A 3D baroclinic model of the Burdekin River Plume, Australia

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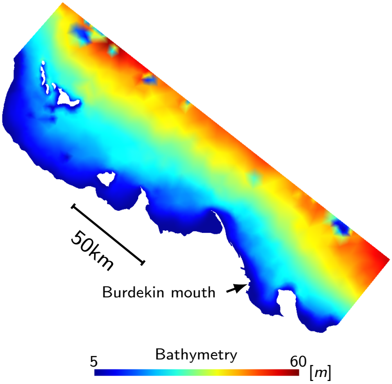
JONSMOD 2014

May 14, 2014

The problem

Goal : Understanding the key proccesses controlling the fate of sediment exported by the Burdekin River to the Great Barrier Reef [Lewis et al. *EPSL*, 2014]



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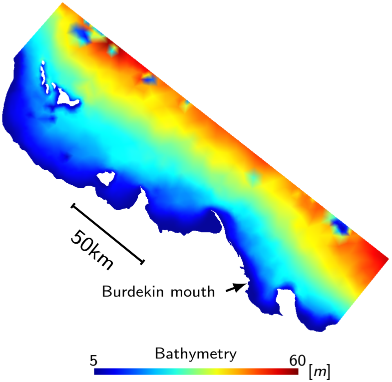


⇒ 3D modelling

SLIM 3D : a baroclinic dg-finite element model

Second-generation Louvain-la-Neuve Ice-ocean Model[1]

- Spatial features
  - P_1 dg-finite element discretisation
  - prismatic elements
  - ALE formulation on a moving mesh

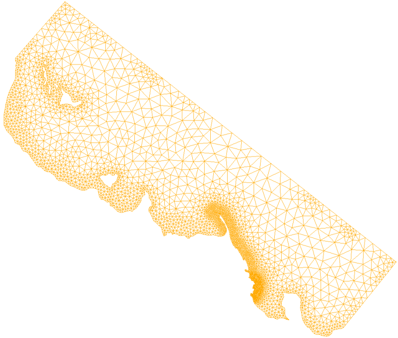
- Time discretisation
  - split-explicit approach
  - implicit vertical diffusion on every column

[Kärnä et al. *OM*, 2013]

[1] www.climate.be/slim

Applying SLIM 3D to the Burdekin River Plume dynamics

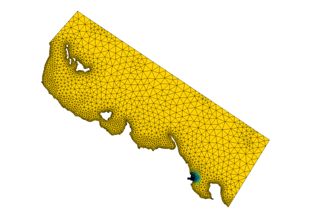
- Until now:
  - Square boxes geometry
  - flat or linear bathymetry
- The Challenge:
  - Complex geometry
  - Complex bathymetry
  - Actual forcings

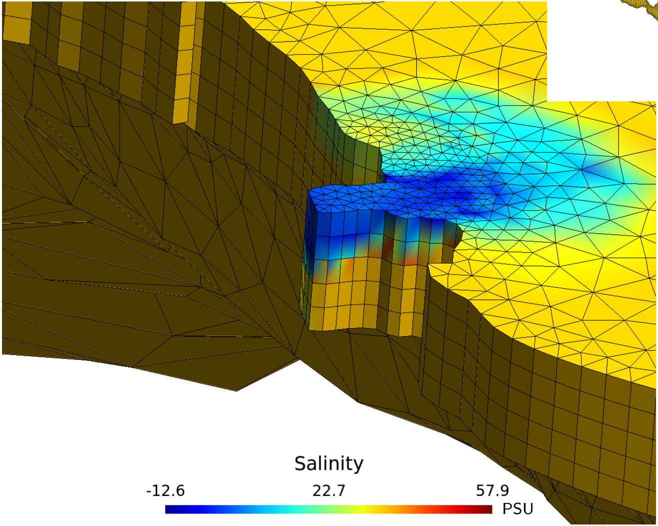


Mesh generated with Gmsh Software[2]

