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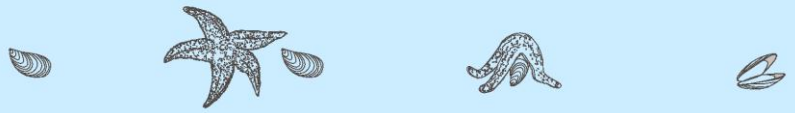
Do Local Interactions or the Landscape Determine Spatial Self-organization in Wetland Ecosystems?

Johan van de Koppel
Tjeerd Bouma
Peter Herman

Royal Netherlands Institute for Sea Research (NIOZ)
Yerseke, The Netherlands.




Netherlands
Nordrhein-Westfalen
Vlaams Gewest
Belgium

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Spatial self-organization

Spatial self-organization is the process where small-scale interactions between individuals generate structure or pattern at large spatial scales without a central authority or external element imposing it.

Is it?

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This talk

Self-organization in

- mussel beds

- Diatom biofilms

- Salt marshes

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What governs mussel growth?

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Safety in numbers

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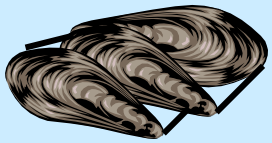
A case study on mussel beds

Mussel beds in the Wadden Sea

Mussels close by

Competition



Facilitation

Scale-dependent feedback

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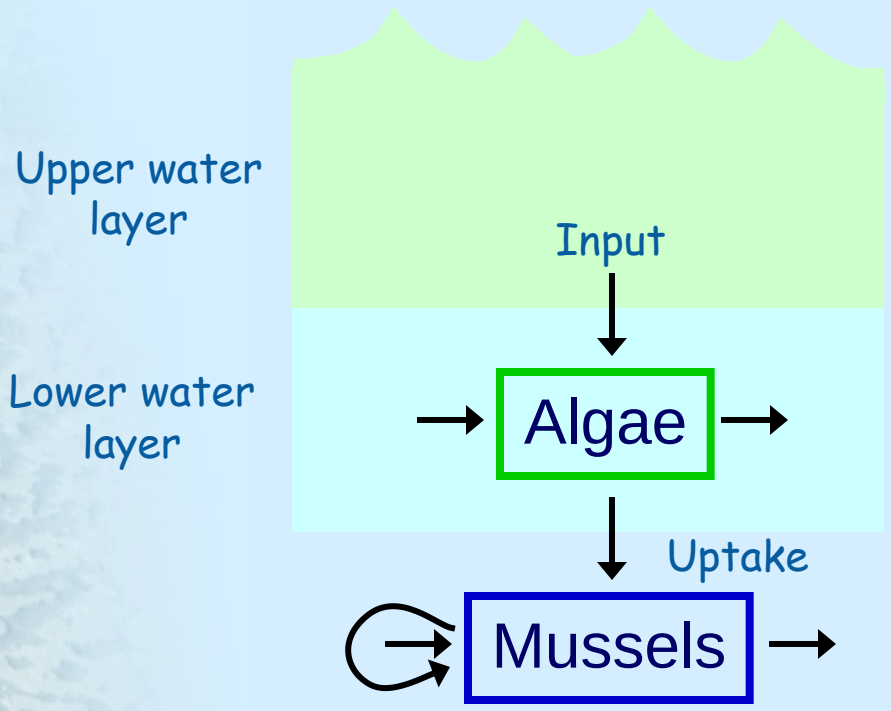
A spatial model



Model assumptions:

- Two water layers
- Lower layer can be depleted by mussels
- Algae limit mussel growth
- Lower mussel losses at higher densities

