EGU21-6266
https://doi.org/10.5194/egusphere-egu21-6266
EGU General Assembly 2021

A Budyko-like framework for exploring the controls of long-term flood risk in coupled human-flood systems

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Long term dynamics in human-flood systems differ due to differences in hydrological and societal characteristics. By contrasting and comparing different human-flood systems we increase our understanding of which characteristics lead to which dynamics, which might help to counteract unfavorable developments. We propose a framework for comparing human-flood systems analogous to the Budyko one for traditional catchment hydrology. While in the Budyko framework catchments are classified as either water limited or energy limited, in the framework proposed here the human-flood systems are classified as either hydrology limited or exposure limited. In analogy to the precipitation, potential evapotranspiration and actual evapotranspiration components of the Budyko space we formulate the components of the "flood risk space" as hydrological potential loss, manmade potential loss and actual flood loss. The framework is applied to four stylised theoretical systems, investigating how their position in the flood risk space may change under the influence of hydrological, technical and demographic changes. Results show that hydrological changes have the largest effect on a system's position in the flood risk space: with an increasing skewness and CV systems become more hydrology limited. The framework's value for comparing empirical case studies is demonstrated through an application to two case studies in Germany: Dresden on the Elbe and Cologne on the Rhine. The framework allows us to identify the differences in dynamics between the two case studies, as they are located in different areas of the flood risk space. The difference in dynamics between the Dresden and Cologne systems seems to be mostly caused by the hydrological parameters (i.e. the skewness) rather than the social parameters. The flood frequency distribution is more skewed in the case of the Elbe in Dresden than in the case of the Rhine in Cologne. Therefore, Dresden experiences more shocks to the system (i.e. unexpectedly large floods) than Cologne.