RIVER FLOW 2016

Cutoff processes and their importance for bed and planform morphodynamic adaptation

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July 14th 2016

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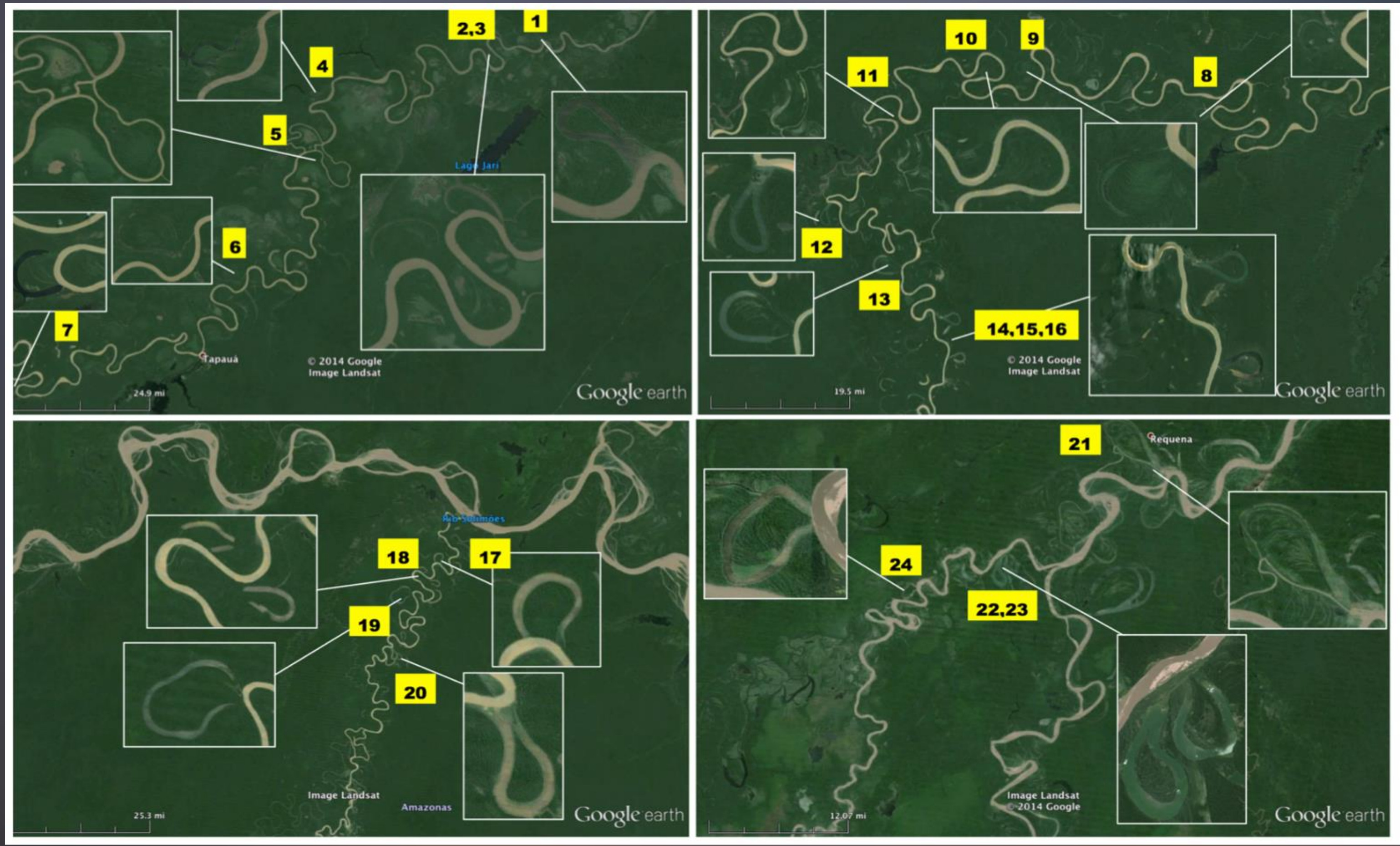
Cutoffs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The model includes the following components:

EDF R&D

- Hydrodynamics:
  TELEMAC-2D is used. It solves the 2D Saint-Venant equations using the FEM on unstructured mesh of triangular cells.

- Morphodynamics:
  SISYPHE is used to model morphodynamic processes. It can be tightly coupled to the TELEMAC-2D. The Exner equation to balance sediment transport and bed morphodynamics, with the Meyer-Peter and Müller equation to determine bed load transport capacity.

Prof. Abad's group
In collaboration with Dr. Langendoen and EDF

- Bank erosion/accretion, channel migration, neck cutoff detection and mesh refreshing:
  The module MEANDRE is used, which is a bunch of codes that can simulate the migration of channel and dynamically adjust the mesh. Currently it treats fluvial erosion/accretion based on critical shear stress. Fluvial erosion plus geotechnical failure is being developed. It will be added to the Telemac modeling system in the future.

Governing equations of channel migration:

$$\begin{cases} E = M_e\left(\dfrac{\tau}{\tau_{ce}} - 1\right) & \text{if} \quad \tau > \tau_{ce} \\ A = M_a\left(1 - \dfrac{\tau}{\tau_{ca}}\right) & \text{if} \quad \tau < \tau_{ca} \end{cases}$$

$$\vec{d} = E\Delta t\overrightarrow{e_n} \quad \text{and} \quad \vec{d} = A\Delta t\overrightarrow{e_n}$$

Notes:

(1) Let $M_e = M_a$ and $\tau_{ce} = \tau_{ca}$ to maintain a steady channel width;

(2) Bank geotechnical failure is neglected in the current version;

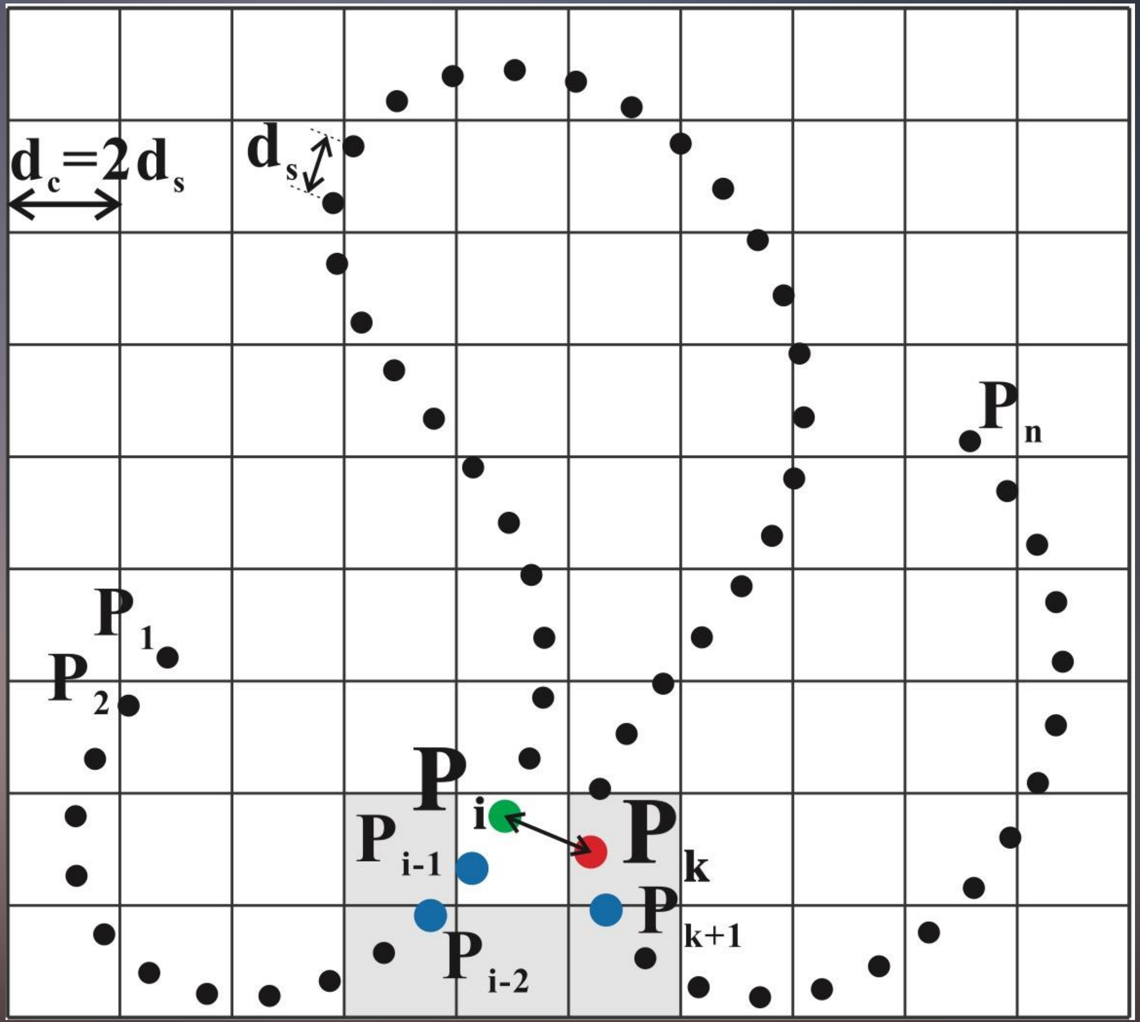
(3) More details please refer to:

Langendoen, E. J., A. Mendoza, J. D. Abad, P. Tassi, D. Wang, R. Ata, K. El kadi Abderrezzak, and J.-M. Hervouet (2015), Improved numerical modeling of morphodynamics of rivers with steep banks, Advances in Water Resources.

