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Statistical Downscaling of Climatic Variables in Shadegan Wetland, Iran

Halime Etemadi*, Seyedeh Zahra Samadi and Mohammad Sharifikia

Natural Resources and Marin Science Faculty, Tarbiat Modares University, Tel: +989173914870, Iran

Abstract

Wetlands are principle element of the ecosystems where exposed with the adverse effects of climate change. Shadegan is the largest international wetland in Iran with area around 400 ha. This paper describes one downscaling methods, LARS-WGS facilitated in downscaling of daily precipitation and temperature over a highly vulnerable catchment (Maroon-Jarrahi) in the south eastern part of Iran by 2010–2039.According to LARS-WGS projection, minimum and maximum temperature will decrease up to 0.12°C and 0.34°C and daily precipitation will decrease up to 45 mm in the future respectively. LARS-WGS outputs presented the most reduction of precipitation will happen in winter and a slight increase during the summer, also daily temperature will increase in the winter and will be changeable in the rest of seasons. As a result increasing in temperature tends to actively increase the evaporation process and reduce water level in the wetland. Therefore climatic variables changes corresponding to downscaled future projections presented changes in water availability in this area. This study attempts to downscale climatic variables by statistical downscaling technique in an arid area and therefore contributes to an improvement of the quality of predictions of climate change impact assessment in regions of this type.

Keywords: Climate change; Downscaling; LARS-WG; Shadegan wetland; Iran

Introduction

A rising trend of the Earth's temperature and changes in the associated weather conditions across the globe are referred to as climate change. This problem was first posed in the mid 1960s, when it was demonstrated that greenhouse gases were accumulating in the atmosphere [1]. In the absence of suitable mitigation and adaptation measures, climate change is likely to affect major sectors of the world, such as environment, water resources, and tourism. According to the reports of the Intergovernmental Panel on Climate Change (IPCC) in 2001, confirmed in 1995, the global average temperature will rise by about 3.6°C, with a range of 1.5-4.5°C, depending on the model used [2]. These results are still uncertain, due to the natural temperature variability from place-to place, day-to-day, and season-to-season, as well as the modeling uncertainties. The climatic response to the enhanced greenhouse effect is calculated by means of highly complex General Circulation Models (GCMs). GCM simulations of local climate at individual grid points are often poor especially when the area has complex topography [3]. Even if global climate models of high resolution are developed in the future, the downscale techniques might be still needed for evaluating the impact of climate change on environment because the spatial resolution of GCMs remains quite coarse and it has no accurate for environment studies. In the other hands the outputs of these models don't have local and temporal adequate accuracy for climate change impacts studying on environmental systems. Therefore downscaling method can be use as a reliable technique for projection of future climatic variables. This study relies on one statistical downscaling model, based on observed data; LARS-WGS define relationships between the large-scale variable data, derived either from climate model outputs or observations, and local-scale surface conditions. A number of generators have been progressed [4] They can be very simple series [5] and Markov chain based models [6] or complicated methods based on the observed hierarchical organization of rainfall and on rain cell space and time-clustering process [7]. LARS-WG is a stochastic weather generator which can be used for the simulation of weather data at a single site [5], [8,9] under both current and future climate conditions. These data are in the form of daily time-series for a suite of climate variables, namely, precipitation (mm), maximum and minimum temperature (°C) and solar radiation (MJm-2day-1). Stochastic weather generators are used in a wide range of studies such as environment management, hydrological application, and agricultural risk assessment [10]. It has been tested for diverse climates and found better than some other generators e.g. WGEN; WGEN uses simple standard distributions, whereas LARS-WG tends to use the more flexible semi-empirical distributions. In the results of testing the generators over the 18 diverse sites, with LARS-WG able to match the observed data much better than WGEN [5]. A study by [11] has tested the skill of the LARS-WG stochastic weather generator to simulate extreme weather events at 20 locations with diverse climates, and has shown its ability to model rainfall extremes with reasonable skill. The weather generator has been examined in varied climates in Asia, Europe and New Zealand, North America the results has shown The weather generator had the power to reproduce most of the characteristics of the observed data reliability at each site [12]. Likewise LARS-WG is able to generate synthetic data adequately close to the observed climate variables in statistical properties, such as daily precipitation and daily minimum and maximum temperature [13]. Abbaspour et al. [14] generated and Downscaled for 37 stations climate for the periods from 2010 to 2040 and 2070 to 2100. They found that in general, wet regions of the country will receive more rainfall, while dry regions will receive less in Iran. Climate appears to be generally changeable precipitation and temperature during the last half of the 20th century particularly in arid regions. Regions with arid climates could be sensitive even to insignificant changes in climatic characteristics. Understanding the relationships among the climate variables, and anthropogenic effects are important for the sustainable management of environmental resources in these regions.

***Corresponding author:** Halime Etemadi, Natural Resources and Marin Science Faculty, Tarbiat Modares University, Tel: +989173914870, Iran, E-mail: etemadi.halime@yahoo.com

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The goal of this study is to study one statistical downscaling model then applied its downscaled results in the future impact studies. In fact, the ultimate goal of downscaling approach is to generate an estimate of meteorological variables corresponding to a given scenario of future climate so these research meteorological variables will be used as a basis for any climate change impact assessments. The objective of this study is to assess future climate change in an international wetland due to one downscaling model using global circulation model (GCM) simulated predictors instead of the observed NCEP predictors. This analysis provides some indication of how downscaling model will generate of future climatic variables on the GCM outputs.

