Comparison of Historical Precipitation Data between Cordex Model and Imd Over Malaprabha River Basin, Karnataka State, India

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Abstract*: Validation of precipitation data is important for hydrological modeling. Though there are many models available, rainfall prediction is difficult due to various uncertainties. This study is an attempt to compare and assess the Coordinated Regional Climate Downscaling Experiment (CORDEX) model data and India Meteorological Department (IMD) observed gridded data over Malaprabha river basin, Karnataka state, India. Both gridded data sets were downscaled at 0.25° × 0.25° resolution and then processed into a 12 × 115 matrix form by using QGIS (2.18.24) and MATLAB (R2003a). These two products were compared over the period 1961-2015 to evaluate their behavior in terms of fitness by using statistical parameters such as NSE, D, R, MAE, MBE and RMSE values. Results showed that out of 16 grid points, fourteen grid points showed medium correlation ranging between 0.30 and 0.49.

***Index Terms*: CORDEX model, Data compression, Malaprabha river basin, Validation of IMD and CORDEX model data.**

I. INTRODUCTION

Precipitation is one of the vital components of the physical environment and plays a major role in the growth and prosperity of any developing country. Insufficient real-time monitoring of data is a major obstruction to regional scale studies. Even though various satellite data sets are available with different spatial resolutions, it is difficult to predict the accurate rainfall. The number of rain gauges throughout India are limited and unevenly distributed, and most of the gauge network is either old or not functioning properly. Satellite rainfall estimations are being used widely to replace the gauge observations. But systematic validation of satellite data is necessary to be able to use it for further applications. Specifically, the satellite data do not reflect the strong influence of topography on precipitation in some of the basins (Hughes 2005). Many global and regional simulated models end up with large correlation difference with observed datasets (McMahon et al. 2015). The huge requirement of accurate rainfall data with high spatial and temporal resolutions has resulted in techniques for conversion of point rainfall time series into spatially continuous rainfall time series (Legates and Willmott, 1990; Jones and Hulme, 1996). Rainfall time series for any site may be either point data or gridded data. Point data are obtained through rain gauges and are usually considered the most accurate source for validating satellite rainfall data. But point data can be used only where the instruments are located and hence there will be uncertainties between them and modelled data (Tsintikidis et al., 2002). Technologically advanced instruments and techniques are now implemented for more accurate estimation of spatially continuous precipitation datasets, for example spatial interpolation of rain gauge data, weather radar, satellite and multi-sensor estimations (Seo et al., 1990. Haberlandt, 2007. Xu et al., 2015. Nastos et al., 2016). Validation of different model data sets with IMD by different statistical parameters such as NSE, RMSE and R, concluded that CORDEX and NCEP had shown good correlation (Bandyopdhyay et al., 2018). It was also found that TRMM-3B43, CMAP, CMORPH, TAMSAT and TRMM-3B42 performed well with rain gauge data in East Africa (Dinku et al. 2007).

The aim of this study is to test the performance of CORDEX model data with the IMD gridded data set for the Malaprabha river basin, Karnataka for the period 1961–2015 using various statistical indicators.

II. STUDY AREA AND DATA SOURCE

River Malaprabha is the one of the major tributaries in Krishna river basin. The river originates in the Western Ghats of Sahyadri at an altitude of 792.4 meters in a small village,

Kanakumbi which is located at about 16 km west of Jamboti village of Khanapur taluka in Belagavi district, Karnataka, India. The river originates at 15.420º North latitude and 74.130º East longitude

