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WAVES: AN OCEAN OF MODELLING OPTIONS

Introduction

Half of the world's population lives within 60 km of the coastline, and 8 of the 10 most populated cities are located at the coast. All of these cities have major harbor infrastructure, which has to withstand the power of the ocean waves. An optimal design of coastal and offshore structures is only achievable by having an as good as possible understanding of the physical properties of ocean waves, such as surface elevation, orbital velocities, dynamic pressure, wave energy. This is done by attempting to describe the real-life behavior with mathematical models. There are several possibilities to model ocean waves, each one with its advantages and disadvantages. The goal of this research is to highlight the ones applied by coastal engineers. Each modelling option will be explained, together with a score for computational cost, accuracy and simplicity. The given list is far from complete, but tries to demonstrate that a lot of options are available and often the coastal engineer needs to make a choice between accuracy and computation time.

1. ANALYTICAL MODELS

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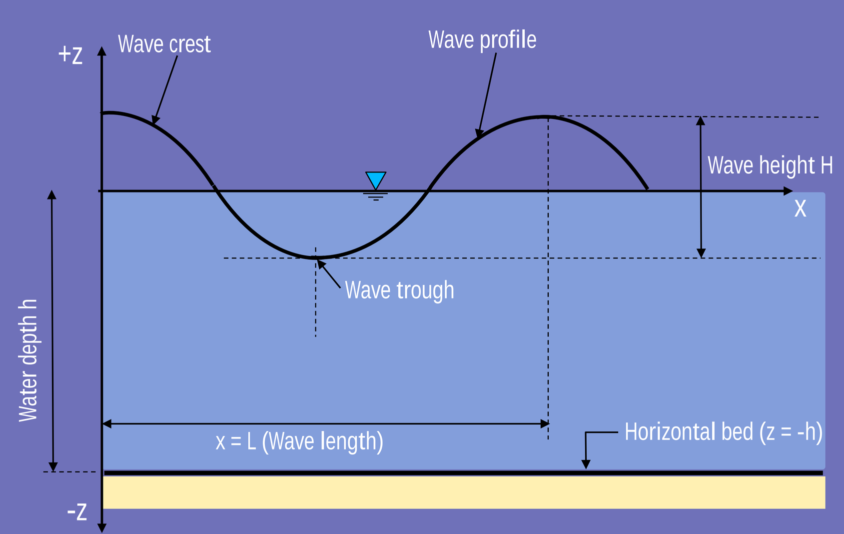
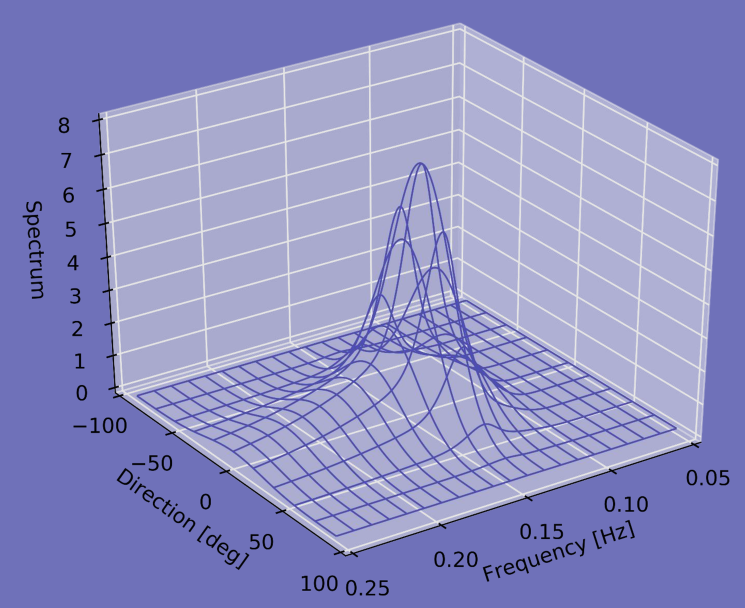
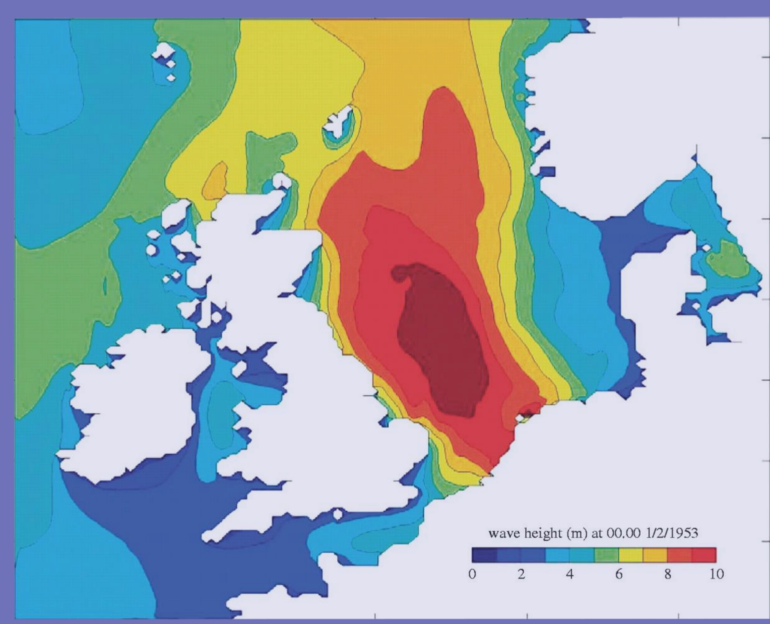
The linear wave theory is the most basic wave model, assuming a regular sinusoidal profile for the wave elevation. This theory was developed by George Biddell Airy in the 19th Century. It assumes a constant water depth, and an inviscid, incompressible and irrotational fluid flow. Airy wave theory is often applied in ocean engineering and coastal engineering for the modelling of random sea states – giving a description of the wave kinematics and dynamics of high-enough accuracy for many purposes. Further, several second-order nonlinear properties of surface gravity waves, and their propagation, can be estimated from its results. This theory was later extended to higher-order solutions, but always focusing on single, regular waves.



