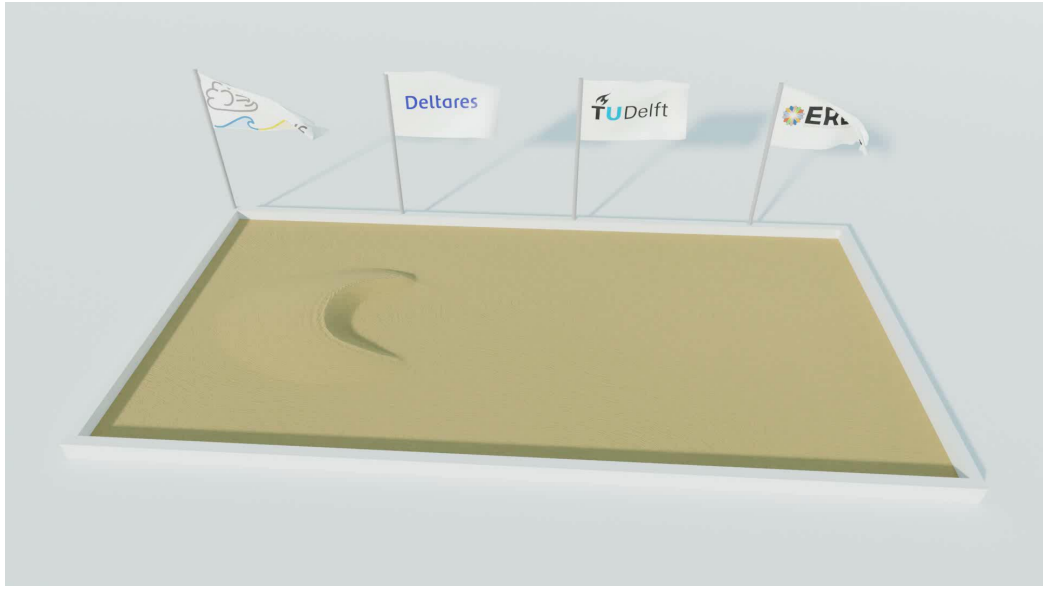
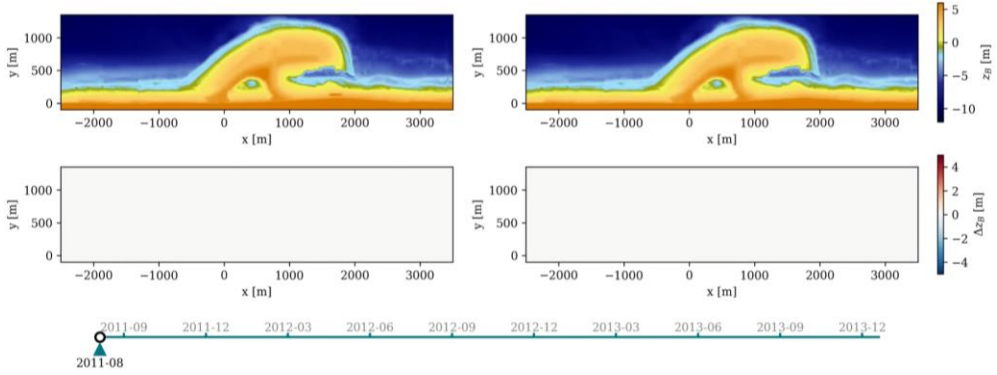
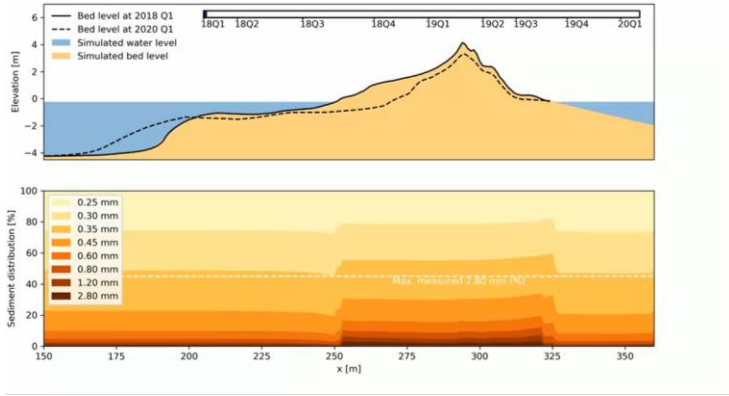
Image courtesy of Patrick Hesp

