XBeach modeling at various temporal and spatial scales

//oss.deltares.nl/web/xbeach

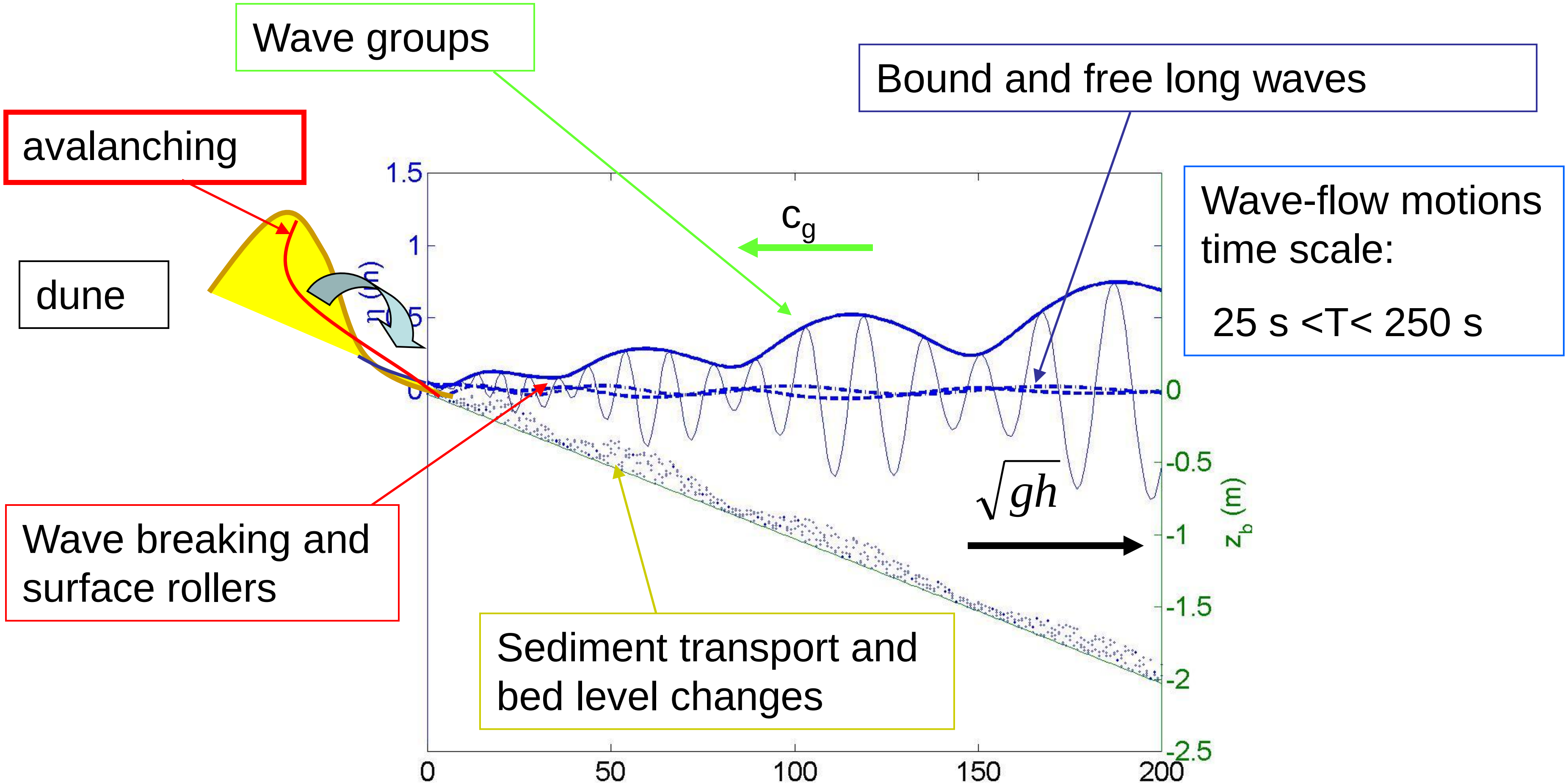
Ad Reniers, RSMAS, UM

CSDMS 2011 Annual meeting: Impact of time and process scales

USGS science for a changing world

CSDMS COMMUNITY SURFACE DYNAMICS MODELING SYSTEM

XBeach modeling concepts



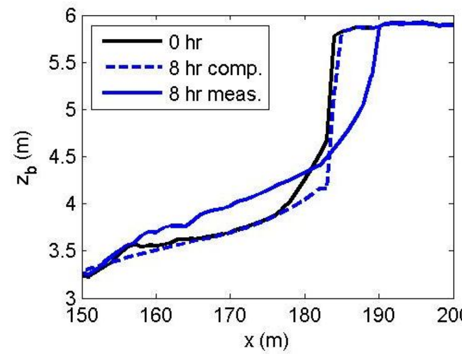
XBeach dune erosion

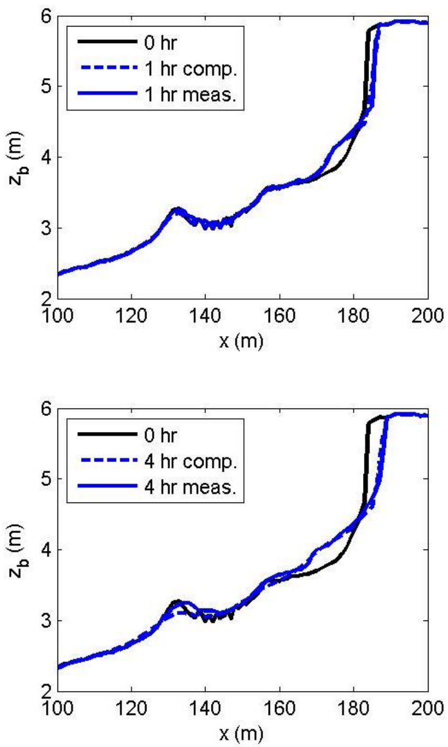
Δx~1m

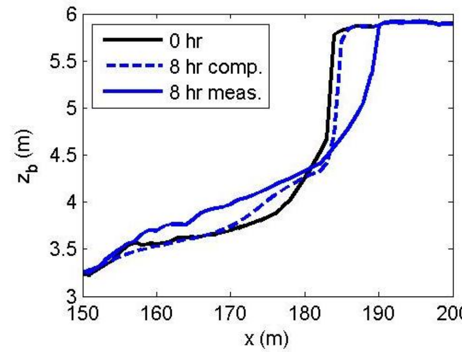
L~200 m

D~O(1)hr

No avalanching







No wave groups

Need smaller scale processes such as wave groups and avalanching for dune erosion prediction!