2. SPECTRAL WAVE MODELS

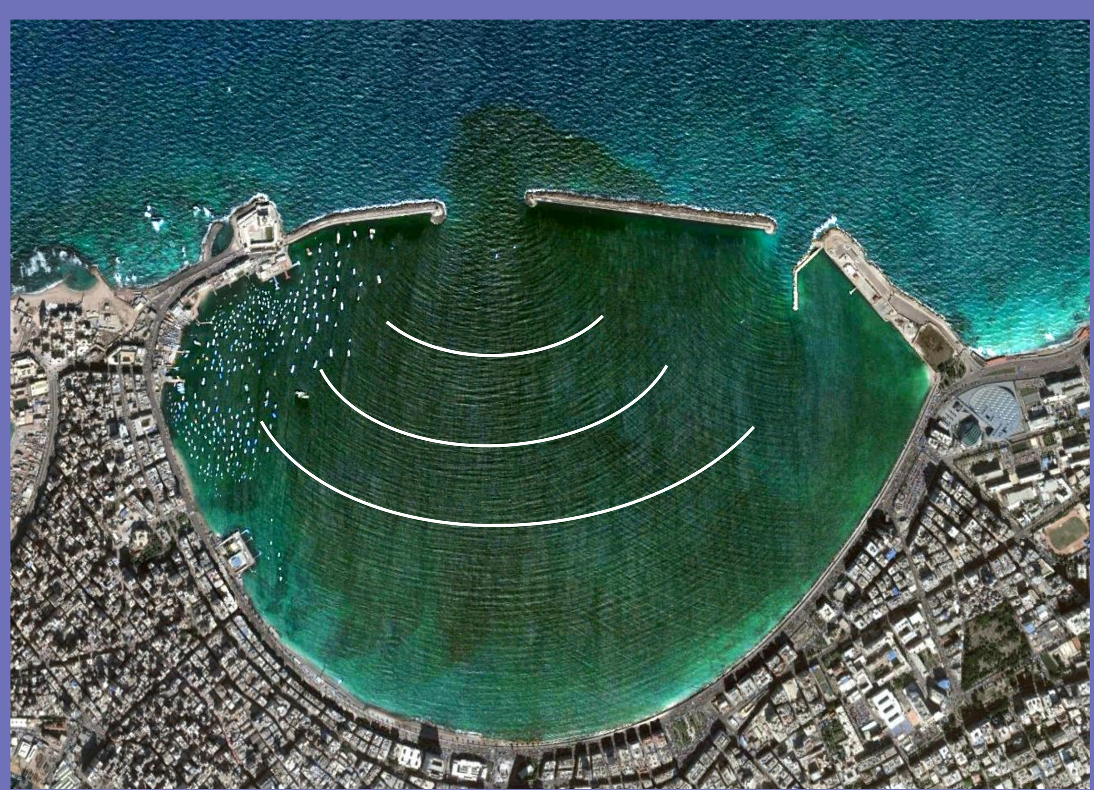
In real life, ocean waves do not have a nice regular sinusoidal wave profile. In contrast, a real sea state is characterized by wave components which differ in a lot of different directions and frequencies. This type of sea state can be described by a directional wave spectrum, which provides the energy density of each wave component. Spectral wave models are mostly used to assess the wave climate at a certain offshore or nearshore location. These solve the random phase spectral action density balance equation for wavenumber-direction spectra. Examples of this type are SWAN, WAVEWATCH, TOMAWAC.

