New Analytical Approaches for the Assessment of Shoreline Evolution in the Vicinity of Coastal Structures

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Motivation

GOAL: Development of new analytical solutions to the problem of shoreline evolution, which could incorporate time-varying input-data, and describe more complicated morphological situations than in the past.

Specifically, the case of shoreline evolution in the vicinity of a groyne and a river delta has been examined as well as sediment transport between successive groyne compartments.

Borth beach

As a case-study, Borth beach in Wales was chosen, (Figure 1a). The River Dyfi on its right side acts as a net source of sediment, (Figure 1b). Wave action causes serious erosion problems on the beach.

For this reason a new coastal defence scheme has recently been constructed (Figure 1c), consisting of shore normal and shore parallel rock structures.

Hindcast wave-data over a 12 years time-span is available for the models' evaluation.

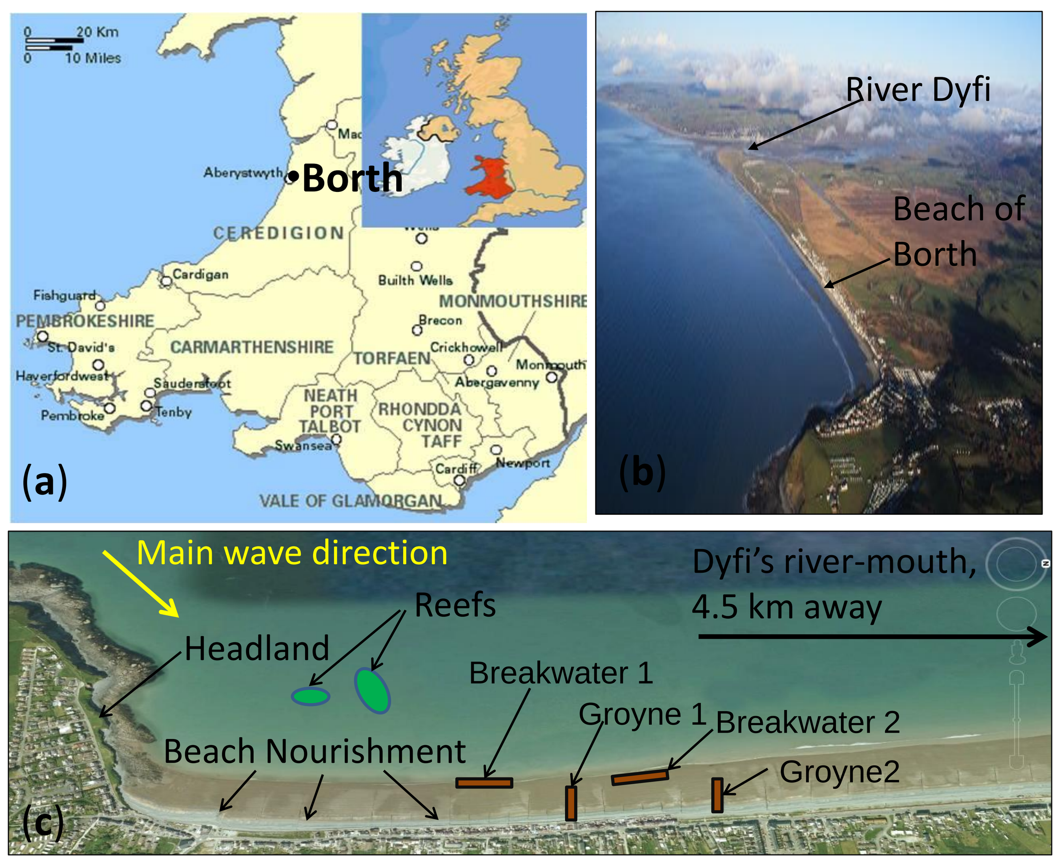


Figure 1.

