EFFECTS OF CLIMATE CHANGE ON COASTAL HYDRODYNAMICS ALONG THE GERMAN BALTIC SEA COAST

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INTRODUCTION

The German federal state of Schleswig-Holstein is developing a Baltic Sea Coast 2100 strategy under the leadership of the Ministry for Energy Transition, Climate Protection, Environment and Nature. The aim of the strategy is a sustainable adaptation of the coastal region to climate change, taking into account the demands of nature conservation, tourism and coastal protection. Basis for this strategy is detailed information on the current status and possible future changes in coastal hydrodynamics and sediment dynamics, including morphological changes.

In a joint research project from 2019 to 2023, the Institute of River and Coastal Engineering of Hamburg University of Technology (TUHH) carried out model-based investigations to describe and analyze currents and transport processes along the entire Baltic Sea coast of Schleswig-Holstein (>400 km) for the current state as well as for possible future conditions, taking into account various scenarios for sea level rise and climate change-induced changes of wind conditions.

APPRAOCH

In order to analyze the current and future local hydrodynamic conditions, a model chain consisting of hydrodynamic-numerical models with different temporal and spatial resolution was developed based on the Telemac-Mascaret suite. A nesting approach based on three hydrodynamic-numerical models that cover the North Sea, Baltic Sea and the study area with a high spatial resolution up to 10 m was applied due to the need to consider large-scale effects that influence the small-scale processes in the study area.

The module "Telemac2d" from the Telemac-Mascaret solver suite is used for the calculation of water levels and currents.

For the hindcast of the current hydrodynamics, the entire model chain is driven by hourly wind and sea level pressure fields from the reanalysis dataset COSMO-REA 6 (Bollmeyer et al., 2015) for a selected time period of one year with representative local wind conditions. In addition, wind data for selected storm events leading to storm surges and/or high wave heights along the coast were used to analyze and evaluate the processes under extreme conditions.

An extended delta approach was used to investigate possible future changes. This approach is based on the fact that the meteorological and hydrodynamic boundary conditions (wind and mean sea level) of the simulations for the hindcast of the current hydrodynamics are adapted on the basis of scenarios for possible future changes in local wind conditions and water levels and are used to drive simulations of future hydrodynamics.

Possible changes in regional mean sea level (RMSL) were derived on the basis of various projections from the 6th Assessment Report of IPCC (Fox-Kemper et al., 2021; Garner et al., 2021). All scenarios used for the hydrodynamic and meteorological changes are based on the results for the forcing with RCP8.5 or SSP5-8.5, as this can be seen as an upper estimate of possible future changes.

A RMSLR of +0.25 m and +0.75 m for the years 2050 and 2100 as well as relative and absolute monthly changes in wind speed and wind direction for average conditions and in wind speed for extreme events were determined for the periods 2050 and 2100 compared to the reference period 1971-2000. The changes of the wind conditions were compiled from detailed evaluations of a subset of high-resolution regional climate projections for RCP8.5 from CORDEX-EUR-11 (Jacob et al., 2020). On this basis, four scenarios were derived for possible future changes in wind conditions and sea level rise.

To derive the changes in future hydrodynamic conditions, extensive numerical simulations were carried which were driven by modified meteorological and hydrodynamic boundary conditions (wind and mean sea level) and compared with the hindcast simulations.

RESULTS

The analysis of the changes in the wind events from westerly wind directions show a tendency towards an increase in wind speed and of changing the wind direction towards more westerly directions at the end of the 21st century 2071-2100 and compared to the reference time period 1971-2100. For wind events from easterly wind directions a tendency towards a decrease in wind speed and changes towards more easterly directions have been found.

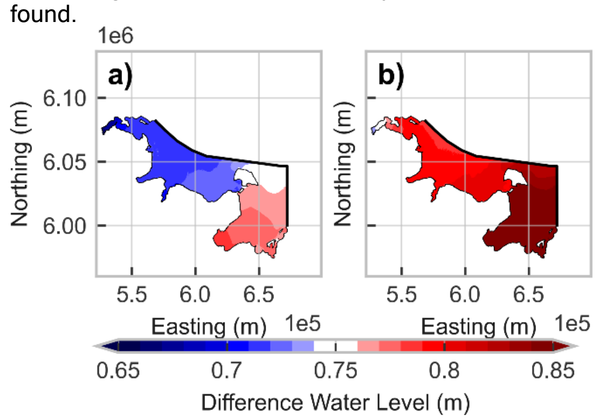

Figure 1 Absolute difference in future local water levels for a selected timestep during a storm event on 2nd January 2019 and for a RMSL of +0.75m, a) without and b) with changes of wind conditions

For higher wind speeds, e.g. the 99.9th percentile of wind speed, both increases respectively decreases have been found for wind events from westerly respectively easterly wind directions during the storm surge season (October to March).

