Integrated biogeomorphological modelling using Delft3D

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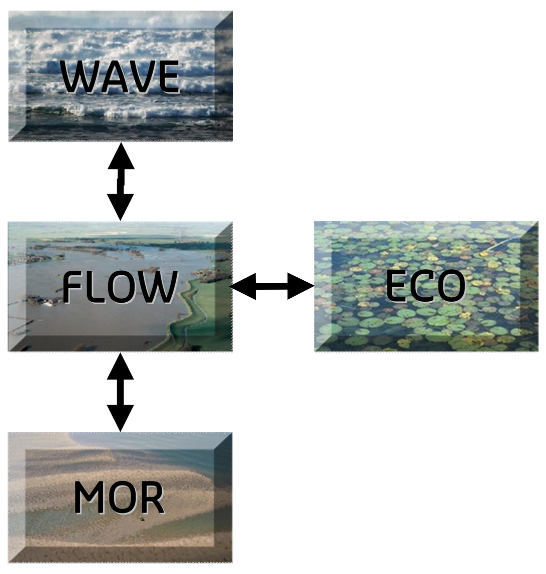
abstract

The skill of numerical morphological models has improved significantly from the early 2D uniform, total load sediment models (with steady state or infrequent wave updates) to recent 3D hydrodynamic models with multiple suspended and bed load sediment fractions and bed stratigraphy (online coupled with waves). Although there remain many open questions within this combined field of hydro- and morphodynamics, we observe an increasing need to include biological processes in the overall dynamics.

In riverine and inter-tidal environments, there is often an important influence by riparian vegetation and macrobenthos. Over the past decade more and more researchers have started to extend the simulation environment with wrapper scripts and other quick code hacks to estimate their influence on morphological development in coastal, estuarine and riverine environments. Although one can in this way quickly analyze different approaches, these research tools have generally not been designed with reuse, performance and portability in mind.

We have now implemented a reusable, flexible, and efficient two-way link between the Delft3D open source* framework for hydrodynamics, waves and morphology, and the water quality and ecology modules. The link will be used for 1D, 2D and 3D modeling on networks and both structured and unstructured grids. We describe the concepts of the overall system, and illustrate it with some first results.



* oss.deltares.nl

concepts & approach

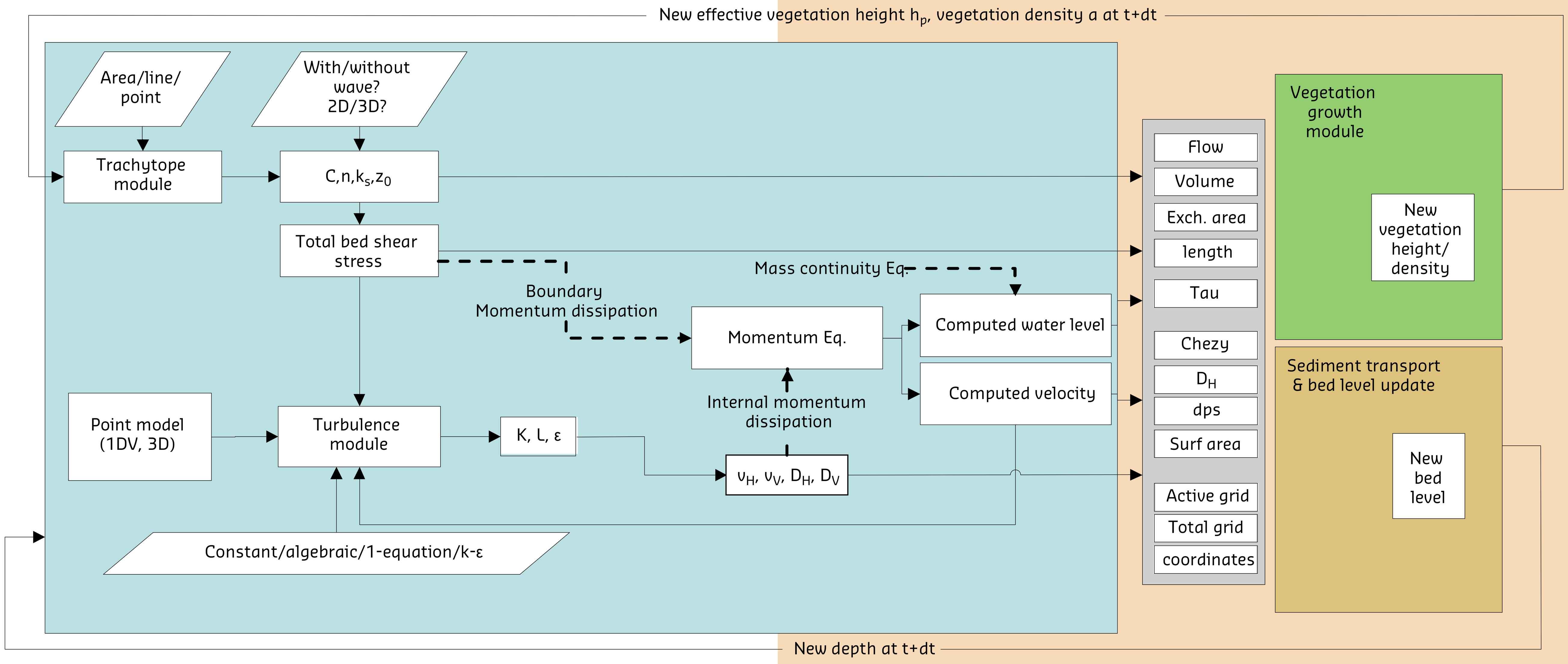
Delft3D-FLOW simulates both the hydrodynamics and morphodynamics. It passes hydrodynamic data to the Delft3D-WAVE wrapper for SWAN, which passes wave forces back to influence the currents and bed shear stresses. The morphodynamic processes include: tidal flow, tidal asymmetry (residual current), suspended sediment transport, bed load transport (with bed slope effect), adjacent dry cell erosion, sediment sorting in vertical and horizontal direction; mud segregation, and bed level update.

