DGCOAST

Modeling and Analysis of Coastal Hydrodynamics and Erosion

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TEAM

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Background

The increasing risk and associated impacts have catalyzed efforts to increase our understanding of the coastal ocean environment and our ability to make quantitative predictions of coastal hydrodynamics; in particular, the impacts of currents, waves and rising water levels on coastal flooding and/or the transport and erosion of coastal sediments.
Accurate modelling of coastal ocean processes requires mathematical models which go beyond the traditional shallow water equations typically used to model long-wave ocean currents. In addition, understanding the true impacts of processes such as the sea-level rise and severe storms requires coupling such models with transport models of sediment erosion/deposition.

Approach/Methodology

Our aim has been to develop a dispersive-wave numerical code, named DGCOAST, for coastal ocean modeling, based on higher-order finite element methods on unstructured meshes, which includes appropriate wave physics at various wave-lengths and wave numbers. The code is based primarily on the so-called Serre-Green-Naghdi models which account for the interaction of long-wave and short-wave phenomena. The model will improve upon traditional numerical methods by being able to capture multi-scale wave physics from deep ocean basins to the continental shelf to complex coastal systems including barrier islands, inlet, bays, and estuaries. The resulting code will be coupled with the Exner equations for modelling bed-load transport or with existing models such as XBEACH which is a 2DH numerical model used in the simulation of nearshore circulation, coastal morphodynamics, island breaching and over wash.
After validating the code, we plan to estimate the seabed evolution around the Ria Formosa lagoon and compare our results with observations or data obtained with commercial-grade software.

Implementation Challenges

• Discretisation of the Ria Formosa region which implied requesting high-resolution bathymetric LiDAR data (LiDAR is a bathymetric and topographic multi-sensor airborne system) from the Portuguese research community and interpolating it with GEBCO (General Bathymetric Chart of the Oceans) data so that a grid that contains the entire Ria Formosa region with inlets and coastal areas and a part of the surrounding open ocean could be constructed.

• Implementation and calibration of the DGCOAST numerical code in such a way that it can switch between the nonlinear shallow water equations and the dispersive correction parts of the Green-Naghdi equations according to the coastal area where it is applied to.

• Lack of post-doctoral help at IST to run the DGCOAST code. The postdoc position was opened twice but no good candidates met the requirements of FCT (recognition of the doctoral degree in Portugal and less that 3 years since PhD). Besides, the period of time for the position (one year from November to October) was far from ideal.

Main Findings

Our numerical model shows a lot of promise to be used in studies of coastal hydro-morphodynamics driven by dispersive water waves. In fact, the numerical results highlighted in the attached file show the ability of the Green-Naghdi equations to capture hydrodynamics more accurately than the nonlinear shallow water equations in situations where dispersive wave properties are prevalent.
The hydrodynamic part of the model not only resolves accurately the water motion and the dispersive wave effects but also provides the ability to ignore the dispersive terms where needed, e.g. in surf zones, and includes wetting-drying, breaking wave detection, and slope-limiting features. The morphodynamic part (still under development) can already capture the major features of bed erosion and deposition.
Moreover, our preliminary experiments indicate that the model reduces substantially the computational effort required to perform the numerical simulations and has thus a great potential to be used in modelling hydro-morphodynamic processes caused by dispersive waves in large coastal areas such as the Ria Formosa lagoon.

Expected Impact

The DGCOAST numerical code will be of open access and thus available for researchers working in hydro-morphodynamic modelling of coastal circulation.
The software is under development but can be accessed at www.github.com/UT-CHG/dgswemv2.

Project Highlights

• A successful implementation of a dispersive wave hydrodynamic model based on hybridized discontinuous Galerkin finite element method over unstructured grids and development of a massively parallel solver which has the capacity to execute numerical simulations of water waves using both discontinuous Galerkin discretizations of the nonlinear shallow water and the dispersive Green-Naghdi equations.
• Coupling the Green-Naghdi equations (the hydrodynamic part) with the sediment continuity Exner equation (the morphodynamic part).
• Capacity of the model to capture hydrodynamics more accurately than the nonlinear shallow water equations in situations where dispersive wave properties are prevalent.
• Validation of the model with numerical experiments in the Ria Formosa lagoon area.
• Capacity of the model to estimate sediment erosion and deposition amounts due to suspended and bed load transport.