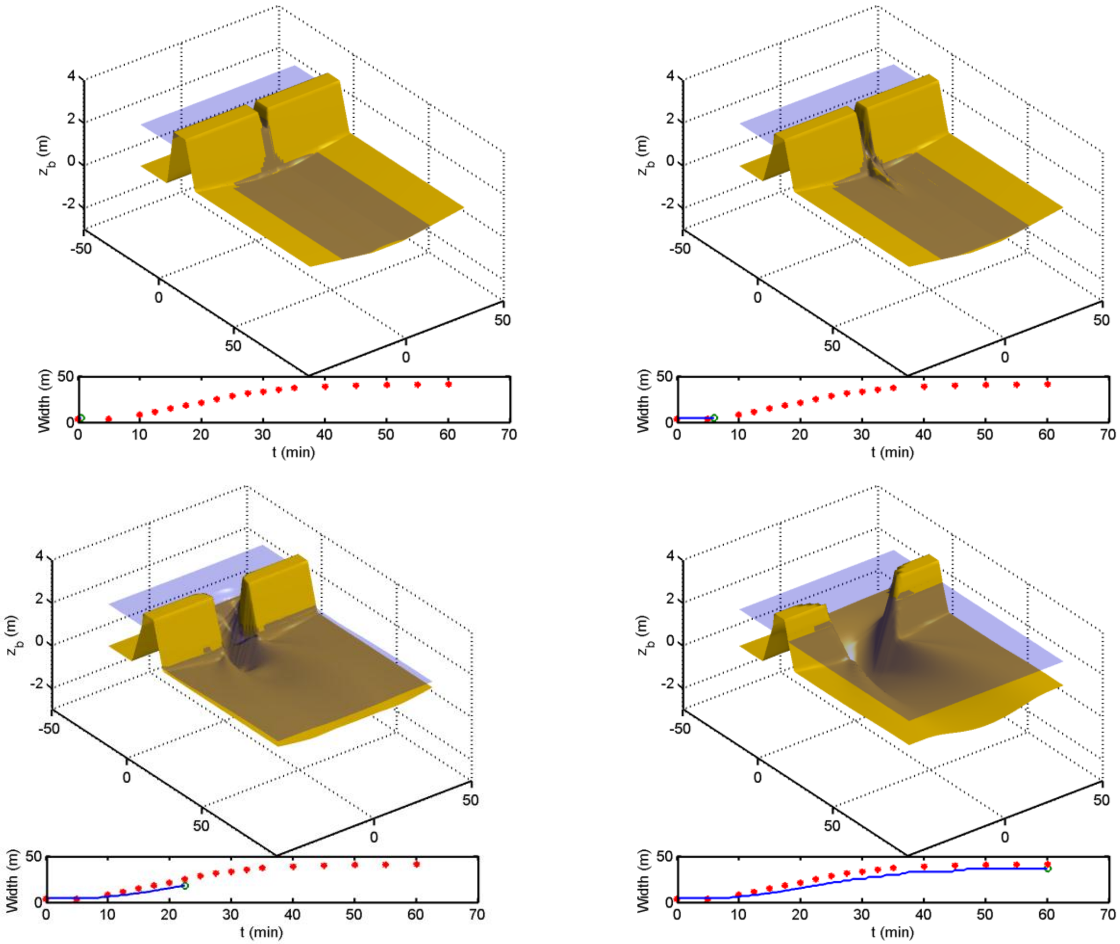
Roelvink et al., 2009

XBeach breaching

Δx, Δy ~0.5-50m

L~100 m x 100 m

D~O(10) hr



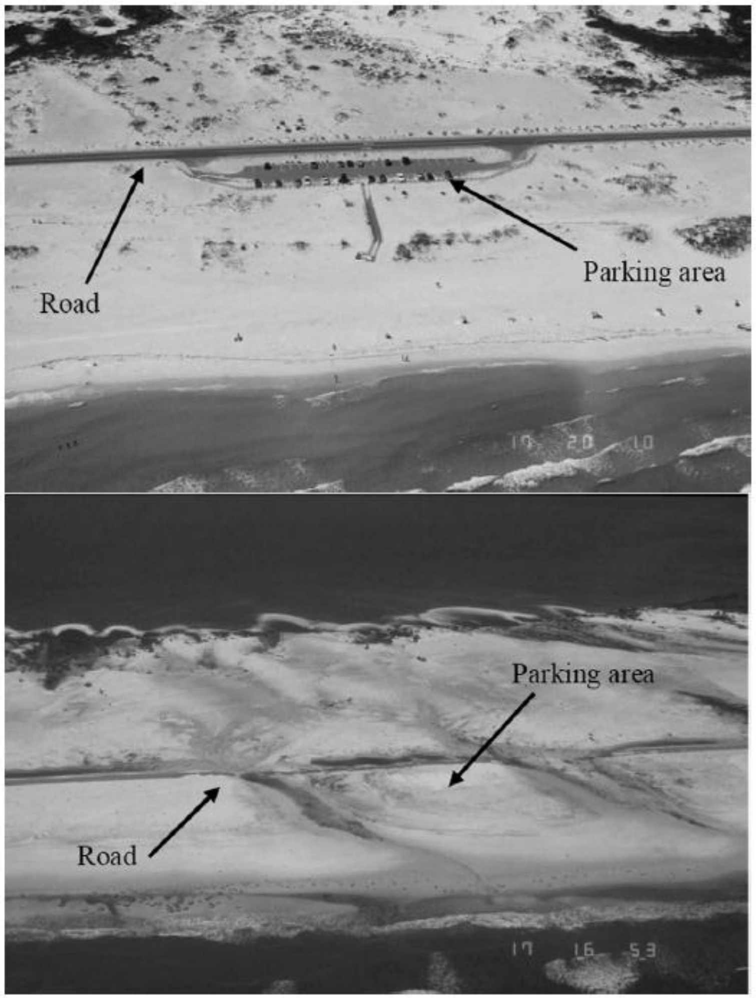
Roelvink et al., 2009

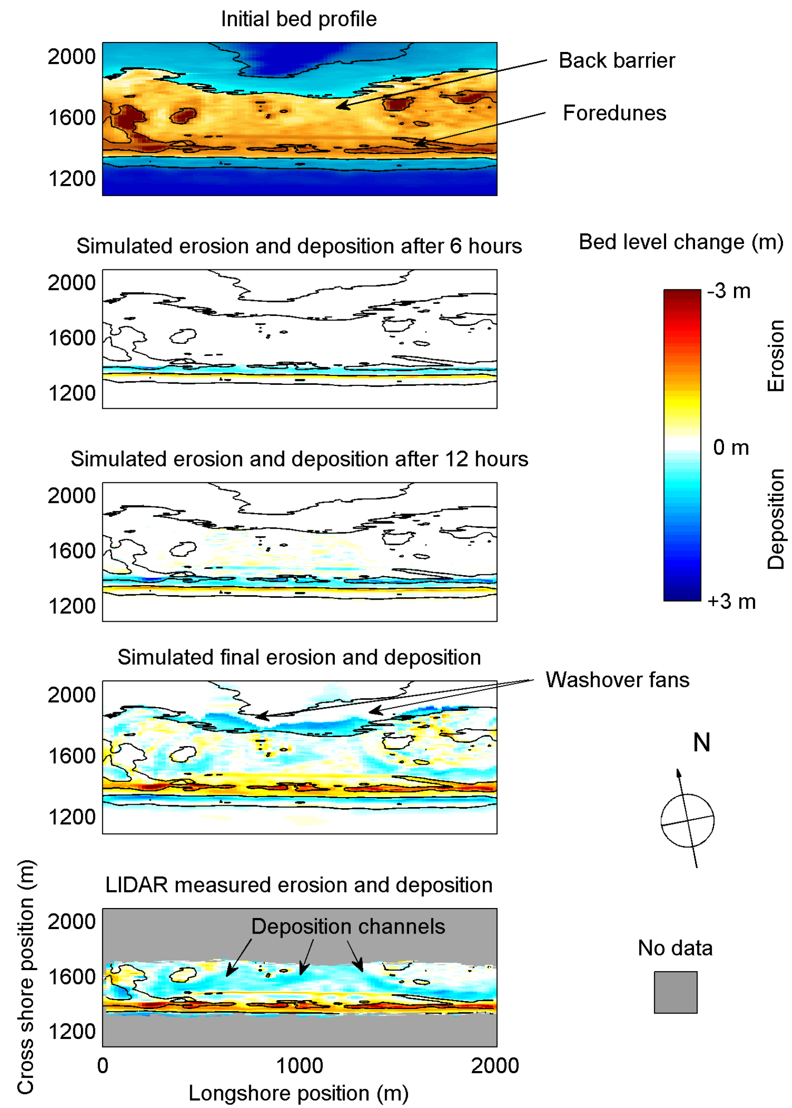
Xbeach overwash

Δx, Δy ~0.5-50m, 20 m

L~3000 m x 3000 m

D~O(10) hr





McCall et al., 2010

Good model skill!

Longer time scales

- Xbeach is typically operated on the storm time scale (order of days)!
- Need for ***longer simulations*** including ***beach recovery*** to assess coastal resilience/safety

Easier said than done!

In-model acceleration techniques

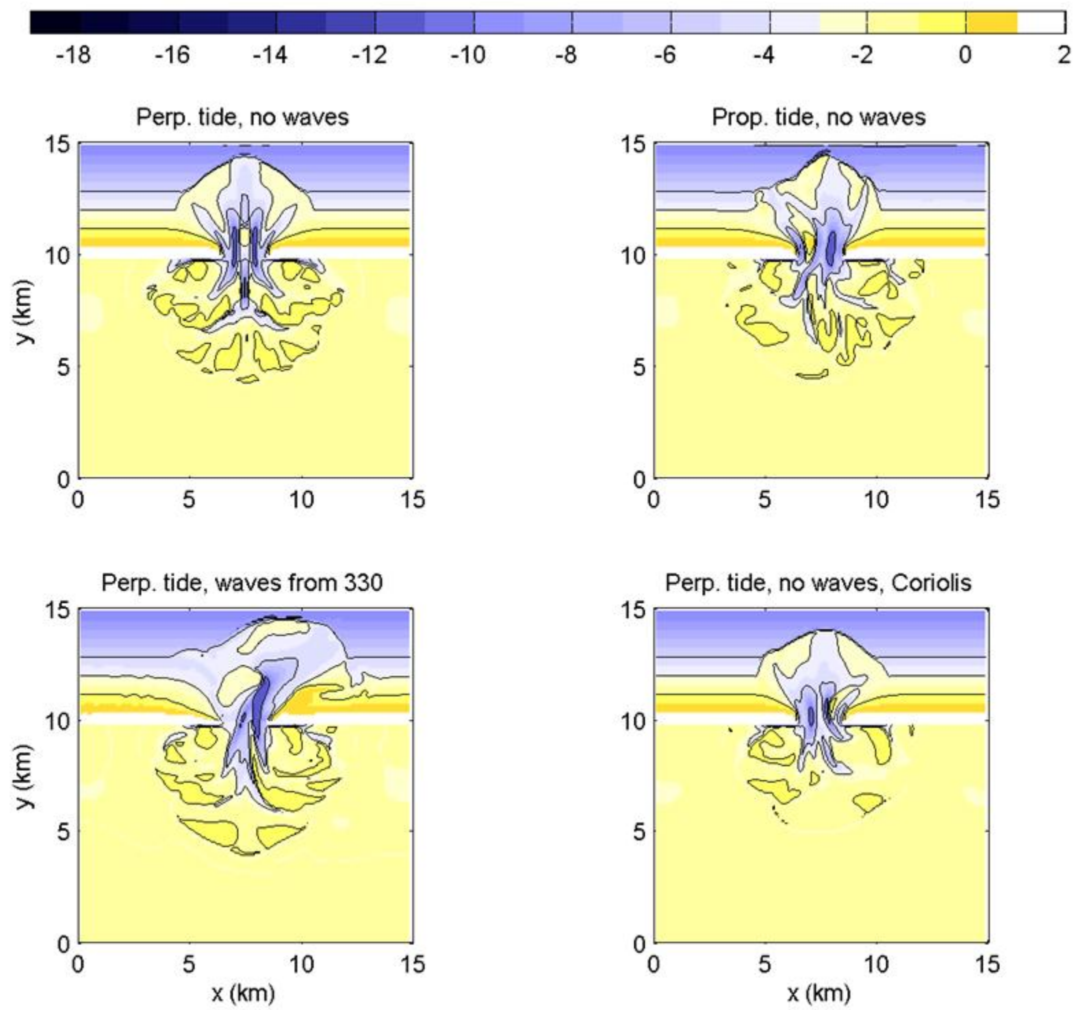
Δx, Δy ~100m, L~15 km^2

D~O(hr), morfac = 100

T = 200 days

- Morphological factor
- Wave and tidal schematizations
- Continuity correction
- Parallel computing

Does not add functionality!



Roelvink and Reniers, 2011

Short-term vs long-term

Waves
- non-linear bed-shear stress
- wave groups and swash motions
- wave breaking and turbulence
- Stokes drift

Currents
- streaming
- return flow
- rip currents
- longshore currents
- tidal currents