[2] www.geuz.org/gmsh

Overshoot problems





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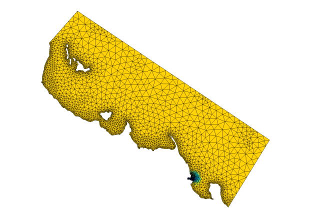
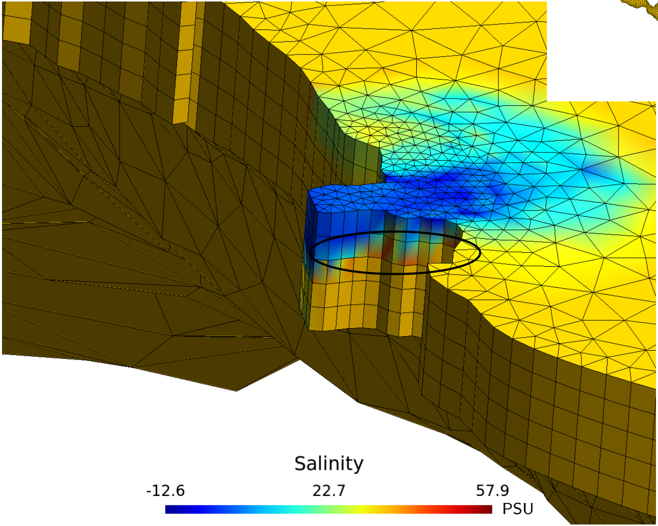
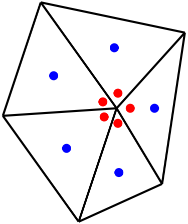


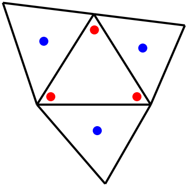


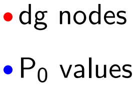
Limiters are necessary !

- Kuzmin [*JCAM*, 2010], Aizinger [2011]



- Cockburn and Shu [*JCP*, 1998]





Limiter principle

- Original value for node #i of Element #e: S_i^e
- P_0 value: $\|S^e\| = \sum_i S_i^e w_i^e$

- Choose $\hat{S}_i^e$ such that: $\min_e \leq \hat{S}_i^e \leq \max_e$

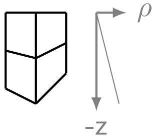
$$\hat{S}_i^e = \lambda_e S_i^e + (1 - \lambda_e)\frac{\|S^e\|}{\sum_i w_i^e}$$

  - $\lambda_e = 1$: original value
  - $\lambda_e = 0$: P_0 value

Cockburn's limiter

No more overshoots, but it has a cost:

- Invalid lake at rest for a stratified water column.



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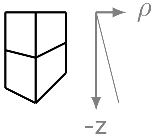

- Constant fields on an element where strong gradients appear $\Rightarrow$ Loss of precision.

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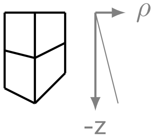

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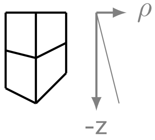
  $\Rightarrow$ Choose boundary condition for limiter



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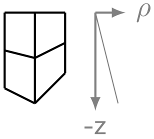
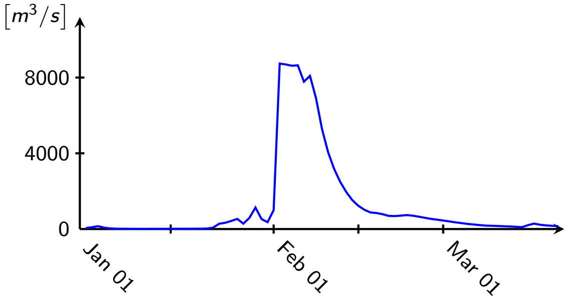


- Constant fields on an element where strong gradients appear
  ⇒ Loss of precision. ⇒ Adaptive mesh
- This can lead to non-physical behaviour for σ-layers vertical discretisation. ⇒ Constant depth for upper layers