Modelling dune building dynamics

<u>Bart van Westen</u>
PhD Student
Deltares &
TU Delft



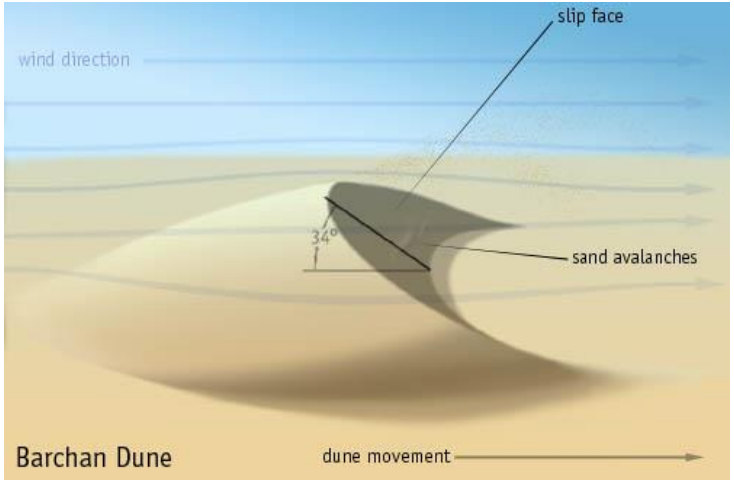




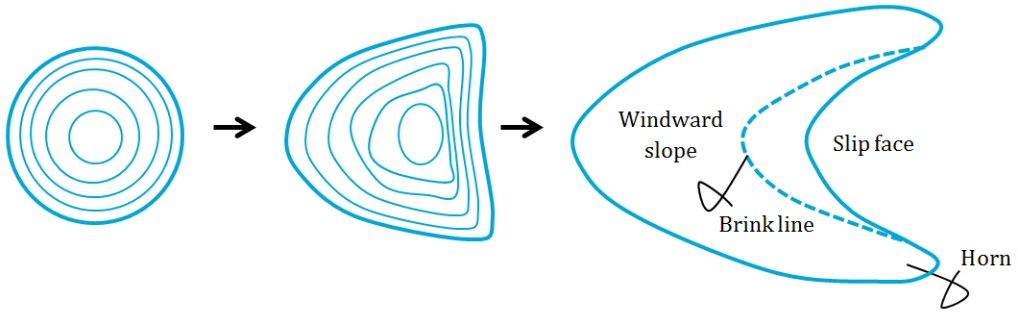
Barchan Dunes

http://www.anastasia-photo.com/george-steinmetz-desert-air

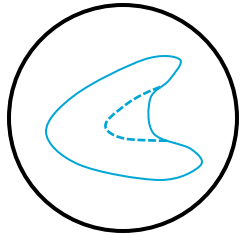
Barchan Dune



- A crescentic dune that faces the wind
- Conditions:
  - Well sorted sediment
  - Unimodal winds
  - No vegetation



Key Processes

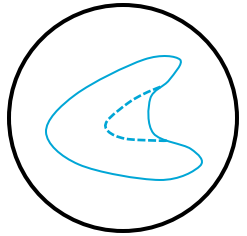


✓ 1. Aeolian sediment transport (transport-limited)