Sediment
- grain size
- hiding

Wind
- storm surge
- wind stress
- upwelling/downwelling

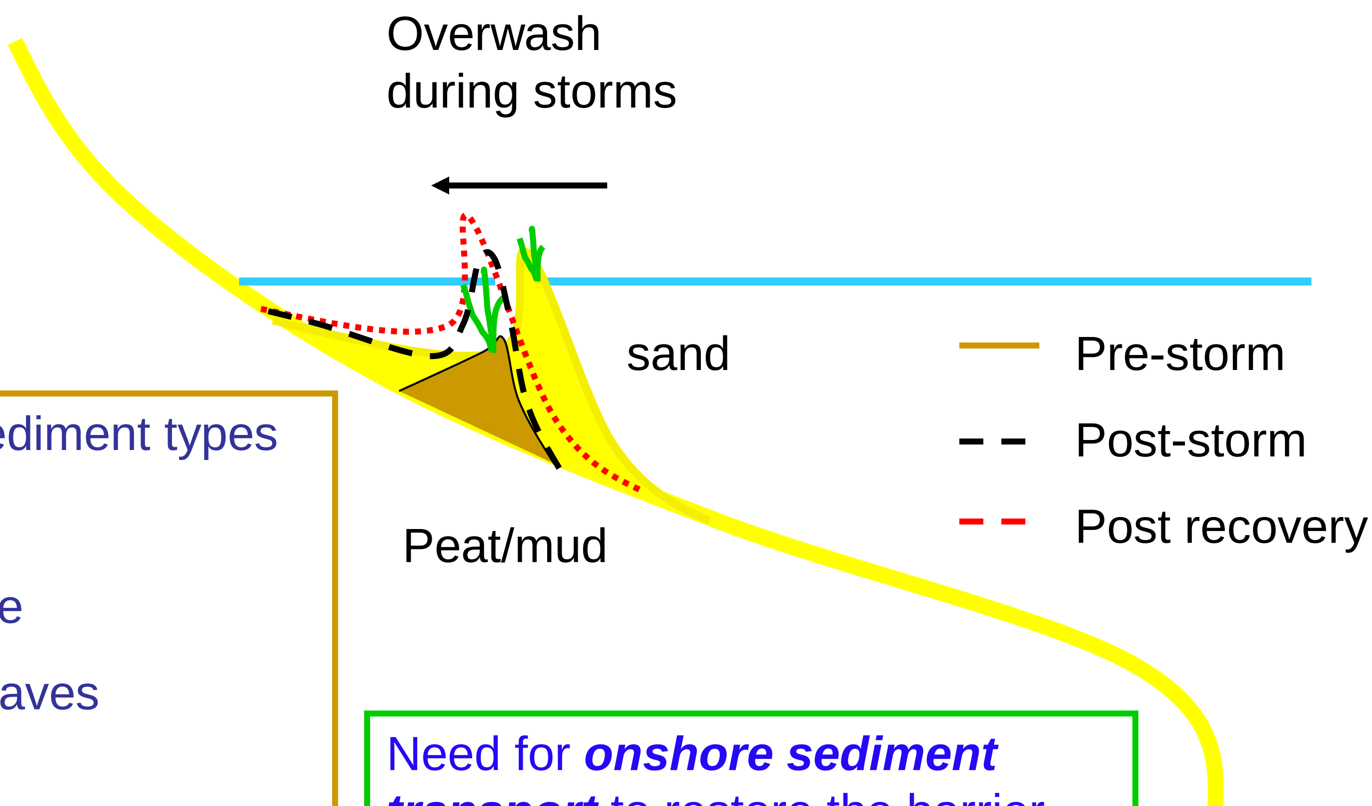
Stratigraphy
Vegetation
Urbanization
Dredging
Nourishments
Revetments
Sea level rise
Storm intensity

Barrier island roll-over
Tidal delta-formation
River mouth migration
Cyclic sand bars
Coastal erosion

Sediment transport

Big question: How to pull this off?

Example:Barrier Island Recovery

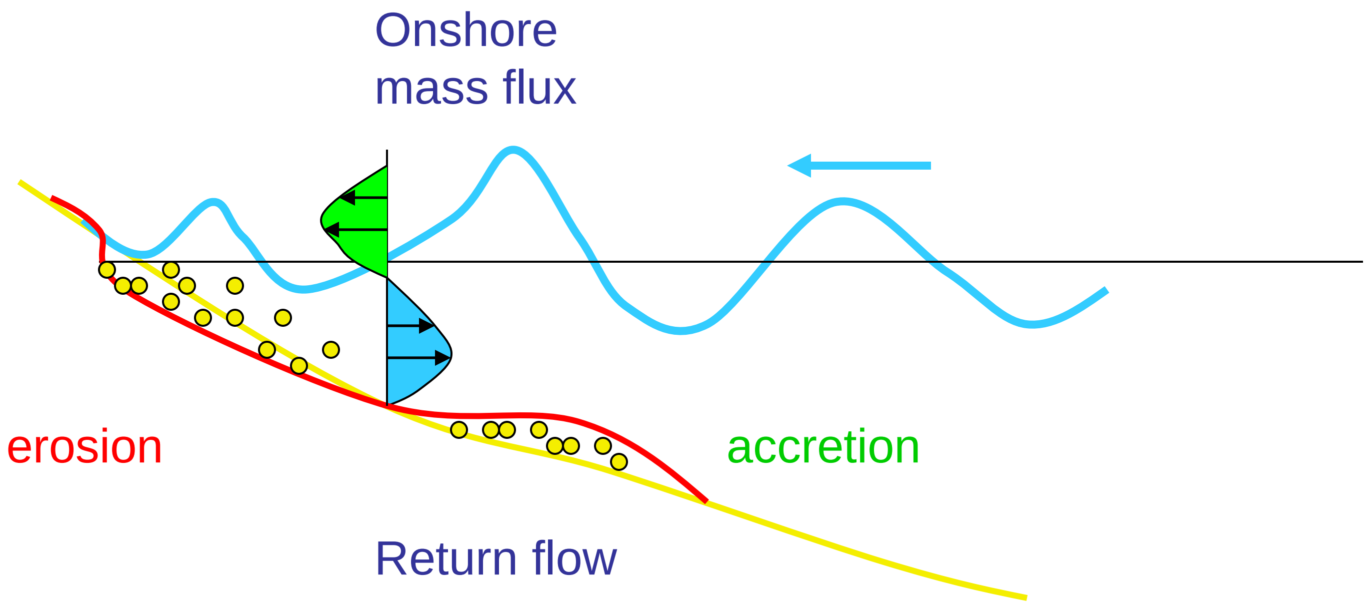


- Different sediment types
- Vegetation
- Storm surge
- Breaking waves
- Wind
- Sea level

Need for ***onshore sediment transport*** to restore the barrier island!

XBeach process modeling

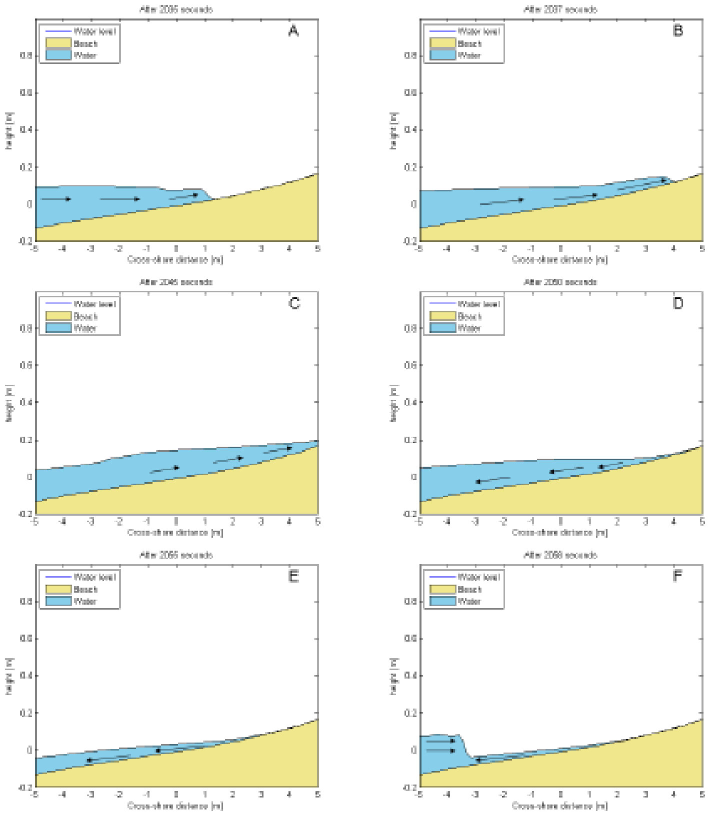
Typical xbeach modeling leads to persistent erosion of the shore line and cannot explain the profile recovery.



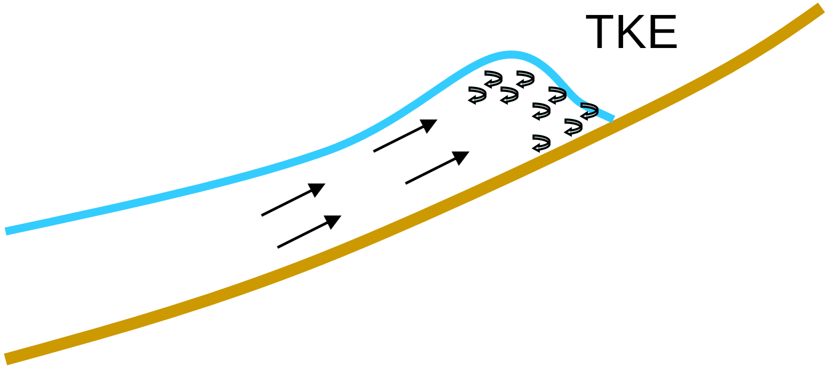
What are we missing?

