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Impact of climate change on wave statistics

A case study for the estuary of the river Elbe

Departmental Research Programme

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Introduction

Hydrodynamics in coastal waters and estuaries extend their influence on many ecological and water quality processes. Besides tidal water levels and currents, also sea waves are an essential part of hydrodynamics. Especially waves strongly influence the settlement and remobilisation of sediments over tidal flats as well as the stability of vegetation on forelands. Therefore changes in wave statistics need to be considered for a holistic view of climate change impacts.

Approach

The changes in the statistics of wave parameter, like significant wave height (H_s) and mean wave period (T_{01}) are derived by combining the results of long-term regionalized coupled numerical modeling of atmosphere and ocean (Hein et al. 2013) with short-term numerical modeling of waves. A flow chart of the calculation scheme (Mai et al. 2008) is given in Fig. 1.

The methodology is exemplified here for the estuary of the river Elbe between Cuxhaven and Hamburg.

Short-term wave simulations

For the short-term calculations of wave parameters as a function of water level, wind speed and direction the numerical model SWAN (Booij et. al 1999) is used. The calculations were carried out on a curvilinear computational grid of the topography of the year 2006 with a resolution of approx. 20 m along the river and approx. 2 m across the river (Berkhahn and Mai 2004). An example of the wave field calculated for one of 840 combinations of boundary conditions, i.e. water levels and winds, is given in Fig. 2 The whole set of wave simulations is used to derive transfer functions from water level and wind to wave parameters (Fig. 3).

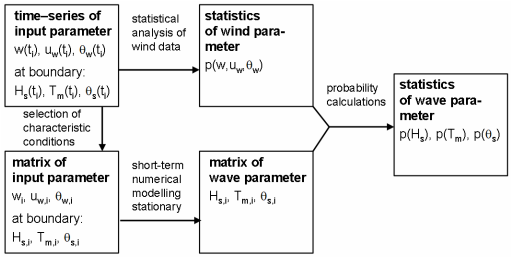

Figure 1: Calculation scheme combining time-series of water level and wind with wave parameters

Long-term model of atmosphere and ocean

Time-series of water level and wind are derived from the global climate run A1B MPI-OM, which was regionalised to the North-Sea with the coupled models HAMSOM/Remo (Pohlmann 2006). Further details are given in Hein et al. (2013). An analysis of the statistics of water level and wind is given for the climate periods 1971-2000, 2021-2050 and 2070-2099 in Fig. 4. To consider multi-decadal fluctuations (Hein et al. 2011) a continuous statistical analysis was also carried out.

Results

The transfer functions from short-term wave modelling are used to calculate time-series of wave parameters from the time-series of water level and wind. An analysis of the statistics of the wave parameters, significant wave height and mean period is given for the climate periods 1980-1999, 2030-2049 and 2080-2099 in Fig. 5. The climate projection of this case study leads to a change in the 90%-tile of wave heights or mean wave periods of less than 5 % near Wischhafen corresponding to the little changes in wind statistics.

References:

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Booij, N., R. C. Ris, and L. H. Holthuijsen (1999), A third-generation wave model for coastal regions: 1. Model description and validation, J. Geophys. Res., 104(C4), 7649–7666.

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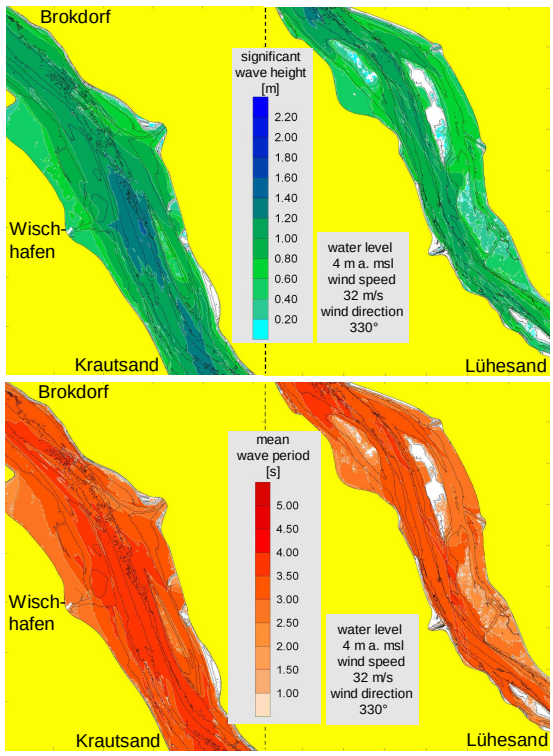

Fig. 2: Wave heights and periods in the river Elbe

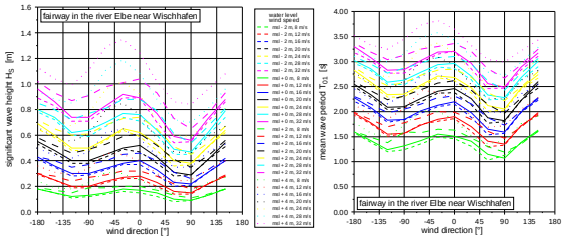

Fig. 3: Transfer functions for wave height and period

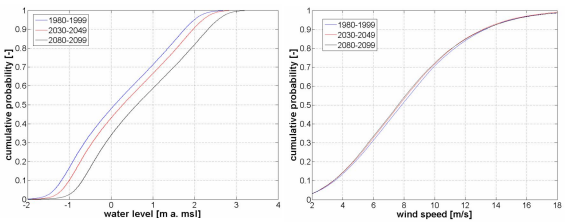

Fig. 4: Statistics of water level and wind

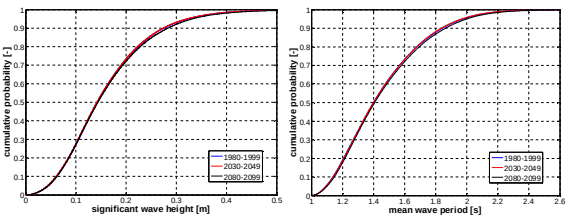

Fig. 5: Statistics of wave height and period

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