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Climate Change Impact on Precipitation Extreme Events in Uncertainty Situation; Passing from Global Scale to Regional Scale

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Global warming, and consequently climate change are important topics studied extensively by researchers throughout the world in the recent decades where changes in climatic parameters are investigated. Considering large-scaled output of AOGCMs and low precision in computational cells, uncertainty analysis is one of the principles in hydrological studies. For this reason, the uncertainty due to precision of computational cells and in passing from global scale to regional scale through LARS-WG model and CRU institute, precipitation changes in Mashhad synoptic station located in Ghareghom basin were analyzed. The results showed enough ability of the model to simulate precipitation parameter in the base period. Downscaled output of HadCM3 generated by CRU with high precision shows gradual decreasing of precipitation trend for frequency and sum values. Comparing the downscaled output of the AOGCM with 2.5*3.75 resolution and the output of CRU with 0.5*0.5 resolution, the uncertainty is due to precision of computational cells from global to regional scale: the latter scale is closer to real values.

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1. INTRODUCTION

Increasing greenhouse gases is one of the effects of human intervention in nature. By increasing these gases, the amount of solar reflection from ground absorbed by greenhouse gases increases and creates the phenomenon of global warming and as a consequence climate change. The effects of this phenomenon on various factors such as water resources availability, rainfall patterns, ecosystem functions as well as other factors is crucial for human well-being. The first step to deal with the adverse impacts of this phenomenon is determining the baseline conditions through regional studies [1, 2].

In such studies, there is a need to predict climate parameters for future periods using global circulation models such as AOGCM [1]. These simulations are generally based on climatic and non-climatic scenarios for the entire world. The basic problem of these models is the large-scale computational cells that cause decrease in the accuracy of predicted results at regional and local scales. Therefore, performing downscaling technique is necessary [3].

Various methods fordownscalingare presented. Important and principle stage in using these methods is investigating uncertainty on their final output. For this purpose, different sources affecting the uncertainty could be calculated. These sources are from AOGCMs and the theory used in simulation of climatic and non-climatic scenarios and also due to the downscaling method. Many researches throughout the world used the output of different AOGCMs and emission scenarios and also different methods to analyze the uncertainty [4, 5].

Nowadays, downscaling models have an important role in climate change studies and data with high spatial resolution is used in regional and large-scale assessments throughout the world.

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1 - Atmosphere-Ocean General Circulation Model

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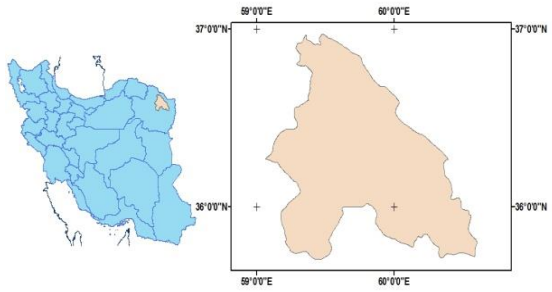

Figure 1. Location of the study region

Schuls and Abbaspour (2007) investigated the data generated in the CRU[3] database with two methods and then, SWAT model was run with the data. In their study, the simulation of monthly and yearly river discharges for a 25-year period is performed in some stations using daily measured data [6].

In England, Hulme and Brown [7] extracted the observed annual rainfall and temperature for the 1896–1996 period from CRU to study climate change effects. They investigated the anomalous situation of temperature and rainfall simultaneously. The results indicated an increasing trend in temperature and a decreasing trend in rainfall for historical data. The climatic changes in the region were calculated by the HadCM2 general circulation model analyzing 1,000 years of data. Their results showed that only in the last years – 1987 to 1996 – temperature and rainfall in the studied region were out of critical limits of climatic variability which significantly indicated climate change. To assign various limits of uncertainty in the simulation of temperature and rainfall as climatic parameters in future periods, the IS92 scenario was considered under all AOGCM models by MAGICC software, and use of pattern scaling simulated the parameters for the 2040–2069 period. It is observed that temperature and rainfall changes in future will be attributable to climate change caused by increasing greenhouse gases and are not categorized as typical climatic changes [7].

Khan et al. [8] used Bootstrap method to estimate uncertainty band in 95% confidence level for three downscaling models including SDSM, LARS-WG and ANN. They concluded more precision of SDSM and LARS-WG models and low ability of ANN model in downscaling process [8].

Farzaneh et al. [9] investigated uncertainty due to downscaled data of A2 emission scenario, HadCM3 model and SDSM downscaling model. They also studied changes of temperature and precipitation parameters (2040-2069 period) in Shahrekord synoptic station. The results indicated a 49% decrease in total precipitation comparing with (1961-1990) period under A2 scenario as the most critical situation [9].

Fakhri et al. [10] used downscaled data by CRU to investigate the uncertainty effective on estimating wet and dry spells under climate change. They concluded an increasing uncertainty band with the passing of time whereas approaching the middle-future period (2040-2069), the effects become more pronounced [10].

