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Climate Change Scenarios for Tawi catchmentobtained using StatisticalDownscaling method

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Abstract:-The study describes the application of statistical downscaling method (SDSM) to downscale rainfall and temperature data. In order to explore the SDSM method, the stations at Udhampur and Chatha, Jammu have been selected as a study site to test the methodology for rainfall and temperature respectively. The study included calibration and validate with large-scale atmospheric variables encompassing NCEP reanalysis data, the future estimation due to a climate scenario, which is HadCM3 A2. Results of downscaling show that during the calibration and validation stage, the SDSM model can be well acceptable regard its performance in the downscaling of daily precipitation and temperature. The result of climate projection reveals that the SDSM model has very good ability to replicate the historical maximum and minimum temperature for the observed period; but less for the observed precipitation with the simulated precipitation due to its conditional nature and high variability in space. Both the minimum and maximum temperature shows an increasing trend in all future time horizons for both A2 and B2 scenarios. For precipitation there is decreasing trend in the beginning of the rainy season (May & June) and increasing trend towards the end of rainy season (Sep & Oct).

Keywords:-SDSM, GCMs, climate change, downscaling.

I. INTRODUCTION

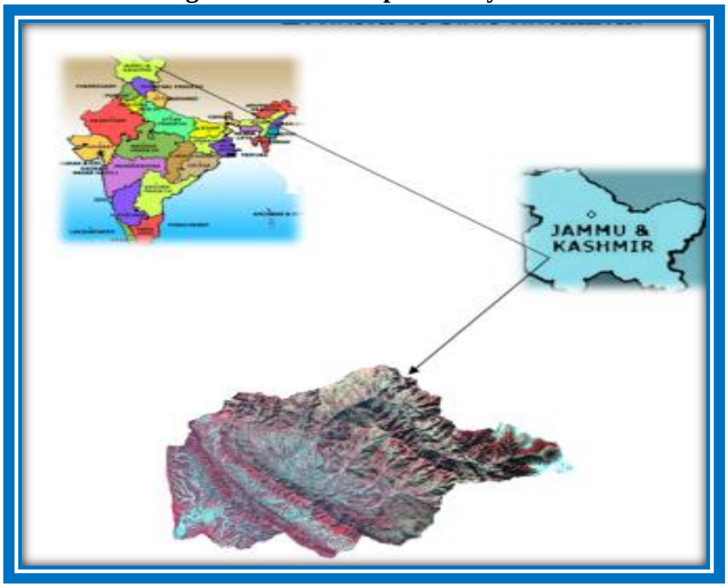
In terms of hydrology, climate change can cause significant impacts on water resources by resulting changes in the hydrological cycle. Temperature and rainfall are the main variables, which influences directly and cause from climate change. To estimate future climate change resulting from the continuous increase of greenhouse gas concentration in the atmosphere, Global Climate Models (GCMs) are used. GCMs output cannot directly use for hydrological assessment due to their coarse spatial resolution. Therefore, downscaling is used to converting the coarse spatial resolution of the GCMs output into a fine resolution which can involve generating point/station data of a specific area by using the GCM climatic output variables[6], [10], [1], [3], [4]. Downscaling methods can be divided into two types, which are dynamical downscaling (DD) and statistical downscaling (SD).

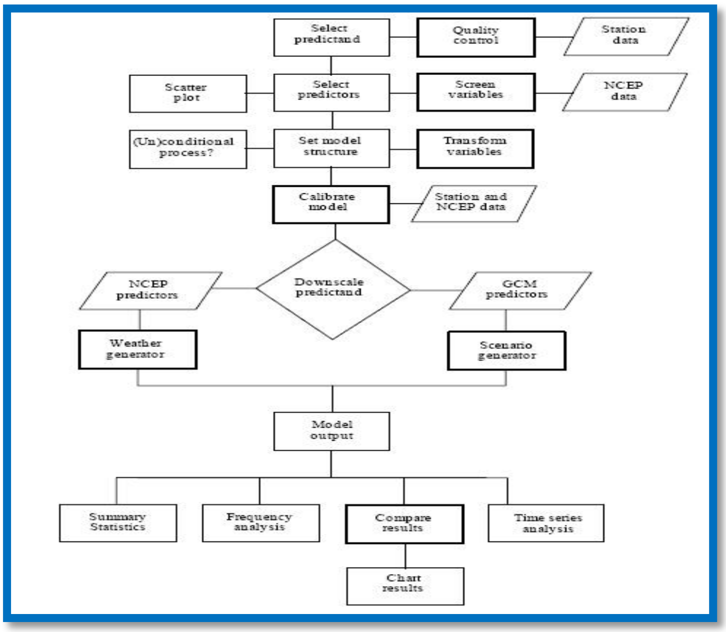
In this study, SD has been used, and it is a method which is seeking to derive the local-scale information from the larger scale through inference from the cross scale relationship using some random and/ordeterministic functions [7]. Statistical downscaling is also the method which used to achieve the climate change information at the fine resolution through the development of direct statistical relationships between large scale atmospheric circulation and local variables (such as precipitation and temperature). It can be defined as developing quantitative relationships between large-scale atmospheric variables (predictors) and local surface variables (predictands). The presently updated version of statistical downscaling software is SDSM 3.1 and has been used in the study. The objective of this paper is to investigate the adaptability of SDSM for simultaneously downscaling maximum temperature, minimum temperature and precipitation.