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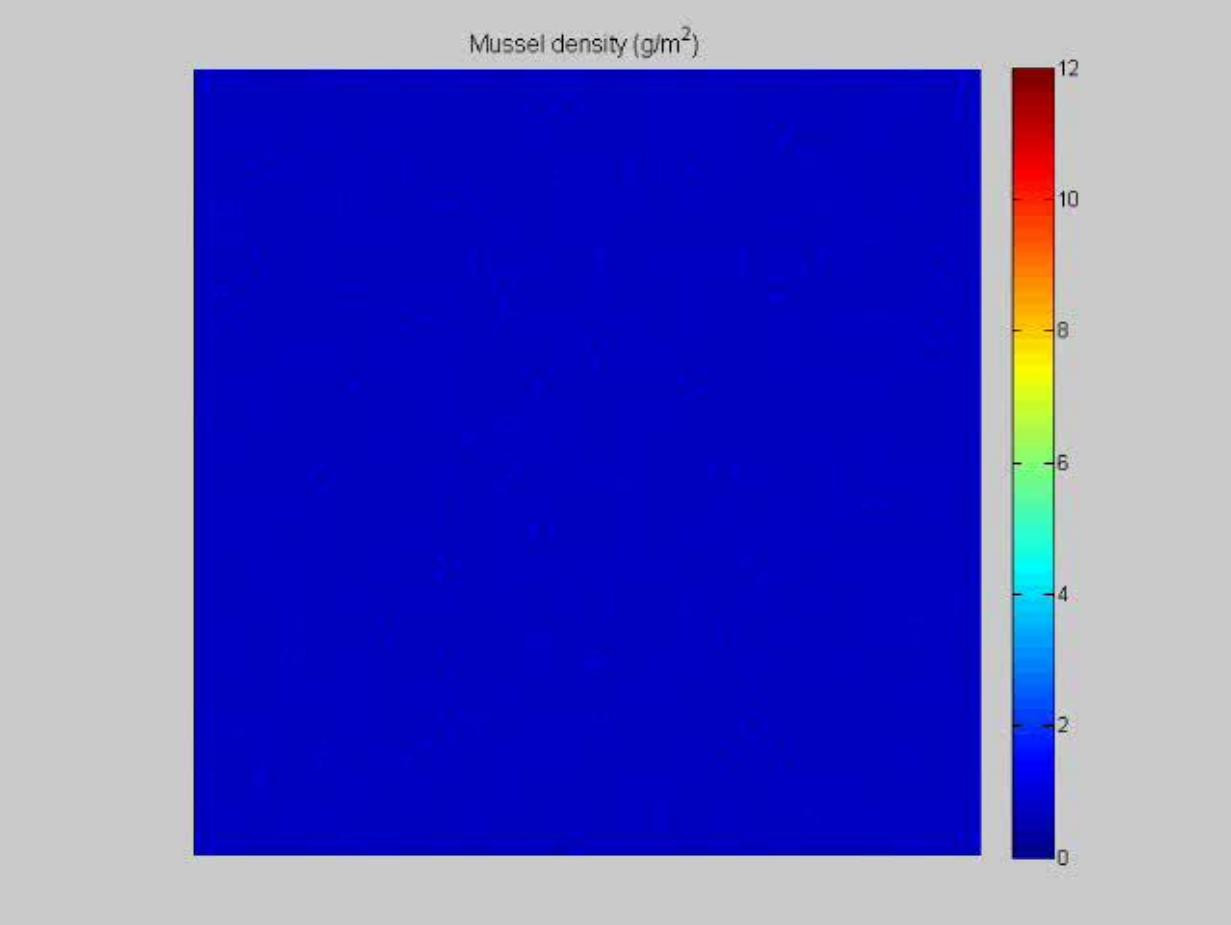
Self-organization in mussel banks



Van de Koppel et al, AmNat 2005

August, 2009

September, 2009

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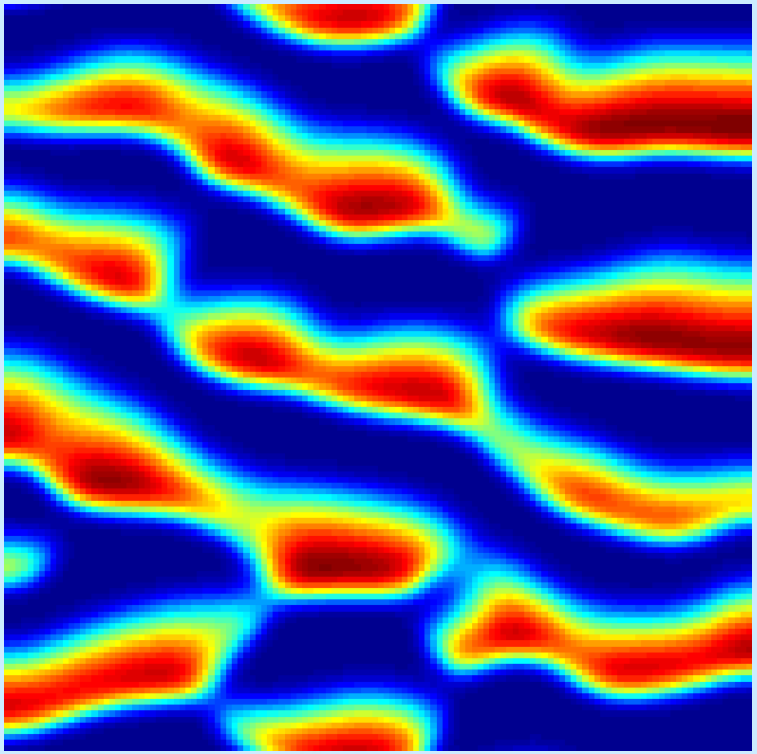
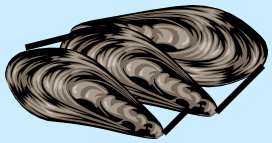
Who needs biomechanics?