Study Area and Data Source

The study Area includes the Jarrahi Basin in southwest of Iran. The area of Jarrahi Basin is approximately 24310 km^2; it is characterized by a Mediterranean climate consisting of hot and dry summers and mild and rainy winters. Jarrahi River network consists of two large reservoirs (Maroon and Jarrehi) which are the main freshwater supplier of Shadegan Wetland, the largest international wetland of Iran covers about 4000 Km^2 and creates a suitable habitat for a number of migrating waterfowls, which fly to this area from north Europe, Canada and Siberia in autumn. Location map of Shadegan Wetland in Maroon-Jarrahi catchment is shown in figure 1 and 2. In this study, data is collected, from three meteorological stations as they have sufficient record length as required by LARS-WG, Ramhormoz (R), Mashahr harbor (M), Behbahan (B) (Table1). The daily rainfall and temperatures data of R and M stations is available for 1986 to 2005(20 years). The observed data was obtained from Iranian Meteorological Organization (www.irimet.net). Daily precipitations as well as daily maximum and minimum temperature data were defined as predicted variables for the downscaling experiments. Climatic variables corresponding to the future climate change scenario for the study area are extracted from the ECHO-G GCM output is from Hamburg University and Southern Korea-A2 Emission Scenario-with 2/8*2/8digree of resolution (300*300 Km at a grid point which is closest to the study area. Data is extracted for one distinct periods that covering a 30 years period between 2010 and 2039).

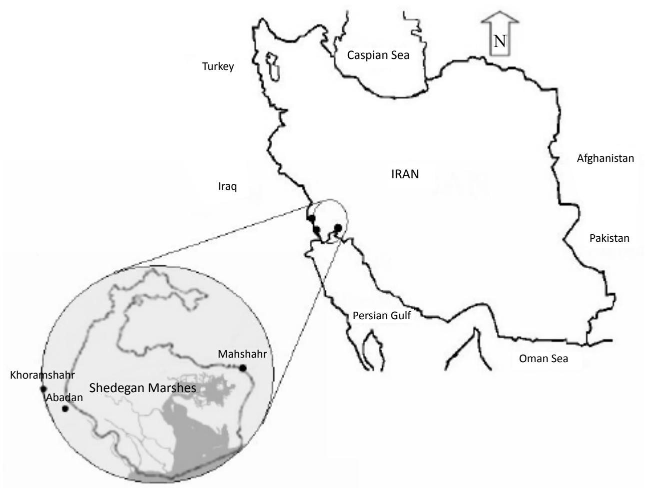

Figure 1: Location map of Maroon-Jarrahi catchment in Iran.

Station	current period	Geographical characteristic			Station Type
		ELEVATION (m)	**LATITUDE**	**LONGITUDE**	
Behbahan	1991-2005	313m	'N36◦30	'E14◦50	SYNOPTIC
Ramhormoz	1986-2005	150.5	'N16◦31	'E36◦ 49	SYNOPTIC
Mahshahr	1986-2005	6.2	30◦33'N	'E9◦49	SYNOPTIC

Table1: Characteristic of meteorological study stations.

Method

Stochastic weather generator

LARS-WG is based on the series weather generator described in [5].

Calibration and validation of Lars-WG: LARS-WG model calibration consists of calculating the relevant statistical parameters for each meteorological variable from the observed historical data. These parameters or the once modified based on future climate change scenario are then used to stochastically generate realistic climate data corresponding to the present and future climate scenario, respectively. For the first set of experiment, mean of observed daily precipitation as well as daily maximum and minimum temperatures at the stations of Maroona-Jarrehi catchment for the period 1986-2005 were used to extract the statistical parameters of the current climate. For precipitation, these parameters consist of monthly histogram intervals and frequency of events in each interval for dry and wet spell lengths, as well as precipitation amounts. On the other hand, temperature is modeled in LARS-WG by using Fourier series which can be constructed with parameters such as mean value, amplitude of the sine and cosine curves and phase angle. Both maximum and minimum temperatures are modeled more accurately by considering wet and dry days separately; therefore, the temperature parameters for wet and dry days are derived separately. The weather generator also uses parameters corresponding to average autocorrelation values for minimum and maximum temperature derived from observed weather data. After the observed weather data is analyzed in this way, the derived statistical parameters are used to generate synthetic weather data representing the current climate. To get a representative statistics of the synthetic data, a 30-year data was generated for each climate variable considered. Finally, statistical tests are performed to see if the data generated by the weather generator comes from the same population as the observed ones. Flowchart of the research process is shown in Figure 3.

Model evaluation techniques

For each station the reliability of the model is assessed using five different criteria. The criteria used include Mean Absolutely Error (MAE), RSQ, Root Mean Square Error (RMSE), Nash-Sutcliffe Coefficient (Nr) and Percent bias (PBIAS). Each of the criteria is briefly described below:

$$MAE = 1/n\sum_{i=1}^{n}(S_i - O_i) \quad (1)$$

$$R^2 = \left[\frac{\frac{1}{n}\sum_{m=1}^{n}\left(S_i - \bar{S}\right)\left(O_i - \bar{O}\right)}{\sigma_S \times \sigma_O}\right]^2 \quad (2)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(S_i - O_i)^2\right]^{1/2} \quad (3)$$

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$$NSE = 1 - \frac{\sum_{t=1}^{N}\left(O_i - S_i\right)^2}{\sum_{t=1}^{N}\left(O_i - \bar{O}\right)^2} \qquad (4)$$

$$PBIAS = \left[\frac{\sum_{i=1}^{n}(O_i - S_i) * 100}{\sum_{i=1}^{n}(O_i)}\right] \qquad (5)$$

