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Study of Climate Change for Precipitation over Tighra Dam Catchment Gwalior, Madhya Pradesh, India

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Abstract— **This paper describes about the effect of climate change using Statistical Downscaling Model (SDSM) on precipitation over Tighra Dam Catchment, Gwalior, Madhya Pradesh, India. Global Climate Models (GCMs), CGCM3 have been used to project future precipitation over Tighra dam catchment. The predictor variables are extracted from 1) the National Centre for Environmental Prediction (NCEP) reanalysis dataset for the period 1979-2003, 2) the simulations from the third-generation Coupled Global Climate Model (CGCM3) variability and changes in precipitation under scenarios A1B and A2 of CGCM3 model have been presented for future periods: 2020s, 2050s and 2080s. The cross-correlations are used for verifying the reliability of the simulation. Downscaled future precipitation shows increasing trends for all scenarios. This projection is further used for water resources planning and adaptation to combat the adverse impact of climate change**

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Index Terms—Climate change, Global Circulation Model (GCM), SDSM, CGCM3 Model, Downscaling.

I. Introduction

The different reports of Intergovernmental Panel on Climate Changes [1] and other independent researchers has confirmed that climate is changing on global and regional scale which likely to affect availability and supplies of water [2],[3], health, agriculture and livestock [4],[5],[6],[7] and many more areas of human life. It can be emphasized here that changing climate has intensified probability of extreme events such as floods [8], droughts [9] etc. The temperature among other climatological parameters is the most important and easily detectable parameter to show the impact of climate change on water availability and demands, agriculture production, human health and many more areas of life. The prediction of future climate, its implication and adaptation measures are keys to cope up the future challenges.

The problem of coarse grid data can be solved by downscaling GCMs to local and basin scale with the help of dynamic or statistical downscaling techniques that bridge the large-scale atmospheric conditions with local scale climatic data [10],[11],[12]. The dynamic downscaling techniques use physically based model run in time-slice mode and limited area [13] having the major drawback of dynamic downscaling is its complexity and high computation cost [14] and propagation of systematic bias from GCM to RCM [15]. However, statistical downscaling techniques are reasonably accurate in developing relationships between GCM predictors and regional/station climatic data [16] simple, flexible in adjustment and movement to different regions, less costly and computationally undemanding in comparison to dynamic downscaling proved its reliability and compatibility in future projections [17],[18],[19],[20]. In the present study, statistical downscaling model (SDSM 5.2) has been used to predict variability in precipitation using Canadian Global Circulation Model (CGCM) weather predictor data for A1B and A2 SRES scenarios. The problem of coarse grid data can be solved by downscaling GCMs to local and basin scale with the help of dynamic or statistical downscaling techniques that bridge the large-scale atmospheric conditions with local scale climatic data [10],[11],[12]. The dynamic downscaling techniques use physically based model run in time-slice mode and limited area [13] having the major drawback of dynamic downscaling is its complexity and high computation cost [14] and propagation of systematic bias from GCM to RCM [15]. However, statistical downscaling techniques are reasonably accurate in developing relationships between GCM predictors and regional/station climatic data [16] simple, flexible in adjustment and movement to different regions, less costly and computationally undemanding in comparison to dynamic downscaling proved its reliability and compatibility in future projections [17],[18],[19],[20]. In the present study, statistical downscaling model (SDSM 5.2) has been used to predict variability in precipitation using Canadian Global Circulation Model (CGCM) weather predictor data for A1B and A2 SRES scenarios.

II. Study Region and Data Extraction

Gwalior, an ancient city known for the great musician Tansen, is situated in the north region of Madhya Pradesh. The city is gifted with a number of historical places and tourist places. The Tighra reservoir, the lifeline of Gwalior, was primarily constructed to fulfil the water supply of the city. Tighra reservoir is the major source of drinking water to Gwalior city. Besides, the water of Tighra reservoir is also used for irrigation and pisciculture. The Tighra reservoir is situated about 20 km west of Gwalior city, near Tighra village which is in close proximity to SADA Magnet city. It lies on 26 13` N latitude and 78 30' E longitude at an altitude of 218. 58 m. The reservoir is surrounded by hills from three sides. The construction of the reservoir was started in the year 1910 across a seasonal rain-fed Sank river primarily to fulfill the water supply of the city. The reservoir is irregular in shape having shallow embayment at its periphery [20].