Mussels close by

Competition



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Scale-dependent feedback

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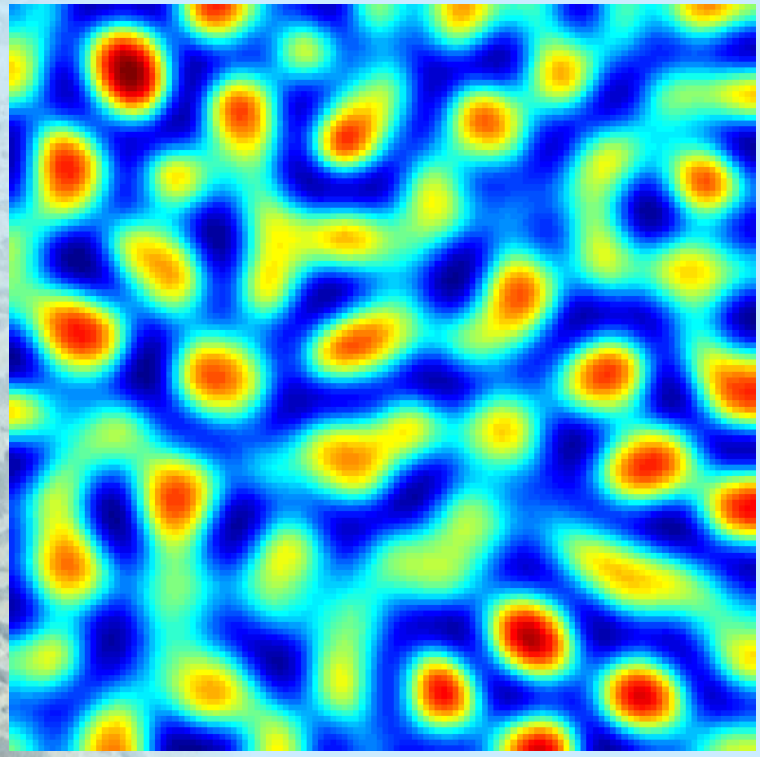
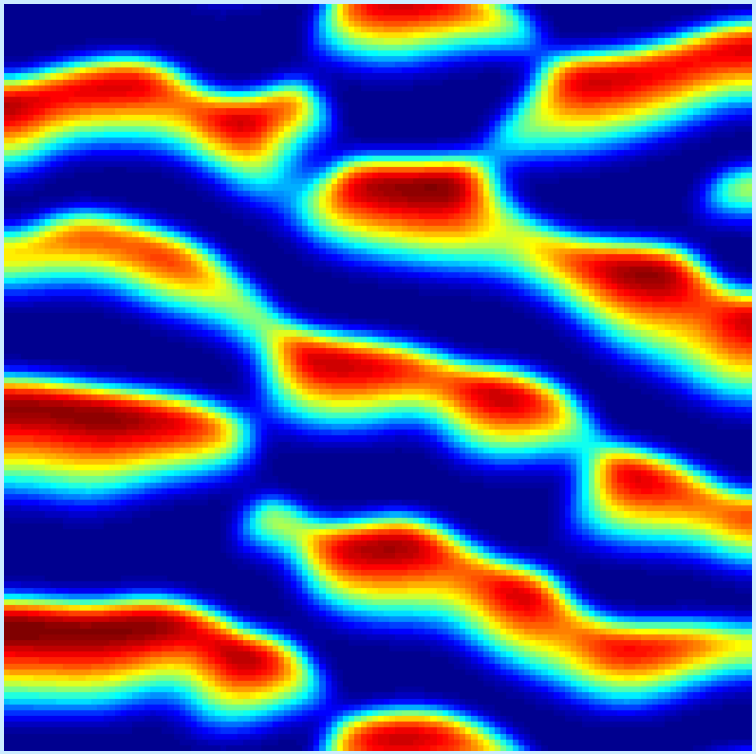
Effects of the landscape

Stagnant conditions



Flowing conditions



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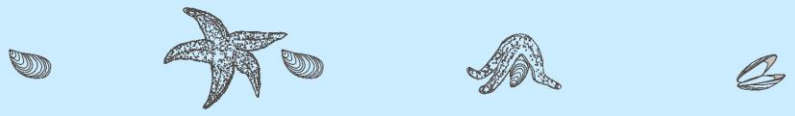
Self-organization and the landscape

- Ecological mechanism underlies pattern
- Scale-dependence is imposed by tides
- Water flow determines the shape of the pattern

