Imperial College London

Natural Environment Research Council

2024_33_ESE_MP: Using Advanced Multi-Scale Numerics and Machine Learning to Assess Coastal Flood Risk

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This project will consider the combination of advanced numerical methods able to resolve a very wide range of spatial scales and complex geometries, machine learning based surrogate modelling, data science analysis of large data sets in order to provide accurate, efficient and robust assessments of coastal flood risk. Flooding due to storm surge as well as tsunami events will be considered under sea level rise scenarios and a changing climate that may lead to more frequent and extreme storms.

Through collaboration with the insurance sector this project will have access to real-world case studies, to insured risk databases facilitating so-called catastrophe (CAT) modelling, to large data sets describing potential future extreme atmospheric events, and a route to provide industrial impact.

The advanced numerical methods aspects of the work will focus on the use of coastal ocean modelling software that utilises adaptive and unstructured grids to allow for the accurate inclusion of estuaries and similar smaller scale geographical features within inundation models. As well as these novel multi-scale modelling capabilities, our modelling framework has been developed in a way that allows adjoint-based sensitivity information to be efficiently calculated. In collaboration with the UK's Flood Forecasting Centre, recent work within the host research group has used this technology to improve the uncertain bed friction field used in the UK's operational storm surge model, thus improving its predictive accuracy. Through this link the student on this project will therefore additionally have access to the software underlying the UK's current operational flood risk model and associated forcing fields and case studies with a UK focus. As well as enhanced model calibration, the use of adjoint methods will be used to efficiently calculate risks and uncertainties.

Machine learning and (big) data science techniques will be considered in order to (1) help identify those storm surge or tsunami source conditions that should be explicitly simulated, (2) automate the analysis of remote sensing data to calculate time series of flood events and to construct building fragility curves, (3) provide corrections to process based models to account for the presence of key under-resolved features such as hard and soft flood defence structures, and (4) to provide rapid surrogates to complement the use of costly adjoint methods for risk and uncertainty calculations.

In summary, the project will provide training in a range of cutting-edge flood modelling methodologies, probabilistic hazard assessments, uncertainty quantification and machine learning techniques to extend the state of the art in coastal flood risk, and to apply these to a number of real world case studies. Science applications will focus on understanding how risk changes under sea level rise and a changing climate, and how these changes may be region and local flood-defence design dependent.