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Short Communication

Assessing future precipitation and temperature changes for the Kesinga Basin, India according to CORDEX-WAS climate projections

PERELI CHINNA VANI[1], B.C. SAHOO[1], J.C. PAUL[1], A.P. SAHU[1] and A.K.B. MOHAPATRA[2]

[1]Department of Soil and Water Conservation Engineering, College of Agriculture Engineering and Technology, OUAT, Bhubaneswar-751003, Odisha, India
[2]Department of Agricultural Meterology, College of Agriculture, OUAT, Bhubaneswar-751003, Odisha, India
Author email: chinnavani14@gmail.com

In recent decades, there has been a noticeable increase in the occurrence of extreme weather events, with heat waves and heavy precipitation being particularly prominent in various regions across the globe (Haftu and Haftom, 2022). The average temperature on the earth surface is expected to increase between 0.3 and 0.7 °C, globally from 1986 to 2035 (IPCC, 2014; Boomiraj *et al.*, 2010). Although climate change has been scientifically shown, it is still important to assess how the Earth and its human population will be affected by the non-stationary circumstances brought on by climate change (Tyagi *et al*., 2022). Planning for hydrological processes and managing water resources requires considering how climate change and human activity, such as rising pollution and shifting land use, interact, especially in global warming.

The climate model and statistical analysis of historical data have been used to analyse different hydro-climatic variables in the Mahanadi River Basin (MRB), India (Netrananda *et al.,* 2020). Watersheds will experience the climate change impacts and the rise in temperature is one of the indicators of this change that will alter surface and ground waters over time and progressively bring about extreme weather events such as flash floods and droughts. The GCM (General Circulation Model) simulations rely on different climate-forcing scenarios that are regularly updated by the report of the Intergovernmental Panel on Climate Change (IPCC, 2014) on the emissions scenarios to the Representative Concentration Pathways (RCP) scenarios (Taylor *et al*., 2012; Rijwana *et al.,* 2023). The RCPs provide a depiction of the trajectory and concentration of emissions by the year 2100, and the resulting forcing is also described in each scenario.

An analysis has been done to assess the climate change projection over Kesinga catchment of Mahanadi River Basin (MRB) with 11,855 km^2 area, and located between 19º 16'-20º 44' N and 82º 03'-83º 24'E. The Kesinga catchment is the source of water for Nuapada, Balangir, Kalahandi, and Nabarangpur of Odisha state and Gariaband of Chhattisgarh state. The maximum, minimum temperatures and precipitation data were obtained from CORDEX-WAS and CWC (Central Water Commission, Bhubaneswar) (Tassia *et al*., 2023). In this study, a set of 3 CORDEX -RCMs was used (Table 1). The calculation of the multiple model mean or ensemble for maximum, minimum temperatures and precipitation was carried out using RCP 4.5 (moderate emission scenario) and RCP 8.5 (high emission scenario) concerning both the ensemble and observed datasets (Riahi *et al*., 2007). The CWC daily climatology factors, such as daily maximum and minimum temperatures, precipitation, and other variables, are updated in the monthly climate data (Abhijeet and Tripathy, 2019). In terms of future prospects, there were two distinct categories, MC (mid-century) and EC end century).

The observation period 1974-2003 (historical), 2021-2050 (MC), and 2070-2099 (EC) were selected after correcting for the bias in the CORDEX dataset. To assess the spatial distribution of precipitation in the region, the analysis has been carried out, using both model experiments and observational data from 1974 to 2003. The variance between the long term (30-year) average of the climate variable in the future and the historical period is described as a factor of change (Baljeet *et al.,* 2022).

Statistical bias correction procedure

The CMhyd tool has been used for applying DM (Distribution Mapping) to the Kesinga catchment precipitation and temperature data (Rathjens *et al*., 2016). In order to use observed data over a similar length period the bias correction of climate

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Table 1: List of CORDEX - RCMs used in this study with r1i1p1 ensemble

Contributing CORDEX modelling Centre or Group	CORDEX RCM Model	Period (Historical & Future)
Centre for Climate Change Research (CCCR), Indian Institute of Tropical Meteorology (IITM), Pune (2 Ensemble Members)	CSIRO-QCCCE-CSIRO CCCma-CanESM2	1951–2005 2006–2099
Rossy Centre Swedish Meteorological & Hydrological Institute (SMHI), Sweden (1 Ensemble members)	IPSL-CM5A-MR	1951-2005 2006-2100