=> Landscape determines pattern shape



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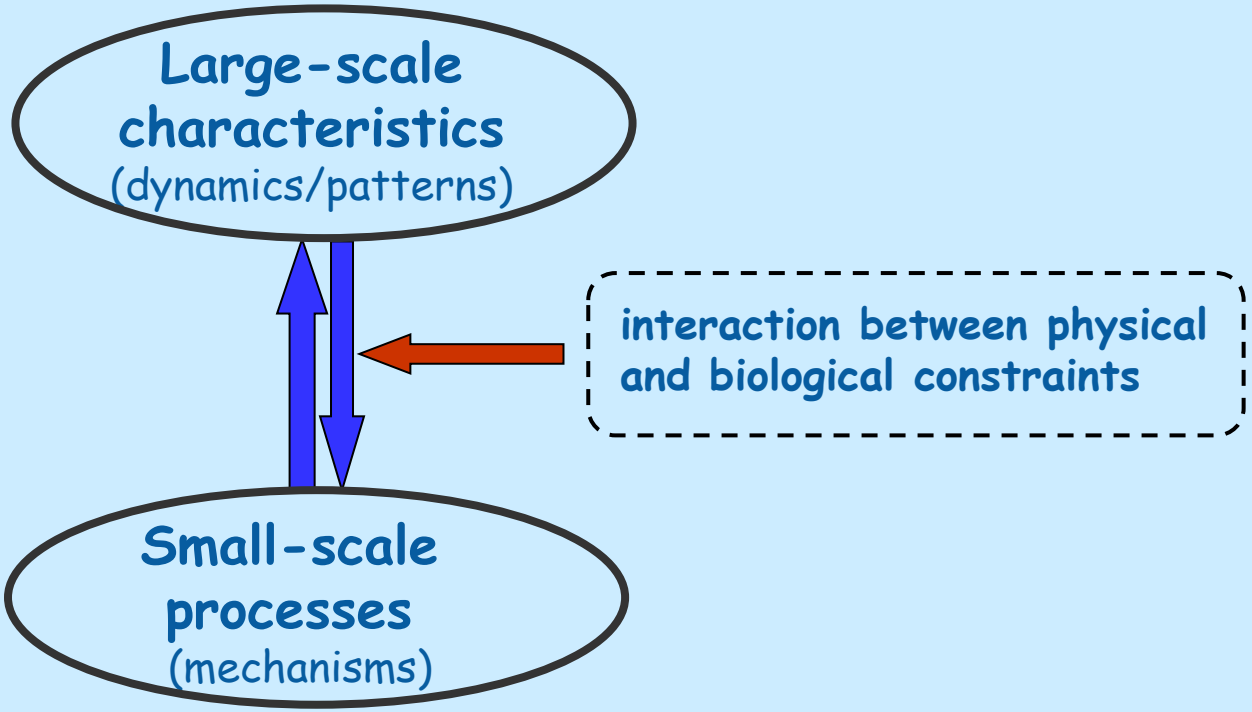
A framework

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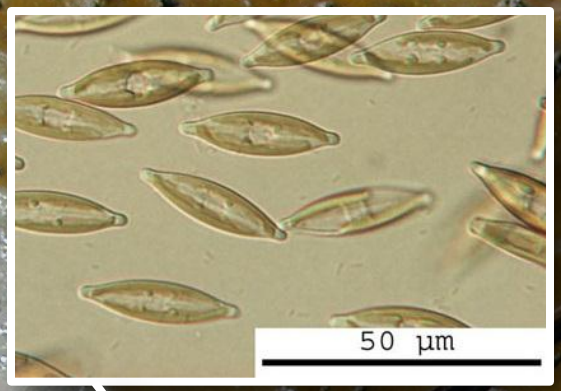
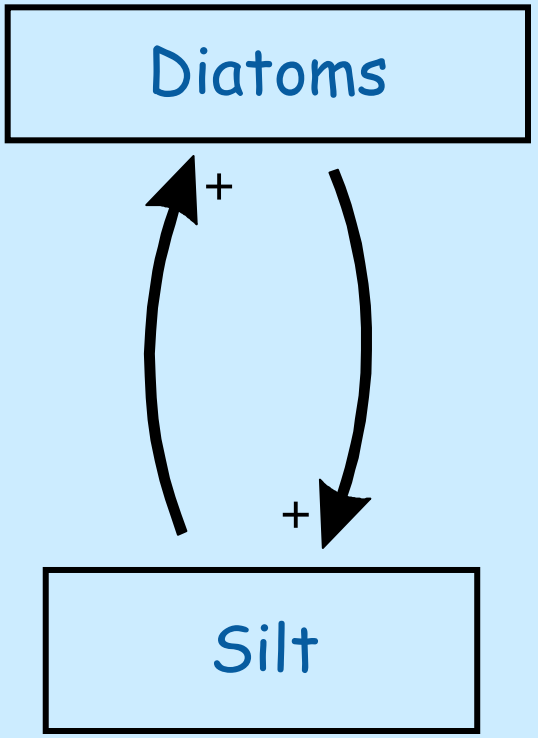
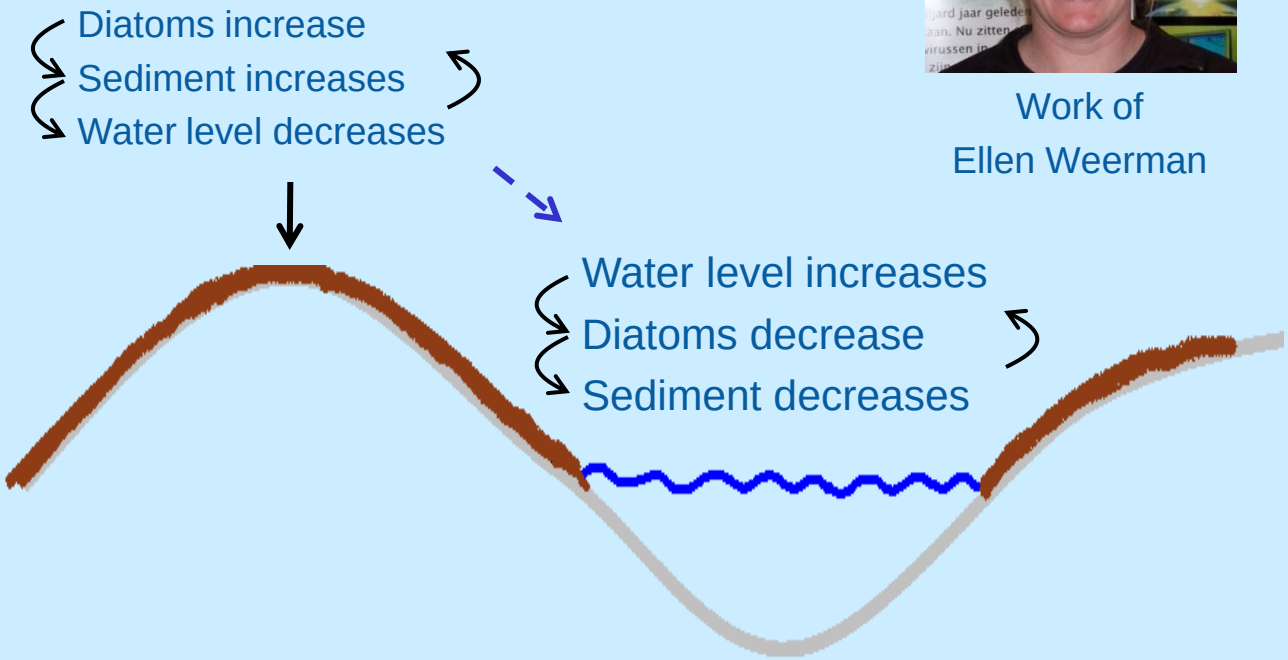