2. Spatially varying wind field due to local morphology

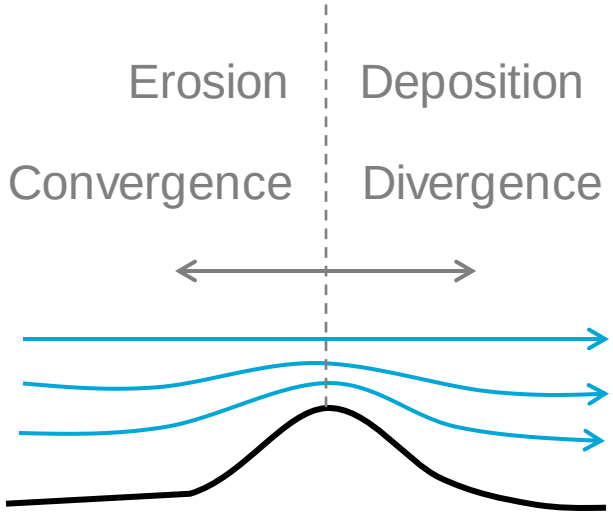
3. Avalanching

Wind Field

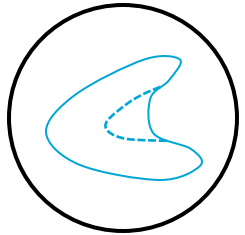


Spatial variation in wind field in response to morphology

Stream lines over flat bed

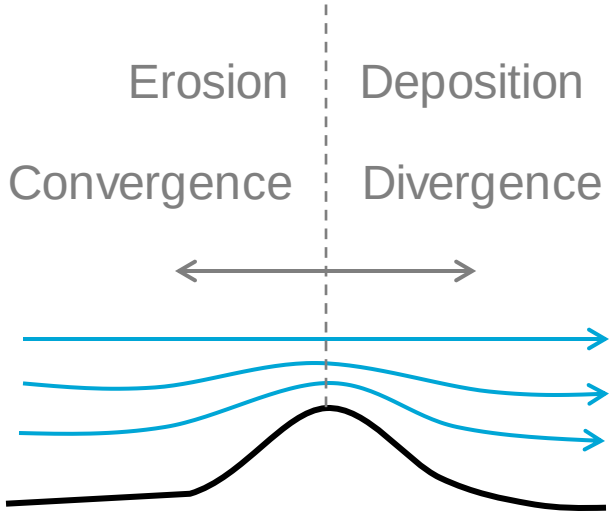


Wind Field

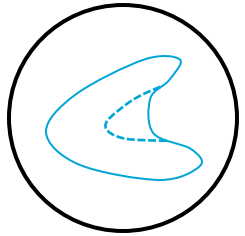


Spatial variation in wind field in response to morphology

- Dune evolution and migration

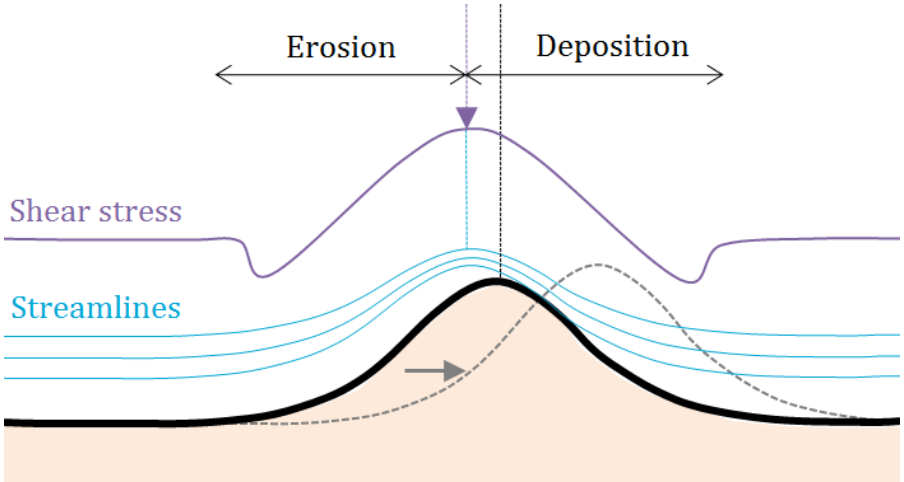


