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Modeling of bedrock channel and cave evolution using computational fluid dynamics

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Overview

- Introduction
- Existing literature on bedrock channel cross-section modeling
- Limits of cross-section models
  - Example of sediment influence
- 3D computational fluid dynamics (CFD) modeling
- Results

Motivation

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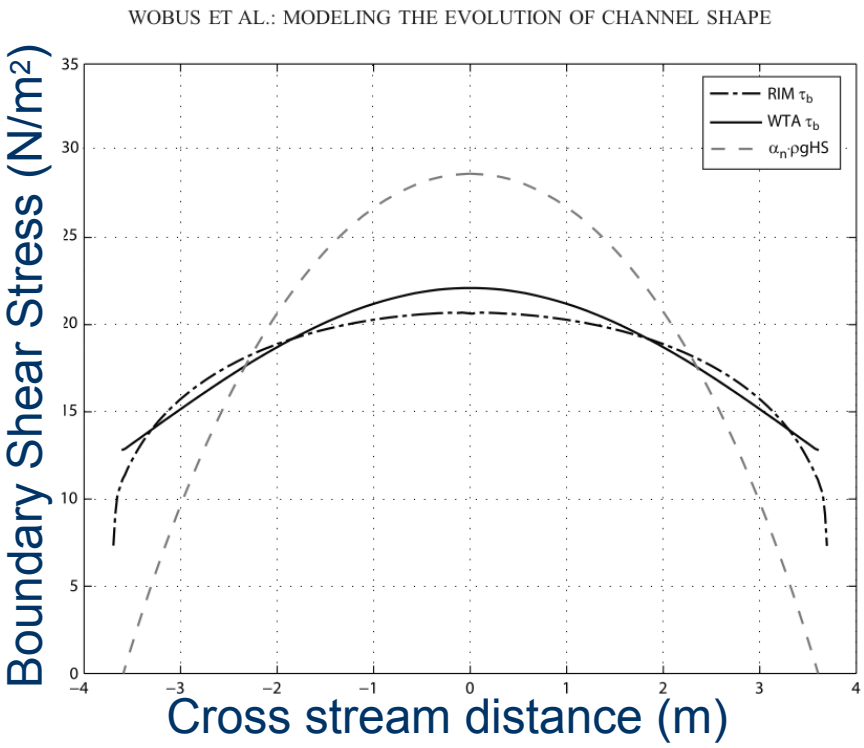
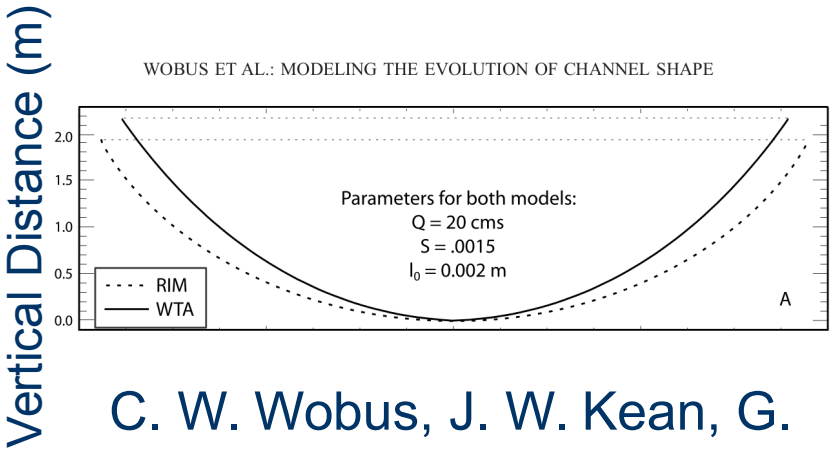
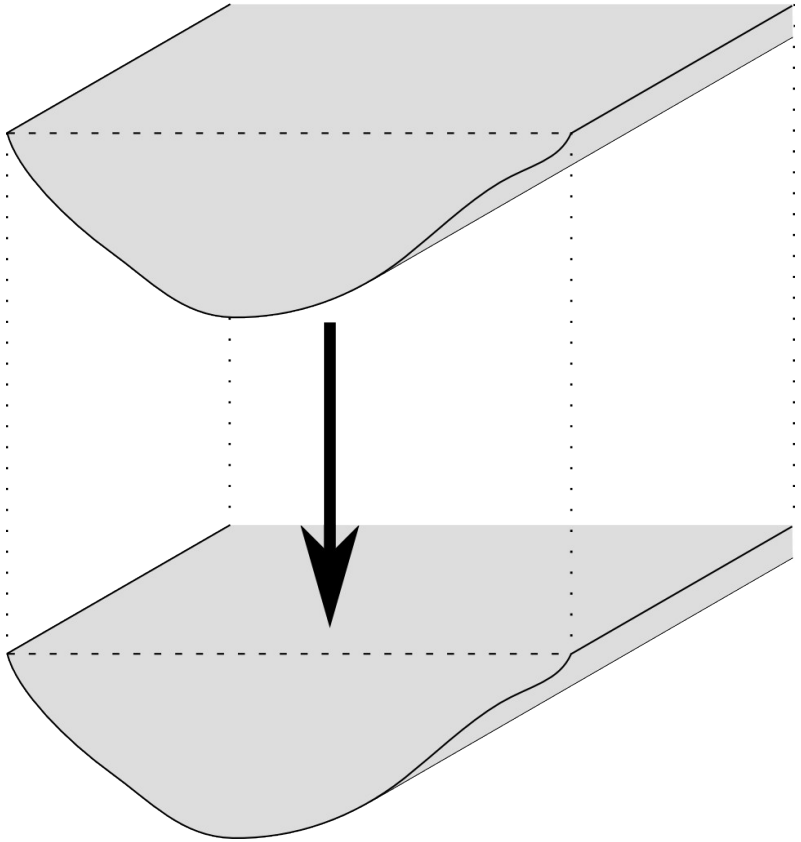
Numerical modeling of bedrock channel cross-sections