The differences in future local water levels for a RMSLR of +0,75 m are exemplarily shown for a selected timestep during a storm event on 2nd January 2019 in Figure 1 a). As shown in Figure 1 a), the local water levels show lower differences of ca. +/- 0,04 m and compared to the RMSLR, with maximum or minimum values near the coast in the Bay of Lübeck or the Flensburg Firth.

In general, the changes in local water levels and currents are depending both on the RMSLR and the changes in wind conditions, which is exemplarily shown in Figure 1 b) for the same storm event.

In the presentation we will show exemplarily results for the changes in local water levels and currents for both average conditions and extreme events.

REFERENCES

Bollmeyer, C., Keller, J.D., Ohlwein, C., Wahl, S., Crewell, S., Friederichs, P., Hense, A., Keune, J., Kneifel, S., Pscheidt, I., Redl, S., Steinke, S. 2015: Towards a high-resolution regional reanalysis for the European CORDEX domain. Q.J.R. Meteorol. Soc. 141 (686), 1-15.

Fox-Kemper, B., Hewitt, H., Xiao, C., Aðalgeirsdóttir, G., Drijfhout, S.S., Edwards, T.L., Golledge, N.R., Hemer, M., Kopp, R.E., Krinner, G., Mix, A., Notz, D., Nowicki, S., Nurhati, I.S., Ruiz, L., Sallée, J.-B., Slangen, A., Yu, Y. 2021: Ocean, Cryosphere and Sea Level Change Supplementary Material, in: IPCC (Ed.), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Garner, G.G., Hermans, T., Kopp, R.E., Slangen, A.B.A., Edwards, T.L., Levermann, A., Nowikci, S., Palmer, M.D., Smith, C., Fox-Kemper, B., Hewitt, H.T., Xiao, C., Aðalgeirsdóttir, G., Drijfhout, S.S., Golledge, N.R., Hemer, M., Krinner, G., Mix, A., Notz, D., Nowicki, S., Nurhati, I.S., Ruiz, L., Sallée, J.-B., Yu, Y., Hua, L., Palmer, T., Pearson, B. 2021: IPCC AR6 Sea-Level Rise Projections: Version 20210809, PO.DAAC, CA, USA. https://podaac.jpl.nasa.gov/announcements/2021-08-09-Sea-level-projections-from-the-IPCC-6th-Assessment-Report (accessed 25.11.2021).

Jacob, D., Teichmann, C., Sobolowski, S., Katragkou, E., Anders, I., Belda, M., Benestad, R., Boberg, F., Buonomo, E., Cardoso, R.M., Casanueva, A., Christensen, O.B., Christensen, J.H., Coppola, E., Cruz, L.D., Davin, E.L., Dobler, A., Domínguez, M., Fealy, R., Fernandez, J., Gaertner, M.A., García-Díez, M., Giorgi, F., Gobiet, A., Goergen, K., Gómez-Navarro, J.J., Alemán, J.J.G., Gutiérrez, C., Gutiérrez, J.M., Güttler, I., Haensler, A., Halenka, T., Jerez, S., Jiménez-Guerrero, P., Jones, R.G., Keuler, K., Kjellström, E., Knist, S., Kotlarski, S., Maraun, D., van Meijgaard, E., Mercogliano, P., Montávez, J.P., Navarra, A., Nikulin, G., Noblet-Ducoudré, N.d., Panitz, H.-J., Pfeifer, S., Piazza, M., Pichelli, E., Pietikäinen, J.-P., Prein, A.F., Preuschmann, S., Rechid, D., Rockel, B., Romera, R., Sánchez, E., Sieck, K., Soares, P.M.M., Somot, S., Srnec, L., Sørland, S.L., Termonia, P., Truhetz, H., Vautard, R., Warrach-Sagi, K., Wulfmeyer, V. 2020: Regional climate downscaling over Europe: perspectives from the EURO-CORDEX community. Reg Environ Change 20 (2), 1-20.