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Probabilistic reanalysis of storm surge extremes in Europe

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Extreme sea levels are a significant threat to life, property, and the environment. These threats are managed by coastal planers through the implementation of risk mitigation strategies. Central to such strategies is knowledge of extreme event probabilities. Typically, these probabilities are estimated by fitting a suitable distribution to the observed extreme data. Estimates, however, are often uncertain due to the small number of extreme events in the tide gauge record and are only available at gauged locations. This restricts our ability to implement cost-effective mitigation. A remarkable fact about sea-level extremes is the existence of spatial dependences, yet the vast majority of studies to date have analyzed extremes on a site-by-site basis. Here we demonstrate that spatial dependences can be exploited to address the limitations posed by the spatiotemporal sparseness of the observational record. We achieve this by pooling all the tide gauge data together through a Bayesian hierarchical model that describes how the distribution of surge extremes varies in time and space. Our new approach has two highly desirable advantages: 1) it enables sharing of information across data sites, with a consequent drastic reduction in estimation uncertainty; 2) it permits interpolation of both the extreme values and the extreme distribution parameters at any arbitrary ungauged location. Using our model, we produce the first, to our knowledge, observation-based probabilistic reanalysis of surge extremes covering the entire Atlantic and North Sea coasts of Europe for the period 1960-2013.