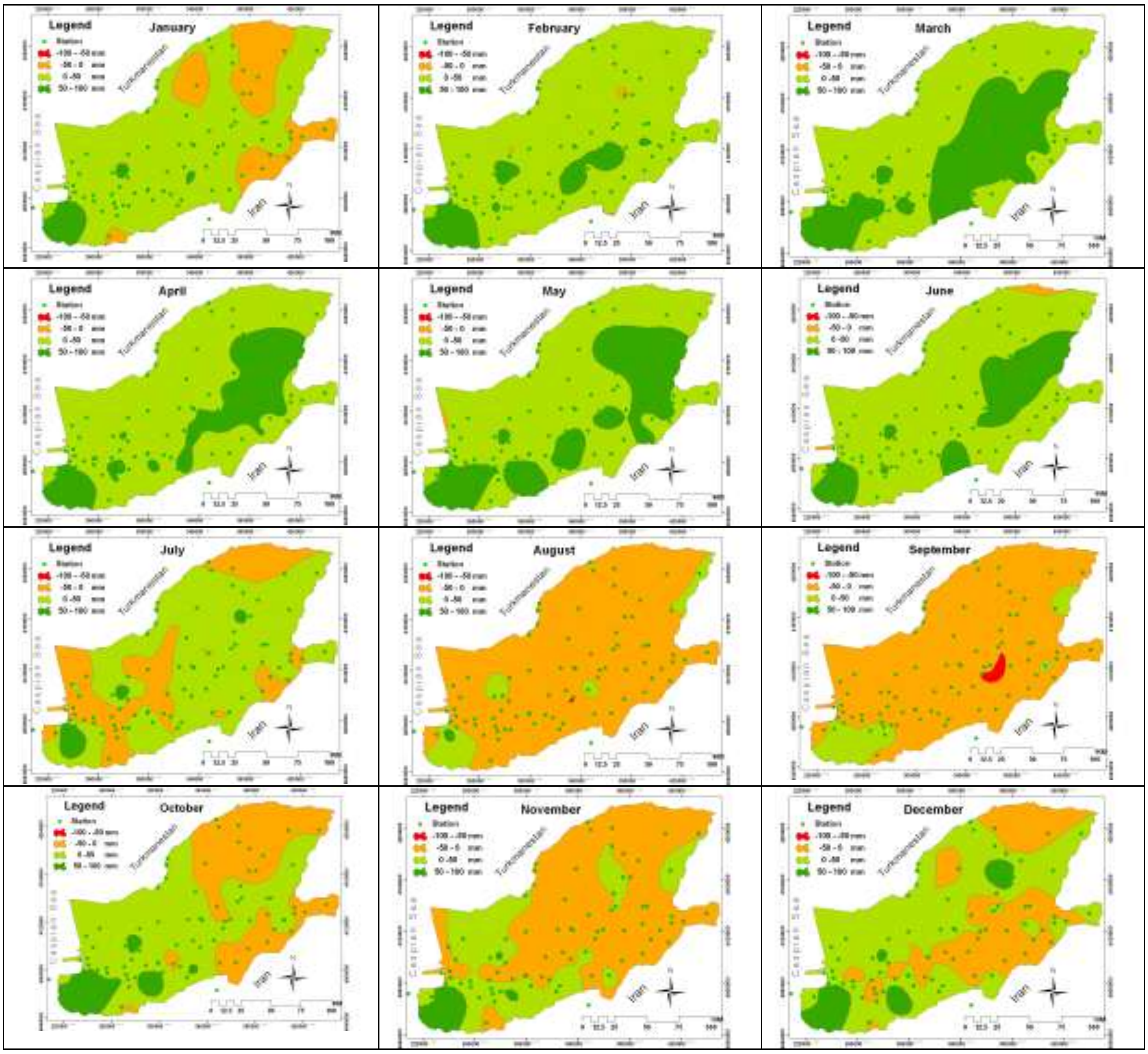

Fig. 5. Spatial-temporal distribution of precipitation changes of Golestan province for the years 2021 to 2040 of B2 scenario in comparison to the basic era, 1971 to 1990.

