IMPACT OF SEA LEVEL RISE ON THE ACCESSIBILITY OF COASTAL PORTS: A CASE STUDY OF THE PORT OF ZEEBRUGGE (BELGIUM)

Gerasimos A. Kolokythas, Flanders Hydraulics Research, Belgium, Gerasimos.Kolokythas@mow.vlaanderen.be
Bart de Maerschalck, Flanders Hydraulics Research, Belgium, Bart.Demaerschalck@mow.vlaanderen.be
Joris Vanlede, Flanders Hydraulics Research, Belgium, Joris.Vanlede@mow.vlaanderen.be
Kai Chu, International Marine & Dredging Consultants, Belgium, kai.chu@imdc.be

INTRODUCTION

The effect of sea level rise on the hydrodynamic flow in the Belgian coastal zone is investigated in the light of the nautical accessibility of the port of Zeebrugge in Belgium. To this end, numerical simulations are performed considering three different scenarios of sea level rise along with a reference scenario (current situation). Specifically, a moderate, a warm and a worst case scenario of sea level rise (SLR) equal to 60 cm, 90 cm and 200 cm by the year 2100, are considered. The main objective is to find out how the strong tidal currents, which are mainly directed transversely to the access channel and limit the access to the port to a certain tidal window, will be affected by the considered SLR scenarios.

MODELLING STRATEGY

The simulations are conducted in three levels: First a continental shelf model (CSM) is run in order to provide the boundary conditions of the second-level nested model (ZUNO), which includes the southern North Sea and the Channel. In turn, the latter model feeds the third-level coastal model (BCM). SLR is applied at the boundary of CSM, keeping the tidal constituents constant. This is deemed permissible because the water depth change at the offshore boundaries of CSM is limited (<1%). The important processes are still resolved including the impact of SLR on the tidal dynamics on the shallow shelf (Kelvin wave propagation speed, location of amphidromic points, etc.). The ZUNO model is used as an intermediate between the low-resolution CSM model and the high-resolution BCM model, which accounts much better for the representation of the nearshore hydrodynamics.

METHODS & FORMULATION

The WAQUA module of the SIMONA software (Rijkswaterstaat, 2013) is used for the simulations of the two larger-scale models, CSM and ZUNO. WAQUA is a two-dimensional, depth-averaged flow model which solves the shallow water equations either on rectilinear grids or curvilinear grids. The BCM-model hydrodynamic simulations are performed by means of TELEMAC3D software (Hervouet, 2007), which solves the three-dimensional Navier-Stokes equations on unstructured meshes using the finite element method.

MODEL SETUP

For the first level (CSM) a rectilinear grid in spherical coordinates is utilized, whereas the simulations in the second level (ZUNO) are performed using a curvilinear grid in Cartesian coordinates (Figure 1). The cell sizes of the first grid range from 6.5 km to 9.5 km, while those of the second grid are from 1km (close to the Belgian coast) to 6 km (at the English coast). As for the third level (BCM), an unstructured grid consisting of about 300,000 nodes was constructed on an domain that covers the Belgian coast, part of the Dutch coast and the Scheldt estuary (Figure 1). The grid resolution varies from 5 to 10 m in the port of Zeebrugge, becomes 20 m within a radius of about 4.5 km around the port and reaches a size up to 3 to 4 km at the semi-circular offshore boundary of the model. In the vertical direction, ten layers in a non-uniform sigma-coordinate system are used. The considered simulation period is one month (April 2009).

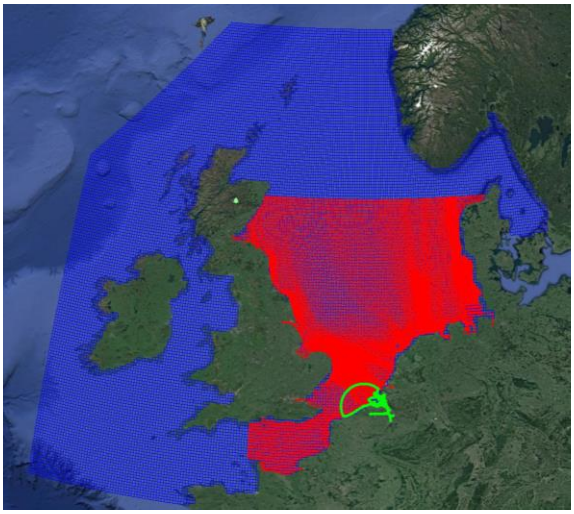

Figure 1: Computational grids of the implemented three-level modelling. The blue grid corresponds to the CSM, the red one to ZUNO model and the green to the BCM.

RESULTS

The numerical results show that SLR is expected to affect the tidal amplitude, which increases at the Belgian and Dutch coast and upstream the Scheldt estuary. For the worst case scenario, for instance, the amplitude during spring tide increases up to 10 cm at the area around the port of Zeebrugge. SLR also causes a shift in the tidal phase of water level (about 15 minutes around the port). Although the maximum depth-averaged velocities near the Scheldt mouth area are increased, in general the maximum speed of the currents in the vicinity of the port of Zeebrugge decreases for the SLR scenarios. During the ebb phase, though, a local increase of just a few cm/s (15 cm/s in the worst case scenario), is observed in front of the port entrance. The tidal window during which nautical access to the port is possible is not substantially affected by the considered SLR.

REFERENCES

Hervouet (2007): Hydrodynamics of free surface flows: Modelling with the finite element method, WILEY, 360pp.
Rijkswaterstaat (2013): User's guide WAQUA: General information, Rijkswaterstaat, The Netherlands.