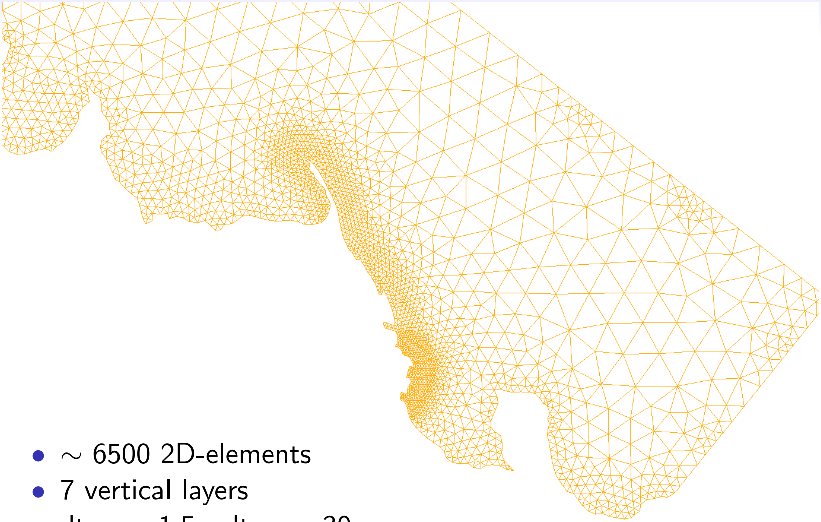
Burdekin River Plume dynamics

- Burdekin river discharge for 2007 flood season



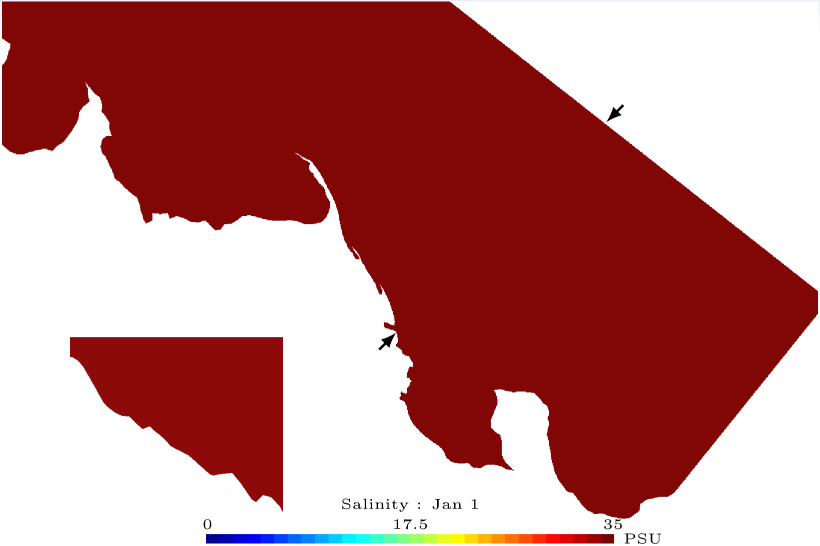
- Wind forcing
- Tidal forcing
- Varying sediment concentration discharge

Salinity dynamics



- $\sim$ 6500 2D-elements
- 7 vertical layers
- $dt_{2D} = 1.5s$, $dt_{3D} = 30s$
- 18 times faster than physical time on 11 CPUs

Salinity dynamics



Sediment model

C : sediment concentration $\left[kg/m^3\right]$ [Lambrechts et al., 2010]

- Settling

$$w_s = -\min(10^{-2}C,\ 2\cdot 10^{-4}) \qquad [m/s]$$

$$D = \begin{cases} C\ w_s\left(1 - \frac{|\mathbf{u_b}|}{u_d}\right)^2 & \text{if } |\mathbf{u_b}| < u_0 \\ 0 & \sim \end{cases} \qquad \left[kg/(m^2\ s)\right]$$

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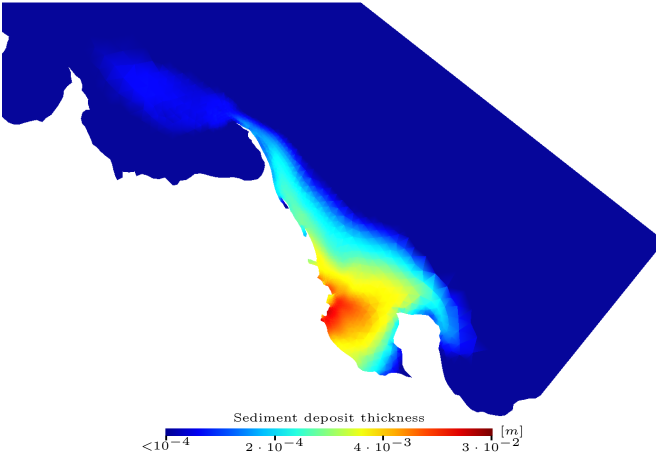
- Erosion

$$E_0 = A_0 \left(\frac{|\mathbf{w}|}{w_0}\right)^3 \left(\frac{|\mathbf{u_b}|}{u_0}\right)^4 F, \qquad E_1 = \begin{cases} A_1 \left(\left(\frac{|\mathbf{u_b}|}{u_0}\right)^4 - 1\right) & \text{if } |\mathbf{u_b}| > u_0 \\ 0 & \sim \end{cases}$$

$$E = E_0 + E_1 \qquad \left[kg/(m^2\ s)\right]$$

Results

- Only with settling effect :
  $>$50km region : deposit thickness $<$ 0.1mm
  $\Rightarrow$ accordance with Lewis et al. [*EPSL*, 2014]



Conclusions and Perspective

- Burdekin River model

- SLIM 3D model

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  - SLIM 3D is ready to model actual coastal applications for a small ratio max(bath)/min(bath)
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Thank you for your attention !