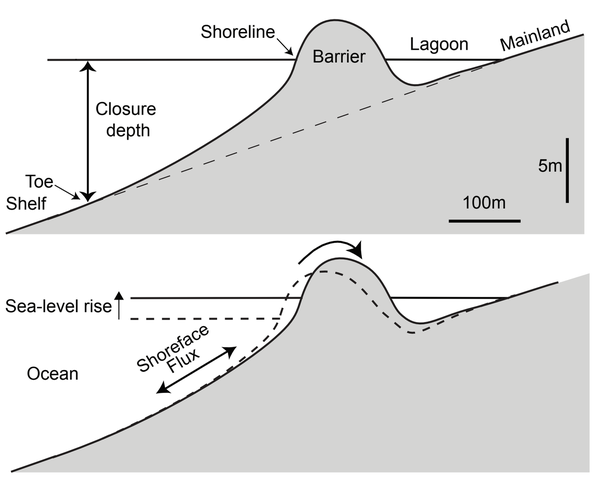
A simple model of coupled overwash-shoreface morphodynamics reveals complex modes of barrier response to sea-level rise

Jorge Lorenzo-Trueba and Andrew Ashton
Geology and Geophysics Department, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

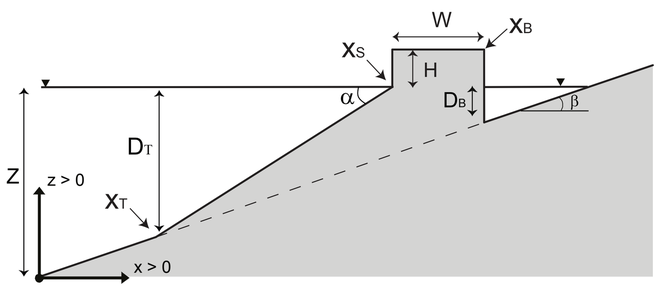
Introduction:

Barriers are known to keep pace with sea-level rise via storm overash sedimetation. Is there a threshold sea-level rise rate beyond which barriers cannot maintain themselves?



Idealized geometry:

This morphodynamic model
1) focuses on the interplay between shoreface evolution, overwash deposition and sea-level rise.
2) is simple enough to explore barrier behavior for a wide range of input parameter values.



$$\frac{dH}{dt} = \frac{Q_{OW,H}}{W} - \dot{z}$$

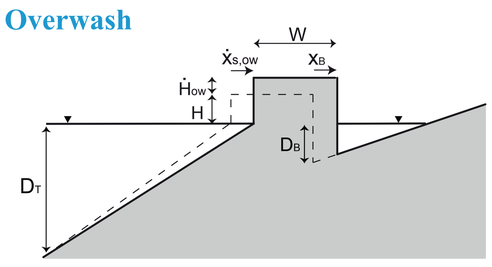
$$\frac{dx_S}{dt} = \frac{2Q_{OW}}{2H + D_T} - 4Q_{SF}\frac{H + D_T}{(2H + D_T)^2}$$

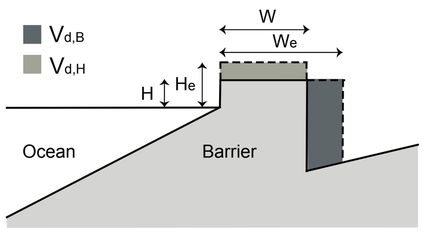
$$\frac{dx_T}{dt} = 2Q_{SF}\left(\frac{1}{2H + D_T} + \frac{1}{D_T}\right) + \frac{2\dot{z}}{\alpha}$$

$$\frac{dx_B}{dt} = \frac{Q_{OW,B}}{H + D_B}$$

Processes:

1) Overwash

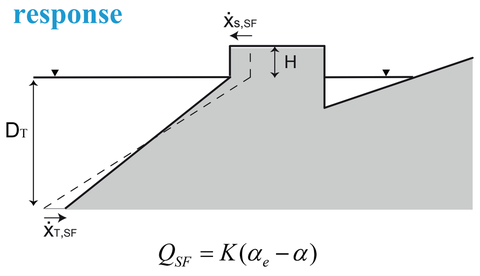




$$Q_{OW,B} = Q_{OW,max}\frac{V_{d,B}}{V_{d,\max}}$$

$$Q_{OW,H} = Q_{OW,max}\frac{V_{d,H}}{V_{d,\max}}$$

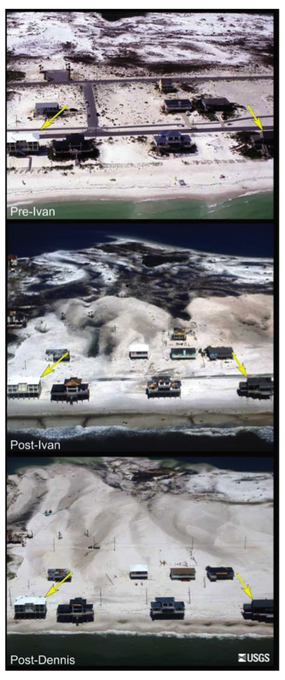
2) Shoreface response



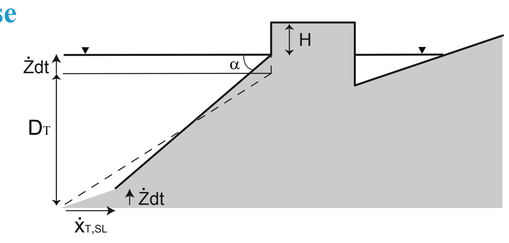
$$Q_{SF} = K(\alpha_e - \alpha)$$

K = Shoreface response rate [m^3/m/y]

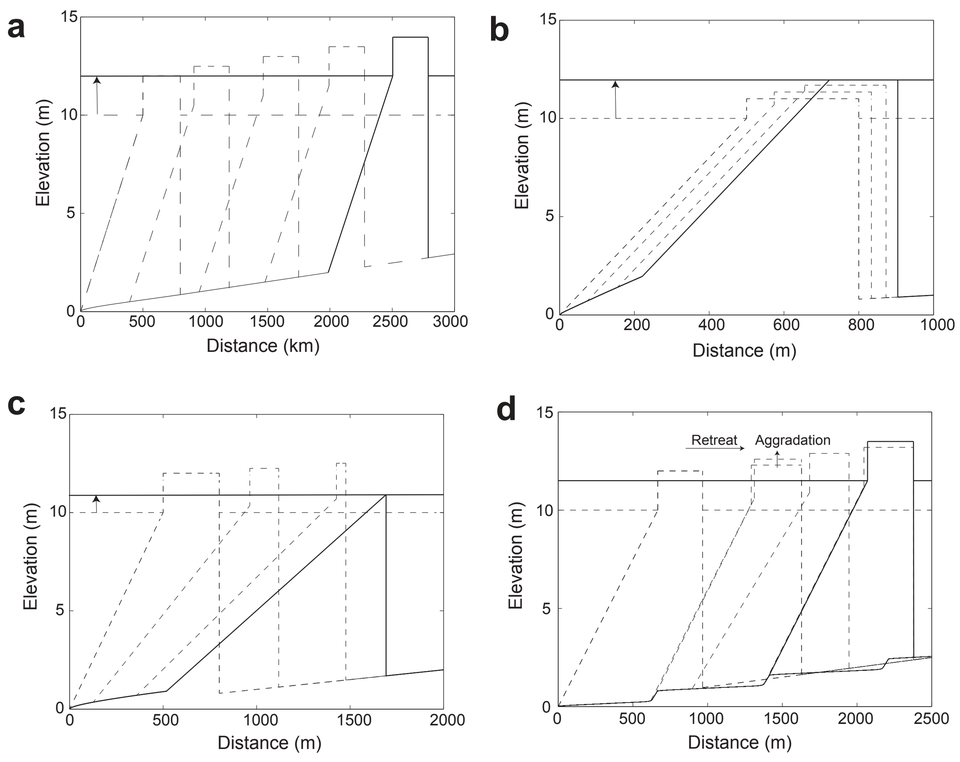
α_e = Equilibrium shoreface slope



3) Sea-level rise



Natural behaviors under constant sea-level rise:



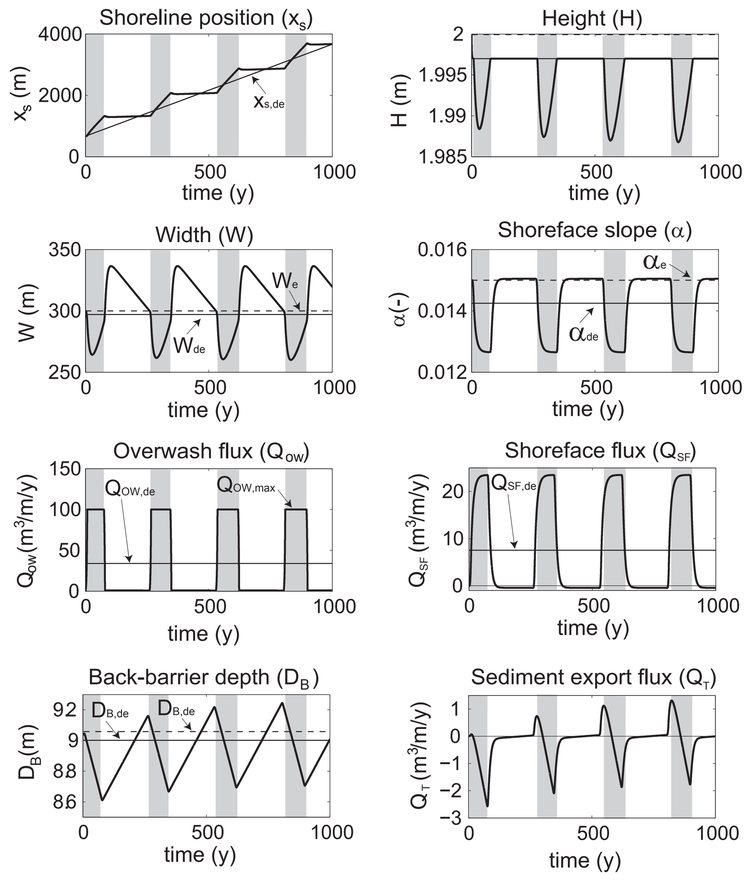
a) Dynamic equilibrium
Overwash and shoreface fluxes are sufficiently high to maintain the geometric configuration of the barrier during landward migration.

b) Height drowning
Overwash fluxes are insuficient to maintain the landward migration rate required to to keep in pace with sea-level rise.

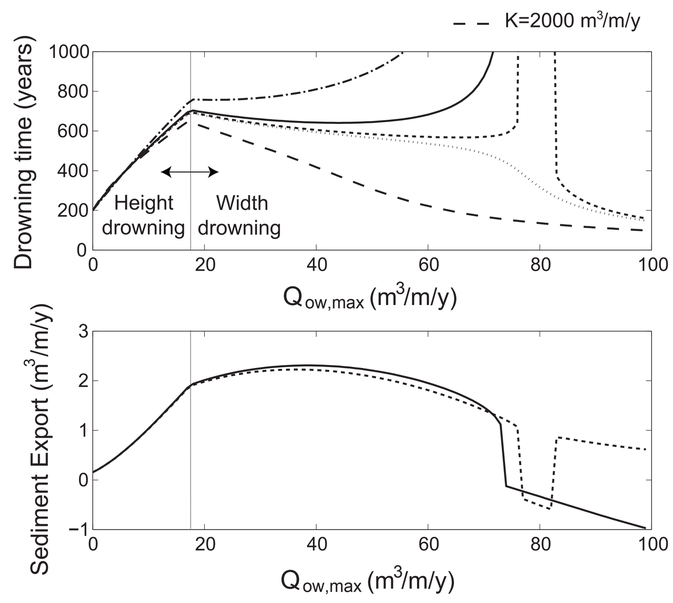
c) Width drowning
Low shoreface response rate, which results in a rapid loss of barrier width.

d) Periodic discontinuous retreat
Timelags in the shoreface response can lead to abrupt changes in the rate of shoreline retreat.

Discontinuous retreat:



Time of drowning:

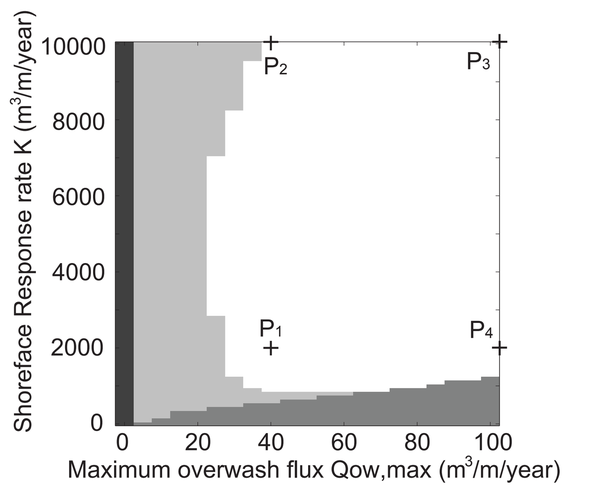


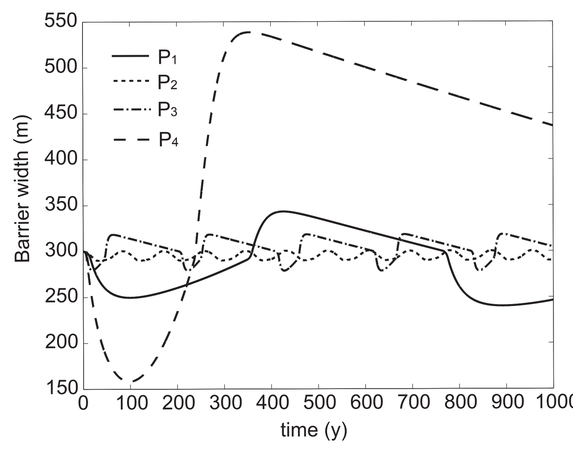
Height drowning is numerically identified when the barrier height is completely submerged (i.e., $H < 0$).

