MILDwave
A Numerical Wave Propagation Model

Introduction

As an alternative to physical small-scale model tests, numerical models are available to estimate wave propagation over uneven bottoms and wave disturbance inside a harbour. Amongst the most widely used models are those based on the Boussinesq equations and recently also those based on (a variant of) the mild slope equation. The Boussinesq models are developed to a high degree of sophistication (wave breaking, non-linear wave-wave interaction,...) but are difficult to implement and often lack stability. The Boussinesq type models are restricted to finite amplitude waves in shallow water.

The mild slope equations are easier to implement and to use, making them very well suited for first stage design processes. The mild slope equation models are restricted to small amplitude waves in water of slowly varying depth (from where its name: mild slope).

The original mild slope equation has been derived first by Berkhoff in 1972. The mild slope equation reduces to the Helmholtz equation in deep water and constant water depth, and reduces to the shallow water equations in shallower water. The original form of the mild slope equation was elliptic (thus rather difficult to solve) and only applicable to regular waves. A parabolic approximation has been developed, e.g. by Radder in 1979, which was easier to solve (better computer efficiency) but treated the forward propagating part of the wave field only and lacked general applicability for harbour lay-outs.

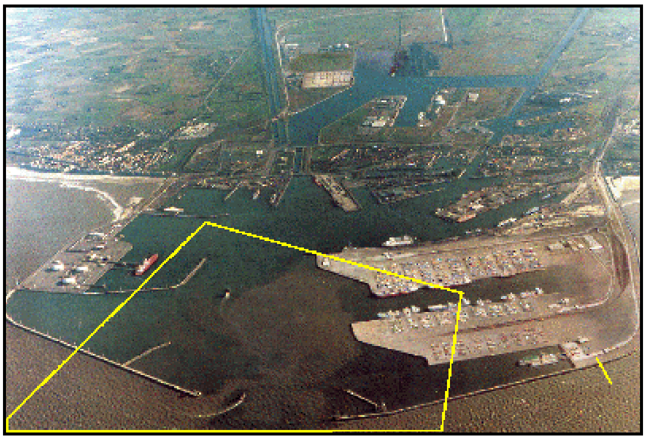

Fig. 1. *Aerial picture of Zeebrugge harbour, and location of the computational domain used in the simulations.*

Recently a new -hyperbolic- form of the mild slope equation has been used, based on the Hamiltonian theory of surface waves and variational calculus. The hyperbolic equation is rather easy to implement in a numerical model using a finite difference discretisation which provides a time-stepping solution for irregular multidirectional wave trains.

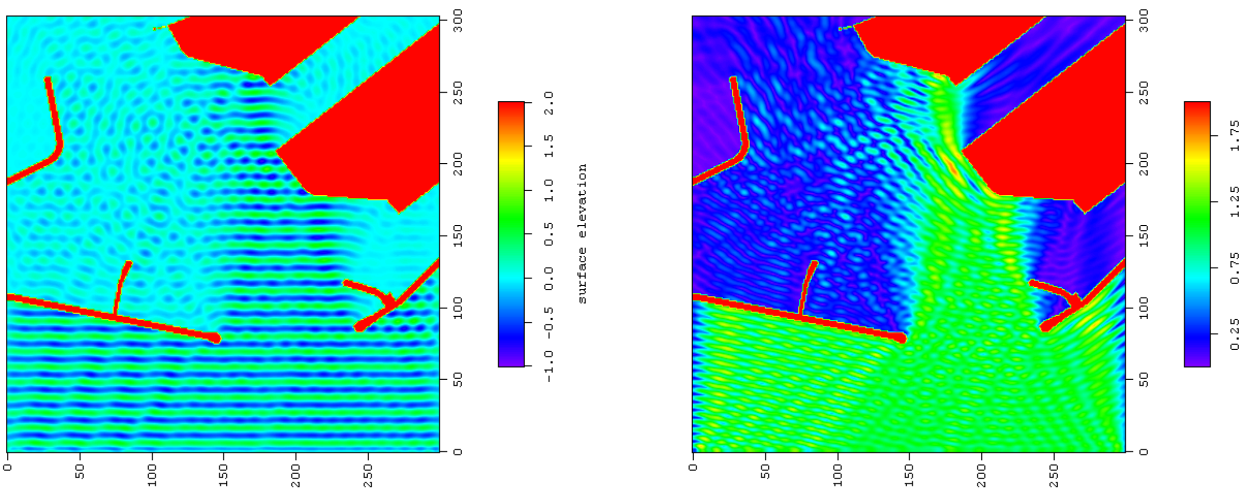

Fig. 2. *Numerical simulation results using MILDwave for penetration of regular waves from North direction into Zeebrugge harbour, with (a) surface elevations of waves at t = 2000 s, and (b) derived disturbance coefficient k_d, for the whole simulation domain.*

DEPARTMENT OF CIVIL ENGINEERING - GHENT UNIVERSITY

Technologiepark 904, B-9052 GHENT - BELGIUM ☎++32 (0)9 264 54 89 🖷++32 (0)9 264 58 37