These calculations are done only once per certain time of hydrodynamic and morphodynamic modeling, which we call it a “cycle”.

A cycle should be approximately equal to the necessary time to get hydro- and morpho-equilibrium due to the channel migration and bed adaptation.

Cutoff detection algorithm

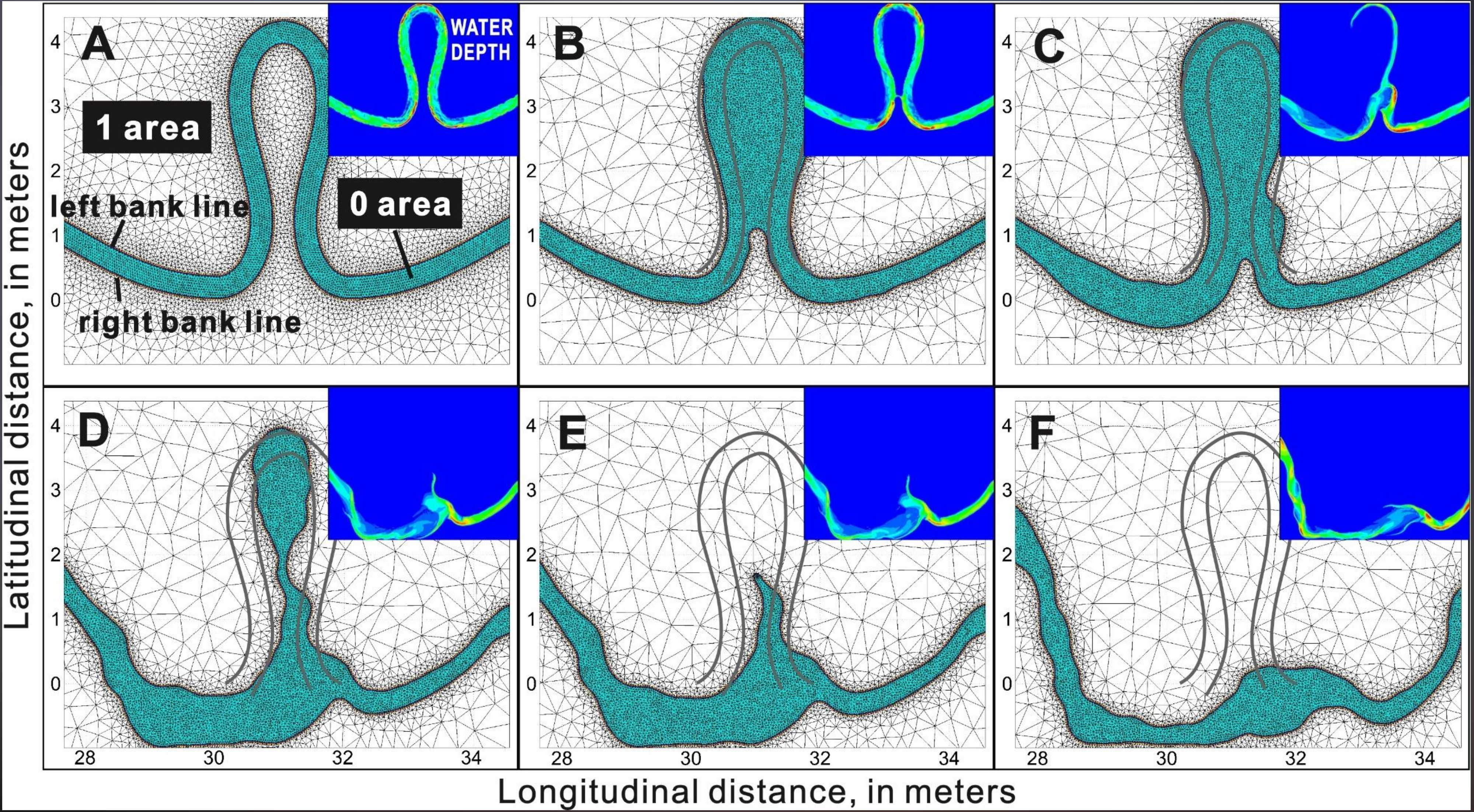


The algorithm is adapted from:

Camporeale, C., P. Perona, A. Porporato, and L. Ridolfi (2005), On the long-term behavior of meandering rivers, Water resources research, 41(12).

The left/right bankline is used instead of the river centerline, so that the model can deal with varying channel width cases.

Dynamically mesh refreshing

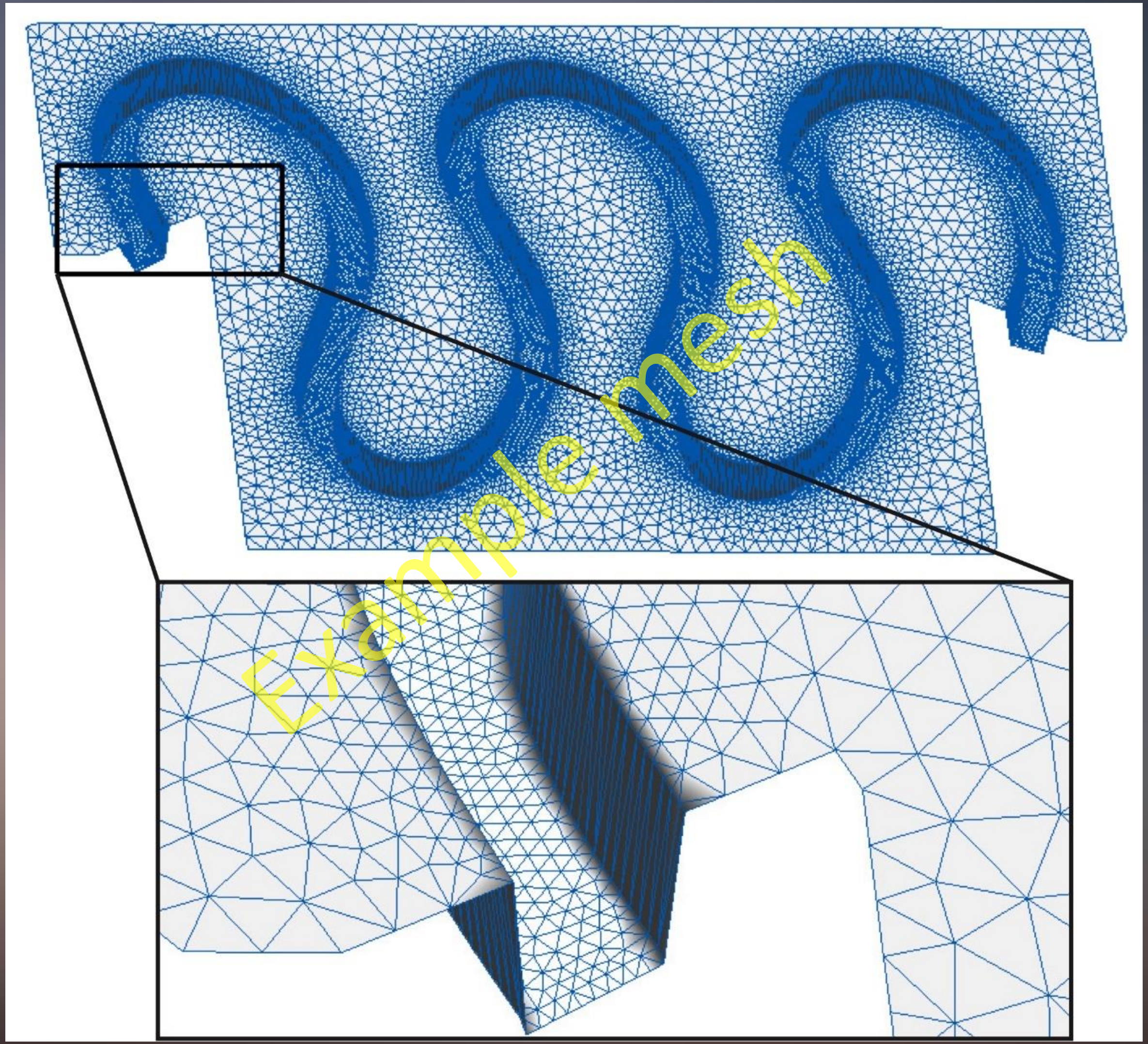


A model capable of describing the transitional morphodynamics of meander neck cutoff is presented and validated using mobile bed laboratory experiment.

