F110oostr[001-003]: Oosterschelde

Purpose

The inlet of the Eastern Scheldt estuary (west of the storm surge barrier) in the south west of the Netherlands is characterised by banks, tidal channels and a shallow foreshore. As such, this field site is suitable for studying the performance of SWAN with respect to the penetration of low-frequency waves over a complex bathymetry.

Physical conditions

The Eastern Scheldt estuary is situated in the south west of the Netherlands. It consists of a complex system of sand banks and tidal channels (Figure 4.1). The mouth of the estuary is partially closed off by the Eastern Scheldt storm surge barrier, which limits the penetration of offshore waves. Therefore, only the region seaward of the barrier is relevant for the present purpose. In front of this storm surge barrier, the shallowest sand banks lie at about -8 m NAP, and the deepest channels reach depths of about -30 m NAP. During the last three decades, long-term wave observations have been carried out at four locations near the inlet of the Eastern Scheldt estuary, namely SCHB, DORA, BG2 and OS4 (Figure 4.1). The 20 highest wind speed events over the period 1982-2002 recorded by KNMI in this region (at wind station 312) show that the strongest winds (>24 m/s) to come from the directional sector 220-320 ^{o}N (Svasek 2007). The Eastern Scheldt is therefore directly exposed to the largest storm waves, which will enter the complex tidal inlet system.

Wave penetration into the Eastern Scheldt inlet has been investigated in hindcast and analysis studies by Svasek (2007) and Alkyon (2008). The analysis of Alkyon (2008) suggest the following relevant physical processes in SWAN for this area: In the deeper regions offshore of the shallow banks, the deep water source terms of wind input, whitecapping and quadruplet interaction dominate. Moving shoreward, bottom friction becomes increasingly important with reducing depth, in particular over the shallow sand banks. Because of the size of these areas, the cumulative effect of bottom friction is responsible for significant dissipation of low-frequency energy. Depth-induced wave breaking is strong in a narrow strip on the outer (seaward) edges of the sand banks, whereas triad interactions are also strong further onto the shallow areas. Wave refraction is important for the propagation of wave energy, in particular the low-frequency components, along the channels and over the shallow banks. In addition, studies by Magne et al. (2007) and Gerosthathis et al. (2005) suggest that diffraction along the channel edges may also play an important role in this regard. Therefore, this field site is well-suited to study the performance of SWAN with respect to the penetration of low-frequency wave components into complex tidal inlet systems.

Case selection

In the hindcast study of Svasek (2007), two storms, namely 25-30 December 2001 and 20-24 December 2003, were selected based on the availability of wave data and additional model input (wind, water levels, bathymetry). In particular, the emphasis was laid on conditions with simultaneous occurrence of swell and wind sea, with the swell period preferably longer than 10 s. It is noted that due to these constraints, the selected storms did not rank amongst the severest storms mentioned above. Svasek (2007) considered a set of six instants recorded during these two storms, which are given in Table 4.1 below:

Code	**Date**	**Time**	U_{10} **[m/s]**	U_{dir} **[°N]**
A1	26 Dec. 2001	09:00	16	310
A2	26 Dec. 2001	12:00	13	315
A3	29 Dec. 2001	15:00	9	280
B1	21 Dec. 2003	13:30	18	317
B2	21 Dec. 2003	16:00	17	300
B3	23 Dec. 2003	02:30	9	295

Table 4.1: Storm events in the Eastern Scheldt considered by Svasek (2007). Wind speed and direction at the offshore station EUR.

From the list of instants given above, the three storm events A1, A2 and B3 are selected here as validation cases. These cases correspond to those considered in the analysis of Alkyon (2008). The first two events (A1 and A2), featuring near gale force winds (on the Beaufort scale), were selected because they have wind and offshore wave directions pointing straight into the ebb-tidal delta. The third event (B3) was selected because of its high amount of low-frequency energy in front of the surge barrier - which is strongly underestimated by SWAN - in combination with a low wind speed (a strong breeze on the Beaufort scale). This selection is considered to give a representative set of conditions from this dataset. For these storm instants, non-directional wave information is available at SCHB, DORA, BG2 and OS4 in the vicinity of the inlet. In addition, directional wave data are available at the offshore location EUR, and non-directional wave data at location LEG. Observed wind time series are available at the offshore location EUR and the nearshore stations LEG, BG2 and OS4.