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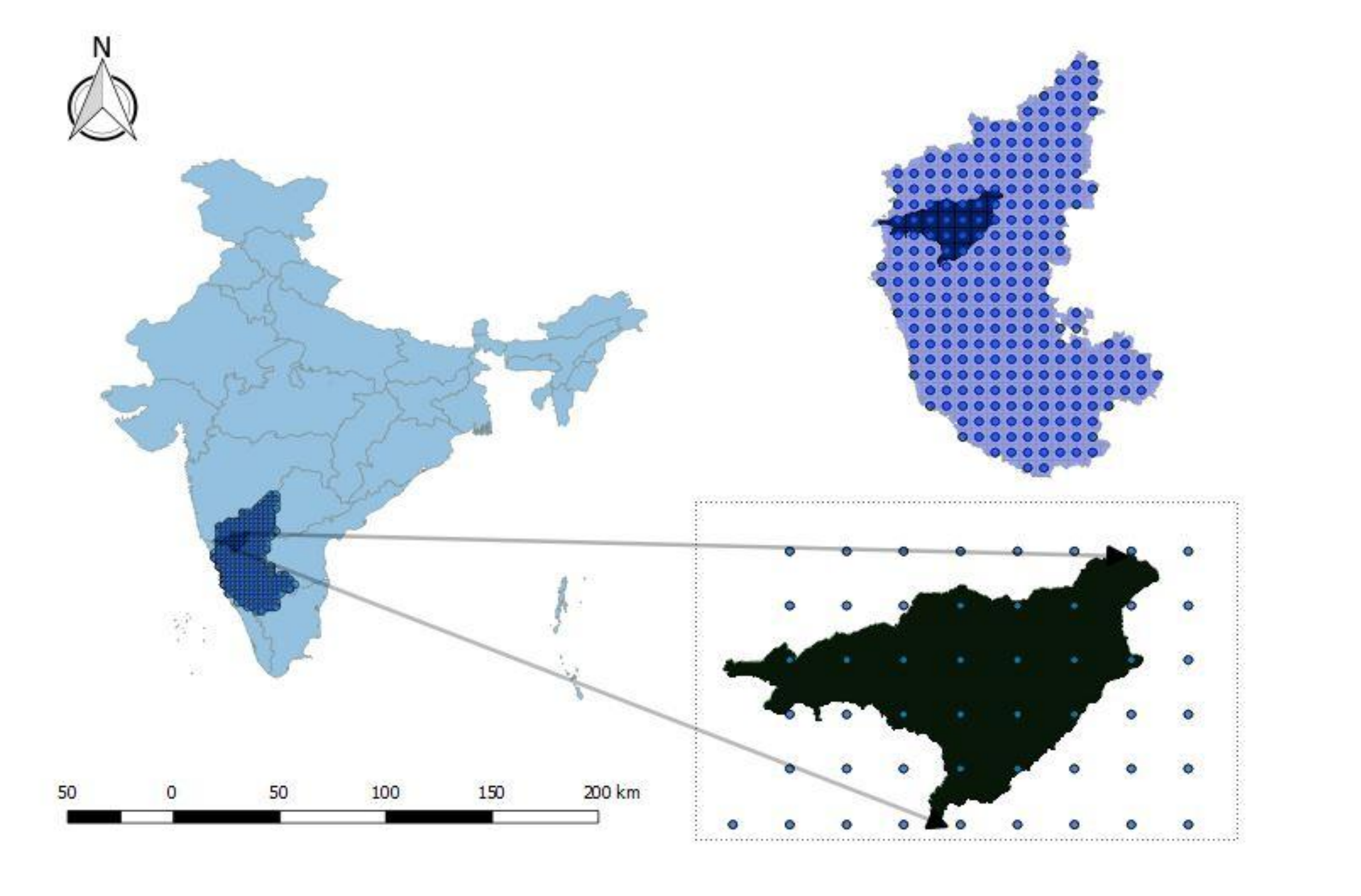

Fig.1 Location of grid points at Malaprabha river basin, Karnataka

(http://india-wris.nrsc.gov.in). River Malaprabha flows for a distance of 304 km and joins the Krishna River at Kudalasangam (Bagalkot district of Karnataka).