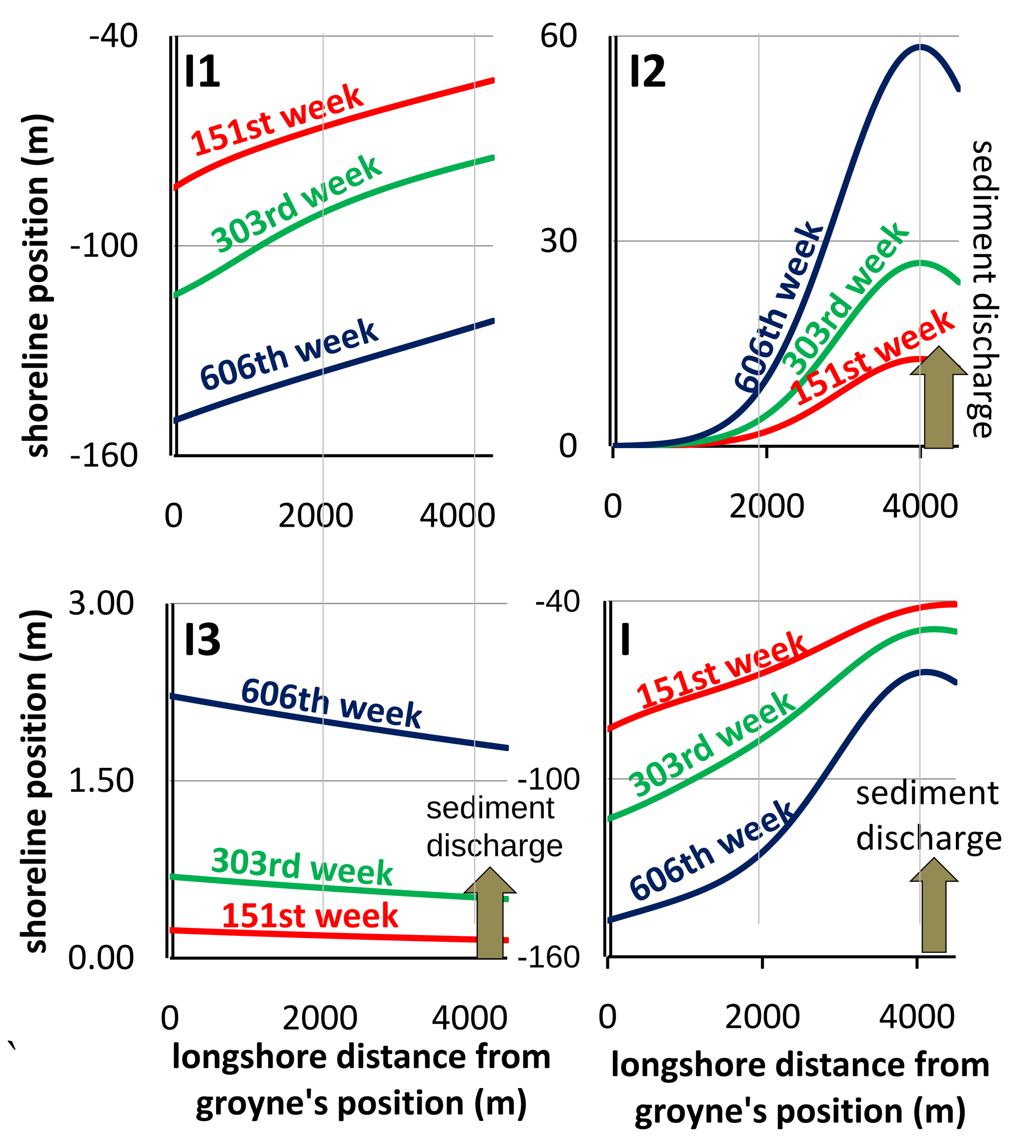
First Approach

METHODOLOGY: Only the area on the right side of Groyne 2 up to the river-mouth was considered for the shoreline assessment:

By applying Laplace transforms, a new analytical solution was developed.

Discretization in time of this analytical solution was achieved with a Heaviside scheme (Walton and Dean 2011; Valsamidis et al. 2013).

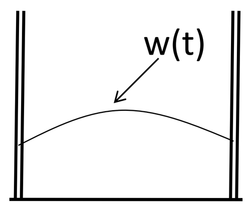
RESULTS: Evaluation of the model was performed. The first term of the analytical solution corresponds to the impact of wave action (**I1**); the second one to the formation of the river's delta (**I2**); and the third one to the accretion caused near the groyne due to the river's sediment discharge (**I3**). The final solution **I** is given as the sum of **I1**; **I2**; and **I3**:



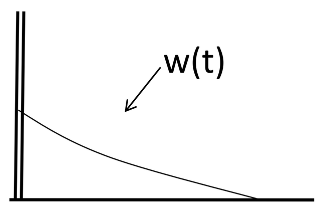
Second Approach

METHODOLOGY: A combination of existing semi-analytical solutions was used for the simulation of the whole case-study. They have gained the epithet "semi-analytical" because although they are derived analytically, their evaluation is performed by numerical means.