Swash processes

Intra-wave XBeach



Turbulent bore transports sediment on to the beach



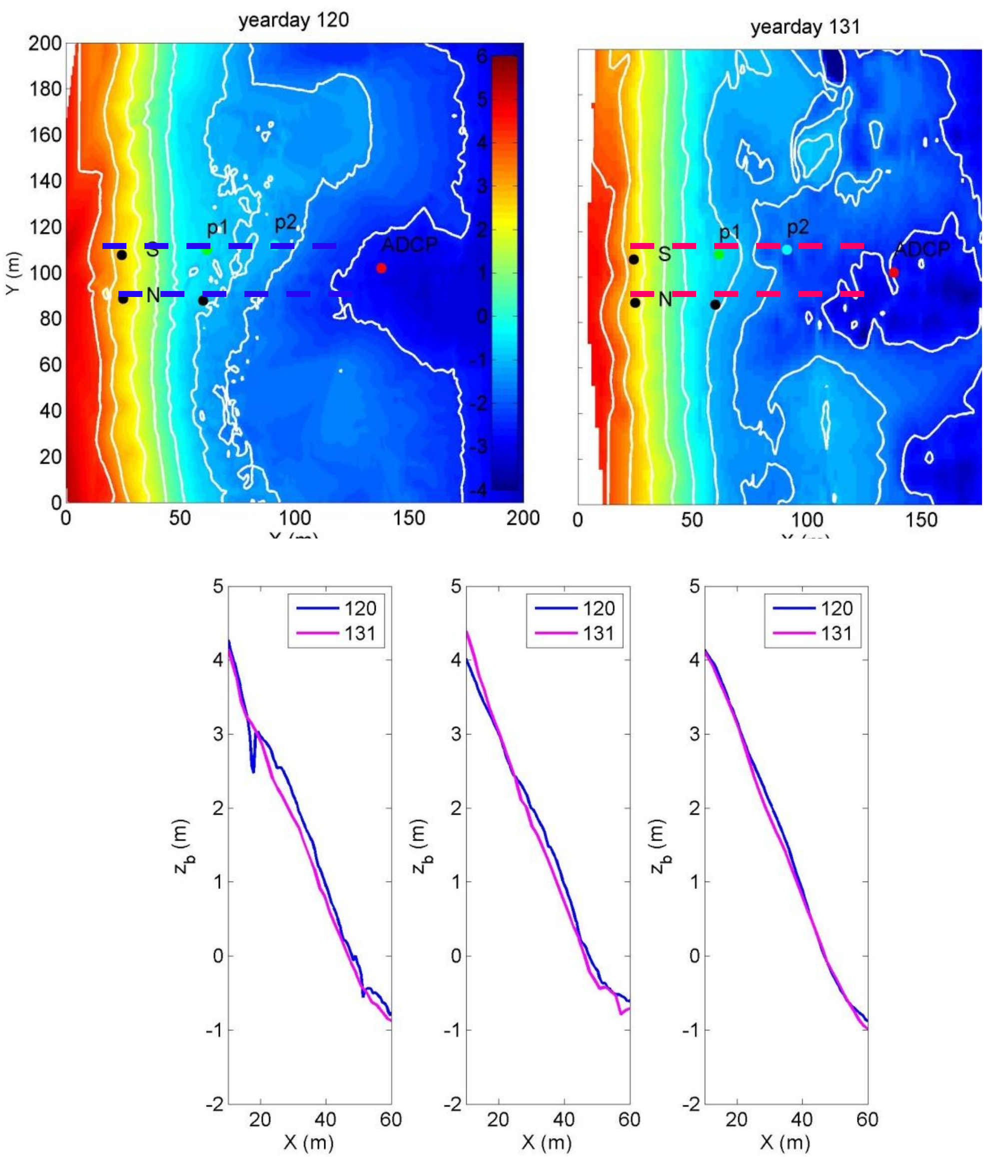
Intra-wave processes

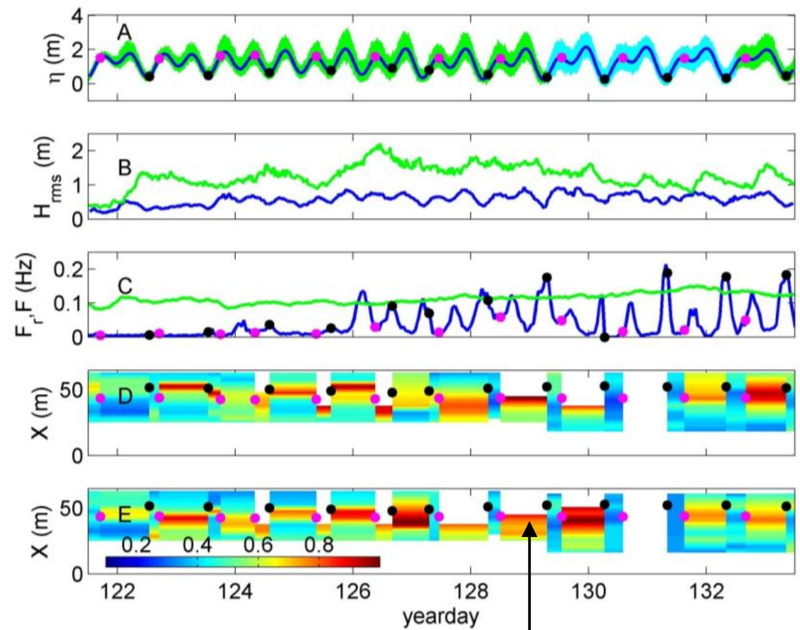
Even smaller scales!!

Van Rooijen, A., 2011

Profile stability

Gallagher et al., 2011





Grain size varies in time and space!

Alongshore average profile is (surprisingly) stable. Grain size is morphologically coupled. Can we model this?

Multiple sediment classes

Equilibrium conc. for each class:

$$C_{eq}^{*} = f\left(TKE, U, slope, D\right)$$

$$C_{eq}(i) = frc(i,1)C_{eq}^{*}(i)$$

Volumetric fraction of each class:

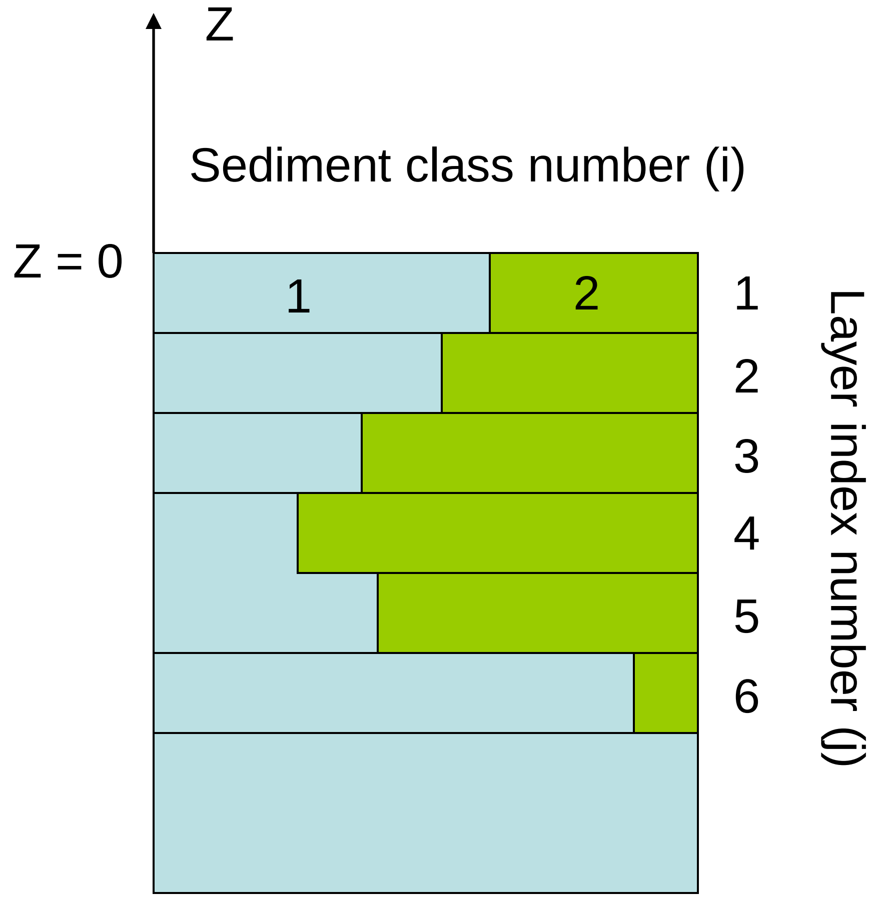
$$frc(i,j) = \frac{Vol(i,j)}{\sum_{i=1}^{i=N} Vol(i,j)}$$

Bed level change for each class:

$$\Delta z_i = \frac{\Delta t}{1-n_p}\left[\frac{\partial S_{i,x}}{\partial x} + \frac{\partial S_{i,y}}{\partial y}\right]$$

Total bed level change:

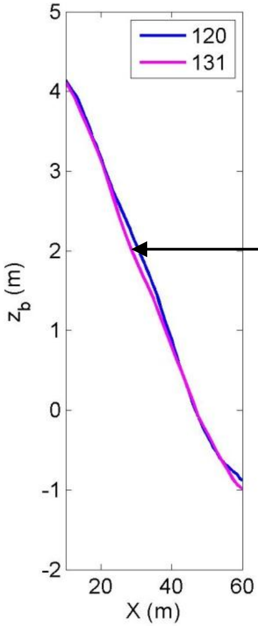
$$\Delta z = \sum_{i=1}^{i=N} \Delta z_i$$