A. Data Extraction

The monthly mean atmospheric variables were derived from the National Centre for Environmental Prediction (NCEP/NCAR) reanalysis dataset for the period from January 1979 to December 2003. The data have a horizontal

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resolution of 2.5˚ × 2.5˚ and seventeen constant pressure levels in the vertical.

The GCM selected in this study are CGCM3 (3.75˚ latitude × 3.75˚ longitude). CGCM3 is developed by Canadian Centre for Climate Modelling and Analysis. The future scenarios considered in this study are A1B and A2 for CGCM3 model. The predictor variables are available for period 2001-2100 for CGCM3 model. The selection of CGCM3 is made on the basis of literature review and availability of data in SDSM compatible format. Further, this model has been extensively used in statistical downscaling of climate variables over Indian Sub-continent [14], [23].The gridded predictor variables of NCEP/NCAR and CGCM3 for the nearest grid in the study area have been directly downloaded from the websites of Data Access Integration (DAI) (http://loki.qc.ec.gc.ca/DAI/predictors-e.html) and Canadian Climate Impacts Scenarios (CCIS) (http://www.cics.uvic.ca/scenarios/index.cgi) respectively. The predictors are simulated under historical GHG and aerosol concentration experiment as well as Special Report on Emission Scenarios (SRES) A1B and A2 for CGCM3 model.3) Long term series of observed daily precipitation from 1979 to 2003 from (http://globalweather.tamu.edu/) has been used in this study.

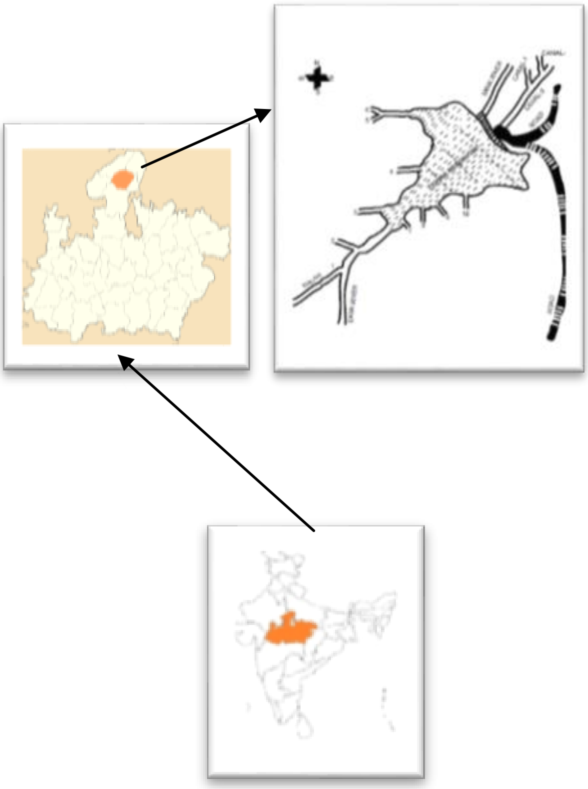

Fig 1. Tighra dam map, Gwalior City, Madhya Pradesh, India

III. Methodology

The methodology for application of SDSM for generation of precipitation series for future climatic scenarios consist of verification of predictant and predictors series, analysis of predictand, predictor relationship and selection of appropriate predictors which can explain the temporal and spatial variability of predictant with reasonable degree of agreement, calibration and validation of model, generation of future time series using GCM predictors series, computation of statistics and comparison of statistics of present and future scenarios. In the present study, correlation coefficient, partial correlation coefficient, and P-value based method along were used. The correlation coefficients between predictand (observe precipitation) and predictors (26 NCEP rescaled parameters) were computed using conditional approach for monthly precipitation. The correlation coefficients were then arranged in descending order and top ten predictors were selected for further analysis. The predictors ranked first in this process can be termed as a super predictor (SP) and using this super predictor, absolute correlation coefficient, absolute partial correlation and the P-value were computed for remaining nine predictors with predictand. In order to avoid multi-co-linearity, all predictors having P-value more than 0.05 and other predictors having high individual correlation with super predictor (more than 0.70 for this study) were removed from consideration. The percentage reduction in an absolute partial correlation (PRP) was then computed for remaining predictors using following equation.