Diatom-sediment feedbacks



Modelling diatom pattern formation

Work of
Ellen Weerman



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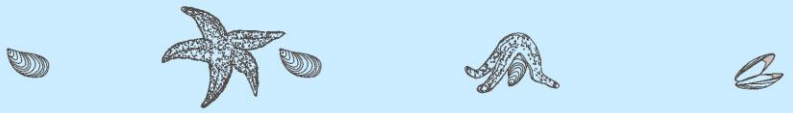
Model structure & assumptions

- Water flows downwards:
  shallow water equations
- Low erosion when water layer is thin
- Scale difference: water flows on much faster time scales than diatom growth



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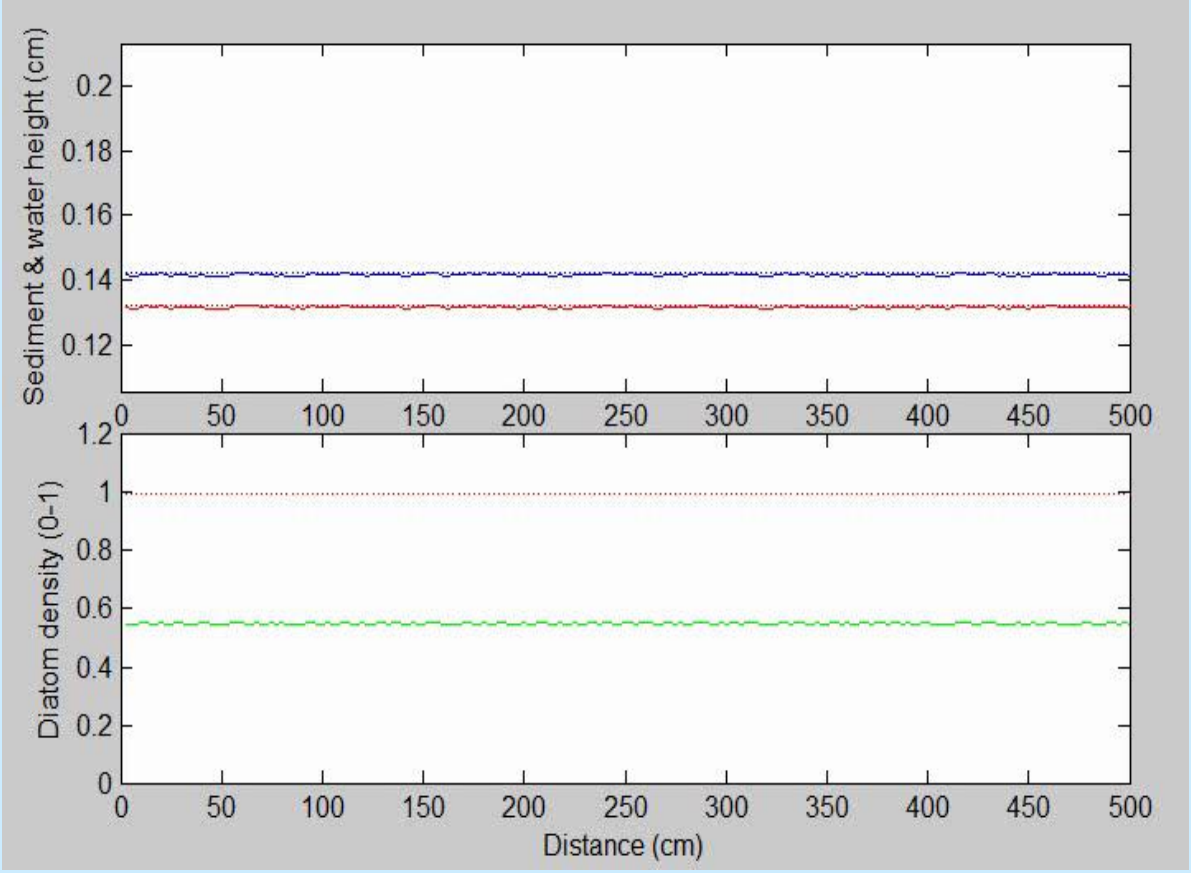
Mudflat pattern development