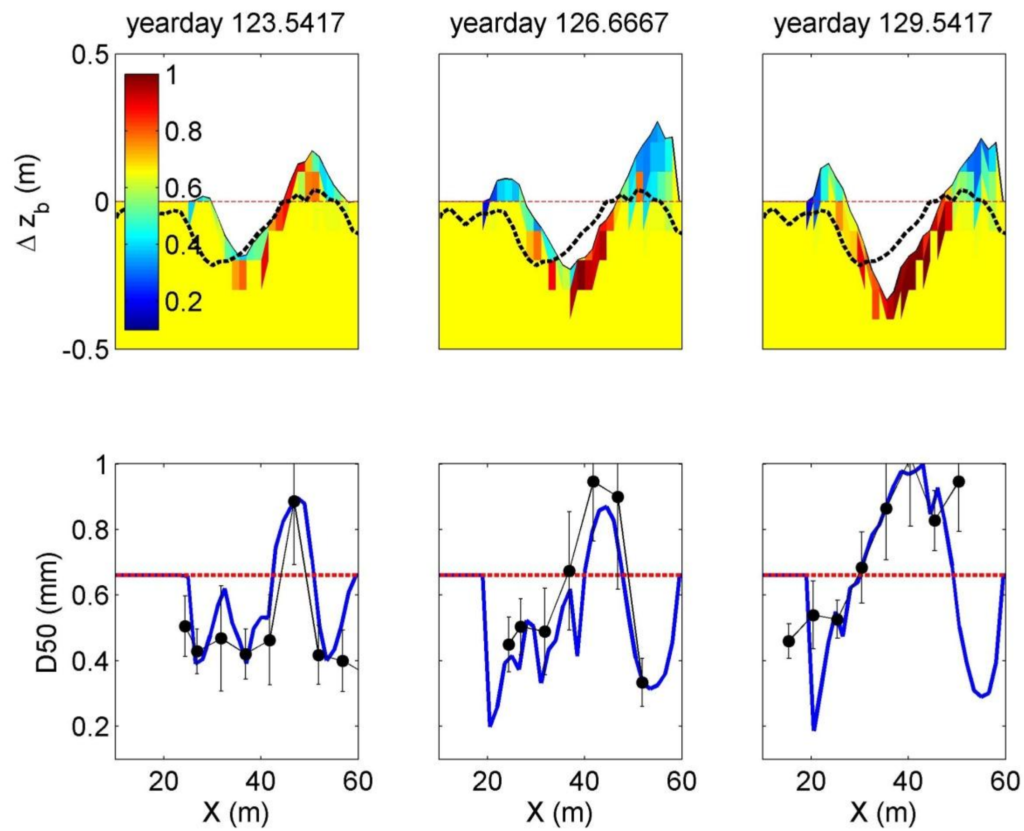
XBeach intra-wave modeling

Δx =1 m, Δz = 0.1 m, 10 layers

L= 65 m, 10 grain sizes (0.1-1.5 mm), D~O(10) hr, T = 10 days



--- Observed profile change



- Observed mean surface grain size

Stable profile

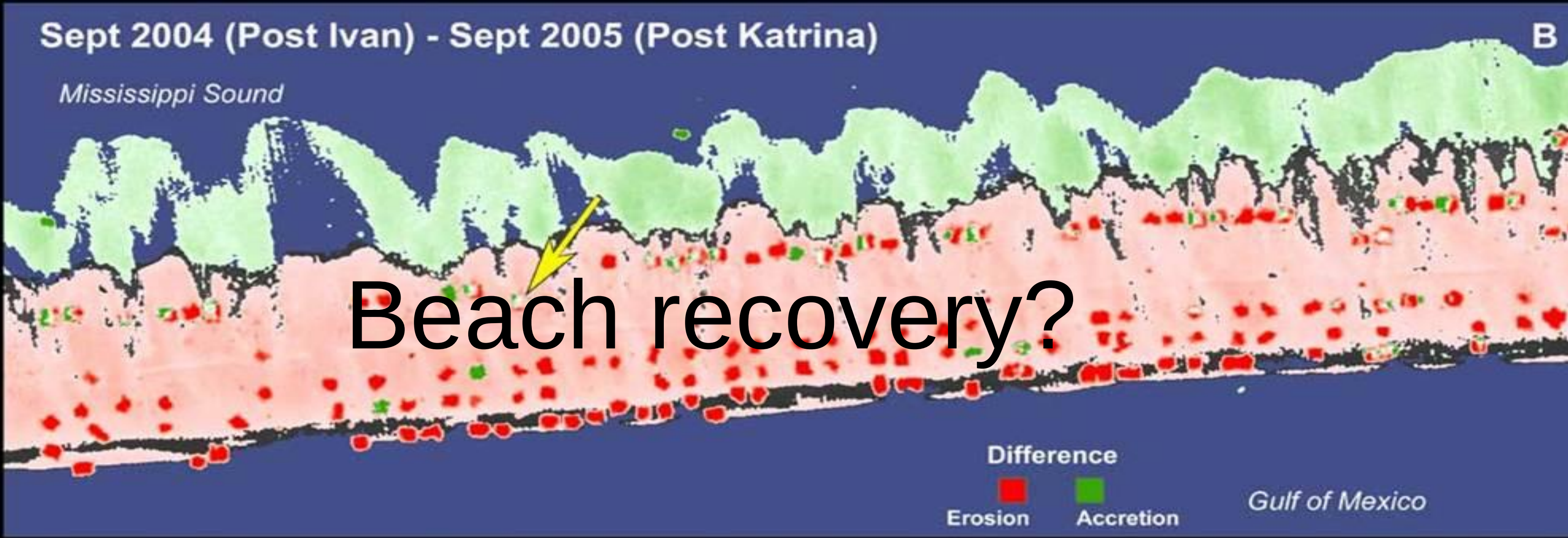
Grain size sorting

Gallagher et al., 2011

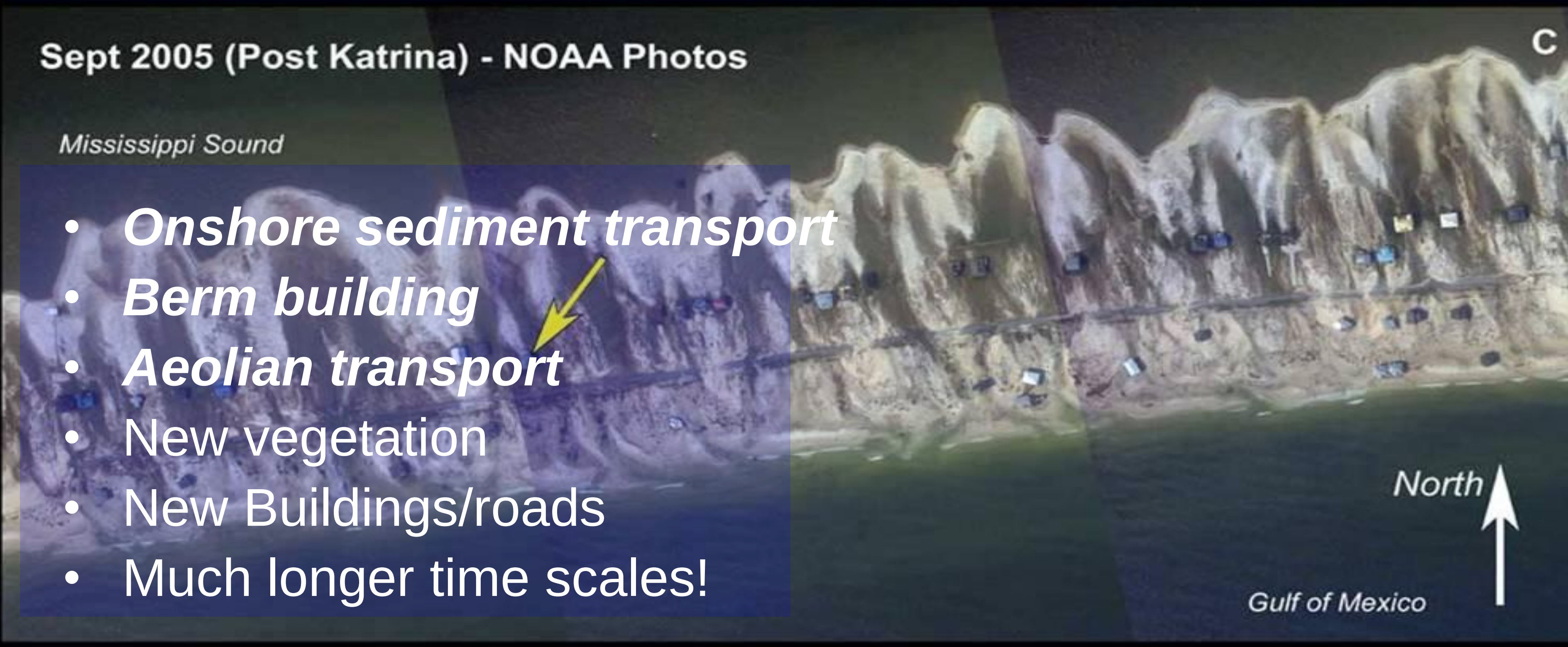
Synopsis

- To predict onshore sediment transport required for recovery we had to include smaller scale processes!
- Seems like a long way to go before we can say something about long time scales

1. *Need to aggregate the small scale process results to longer time scales*
2. *Need to couple systems to enhance functionality*

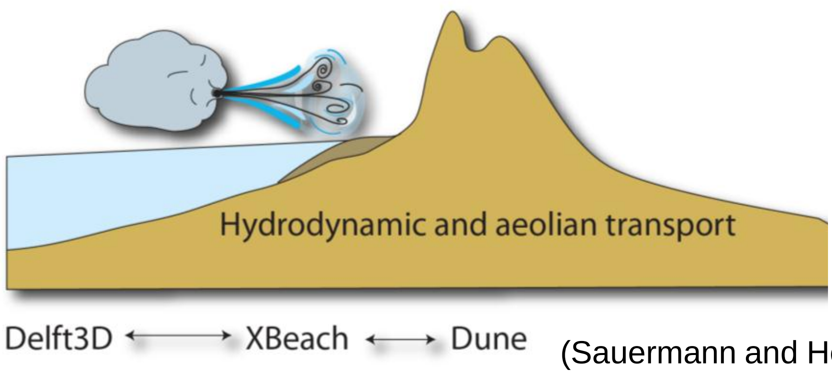


Beach recovery?

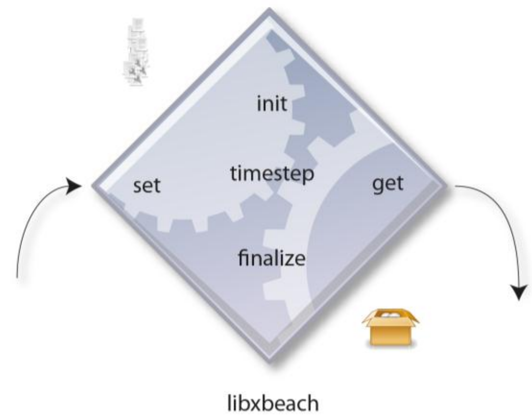


- ***Onshore sediment transport***
- ***Berm building***
- ***Aeolian transport***
- New vegetation
- New Buildings/roads
- Much longer time scales!

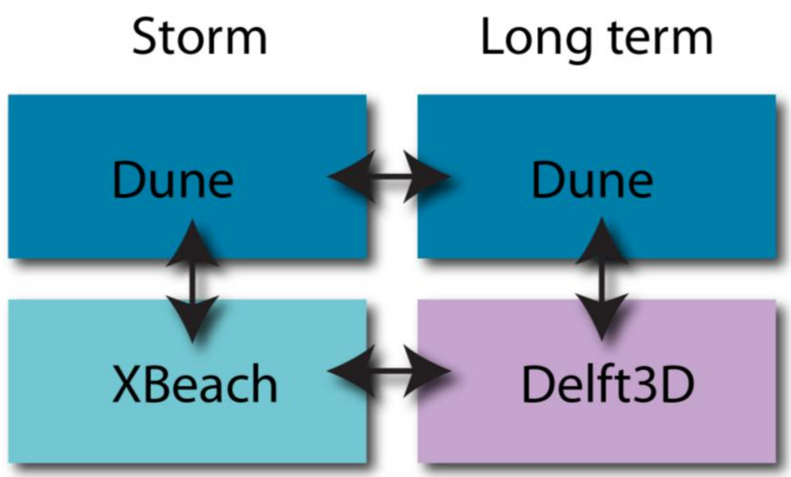
Systems coupling



(Sauermann and Hermann)



OpenMI ESMF **CSDMS**



Assateague Island

USGS science for a changing world

Fedor Baart, Gennadii Donchyts Jaap van Thieldevries, Martijn Muller, Nathaniel Plant, Bert Jagers, e.o.

