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High-resolution urban flood modelling - a joint probability approach

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The hydrodynamic modelling of rapid flood events due to extreme climatic events in urban environment is both a complex and challenging task. The horizontal resolution necessary to resolve complexity of urban flood dynamics is a critical issue; the presence of obstacles of varying shapes and length scales, gaps between buildings and the complex geometry of the city such as slopes affect flow paths and flood levels magnitudes. These small scale processes require a high resolution grid to be modelled accurately (2m or less, Olbert et al., 2015; Hunter et al., 2008; Brown et al., 2007) and, therefore, altimetry data of at least the same resolution. Along with availability of high-resolution LiDAR data and computational capabilities, as well as state of the art nested modelling approaches, these problems can now be overcome.

Flooding and drying, domain definition, frictional resistance and boundary descriptions are all important issues to be addressed when modelling urban flooding. In recent years, the number of urban flood models dramatically increased giving a good insight into various modelling problems and solutions (Mark et al., 2004; Mason et al., 2007; Fewtrell et al., 2008; Shubert et al., 2008). Despite extensive modelling work conducted for fluvial (e.g. Mignot et al., 2006; Hunter et al., 2008; Yu and Lane, 2006) and coastal mechanisms of flooding (e.g. Gallien et al., 2011; Yang et al., 2012), the amount of investigations into combined coastal-fluvial flooding is still very limited (e.g. Orton et al., 2012; Lian et al., 2013). This is surprising giving the extent of flood consequences when both mechanisms occur simultaneously, which usually happens when they are driven by one process such as a storm. The reason for that could be the fact that the likelihood of joint event is much smaller than those of any of the two contributors occurring individually, because for fast moving storms the rainfall-driven fluvial flood arrives usually later than the storm surge (Divoky et al., 2005). Nevertheless, such events occur and in Ireland alone there are several cases of serious damage due to flooding resulting from a combination of high sea water levels and river flows driven by the same meteorological conditions (e.g. Olbert et al. 2015). A November 2009 fluvial-coastal flooding of Cork City bringing €00m loss was one such incident. This event was used by Olbert et al. (2015) to determine processes controlling urban flooding and is further explored in this study to elaborate on coastal and fluvial flood mechanisms and their roles in controlling water levels.

The objective of this research is to develop a methodology to assess combined effect of multiple source flooding on flood probability and severity in urban areas and to establish a set of conditions that dictate urban flooding due to extreme climatic events. These conditions broadly combine physical flood drivers (such as coastal and fluvial processes), their mechanisms and thresholds defining flood severity. The two main physical processes controlling urban flooding: high sea water levels (coastal flooding) and high river flows (fluvial flooding), and their threshold values for which flood is likely to occur, are considered in this study.

Contribution of coastal and fluvial drivers to flooding and their impacts are assessed in a two-step process. The first step involves frequency analysis and extreme value statistical modelling of storm surges, tides and river flows and ultimately the application of joint probability method to estimate joint exceedence return periods for combination of surges, tide and river flows. In the second step, a numerical model of Cork Harbour MSN_Flood comprising a cascade of four nested high-resolution models is used to perform simulation of flood inundation under numerous hypothetical coastal and fluvial flood scenarios. The risk of flooding is quantified based on a range of physical aspects such as the extent and depth of inundation (Apel et al., 2008)

The methodology includes estimates of flood probabilities due to coastal- and fluvial-driven processes occurring individually or jointly, mechanisms of flooding and their impacts on urban environment. Various flood scenarios are examined in order to demonstrate that this methodology is necessary to quantify the important physical processes in coastal flood predictions. Cork City, located on the south of Ireland subject to frequent coastal-fluvial flooding, is used as a study case.