Wind Field



Spatial variation in wind field in response to morphology

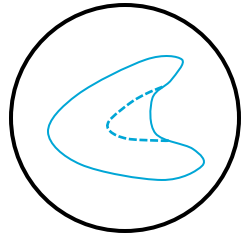
- Dune evolution and migration



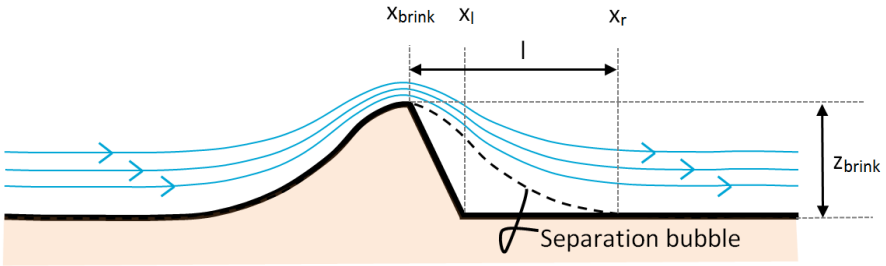
- Implementation: Analytical perturbation theory (Weng, 1991)

(Implemented in AEOLIS by Pieter Rauwoens @KU Leuven)

Wind Field



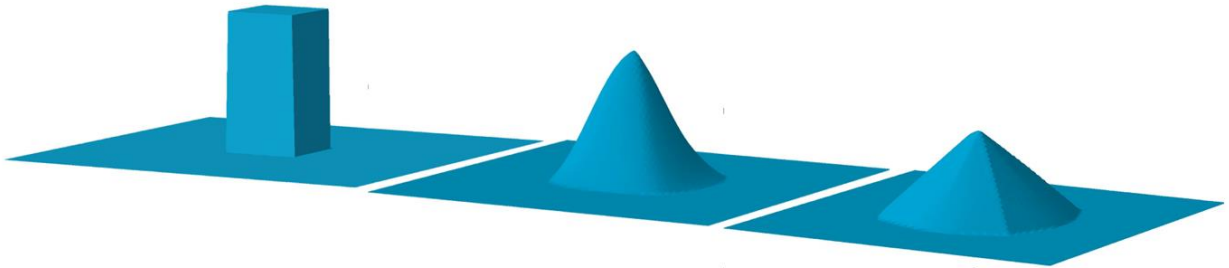
- Theory only suitable for “smooth” hills
  - Does not describe flow separation
- Implementation: Separation bubble (Sauermann, 2001)



