Salt marsh

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Next Subsection

Saltmarsh

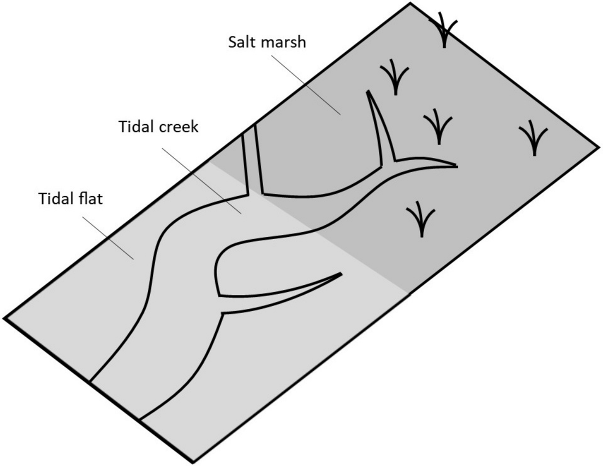


Figure: Intertidal zone.

Wanted

Figure: Model area.

Wanted

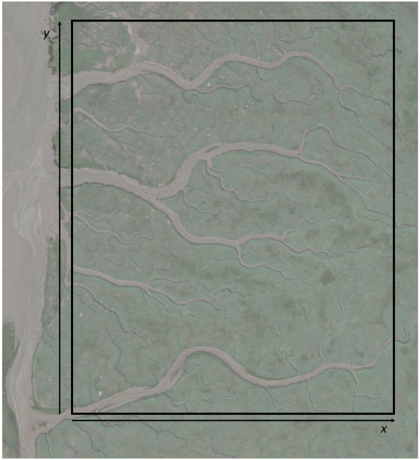


Figure: Computational domain.

Next Subsection

Results

Results

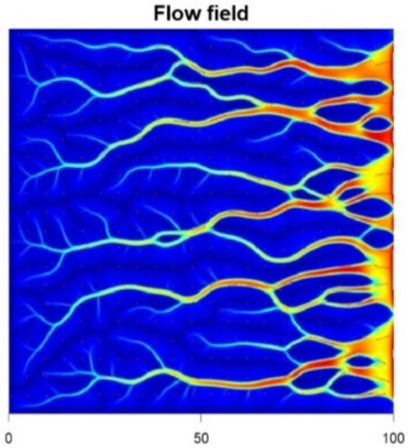


Figure: Flow field.

Results

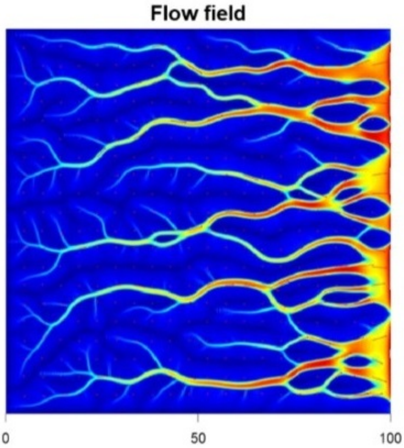
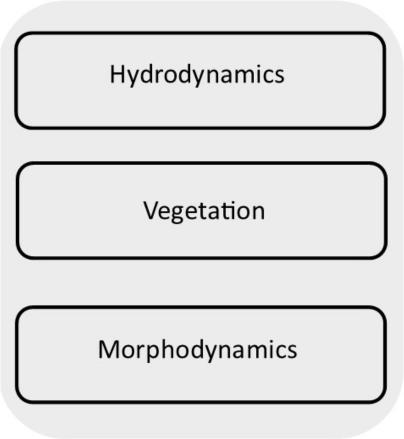


Figure: Flow field.

Figure: Salt marsh.

Overview



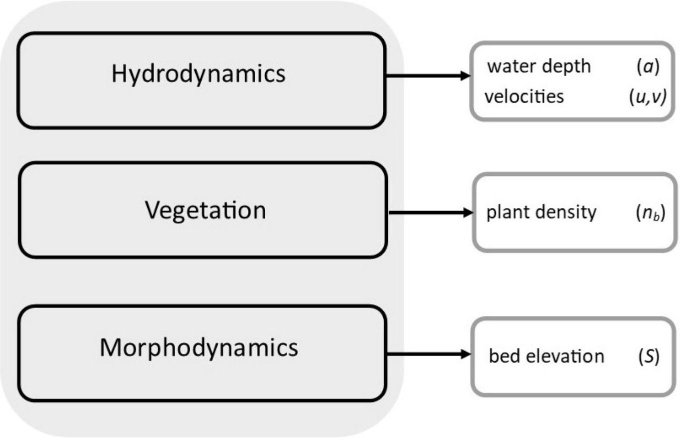
Hydrodynamics

Vegetation

Morphodynamics

Figure: Model components.