Table 2: Statistical normalized of the CORDEX-WAS models, their ensemble, and CWC observation data

CORDEX-RCM Model	Rainfall (mm)		T_{max}		T_{min}	
	r		r		r	
CSIRO-QCCCE-CSIRO	0.81	0.94	0.94	0.6	0.85	0.95
CCCma-CanESM2	0.83	0.85	0.78	0.79	0.78	0.80
IPSL-CM5A-MR	0.79	0.9	0.94	0.56	0.77	1.20
Ensemble	0.95	0.4	0.95	0.4	0.8	1.00
CWC observed data	0.82	0.89	0.91	0.80	0.78	1.10

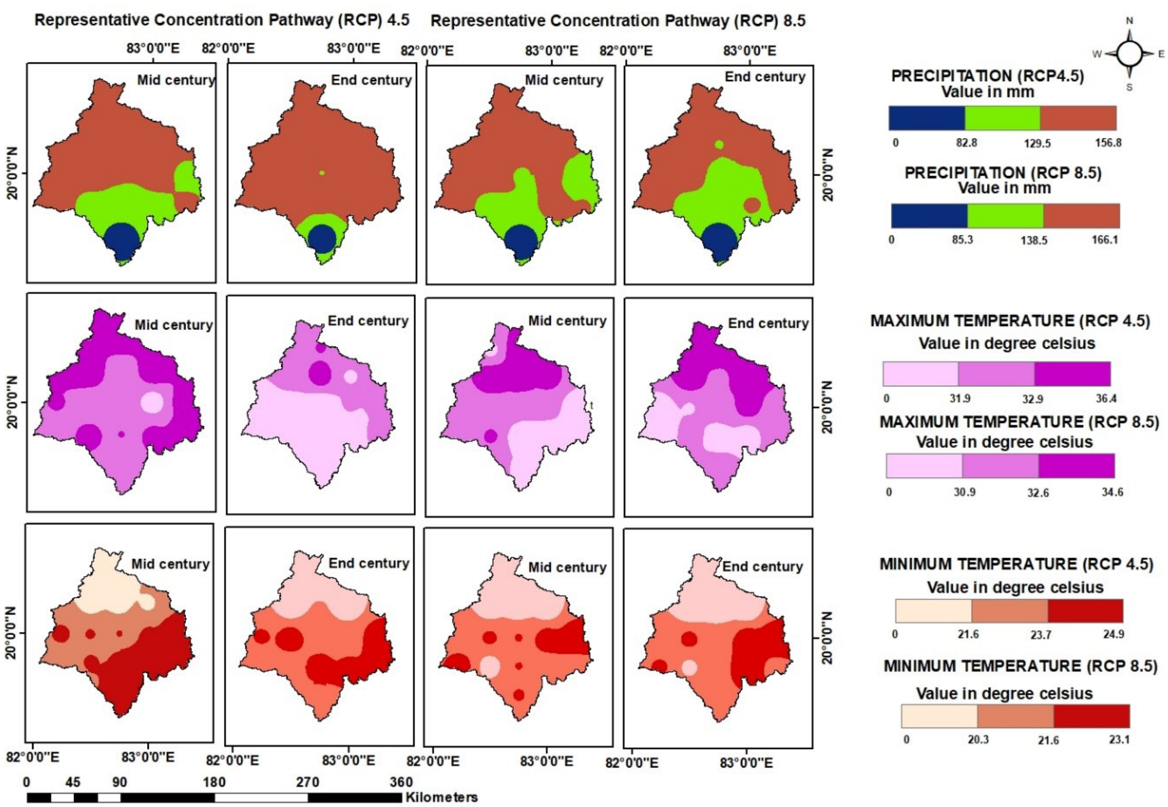

Fig. 1: Projected spatial variation of annual average precipitation and temperature (maximum & minimum) in Kesinga catchment from MC to EC of RCM (RCP 4.5 and RCP 8.5)

simulation model time series was applied for the baseline period (1974–2003). The different dataset used in this study had a spatial resolution of 0.5° × 0.5°, but after downscaling them using the CMhyd tool, the scale of the dataset was improved to 0.25° × 0.25.