- Assumption: Inside separation bubble: $\tau = 0$

Avalanching

- Slopes steeper than angle of repose (33˚ for dry sand) → Avalanching



Barchan dune simulation

Simulation time	2 year
Wind velocity	6 m/s

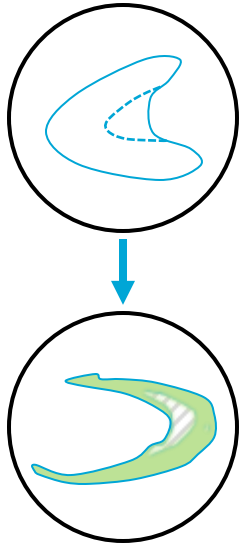
3D View

Top View

100 m

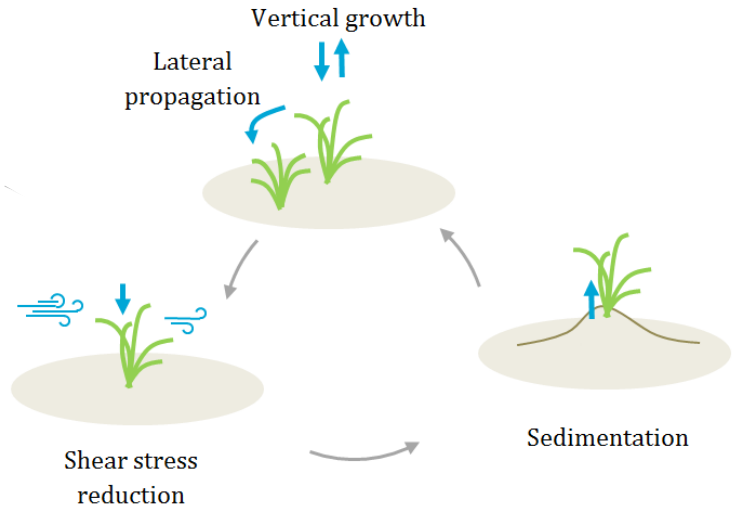
Parabolic Dunes

Key Processes



1. ✓ Aeolian sediment transport (transport-limited)
2. ✓ Spatially varying wind field due to local morphology
3. ✓ Avalanching

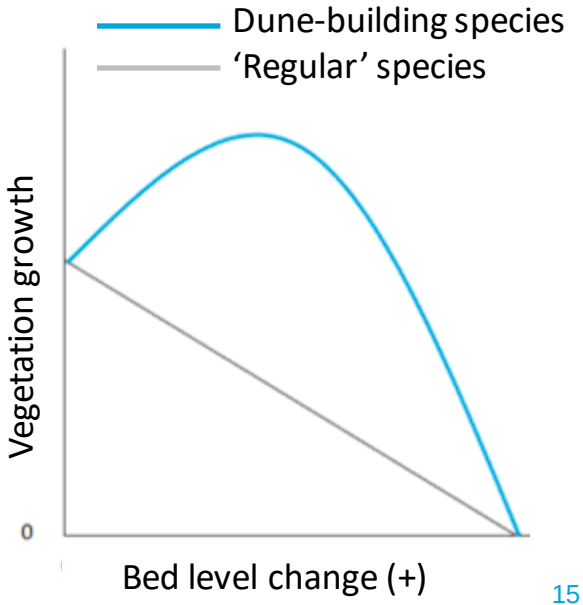
Vegetation

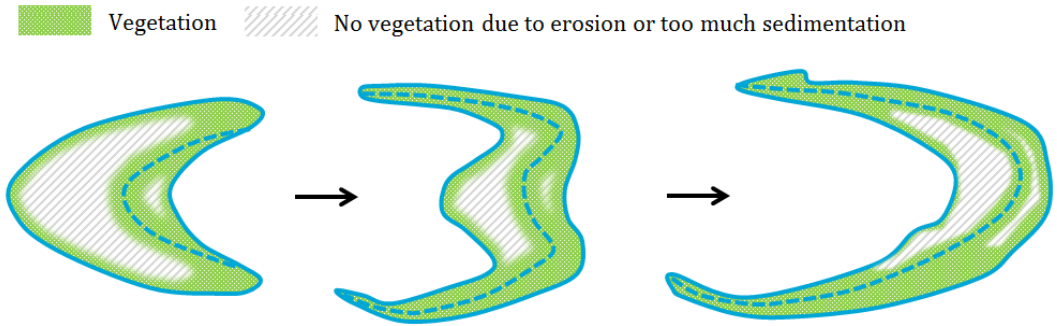

Vertical growth
Lateral propagation
Shear stress reduction
Sedimentation

Vegetation

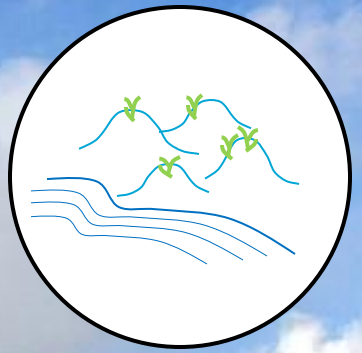
- Vegetation growth related to bed level change
  - Optimal growth at stable bed
- Differs for dune-building species
  - Sedimentation can stimulate growth
- Implementation:

  Vegetation formula (Duran, 2006)




