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Climatic changes of extreme precipitation in Denmark from 1874 to 2100

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During the past 30 years rather dramatic changes in extreme precipitation have been observed in Denmark. These changes are mainly in the frequency of extreme events, but there is also a tendency towards more severe events. Both are considered effects of anthropogenic climate change. The increase in precipitation extremes has led to inundations in most of the larger cities during the last 10 years. The flood in Copenhagen in 2011 implied the second highest damage costs measured in Denmark during the last 100 years. To establish cities that are resilient to pluvial floods robust projections of the frequency and intensity of extreme precipitation events in a changing climate are needed. Additionally, it is equally important to understand the natural variation on which the anthropogenic changes are imposed. This study presents the results of a coordinated effort to estimate the changes and uncertainties in Danish design rainfall.

Trends and oscillations are identified in five daily precipitation records from 1874 to present, 83 records from high-resolution rain-gauges from 1979 to present and 18 state-of-the-art climate model simulations. It is shown that the frequency of extreme events in the past has oscillated with a cycle of 25-35 years, a behavior that can in part be explained by sea level pressure differences over the Atlantic. Projections based on the historical observations suggest that precipitation extremes in the Eastern part of Denmark should have been ascending in the last two decades. However, the increase has continued longer than expected and with larger amplitude in the most recent years. This indicates a likely influence from anthropogenic greenhouse gas emissions. With the complex combination of general increase and natural variation several additional years of observation are needed before this hypothesis can be evaluated by statistical means.

Extensive analysis of 18 different regional climate model (RCM) simulations shows that anthropogenic activity will very likely contribute to a significant increase in extreme precipitation amount and occurrence in Denmark. It is argued that climate models are incapable of simulating extreme precipitation at the temporal scales relevant for evaluation of the urban pluvial inundation risk. Hence statistical downscaling methods have been applied. Furthermore, the effect of the emission scenario, the spatial resolution of the RCM and the interdependency between RCMS are discussed. Accounting for the uncertainty introduced by these factors a 10-year event is expected to increase by 30% over a projection period of 100 years. This is less than the variation within one natural oscillation cycle, indicating that it is crucial to understand and account for the future multi-decadal variations of extreme precipitation.