For 30-year of precipitation and temperature, the historical records from CWC in terms of correlation (r), standard deviation (δ), and normalized root mean square (NRMS) difference (maximum and minimum) demonstrate a consistent pattern across all CORDEX-WAS experiments (Table 2). The normalized RMSE difference for all models is ~1.3 with CWC observation. The precipitation statistics normalization indicates that CCCma_IITM

Table 3: Projected precipitation change (%) concerning the historical period

Period	Scenario	Change
Mid Century	RCP 4.5	-47.31% to 74.77%
	RCP 8.5	-96.27% to 61.08%
End of Century	RCP 4.5	-88.56% to 71.94%
	RCP 8.5	-41.25% to 92.12%

(0.82) and CSIRO_IITM (0.83) are highly correlated with observed data.

CORDEX-WAS and future projections

Fig.1 shows annual precipitation and temperature (maximum and minimum) throughout a regional representation from the MC to EC regarding the two emission scenarios (RCP 4.5 and RCP 8.5). The MC precipitation patterns, it has been forecasted that there will be a 14.8% increase in the annual average under the RCP 4.5, whereas RCP 8.5 is expected to bring about 1% decrease, while for projection for EC indicates a decrease of 12.6% in RCP 4.5 and an increase of 22.% in RCP 8.5 Is from MC to EC, the annual average maximum temperature is expected to increase by approximately 1.6 ◦C to 1.4 ◦C and 2.8 ◦C to 4.2 ◦C under RCP 4.5 and RCP 8.5 respectively. The annual average minimum temperature has increased from 0.6 ℃ to 1.45 ℃ in MC to EC under RCP 4.5, while for the RCP 8.5, increased from 1.0℃ to 3.2℃ in MC to EC.

Annual variability of projected precipitation and temperature

The term 'climate' refers to the average and variability of key quantities, for instance temperature or precipitation. According to the World Meteorological Organisation, a 30-year time is necessary for study these averaging of these variables (Phoncharoen *et al.,* 2021). Climate variability denotes the changes in climate parameters that are expressed through the mean state, i.e., the standard deviation, correlation coefficient, statistics of extremes, etc., and the analysis takes into account temporal and spatial scales that transcend individual weather events.

Precipitation changes

Table 3 shows the projected percentage change in annual rainfall in the ensemble CORDEX-WAS model simulation from the historical era (1974-2003) to the MC (2021-2050) and EC (2070-2099). The catchment's average annual rainfall is expected to decrease in MC and increase toward the EC under RCP 4.5, whereas it is predicted to decrease toward MC and increase toward the EC under RCP 8.5. Hence, the conclusion is compared to the MC climatic scenario, the estimated proportion of the increase in rainfall is particularly significant for EC.

Temperature (maximum & minimum) changes

Table 4 shows the expected temperature changes during the same time period, and the extent of these changes as determined by the CORDEX-WAS runs. Both figures demonstrate the temperature changes for moderate and high emission scenarios (RCP 4.5 & RCP 8.5) from MC to EC. As indicated in the projections, the temperature is expected to increase by 0.06 °C to 7 °C over the period. For the

Table 4: Projected annual maximum and minimum temperatures concerning the historical period

Period	Scenario	Change (◦C)	
		Temperature (Max)	Temperature (Min)
Mid-century	RCP 4.5	0.29-4.94	0.99-1.26
	RCP 8.5	0.95-4.67	0.93-1.34
End century	RCP 4.5	0.54-5.6	0.06-2.5
	RCP 8.5	1.27-7.02	1.95-5.19

MC (2021-2050), warming is estimated to range from 0.29°C to 4.94°C and 0.95°C to 4.67°C under RCP 4.5 & 8.5, respectively. For the EC (2070-2099), the projected temperature increases under RCP 4.5 & RCP 8.5 scenarios, from 0.54 °C to 5.6 °C and 1.27 °C to 7.02 °C, which would cause a significant danger to the whole catchment. Regarding the RCP 4.5 and RCP 8.5 scenarios, the majority of regions will experience considerable warming in both the mid-century and end-century. The RCP 4.5 scenario predicts that these indicators will stabilize and exhibit no significant catchment patterns in the MC.

The result indicated that in Kesinga catchment of Mahanadi river basin, the annual average maximum and minimum temperature will experience an increase of over 5℃. Estimated precipitation is expected to change between 23% to 40% of the historical period data towards the end of the 21st century for both RCP scenarios.

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***Data availability*:** The data can be made accessible upon a reasonable request. Data Source: https://esg-dn1.nsc.liu.se/search/cordex/

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