Vegetation
No vegetation due to erosion or too much sedimentation

Deltares
TU Delft

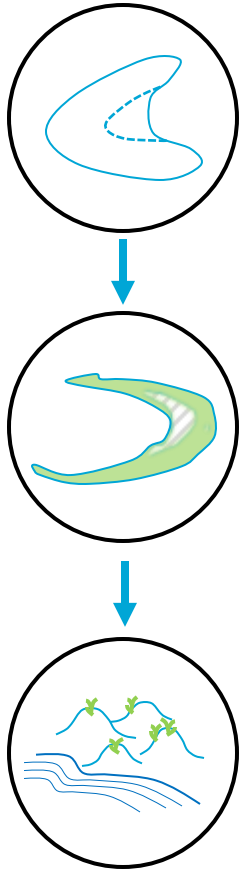


Embryo Dunes

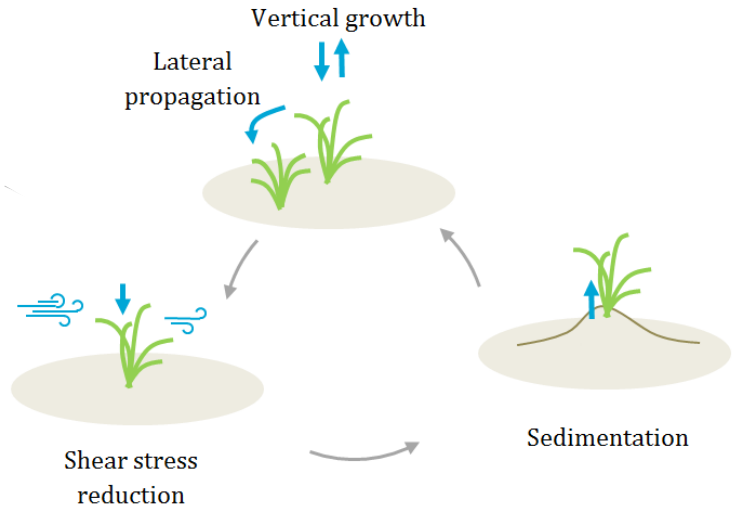
https://www.ecomare.nl/en/in-depth/reading-material/wadden-sea-area/dutch-wadden-region/texel/the-hors/

Key Processes

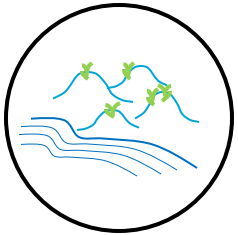
1. ✓ Aeolian sediment transport (transport-limited)
2. ✓ Spatially varying wind field due to local morphology
3. ✓ Avalanching
4. ✓ Vegetation



Vegetation


Vertical growth
Lateral propagation
Shear stress reduction
Sedimentation

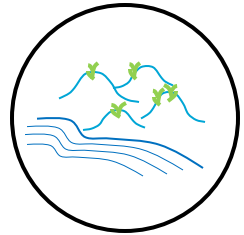
Vegetation

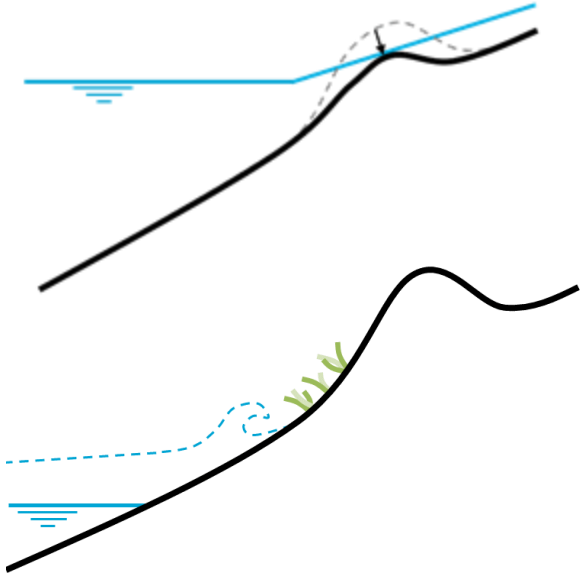


- Vegetation establishment + lateral propagation

- Implementation (Keijsers et. al 2016):
  - Probabilistic value (Lateral: only for adjacent cells)
  - Spatially uniform (over-simplified)