Where N represents the number of observations in the time series, Si is the simulated values, Oi is the corresponding observed values, σ is the variance and Ō and S¯ are the observation and simulation averages, respectively. The coefficient of determination (R2) measures the tendency of the simulated and observed values to vary together linearly and ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable [15]. NSE ranges between -∞ and 1.0, with NSE =1 being the optimal value. Values between 0.0 and 1.0 are generally viewed as acceptable levels of performance, whereas values <0.0 indicates that the mean observed value is a better predictor than the simulated value. The optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation bias [16]. RMSE varies from the optimal value of 0 to a large positive value, which zero RMSE indicates perfect model simulation. If RMSE and MAE be less it shows the strange relationship, so the lower, the better the model simulation performance. Results of model validation observation and LARS-WG model output showed in table 2 for monthly temperature and precipitation of Shadegan wetland stations. The results of statistical parameters analyses indicated good model simulation for temperature not for rainfall because overly the relatively low Rsq for daily rainfall in an arid region is acceptable for global standards and LARS -WGS has a large stochastic component so you would not expect the model to replicate the exact daily sequences found in observations. Also the level of predictability of site-level precipitation from regional-scale predictors is invariably low. In this manner differences among the values of monthly mean daily min temperature, max temperature and precipitation for observed and modeled base period in three stations were determined by pair sample T test and the significance was defined at P<0.05.

Downscaling technique of lars-wgs model

Data corresponding to future scenarios using LARS-WG, site analysis is made using the daily GCM data for both the baseline (current) and future time periods. To incorporate the change in climate, one needs to calculate the relative change in monthly mean precipitation and monthly mean wet and dry series lengths from the GCM output of the baseline and future time-period. Similarly, relative change in mean temperature and standard deviation for each month is calculated from GCM outputs. All these values are calculated from the parameter files generated during the site analysis of the corresponding climate variables (GCM outputs) for the baseline and future time periods. This information is then apply to construct the climate change scenario file which LARS-WG uses to determine how the weather generator parameter values (obtained from the observed precipitation and temperature data) should be perturbed to generate regional climate scenario. That means, the relative changes observed in the GCM outputs are the forcing to LARS-WG based on which it generates the daily weather data representing future climate at the particular site.

Results

Observed, current period and future ECHO-G modeled mean monthly t min and t max Mahshahr station exhibit in figures 4a and 4b.

Statistical factor	Behbahan			Bandar Mahshahr			Ramhormoz		
	Tmin	Tmax	Prec	Tmin	Tmax	Prec	Tmin	Tmax	Prec
PBIAS	0.569	0.371	7.373	0.716	0.308	1.492	0.185	0.380	2.795
MAE	-0.097	-0.119	-0.068	-0.132	-0.100	-0.009	-0.036	-0.124	-0.026
RMSE	0.368	0.465	0.309	0.412	0.470	0.189	0.710	0.844	0.148
NSE	0.998	0.998	0.915	0.997	0.998	0.909	0.992	0.993	0.981
RSQ	0.998	0.998	0.920	0.997	0.998	0.914	0.992	0.995	0.986

Table 2: Results of model validation monthly temperature and precipitation of observation and LARS-WG model output, Shadegan wetland stations.

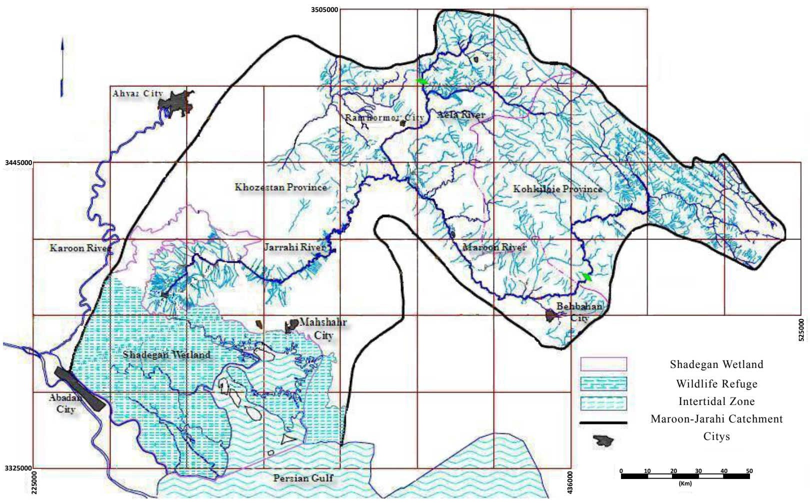

Figure 2: Location map of Shadegan Wetland in Maroon-Jarrahi catchment.

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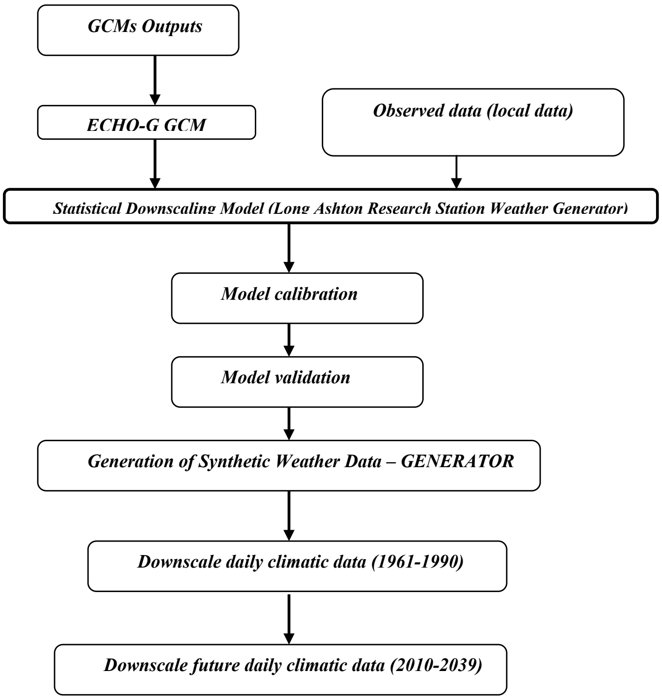

Figure 3: Flowchart of the research process.