C. W. Wobus, J. W. Kean, G. E. Tucker, R. S. Anderson: Modeling the evolution of channel shape: Balancing computational efficiency with hydraulic fidelity, *Journal of Geophysical Research* **113** (F2) (2008)

Numerical modeling of bedrock channel cross-sections

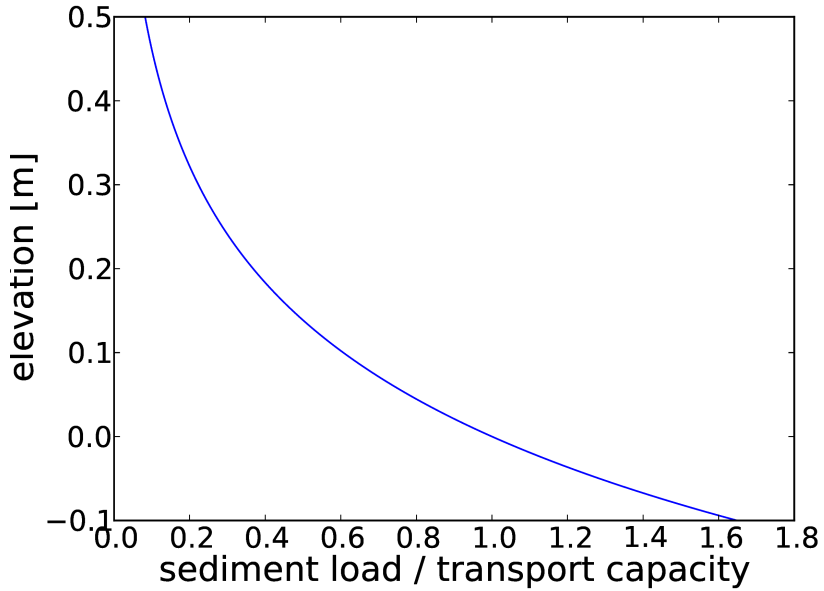


Sediment behavior

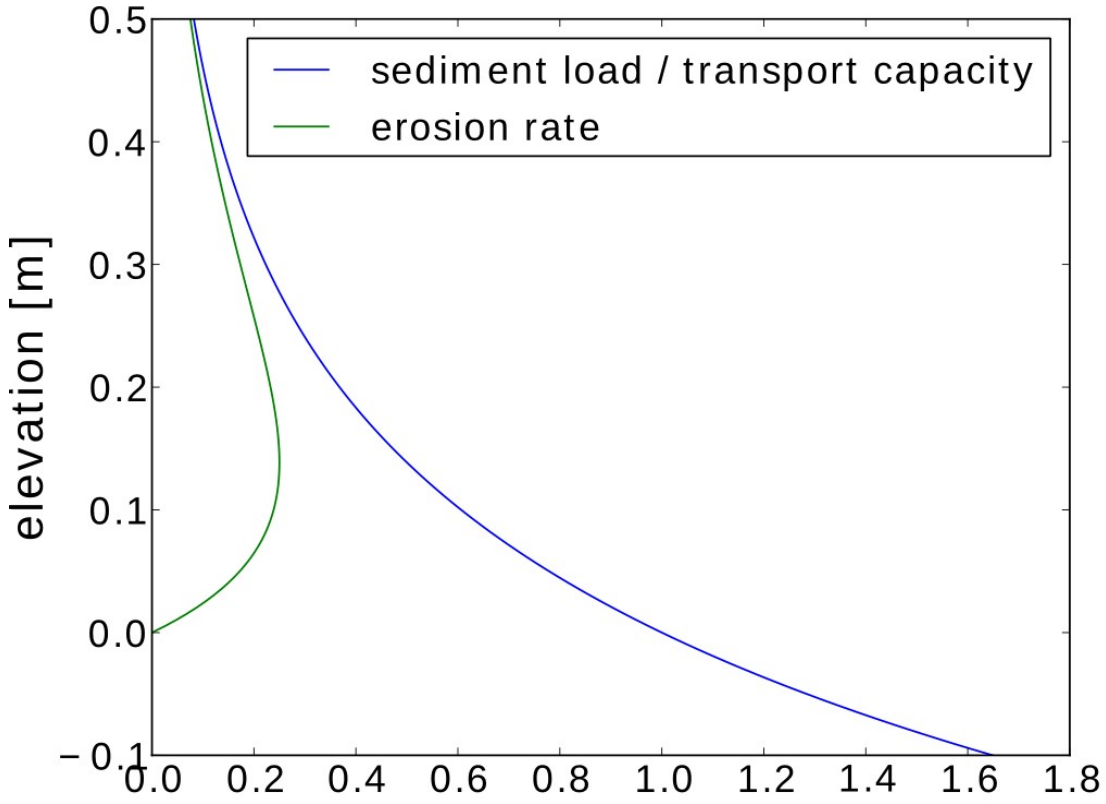
- Erosion is caused by sediment
- Local boundary shear stress is **not** the only variable influencing erosion rates along the boundary
