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Evaluating the anthropogenic impacts on fluvial flood risks in a coastal mega-city during its transitional economy (1979-2009): the interaction between land subsidence, urbanization and structural measures

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Flood risk in a specific geographical location is a function of the interaction between various natural (e.g. rainfall, sea-level rise) and anthropogenic processes (e.g. land subsidence and urbanization). These processes, whether a driver or an alleviating factor, often encompass a large degree of spatial and temporal variability. Looking at a specific process in isolation is likely to provide an incomplete picture of the risks. This paper describes a novel approach to the evaluation of anthropogenic impacts on flood risks in coastal mega-cities by incorporating three anthropogenic variables (land subsidence, urbanization and flood defence) within a scenario-based framework where numerical modelling was undertaken to quantify the risks. The evolving risks at four time points (1979, 1990, 2000 and 2009) were assessed for the Huangpu River floodplain where the City of Shanghai is located. Distributed data of land subsidence rate, urbanization rate and flood defence heights were obtained. Scenarios were designed by representing the rate of land subsidence and flood defence height through the modification of DEM. Effect of urbanization is represented by a roughness parameter in the model simulations. A 2D hydrodynamic model (FloodMap-Inertial) was used to estimate the flood risks associated with each scenario. Flood events with various return periods (10-, 100- and 1000-year) were designed based on a one in 50 year flood event occurred in Shanghai in August 1997.

Results demonstrate the individual as well as the combined impacts of the three anthropogenic factors on the changing fluvial flood risks in the Huangpu River basin over the last three decades during the city's transitional economy (1979-2009). Land subsidence and urbanization were found to lead to proportionate but non-linear impact on flood risks due to their complex spatial and temporal interaction. The impacts and their sensitivity are the function of the rate & spatial distribution of each evolving factor. They also manifest differently in floods of different magnitude. While the pattern of response to individual anthropogenic variables is largely expected, the combined impacts demonstrate greater spatial and temporal variation. Flood defences offer considerable benefits in reducing the total inundated areas in the Huangpu River basin over the periods considered, for all magnitude floods. This, to a large extent, alleviates the adverse impacts arising from land subsidence and urbanization. However, even with an enclosed and completed defence system in 2009, extensive flood inundation is still expected for a 10-year event, albeit largely restricted to the upstream of the river where urban settlements are limited.

The scenario-based approach described herein could be adopted for applications in other urbanized and subsided coastal floodplains, especially in places where the rate of land subsidence is still accelerating, urbanization is still undergoing and the local sea level keeps rising. Risk scenarios that encompass probable future anthropogenic projections may assist decision makers and other concerned stakeholders in better understanding the underlying drivers of changing flood risks, and thus help to design proper adaptation options for sustainable flood risk management and urban planning.