We have extended the time loop of the Delft3D-FLOW module with an option to have two-way communication with the Delft3D-WAQ/ECO module. The latter module comes by default with a pre-filled process library with over 500 substances and 700 associated processes with which up to 5000 process parameters are associated. Users can make any sub-selection of these processes, but for this application we have used the Open Process Library (OPL) feature to extend the module with our own variables and processes. The new processes include vegetation growth and mortality, spatial expansion, seed dispersal and competition within one species and between two species.

Extending the process library requires only

- the specification of the meta data for the new main variables, here: average height, age, and density of the simulated vegetation specifies, and
- a FORTRAN routine with standardized interface for each new process included.

The vegetation characteristics per computational cell averaged over the various species is passed back from the WAQ/ECO module to FLOW. The vegetation characteristics can subsequently in FLOW be used to compute the flow resistance (in 2D depth averaged mode) or to generate a 3D profile of vegetation stems which results in both direct flow blockage and turbulence generation. In both cases the bed shear stress will be reduced within the vegetated areas. The vegetation parameters are also passed on to WAVE to affect the wave pattern.



example application

The wetland in Nisqually estuary, south of Puget Sound, US, is planned to be restored by removing the dike ring along the seaside. Concerns have been raised on the ecological features and morphology change in the near future caused by the dike removal project. Three geographical elements are involved, i.e. Puget Sound (salt water source), Nisqually River (fresh water source) and the Nisqually estuary between them. The main forces then include tidal force and river flow. Sediment type is varying from sand to clay. More than 12 vegetation species exist in this area. The complex interaction of ecological processes and morphological processes make this area of great interests for integrated eco-morphological modelling practice.