III. MATERIALS AND METHODOLOGY

The precipitation data (CORDEX) for all the 250 grid points covering Karnataka state were downloaded from Centre for Climate Change Research, Pune, India (http://cccr.tropmet.res.in/home/data_cccrdx.jsp). Since the data for all the 50 years were in the form of .nc format at 0.44° × 0.44° resolution, preprocessing was done by using QGIS (2.18.24) and MATLAB (R2003a) to convert the data to 0.25° × 0.25° resolution. To obtain transparent results, CORDEX model data then compared with India Meteorological Department (IMD) data set having same resolution and timeframe. The Cartosat DEM tiles corresponding to the Malaprabha watershed were downloaded from the NASA website (https://earthdata.nasa.gov). QGIS 2.18.24 was used for the geo-processing activities. The tiles were merged, clipped and re-projected. The drainage directions and stream segments were extracted. The coordinates of the outlet point at 16.20° North latitude and 76.06° East longitude were marked and the watershed corresponding to the outlet point was generated.

The area of the watershed created was around 11550 sq. km (Figure 1). Statistical tests listed in Table 1 were performed to check the validation of the CORDEX model data for the basin.

Nash-Sutcliffe Coefficient of Efficiency (NSCE) is an indicator of model fit between the simulated and observed data. NSE ranges from -∞ to 1. Essentially, closer to 1 the NSCE, more accurate the model is. The index of agreement (d) measures the degree of model prediction error, which varies between 0 and 1. The index value of 1 indicates a perfect match, and 0 indicates no agreement at all (Willmott 1990). Pearson Correlation Coefficient (CC) reflects the degree of linear correlation between model precipitation and gauge observations. The r value of 1 indicates a perfect match and 0 means that the two variables don't have any linear relation. In terms of error and bias, three different statistical indices are used widely for validation. The mean absolute error (MAE) represents the average magnitude of the error. Although the root mean square error (RMSE) also measures the average

Table 1. List of statistical indices used to compare the CORDEX model data and the IMD observations (Yong et al. 2010; Bandyopdhyay et al. 2018).

Statistical Index	Unit	Equation	Perfect value
Nash-Sutcliffe Coefficient of Efficiency (NSCE)	NA	$NSE = 1 - \frac{\sum_{i=1}^{n}(\mathrm{OBS}_\iota - \mathrm{SIM}_\iota)^2}{\sum_{i=1}^{n}(\mathrm{OBS}_\iota - \overline{OBS})^2}$	1
Index of agreement (d)	NA	$d = 1 - \frac{\sum_{i=1}^{n}(O_\iota - P_\iota)^2}{\sum_{i=1}^{n}\left(\lvert P_\iota - \overline{O}\rvert + \lvert O_\iota - \overline{O}\rvert\right)^2}$	0
Correlation Coefficient (CC)	NA	$r = \frac{\sum_{i=1}^{n}(O_\iota - \overline{O})(P_\iota - \overline{P})}{\sqrt{\sum_{i=1}^{n}(O_\iota - \overline{O})^2}\sqrt{\sum_{i=1}^{n}(P_\iota - \overline{P})^2}}$	1
Mean Absolute Error (MAE)	mm	$MAE = \frac{1}{n} \times \sum_{i=1}^{n}\lvert O_\iota - \overline{P}\rvert$	0
Mean Bias Error (MBE)	mm	$MBE = \frac{1}{n}\sum_{i=1}^{n}\lvert O_\iota - \overline{P}\rvert$	0
Root Mean Squared Error (RMSE)	mm	$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{\mathrm{OBS},\iota} - X_{\mathrm{model},\iota})^2}{n}}$	0

error magnitude, it gives greater weight to the larger errors relative to MAE. These are always non-negative, and a value of 0 (almost never achieved in practice) would indicate a perfect fit to the data. Mean bias error (MBE) is primarily used to estimate the average bias in the model and to decide if any steps need to be taken to correct the model bias. A smaller value of MBE is preferred and ideally, it should be zero. A positive value gives the average amount of overestimation in the calculated value and vice versa (Yong et al. 2010).