Width drowning is numerically identified when the barrier width disintegrates (i.e., $W < 0$).

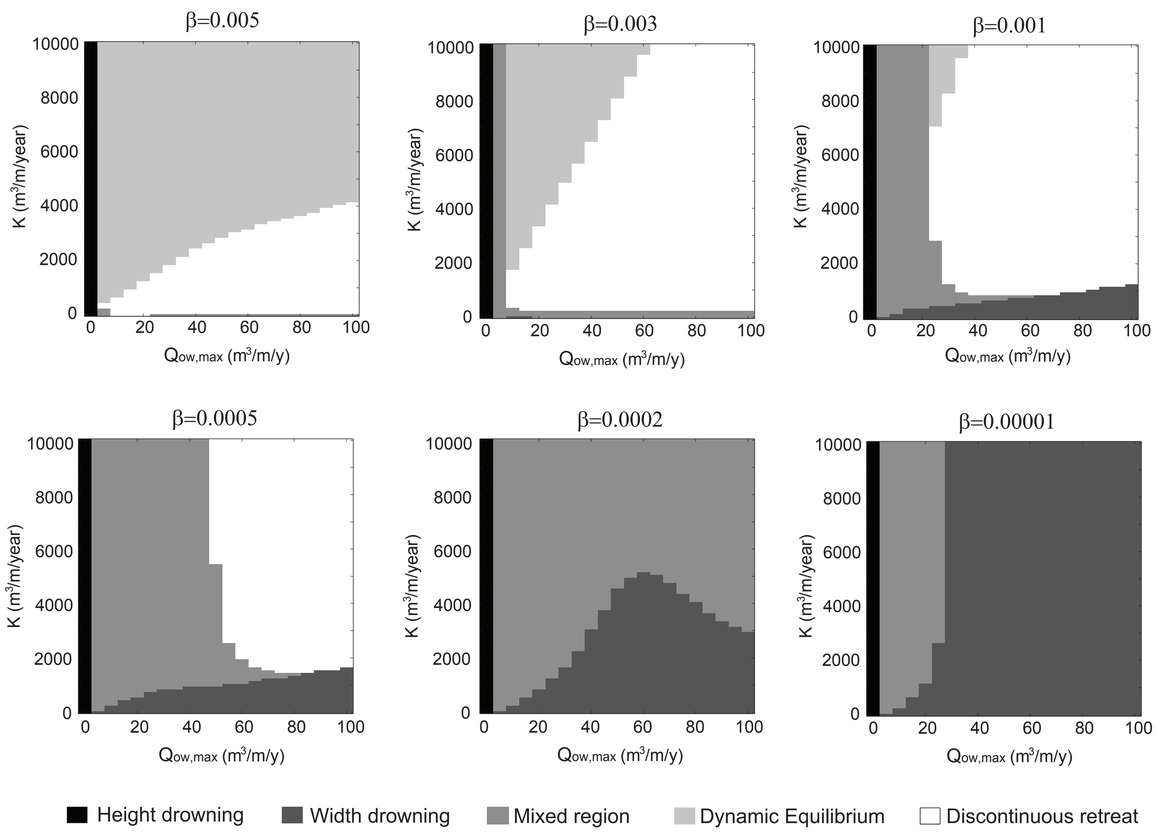
Discontinuous retreat:
(1) the mean amplitude of the barrier width oscillations must be higher than 1m, and
(2) the amplitude of the width oscillations at any time must be within 80% of the mean amplitude.

