EGU2020-22494
https://doi.org/10.5194/egusphere-egu2020-22494
EGU General Assembly 2020

Interactions of extreme river flows and sea levels for coastal flooding

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Coastal flooding worldwide causes the vast majority of natural disasters; for the UK costing £2.2 billion/year. Fluvial and surge-tide extremes can occur synchronously resulting in combination flooding hazards in estuaries, intensifying the flood risk beyond fluvial-only or surge-only events. Worse, this flood risk has the potential to increase further in the future as the frequency and/or intensity of these drivers change, combined with projected sea-level rise. Yet, the sensitivity of contrasting estuaries to combination and compound flooding hazards at sub-daily scales – now and in the future – is unclear. Here, we investigate the dependence between fluvial and surge interactions at sub-daily scales for contrasting catchment and estuary types (Humber vs. Dyfi, UK), using 50+ years of data: 15-min fluvial flows and hourly sea levels. Additionally, we simulate intra-estuary (<50 m resolution) sensitivities to combination flooding hazards based on: (1) realistic extreme events (worst-on-record); (2) realistic events with shifted timings of the drivers to maximise flooding; and (3) modified drivers representing projected climate change.

For well-documented flooding events, we show significant correlation between skew surge and peak fluvial flow, for the Dyfi (small catchment and estuary with a fast fluvial response on the west coast of Britain), with a higher dependence during autumn/winter months. In contrast, we show no dependence for the Humber (large catchment and estuary with a slow fluvial response on the east coast of Britain). Cross-correlation results, however, did show correlation with a time lag (~10 hours). For the Dyfi, flood extent was sensitive to the relative timing of the fluvial and surge-tide drivers. In contrast, the relative timing of these drivers did not affect flooding in the Humber. However, extreme fluvial flows in the Humber actually reduced water levels in the outer estuary, compared with a surge-only event. Projected future changes in these drivers by 2100 are likely to increase combination flooding hazards: sea-level rise scenarios predicted substantial and widespread flooding in both estuaries. However, similar increases in storm surge resulted in a greater seawater influx, altering the character of the flooding. Projected changes in fluvial volumes were the weakest driver of estuarine flooding. On the west coast of Britain containing many small/steep catchments, combination flooding hazards from fluvial and surges extremes occurring together is likely. Moreover, high-resolution data and hydrodynamic modelling are necessary to resolve the impact and inform flood mitigation methodology.

How to cite: Robins, P., Harrison, L., Elnahrawi, M., Lewis, M., Coulthard, T., and Coxon, G.: Interactions of extreme river flows and sea levels for coastal flooding, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-22494, https://doi.org/10.5194/egusphere-egu2020-22494, 2020