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

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The problem

**Goal:** Understanding the key processes 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

• 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]

1www.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\textsuperscript{2}

\textsuperscript{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.

\[ \rho \]

\[ -z \]
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- Constant fields on an element where strong gradients appear
  $\Rightarrow$ Loss of precision.
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  \( \Rightarrow \) Choose boundary condition for limiter

- Constant fields on an element where strong gradients appear  
  \( \Rightarrow \) Loss of precision.  \( \Rightarrow \) Adaptive mesh

- This can lead to non-physical behaviour for \( \sigma \)-layers vertical discretisation.  \( \Rightarrow \) Constant depth for upper layers
Burdekin River Plume dynamics

- Burdekin river discharge for 2007 flood season

\[ m^3/s \]

- 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 $[kg/m^3]$  

- **Settling**

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

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

- **Erosion**

\[
E_0 = A_0 \left(\frac{|w|}{w_0}\right)^3 \left(\frac{|u_b|}{u_0}\right)^4 F,
\]

\[
E_1 = \begin{cases} 
A_1 \left(\left(\frac{|u_b|}{u_0}\right)^4 - 1\right) & \text{if } |u_b| > u_0 \\
0 & \text{otherwise}
\end{cases}
\]

\[
E = E_0 + E_1 \quad [\text{kg} / (\text{m}^2 \text{s})]
\]

[Lambrechts et al., 2010]
Results

- Only with settling effect:
  >50km region: deposit thickness < 0.1mm
  \[ \Rightarrow \text{accordance with Lewis et al. } [EPSL, 2014] \]
Conclusions and Perspective

- Burdekin River model

- SLIM 3D model

During a flood event, the sediments do stay in the region defined by Lewis et al. [EPSL, 2014]. For a larger simulation, the erosion rate needs to be enhanced.

SLIM 3D is ready to model actual coastal applications for a small ratio max(bath)/min(bath). For a better accuracy, SLIM 3D needs to be able to manage z-layers or hanging nodes.

Thank you for your attention!
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