- P. A. Nelson, G. Seminara, Modeling the evolution of bedrock channel shape with erosion from saltating bed load, *Geophysical Research Letters* **38** (2011)

Influence of sediment

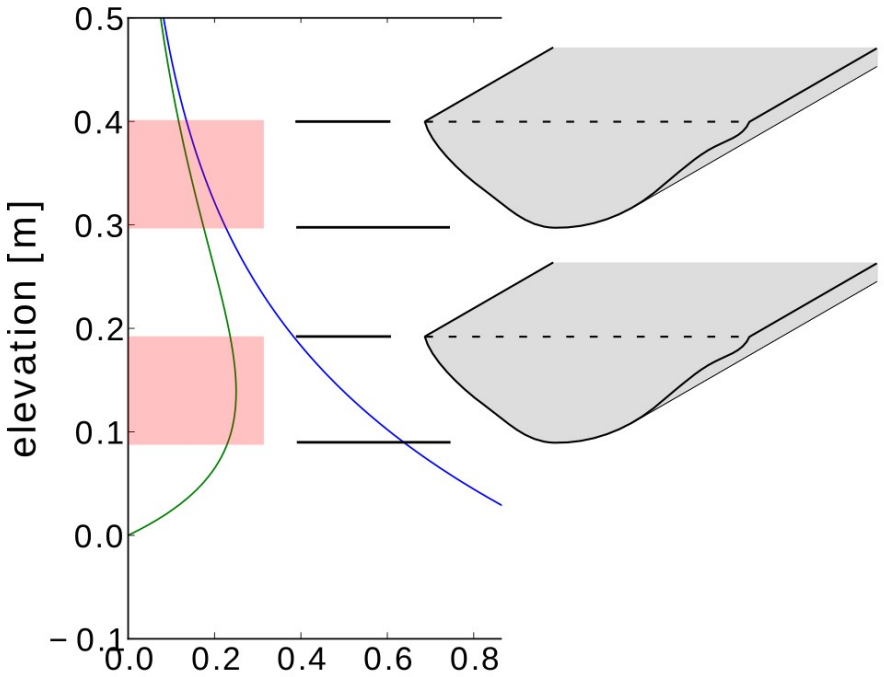
- L. S. Sklar, W. E. Dietrich, A mechanistic model for river incision into bedrock by saltating bed load, Water Resources Research **40** (2004)
- Tools effect: bedrock is abraded by bed load
- Cover effect: bed load protects bedrock from erosion
- Erosion is fastest when 1/2 surface is covered