II. STUDY AREA AND DATA USED

Tawi is a river that flows through the city of Jammu. Tawi River is also considered sacred and holy, as is generally the case with most rivers in India. Tawi River is a major left bank tributary of river Chenab. The river originates from the lapse of Kali Kundiglacier and adjoining area south-west ofBhadarwah in Doda District. Tawi river catchment is delineated by latitude 320 35' -330 5' N and longitude 740 35' - 750 45' E (Figure 1). The catchment area of the river up to Indian border (Jammu) is 2168nbsp; km², andfalls within the districts of Jammu, Udhampur and a small part of Doda.The elevation values in the catchment varies from 255 to 4235 m and total length of the river is about 141nbsp; km. The river in general flows through steep hills on either side excepting the lower reach for about35nbsp;km. Width of the river at Jammu is about 300 m and below Jammu the river crosses into Pakistan.

Fig1:- Location Map of Study Area





SDSM Version 3.1 climatescenario generations (Dawson &Wilby, 2007)

Two parameters of meteorological data is used for study i.e. rainfall and temperature. The data is collected from different stations. One is located at Sher-e-Kashmir Agriculture University of Science and Technology, Chatha Campus, the second one at Flood Control department Udhampurand another one is at Air Force Station, Udhampur. The data is collected from the year 2000 to 2010 on daily basis and given to the model as an input.

Climate Scenario data

The climate Scenario data used for statistical downscaling model (SDSM) was obtained from the Canadian Institute for climate studies website for model output of HadCM3 (http://www.cics.uvic.ca/scenarios/sdsm/select.cgi).The predictor variables are supplied on a grid by grid basis so that the data was downloaded from the nearest grid box to the study area.

III. METHODOLOGY

There are several steps that have been used to downscaled GCMs, which is HadCM3 for current and future of both the stations. First, inputs of SDSM are predictand and predictors are defined and screening.

Predictand data sets used are temperature and rainfall, and predictors are NCEP-reanalysis and HadCM3 (scenario A2). Predictor data sets are selected by using correlation analysis, partial correlation analysis and scatter plots, and the physical sensitivity between selected predictand and predictors [5]. Second, a multi-linear regression is used in SDSM to manipulate predictand and predictors and this process called calibration. The model is generating for current and future daily precipitation (rainfall) and temperature of each station. Monthly and annual rainfall and temperature are calculated from daily rainfall and temperature series respectively. Average of all stations for rainfall and temperature for current and future are constructed by average values for all stations.

Structure and Working of SDSM

The SDSM software reduces the task of statistically downscaling daily weather series into seven discrete processes denoted by heavy boxes [9].

Description		A. Precipitation		B. Maximum Temperature		C. Minimum Temperature	
		Partial r	P value	Partial r	P value	Partial r	P value
ncepp500as	500 hpa geopotential height			0.038	0.0396	-0.129	0.0
ncepmslas	Mean sea level pressure			-0.041	0.0256		
ncepshums	Surface specific humidity	0.060	0.0007	-0.103	0.0000	0.245	0.0
nceptempas	Mean temperature at 2 m			0.115	0.0000	0.605	0.0
ncepp_thas	Surface wind direction					0.181	0.0
ncepp8_vas	850 hpa meridional velocity	0.005	0.5343				

Table: Partial correlation between NCEP-reanalysis with A. Observed precipitation, B. Observed maximum temperature and C. Observed minimum temperature