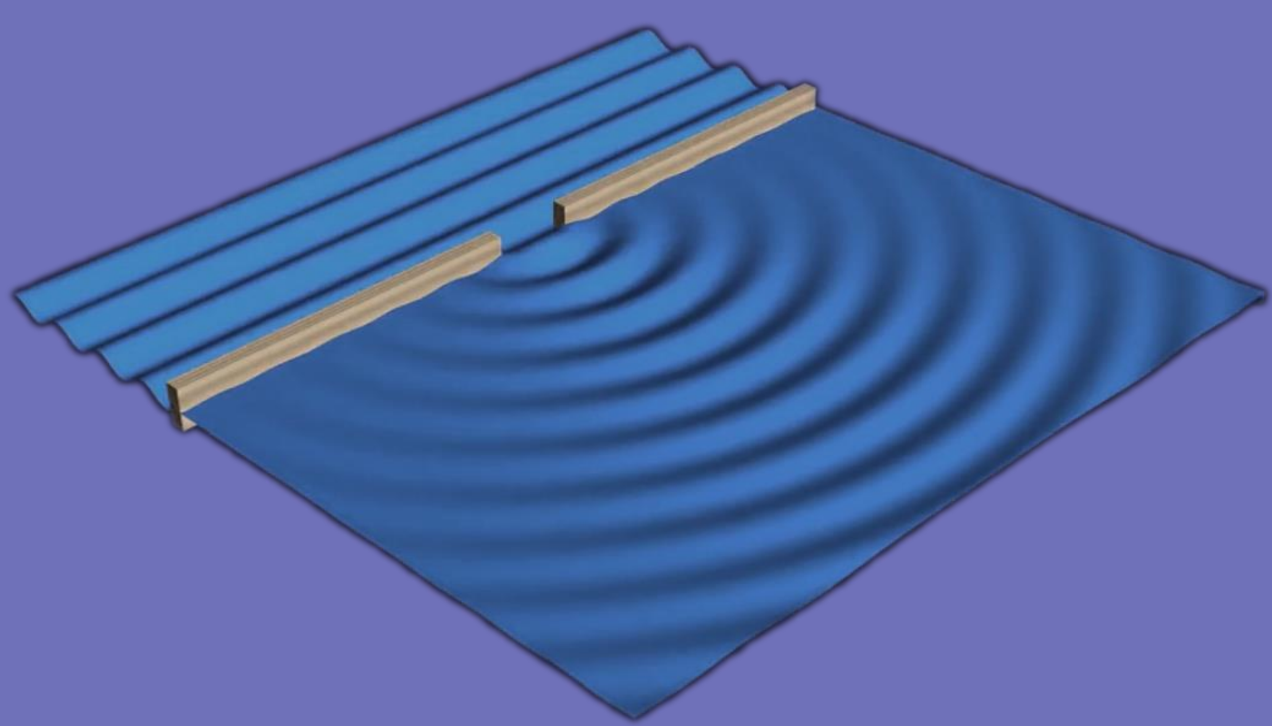




3. DEPTH-AVERAGED MODELS

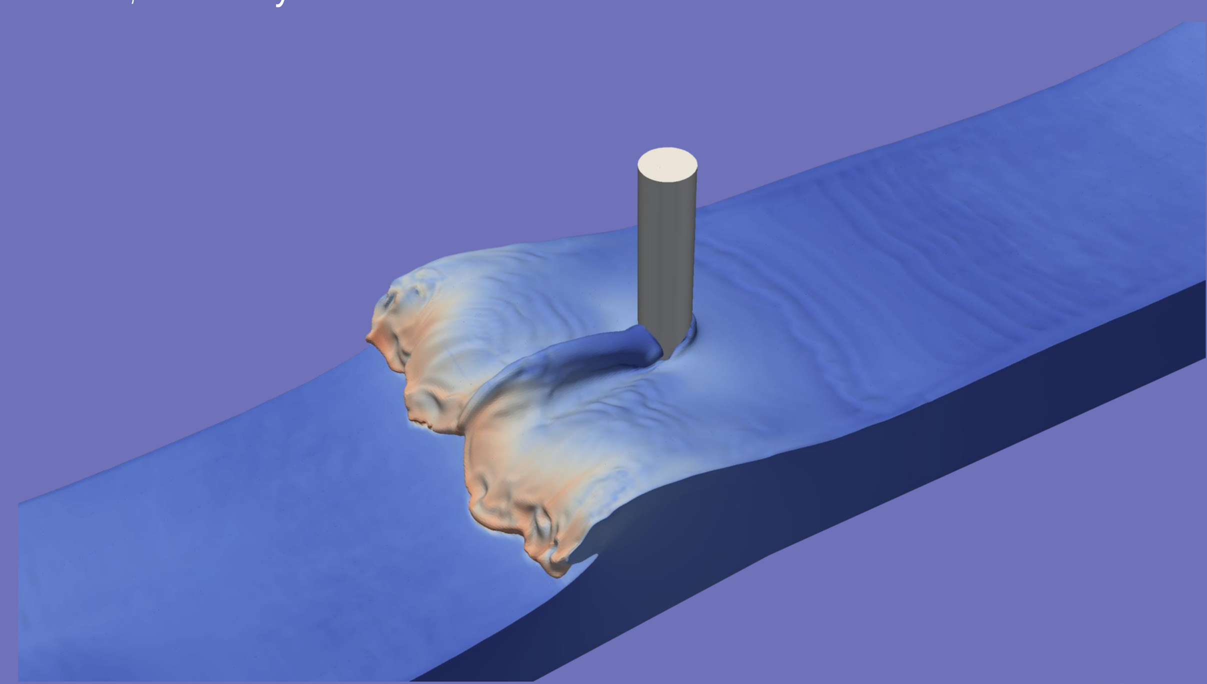
Design of harbors and coastal structures is one of the most important parts of coastal engineering. Within the harbor, ships and quay walls need to be protected from the powerful ocean waves. This is done by constructing breakwaters. This is a fixed trapezoidal structure, composed of a core with armor elements on top. Waves hitting a breakwater, are reflected back into the ocean. Ships sail into the harbor through an opening in the breakwater. Here, waves are diffracted and change direction. Phase-resolving models are used to study the wave penetration pattern in ports, around islands and variable bathymetry. Examples are Artemis and MILDwave.