Influence of sediment

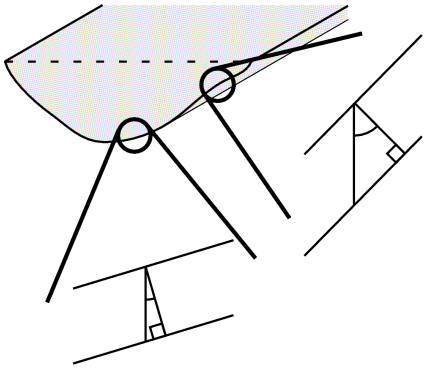


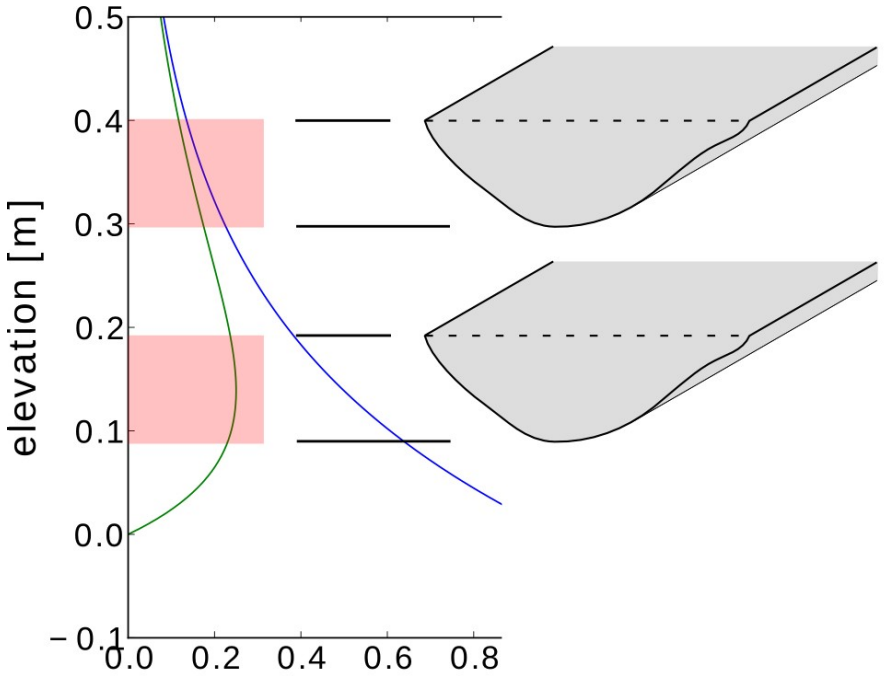
Stability



- In stable cross-sections, bigger local bank slope means smaller erosion rate
- If erosion rate maximum does not occur at the lowest point, the cross-section is unstable

