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Effect of surface biofilm on sediment transport implemented in a 1D model

Elena Bastianon[1], Jonathan Malarkey[1,2], Daniel Parsons[1]

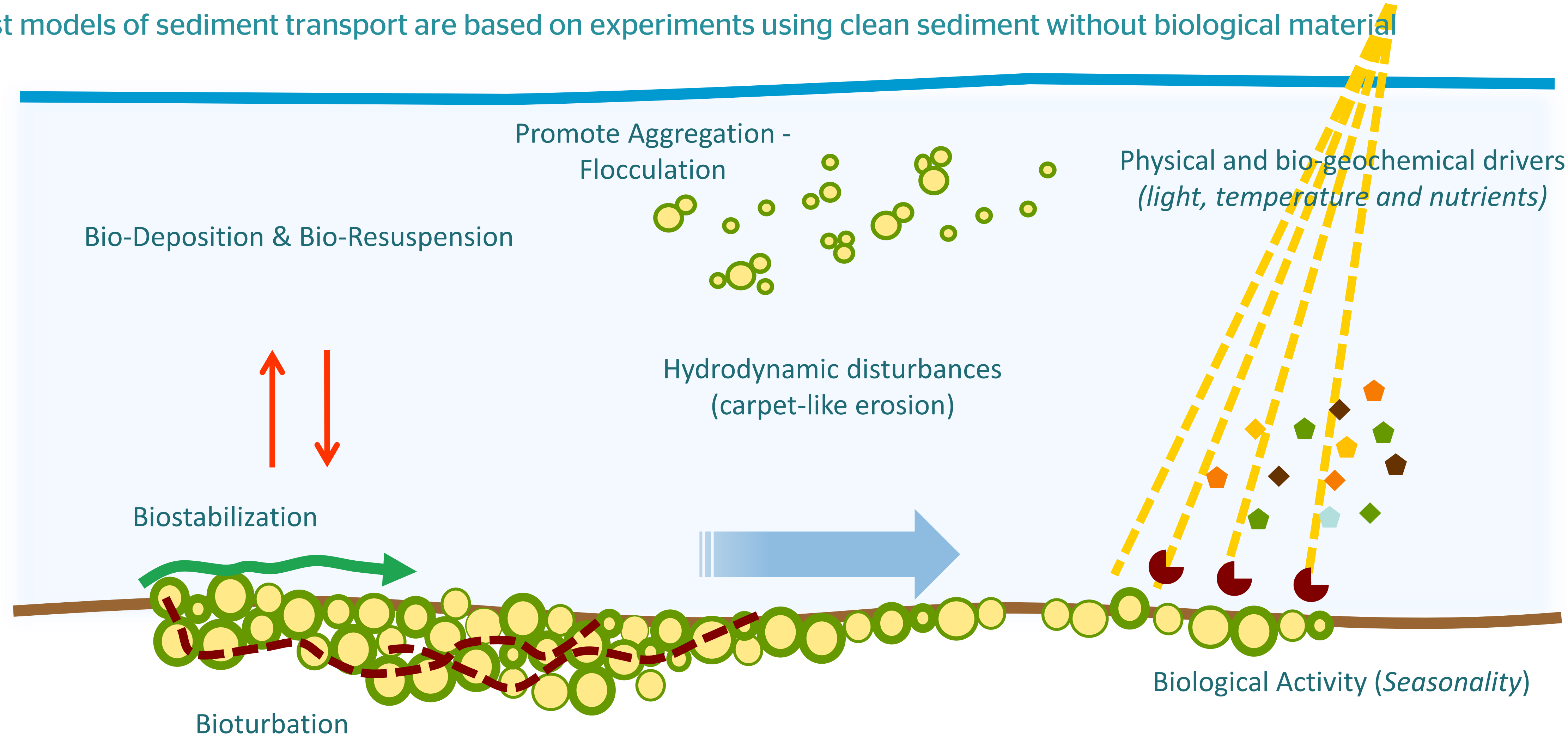
[1]Energy and Environment institute, University of Hull, UK. [2]School of Ocean Sciences, Bangor University, UK

e.bastianon@hull.ac.uk

Erosion-transportation-deposition-consolidation cycle

Benthic biofilm is commonly found in shallow coastal areas, such as intertidal environments
A biofilm consists of microbial cells, e.g., diatoms, aggregated within a gel, which is a matrix of extracellular polymeric substances

Most models of sediment transport are based on experiments using clean sediment without biological material



Objectives:

- Implement a simple morphodynamic model for growth of benthic biofilm on the bed surface and with a biofilm-dependent erodibility (biostabilization)

- Examine the larger time and space scale effects of biological system interaction

Biofilm mediated sediment

Biofilm (B) promotes biostabilization by decreasing sediment erodibility due to the binding effect of EPS on sediment particles