IV. RESULTS AND DISCUSSION

4.1. Selecting Predictor Variables

Many procedures are being suggested to choose suitable predictor variables, such as a partial correlation analysis, step-wise regression, or information criterion. Each statistical analysis is used to choosing a sensible combination of predictors from the available data. The screen variable option in SDSM assists the choice of appropriate downscaling predictor variables through seasonal correlation analysis, partial correlation analysis, and scatter plots. Annual analysis period is used, which provides the predictor-predictand relationship all along the months of the year. The default value of significance level which is $p<0.05$ is used to tests the significance of predictor- predictand process. The predictor variables and partial correlation for precipitation and temperature can be shown as Table 1. The choosing of predictors variables depend on explained variance and correlation between predictand-predictor that being analysis in SDSM 3.1. From the analysis, the correlation (partial r) between a set of predictor variables and each individual predictand is not high (partial r equal or not with 1 or -1) for a case of daily precipitation. This statement has been supported with [9] and [2]. As a result, the set of predictor variables which given a high probability to be happen (p is equal or not with 0) will be taken as predictors of individual station.

4.2. Calibration and Validation of SDSM

The calibration model processconstructs downscaling models based on multiple regression equations, given daily weather data (predictand) and regional-scale, atmospheric (predictor) variables [3]. The model structures of calibration can be category as the condition or un-condition process. By manual of SDSM 3.1, has stated that in conditional models a direct link is assumed between the predictors and predictand. In unconditional models, there is an intermediate process between the regional forcing and local weather (e.g., local precipitation amounts depend on wet/dry-day occurrence, which in turn depend on regional-scale predictors such as humidity and atmospheric pressure). Therefore, predictand of temperature is set as un-condition and rainfall as the condition. The calibration process is done by using output from NCEP reanalysis data, whose predicator variables has been used in screening. In this study, baseline (observed data) of station is 10 years and divided into two period times, which 5 years for calibration model and another 5 years for validation model. For validation process, Weather Generator in SDSM 3.1 is used. It enables to produce synthetic current daily weather data based on inputs of the observed time series data, and the multiple linear regression parameters produced. 5 years of observed data, will be used in Weather Generator as independent observe data and not used during calibration procedure.

Figure 2 shows a validation result of SDSM model downscaling of daily A- Precipitation, B-Temperature. The rainfall results give a poor in estimating of the mean month rainfall (Figure 2-A) but validation of maximum temperature and minimum temperature (Figure 2-B and Figure 2-C, respectively) gives a good satisfactory as observed data. The large error of rainfall is less significance to this study because downscaling of rainfall (precipitation) is more problematic than temperature. Besides, the rainfall results give reasonable estimation the mean rainfall.