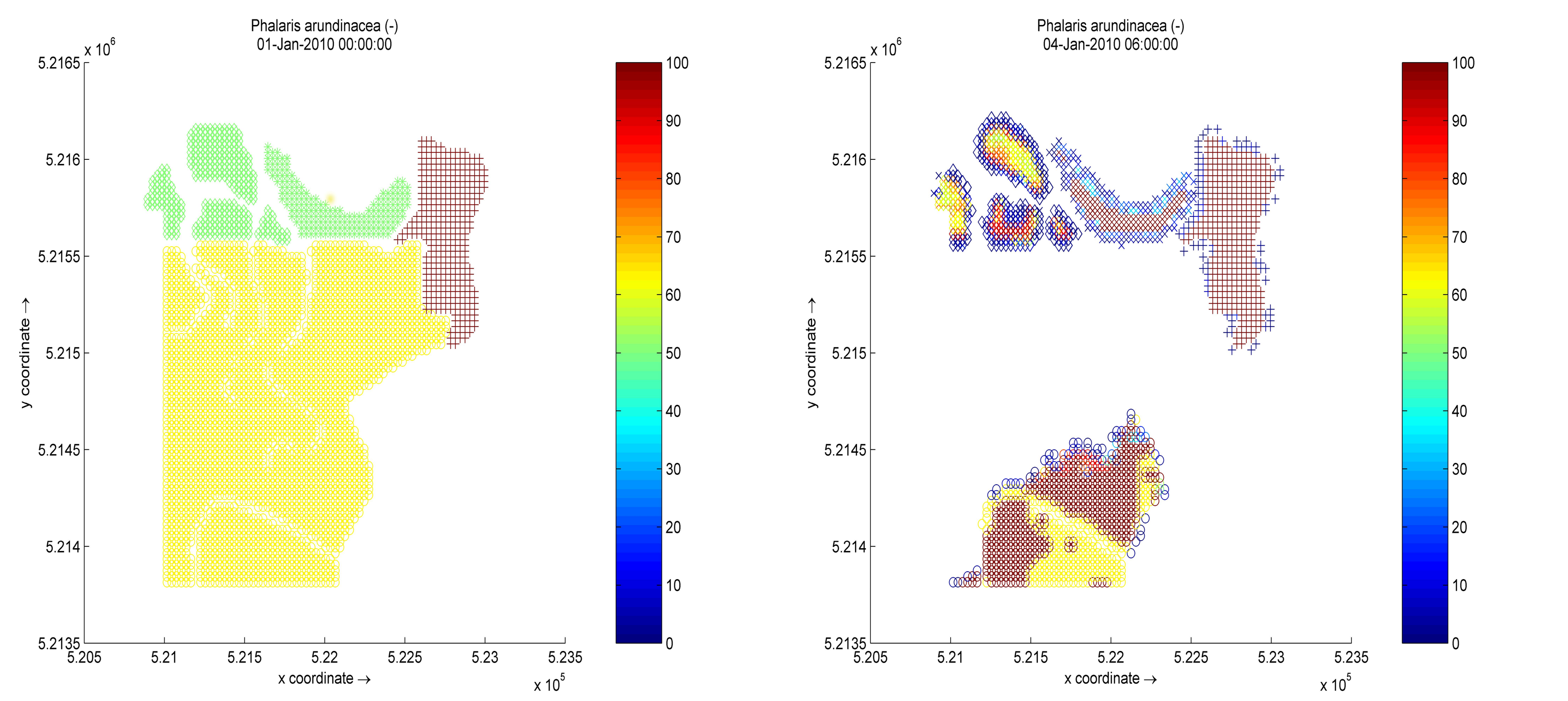
Nisqually estuary before (2009 before the removal of the dike, in the left panel) and 7 months after dike removal (June, 2010, in the right panel) (from Google Earth). The red square indicates the model area.

Vegetation species modeled in this case. From left to right: a) Phar (Phalaris Arundinacea), a type of initial fresh water vegetation; b) Caly (Carex Lyngbyei) as a type of pioneer salt marsh vegetation; c) Dist (Distichlis Spicata) , a type of salt marsh vegetation; d) Savi(Salicornia Virginica), a kind of slow spreading salt marsh vegetation (pictures from http://plants.usda.gov/).

simulation results

After the bank removal, ecological features react rapidly. The vegetation species distribution changed dramatically due to the inundation of the saline water. The model results are preliminarily compared with the satellite images.

After the bank removal, without vegetation effect, the cumulative sedimentation volume in 6 years in the original embanked area is around 100k m3, while incorporating the vegetation effect, the volume increased 10 times, to 1M m3, which in turn helps the vegetation spread because of higher elevation after sedimentation. With higher river discharge, the sedimentation volume increase another 10 times, to 10M m3 . And moreover, the sedimentation pattern changes. It seems that the river channels tend to be eroding instead of depositing, which may need more measurement to verify.



Simulated vegetation distribution before (in the left panel, initial condition) and 7 months after the restoration project (in the right panel). The color of the markers shows the percentage of capacity for each species. The species Phalaris Arundinacea as "o"; Carex Lyngbyei in "+"; Distichlis Spicata in "x", and Salicornia Virginica in "diamond" (From model)

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