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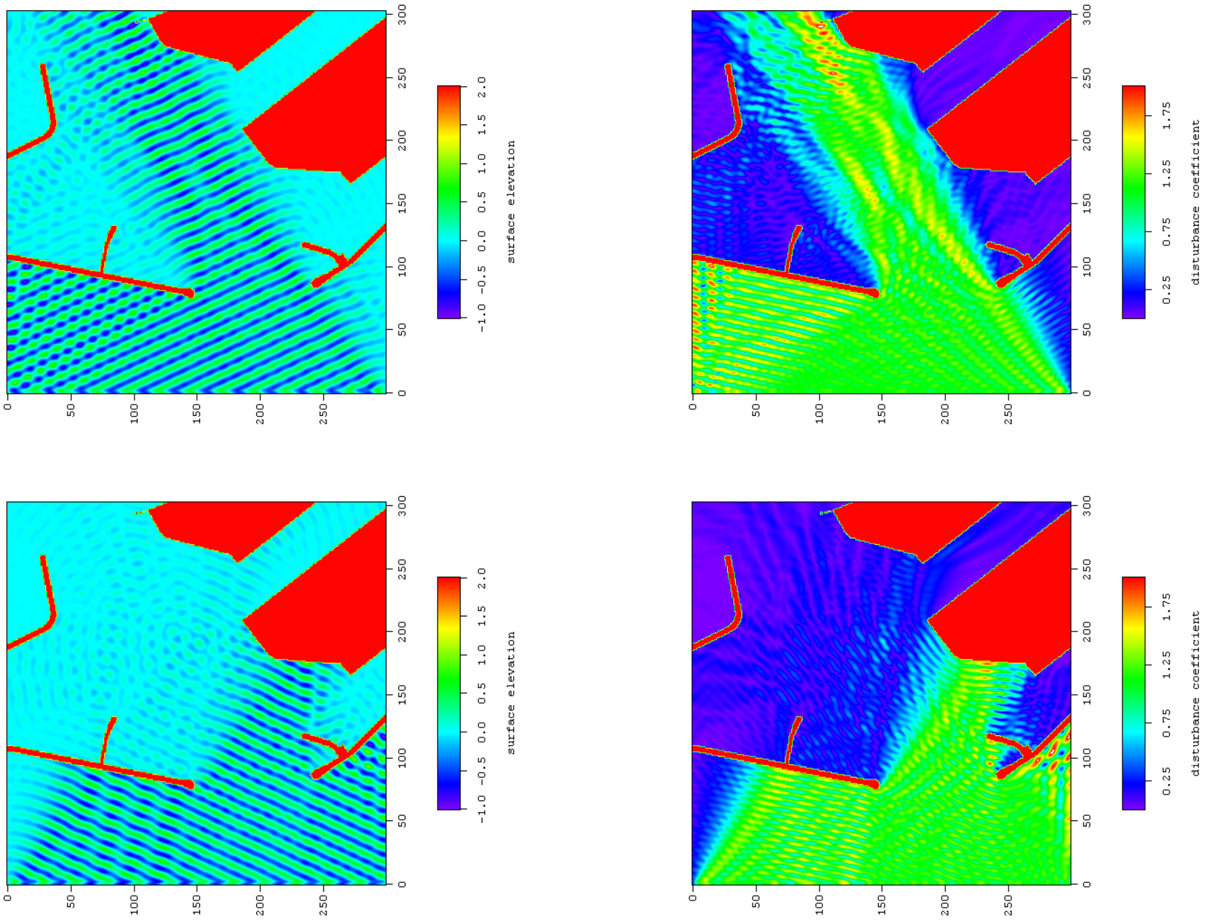

Fig. 3. *MILDwave results (left: surface elevations at t = 2000 s, right: disturbance coefficient k_d) for penetration of regular waves from North West direction (top) and North East direction (bottom).*

Methodology

A numerical wave propagation model, MILDwave, based on the hyperbolic mild slope equation, has been developed at the Department of Civil Engineering. The model is capable to simulate the propagation and transformation of linear regular/irregular uni-directional waves in water of varying depth. Effects of shoaling, diffraction, refraction and reflection are considered by the model equations themselves.

Waves are generated internally along a wave generation line using 'source generation': a volume of water is added corresponding to the change of surface elevation of the incident wave in a time step. A reflected wave can propagate through the source without causing disturbances. Reflected waves do not interact with the wave generation process and can propagate through the source without causing disturbances. At the boudaries of the computational domain waves are absorbed using conventional 'sponge layers'. The code is written in ANSI C and runs under Linux.

Results

An example application is given for penetration of regular waves into Zeebrugge harbour, with simulation domain (Fig. 1), and typical results in Fig. 2 and 3.

Acknowledgements
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Contact
For more information, contact:
PeterB.Troch@UGent.be, or visit the home page of the department at http://awww.UGent.be .