$$PRP = \frac{Pr - R}{R} \qquad (1)$$

Where, Pr and R are the partial and absolute correlation coefficient respectively [22]. At the end, a predictor having lowest PRP value was considered the second Super predictor. A similar approach was applied to get third, fourth and other predictors. In general, one to three predictors are sufficient to model climatic variability [23]. After selecting the appropriate predictors, empirical relations between predictand and selected predictors were developed considering appropriate transformation, process (conditional for precipitation and unconditional for other climatic parameters), 2-fold cross-validation and model types (monthly). In this study, the whole series has divided into 2 pars of subsamples, where one sample is used for calibration while remaining for testing or validation. If results of calibration and validation found appropriate, the weather generator in SDSM can be used to generate future predictor series using predictors obtained from different GCM scenarios.

IV. Quality Control and Screening of Probable Predictors

Recorded metrological data may contain some missing data or outliers. Prior to modal calibration quality control check function is used to identify such error. The missing data can be replaced by -999, it act as a data identifier code [24]. After screening the suitable predictors found for precipitation are ncepmslpgl, nceps500gl and nceps850gl out of 26 predictors.units (in parentheses).

V. Analysis of Result

Table 1: Coefficient of determination and standard error during calibration and validation

Month	Caliberation		Validation	
	R^2	SE	R^2	SE

Jan	0.0706	1.8236	0.0494	1.8462
Feb	0.0978	1.8949	0.0761	1.9226
Mar	0.0196	0.9664	0.0032	0.9798
Apr	0.0332	0.7513	0.0122	0.7635
May	0.0266	1.0178	0.0187	1.0224
Jun	0.0956	8.9573	0.0841	9.0152
Jul	0.0798	15.9161	0.0521	16.215
Aug	0.0571	14.1544	0.0173	14.5992
Sept	0.2093	7.8214	0.1735	8.006
Oct	0.3765	2.5364	0.2803	2.7808
Nov	0.0572	3.4444	0.0019	3.5931
Dec	0.0778	1.6019	0.0583	1.623
mean	0.1001	5.0738	0.0689	5.1972

