Geophysical Research Abstracts
Vol. 21, EGU2019-382, 2019
EGU General Assembly 2019

Increased coastal wave hazard generated by differential wind and wave direction in hyper-tidal estuaries

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Wave overtopping and subsequent coastal flood hazard is strongly controlled by wind and water levels, and is especially critical in hyper-tidal estuaries where even small changes in wave heights can be catastrophic if they are concurrent with high spring tide. Wave overtopping imposes serious hazard in heavily populated and industrialized hyper-tidal estuaries, where infrastructure, transport networks and natural resources may be located. Wave hazard in estuaries is largely attributed to high amplitude shorter period, locally generated wind waves; while low amplitude longer period waves rarely impact low-lying coastal zones up-estuary. The effect of wind and wave properties on up-estuary wave propagation and the sensitivity of significant wave height are investigated numerically along the shoreline of the Severn Estuary, southwest England, as an example of hyper-tidal estuaries worldwide. Delft3D-WAVE is used to simulate significant wave height with representative values for wind speed and direction, wave height, period and direction used to identify key combinations of factors that define the wave hazard generation in the Severn Estuary. The model confirms high amplitude, short period wind waves are sensitive to opposing winds, with a steepening effect that varies along the estuary shoreline, highlighting the effect of estuarine geometry on wave hazard. Low amplitude, long period wind waves respond with greatest variability in significant wave height to strong winds resulting in their propagation further up-estuary. Our results advance current understanding of the compound interaction between wind and waves, and identify critical conditions maximizing the hazard and hazard variability along the shoreline. The outcomes from this research can help to avoid economic losses from operational downtime in ports and harbours, inform sustainable coastal sea defence design and understand how wave hazard may vary under future climate due to changing storm tracks. Results can also long-term coastal defence and management strategies, as sustainable coastal management requires confidence in the knowledge of any possible future changes to wave hazard.