Multiscale challenges in bio-geomorphic modeling of tidal marshes

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1. Introduction

Landscape evolution of tidal marshes results from processes operating on a very wide range of spatial and temporal scales. For example, scale-dependent vegetation-flow-sediment feedbacks around vegetation patches (order of m^2) have been shown to play an important role on creek network formation at the landscape scale (km^2): by obstructing the flow, laterally expanding vegetation patches lead to flow concentration and channel formation between them (Temmerman et al., 2007). From a temporal point of view, landscape evolution (decades) is inextricably linked to tidal oscillations (hours), because flooding is the main mechanism for channel erosion and sediment delivery to the marsh platforms (Fagherazzi et al., 2012).

If numerical models are powerful tools to quantify nonlinear feedbacks between tidal mash ecosystems, morphology and sediment processes (Fagherazzi et al., 2012), innovative strategies are needed to integrate such multiscale processes at decent computer cost (Wu et al., 2016). It is probably even more the case if vegetation dynamics is simulated using stochastic processes (e.g. random establishment), requiring to run ensemble of simulations for a single scenario or parameter set.

In this communication, we will present a novel approach where hydro-geomorphology developments and vegetation dynamics are simulated at two different grid resolutions.

2. Methods

Our numerical model (Figure 1) is based on the finite element suite of solvers TELEMAC, which is used to simulate hydrodynamics and geomorphic development at a medium grid resolution (5m). It is combined with Demeter, an in-house developed cellular automaton to simulate plant establishment, lateral expansion and die-off. Because cellular automata require much less computational power than traditional partial differential equation models, our vegetation model can operate at a much finer grid resolution (0.25m). Compared with a traditional model where all processes are simulated solving partial differential equations at the fine grid scale, this two-grid approach is estimated to reduce computation time by a factor of 10,000.

The other novelty of our approach is the use of computationally effective upscaling and downscaling techniques to transfer variables between the hydro-geomorphic and vegetation models. For example, flow intensity is upscaled from the low-resolution hydro-geomorphic model to the high-resolution vegetation model to estimate establishment, lateral expansion and die-off probabilities.

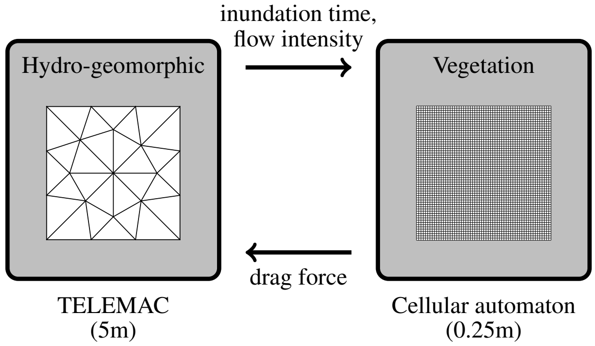

Figure 1. Schematic representation of the model coupling.

On the other way, the vegetation distribution is downscaled from the high-resolution vegetation model to the low-resolution hydro-geomorphic model to compute the drag force exerted by plants on the flow, following the formulation by Baptist et al. (2007).

3. Applications

This new multiscale bio-geomorphic modeling approach will be applied on an idealized marsh test case to investigate the variety of landscape patterns resulting from different vegetation types with different establishment and lateral expansion strategies.

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