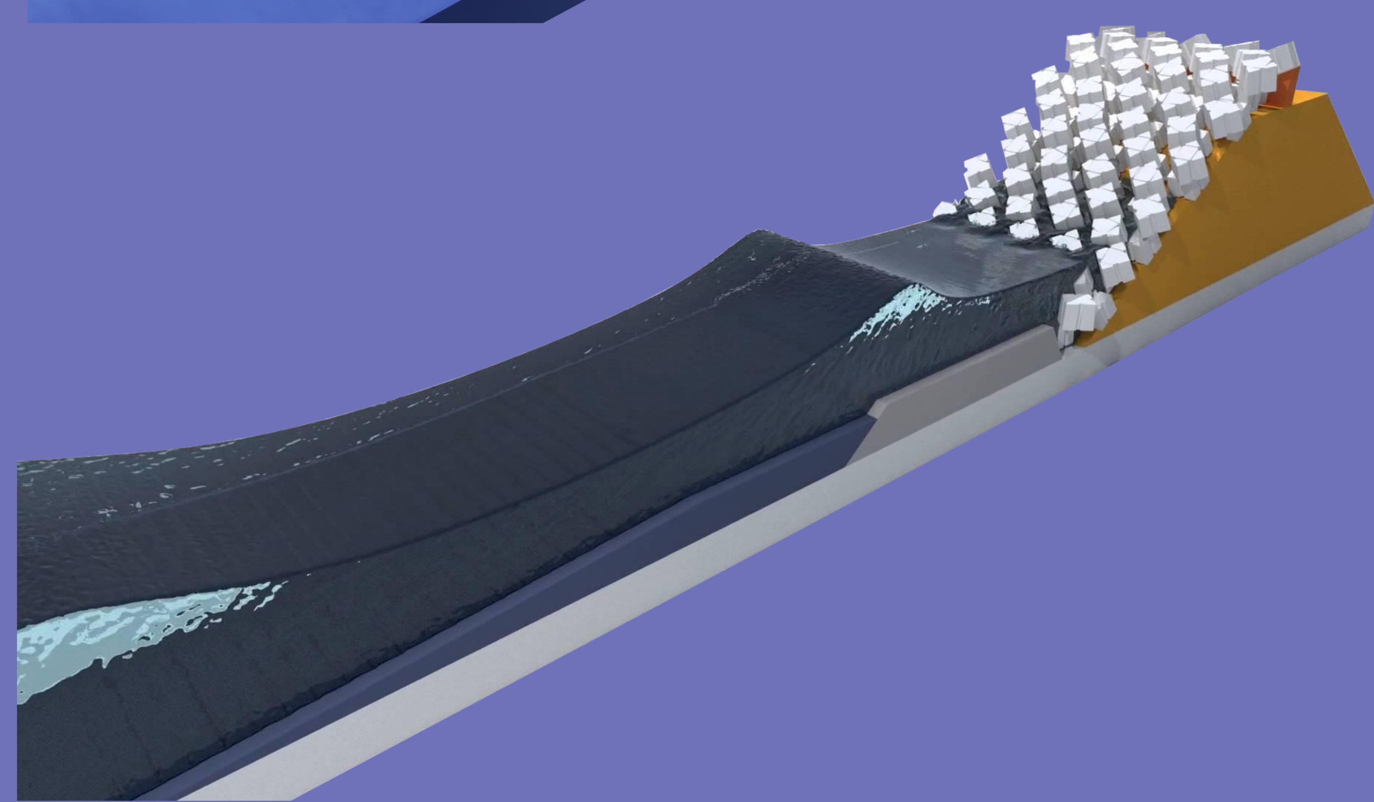




4. COMPUTATIONAL FLUID DYNAMICS (CFD)

When it is necessary to model extreme wave conditions, breaking waves and strong non-linear effects, the previous modelling types are lacking the complexity; they are simplified versions of the full set of equations. Computational fluid dynamics try to solve the problem in its most complex form. A body of water is discretized into thousands to millions of 3D cells. Each of these cells needs to fulfill the governing equations. Generally, a large amount of computing power is needed to solve the equations; but the accuracy of the solution can be very high. An alternative form of CFD is the smoothed particles hydrodynamics, where the body of water is divided into millions of particles, moving according to the physical properties of water. Examples are Ansys Fluent, Flow3D, OpenFOAM, DualSPHysics.





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* = Computational Cost
= Accuracy
= Simplicity

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