project description

SWAN computations for the Holland part of the Dutch coast

assignment

On behalf of RIKZ, Royal Haskoning and WL | Delft Hydraulics determined wave parameters at many locations in front of the constructions in front of the Holland part of the Dutch coast. For a matrix of conditions, given in terms of storm surge level, wind direction and wind speed, the spectral wave model SWAN model transforms offshore wave conditions to wave conditions at locations near the toe of dikes, dunes and other coastal structures.

client

Dutch Department of Public Works (Rijkswaterstaat), National Institute for Coastal and Marine Management (RIKZ)

period

September 2004 – January 2006

Fig. 1 Holland part of the Dutch coast

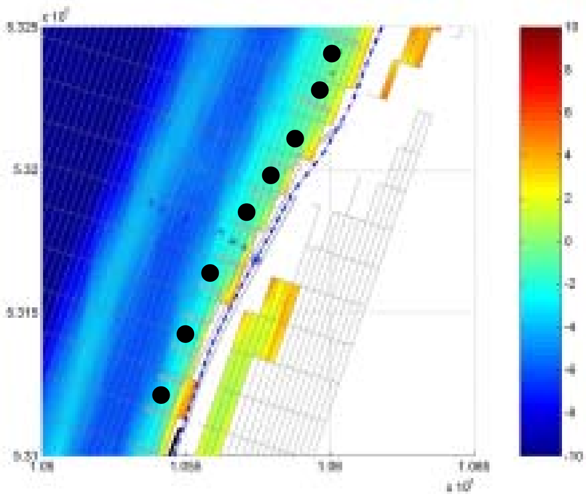

Fig. 2 Output locations in front of a dike

keywords:
spectral wave modelling
wave boundary conditions
parallel computations
hydraulic boundary conditions
evaluation of dike elevations

H4524

WL | delft hydraulics

Outline

A significant part of The Netherlands is below sea level. Dunes and dikes along the Dutch coast protect the mainland behind from flooding. Every five years the Ministry of Public Works has to establish hydraulic boundary conditions (HBC). These are used to evaluate the safety of the dunes and dikes. For dikes the safety is expressed in terms of the amount of wave overtopping or damage to the dike revetments. Erosion and sedimentation on the beach and foreshore have to be evaluated for dunes. All these processes depend on the HBC in front of the water defences. The HBC are determined applying a train of models.

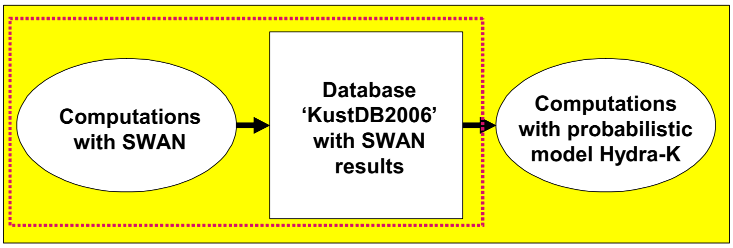

Fig. 3 Train of models to determine HBC

For a matrix of conditions, given in terms of storm surge level, wind direction and wind speed, the stochastic wave model SWAN (version 40.41) has been applied to transform offshore wave conditions to wave conditions at locations near the toe of the water defences. The SWAN results of all computations have been stored in a database 'KUSTDB2006'. In another study the probabilistic model Hydra-K has been applied to determine the wave conditions at all toe locations corresponding to the level of safety. This level is statutorily established and has a return period of 10.000 years for a large part of the Dutch coast.