HP critical shear stress increase proportionally with the biofilm biomass: $\tau_{cr} = \tau_{cr,0} + \alpha B$

Biofilm logistic growth function:

$$\frac{dB}{dt} = P^B \frac{B}{1 + K_B B} - m\,(B - B_{min}) - E$$

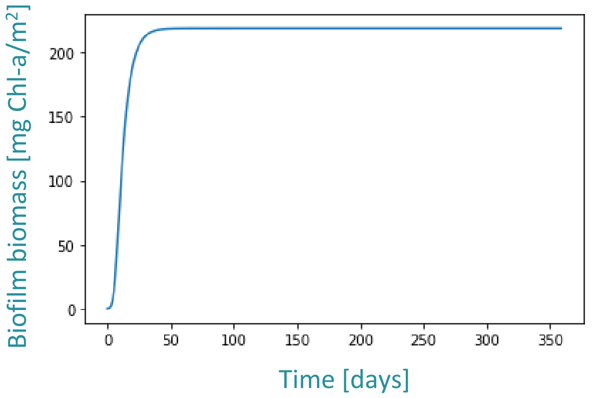
Logistic growth rate *Biomass decay* *Catastrophic removal (extreme hydrodynamic disturbances)*

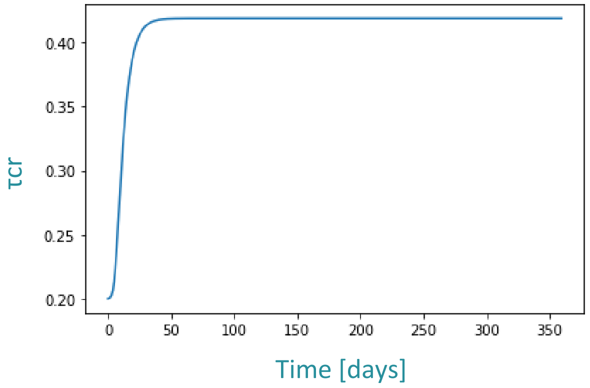
B: biofilm biomass
P_B: effective maximum growth rate
K_B: half-saturation constant for biofilm growth
B_{min}: background biofilm biomass
E: catastrophic erosion
m: self-generated detachment constant

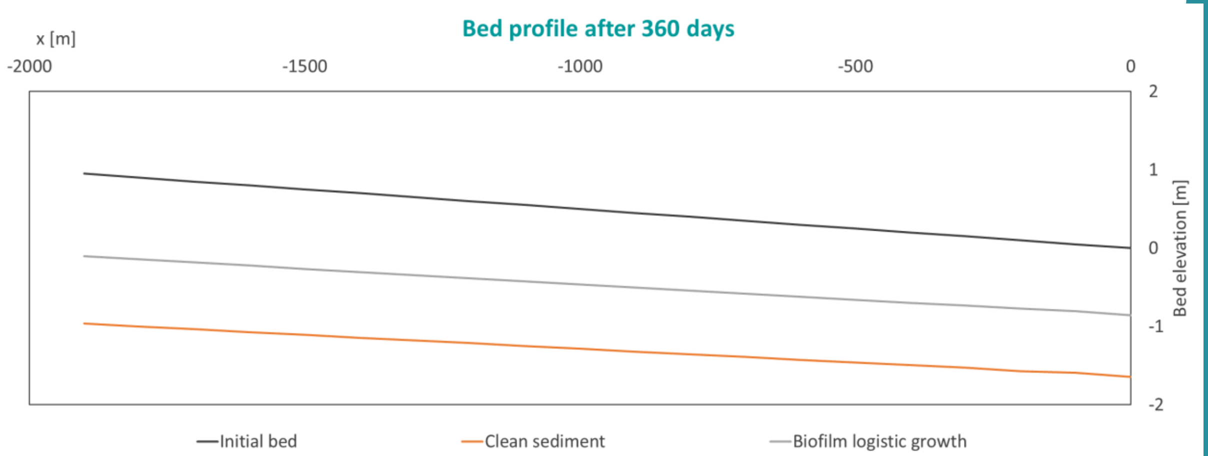
Model formulation:

- 1D shallow water equation for mass and momentum conservation
- Conservation of total bed material (bedload: *Ashida & Michiue* – suspended load: *Smith & McLean*)
- Implementation of process-based biological functioning (biofilm growth) into the morphodynamic prediction model