Sediment/water level

Diatom biomass



Cross-section through the mudflat (m)

Weerman et al, AmNat 2010

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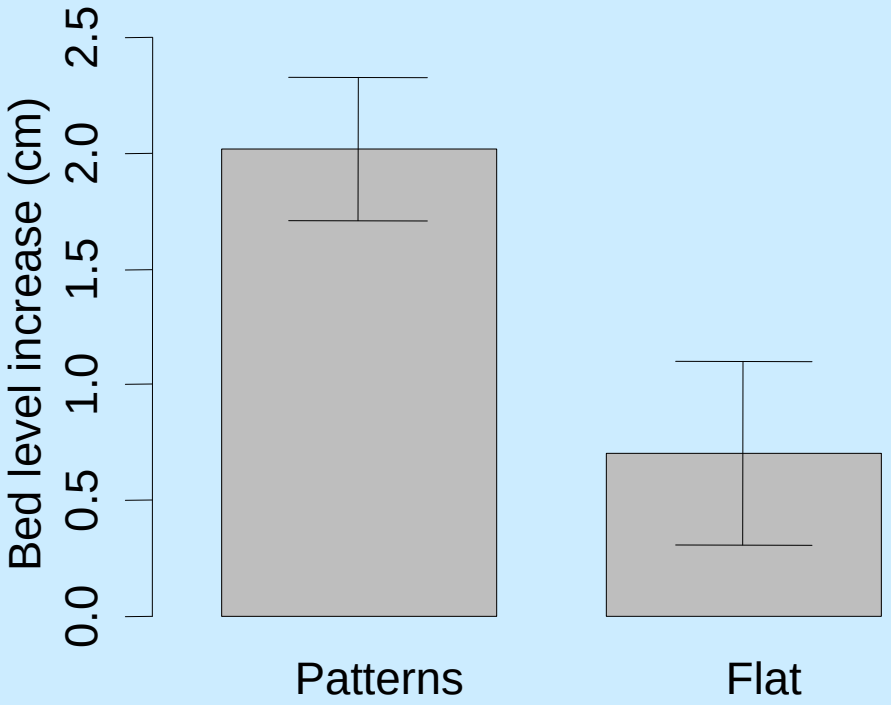
Measuring bed elevation change



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Differences in patterns

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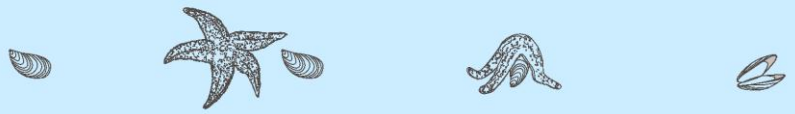
The landscape again?

- Diatoms determine shape the interaction between water and sediment
- Physics is more important, even for basic understanding
- Landscape is again important in shaping the final pattern.



