



## **Expected future changes in the joint distribution of storm surges and waves in the North Sea due to anthropogenic climate change**

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Storms and related marine hazards represent a major environmental threat. Long-term changes in wind, wave and storm surge conditions of the North Sea may occur as a possible consequence of global warming. This could have significant impacts on the coasts and on human activities. For the expected course of anthropogenic climate change, the joint effects of changes in wind-induced water levels and wave heights are investigated in the North Sea. An ensemble of four transient climate projections (1961-2100), reflecting two scenarios of future emissions (IPCC A1B and B1) and two different initial states was used to simulate the water level and wave scenarios. The potential changes in storm surges and wave heights are studied by comparing future statistics (2001-2100) with the corresponding reference conditions (1961-2000).

The climate change signals for both storm surge and wave height extremes show temporal and spatial differences in magnitude and patterns within and between the four climate projections. Superimposed there appears to be an increase of severe conditions in some regions towards the end of the 21st century which is relatively small compared to the decadal variability. Changes in severe storm surge conditions differ in detail temporally and spatially from changes in severe wave conditions. For coastal infrastructure especially the synchronous occurrence of severe waves and surges is crucial. Hence, we focus here on the joint frequency distribution of storm surge and wave heights and on the duration of the synchronous occurrence of extremes. Temporal and spatial differences of this distribution will be discussed for selected areas of the North Sea. For an area off the outer Elbe estuary (German Bight) and for the period 2071-2100 compared to 1961-1990, for example, the increase of the synchronous occurrence can be about 10% higher than the increase of the individual occurrence of severe surges or waves. Altogether this study provides information for further climate change impact estimates in coastal areas and corresponding risk assessment.