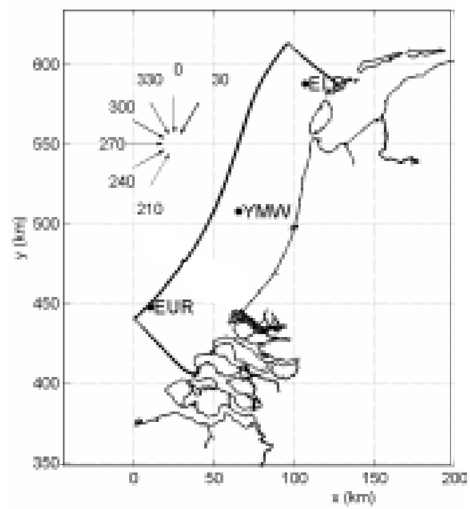

Fig. 4 Computational area with offshore measurement locations

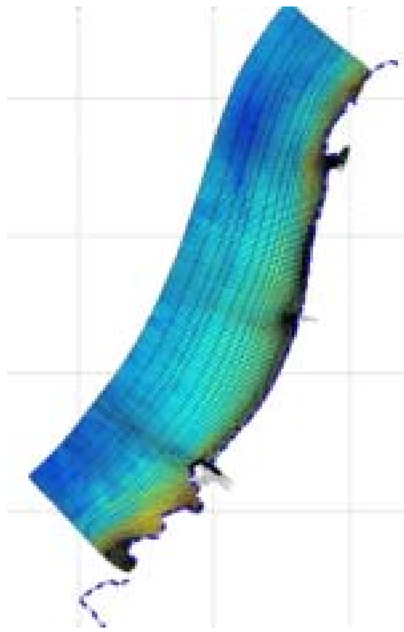

Fig. 5 Curvi-linear grid with depth profile

Set-up of SWAN computations

SWAN computations have been carried out in stationary mode for 252 combinations of 6 wind speeds (15m/s-40m/s), 7 wind directions (210°N-30°N) and 6 storm surge levels (1m-6m). The conditions cover the range of mild storm conditions to extreme conditions representative for the conditions at the North Sea. The curvi-linear grid covers the coastal strip and consists of 1981 by 769 grid points (Fig. 5).

Since the grid is refined in the areas of interest near the coast, the conventional method of grid nesting is no longer necessary. The offshore depth reaches values of 30m. Based on data from three spatially varying wind stations 6x7=42 wind fields have been determined. For all combinations boundary conditions at the offshore boundary have been determined. The novel procedure by Groeneweg and Van Vledder (2005) was used, leading to boundary conditions that do not cause spinning effects due to imbalances between imposed wave spectra and computed spectra in the interior of the domain. Targeting on statistically determined values for wave period and wave height at three measurement locations ELD, YMW and EUR (see Fig. 4), SWAN has been applied in 1D mode over an infinitely long transect against the wind direction through the measurement location under consideration. The statistically determined prescribed wave period determines the fetch needed for SWAN to reach that period. The 2D spectrum at the location on the transect obtained by decreasing the fetch with the distance between the measurement location and the offshore boundary is imposed at the intersection of the offshore boundary and the wind ray transect. SWAN interpolates boundary spectra at intermediate boundary locations. For all conditions the default physical parameter settings have been applied.

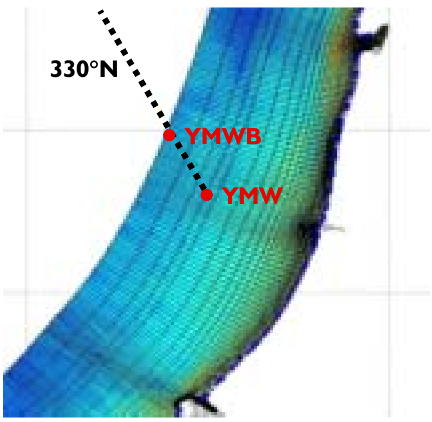

Fig. 6 Transect through YMW for wind direction of 330°N

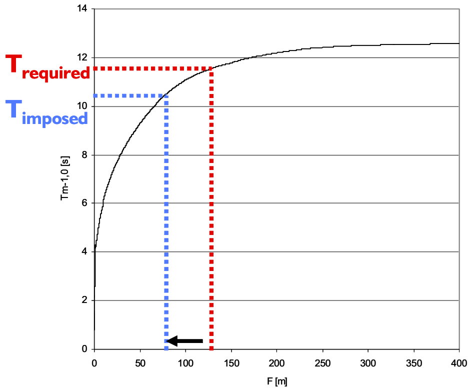

Fig. 7 Growth curve for wave period to determine wave boundary spectra

SWAN computations in parallel mode

Due to the large amount of grid points SWAN cannot be applied on a stand-alone PC. A cluster for parallel computations is required. The SWAN computations for all conditions have been carried out in batch mode on the Hydrax HPC cluster (RedHat-based, 4GB/node, GBit Ethernet) at WL | Delft Hydraulics (Fig. 8). The MPI-version of SWAN ran on 12 nodes.

