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Impact of topographic data resolution on spatial interpolation of hourly rainfall splines for flood inundation modelling

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Abstract: High-quality rainfall data are essential for climate and hydrology studies, particularly for detailed flood modelling, but are difficult to obtain due to scarce sub-daily records and the sparse distribution of stations. In the process of generating high spatial-temporal rainfall data for flood inundation modelling in a fast-response catchment (Nguyen et al., 2024), we investigated the impact of elevation data resolution on the accuracy of hourly rainfall surfaces generated using thin-plate spline interpolation. The hourly rainfall splines were generated using ANUSPLIN version 4.4 (Hutchinson and Xu, 2004). The method is used to represent rainfall patterns and amounts from 2007 to 2022 in the Richmond River catchment in New South Wales, Australia. The catchment area is approximately 7025 km².

Compared to daily or monthly data, the hourly data contains significantly more zeros, which can increase the instability of the interpolation model. Performance of the interpolation was enhanced by using a stable spatial occurrence analysis to reliably remove false zeroes from the data. About 0.26% of the data were found to be false zeroes in the hourly gauged measurements.

A 1 km DEM derived from the 5 m LiDAR DEM (Geoscience Australia) using average resampling was used to define the boundary of the rainfall surfaces in the ANUSPLIN package. A set of 1 km resolution smoothed DEMs was prepared by calculating the focal mean with distances from 2 to 10 km to investigate the impacts of topographic smoothing on the rainfall surfaces. The independent variable for the transformation of the DEM is h/a, where h [m] is the elevation value and a is the transformation parameter. The usual recommended a value for interpolating monthly and daily data is 1000. In this analysis for hourly splines, a was calibrated in the range from 1000 to 10,000. The days of hourly rainfall data were categorised into two groups, including 3379 light rain days (days with average hourly rainfall between 0 and 1 mmh^{-1}) and 111 medium to high rainfall days (days with average hourly rainfall exceeding 1 mmh^{-1}). The days with zero rainfall across the whole data network were omitted from the calibration. We also tested the performance of the interpolation model using bivariate (without the elevation variable) and trivariate (with the elevation variable) analyses.

The light rainfall days indicate varying dependences on the topographic parameters, with an optimum DEM focal distance around 10 km or possibly larger. The elevation data has greater impacts for high rainfall days and results in the clear optimal values for the DEM transformation parameter around 4000 and the smoothing distance around 5 km. The optimal DEM focal distance of 5 km showed that similarly averaged DEMs with focal distances from 5 to 10 km performed best in interpolating monthly rainfall across Australia, consistent with the analysis of Sharples et al. (2005). The DEM transformation parameter for hourly data is 4 times higher than the one suggested for daily and monthly data, which suggests that hourly rainfall, though significantly influenced by elevation, has a less consistent dependence on elevation than rainfall values recorded at longer time scales.

The evaluation showed that the 1 km hourly rainfall dataset is strongly correlated with point measurements at both hourly and daily scales (correlation coefficients of 0.949 and 0.935, respectively). Compared with other widely used gridded datasets in Australia, the hourly rainfall dataset demonstrated superior performance for capturing the flood dynamics during extreme events, highlighting its potential for generating high-resolution hourly rainfall data at a continental scale.

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