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Challenges of Modeling Flood Risk at Large Scales

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Flood risk management is a major concern for many nations and for the insurance sector in places where this peril is insured. A prerequisite for risk management, whether in the public sector or in the private sector is an accurate estimation of the risk. Mitigation measures and traditional flood management techniques are most successful when the problem is viewed at a large regional scale such that all inter-dependencies in a river network are well understood. From an insurance perspective the jury is still out there on whether flood is an insurable peril. However, with advances in modeling techniques and computer power it is possible to develop models that allow proper risk quantification at the scale suitable for a viable insurance market for flood peril. In order to serve the insurance market a model has to be event-simulation based and has to provide financial risk estimation that forms the basis for risk pricing, risk transfer and risk management at all levels of insurance industry at large. In short, for a collection of properties, henceforth referred to as a portfolio, the critical output of the model is an annual probability distribution of economic losses from a single flood occurrence (flood event) or from an aggregation of all events in any given year.

In this paper, the challenges of developing such a model are discussed in the context of Great Britain for which a model has been developed. The model comprises of several, physically motivated components so that the primary attributes of the phenomenon are accounted for. The first component, the rainfall generator simulates a continuous series of rainfall events in space and time over thousands of years, which are physically realistic while maintaining the statistical properties of rainfall at all locations over the model domain. A physically based runoff generation module feeds all the rivers in Great Britain, whose total length of stream links amounts to about 60,000 km. A dynamical flow routing algorithm propagates the flows for each simulated event. The model incorporates a digital terrain model (DTM) at 10m horizontal resolution, which is used to extract flood plain cross-sections such that a one-dimensional hydraulic model can be used to estimate extent and elevation of flooding. In doing so the effect of flood defenses in mitigating floods are accounted for. Finally a suite of vulnerability relationships have been developed to estimate flood losses for a portfolio of properties that are exposed to flood hazard. Historical experience indicates that a for recent floods in Great Britain more than 50% of insurance claims occur outside the flood plain and these are primarily a result of excess surface flow, hillside flooding, flooding due to inadequate drainage. A sub-component of the model addresses this issue by considering several parameters that best explain the variability of claims off the flood plain.

The challenges of modeling such a complex phenomenon at a large scale largely dictate the choice of modeling approaches that need to be adopted for each of these model components. While detailed numerically-based physical models exist and have been used for conducting flood hazard studies, they are generally restricted to small geographic regions. In a probabilistic risk estimation framework like our current model, a blend of deterministic and statistical techniques have to be employed such that each model component is independent, physically sound and is able to maintain the statistical properties of observed historical data. This is particularly important because of the highly non-linear behavior of the flooding process. With respect to vulnerability modeling, both on and off the flood plain, the challenges include the appropriate scaling of a damage relationship when applied to a portfolio of properties. This arises from the fact that the estimated hazard parameter used for damage assessment, namely maximum flood depth has considerable uncertainty. The uncertainty can be attributed to various sources among which are imperfections in the hazard modeling, inherent errors in the DTM, lack of accurate information on the properties that are being analyzed, imperfections in the vulnerability relationships, inability of the model to account for local mitigation measures that are usually undertaken when a real event is unfolding and lack of details in the claims data that are used for model calibration. Nevertheless, the model once calibrated provides a very robust framework for analyzing relative and absolute risk. The paper concludes with key economic statistics of flood risk for Great Britain as a whole including certain large loss-causing scenarios affecting the greater London region. The model estimates a total financial loss of 5.6 billion GBP to all properties at a 1% annual aggregate exceedance probability level.