Overview



Hydrodynamics

Vegetation

Morphodynamics

water depth (a)
velocities (u,v)

plant density (n_b)

bed elevation (S)

Figure: Model components.

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   - Hydrodynamics
   - Morphodynamics
   - Vegetation
3. Graphics Processing Unit
   - General information
4. Research Questions
   - Overview
   - Question 1
   - Question 2
   - Question 3
   - Optional

Hydrodynamic model

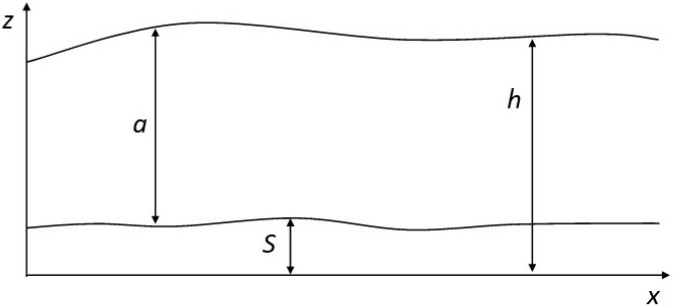

Figure: Sketch of the relevant variables.

Hydrodynamic model

Components current model

- Shallow water equations

Hydrodynamic model

Components current model

- Shallow water equations
  - Bottom friction

Hydrodynamic model

Components current model

- Shallow water equations
    - Bottom friction
- Wetting-drying algorithm

Shallow water equations

Assumed: horizontal distance much larger than vertical

Shallow water equations

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$$\frac{\partial \mathbf{u}}{t} + \mathbf{u}(\nabla \cdot \mathbf{u}) + g\nabla h - A(\nabla \cdot \nabla \mathbf{u}) + S\mathbf{u} = 0$$

$$\frac{\partial a}{\partial t} + \nabla a\mathbf{u} = 0$$

Shallow water equations

Assumed: horizontal distance much larger than vertical

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$\mathbf{u} = (u,\ v)^T$

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- One layer

Shallow water equations

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- One layer
- No wind stress

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Shallow water equations

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$\mathbf{u} = (u,\ v)^T$

- One layer
- No wind stress
- No Coriolis forces

Wetting drying algorithm

Wetting drying algorithm

Simple thin film algorithm with loss of conservation

Fluid over the entire computational domain

$$a = \max(a, H_{crit})$$

Wetting drying algorithm

Simple thin film algorithm with loss of conservation

Fluid over the entire computational domain

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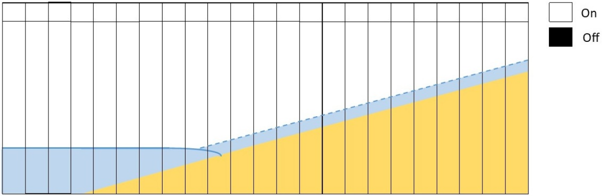

Figure: Thin film algorithm.

Wetting drying algorithm

Simple thin film algorithm with loss of conservation

Fluid over the entire computational domain

$$a = \max(a, H_{crit})$$

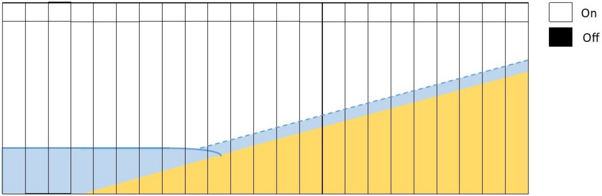

Figure: Thin film algorithm.

→ SWE can be applied to each grid point.

Bottom friction

Bottom friction

Bottom friction

$$\boldsymbol{\tau}_b = \rho g \mathbf{u} \|\mathbf{u}\| \frac{1}{C^2}$$

in which C represents the Chézy coefficient.