Stability





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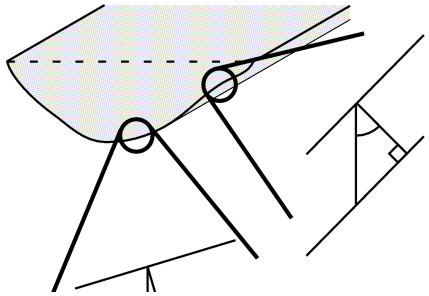
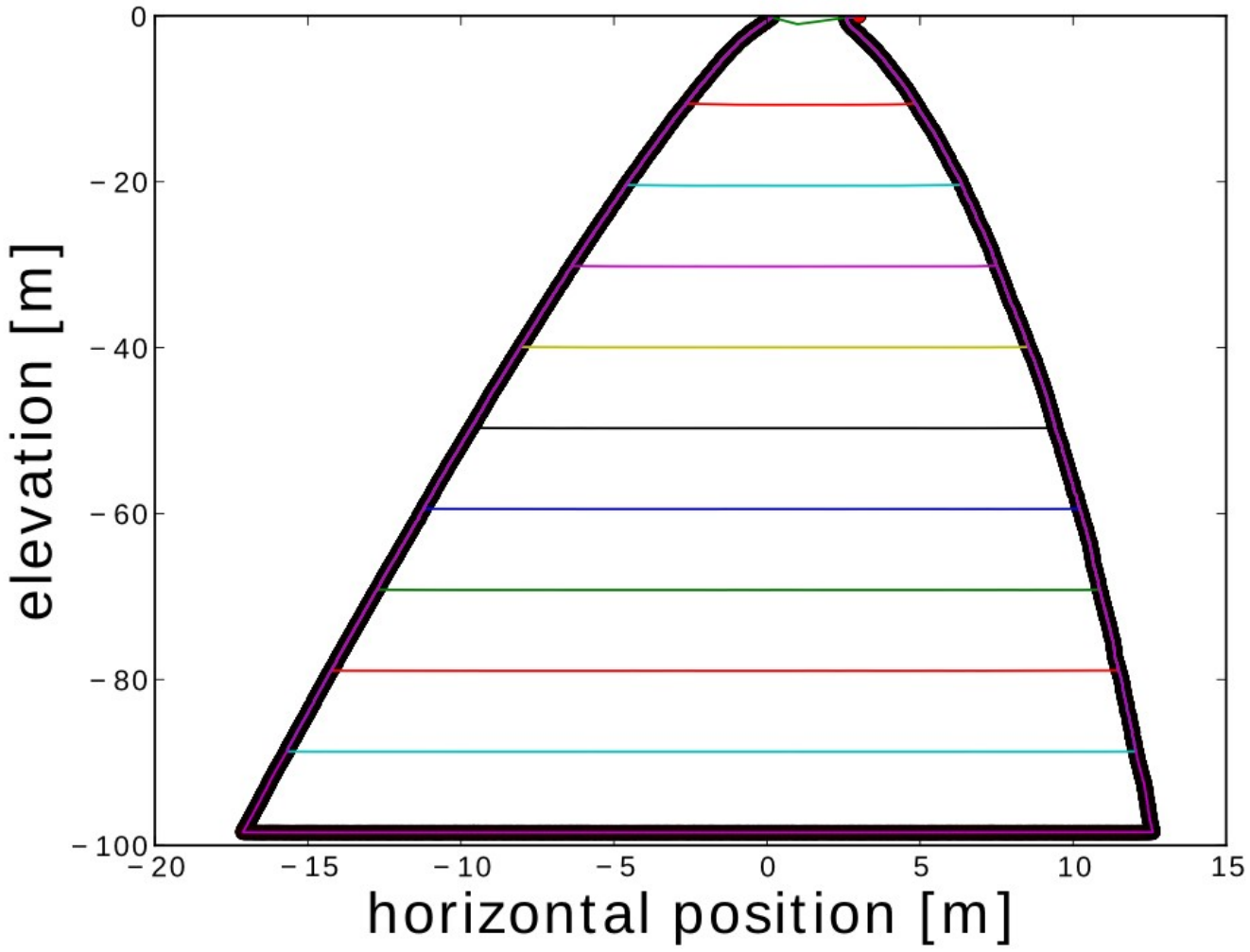
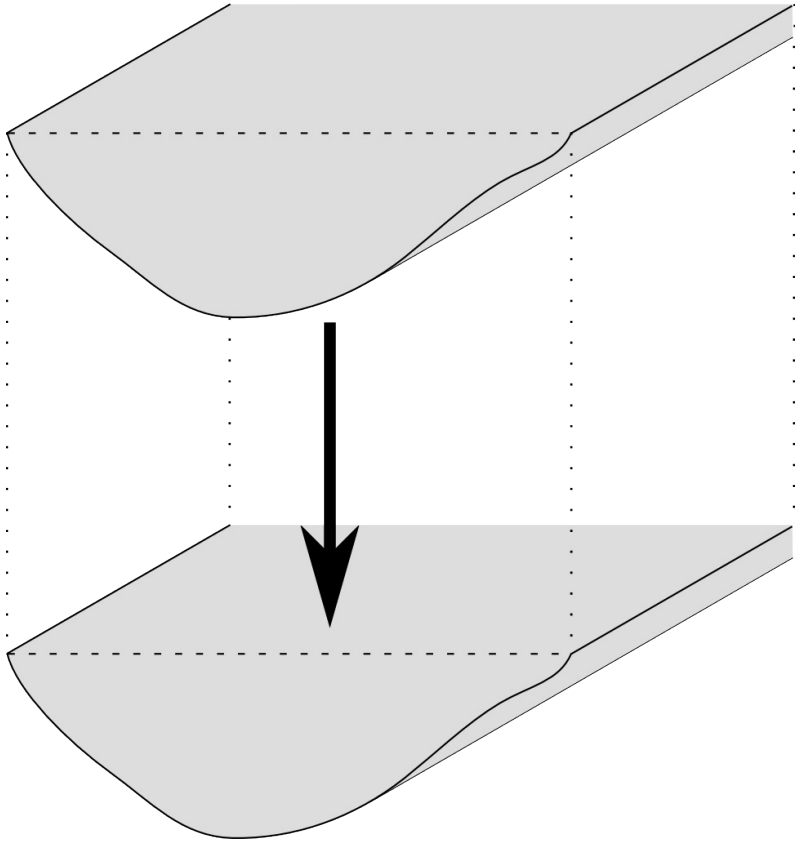



