EGU21-7826, updated on 28 Oct 2021
https://doi.org/10.5194/egusphere-egu21-7826
EGU General Assembly 2021

Bayesian Hierarchical Modeling of Sea Level Extremes on the Finnish Coast

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Coastal cities are going through rapid and challenging changes. Accurate estimates of probabilities of extreme sea levels are a highly valuable asset to face flooding hazards and support safe planning of coastal zones in the future climate. Probabilities of specific extreme events have been traditionally estimated from the observed extremes independently at each tide gauge location. However, this approach has shortcomings. Firstly, sea level observations often cover a relatively short historical time period and thus contain only a small number of extreme cases (e.g. annual maxima). This causes substantial uncertainties when estimating the distribution parameters. Secondly, exact information on sea level extremes between the tide gauge locations and incorporation of dependencies of adjacent stations is often lacking in the analysis.

One way to partially tackle these issues is to exploit spatial dependencies exhibited by the sea level extremes. These dependencies emerge from the fact that sea level variations are often driven by the same physical and dynamical factors at the neighboring stations. Bayesian hierarchical modeling offers a way to model these dependencies. The model structure allows to share information on sea level extremes between the neighboring stations and also provides a natural way to represent modeling uncertainties.

In this study, we use Bayesian hierarchical modeling to estimate return levels of annual sea level maximum on the Finnish coast, located in the northeast parts of the Baltic Sea. As annual maxima are studied, we use the generalized extreme value (GEV) distribution as the basis of our model. To tailor the model specifically for the target region, spatial dependencies are modeled using covariates, which reflect the distinct geometry of the Baltic Sea. We also account for inter-annual and decadal-scale variations in the distribution parameters by including teleconnection indices such as North Atlantic oscillation (NAO) in our model. Preliminary results show that hierarchical modeling provides added value in comparison to the traditional approach, when applied to the available long-term tidegauge time series in Finland. The work presented here is a part of project PREDICT (Predicting extreme weather and sea level for nuclear power plant safety) that supports nuclear power plant safety in Finland.