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Morphodynamic model

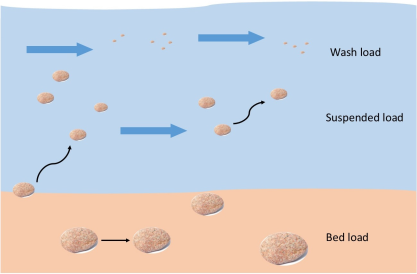

Figure: Sediment transport.

Morphodynamic model

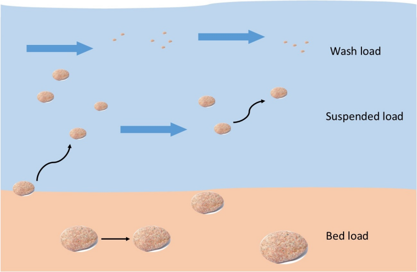

Figure: Sediment transport.

- Cohesive (*mud*) or non-cohesive (*sand/bed load*)

Morphodynamic model

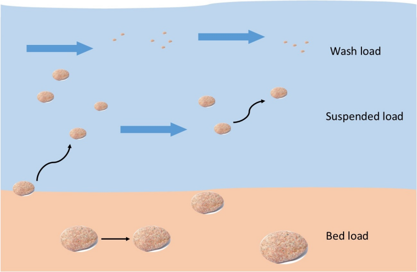

Figure: Sediment transport.

- Cohesive (*mud*) or non-cohesive (*sand/bed load*)
    - Cohesive sediments form larger particles

Morphodynamic model

Components current model

- Bed elevation

Morphodynamic model

Components current model

- Bed elevation
  - Sedimentation
  - Erosion
  - Diffusion

Morphodynamic model

Components current model

- Bed elevation
  - Sedimentation
  - Erosion
  - Diffusion

$$\frac{\partial S}{\partial t} = S_{in} a_{eff} - E\left(1 - p_E \frac{n_b}{K}\right)(u^2 + v^2)S + Dif(S, n_b).$$

Next Subsection

Vegetation model

Components current model

- Plant density

Vegetation model

Components current model

- Plant density
  - Dispersal
  - Growth
  - Mortality

Vegetation model

Components current model

- Plant density
  - Dispersal
  - Growth
  - Mortality

$$\frac{\partial n_b}{\partial t} = D\left(\frac{\partial^2 n_b}{\partial x^2} + \frac{\partial^2 n_b}{\partial y^2}\right) + r\left(1 - \frac{n_b}{K}\right) n_b \left(\frac{K_p}{K_p + a}\right)$$

$$- E_p n_b \sqrt{u^2 + v^2}.$$

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Friction coefficients

$$\boldsymbol{\tau}_b = \rho g \mathbf{u} \|\mathbf{u}\| \frac{1}{C^2}$$

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- Emergent vegetation
- Submergent vegetation

Friction coefficients

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$$C_e = \sqrt{\frac{1}{\frac{1}{C_b^2} + \frac{C_D m D a}{2g}}}$$

Friction coefficients

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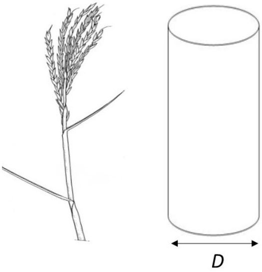

Figure: Rigid cylinder.

Friction coefficients

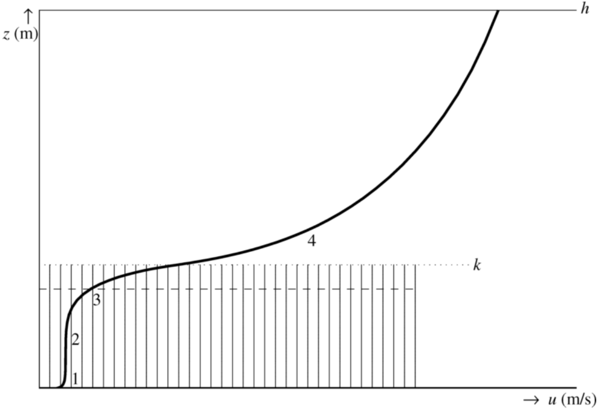

Figure: Four zones in the vertical profile for horizontal velocity.

