Spatial Assessment of Extreme Precipitation Probability in Central Java, Indonesia Using Satellite Data

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Introduction

Accurately estimating extreme precipitation is crucial to disaster risk reduction as well as for infrastructure planning and development. However, many countries, including Indonesia, face challenges in estimating extreme precipitation due to limited spatial distribution of ground stations [1]. Satellite precipitation products have commonly been implemented to overcome the insufficient ground stations problem; however, they tend to underestimate extreme precipitation intensities because of systematic errors [2]. We found a large gap in precipitation time series between the data of GSMaP and ground stations. Therefore, this study aims to predict spatial distribution of extreme precipitation probability using GSMaP data.

Experimental Procedures

This study utilized 20 years (2001–2020) of daily precipitation data from 118 ground stations in Central Java and GSMaP-gauge V8 satellite product. GEVr distribution (Generalized Extreme Value based on r-largest order statistics) having three parameters, location- (μ), scale- (σ), and shape- (ξ) parameters, was applied allowing more samples (the five largest daily precipitation each year) to be included [3]. The workflow of this study consisted the following steps: 1) estimation of GEVr parameters from ground stations and GSMaP; 2) calculation of correction factors for GEVr parameters of GSMaP to predict those of ground stations and; 3) modeling and predicting the correction factors for GSMaP GEVr parameters from original GSMaP GEVr parameters value using machine learning algorithms (Random Forest and XGBoost); 4) estimation of return levels for all ungauged GSMaP grids by using corrected GEVr parameters.

Results and Discussion

The overall agreement between ground stations and original GSMaP for the extreme daily precipitation data was weak, as indicated by a correlation coefficient of 0.35, root means square error (RMSE) of 43.37 mm/day, and means bias error (MBE) of –28.73 mm/day. GSMaP generally underestimated extreme precipitation events. The GEVr distribution parameters exhibited poor correlation between ground stations and GSMaP across all parameters, with correlation coefficients of –0.07, 0.04, and –0.21 for location-, scale-, and shape-parameters, respectively.

The GSMaP GEVr parameters were corrected using modeled correction factors. Correlation coefficients improved for all parameters: location (0.8), scale (0.55), and shape (0.52). Location parameter achieved the highest correlation coefficient, while the shape parameter showed the poorest performance. In some areas, shape parameter values showed opposite sign (positive and negative) between ground stations and GSMaP. This discrepancy highlights the challenge of accurately modelling the shape parameter. The limited record length of precipitation data and uneven spatial distribution of ground stations also become a limitation in this study.

Return levels were estimated using corrected-GSMaP GEVr parameters for 10-, 25-, 50-, and 100-year return periods. Prior to correction, original GSMaP exhibited low performance with correlation coefficients below 0.1, RMSE ranging from 65 – 94 mm/day, MBE more than -50 mm/day, FSE more than 0.39 and NSE less than -4 across all return periods. The model demonstrated robust performance across all evaluation metrics: correlation coefficients (0.74-0.79), RMSE (15.38-27.86 mm/day), MBE (0.001 to -1.52 mm/day), FSE (0.09-0.12), and NSE (0.54-0.62). This correction methodology efficiently enhanced the original GSMaP performance. On the maps of return levels, extreme precipitation was predominantly concentrated in the central region and southwestern coastal areas. The model demonstrated accuracy in both magnitude estimation and spatial representation of extreme precipitation patterns.

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References

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