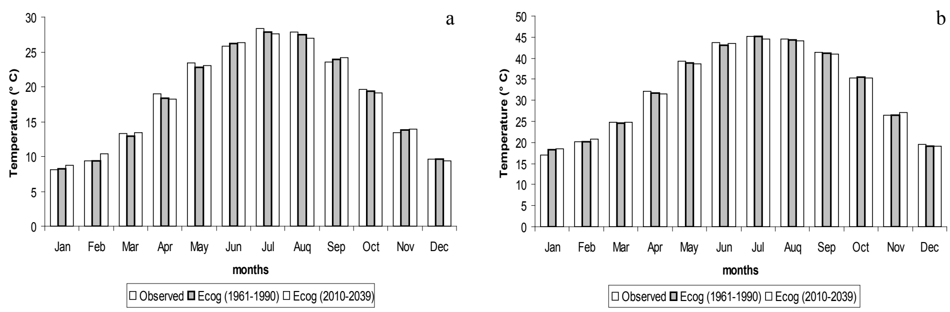

Figure 4: Monthly mean daily min temperature (a) and max temperature (b) (observed and model) for the current and future periods in Mahshahr.

Maximum and minimum different of observed and past modeled t min is 0.7°C and0.0 °C in the months of April and December respectively. The results indicated that maximum decreasing and increasing of observed and modeled future t min is 0.98°C in the month of February and 0.12°C in March respectively. In figure 4b Maximum and minimum different of observed and modeled past t max is 1.22°C and 0.02°C in the months of January and November respectively. Also maximum decreasing and increasing of observed and modeled future t max is 0.62°C in the month of July and 1.37°C in January respectively. Figures 5a and 5b show current and future ECHO-G modeled and Observed mean seasonally t min and t max Mahshahr station. According to this Figures LRARS-WG has simulated current ECHO-G modeled t min accurately in winter and autumn. Maximum increasing and decreasing future ECHO-G modeled seasonally tmin0.58°C and 0.3°C in the season of winter and summer respectively. According to figure 5b, LRARS-WG has projected t max in summer and autumn season precisely but is rationally unable to downscale summer season additionally. The results indicated that maximum increasing and decreasing seasonally ECHO-G (2010-2039) t max is 0.68 and 0.46 in the season of winter and summer respectively. Result of monthly and seasonally mean daily precipitation for the current and future periods in Mahshahr station exhibited in figures 6a and 6b. Maximum and minimum different of observed and current modeled sum precipitation defined 8.44 mm in the months of January and 0.00 mm in the months of Jun, July, August and September respectively. LARS-WG model has downscaled precipitation closer to observed data in most of months except January and March in Mahshahr station. Sum of future maximum and minimum monthly precipitations are predicted 48.9 mm in December and 0.00 mm in July respectively. Maximum decreasing and increasing of future monthly mean daily precipitation respectively occur in the month of January 17.43 mm and in the month of May 0.93 mm. With respect to future trends, precipitations continuously decrease from October to April. LARS-WG model has downscaled precipitation closer to observed data in most of season except winter. Figure 6b exhibits that precipitation in coming decade will decrease 11.08 mm, 1.23 mm, 4.40 mm in winter, spring and autumn and will increase

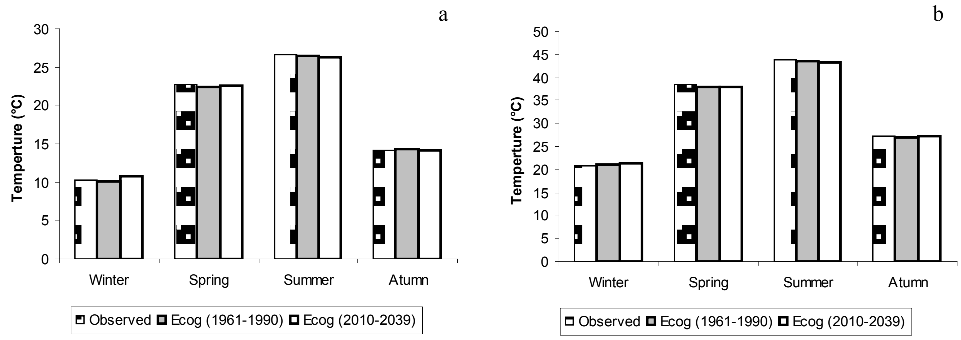

Figure 5: Seasonally mean daily min temperature (a) and max temperature (b) (observed and model) for the current and future periods in Mahshahr.