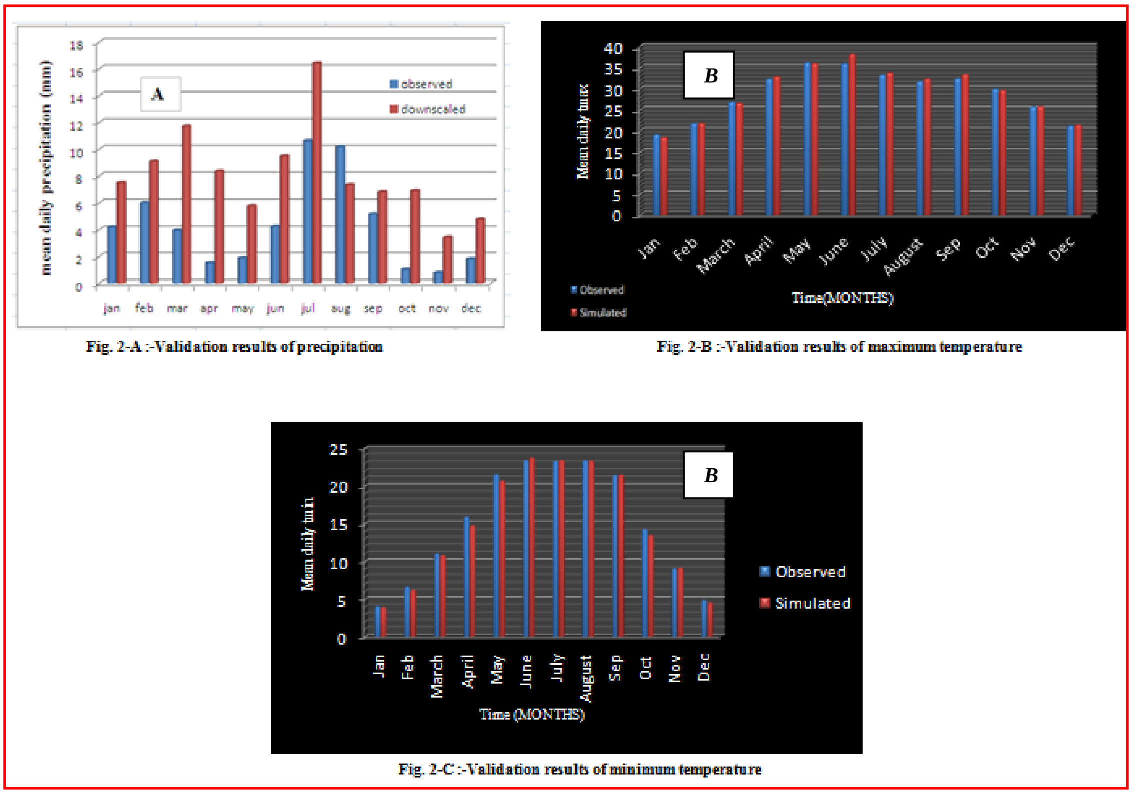


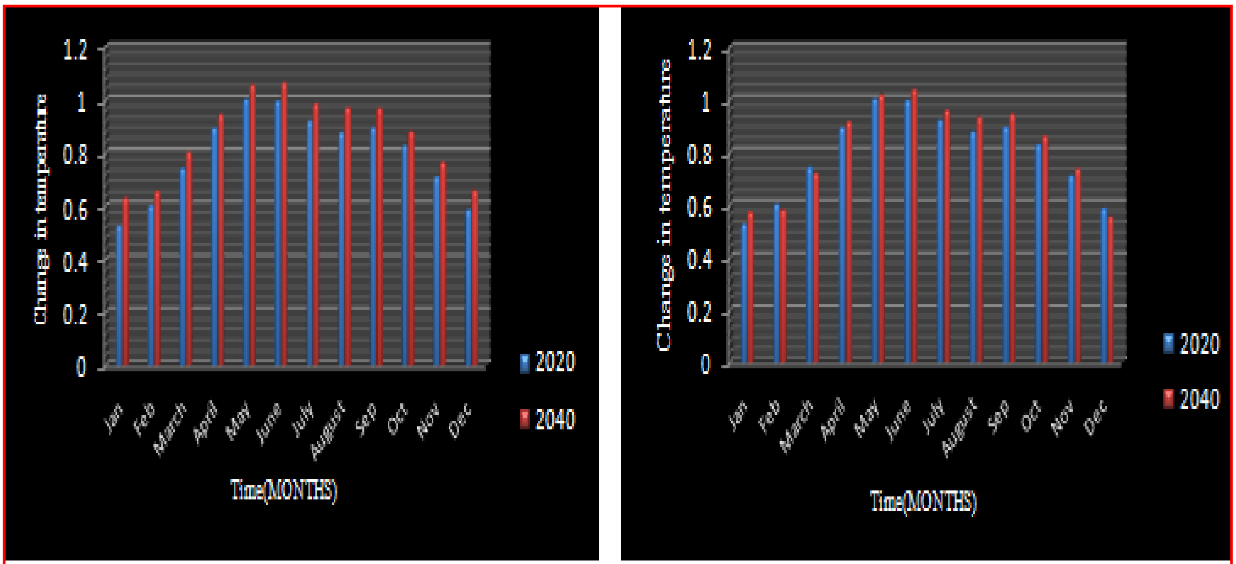
Figure 2:- Validation result of SDSM Model

4.3. Downscaling for future emission scenarios

In SDSM 3.1, the scenario generator operations are used to produce ensembles of synthetic daily weather series given daily atmospheric predictor variables supplied by a GCM. After the calibration and validation of SDSM model carried out, the daily future climate variables are projected for the next 30 years using the HadCM3 Global Circulation Model. The projection generates 10 ensembles of daily climate variables, which are equally plausible hence; these ensembles are averaged out in order to consider the characteristics of all those 10 ensembles. The climate Scenario for future was developed from 2011 to 2040. The outcome was divided into two time periods which is 2020s (2011-2020) and 2040s (2020-2040).