0
−20
−40
−60
−80
−100
elevation [m]
−20
−15
−10
−5
0
5
10
15
horizontal position [m]

Beyond steady-state assumption



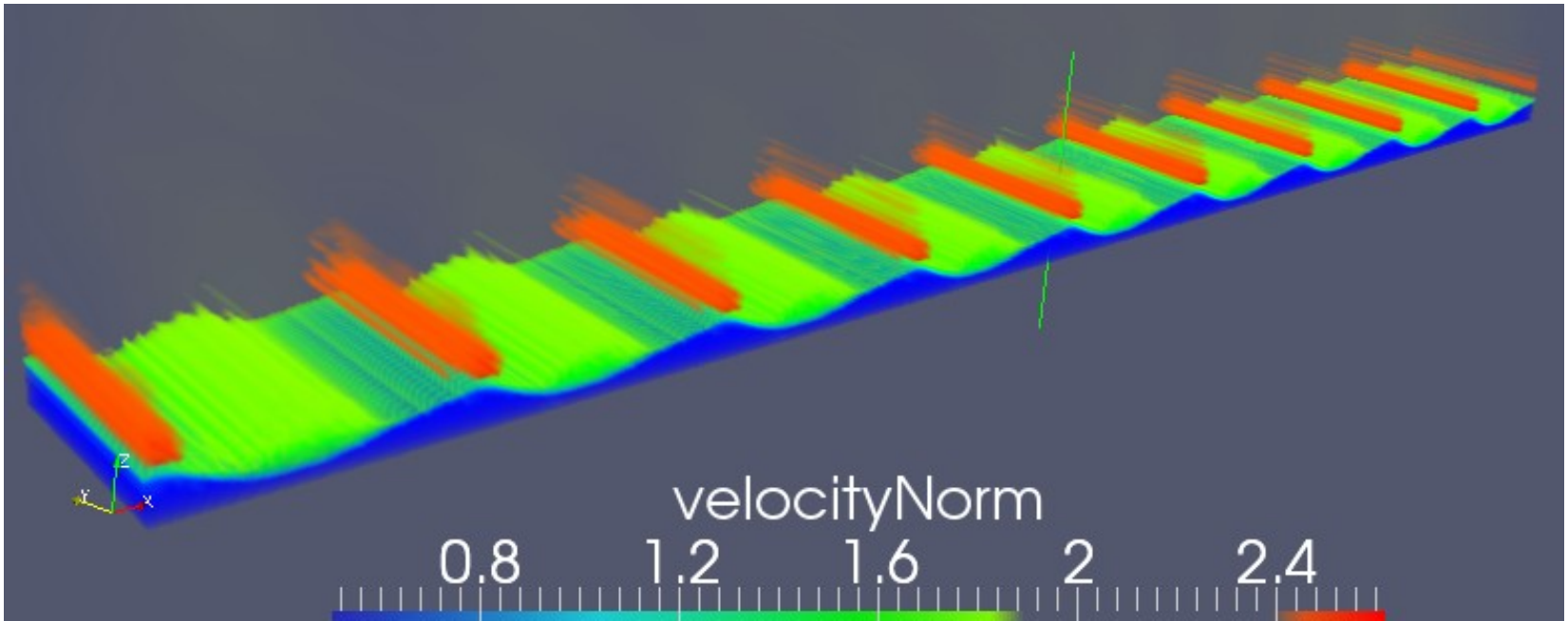
- Cross-section (and slope) stays constant through time
- Cross-section (and slope) stays constant along the channel