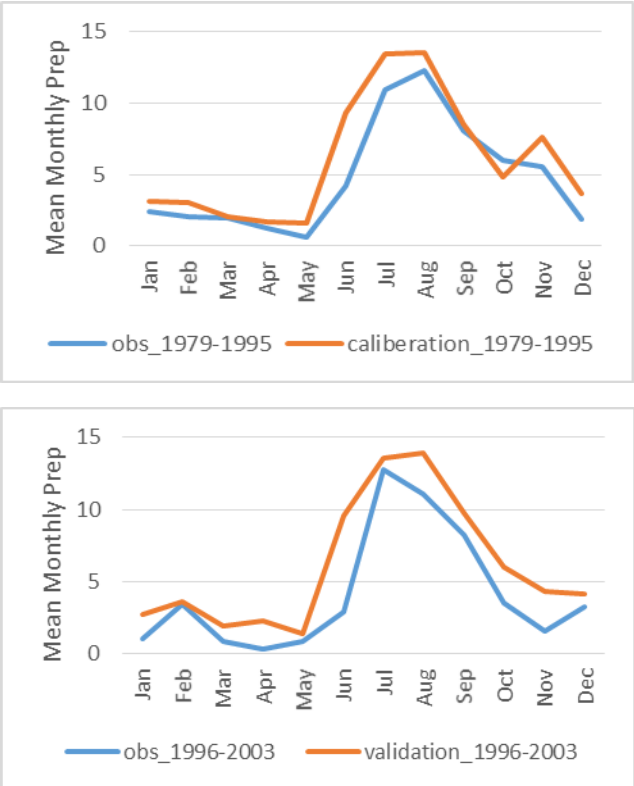

Fig. 2: Observed and calibrated/validated mean monthly Precipitation in SDSM

A. *CGCM A1B Forcing Condition*

The finally selected combination of variables with calibrated parameters was used to synthetically generate series for three future periods FP-1(2020-2035), FP-2 (2046-2064) and FP-3 (2081-2100) using gridded predictors obtained from Canadian general circulation model (CGCM) under the climatic forcing condition of A1B. The statistics including mean monthly precipitation, variance, inter-quantile range etc. were computed. The mean monthly precipitation of base period (1979-2003) and all three periods FP-1, FP-2 and FP-3 can be seen in Fig. 3. From the analysis, it has been observed that mean monthly precipitation may increase by 58.99% to 90.99% under A1B climate forcing condition.

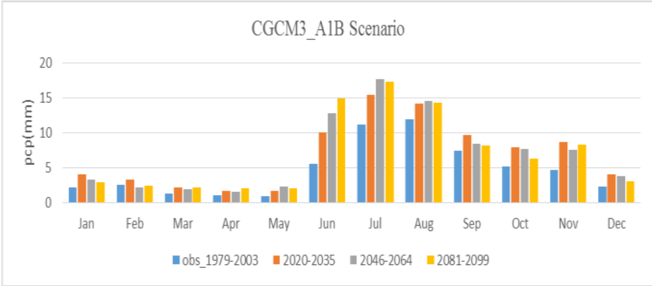

Fig. 3: Comparison of mean monthly precipitation for different periods of generated data with observed data under A1B climatic scenario

B. *CGCM A2 Forcing Condition*

The weather generator tab of SDSM was used to generate for three different periods FP-1 (2020-2035), FP-2 (2046-2064) and FP-3 (2081-2100) using CGCM gridded data under A2 forcing condition. The generated series for all the periods were used to compute statistics including mean, maximum, minimum, variance etc. and compared with the same for the period 1996-2003. The mean monthly precipitation series for different periods with observed data have been presented in Fig. 4. From the analysis, it has been found that the mean monthly precipitation may increase by 53.05% to 64.81% annually.

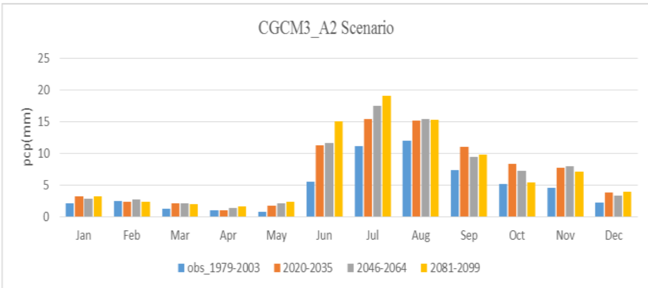

Fig. 4: Comparison of mean monthly precipitation for different periods of generated data with observed data under A2 climatic scenario

VI. CONCLUSION

In the present study, the statistical downscaling technique was used an alternative tool to downscale the Global Climate Model dataset into a fine-scale hydrological region over the Tighra Dam Catchment Gwalior, Madhya Pradesh, India. During the calibration and validation process, the SDSM model showed a good simulation of the daily rainfall can be estimated well by the NCEP reanalyzed set data, which was shown in good linear relation with the observed dataset. Whereas, it was demonstrated that the downscaling of rainfall by using SDSM is more problematic than temperature. In this study found for rainfall, a volume of daily rainfall and total annual rainfall may continuously increase by 58.99% to 90.99% and 53.05% to 64.81%under A1B and A2 climate forcing condition respectively. within the Tighra Dam Catchment. This result of future climate prediction can be used for water resources planning, management in the basin, plants and crop management in this region.

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