DETERMINING THE WIND DRAG COEFFICIENT IN HYDRODYNAMIC MODELLING OF A SHALLOW, FETCH-LIMITED WATER SYSTEM

A CASE STUDY IN FRIESLAND, THE NETHERLANDS

A well-known effect of high sustained winds is wind set-up: increased water levels on the downwind side of a water system. To accurately represent the wind effects on water levels in inland water systems by means of a hydrodynamic model is difficult, especially in fetch-limited water bodies. There is limited information available for practical applications. The transmission of momentum between wind and water is generally formulated as a shear stress term, scaled with the wind drag coefficient. The theory suggests that this coefficient can vary significantly within a water system and for different wind characteristics, mainly due to wind shielding in combination with varying fetch lengths and roughness differences. This study examined whether, and to what extent, the wind drag coefficient in a shallow, fetch-limited, inland water system varied spatially and/ or with the wind characteristics. Moreover, it examined whether the drag coefficient should vary for these dependencies to yield significantly better model predictions of water levels.

The Frisian bosom, consisting of openly connected lakes through a dense system of canals (Figure 1), served as case study. Different wind events, classified based on their wind direction and wind speed, were simulated in the Frisian bosom by means of a 2D hydrodynamic model, which was set up with 3Di software. A calibration method was set up and used to optimize the wind drag coefficient, such that the simulated water levels matched the observations as closely as possible. For each wind class, an optimal wind drag coefficient was retrieved for the whole model domain, as well as for each measurement location separately. The results were analysed to find different wind drag dependencies. Moreover, the results were compared to a reference case to provide an indication of the significance of the improvements in terms of model accuracy.

This study demonstrated relations between the location in the water system, the wind direction and the optimal wind drag coefficient. Overall, the drag coefficient was significantly lower at locations with greater fetch-limitations, due to their water body geometry in-line with the wind direction. These smaller fetches allocated less momentum transmission between water and wind, as wind shielding had a greater impact. The overall accuracy of the model with a drag coefficient varying spatially, and per wind direction, improved compared to the reference model with 44%. Based on these results there is good reason to believe that the wind set-up predictions will improve if a spatially and/ or wind direction varying wind drag coefficient is included in a hydrodynamic model of a shallow, fetch-limited, inland water system. Follow-up research can be performed by implementing the opportunity to vary the wind drag coefficient in a hydrodynamic model. This can demonstrate the wind drag dependencies and model improvements explicitly.

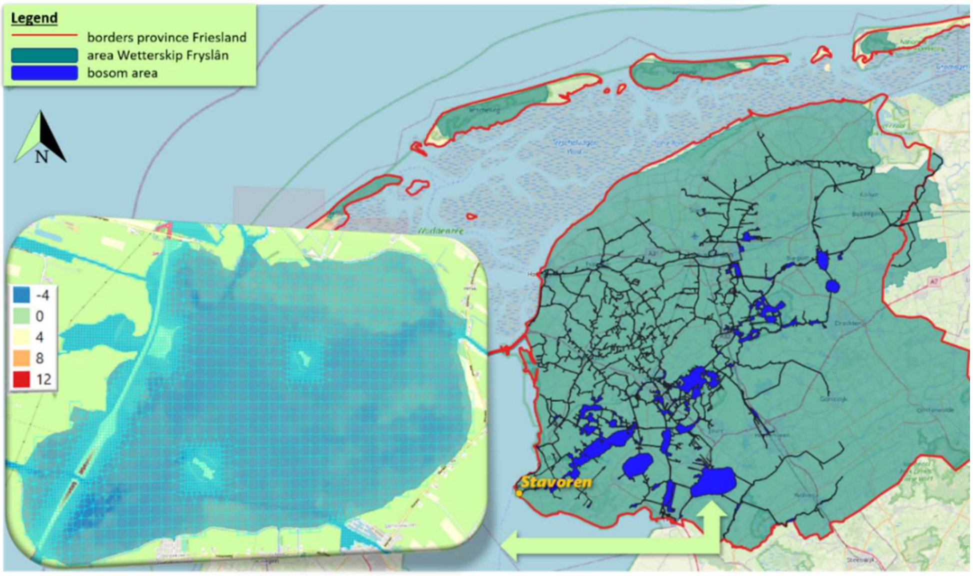

Figure 1: Overview of the Frisian bosom (in blue) and part of the model at Tjeukemeer, one of the Frisian lakes. Provided are the bottom depths (legend in m+NAP) and the computational grid cells

Stijn Overmeen

Graduation Date:
15 April 2021

Graduation committee:
University of Twente
Dr. J.J. Warmink
Dr. ir. A. Bomers

Nelen & Schuurmans
Dr. N.D. Volp
T. Berends (MSc)

UNIVERSITY OF TWENTE.