Computational Fluid Dynamics (CFD)

- Using numerical methods to calculate fluid flow
- In our context: calculating fluid flow using some efficient universal software package developed by someone else (instead of crude methods we are able to implement)

Lattice-Boltzmann Method

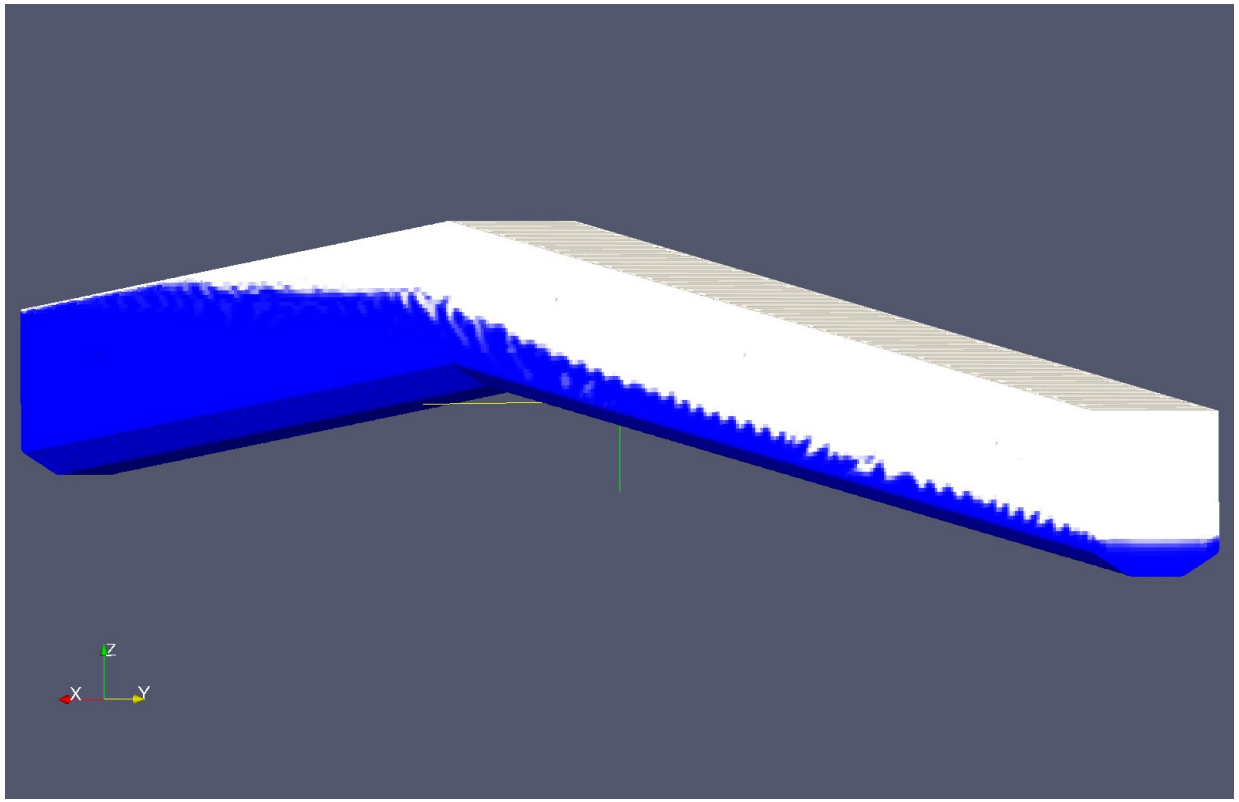
- Used in our group to look at turbulent flow structures over soluble bedforms
- Joe Myre, 345-12, Wednesday 4:05pm



