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Identification of trends in intensity and frequency of extreme rainfall events in part of the Indian Himalaya

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Extreme monsoon rainfall is the primary reason of floods and other secondary hazards such as landslides in the Indian Himalaya. Understanding the phenomena of extreme monsoon rainfall is therefore required to study the natural hazards. In this work, we study the characteristics of extreme monsoon rainfall including its intensity and frequency in the Garhwal Himalaya in India, with a focus on the Mandakini River Catchment, the site of devastating flood and multiple large landslides in 2013. We have used two long term rainfall gridded data sets: the Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) product with daily rainfall data from 1951-2007 and the India Meteorological Department (IMD) product with daily rainfall data from 1901 to 2013. Two methods of Mann Kendall and Sen Slope estimator are used to identify the statistical significance and magnitude of trends in intensity and frequency of extreme monsoon rainfall respectively, at a significance level of 0.05. The autocorrelation in the time series of extreme monsoon rainfall is identified and reduced using the methods of: pre-whitening, trend-free pre-whitening, variance correction, and block bootstrap. We define extreme monsoon rainfall threshold as the 99th percentile of time series of rainfall values and any rainfall depth greater than 99th percentile is considered as extreme in nature. With the IMD data set, significant increasing trend in intensity and frequency of extreme rainfall with slope magnitude of 0.55 and 0.02 respectively was obtained in the north of the Mandakini Catchment as identified by all four methods. Significant increasing trend in intensity with a slope magnitude of 0.3 is found in the middle of the catchment as identified by all methods except block bootstrap. In the south of the catchment, significant increasing trend in intensity with a slope magnitude of 0.86 for pre-whitening method and 0.28 for trend-free pre-whitening and variance correction methods was obtained. Further, increasing trend in frequency with a slope magnitude of 0.01 was identified by three methods except block bootstrap in the south of the catchment. With the APHRODITE data set, we obtained significant increasing trend in intensity with a slope magnitude of 1.27 at the middle of the catchment as identified by all four methods. Collectively, both the datasets show signals of increasing intensity, and IMD shows results for increasing frequency in the Mandakini Catchment. The increasing occurrence of extreme events, as identified here, is becoming more disastrous because of rising human population and infrastructure in the Mandakini Catchment. For example, the 2013 flood due to extreme rainfall was catastrophic in terms of loss of human and animal lives and destruction of the local economy. We believe our results will help understand more about extreme rainfall events in the Mandakini Catchment and in the Indian Himalaya.