Thank you

Dano Roelvink

Ap van Dongeren

Jaap van Thieldevries

Jamie Lescinski

Robert McCall

Fedor Baart

Bram van Prooijen

Arnold van Rooijen

Pieter van Geer

Bas Hoonhout

Bert Jagers

Gennadii Donchyts

Martijn Muller

Nathaniel Plant

Dave Thompson

Edie Gallagher

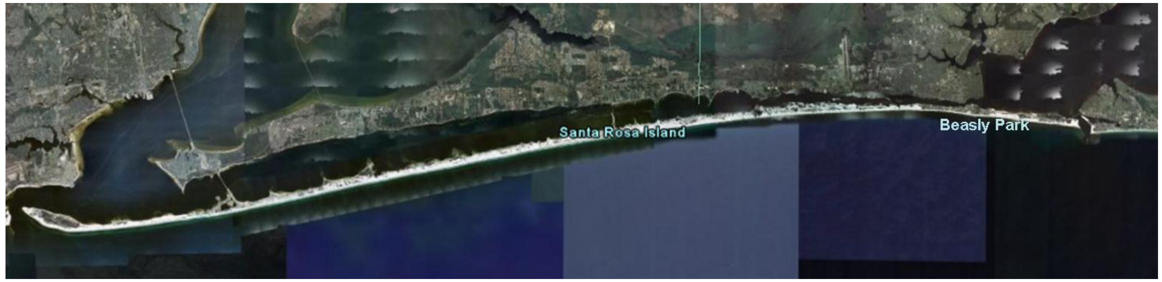
Ed Thornton

Jamie MacMahan

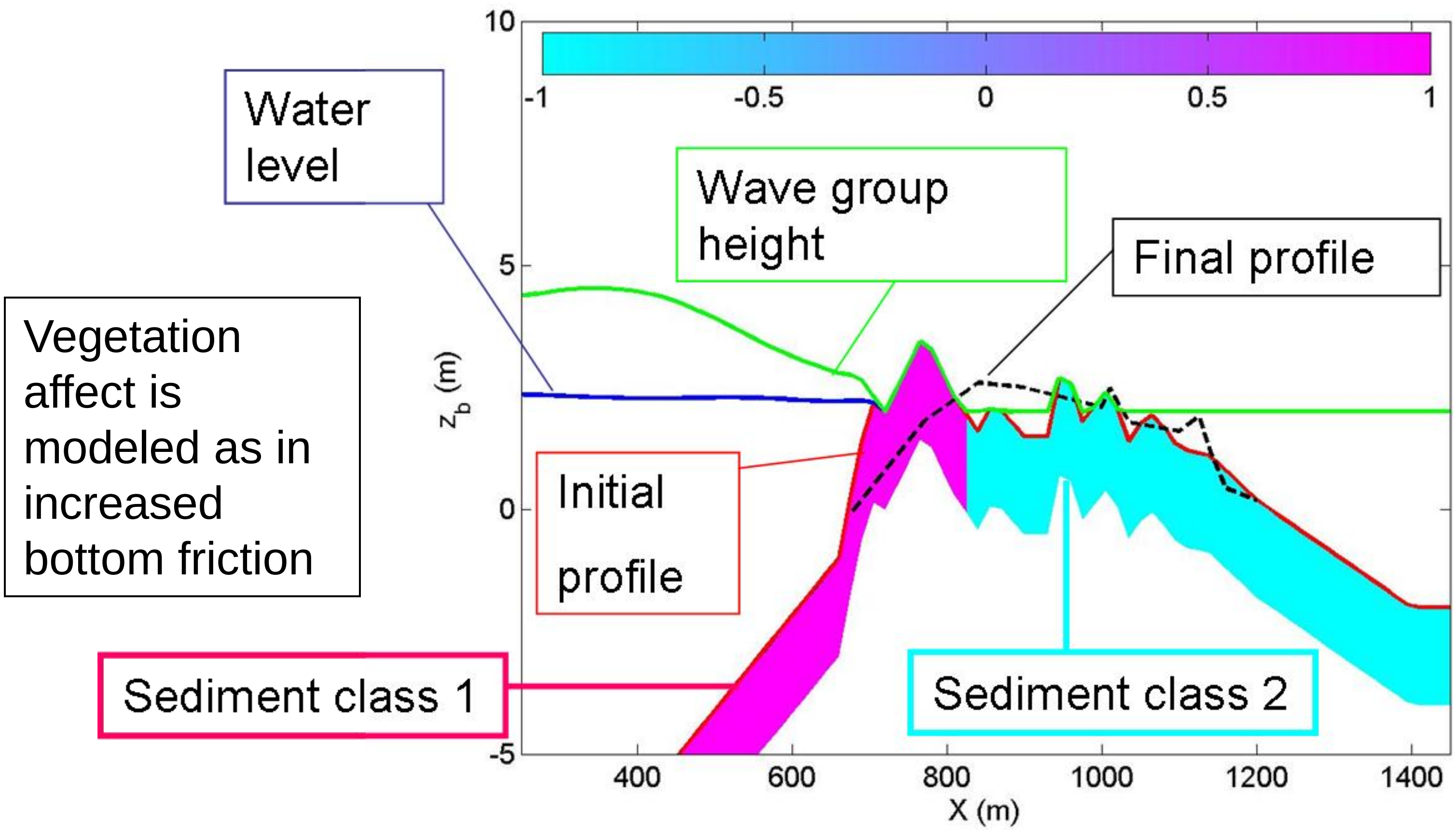
Ad van der Spek

And many others

Overwash

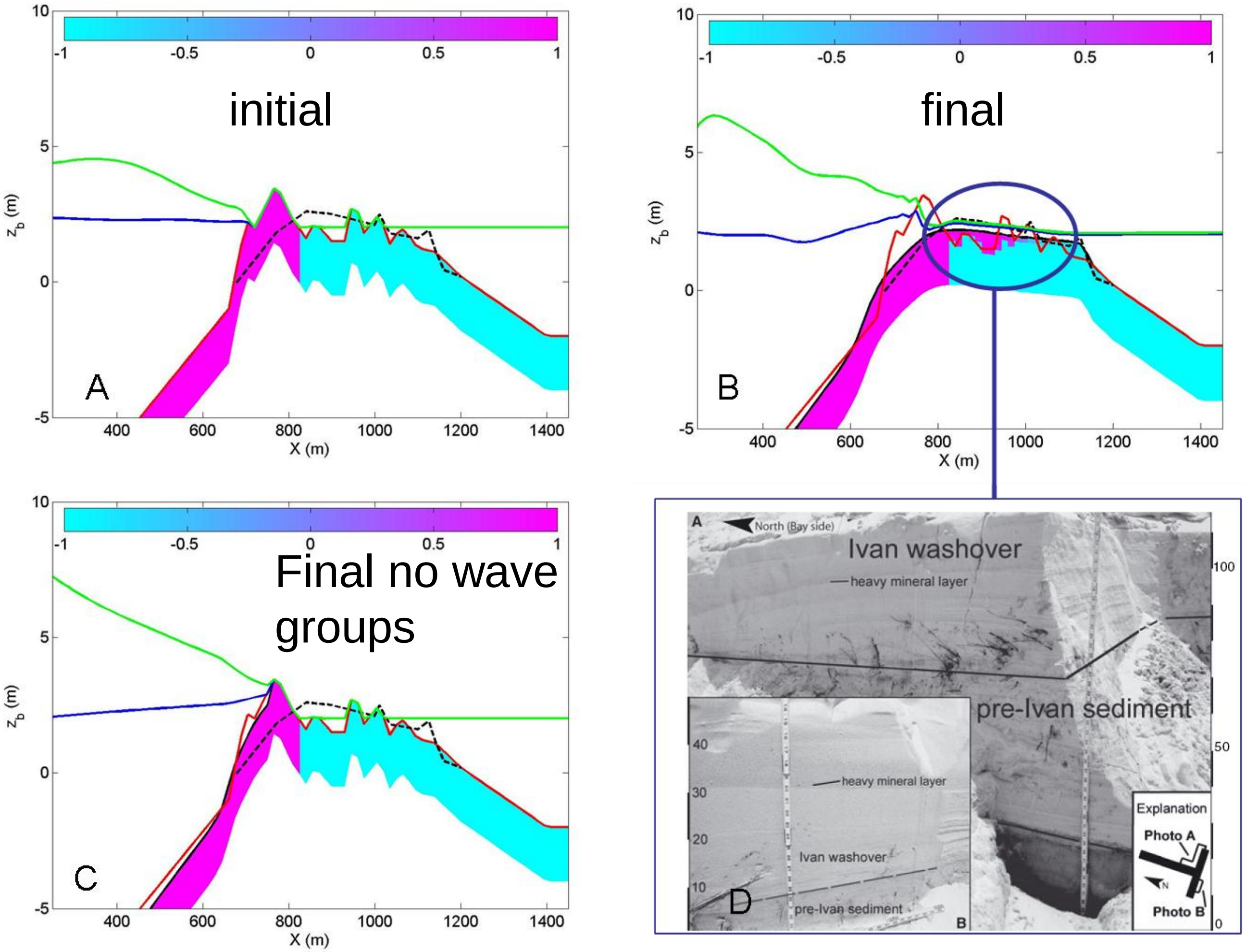


Santa Rosa Island
Beasly Park

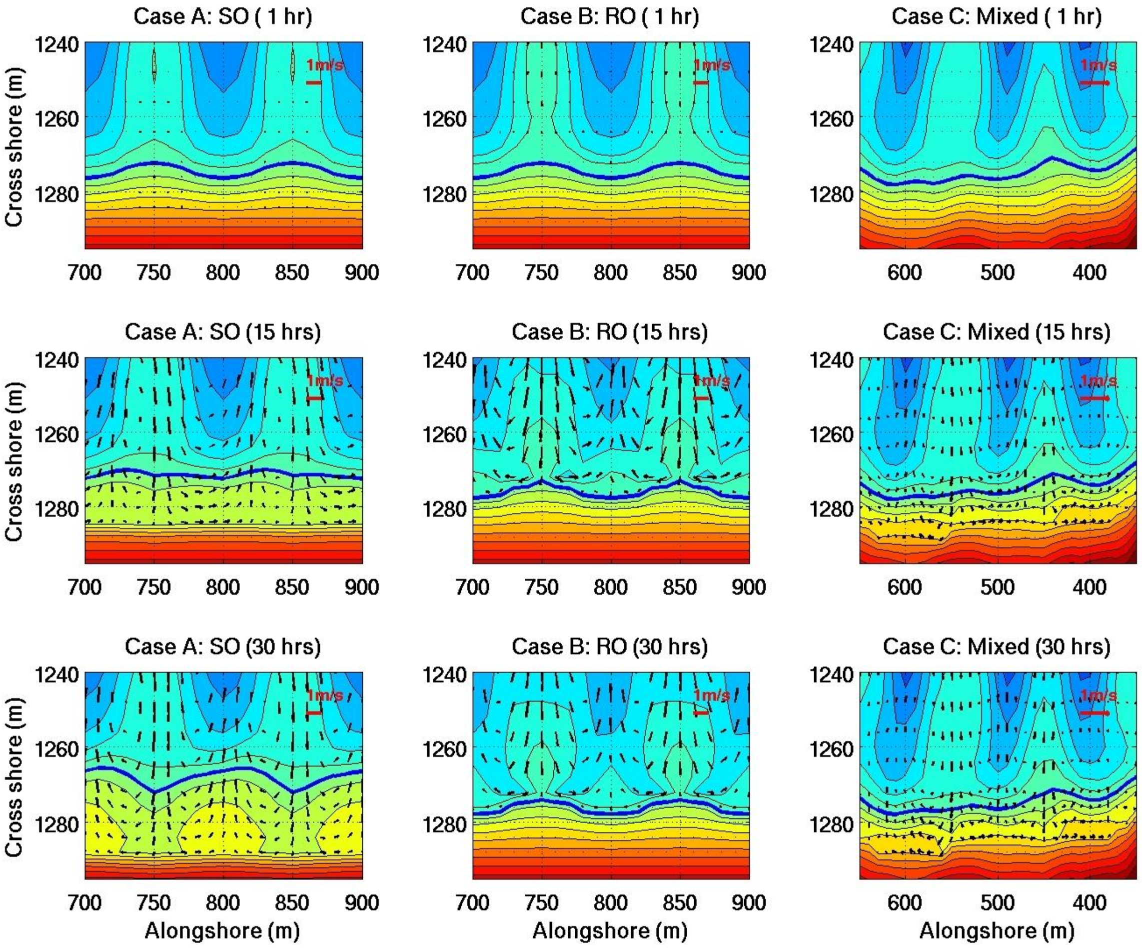


Water level
Wave group height
Final profile
Vegetation affect is modeled as in increased bottom friction
Initial profile
Sediment class 1
Sediment class 2
-1
-0.5
0
0.5
1
10
5
0
-5
z_b (m)
400
600
800
1000
1200
1400
X (m)