Case I: Logistic growth rate





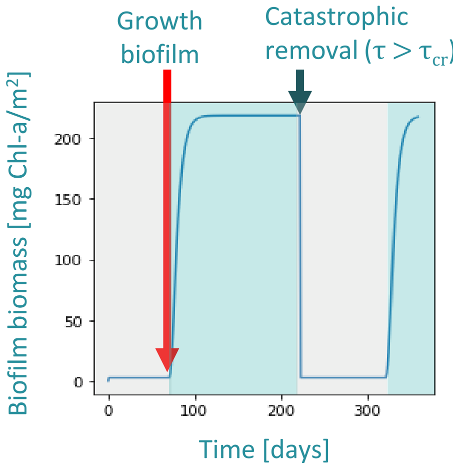


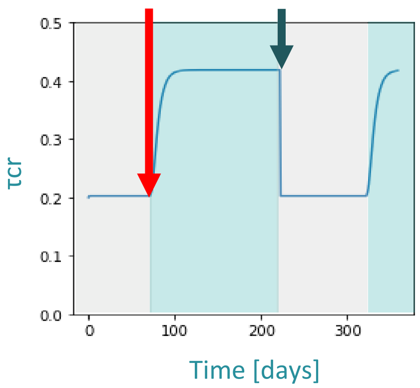
Urs et al., 1996; Boulétreau et al., 2008; Mariotti & Fagherazzi, 2012

Case II: Logistic growth rate + removal function

$$\frac{dB}{dt} = P^B \frac{B}{1 + K_B B} - m\,(B - B_{min}) - E$$

Logistic growth rate — *Biomass decay* — *Catastrophic removal (extreme hydrodynamic disturbances)*





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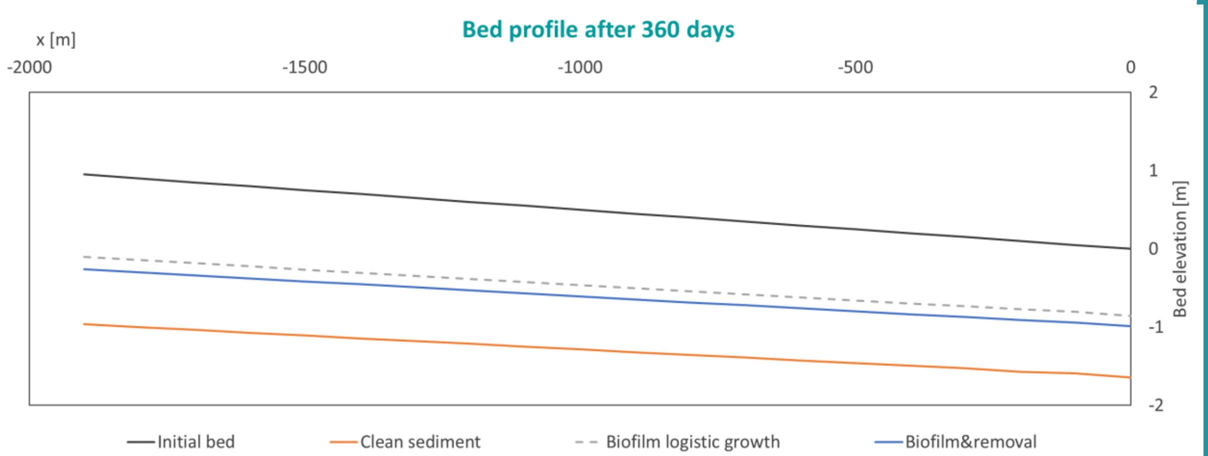
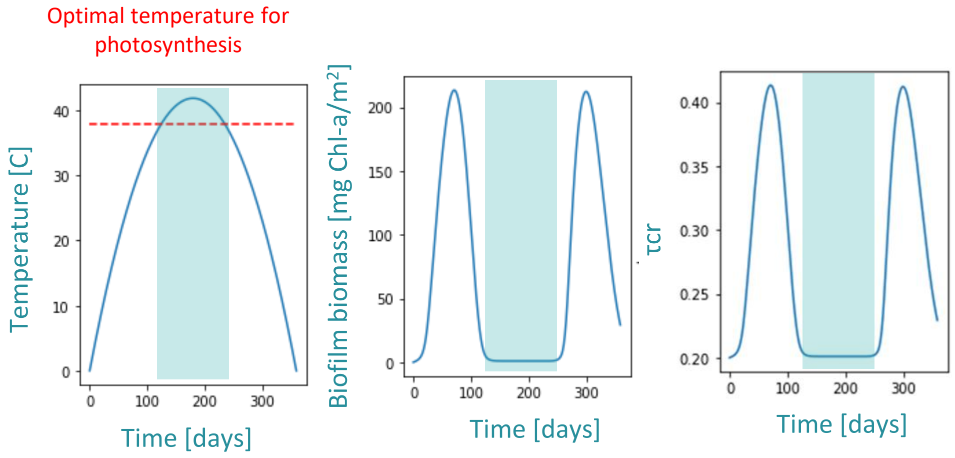
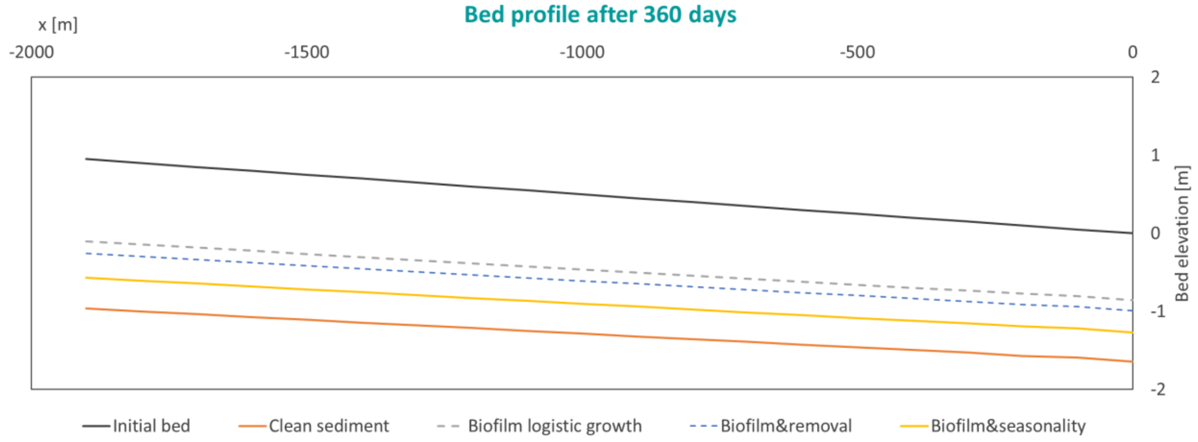