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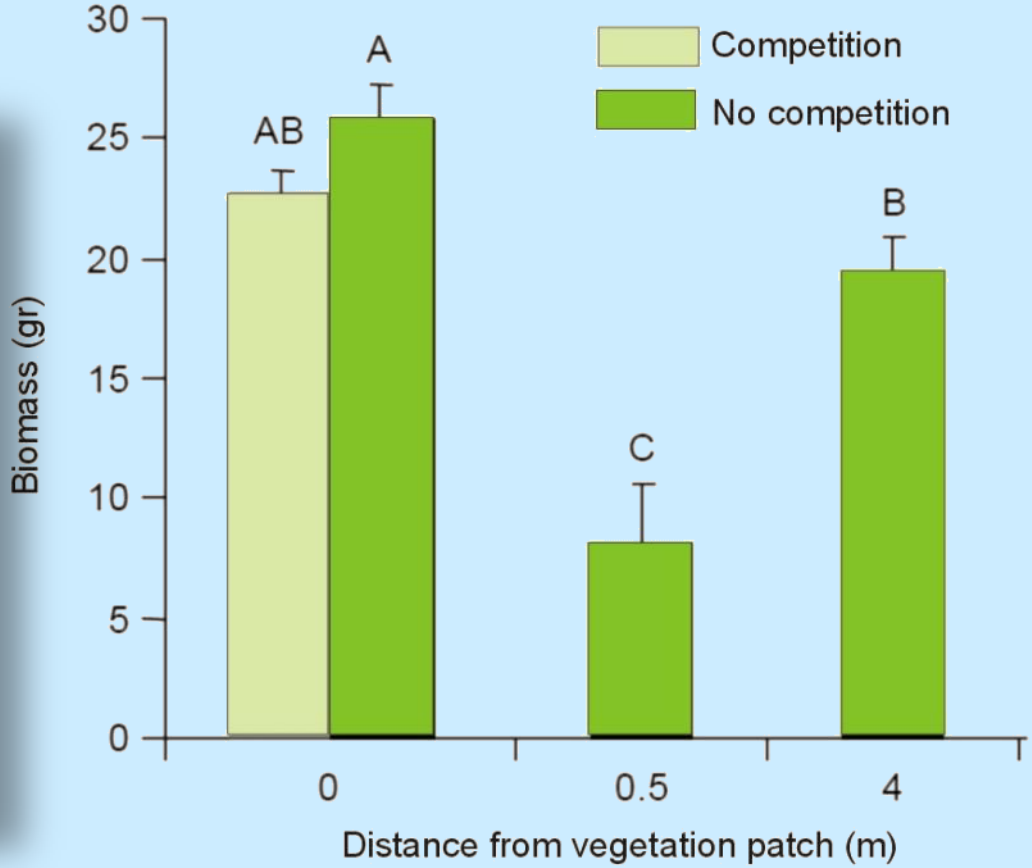
Tussock effects

Work of Bregje van Wesenbeeck

Scale-dependent feedback



Van Wesenbeeck et al. 2008

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Explaining the landscape?