Faramarzi et al. using different emission scenarios of CGCM3 model, studied climatic parameters in the future period and using SWAT model estimated blue and green water resources and climate change effect and also analyzed virtual water business throughout Iran [11, 12]. Climate variability and change is threatening water resources around the world [13].

Following previous studies, in this paper HadCM3, A2 scenario and LARS-WG downscaling model were used.Initially,the model precision in precipitation estimation was assessed. Then, this parameter was estimated for three future periods. The data of CRU bank is also used as artificial scenario introduced to the model. The uncertainty of downscaled data by LARS-WG with regional data downscaled by CRU was investigated and also estimated conditions of three defined sets of precipitation for the future periods were studied.

2. MATERIALS AND METHODS

2. 1. Study Area Mashhad synoptic station at 59° 38' E, and 36º 16' N is chosen for this study (Figure 1). The elevation is 999.2 m with semi-arid climate. Location of the region in Ghareghom basin in Iran is shown in Figure 1.

In order to gain suitable results in climate change studies, downscaling process in scale of a meteorological station was performed and then output parameters of AOGCMs were analyzed. Among different stations of Ghareghom basin, Mashhad station was chosen as base station because of having the longest duration of precipitation data.

2. 2. LARS-WG Model LARS-WG model is one of the most popular meteorological data generator models which generates daily values of maximum and minimum temperature, precipitation and sunshine duration in one station under situation of current and future climate. Initial version of this model has beenpresented as a part of assessment project of agriculture risks in Budapest in 1990. The main core of the model uses Markov chain repeatedly. LARS-WG contains three basic sections including calibration, assessment, and generating meteorological data for the future decades. The main requirement of the model in calibration stage is the file recognizing climate behavior in historical period [14-16]. This file is prepared using

3 - Climatic Research Unit

daily climatic data in the studied synoptic station, achieved from Iranian Meteorological Organization, and the model was run regarding a 30-year duration (1976-2005) as base period.

2. 3. Emission Scenario Uncertainty in future population, land use, CO_2 concentration in atmosphere, and other parameters that affect the earth's climate makes the parameter prediction for future periods difficult. The emission scenarios regarding different elements of human-affected environment allow future climate research for the most optimistic situation to the most pessimistic one [17, 18]. A2 scenario shows rapid growth of the world population along with inhomogeneous economic development in different regions and therefore draws a medium climate change for future periods [19]. LARS-WG model using this scenario confirmed by IPCC was run and daily values of precipitation parameter for the three periods were simulated.

2. 4. Assessment of Precipitation Scenario Daily long duration precipitation of Mashhad synoptic station was derived and using A2 emission scenario in HadCM3 and LARS-WG downscaling model, for 1976-2005 period as base period and three future periods (2011-2030, 2046-2065 and 2080-2099)as near, middle and far future periods, respectively, the downscaling process was performed. This process was repeated for the scenario generating precipitation using downscaled output of HadCM3 by CRU with high spatial resolution. Then, the downscaled data uncertainty due to resolution of computational cells from global scale to regional scale was analyzed. CRU data bank is regional and its resolution is confirmed in various studies; but, it seems that re-downscaling and comparing the results with the large-scale data could better assess the role of computational cells resolution.

To do so, first of all, LARS-WG model was run for HadCM3 and the results were studied. Afterwards, the data presented by CRU for HadCM3 and A2 emission scenario for the same periods was derived and used as input scenario in LARS-WG. Finally, comparing results of the two references, the uncertainty due to computational cells resolution is investigated. For this, the generated data was categorized into three sets including: more than zero (wet days), more than 10 mm (medium extreme values), and more than 50 mm (severe extreme values).

3. RESULTS AND DISCUSSION

In the first stage, comparing the sets of precipitation in the base period (1976-2005) with the modeled values by LARS-WG, the model precision in extreme values estimation was studied.

As shown in Table 1, comparing the base period LARS-WG was able to generate precipitation data with good accuracy as in the three indices the values of frequency and total are tveryquitclose to the observed values. The result for severe extreme values was not ideal and the model cannot estimate the only one event happened in the historical period. It means that in simulating this kind of extreme value, the model has lower resolution than the other two values. Since just one event happened, it is not possible to conclude certainly and the regions having these events more frequently,should be studied. Therefore, the model was able to generate precipitation data appropriately and gaining confidence from the accuracy of assessment results and the model capability in simulating precipitation; inthe next stage, simulation of precipitation in three future periods including (2011-2030), (2046-2065), and (2080-2099) under HadCM3 and A2 scenario was considered.

In the next step, HadCM3 under A2 emission scenario was run by LARS-WG model and precipitation parameter in the three future periods was generated.

Running LARS-WG model, results of Table 2 for the three periods were achieved. Comparing with the observed period, the values in the near future were close with no significant changes, but totally gradual increasing is estimated. In the middle future, total value increased and except wet days index, the other two indices were increased which shows one of the potential effects of climate change is on extreme events in the studied region. In the far future period both frequency and total values showed a completely decreasing trend.

