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Kiel Canal: Past and future threats for shipping resulting from precipitation, wind surge and sea level rise

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The Kiel Canal is the most frequented artificial waterway in the world. It connects the North Sea and the Hamburg Harbor with the Baltic Sea and has a length of about 100 km. The Canal receives its water from the upper catchment of the river Eider. Discharge from the Canal towards the North Sea is via the sluices at Brunsbüttel (90%) into river Elbe and into the Baltic Sea via the sluices at Kiel-Holtenau. A risk of closure of the Canal occurs when high precipitation in the catchment meets high water levels in the river Elbe and/or the Baltic preventing the discharge of excess Canal water. Future sea level rise jointly with other effects such as possibly increasing wind surge and precipitation will close the gap between the inner and outer water levels, so that someday the outside levels will surmount the inner one. The German Federal Ministry of Transport and Digital Infrastructure (BMVI) tasked its internal Network of Experts to run a case study on the evolution of critical water levels in order to estimate risks and vulnerabilities for adaptation measures.

First step of the investigation is a search for factors or combination of factors responsible for closures in the past. Candidates are factors such as higher water levels at low tides, high precipitation events on land, soil moisture and human factors like preventive water management measures. Second step will be the search for the natural criteria in climate projections.

Here we report on the results of the first step of the case study with a focus on the exit towards the North Sea. There, discharge is possible only during low tide. Presently still sufficient difference in height exists between the levels in the Canal and the river Elbe allowing for a free flow of excess Canal water. Shipping is ceased when levels in the Canal surpass safety limits due to high precipitation events in the catchment jointly with high outer water levels.

We used atmospheric data from ERA-Interim reanalysis instead of gauge data for reconstructing the history in order to provide metrics that in the second step can be searched in Atmosphere Regional Climate Model runs. Water levels at Brunsbüttel were determined with hourly resolution using atmospheric conditions and astronomical tide. Ocean Model results were and will be excluded because of the small number of runs with astronomical tides and sufficient resolution. Past inflow from the tributary rivers into the Canal was simulated via antecedent and event precipitation derived from the REGNIE data set. Finally, the potential of critical situations in the past was calculated by combining both results and compared their occurrences with the recordings of the responsible waterway authority.

In the second step we will analyze the proxies elaborated in step one in regional climate projections and combine them with expected changes of the sea levels in the North and Baltic Seas.