Friction coefficients

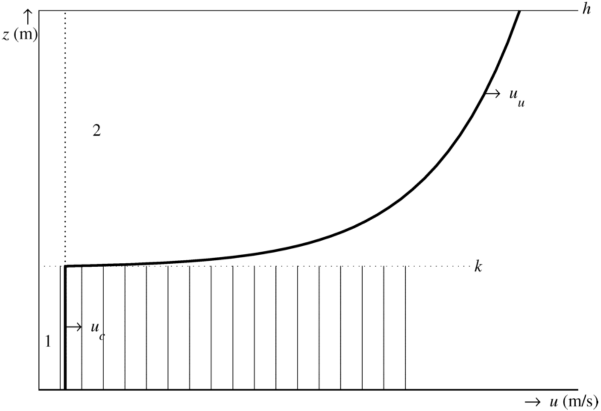

Figure: Two zones in the vertical profile for horizontal velocity.

Friction coefficients

- Submergent vegetation

$$C_s = \sqrt{\frac{1}{\frac{1}{C_b^2} + \frac{CmDk}{2g}}} + \sqrt{\frac{g}{K_0}} \ln\left(\frac{a}{k}\right)$$

Friction coefficients

- Submergent vegetation

$$C_s = \sqrt{\frac{1}{\frac{1}{C_b^2} + \frac{CmDk}{2g}}} + \sqrt{\frac{g}{K_0}} \ln\left(\frac{a}{k}\right)$$

Current model: C_s

Next Subsection

Graphics processing unit

Figure: Salt marsh.

Graphics processing unit

A GPU

- was designed to support computer graphics

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- consists of thousands of small, efficient cores, while a CPU consists only of a few cores

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Graphics processing unit

A GPU

- was designed to support computer graphics
- consists of thousands of small, efficient cores, while a CPU consists only of a few cores
- takes over tasks of the Central Processing Unit (CPU)
- is a Single Instruction Multiple Data (SIMD) processor

Graphics processing unit

Need to take into account

Graphics processing unit

Need to take into account

- sending information between CPU and GPU is time-consuming

Graphics processing unit

Need to take into account

- sending information between CPU and GPU is time-consuming
- limited memory is available on GPU

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Research Questions

How can we improve the current salt marsh model in terms of

- the included processes?

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- the included processes?
- the used grid, discretisation and solver?

Research Questions

How can we improve the current salt marsh model in terms of

- the included processes?
- the used grid, discretisation and solver?
- a multi-scale approach?

Next Subsection

Research - Processes

Current model

- Input at whole domain

Research - Processes

Current model

- Input at whole domain
- No ebb and flood

Research - Processes

Current model

- Input at whole domain
- No ebb and flood

Idea

Tides

Research - Processes

Current model

- Input at whole domain
- No ebb and flood

Idea

Tides

$$a(t) = M_S + A_S \sin\left(\frac{2\pi t}{T}\right)$$

Research - Processes

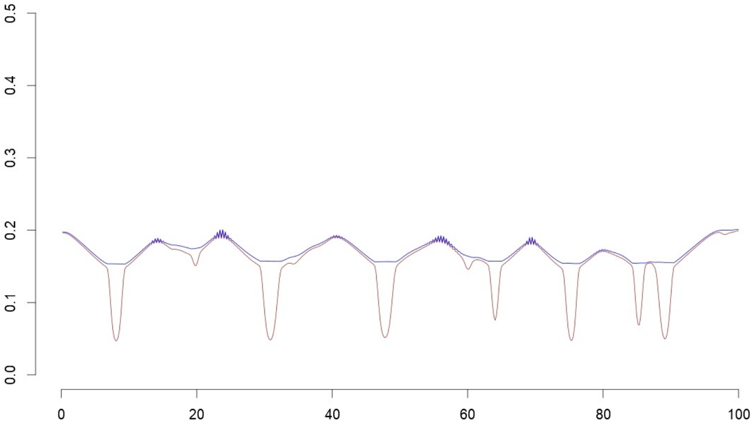

Figure: Result.

Research - Processes

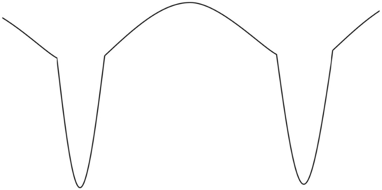

Figure: Current situation.

Research - Processes

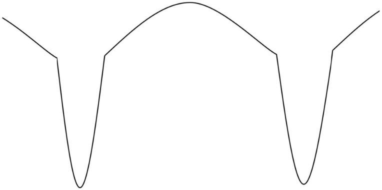

Figure: Current situation.

