Statistical Downscaling of GCM Output for Generating Future Rainfall Scenarios Using SDSM for Upper Godavari Basin, Maharashtra

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1 Introduction

During the 20th century, the global surface temperature has increased by more than half a degree Celsius and the 1990s was, on average, the hottest decade for the last 1000 years [1]. The fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change [2] has listed the various climate scenarios and its drivers. The rising demand for water and the possible decline in future water resources due to climate change, will pose a significant challenge to water resources planners [3]. Therefore, a proper assessment of probable future precipitation and its variability over time should be included in climate change studies [4]. Global Circulation Models (GCMs) are considered as effective tools available today, which uses transient climate simulations to generate climatic conditions for hundreds of years into the past and the future. They play a crucial role in generating future projections of climate change using different emission scenarios [5]. However, GCMs are available at a coarse grid resolution of 1°–2°. Consequently, products of GCMs cannot be used directly for climate impact assessment on a local scale. This has led researches to undertake to development of suitable downscaling methodologies to transfer the GCM information to local scale information. A study of the impacts of

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climate change on the environment and the surroundings includes an account of the hydrological regime for the present and the future years. In order to accurately assess the water balance, generation of future hydrological scenario is essential.

2 Downscaling

Downscaling, or translation across scales, is a set of techniques that relate local and regional scale climate variables to the larger scale atmospheric forcing [6]. The downscaling process plays a crucial role in driving impact assessment models such as drought analysis, water resources management, water demand availability, ecological impacts and risk and vulnerability assessments. Statistical downscaling technique involves transformation using statistical regressions. In order to study the impacts of global warming on a small scale, it is necessary to develop and apply the scenarios to specific issues being faced by the region [7]. It has been emphasized that one of the most important challenges while framing policies is the lack of impact assessment at appropriate scales. Hence it is important to “downscale” in order to address the mismatch in the resolution of the GCM and the local catchment.

2.1 Statistical Downscaling Model (SDSM)

SDSM is a software tool that has been designed for climate change impact assessment studies using a robust downscaling model. The model is also capable of generating scenarios for variables that can not be directly obtained from GCMs. SDSM is a combination of stochastic weather generator and regression-based method. This is because the large scale synoptic variables and the moisture variables are used to condition the small scale variables (like rainfall frequency, intensity and occurrences). SDSM can be used as a windows-based free open source tool for the development of a single site downscaling of data under current and future forcings.

3 Study Area

One of the largest river basins of India, Godavari Basin, has been selected as study area for the present study. Godavari basin extends over states of Maharashtra, Andhra Pradesh, Chhattisgarh and Odessa in addition to smaller parts in

Madhya Pradesh, Karnataka and Union Territory of Puducherry having a total area of 3,12,812 km^2 with a maximum length and width of about 995 and 583 km. Table 1 gives details of study area (Fig. 1; Table 2).

Table 1 Salient features of the Godavari basin

Basin extent	
Longitude	73° 24′–83° 4′E
Latitude	16° 19′–22° 34′N
Total length of Godavari River (km)	1465
Catchment area (km^2)	312,812
Mean annual rainfall (mm)	1093.21

Fig. 1 Godavari river basin. *Source* Central Water Commission, GOI Ministry of Water Resources, 2014

Table 2 Characteristics of climate stations covered in the basin area

Climate station (Upper Godavari basin)	Catchment area (km^2)	Latitude	Longitude
Nasik	650	20°12′	73°32′
Nanded	52,038	19°08′	77°19′
Kopargaon	6840	19°33′	74°14′
Purna	15,000	19°10′	77°02′

3.1 Data Used

In the present study, data from the following sources is used

1. **Large-scale atmospheric variables** (predictors): These were extracted for the grid point closer to each climate station from the Canadian Institute for Climate Studies (CICS) website (http://www.cics.uvic.ca/scenarios).
2. **Observed Data**: The observations used in this study are daily gridded precipitation data, obtained from India Meteorological Department (IMD), Pune. It is available at high spatial resolution 0.25° × 0.25° (latitude × longitude) for a period 1971–2010 (40 years).

4 Methodology

Simulations can be performed through combinations of regressions and weather generators, sequences of daily climatic data for present and future periods by extracting statistical parametersfrom observed data series.

The first step in SDSM is screening of predictor variables. Calibration of the model is done by using the data for the period 1970–2000 and simulation is performed using precipitation data series. The percentage of variance is calculated which is tabulated below.

Climate scenario is generated from the model by simulation of daily precipitation data series for the whole 1961–1990 period with both 'Observed' (NCEP) and 'Modeled' (CanESM2) predictors. Monthly means and variances are compared using t-tests and. Raw CanESM2 precipitation data are used for comparison of monthly residuals with downscaled data. Future climate change projection is divided into three periods, namely 2030s (2011–2040), 2060s (2041–2070) and 2090s (2071–2100).

5 Results and Discussions

Results in terms of 'explained variance' during the calibration at each meteorological station is presented in Table 3 in terms of statistical parameters by giving the percentage of explained variance for the selected predictors. For precipitation, the best and the worst performance of the model is seen to be 45.6 and 20.5%.