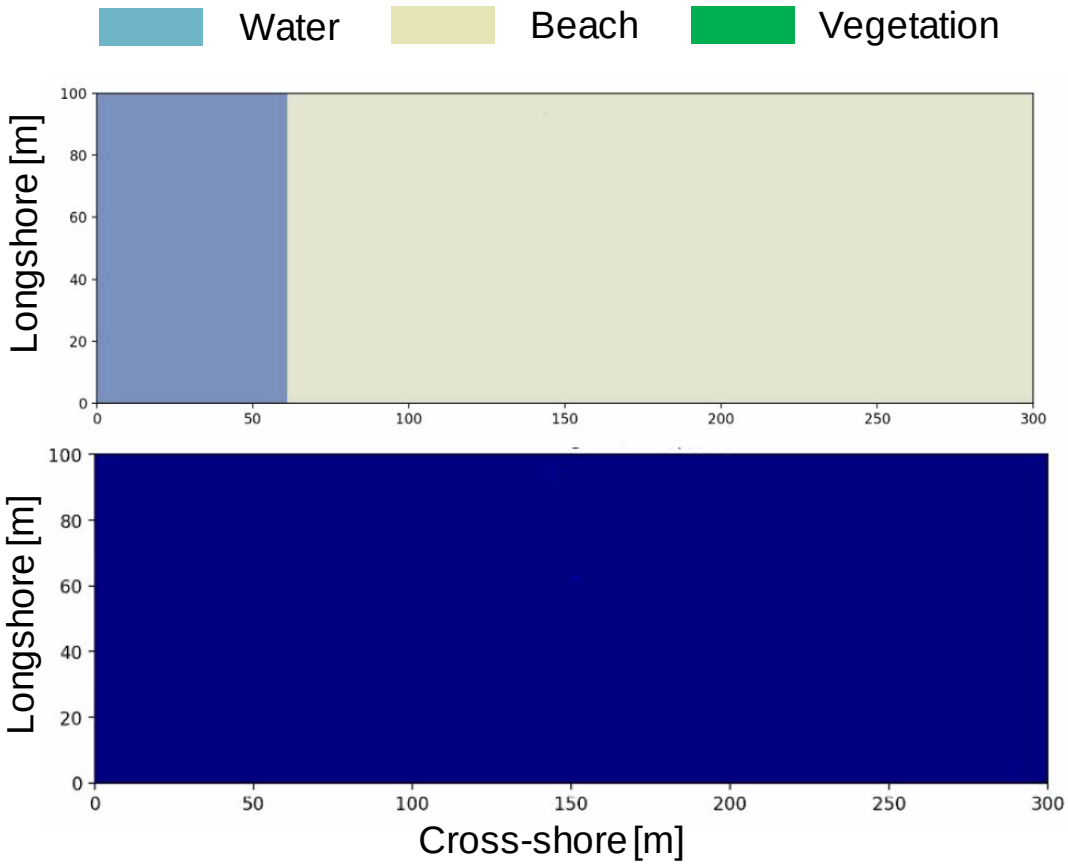
Marine influences





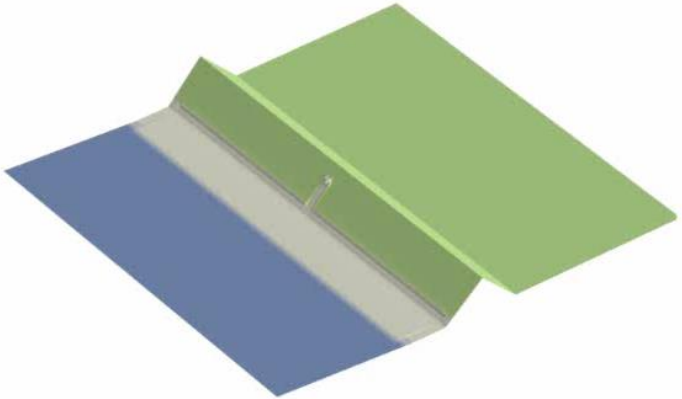
- Direct erosion / accretion on the bed
- Destroying vegetation
- Increase velocity threshold due to surface moisture content