IV. RESULTS AND DISCUSSION

Precipitation estimates from CORDEX were compared with IMD data for each selected grid over Malaprabha basin by adopting various statistical indicators as summarized in Table 2. Out of 16 grids, the value of NSE is between 0 and 1 for six grids (grids #3, #12–16), which can generally be viewed as acceptable levels of performance between the CORDEX and IMD data (Moriasi et al. 2007). The index agreement (d) for most of the grid points ranged between 0.5 and 0.6; the maximum value of 0.672 and the minimum value of 0.415 were found in grid #02 and #15, respectively. The maximum R value of 0.672 and the minimum value of 0.315 was observed in grids #13 and #03, respectively. The average of R between the model and IMD data for the basin was found to be 0.423. Except in grids #12 and 13, R was between 0.3 and 0.5, which indicates that a medium correlation exists between the model and IMD data.

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Table 2. Validation of statistics parameters

Grid number	LAT	LONG	NSE	D	R	MAE	MBE	RMSE
1	15.25	75.5	-0.246	0.587	0.372	47.87	-7.973	83.852
2	15.25	75.25	-0.147	0.672	0.478	44.745	-11.11	72.935
3	15.5	75.75	0.015	0.425	0.315	70.705	42.688	149.406
4	15.5	75.5	-0.34	0.624	0.403	44.957	-0.779	74.272
5	15.5	75.25	-0.0445	0.61	0.391	48.428	0.255	80.05
6	15.5	75	-0.673	0.6	0.394	45.142	-7.225	75.175
7	15.75	76	-0.13	0.572	0.35	43.757	0.826	73.224
8	15.75	75.75	-0.174	0.612	0.402	43.981	-6.761	71.607
9	15.75	75.5	-0.123	0.636	0.436	44.367	-8.389	71.11
10	15.75	75.25	-0.238	0.444	0.41	269.6	260	492.7
11	15.75	75	-0.231	0.472	0.486	259.274	251.15	456.97
12	15.75	74.75	0.198	0.459	0.614	273.046	227.934	449.76
13	15.75	74.5	0.247	0.598	0.672	121.88	97.906	227.618
14	16	75.75	0.079	0.558	0.35	45.343	4.919	77.619
15	16	75.5	0.025	0.415	0.362	55.704	21.525	122.986
16	16	75.25	0.012	0.503	0.342	45.666	10.001	84.629

The maximum MAE of 273 and minimum MAE of 43.757 were observed at grids #12 and #7, respectively. The average and standard deviation of MAE were 94.02 mm and 88.17 mm. In contrast, the standard deviation was found to be 7.752 mm by considering the ten grid points for which MAE was less than 50.

Larger deviation was found in MBE with a maximum value of 260 and minimum of -11 grids #10 and #2, respectively. Six grid points showed negative bias and others showed positive bias with higher values observed in grids #10–13.

The RMSE varied between 492.7 and 71.11 with a standard deviation of 154.452 mm. Grids #3, 10-13 and 15 showed high RMSE values and for other grids the value was less than 85.

V. CONCLUSION

The fifty year rainfall data (1961–2015) of Malaprabha catchment was downloaded from the Centre for Climate Change Research (CCCR) and was analysed to check the statistical evidence of the quantitative deviation that exists between CORDEX model data and IMD data. The highest NSE for precipitation was 0.247 with a standard deviation of 0.222; NSE was between zero to one in six grid points signifying the acceptable levels of performance between the model and the observed data. The index of agreement for all the grids fell in the range between 0.5 and 0.6. The average of R was found to be 0.423 for the basin, indicating a medium correlation between the model and IMD data. The average MAE for the basin was 94.02. RMSE was less than 85 for ten grid points and for the rest it was in a higher range. The overall statistical observation of the results showed that there exists a systematic deviation in R, NSE and MAE, which leads to the conclusion that CORDEX model estimates differ with IMD estimates and possess medium correlation in most cases.

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