In the third stage, output of HadCM3 downscaled by CRU spatial accuracy more than the previous stage (0.5*0.5) was considered as input artificial scenario.

Table 3 indicates that precipitation values in frequency and total for each three periods have decreasing trend and closing to the far future the trend is getting more severe, and also in two periods of middle and far future any precipitation more than 50 mm do not exist.

TABLE 1. Precipitation values in the base period compared with model outputs

Precipitation (mm)	Frequency	Total	
>0	1908	8055.1	Modeled
>10	220	3993.9	
>50	0	-	
>0	1978	8124.2	Observed
>10	235	3977	
>50	1	52	

TABLE 2. Precipitation values in the three future periods under HadCM3 and A2 scenario

Precipitation (mm)	Frequency	Total	
>0	1885	8352	Near Future
>10	252	4491.1	
>50	1	61.5	
>0	1880	8361.1	Middle Future
>10	256	4605	
>50	4	227	
>0	1886	7227.6	Far Future
>10	212	3628	
>50	0	-	

TABLE 3. Precipitation values in the three future periods under HadCM3 and A2 scenario using downscaled data by CRU

Precipitation (mm)	Frequency	Total	Frequency
>0	1913	7664	Near Future
>10	204	3610.9	
>50	1	53.3	
>0	1923	7262.7	Middle Future
>10	200	3702.2	
>50	0	-	
>0	2010	7073.4	Far Future
>10	192	3133.8	
>50	0	-	

Uncertainty due to estimation of different precision of computational cells from global to regional scale is insignificant in the near future, but passing time and closing to the middle and far future periods the difference is getting more and more. The computational precision of HadCM3 and CRU bank are 2.5*3.75 and 0.5*0.5 degree, respectively. Although the data from CRU is regional, downscaling process is done and makes it more regional and detailed.

4. CONCLUSION

Regarding large-scaled data of AOGCMs and low accuracy of the computational cells, uncertainty assessment is one of the principle issues in all hydrologic studies which confirms quality of generated data.

In the present study, it was attempted to investigate and assess the changes of some precipitation characteristics including wet days, medium extreme values, and severe extreme values in three future periods and climate change impact on them, considering important subject of computational cells uncertainty in downscaling studies. This research is done in Mashhad synoptic station utilizing HadCM3 model, A2 emission scenario and LARS-WG downscaling model and also using created scenario by CRU in LARS-WG. The uncertainty due to computational cells precision from global to regional scale which regional scale is closer to reality and CRU uses more local information in data generation process.

Though LARS-WG model could not estimate the only one severe extreme event in the historical period, total results indicate high ability of LARS-WG in simulating precipitation parameter in the period. However, estimating severe extreme events by this method can be a subject for future researches, so that the model is evaluated in more detail.

Assessing the conclusions and paying more attention to the computational cells with high precision (0.5*0.5), decreasing frequency and total precipitation more than zero (wet days), more than 10 mm (medium extreme values) and more than 50 mm (severe extreme values) in the studied future periods is estimated.

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چکیده

گرمایش جهانی و به تبع آن تغییر اقلیم موضوع مهمی است که در دهه‌های اخیر توسط محققین در سرتاسر دنیا مورد مطالعه قرار گرفته است. در این مطالعات تغییرات پارامترهای اقلیمی مورد بررسی قرار می‌گیرد. با توجه به بزرگ‌مقیاس بودن داده‌های مربوط به AOGCM و کم دقت بودن سلول محاسباتی آن‌ها، تحلیل عدم قطعیت یکی از موارد اصولی و زیربنایی جهت انجام کلیه مطالعات هیدرولوژیکی می‌باشد. بدین منظور در این مطالعه تلاش شد با بررسی عدم قطعیت ناشی از دقت سلول محاسباتی در حالت گذار از مقیاس جهانی به منطقه‌ای توسط مدل LARS-WG و مرکز CRUتغییرات پارامتر بارندگی در ایستگاه سینوپتیک مشهد واقع در حوضه قره قوم مطالعه شود. نتایج حاصل نشان دهنده توانایی تقریباًبالای مدل در شبیه‌سازی پارامتر بارندگی در دوره پایه تلقی گردید. استفاده از خروجی ریزمقیاس شده مدل HadCM3 که توسط مرکز CRU با دقت مکانی بالا تولید شده بود، کاهش تدریجی روند بارندگی برای مقادیر فراوانی و مجموع سه شاخص تعریف شده را نشان داد. با مقایسه خروجی ریزمقیاس شده مدل مذکور با دقت 2.5×3.75 و خروجی مرکز CRU با دقت 0.5×0.5 عدم قطعیت ایجاد شده مربوط و ناشی از دقت سلول محاسباتی از مقیاس جهانی به منطقه‌ای ارزیابی می‌گردد که به واقعیت نزدیک‌تر خواهد بود.

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