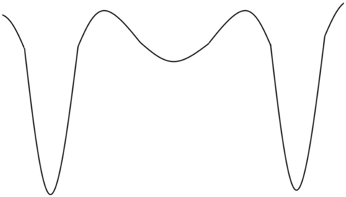

Figure: Wanted situation.

Research - Processes

Current model

$S_{in} a_{eff}$

Research - Processes

Current model

$S_{in} a_{eff}$

→ No small dikes
next to tidal creeks

Research - Processes

Current model

$S_{in} a_{eff}$

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Idea

Other sedimentation formulation

Research - Processes

Current model

$S_{in} a_{eff}$

→ No small dikes next to tidal creeks

Idea

Other sedimentation formulation

Use: transport equation

Research - Processes

Transport equation for mud

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} - \frac{1}{a}\frac{\partial}{\partial x}\left(aD\frac{\partial c}{\partial x}\right) - \frac{1}{a}\frac{\partial}{\partial y}\left(aD\frac{\partial c}{\partial y}\right) - \frac{S}{a} = 0$$

Research - Processes

Transport equation for mud

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} - \frac{1}{a}\frac{\partial}{\partial x}\left(aD\frac{\partial c}{\partial x}\right) - \frac{1}{a}\frac{\partial}{\partial y}\left(aD\frac{\partial c}{\partial y}\right) - \frac{S}{a} = 0$$

- Convection
- Diffusion
- Sources and sinks

Optional - Processes

Hydrodynamic model

Optional - Processes

Hydrodynamic model

- Wind stress

Optional - Processes

Hydrodynamic model

- Wind stress

$$\frac{\boldsymbol{\tau}_s}{\rho_{\text{air}}} = c_f W^2$$

Optional - Processes

Hydrodynamic model

- Wind stress

$$\frac{\boldsymbol{\tau}_s}{\rho_{\text{air}}} = c_f W^2$$

Morphodynamic model

Optional - Processes

Hydrodynamic model

- Wind stress

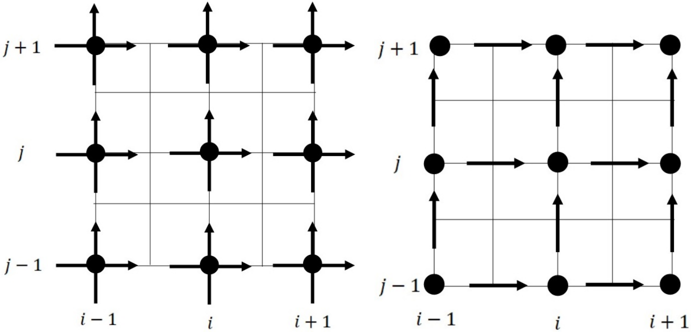
$$\frac{\boldsymbol{\tau}_s}{\rho_{\text{air}}} = c_f W^2$$

Morphodynamic model

- Sediment mobility not dependent on algae?

Next Subsection

Research - Grid



(a) Collocated grid (b) Staggered grid

Figure: →, ↑: velocity components; •: water depth and bottom elevation.

Research - Grid

$$\frac{\partial a}{\partial t} + \frac{\partial}{\partial x}(au) + \frac{\partial}{\partial y}(av) = 0$$

Research - Grid

$$\frac{\partial a}{\partial t} + \frac{\partial}{\partial x}(au) + \frac{\partial}{\partial y}(av) = 0$$

$$\frac{da_C}{dt} + \frac{a_E u_E - a_W u_W}{2\Delta x} + \frac{a_N v_N - a_S v_S}{2\Delta y} = 0$$

Research - Grid

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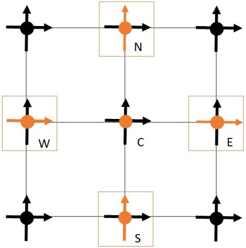

Figure: Decoupling in continuity equation.