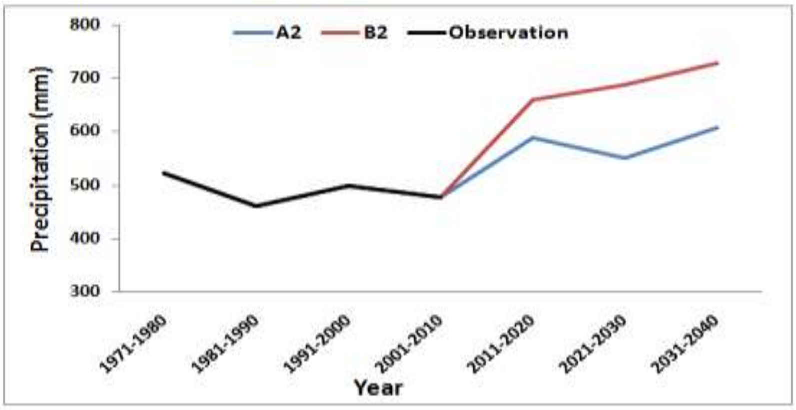

Fig. 6. Changes in the trend of precipitation component for general average of the province from 1971 to 2040

Table 6. The average of changes of precipitation component for general average of the province from 1971 to 2040

Year	A2	B2	Observation
1971-1980	-	-	524
1981-1990	-	-	461
1991-2000	-	-	498
2001-2010	477	477	477
2011-2020	589	659	-
2021-2030	550	688	-
2031-2040	607	729	-

CONCLUSION

The aim of the present study was to introduce novel procedures in statistical downscaling and to minimize modeling error, meaning that in the present method, in spite of other statistical downscaling models, the climate components were predicted and downscaled via a synoptic view. The difference was that most of statistical downscaling methods of the present procedure to predict and downscale atmosphere data of a station just depend on grid predictors' components, in which the intended station was located. But from a synoptic view, while this is a tenet, vorticity in location cannot generally become the precipitation factor in that location too. In other words, the dynamic condition acts on generating clouds, its seeding, and consequently, precipitation in a wider area with further than mono grid dimensions. Thus, it is taken for granted that the grid predictors' components did not suffice, at the station's location and the area of predictors had to be selected beyond one grid through trial and error. Therefore, in this research, the scope of predictors was selected from 1 to 15 grid and the results of this modeling for the statistical period, 1971 to 2020, with different methods tests were estimated for ten selected stations throughout Golestan Province. However, all methods were indicators of minimum and maximum errors respectively for modeling precipitation components, based on 15 and one grid. It should not be forgotten that the intended modeling method for downscaling the precipitation data included multi variable regression and the efficiency of this method for precipitation simulation of each grid was confirmed via Durbin-Watson test. In the rest of the research with the use of sensitivity analysis, the rate of data impact of inserting each parameter on modeled data of station's participation was determined for the suggested grids. Interestingly, results showed that by changing the number of grids, the influencing index of predictors' components on precipitation parameter preceded the changes. But for most stations, change of these indices for each atmosphere circulation component follows almost the same pattern. For instance, in mono grid modeling, the sensitivity analysis index for two atmosphere circulation components 500hPa, wind direction of most stations was positive while in 15-grid modeling the sensitivity analysis indices was negative for 850hPa vorticity. It is worth noting that considering the role of all atmosphere circulation components, altogether, is basis for synoptic studies view. So, based on the procedure in this research, the proportion of atmosphere circulation components that had the least influence on precipitation modeling was taken into consideration too. However, after determining the 15-grid method as the least occurring error method in downscaling the atmosphere data, by means of HadCm3 predictors, general circulation model and two A2 and B2 scenarios the rate of precipitation for the decades 2020-2040 simulation and their changes were compared with the average of basic during the era between 1971 and 1990. General result of these changes for yearly decennial average confirms the additive process of this component, based on two suggested scenarios. But this annual precipitation decennial increase was accompanied by monthly and yearly diversities which were not promising enough for the desired condition management of water resources of the province. The evidence for this claim was precipitation decrease of autumn as a rainy and effective season for water resource reservoir. Also summer's drier climate was another unfavorable change for future decades. Since summer is known as a draught season in the province, one of the issues was lack of access to water resources during the year. On the other hand, simulation results indicate that the rate of winter precipitations towards the basic period increased; in other words, precipitation in the whole year had an important share in getting access to water resources, so the accumulation of precipitation for a given era would cause a decrease this effective efficiency.

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