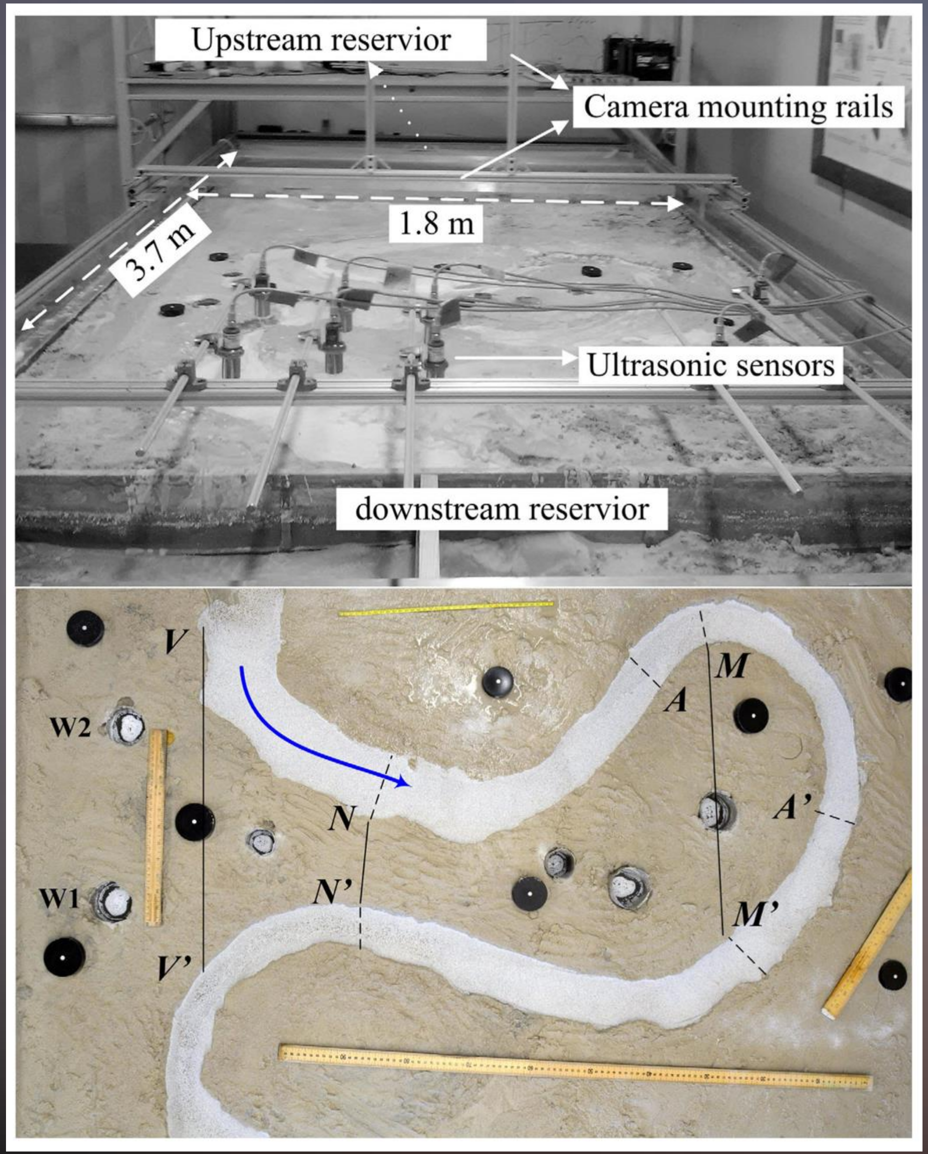
The model shows the following characteristics:

1) Efficient cutoff detection module;
2) Widening of the cutoff cross section;
3) Bed adaptation in the main channel through erosional and depositional waves traveling upstream and downstream, respectively;
4) Formation of oxbow lakes and the preservation of the paleo-channel in the floodplain;
5) Channel longitudinal and planform adaptation.

Initial mesh construction using BlueKenue from National Research Council Canada



(1) Reproduce a cutoff lab experiment

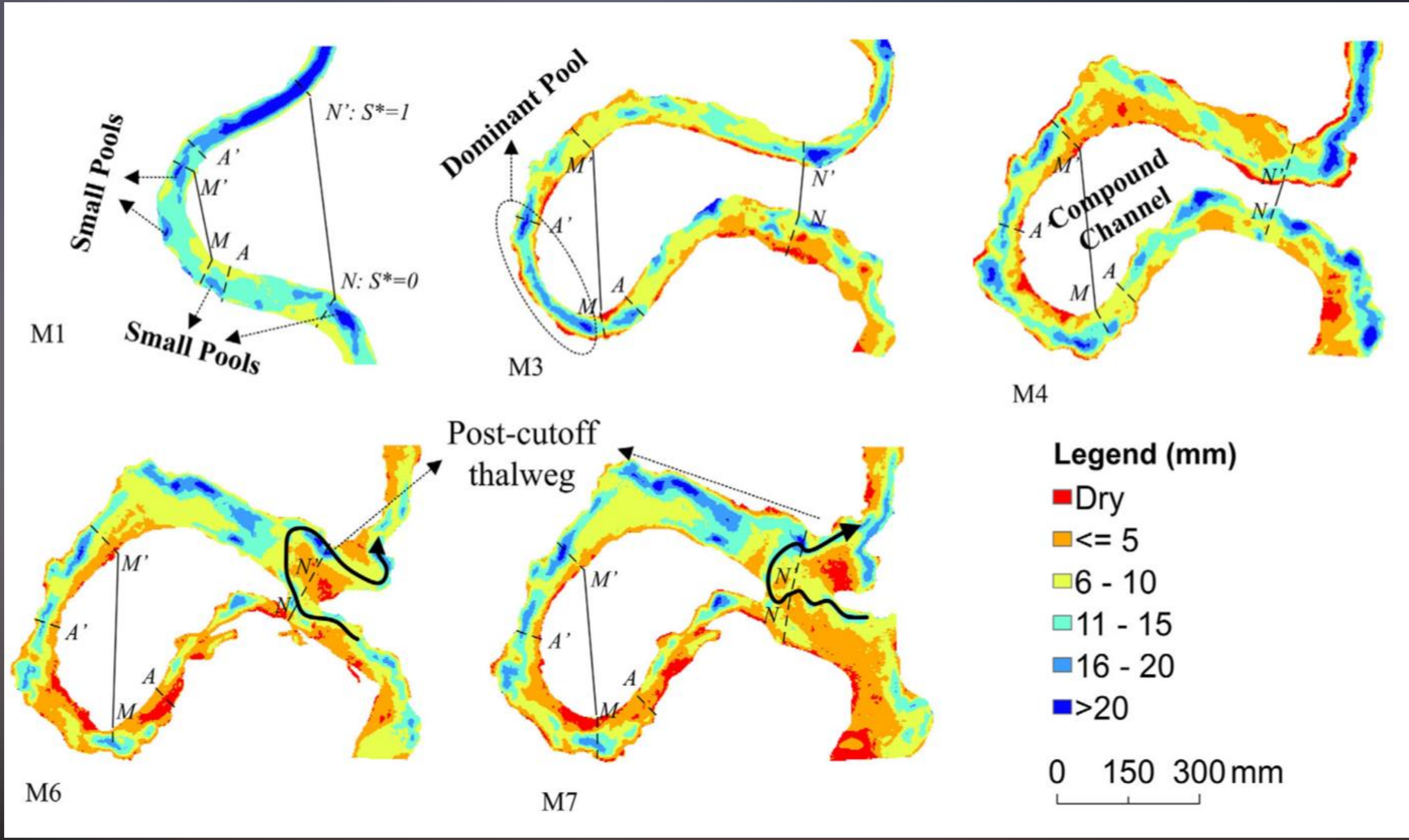


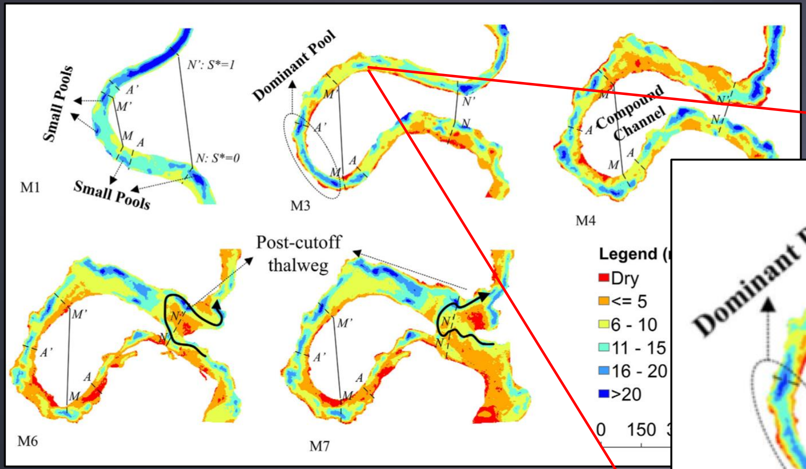
Physical Parameters	Value
River table width	1.8 m
River table length	3.7 m
River table substrate depth	0.15 m
Average channel depth	25 mm
Average channel width	80 mm
Valley slope	1.8%
Median grain size	0.2 mm
Discharge	80 mL/s
Mean velocity	0.04 m/s
Reynolds number, *Re*	3200
Froude number, *Fr*	0.05
Boundary shear stress	0.18 Pa
Critical shear stress	0.15 Pa
Grain Reynolds number	19.6
Weber number, *We*	0.7