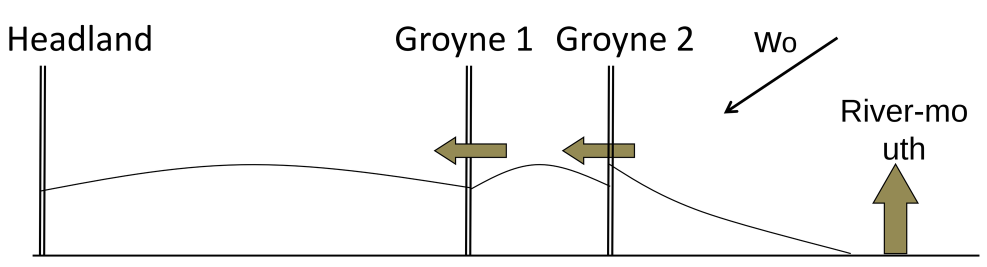
The first such solution (Zacharioudaki and Reeve, 2008) to be used, describes shoreline evolution in an impermeable groyne compartment:



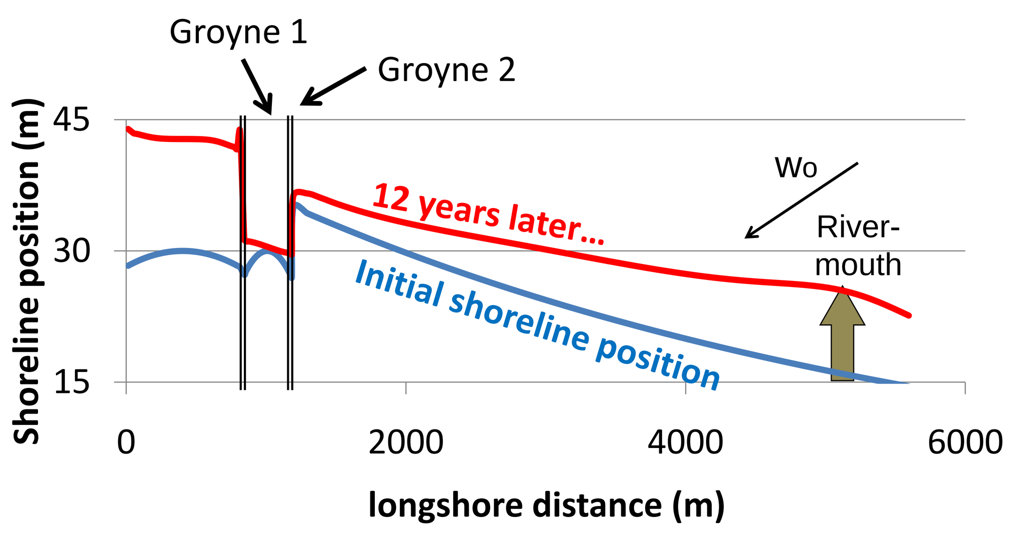
The second one introduced by Reeve (2006) describes shoreline evolution in the vicinity of an impermeable groyne:



By deploying a suitable boundary condition, the two semi-analytical solutions were combined considering groynes 1 and 2 permeable, according to the following scheme:



RESULTS: A pilot application is presented for a constant wave incident propagating towards the beach:



Discussion

In the first approach the Heaviside technique has been used for the discretization in time not only of the wave forcing but also of the sediment discharge from the River Dyfi.

Moreover, the 3rd term (**I3**) of the analytical solution constitutes an innovation since up to date we did not have an analytical expression for the accretion caused on the updrift side of a groyne due to the presence of a river's delta.

For the derivation of the semi-analytical solutions (Second Approach), instead of the Laplace Transforms , Fourier Cosine and Fourier Sine Transforms have been used.

The advantage of this kind of solutions is that they are derived easily and can accept time-varying input-data without any further modification as a prerequisite. The incorporation of initial beach nourishment is feasible as well. The method becomes less wieldy as the number of time steps increases.

On the other hand, the new semi-analytical solution required a significant effort for its evaluation process. For short term predictions it was relatively expensive, but is better suited for extended forecasting periods where many different wave conditions are used.

Conclusions

Analytical solutions cannot describe the level of complexity available in computational models. However, they provide a means of relatively fast evaluations of approximate solutions, indicating the principal trends of shoreline evolution. Furthermore, they are free of instability problems or the cumulative effect of rounding errors which can occur in numerical solutions, and provide a source of solutions against which to validate computational codes.

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