Table 3 Calibration result at selected meteorological stations

Climate station	Explained variance (%)
Nasik	45.6
Nanded	31.2
Kopargaon	23.1
Purna	20.5

Table 4 Statistical performance of simulated result compared to observed data at four stations

Sr. No.	Station	Statistical parameter	Precipitation			
			Calibration period (1961–1990)		Validation period (1996–2005)	
			Observed	Simulated	Observed	Simulated
1	Nasik	Std. dev (mm)	123.62	130.28	128.22	118.41
		R^2	–	0.73	–	0.83
2	Nanded	Std. dev (mm)	143.19	136.34	120.62	131.91
		R^2	–	0.81	–	0.87
3	Kopargaon	Std. dev (mm)	119.71	126.14	134.74	140.11
		R^2	–	0.65	–	0.70
4	Purna	Std. dev (mm)	104.43	117.22	130.16	124.75
		R^2	–	0.79	–	0.74

The results variation in mean precipitation residual is due to unrealistic representation of CanESM2 predictors. It is clearly shown that SDSM performed better using Raw predictors than CanESM2 predictors (Table 4).

5.1 *Climate Change Scenarios (CCCma Under RCP2.6, RCP4.5, RCP8.5) by Downscaling Future Rainfall*

The projected annual precipitation in four meteorological stations for three future periods, compared to the baseline period of 1976–2005 is presented in Table 5. The future rainfall at Godavari basin have been downscaled for the RCP2.6, RCP4.5 and RCP8.5 scenarios.

It is noted that for Nasik region, the annual rainfall is likely to be increased by 2–11% in three of the scenarios respectively. At Nanded station, the annual rainfall is likely to be increased by 2–13% during three scenarios but during RCP4.5 and RCP8.5 in 2060s it may decrease by 4 and 2% respectively. At Kopargaon station also, it may be improved by 1 and 15% but for RCP4.5 over 2060s it is likely to decrease by 9%. However at Purna station, it may be decreased by 2 and 11% except RCP4.5 in 2060s and RCP8.5 2030s. Thus it shows increasing trend for these two RCPs as shown in Table 5 (Fig. 2).

Table 5 Projected Change in annual precipitation for future period compared to baseline period under three RCPs

Sr. No.	Station	Annual precipitation in baseline period	RCP2.6			RCP4.5			RCP8.5		
			2030s	2060s	2090s	2030s	2060s	2090s	2030s	2060s	2090s
			Percentage change compared to baseline period (%)								
1	Nasik	1029.6	3	7	11	2	6	9	3	−7	10
2	Nanded	954	2	4	4	8	−4	13	8	−2	6
3	Koparg–aon	832	1	3	9	15	2	3	−9	10	4
4	Purna	608	−5	−7	−6	−11	8	−2	15	−5	−2

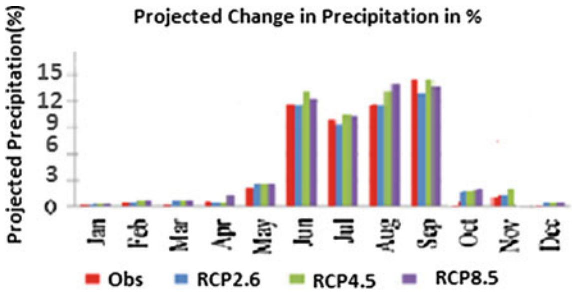

Fig. 2 Projected change in precipitation on the basin

6 Conclusion

The future climate projection for the Upper Godavari basin has been carried out using the outputs of CanESM2 developed by Canadian Centre for Climate Modeling and Analysis (CCCma). In regression based statistical downscaling techniques, the choice of predictors becomes one of the most challenging issues, as different sets of predictors will likely give different results. In SDSM, the choice is made using quantitative tests (explained variance and partial correlation). Study can be carried out by selecting more predictors which are strongly influencing on rainfall as a hydrological parameter. The study shows likely increase in the rainfall at three raingauge stations viz. Nasik, Nanded, and Kopargaon station and decrease in the rainfall at Purna station in Godavari basin, in future, due to climate change.

References

1. Srivastava AK, Rajeevan M, Kshirsagar SR (2008) Development of a high resolution daily gridded temperature data set (1969–2005) for the Indian Region
2. Giorgi F, Hewitson B et al (2001) Regional climate information—evaluation and projections. In: Climate change 2001: the scientific basis. IPCC TAR. Cambridge University Press, Cambridge
3. Huang C, Barnett AG, Wang X, Vaneckova P, FitzGerald G, Tong S (2011) Projecting future heat-related mortality under climate change scenarios: a systematic review. Environ Health Perspect 119:1681–1690
4. Goswami BB, Mukhopadhyay P, Mahanta R, Goswami BN (2010) Multiscale interaction with topography and extreme rainfall events in the northeast Indian region. J Geophys Res 115:D12
5. Fowler HJ, Blenkinsop S, Tebaldi C (2007) Linking climate change modelling to impacts studies: recent advances in downscaling techniques for hydrological modelling. Int J Climatol 27:1547–1578
6. Labat D, Goddéris Y, Probst JL, Guyot JL (2004) Evidence for global runoff increase related to climate warming. Adv Water Resour 27:631–642
7. Wentz FJ, Ricciardulli L, Hilburn K, Mears C (2007) How much more rain will global warming bring? Science 317:233–235