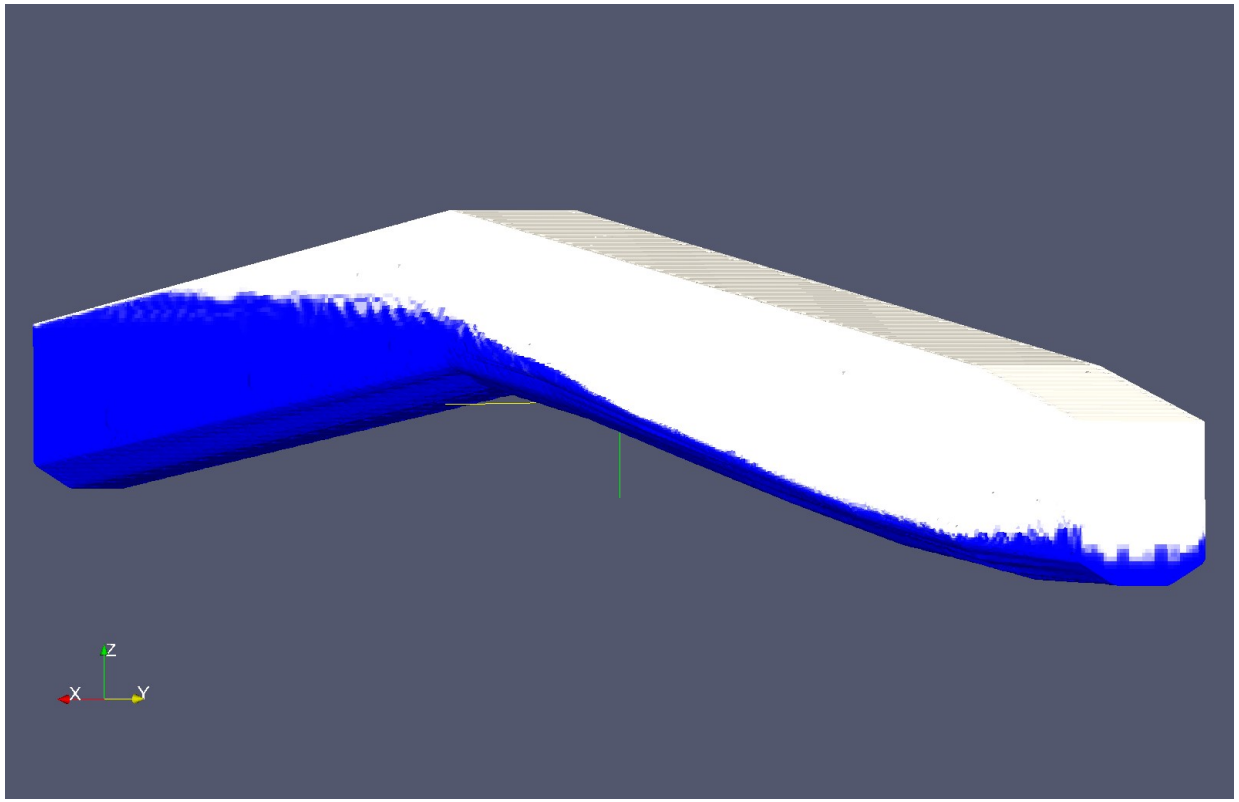
OpenFOAM

- Open source CFD package
  - calculates flow through a 3D channel segment
  - calculates shear stress on the wall

OpenFOAM results



OpenFOAM results



OpenFOAM results