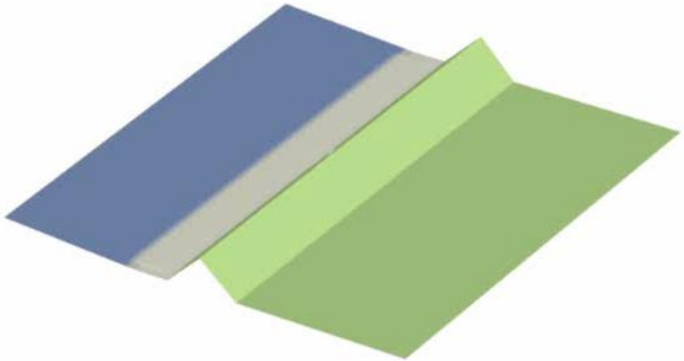
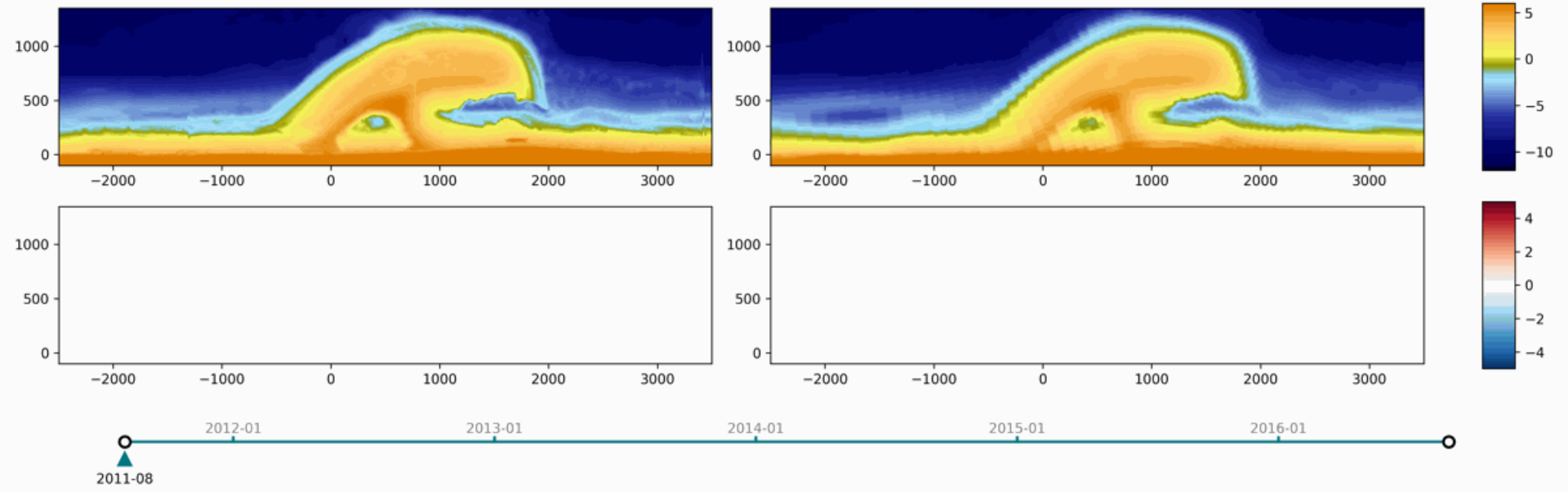
Embryo dune simulation



- Hydrodynamics
  - Vegetation
  - Dunes
- Vegetation
  - Establishment
  - Lateral
  - Growth
- Dunes
  - Growth
  - Coalescing

Future (engineering?) applications





Future (engineering?) applications