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Joint probability and conditional probability of flooding in complex systems

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Understanding flood risk for complex systems such as traffic networks is complicated by the inherent spatial and temporal dependences of the flood-producing rainfall, which can lead to widespread floods throughout the network in one year, and intense localised events affecting only part of the network in another year. Furthermore, a flood 'event' is determined by the unique operating characteristics of the system; for example, an 'event' may occur in an elongated road network when only a single part of the network (e.g. a bridge) is inundated, rendering the entire network inoperable for the duration of the bridge outage. Alternatively, in designing evacuation routes the interest is often understanding the risk of part of the network failing given that another region is flooded or exceeds the level at which evacuation becomes necessary.

Addressing the above problems requires an understanding not only of the spatial dependencies of flood-producing rainfall, but also the dependencies across storm burst duration, given that different parts of the network may be vulnerable to different critical duration storm events. The aim of this research is therefore to demonstrate a new framework to simulate design flood characteristics across a complex network. The framework uses a new inverted max-stable modelling framework to simulate extreme rainfall for a complex network system, taking into account the dependence characteristics of extreme rainfall across both space and duration. This is followed by an event-based rainfall-runoff modelling approach to simulate catchment flows at relevant points in the spatial domain.

The framework is applied on a case study region located along east coast of Australia, where a highway traverses a series of coastal foothills and floodplains for a total length of approximately 20km. Four bridge crossings are simulated along this reach, with each crossing having a contributing catchment area with different time of concentration. The study was supported by data from seven sub-daily stations were with 35 years of record in common for the whole region. The application of the model is designed to address two related questions: (i) What is the probability that the network fails given that each bridge is designed to a specific exceedance probability event (e.g. the 1% annual exceedance probability event); and (ii) given the cost curves for design of each bridge, what is the least cost solution so that the entire network has specified failure probability. Resolution of the above problems enables a very different paradigm to design flood risk estimation, which focuses attention on the risk of the entire system rather than considering individual system elements in isolation.