Xbeach predictions



XBeach applications

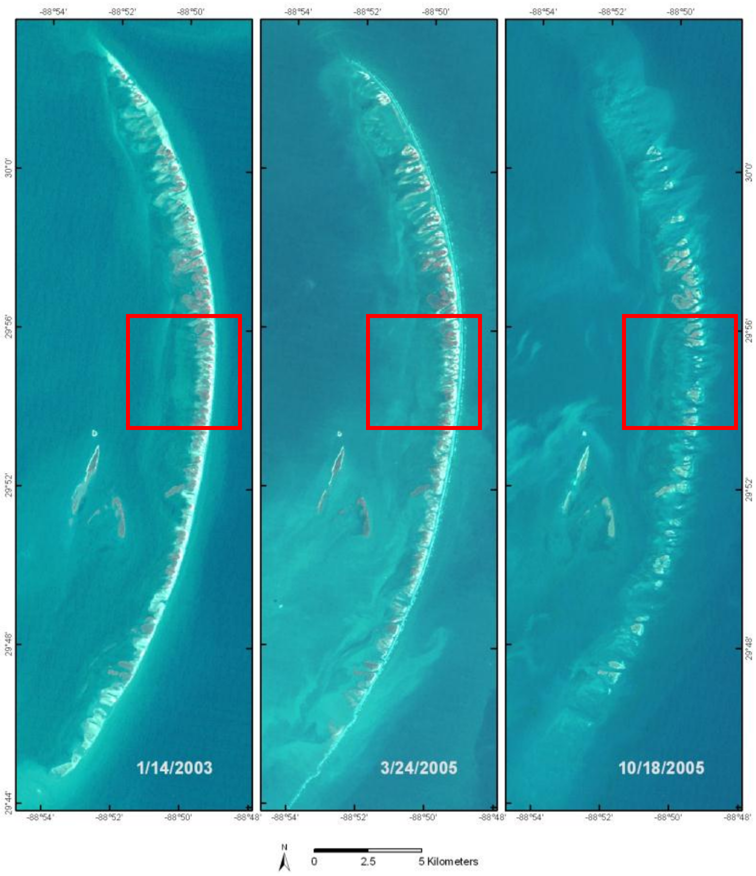


Orzech et al., 2010,

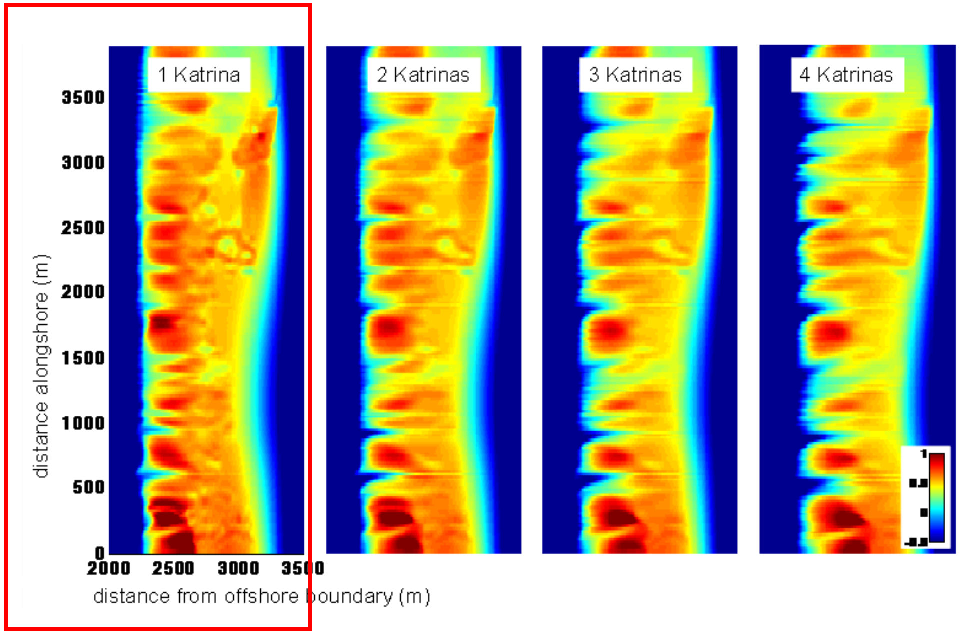
beach cusp formation

XBeach applications

Lindemer et al., 2010, overwash Chandeleur Islands



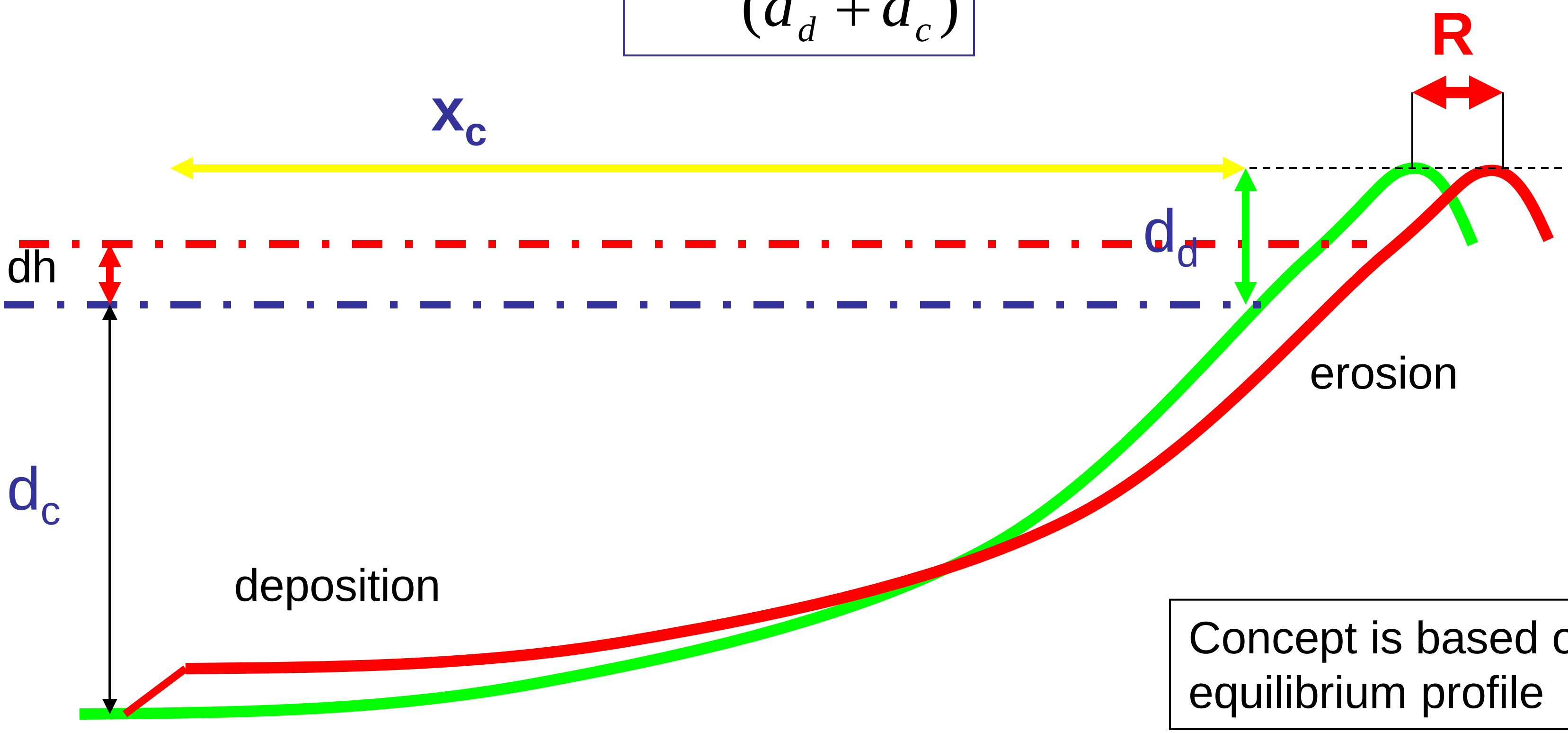
multiple overwash events of Chandeleur Islands ignoring beach recovery!



Example 1: sea level rise

Bruun rule: Beach profile will adapt to new environmental conditions. In case of sea level rise this leads to coastal erosion:

$$R = \frac{x_c dh}{(d_d + d_c)}$$



Concept is based on equilibrium profile

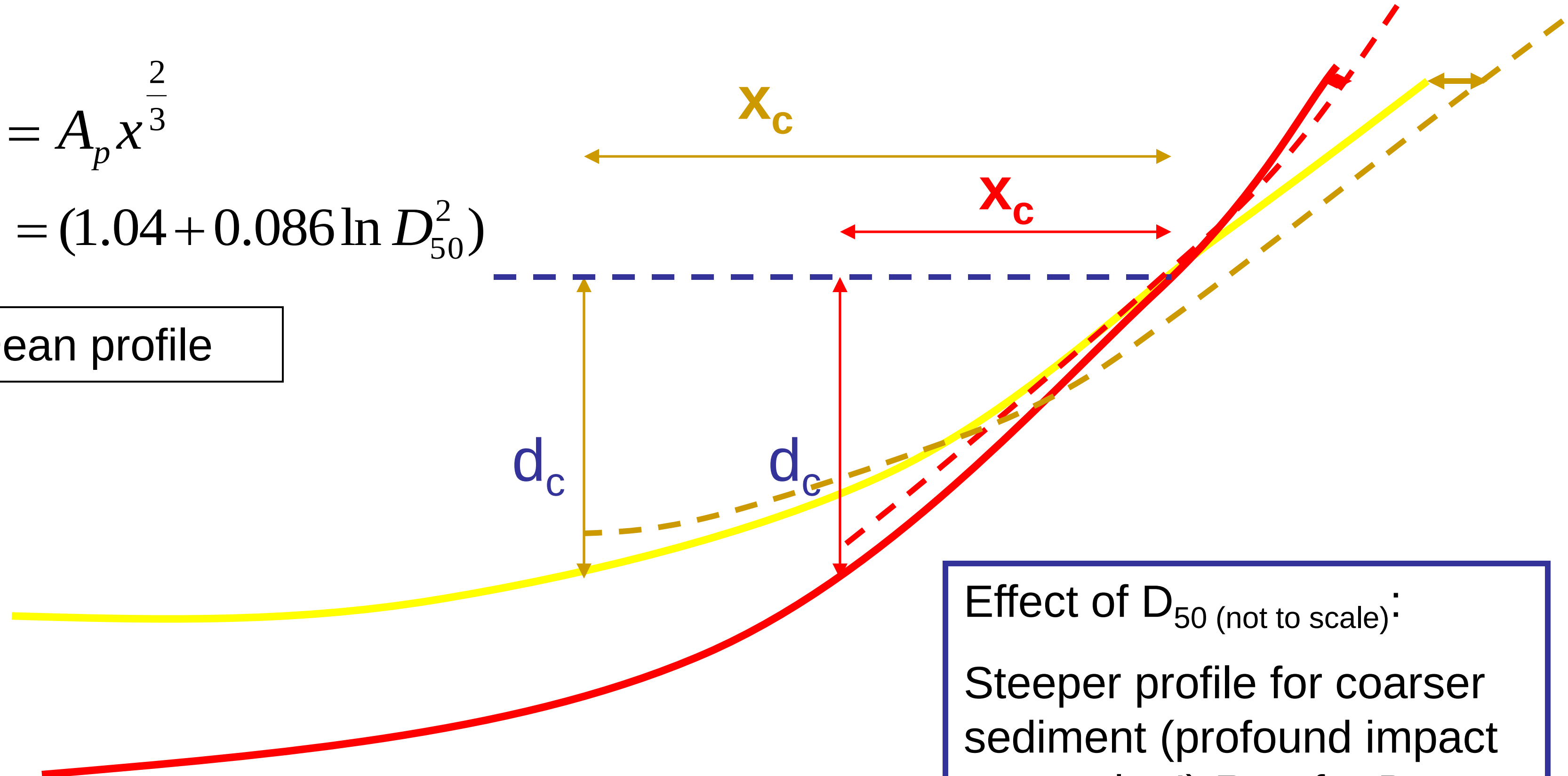
Equilibrium profile

General idea: if wave conditions persist long enough the beach profile will reach an equilibrium where the cross-shore transport gradients equal zero.

$$d = A_p x^{\frac{2}{3}}$$

$$A_p = (1.04 + 0.086 \ln D_{50}^2)$$

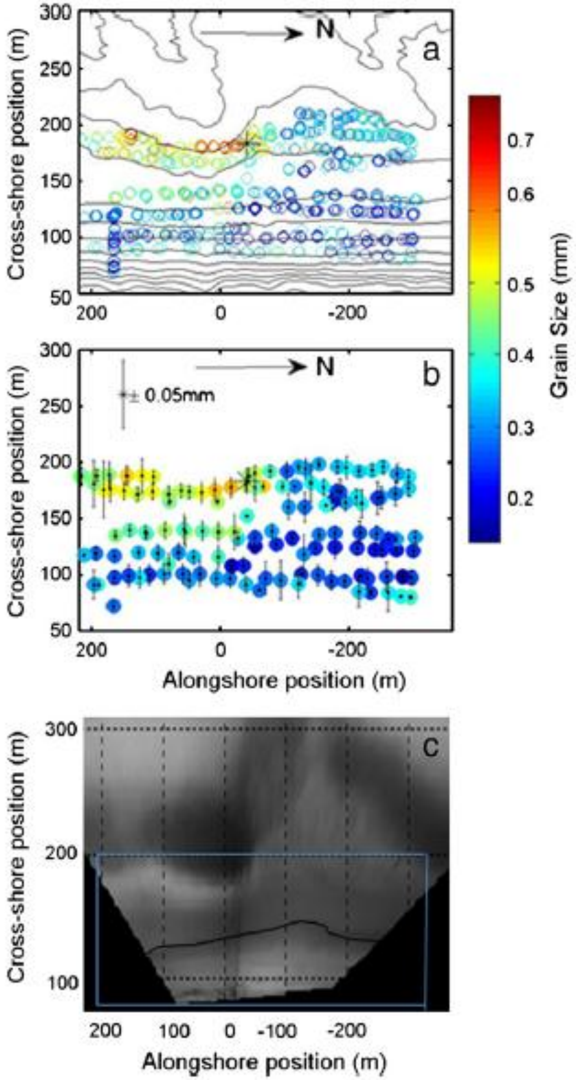
Dean profile



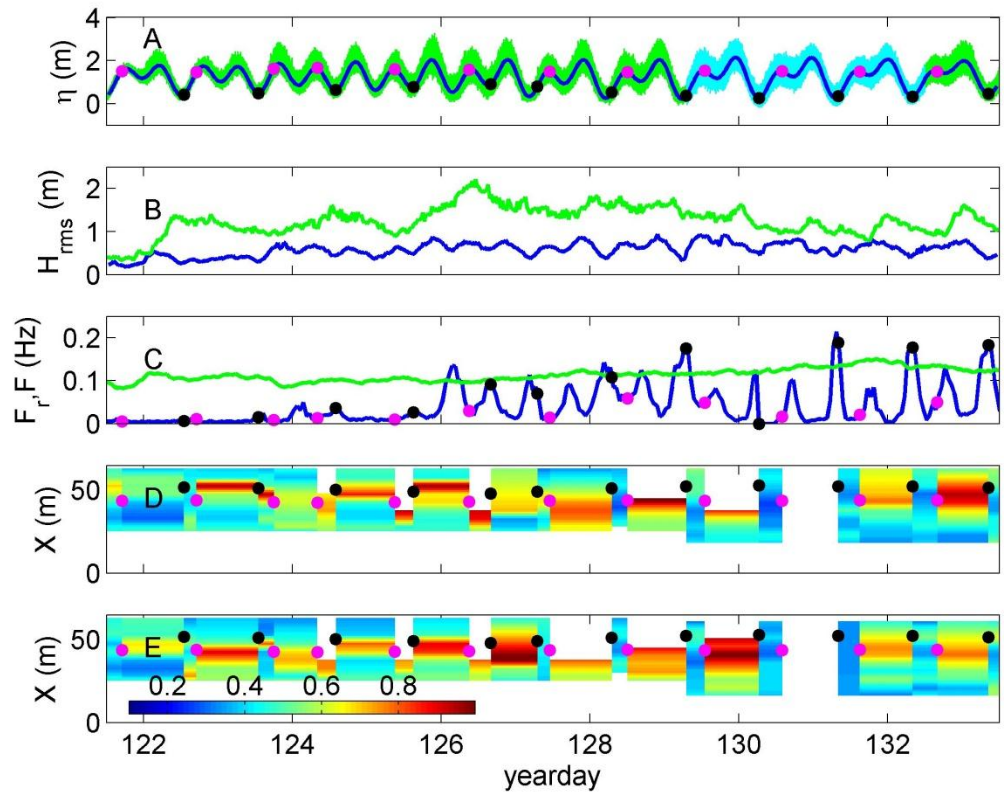
Effect of D_{50} (not to scale):

Steeper profile for coarser sediment (profound impact on erosion!) R>> for D_{50}<<

Q1: constant D50?

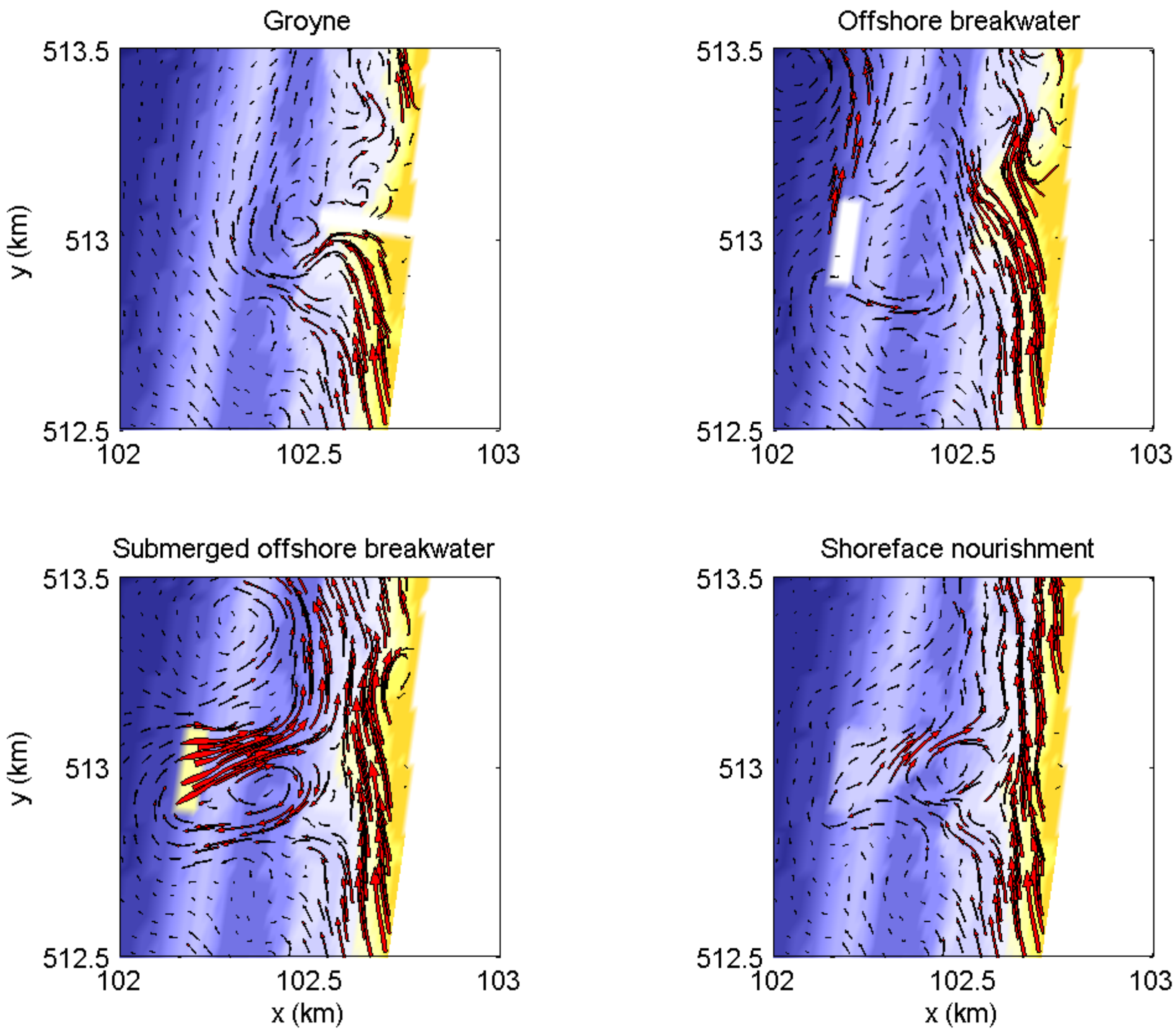


Not really. Varies in time and space. Morphologically coupled!



Gallagher et al., 2011

Morphological acceleration



Roelvink and Reniers, 2011