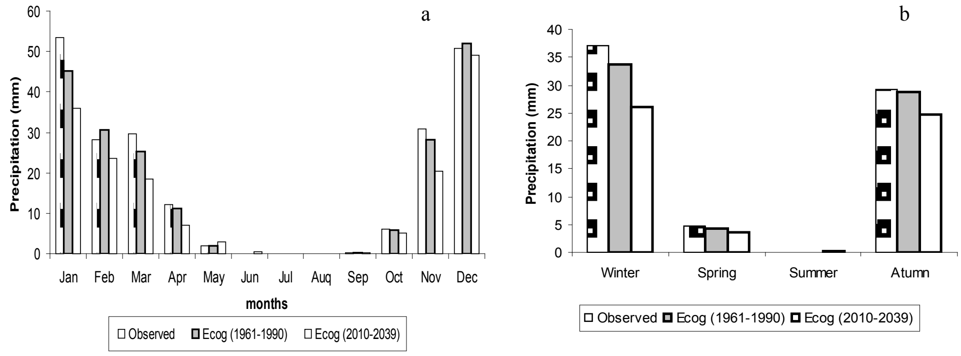

Figure 6: Monthly mean daily precipitation (a) and seasonally mean daily precipitation (b) (observed and model) for the current and future periods in Mahshahr.

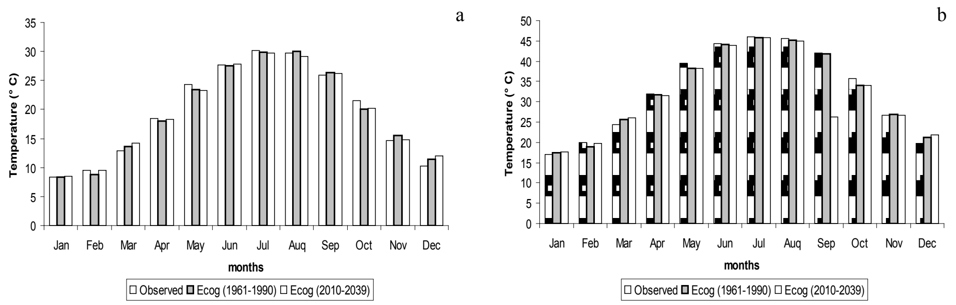

Figure 7: Monthly mean daily min temperature (a) and max temperature (b) (observed and model) for the current and future periods in Ramhormoz.

0.06 mm in summer past and future ECHO-G modeled and Observed mean monthly t min and t max Ramhormoz station exhibit in figures 7a and 7b. Maximum and minimum different of observed and past modeled t min is 1.39°C and0.13°C in the months of December and Jun respectively. The results indicated that maximum decreasing and increasing of future modeled t min is 1.24°C in the month of October and 1.76°C in December respectively. In figure 7b Maximum and minimum different of observed and past modeled t max is 1.62°C and 0.1°C in the months of October and July respectively. Also maximum decreasing and increasing of observed and future modeled t max in Ramhormoz station is 15°C in the month of September and 2.12°C in December respectively.

Figures 8a and 8b show current and future ECHO-G modeled and Observed mean seasonally t min and t max Ramhormoz station. According to this figures LRARS-WG has simulated past ECHO-G modeled t min in winter accurately. Maximum different of observed and past ECHO-G modeled t min is 0.46°C in spring. Maximum increasing and decreasing future ECHO-G modeled seasonally tmin0.44°C and 0.3°C in the season of winter and summer respectively. According to figure 5b, LRARS-WG has projected t max in winter, summer and autumn season precisely but is rationally unable to downscale spring season additionally. The results indicated that maximum increasing and decreasing seasonally ECHO-G (2010-2039) t max is 5.55°C and 0.65°C in the season of winter and summer respectively. Result of monthly and seasonally mean daily precipitation for the current and future periods in Ramhormoz station exhibit in figures 9a and 9b. Maximum and minimum different of observed and current modeled sum precipitation defined 11.83 mm in the months of January and 0.02 mm in the months of June respectively. LARS-WG model has downscaled precipitation closer to observed data in most of months except January, September and December in Ramhormoz station. Sum of future maximum and minimum monthly precipitations

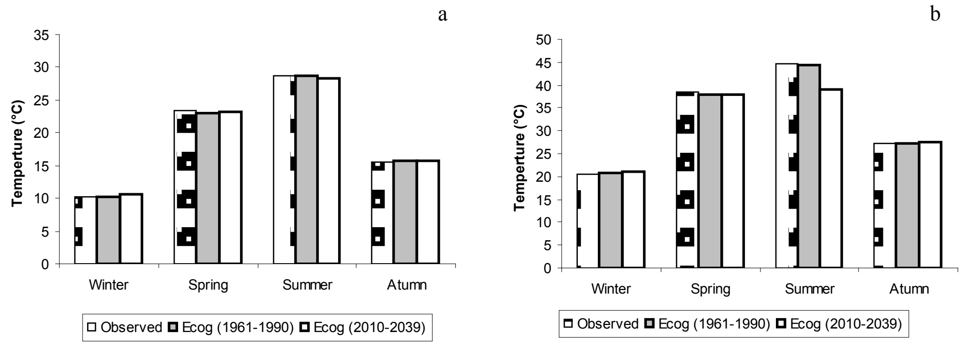

Figure 8: Seasonally mean daily min temperature (a) and max temperature (b) (observed and model) for the current and future periods in Ramhormoz.

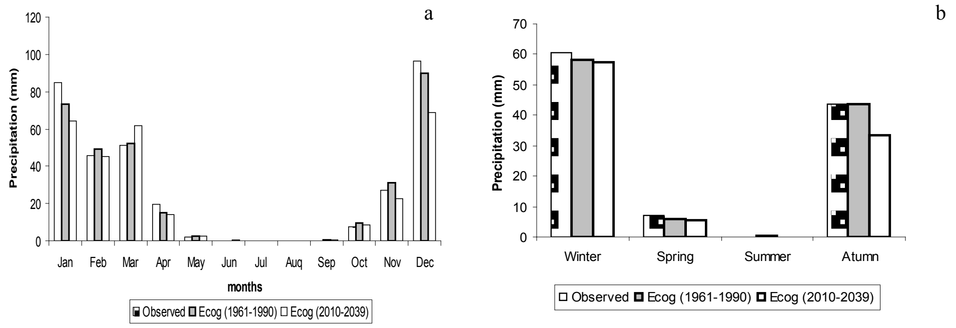

Figure 9: Monthly mean daily precipitation (a) and seasonally mean daily precipitation (b) (observed and model) for the current and future periods in Ramhormoz.

