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Spatial Intensity Duration Frequency Relationships Using Hierarchical Bayesian Analysis for Urban Areas

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In urban areas, quantification of extreme precipitation is important in the design of storm water drains and other infrastructure. Intensity Duration Frequency (IDF) relationships are generally used to obtain design return level for a given duration and return period. Due to lack of availability of extreme precipitation data for sufficiently large number of years, estimating the probability of extreme events is difficult. Typically, a single station data is used to obtain the design return levels for various durations and return periods, which are used in the design of urban infrastructure for the entire city. In an urban setting, the spatial variation of precipitation can be high; the precipitation amounts and patterns often vary within short distances of less than 5 km. Therefore it is crucial to study the uncertainties in the spatial variation of return levels for various durations.

In this work, the extreme precipitation is modeled spatially using the Bayesian hierarchical analysis and the spatial variation of return levels is studied. The analysis is carried out with Block Maxima approach for defining the extreme precipitation, using Generalized Extreme Value (GEV) distribution for Bangalore city, Karnataka state, India. Daily data for nineteen stations in and around Bangalore city is considered in the study. The analysis is carried out for summer maxima (March - May), monsoon maxima (June - September) and the annual maxima rainfall. In the hierarchical analysis, the statistical model is specified in three layers. The data layer models the block maxima, pooling the extreme precipitation from all the stations. In the process layer, the latent spatial process characterized by geographical and climatological covariates (lat-lon, elevation, mean temperature etc.) which drives the extreme precipitation is modeled and in the prior level, the prior distributions that govern the latent process are modeled. Markov Chain Monte Carlo (MCMC) algorithm (Metropolis Hastings algorithm within a Gibbs sampler) is used to obtain the samples of parameters from the posterior distribution of parameters. The spatial maps of return levels for specified return periods, along with the associated uncertainties, are obtained for the summer, monsoon and annual maxima rainfall. Considering various covariates, the best fit model is selected using Deviance Information Criteria. It is observed that the geographical covariates outweigh the climatological covariates for the monsoon maxima rainfall (latitude and longitude). The best covariates for summer maxima and annual maxima rainfall are mean summer precipitation and mean monsoon precipitation respectively, including elevation for both the cases. The scale invariance theory, which states that statistical properties of a process observed at various scales are governed by the same relationship, is used to disaggregate the daily rainfall to hourly scales. The spatial maps of the scale are obtained for the study area. The spatial maps of IDF relationships thus generated are useful in storm water designs, adequacy analysis and identifying the vulnerable flooding areas.