Imperial College London

Natural Environment Research Council

2024_12_Civil_CO: Spatial-temporal modelling of rainfall fields for hydrological applications in a changing climate

Supervisors: Dr Christian Onof (mailto:c.onof@imperial.ac.uk); Athanios Paschalis

Department: Department of Civil and Environmental Engineering

The complexity of precipitation in space and time covering catchments of various sizes makes it difficult to simulate extreme, but realistic, flood events (e.g. the hydraulic interaction from pluvial and fluvial sources and their interaction with drainage-network-overflow). Since such estimates are required for the effective implementation of flood mitigation measures, it is critical to be able to integrate this complex precipitation variability into flood estimation, and flood risk analysis, thereby improving upon existing methods. The latter unrealistically assume spatially uniform rainfall, i.e. so-called “blanket rainfall”. In this project, we propose to build upon the spatial-temporal stochastic rainfall models developed in our research group to enable spatial variability to be represented as it varies over time (Chen et al. 2021).

The project will address three research questions. First, it will quantify how complexity in spatiotemporal rainfall dynamics impacts flood generation in both natural and urban catchments; for this purpose, we shall consider both virtual and real UK catchments. This will enable us to address the reliability of current flood mitigation and engineering practices in the UK, by estimating the amount by which proposed flood retention basins/storages, including natural flood management measures, are likely to be overdesigned, or undervalued when using blanket rainfall rather than stochastically generated spatial rainfall fields.

Second, we will develop a novel methodology for flood risk design in a changing climate, incorporating the spatiotemporal dynamics of rainfall and their uncertainty by combining the strengths of stochastic modelling with state-of-the-art climate modelling at convection permitting scales. While the climate models provide us with estimates of future precipitation fields, these are of limited length and do not enable the full natural variability to be represented. These problems will be overcome by calibrating our stochastic methodology to the projections from these models.

Third, we will address the question of how this methodology can be made more user-friendly, i.e. by proposing heuristics enabling the selection of critical rainfall events among the long series of simulated rainfall fields which this methodology generates, e.g. taking into account flooding hotspots. This will amount to proposing a replacement of the traditional design storm approach which is still by far the preferred design tool in practice. The new approach will require the processing of several storms but not be as computationally prohibitive as processing long series of stochastically generated rainfall fields.

Reference:

Chen, Y., Paschalis, A., Wang, L-P., & Onof, C. (2021) Can we estimate flood frequency with point-process spatial-temporal rainfall models?, Journal of Hydrology, 600, 126667 (https://doi.org/10.1016/j.jhydrol.2021.126667).