Fig. 8 Hydrax HPC cluster

On average SWAN reached convergence after 22 iterations, taking approximately 1 hour of CPU time (see Fig. 9). The entire batch run required less than 12 days.

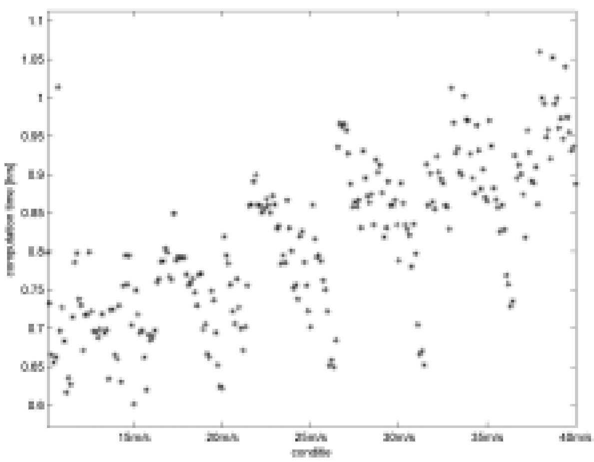

Fig. 9 CPU time for each computation

For each condition the offshore wave conditions, which are related to the statistically determined wave conditions at the measurement locations, have been translated to wave conditions at output locations in front of the dunes and dikes along the Dutch coast. The wave conditions are given in terms of 1D and 2D spectra and integral wave parameters. For checking purposes spatial distributions of a number of wave parameters have been generated, see e.g. Fig. 10.

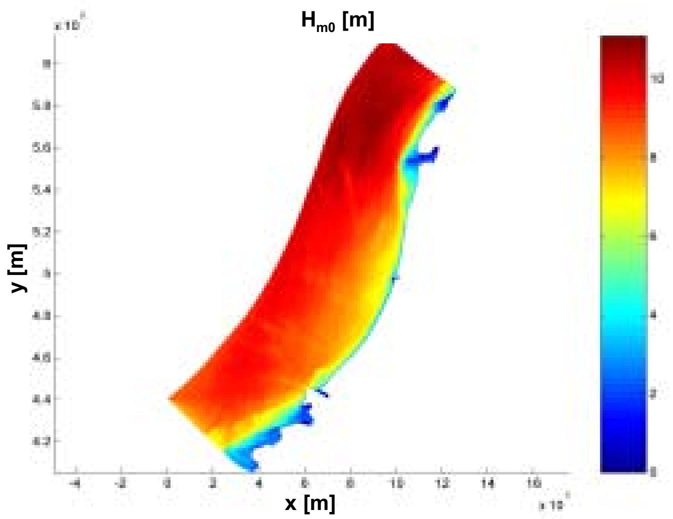

Fig. 10 Significant wave height distribution for a condition with wind speed 30m/s, wind direction 330°N and storm surge level 4m

Verification and storage of generated wave data

Approximately 100GB of generated wave data cannot be checked manually. Therefore routines have been developed that perform procedural and numerical checks. The procedural checks consist of checking on the availability of expected input and output files, the completeness of data files, the existence of error and warning files, and computational time. Numerically the output data is checked on consistency and convergence of the computations.
The checked results of the 252 SWAN computations have been stored in the KUSTDB2006 database. Within this database additional physical checks have been carried out. These checks are related to the correctness and completeness of the procedures (e.g. file administration), and the wave data (e.g. wave height over depth ratio). The final product is a database consisting of results from SWAN computations that have been checked procedurally, numerically and physically. The range of storm surge levels, wind speeds and wind directions enable the probabilistic model Hydra-K to determine for each representative location in front of water defences to determine the HBC corresponding to the required safety level.

WL | Delft Hydraulics

Decisive advice: from multidisciplinary policy studies to design and technical assistance on all water-related issues.

Rotterdamseweg 185
p.o. box 177
2600 MH Delft
The Netherlands
telephone +31 15 285 85 85
telefax +31 15 285 85 82
e-mail info@wldelft.nl
internet www.wldelft.nl