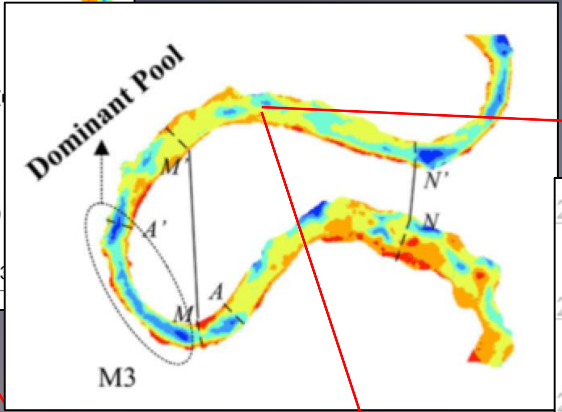
[a] *Re* and *Fr* values were computed using a characteristic length of four times the hydraulic radius.

Han, B., & Endreny, T. A. (2014). Detailed river stage mapping and head gradient analysis during meander cutoff in a laboratory river. *Water Resources Research*, *50*(2), 1689-1703.

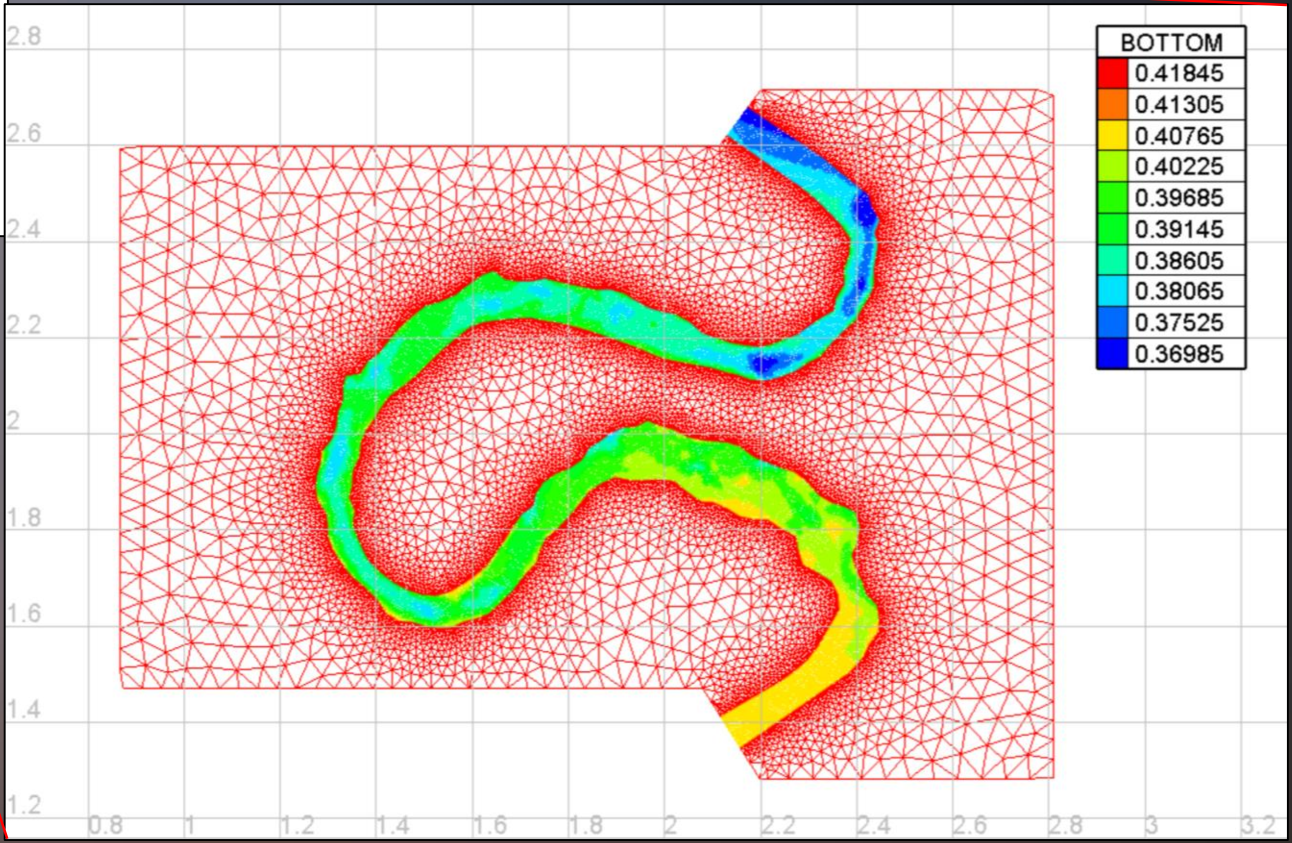
Bed elevation





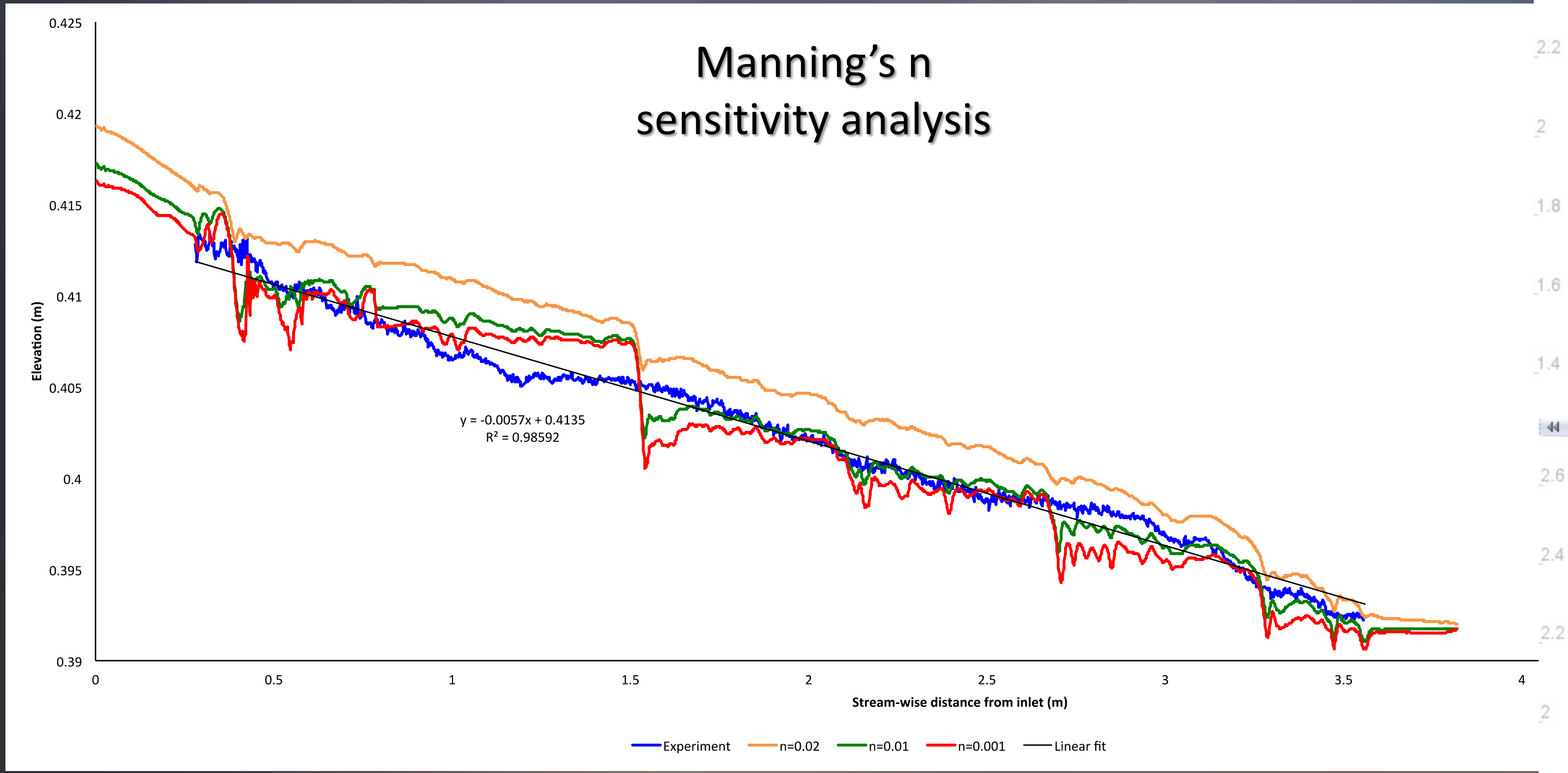


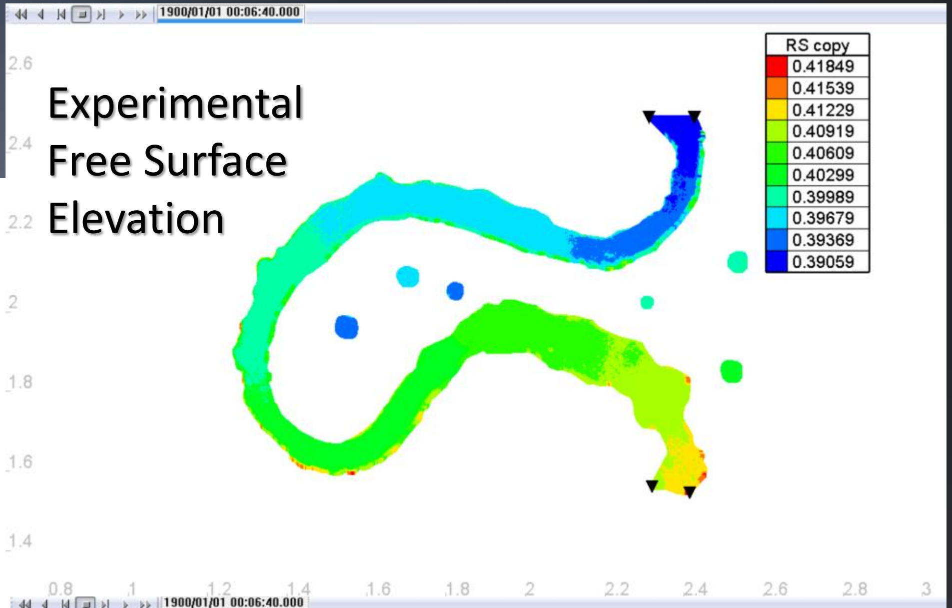
Mesh construction for M3 bathymetry and floodplain