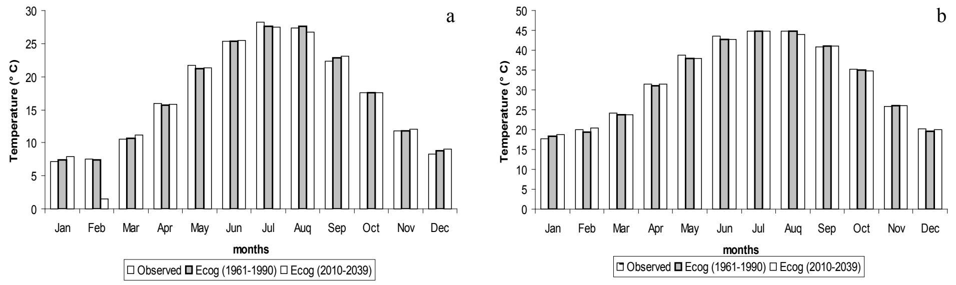

Figure 10: Monthly mean daily min temperature (a) and max temperature (b) (observed and model) for the current and future periods in Behbahan.

are predicted 88.95 mm in December and 0.06 mm in July and August respectively. Maximum decreasing and increasing of future monthly mean daily precipitation respectively occur in the month of December 27.55 mm and in the month of March 10.63 mm. With respect to future trends, precipitations continuously decrease from October to April and increase from May to September. LARS-WG model has downscaled precipitation closer to observed data in summer and autumn. Figure 9b exhibits that precipitation in coming decade will decrease 3.37 mm, 1.54 mm, 1021 mm in winter, spring and autumn and will increase 0.04 mm in summer current and future ECHO-G modeled and Observed mean monthly t min and t max Behbahan station exhibit in figures 10a and 10b. Maximum and minimum different of observed and past modeled t min is 0.67°C and0.0 °C in the months of October and July respectively. LARS-WG model has downscaled t min closer to observed data in most of months except July. The results indicated that maximum decreasing and increasing of observed and modeled t min is 6°C and 0.72°C in the month of February and March respectively. In figure 10b Maximum and minimum different of observed and modeled current t max is 0.93°C and 0.03°C in the months of May and June respectively. Also maximum decreasing and increasing of observed and modeled future t max is 0.79°C in the month of May and 1.12°C in January respectively. Increasing and decreasing of t max will happen in cold and warm seasons as well. Figures 11a and 11b show current and future ECHO-G modeled and Observed mean seasonally t min and t max Behbahan station. According to this figures LRARS-WG has simulated past ECHO-G modeled t min all season accurately. Maximum different of observed and past ECHO-G modeled t min is 0.2°C in spring. Maximum increasing and decreasing future ECHO-G modeled seasonally t min 0.33°C and 1.54°C in the season of autumn and winter respectively. According to figure 11b, LRARS-WG has projected t max in winter, summer and autumn season precisely but is rationally unable to downscale spring season additionally. The results indicated that

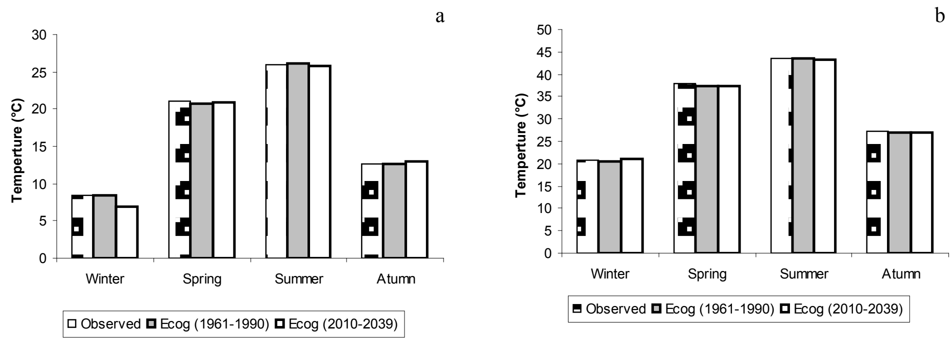

Figure 11: Seasonally mean daily min temperature (a) and max temperature (b) (observed and model) for the current and future periods in Behbahan.

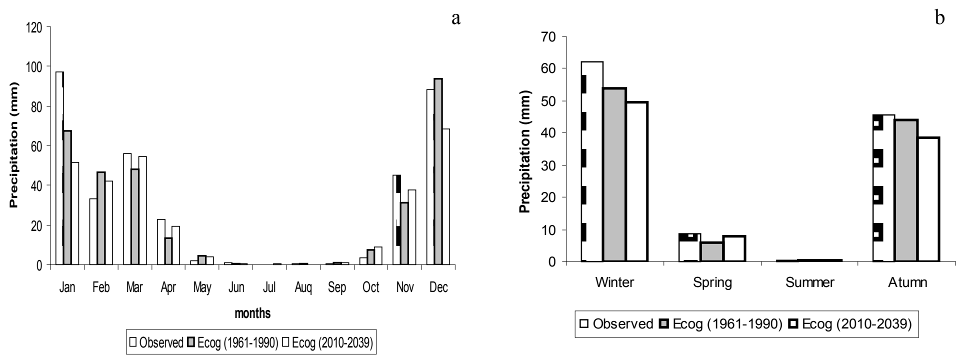

Figure 12: Monthly mean daily precipitation (a) and seasonally mean daily precipitation (b) (observed and model) for the current and future periods in Behbahan.