Research - Grid

Advantages staggered grid

- Avoid odd-even decoupling

Research - Grid

Advantages staggered grid

- Avoid odd-even decoupling
- Smaller number of variables

Research - Grid

Advantages staggered grid

- Avoid odd-even decoupling
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Disadvantages

- Boundary conditions could be hard

Research - Discretisation

- Space discretisation

Research - Discretisation

- Space discretisation
    - Used: finite difference method

Research - Discretisation

- Space discretisation
  - Used: finite difference method
  - Finite volume method

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Research - Multi-time-scale

- Morphological acceleration factor

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$$\frac{\partial S}{\partial t} = f_{MOR}\,(\ldots\ldots)$$

Research - Multi-time-scale

- Morphological acceleration factor

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  - Simple: each iteration

Research - Multi-time-scale

- Morphological acceleration factor

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  - Simple: each iteration
  - Complex: hydrodynamic simulation of period T
    $\rightarrow$ geomorphic simulation of period $f_{MOR}T$.

Research - Multi-time-scale

- Morphological acceleration factor

$$\frac{\partial S}{\partial t} = f_{MOR} \left(\ldots \ldots \right)$$

  - Simple: each iteration
  - Complex: hydrodynamic simulation of period T
    $\rightarrow$ geomorphic simulation of period $f_{MOR} T$.

- Vegetation acceleration factor?

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Optional - Processes

Wetting-drying methods

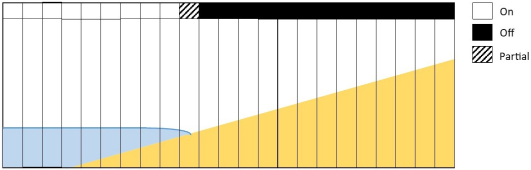
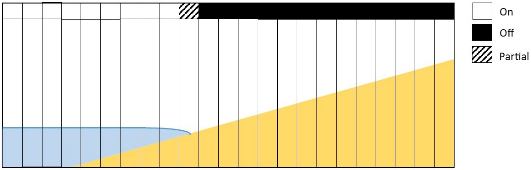


Figure: Element removal algorithm.

Optional - Processes

Wetting-drying methods



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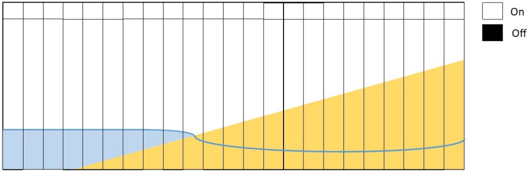

Figure: Negative depth algorithm.

Optional - Processes

Morphodynamic model

Optional - Processes

Morphodynamic model

- Threshold formulation for sedimentation and erosion?

Optional - Processes

Morphodynamic model

- Threshold formulation for sedimentation and erosion?

$$Sr = w_s C_b \left(1 - \frac{\tau}{\tau_{cr,d}}\right) \quad \text{when } \tau < \tau_{cr,d}$$

$$Er = M \left(\frac{\tau}{\tau_{cr,e}} - 1\right) \quad \text{when } \tau > \tau_{cr,e}$$

Optional - Integration

Time integration method

Optional - Integration

Time integration method

- Used: Euler forward

Optional - Integration

Time integration method

- Used: Euler forward
- Implicit

Optional - Multi-space-scale

- Vegetation finer grid?

Optional - Multi-space-scale

- Vegetation finer grid?

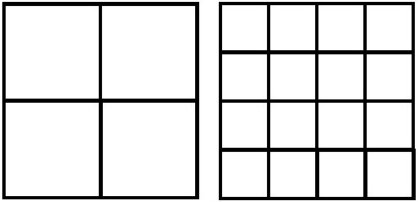

Figure: Coarse and fine grid.

Discussion

Test Problem

(a) Top view "Verdronken Land van Saeftinghe".

(b) Zoomed in on test area.

Figure: Test area.

Result

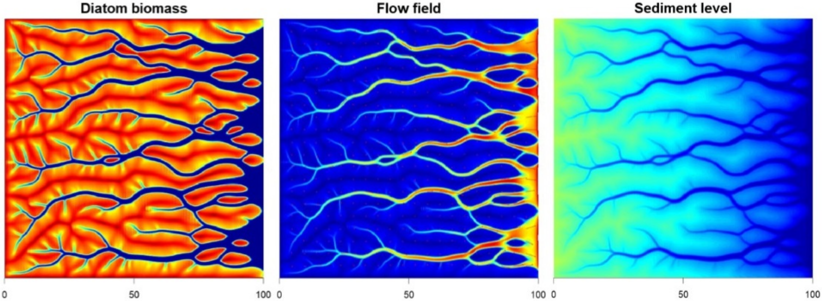

Figure: Result.