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Influence of rain gauge network density on flood model prediction: a statistical investigation using synthetic rainfall fields on basins of different size and a comparison with a real case

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The accuracy of simulation of the catchment hydrologic response is strongly affected by the reliable representation of the spatial rainfall pattern. The present work investigates the role of rainfall sampling and network density on the performance of a lumped and a distributed rainfall-runoff model in predicting extreme floods. The analysis is conducted on a suite of 12 basins of different size ranging from 15 to 1793 km2 , located in Sardinia, Italy.
In order to create a reference framework uncorrupted by errors of measure and of modelling, we assume as reference precipitation an high resolution rainfall field (1.5 km x 1.5 km x 5 min, 80 years long) derived through a downscaling procedure, and as reference discharge the corresponding hydrograph obtained by the two rainfall-runoff models. In order to investigate the sensitivity of the hydrological response to the rain gauge network density we assume that a rainfall series from a single cell (1.5 km x 1.5 km) is equivalent to a potential fictitious rain gauge record and consequently we activate a number of potential gauges ranging from 1 up to 30 (for each considered basin). Then for each fixed network size, we randomly select 100 independent spatial combinations of rain gauge positions providing the rainfall pattern scenarios which are used as input of the two rainfall-runoff models to produce an ensemble of 100 corresponding discharge scenarios.

Performances are evaluated by comparing the discharge scenarios (obtained by a limited number of potential rain gauges) with the reference discharge (obtained by the entire high resolution rainfall fields) and applying different metrics. A critical analysis of the advantage of using distributed vs lumped modelling is performed considering: model performance variability related to the number of rain gauges; model performance dependence on event magnitude; minimum number of rain gauges for a satisfying model performance and its relationship with event magnitude; dependence on the basin size.
Finally we analyse the real case of 2 small basins with a good record of hydrometric and high temporal resolution (5 min) pluviometric observations. Specifically we evaluate the performances by comparing the observed runoff with the hydrographic response produced by the rainfall-runoff models and considering as active a different number of rain gauges. Although this analysis is limited to a maximum of three rain gauges, it confirms the results obtained in the synthetic framework described above.