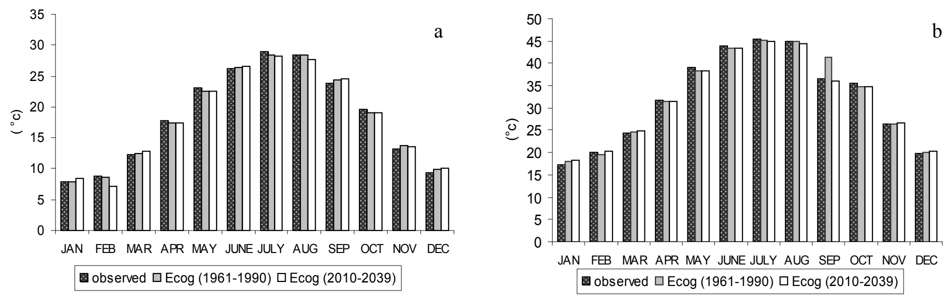

Figure 13: Monthly mean daily min temperature (a) and max temperature (b) (observed and model) for the current and future periods in mean of 3 stations.

maximum increasing and decreasing seasonally ECHO-G (2010-2039) t max is 0.35°C and 0.56°C in the season of winter and spring respectively. Result of monthly and seasonally mean daily precipitation for the current and future periods in Behbahan station exhibit in figures 12a and 12b. Maximum and minimum different of observed and past modeled sum precipitation defined 30.13 mm in the months of January and 0.00 mm in the months of July respectively. LARS-WG model has downscaled precipitation closer to observed data in most of months except January, February and November in Behbahan station. Maximum decreasing and increasing of future monthly mean daily precipitation occurred in the month of January 45.71 mm and in the month of February 10.63 mm respectively. As a result LARS-WG model has downscaled precipitation closer to observed data in summer and autumn. Figure 9b exhibits that precipitation in coming decade will decrease 12.69 mm, 0.85 mm, 7.12 mm in winter, spring and autumn and will increase 0.25 mm in summer. Comparing Minimum temperature at three study stations indicated that LARS-WG model has downscaled t min closer to observed data in most of season except spring. In coming decades, in all three stations, t min decrease in warm season and increase in cold season except in Behbahan station. In all three stations t max will be increasing in winter and decreasing in spring and summer especially in summer of Ramhormoz station. Trend of precipitation changing are similar in all three stations and indicate increasing precipitation in summer. According to figure 13a, Maximum and minimum different of observed and modeled t min in mean of three stations is 0.63°C and0.04 °C in the months of May and August respectively and showed that LRARS-WG has simulated t min in winter accurately. Maximum different of observed and modeled mean monthly t min is 0.48°C in autumn also future mean monthly t min comparing to observed data maximum decreasing and increasing of t min is 1.68°C in the month of February and 0.67°C in May respectively. Reductions of future mean t min are 0.17, 0.21 and 0.28°C

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in winter, spring and summer seasons respectively but increasing of future mean t min occurs in autumn (0.18°C). According to fig 13b maximum and minimum different of observed and modeled t max is 0.79°C and 0.03°C in the months of May and July respectively and LRARS-WG has projected t max in summer season precisely but is rationally unable to downscale winter season additionally. Maximum decreasing and increasing of future t min respectively occur in the month of May (1°C) and in the month of January (0.8°C). With respect to future trends, t max continuously decreases from April to October. In the future increasing of t max will be 0.56 and 0.018°C in the winter and autumn respectively and decreasing of t max will happen in the spring (0.55°C) and summer (0.47°C) respectively. Overall, an increase in temperature tends to actively increase the evaporation process and reduce the soil moisture generally. Result of Monthly and seasonally mean daily precipitation for the current and future periods in mean of three stations exhibit in figures 14a and 14b. Maximum and minimum different of observed and modeled sum precipitation defined 19.8 mm and 0.02 mm in the months of January and July respectively. LARS-WG model has downscaled precipitation closer to observed data in most of months except January, February and March. Different of observed and modeled precipitation in cold season is due to present both of Somoum and Mediterranean air mass in study region. Maximum observed precipitation occurred in the month of January and minimum value happened in the month of June, July, August and September. Downscaling projection exhibited precipitation in the summer season was less and minimum different of observed and modeled Precipitation related to this season. The main reason of that is continuous stability of Azor near tropical zone in the summer which making climate very hot and intolerable in the summers. Furthermore figure 14b exhibits that precipitation in coming decade will decrease 9.5 mm, 1.12 mm, 7.13 mm in winter, spring and autumn and will increase 0.11 mm in summer. Increasing of temperature and decreasing of precipitation in the future winter season will affect on the time of migration of water birds in Shadegan wetland and increasing of uneven precipitation in the future summers will raise the risk of flash floods. Water birds that persist in areas subject to 'coastal squeeze', whereby the landward movement of habitats is prevented by flood defenses are also likely to be particularly vulnerable. Warmer temperatures have resulted in many species advancing aspects of their life cycle. Earlier arrival from wintering grounds and earlier onsets of breeding are well recognized across many species and from numerous locations. Changes in the departure date from breeding grounds should also consider in this wetland, as warming temperatures enable earlier completion of breeding, but also reduce the risk of mortality due to cold temperatures in late autumn and early winter. According to figure 15 LARS-WG model has good skills to produce mean monthly temperature in most of season except spring and show 0.6°C and 0.9°C increasing in mean monthly temperature in winter and autumn, also 0.3°C and 0.39°C decreasing in spring and summer respectively. Therefore in evaporation process will actively decrease in the future summer and spring seasons.