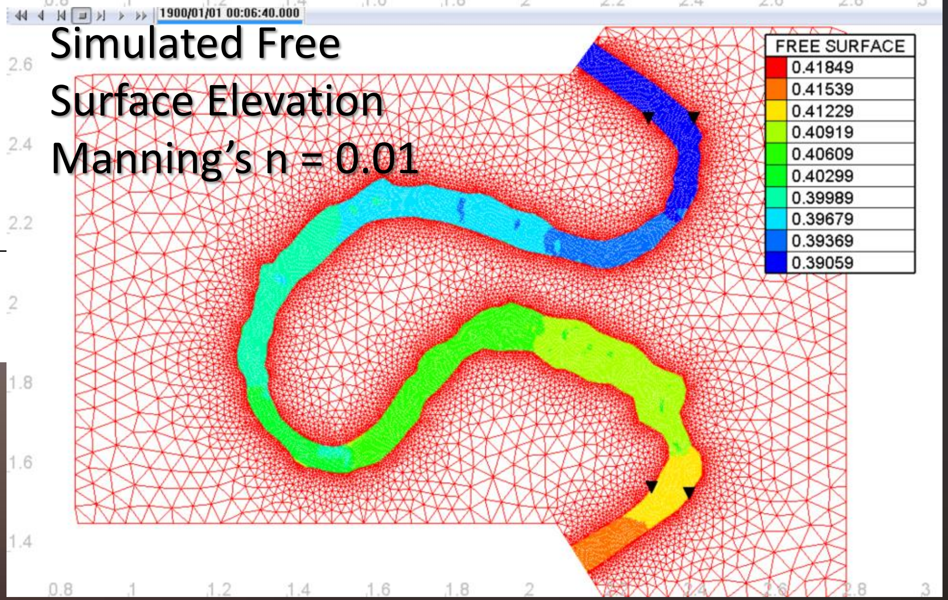


21,072 nodes
41,958 cells

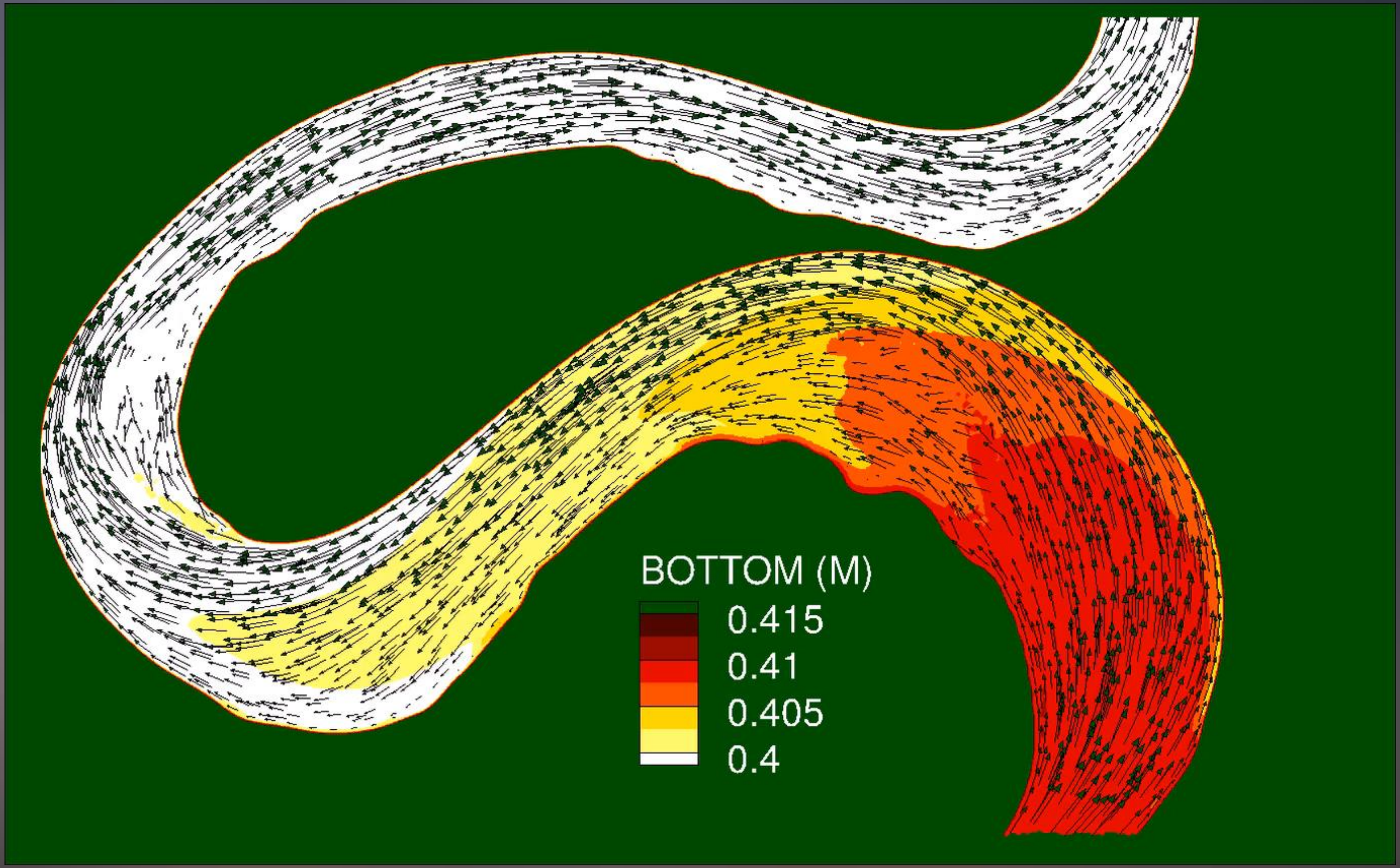
Model calibration



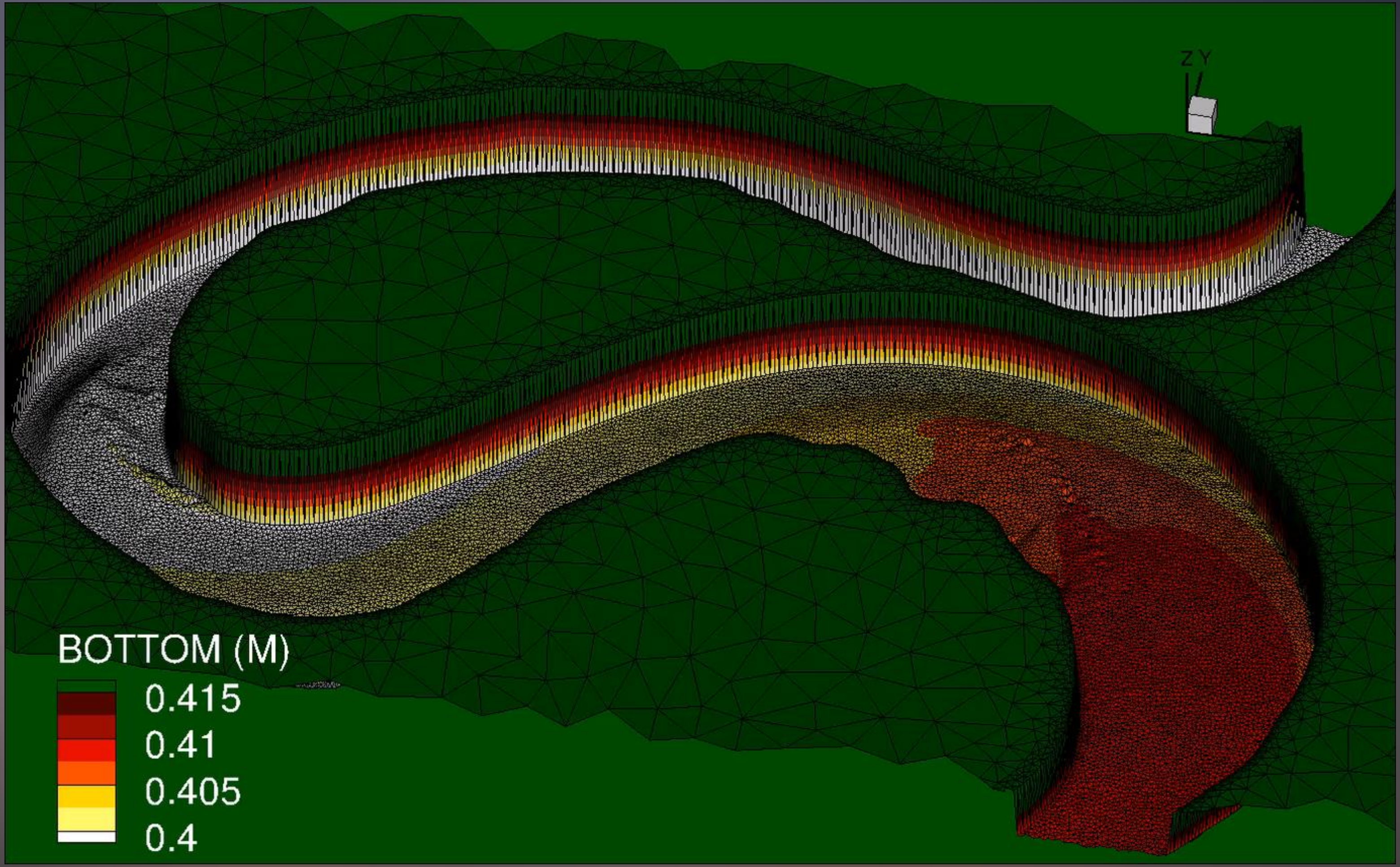