Case III: Effect of seasonality on biomass growth rate $P^B = P^B_{max} \tanh(H_{res}/E_k)$

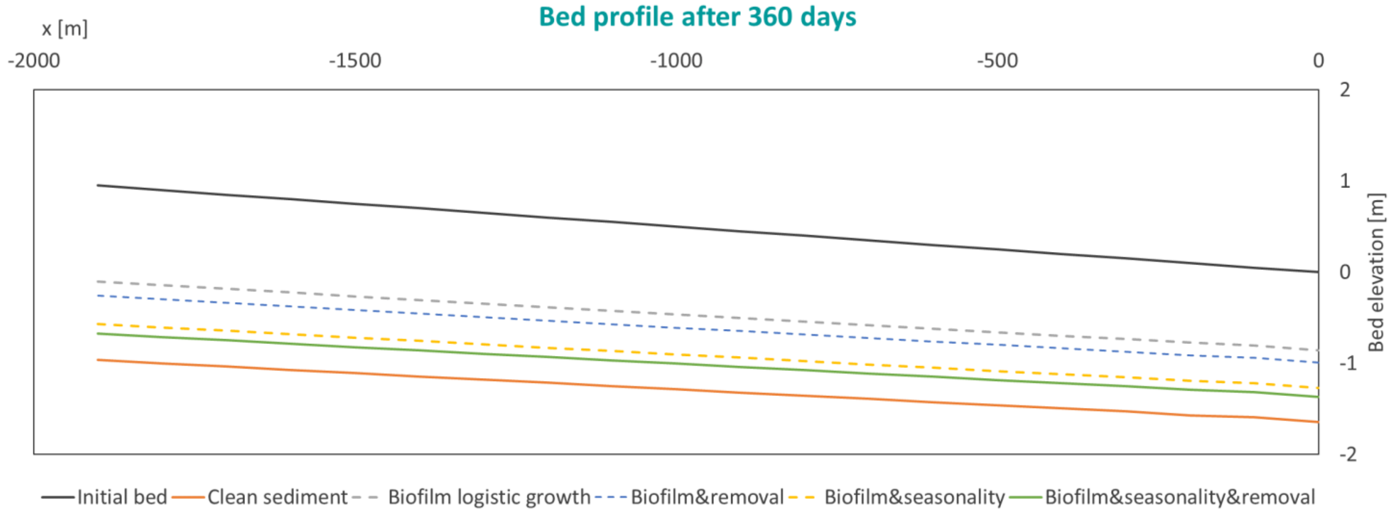
P^B_{max}: growth rate under saturation conditions
H_{res} : residual solar radiation reaching the bottom
E_k: light saturation parameter





Guarini et al., 2000; Pivato et al, 2019

Case IV: Logistic growth rate + combine effect of seasonality and removal function



Observations:

- Biofilm dynamic is regulated by the intensity and frequency of the hydrodynamic disturbances
- Seasonality (sediment temperature and light availability at the bed) significantly affect the bed stabilization properties

Next steps:

- Analyze witch are the significant parameters on biofilm development that affect the sediment transport
- Implement the model with a module that can store information of the EPS in the substratum
- Simulate a range of scenarios (sea-level, hydrodynamics, temperature) that include past and future interactions with fluvial sediment supply and ecology for idealised river-coastal transitions.