Svasek (2007) gives the following description of the selected storm instants:

25-30 December 2001

This storm reached maxima (on the 28th) of almost 24 m/s wind velocity and 5.4 m significant wave height at EUR. The selected moments are less severe, but have rather been chosen on the basis of spectral shape (as mentioned above). At the storm instant 26 December 2001 at 09:00, the constant wind is approximately 16 m/s from 310 °N. Both at SCHB and at BG2 the wave spectrum has a main energy peak at approximately 0.125 Hz and a smaller low-frequency peak at approximately 0.07 Hz. The significant wave height for SCHB was 3.1 m and at OS4, where wave heights vary with tide, it was 1.6 m. Water levels are rising due to a flood current at OS4. At BG2 it is approximately slack tide. At the storm instant of 26 December 2001 at 12:00, wind has reduced slightly to 13 m/s, the direction is 315 °N. The spectra of both SCHB and BG2 show a small energy peak at approximately 0.07 Hz, and a main peak at approximately 0.125 Hz. The significant wave height at SCHB is 3.2 m and at OS4 1.6 m. At OS4 it is high water, and the current velocity is negligible. At BG2 flood velocities are approximately 0.5 m/s, to the northeast.

20-24 December 2003

This north-northwestern storm caused high water levels and high waves, due to winds reaching 21 m/s. This combination gave relatively high waves at especially the location OS4. During this event, the Eastern Scheldt barrier was closed on 21 December from 9:00 to 16:00. At the storm instant of 23 December 2003 at 02:30 the wind came from WNW and dropped to approximately 9 m/s. The significant wave heights at SCHW and OS4 are respectively 2.0 m and 1.2 m. At OS4 it is slack tide, the currents at BG2 are to the NE.

Model setup

The computational grids used for this hindcast are presented in Figure 4.1. The model setup features a set of four nested regular computational grids (K, B, D and F) in the Eastern Scheldt estuary. The K grid is the first in the sequence of nesting: its deep water boundary is close to the stations SCHB and LEG, from which wave boundary conditions are taken. However, since no observed wave directions are available here, a fifth North Sea grid (N) is defined to provide frequency dependent mean wave directions for the nested grid (K). The N grid obtains its boundary values from the directional wave observations at EUR. The observed wind time series at stations LEG, BG2 and OS4 are applied over the grids K, B, D and F. These values, sampled during a few hours before the selected moments (to account for the propagation time of the offshore waves), were visually averaged and applied uniformly over these grids. For the N grid, the wind as measured at EUR was used. Water level and current fields are available from WAQUA simulations carried out by RIKZ, computed on the ‘Kuststrook-fijn’ grid, using boundary conditions generated using Kalman-filtering on the Kuststrook-grof model grid.

Both the completeness and quality of this set of observational data is considered as being good. The data set is suitable for studying the penetration of low-frequency waves into complex tidal inlet systems, similar to that found in the Wadden Sea. Hence, these field cases are considered to be suitable to take up as validation cases in SWIVT.

Default settings

The following settings are default for this case:

```
$ --- Fysische parameter settings
GEN3 WESTH
QUAD iquad=2 lambda=0.25 Cnl4=3.0E7
LIMITER ursell=10 qb=1.0
FRICTION JONSWAP cfjon=0.067
BREA CON alpha=1.0 gamma=0.73
TRIAD trfac=0.05 cutfr=2.5

$ --- Numerieke parameter settings
NUM STOPC 0.00 0.01 0.001 99.5 STAT mxitst=80

$ *** Integrate over frequency range [FMIN,FMAX] to obtain wave
parameters
QUANT HS TMM10 TM01 TM02 FMIN 0.03 FMAX 1.0
```

For the remainder of the settings, we refer to the SWAN command files.

References

Alkyon (2008). Analysis of SWAN hindcasts Wadden Sea, Oosterschelde and Slotermeer. Alkyon Report A2085, May 2008.