Exploring the parameter space:

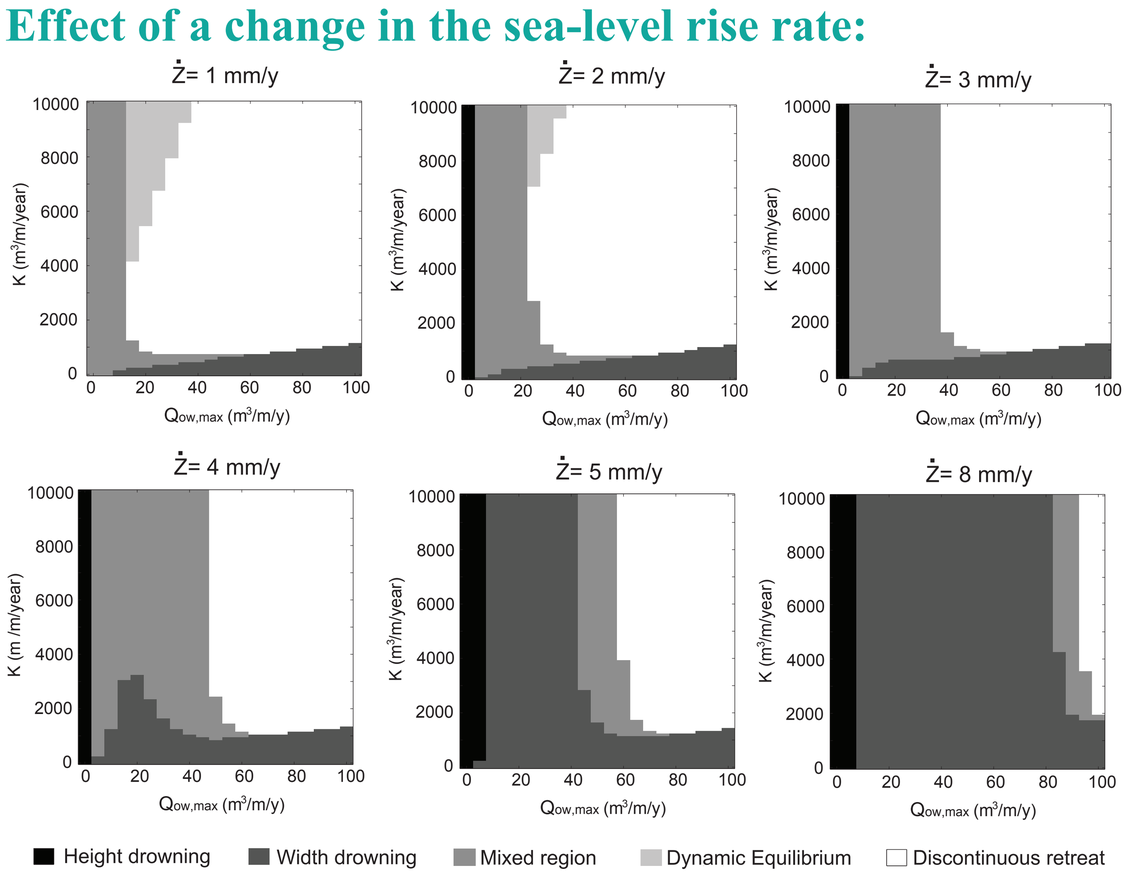




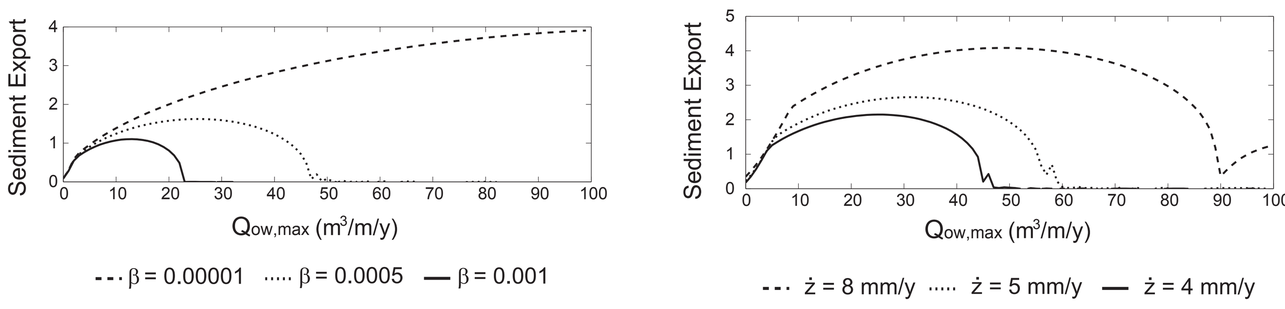
Effect of a change in back-barrier slope:



Effect of a change in the sea-level rise rate:



Sediment Export:



Future work:

- Changes in the frequency and intensty of storms
- Complex back-barrier topography
- Along-shore sediment transport
- Spatial changes in shoreface lithology

Acknowledgment:

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