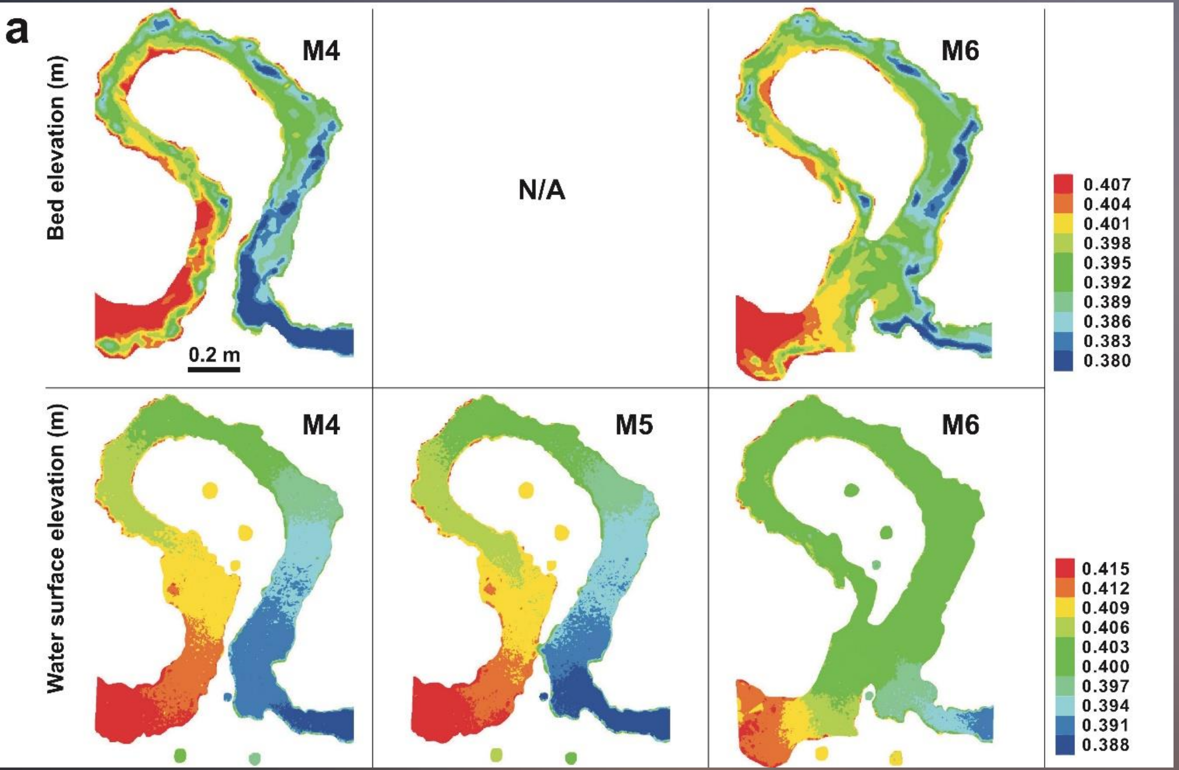
Model results: flow vectors in 2D

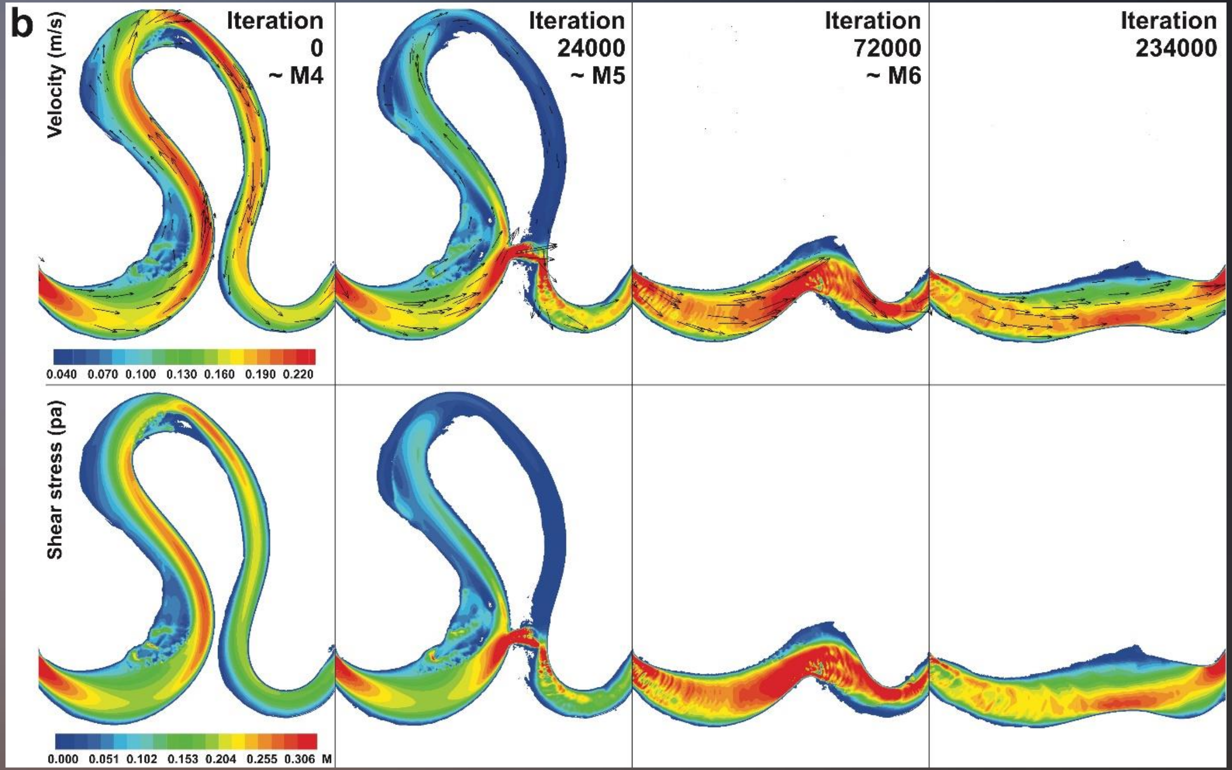


Model results: mesh adaptation in 3D view

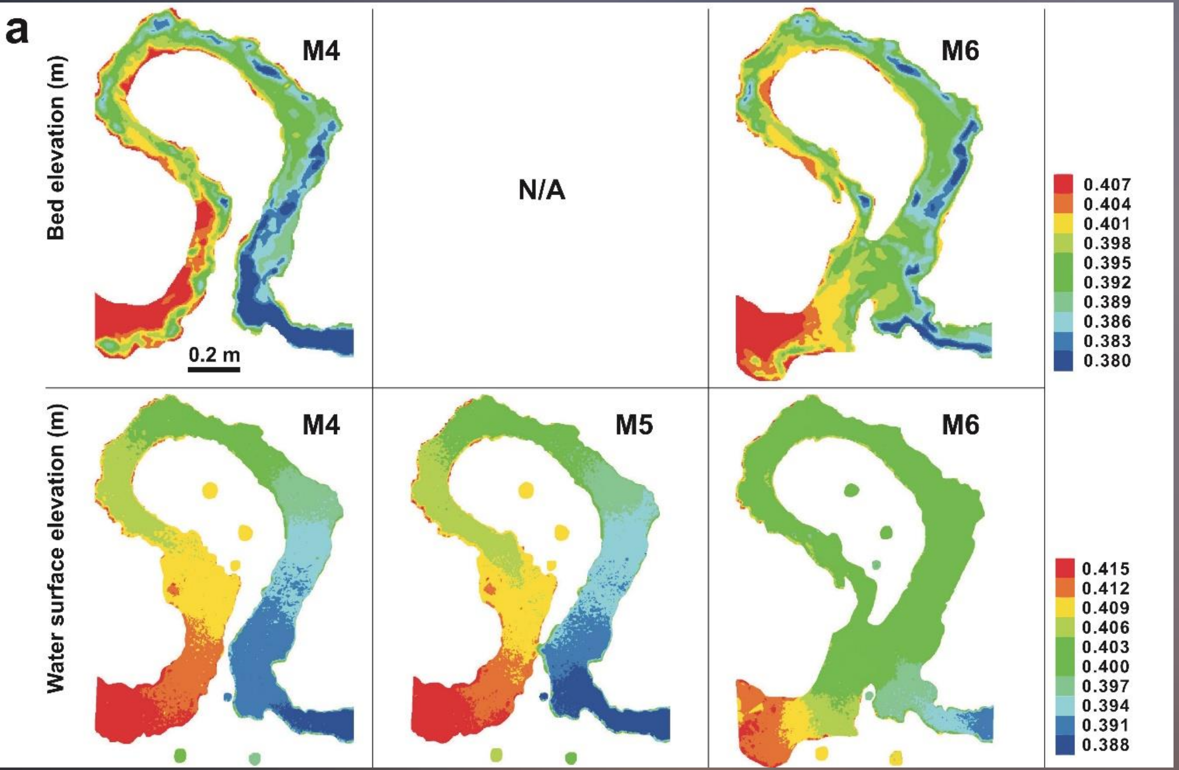