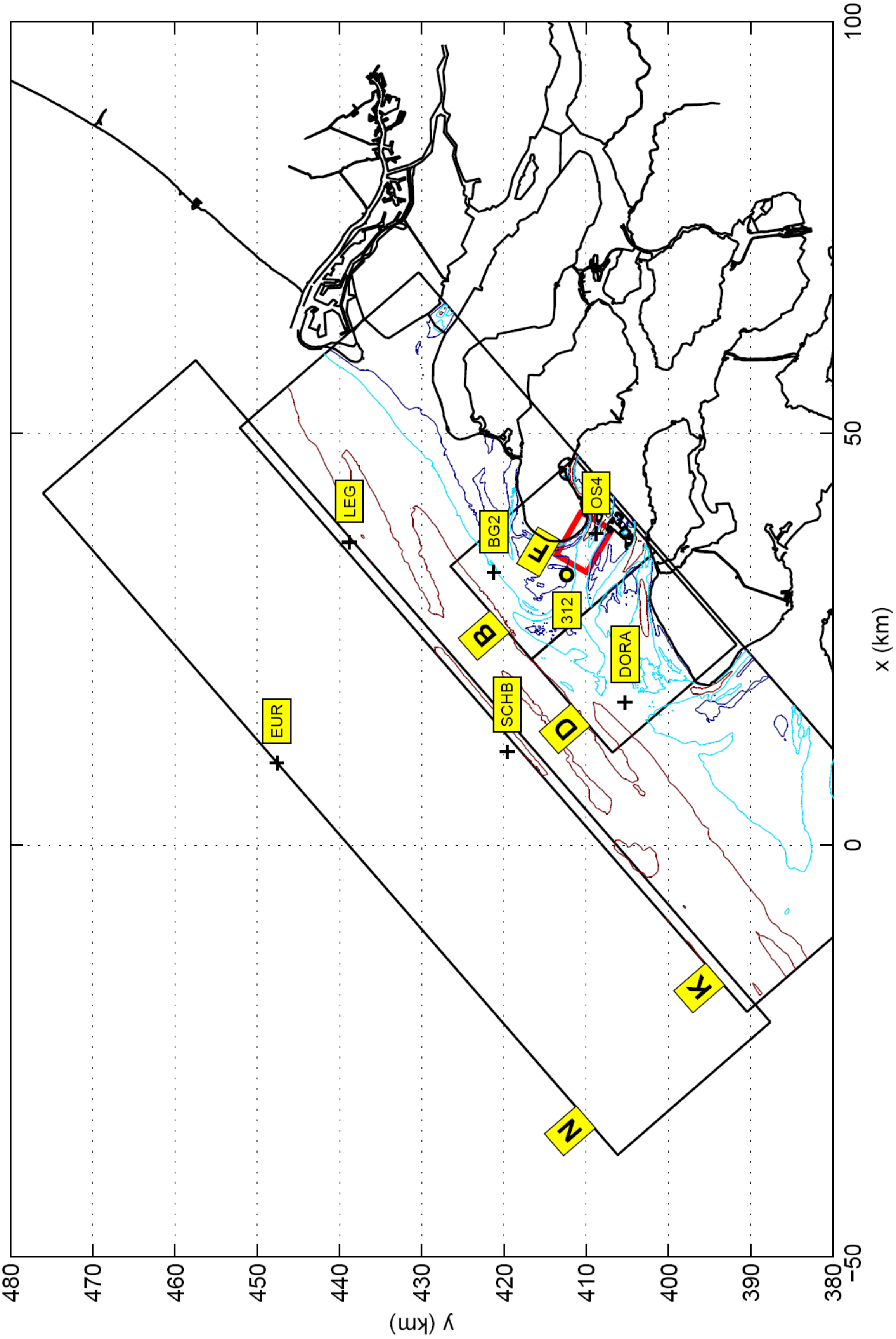
Gerosthathis, T., K. A. Belibassakis, and G. Athanassoulis (2005), Coupled mode, phase-resolving model for the transformation of wave spectrum over steep 3D topography: A parallel-architecture implementation, OMAE 2005, Am. Soc. of Mech. Eng., Halkidiki, Greece.

Magne R., K. A. Belibassakis, T. H. C. Herbers, F. Ardhuin, W. C. O'Reilly, V. Rey (2007), Evolution of surface gravity waves over a submarine canyon, J. Geophys. Res., 112, C01002, doi:10.1029/2005JC003035.

Svasek (2007). Hindcast tidal inlet Eastern Scheldt, Storms December 2001 and December 2003, Svasek Report CG/1461/07542/A, December 2007.

Acknowledgements

The hindcast is part of the SBW (Strength and Loads on Water Defenses) study commissioned by Rijkswaterstaat-Centre for Water Management in The Netherlands.



Field case of Eastern Scheldt for December 2001 and December 2003
with observation stations and computational grids N, K, D, B and F.
Bottom contours on K grid for depths NAP −5 m, −10 m and −20 m (Alkyon 2008).

Validation cases SWIVT

DELTARES

H5107.66

Fig. 4.1