1. Small-scale plant-flow-sediment feedbacks → 2. Large-scale landscape patterns

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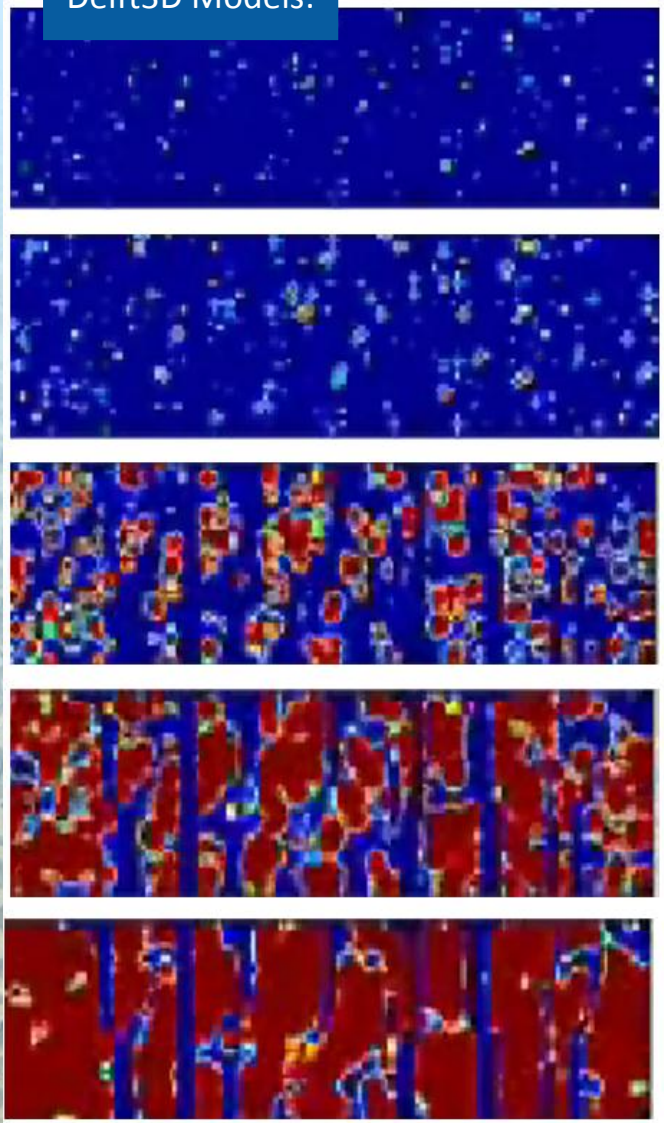
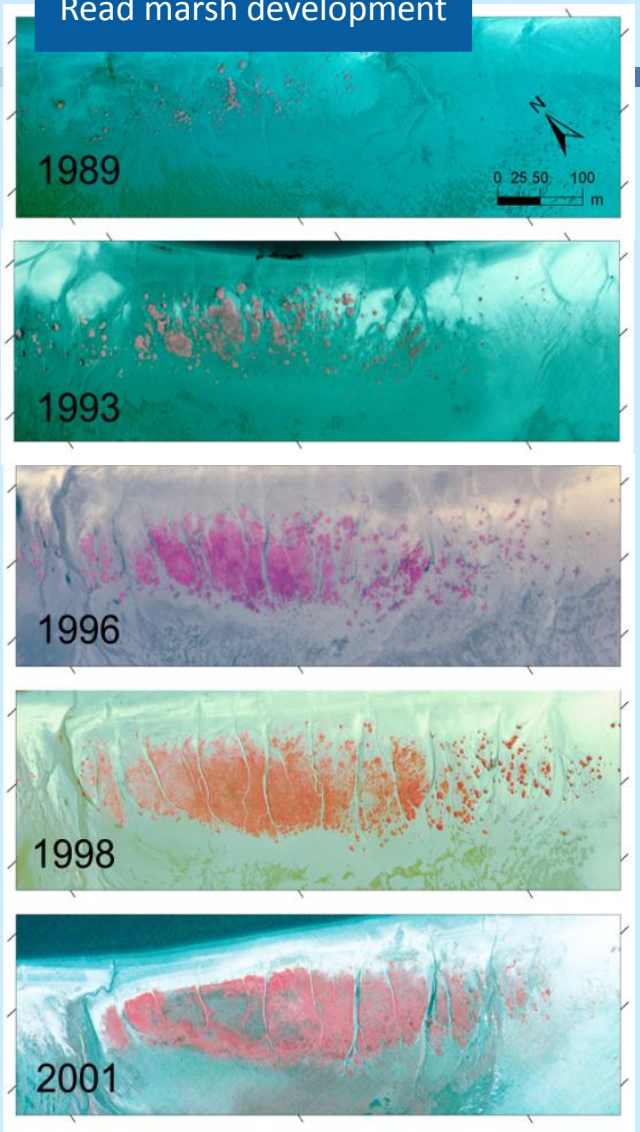
Self-organization of salt marsh

Delft3D Models:



Read marsh development



Work of
Stijn Temmerman

Temmerman et al.
Geology 2007

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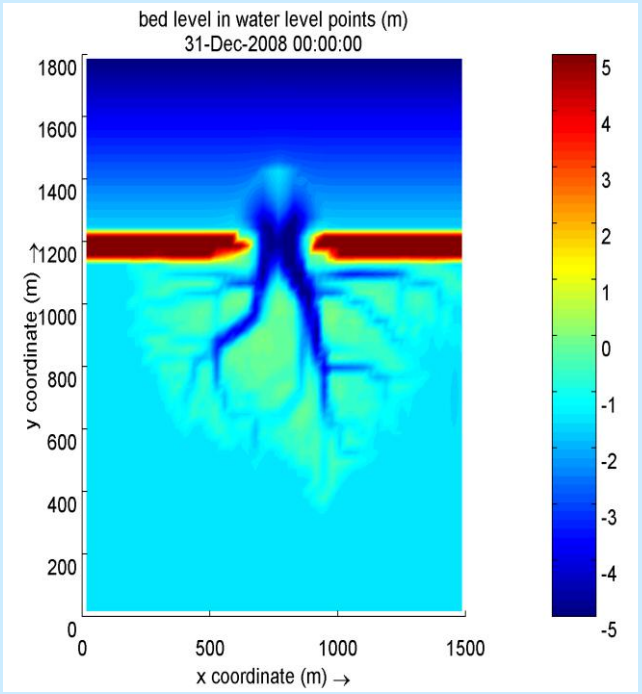
Internal gradients



Work of
Qinghua YE
Deltares

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Spatial self-organization

The process where local interactions generate large scale patterns…

Ideally!

Van de Koppel et al,
Science 2008

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In the real world

- Local feedback processes interact with landscape forcing to determine the shape of self-organized spatial patterns.




Pattern theory

- Regular patterns found in lots of systems
- Local facilitation and large-scale inhibition: Scale-dependent feedback
- Biological-physical interactions in nearly all examples
- Landscape features co-shape the pattern in nearly all case studies

(Van de Koppel, Bouma & Herman, J. Exp. Bio., 2012)