Title MSc graduation

Implementation of unstructured high-order methods for spectral modelling of inhomogeneous ocean waves

Background

Recently, the Quasi-Coherent (QC) approximation has been developed for the SWAN spectral wave model (`https://swanmodel.sourceforge.io`) that includes the effects of spatial inhomogeneity on the wave statistics (Smit et al., 2015; Akrish et al., 2020). It basically generalizes the action balance equation for the generation and propagation of the statistically inhomogeneous wave field. Such fields are due to the interaction of ocean waves and swells with rapidly varying nearshore bathymetry and shear currents, and remain correlated over many wave lengths. The underlying wave spectrum represents both variance and cross-correlation contributions between non-collinear wave components in the wave field. Such a spectrum is known as the Wigner distribution and is considered as an extension of the usual variance density spectrum.

Project description

The governing equation is linear and hyperbolic with a source term added that accounts for the wave scattering due to small-scale medium variations. Such variations are rapid compared to the distance between the crossing waves (at the scale of 100−1000 m). Accordingly, the Wigner distribution can narrow and broaden rapidly during the propagation in coastal regions. In turn, the immediate spatial effects of coherent scattering, interference, refraction, diffraction and wave-current interaction can cause large-scale changes in the wave parameters; see Figure 1. This requires high-order accurate numerical

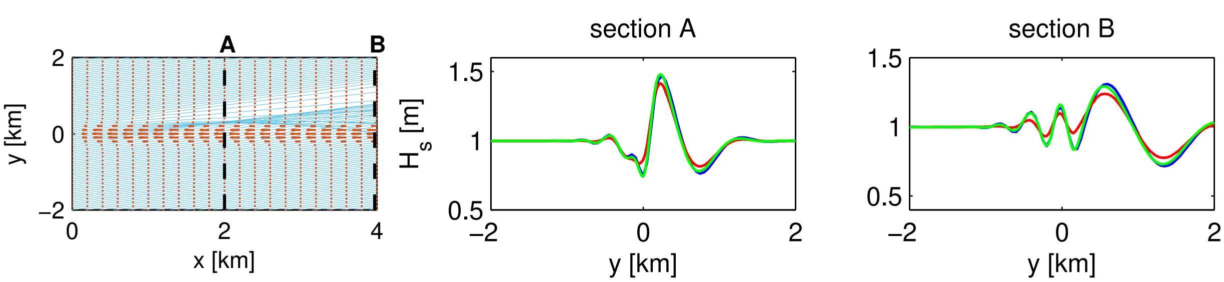

Figure 1: Wave rays over a jet-like current field (left panel) and comparison of predicted wave heights between different mesh resolutions (middle and right panels. Legend: —— structured: $h \sim 50$ m; —— unstructured: $h \sim 35$ m; —— unstructured: $h \sim 10$ m). The structured (rectilinear) grid solution is obtained with the second order BDF scheme and the unstructured (triangular) solutions are achieved using the low-order accurate compact upwind scheme.

schemes with low dispersion and dissipation errors for the advective transport of the Wigner distribution. By contrast, the conventional action balance equation does not need such high order accuracy since the spatial gradients in the variance density are rather low. For this reason, the current unstructured triangular mesh version of SWAN employs a low-order flux-conservative upwind finite difference scheme (akin to a streamline upwind finite element technique). **The aim of this MSc thesis project is therefore to develop and implement a high-order compact finite-element method in an unstructured mesh version of SWAN-QC.**

Practical information

For whom: This project is open for MSc students of the Hydraulic Engineering track of the CEG faculty and the MSc students of the Computational Science and Engineering track (Applied Mathematics) of the EEMCS faculty, with an interest in CFD research on free surface flows.

Starting date: any moment.

Prerequisites: Sufficient knowledge of fluid mechanics, ocean waves and finite elements, and good programming skills (Fortran/Python); in addition, experience with Linux OS is recommended.

Daily supervisors: Deepesh Toshniwal (EEMCS) and Marcel Zijlema (CEG).

Application process: To apply for this project, send an email with motivation and grade list to m.zijlema@tudelft.nl and/or d.toshniwal@tudelft.nl.