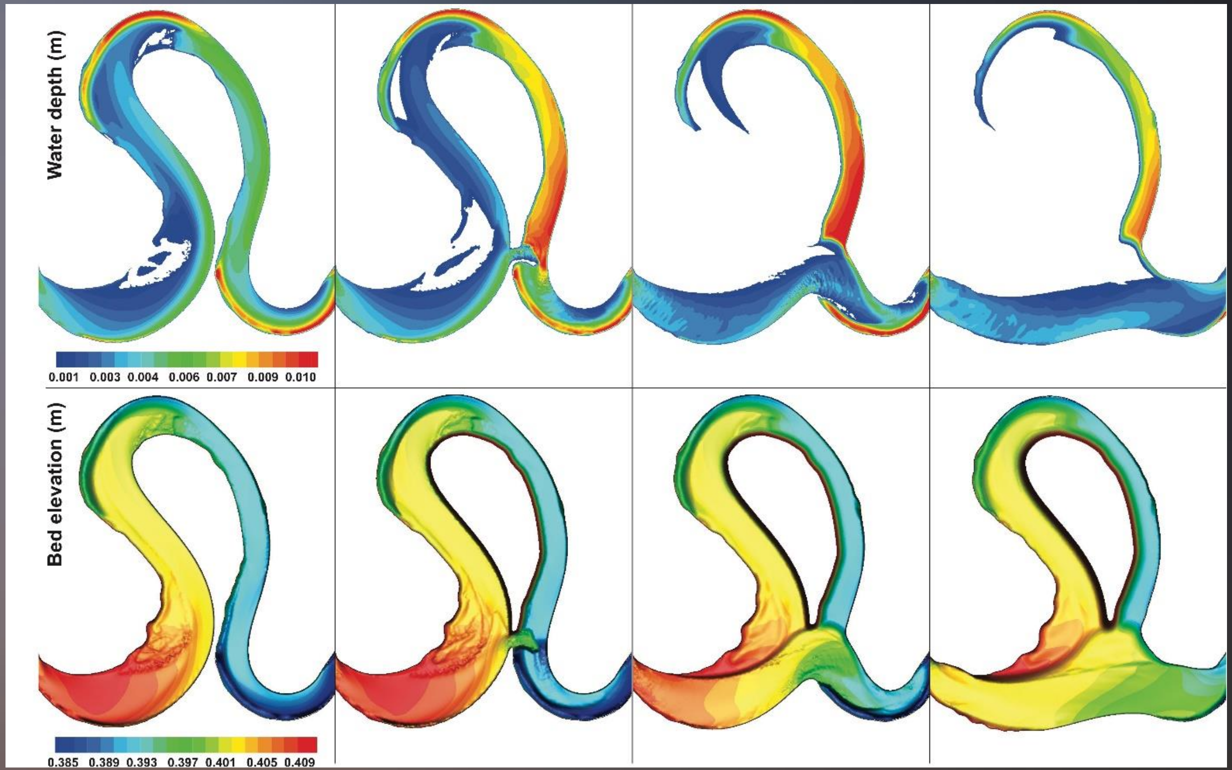
Experiment & Simulation results comparison





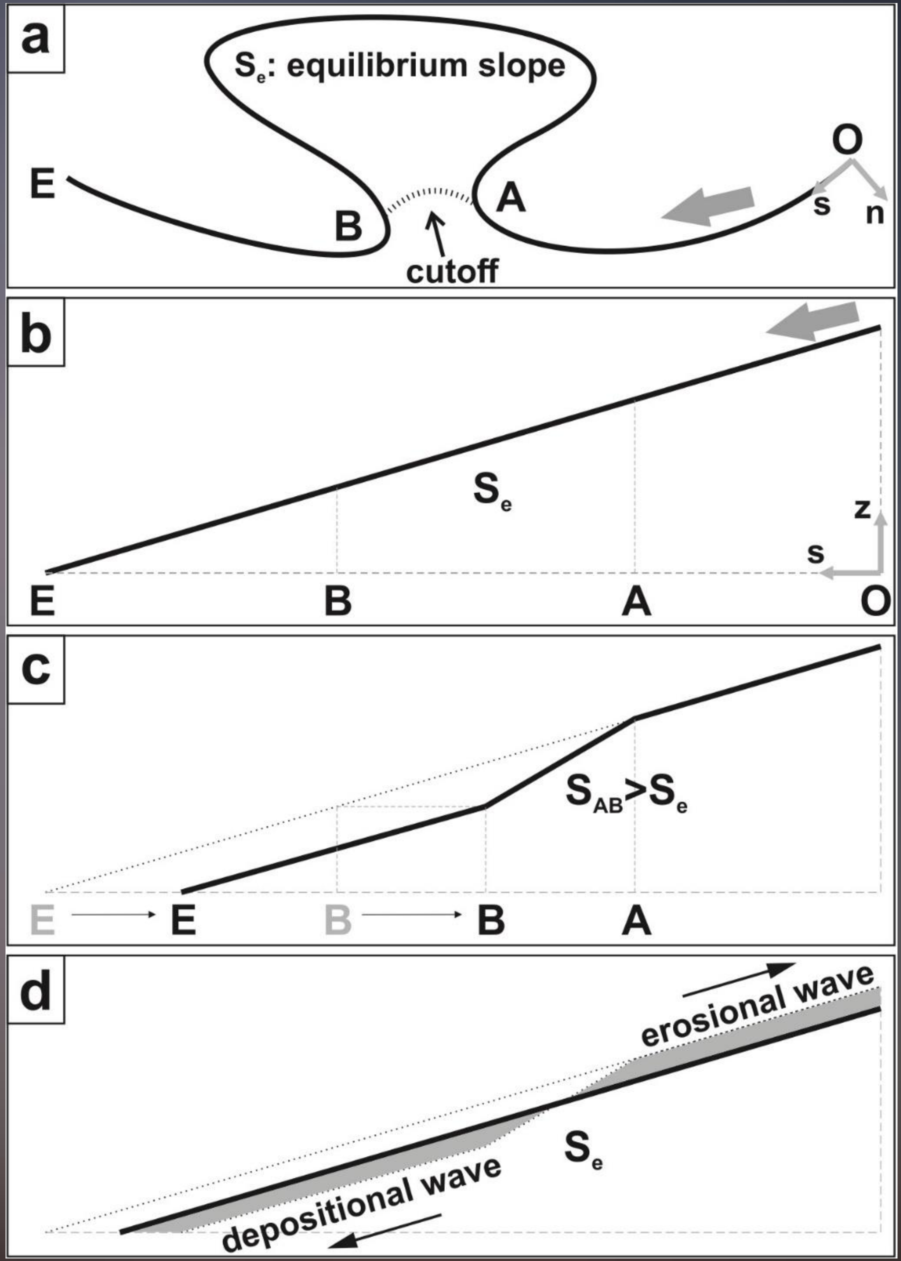
Experiment & Simulation results comparison