Maximum temperature

The downscaled maximum temperature scenario also indicates that there will be an increasing trend for both A2 and B2 scenario. The projected temperature in 2020s indicates that maximum temperature will rise by 0.5^{o}C. In 2040 the increment will be 0.6^{o}C and 0.5^{o}C for A2 and B2 scenario respectively. Comparatively, A2 which is the high emission Scenario prevail higher change in maximum temperature than minimum temperature**(figure 3).**



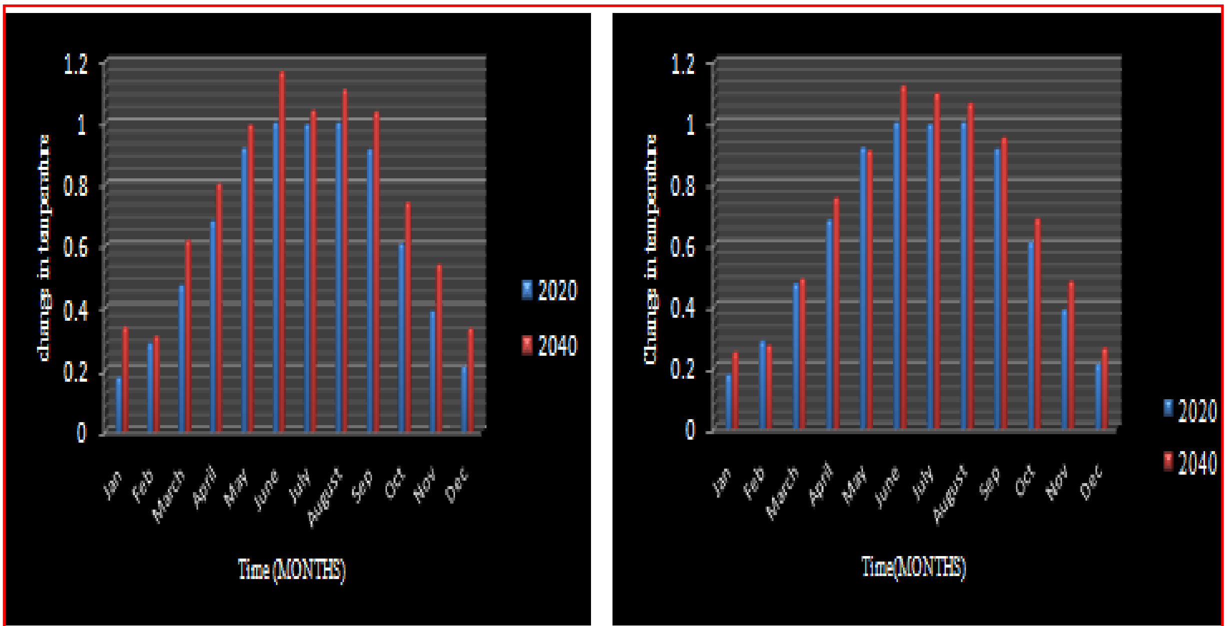
Trend of maximum temperature change (2011 to2040) for HadCM3A2a

Trend of maximum temperature change (2011 to2040) for HadCM3B2a

Figure 3:- Trend of Maximum Temperature for HadCM3A2a and HadCM3B2a

Minimum temperature

The downscaled minimum temperature shows an increasing trend in all future time horizons for both A2 and B2 scenarios. The average annual minimum temperature will be increased by 0.2°C in 2020s. In 2040s the increment will be 0.4°C and 0.3°C for A2 and B2 scenario respective**(figure 4).**



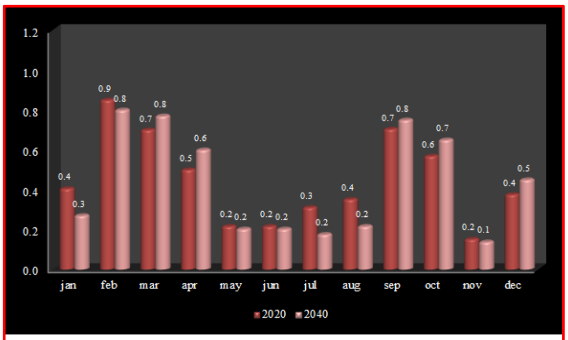
Trend of minimum temperature change (2011 to2040) for HadCM3A2a