Discussions

Wetlands are one of the most important ecosystems with the highest ecological value in the world. The annual production of the wetland ecosystems per hectare is several times of that of tropical rain forest [17]. Besides the climate is already changing with inevitable impacts to both human and natural systems. The consequences of climate change have the potential to significantly affect all the environmental ecosystems. According to the output of this research, climate change effects are predicted to become more noticeable in coming decade in Shadegan wetland. In statistic, model validation is possibly the most important step in the model building sequence. To comparing mean monthly of base modeled data with observed data in three stations, t min, t max and precipitation, has been satisfying (Table 2). Furthermore statistical analysis in three stations showed no significant ($p<0.05$) different between the control and base periods data. In fact Lars WG was well able to produce climatic data almost identical to observation data. This result indicates the ability of Lars WG model in climate simulation for study area. According to results Precipitation in coming decade will decrease in winter, spring and autumn and will increase in summer in all three stations. Since Changes in precipitation will alter water level also Wetland ecosystems depend on water levels, this phenomenon is likely to have a significant impact on these habitats and associated species. Shadegan wetland is the largest global habitat of marble duck (*Marmaronetta angustirostris*). The presence of this species and other migratory overwintering species in Shadegan wetland strongly depend on the continuous existence of water resulting from winter floods so that the abundance of marble duck has exponential relationship with water level in January [18]. Due to decrease of precipitation and increase of temperature consequently increase of evaporation in winter especially in January expected to significantly decrease the abundance of marble duck in coming period then Significant seasonal stresses could occur due to the associated lowering of water levels. Wetland plants are vulnerable to climate change because of the delicate balance between the rainfall, temperature and evapotranspiration that is critical to their physiology functions [19]. The dominant plant community in this wetland is sedge (*Cyperaceae*), typha (*Typhaceae*) reed (*Graminaceae*) that was seen in the north and fresh water wetland. Decrease in water level due to increasing evaporation and decreasing precipitation in winter significantly will reduce vegetation wetland consequently reduce in suitable overwintering habitat of aquatic migratory bird and loss of spawning. Stream flows affecting ecosystem productivity with reducing summer water availability and water quality

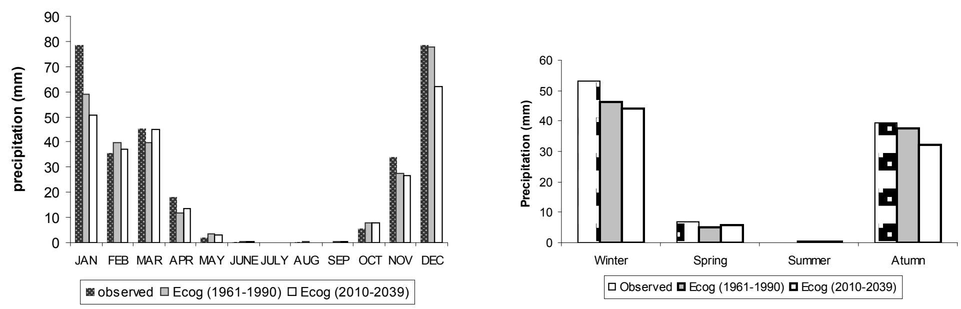

Figure 14: Monthly mean daily precipitation (a) and seasonally mean daily precipitation (b) (observed and model) for the current and future periods in mean of 3 stations.

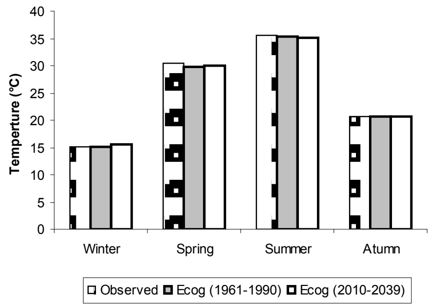

Figure 15: Seasonally means daily mean temperature (observed and model) for the current and future periods in mean of 3 stations.

might be decrees. Consistent with previous studies [20-22] changes in wetlands are more sensitive to temperature changes than to changes in precipitation. Decreasing precipitation and increasing temperature in winter will causes of raising salinity and extension of salty water habitats in Shadegan area. Also in the cold months of the year increase in temperature will expose to danger of significant reduction of water level in Shadegan wetland. If precipitation is quite high (increase of 20%), the effect of increased temperature will be offset. Johnson et al. [23] but If the precipitation is constant or decreasing, exacerbate increased temperature effect consequently wetlands will decrease and waterfowl habitat will be shifted. Overall, arid region wetlands of the Iran are extremely vulnerable to drier conditions. Our results show that climate change could significantly reduce wetlands, which adversely impacts the mitigation of greenhouse gases as wetlands are a carbon and methane sink [24]. If climate change decreases wetlands, thereby triggering further release of CO_2 and CH_4 to the atmosphere, protection and restoration of wetlands is even more important. The pressure of human activity on Shadegan wetland such as the construction of Maroon dam consequently as well as petroleum activities reduces water quality and changed natural and hydrological regime. On the other hands, the entrance of waste water from sugar cone factories, upstream irrigation development projects, the entrance of oil pollution, change in land use and build of gas power have severity damaged to the environment of this international wetland that cause of intensify the impact of climate change to Shadegan environment. Accordingly it is expected decreasing the entrance of migratory bird in Shadegan wetland habitat in the future.

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