Trend of minimum temperature change (2011 to2040) for HadCM3B2a

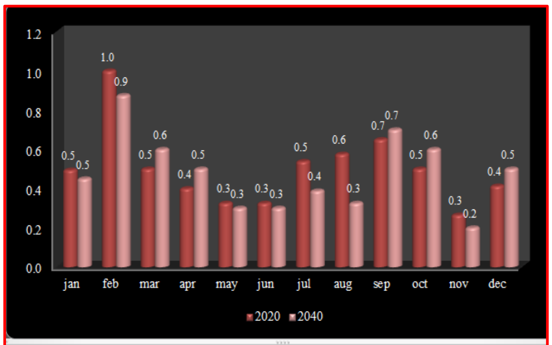
Figure 4:- Trend of Minimum Temperature for HadCM3A2a and HadCM3B2a

Precipitation

Projection of rainfall did not manifest a systematic increase or decrease in all future time horizon unlike that of maximum and minimum temperature which exhibits an increasing trend for both A2 and B2 scenario in all future time horizon. Precipitation will show decreasing trend in beginning of the rainy season and increasing trend towards the end of rainy season. B2 scenario shows the maximum precipitation during the month of February, July and august as compare to A2 scenario. According to A2 scenario rainfall trend will shift as it increases during the month of March, April, September and October from January, Feb., July and august**(figure 5).**



Trend of precipitation change (2011 to2040) for HadCM3A2a



Trend of precipitation change (2011 to2040) for HadCM3B2a

Figure5:- Trend of Precipitation for HadCM3A2a and HadCM3B2a

V. CONCLUSIONS

Statistical downscaling method is an alternative tool to downscale global climate model into a fine scale hydrological region. SDSM has been used for this purpose and being widely applied around the world. The data used are the rainfall, maximum temperature, and minimum temperature of station Udhampur and Chatha. Several conclusions that can be drawn from this study are;

During calibration and validation, the SDSM model shows a good simulation of monthly for rainfall and temperature. The rainfall and temperature (maximum and minimum) can be estimated well by NCEP reanalysis set dataand shows a good linear relation with observed data. However, the SDSM shows a slightly difference between estimation and observed data for the rainfall. It is identified that the downscaling of rainfall by using SDSM is more problematic than temperature. Both the minimum and maximum temperature shows an increasing trend in all future time horizons for both A2 and B2 scenarios. For precipitation there is decreasing tend in the beginning of the rainy season (May & June) and increasing trend towards the end of rainy season (Sep & Oct).

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REFERENCES

[1]. Dawson, R. L. Wilson C. W. (2007). SDSM 4.2 – A Decision Support Tool for the Assessment of Regional Climate Change Impacts.

[2]. Dibike, Y. B. and P. Coulibaly. (2005) –Hydrologic Impact of Climate Change in the Saguenay Watershed: Comparison of Downscaling Methods and Hydrologic Models. Journal of Hydrology 307(1-4): 145-163.

[3]. Fowler HJ, Blenkinsop S, Tebaldi C. (2007).–Linking climate change modeling to impacts studies: recent advances in downscaling techniques for hydrological modeling‖. Int J Climatol 27:1547–1578 27: 1547–1578.

[4]. Hasmiet.al., 2009–Statistical downscaling of precipitation: state-of-the-art and application of bayesian multi model approach foruncertaintyassessment.Hydrol. Earth Syst. Sci.Discuss., 6, 6535–6579, 2009.

[5]. Huang et. Al., 2010–Assessment of the utility of dynamically-downscaled regional reanalysis data to predict streamflow in west central Floridausing an integrated hydrologic model.Reg Environ Change.

[6]. Nguyen, V. T. V., Nguyen, T. D., and Gachon, P. (2005). –Statistical downscaling methods for climate change impact studies‖. Conference on Adapting to Climate Change in Canada 2005: Understanding Risks and Building Capacity. Le Centre Sheraton Montréal Hotel, Montréal, Québec, May 4-7, 2005.

[7]. Salath´e EP. (2003).–Comparison of various precipitation downscaling methods for the simulation ofstream flow in a rain shadow river basin‖. International Journal of Climatology 23: 887–901.

[8]. Schuol, J., Abbaspour, K.C., 2007. A daily weather generator for predicting rainfall and maximum–minimum temperature using monthly statistics based on a half-degree climate grid. Ecol. Model. 201, 301–311.

[9]. Wilby, R.L., Dawson, C.W., and Barrow, E.M. (2002) SDSM – a decision support tool for theAssessment of regional climate change impacts. Environ. Model. Soft, 17: 145–157.

[10]. Wilby, R.L., Wigley, T.M.L. (1997). –Downscaling general circulation model output: a review of methods and limitations. Progress in Physical Geography 21, 530–54.