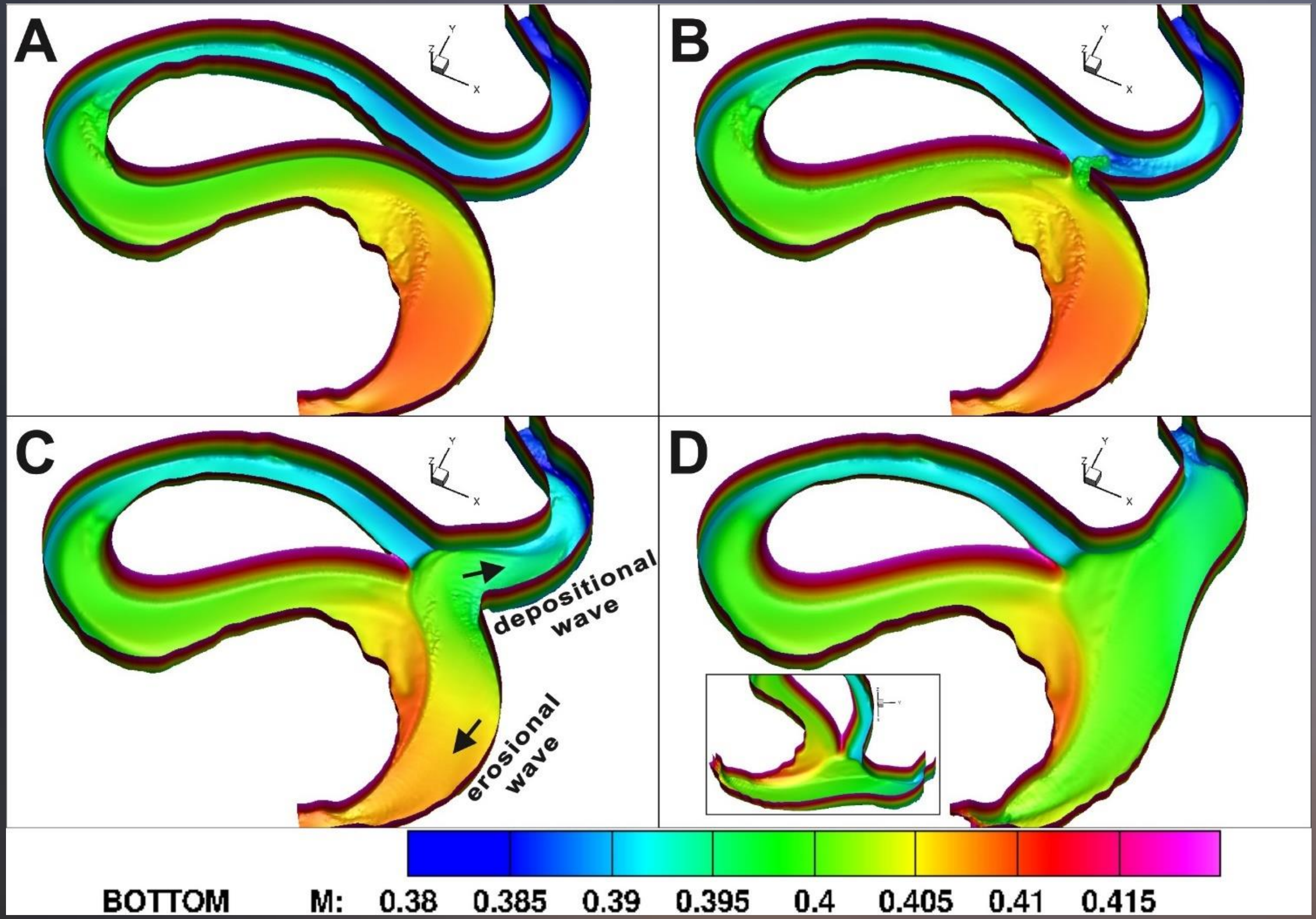


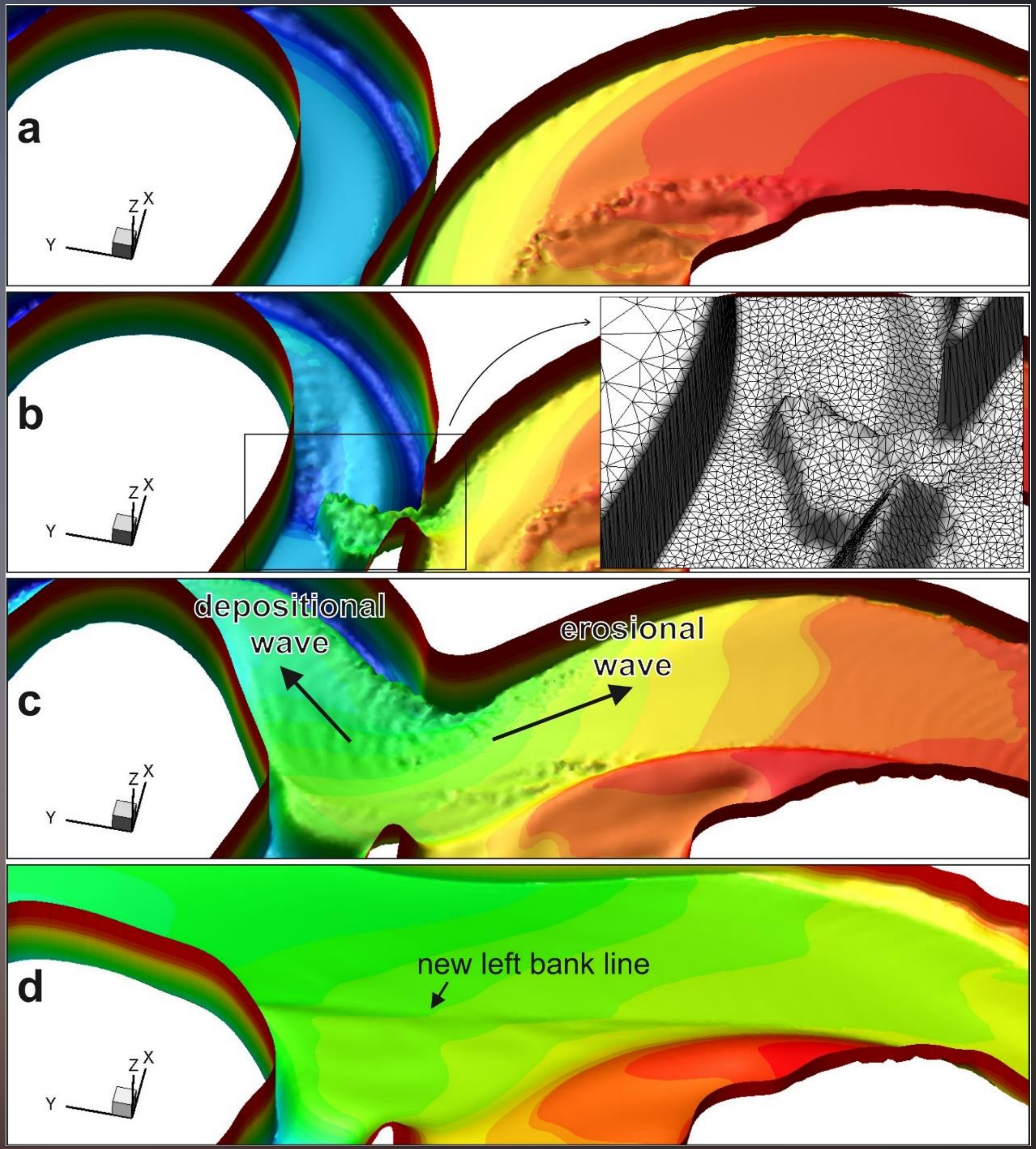
Conceptual model:

-- what we expect for sediment to behave after cutoff



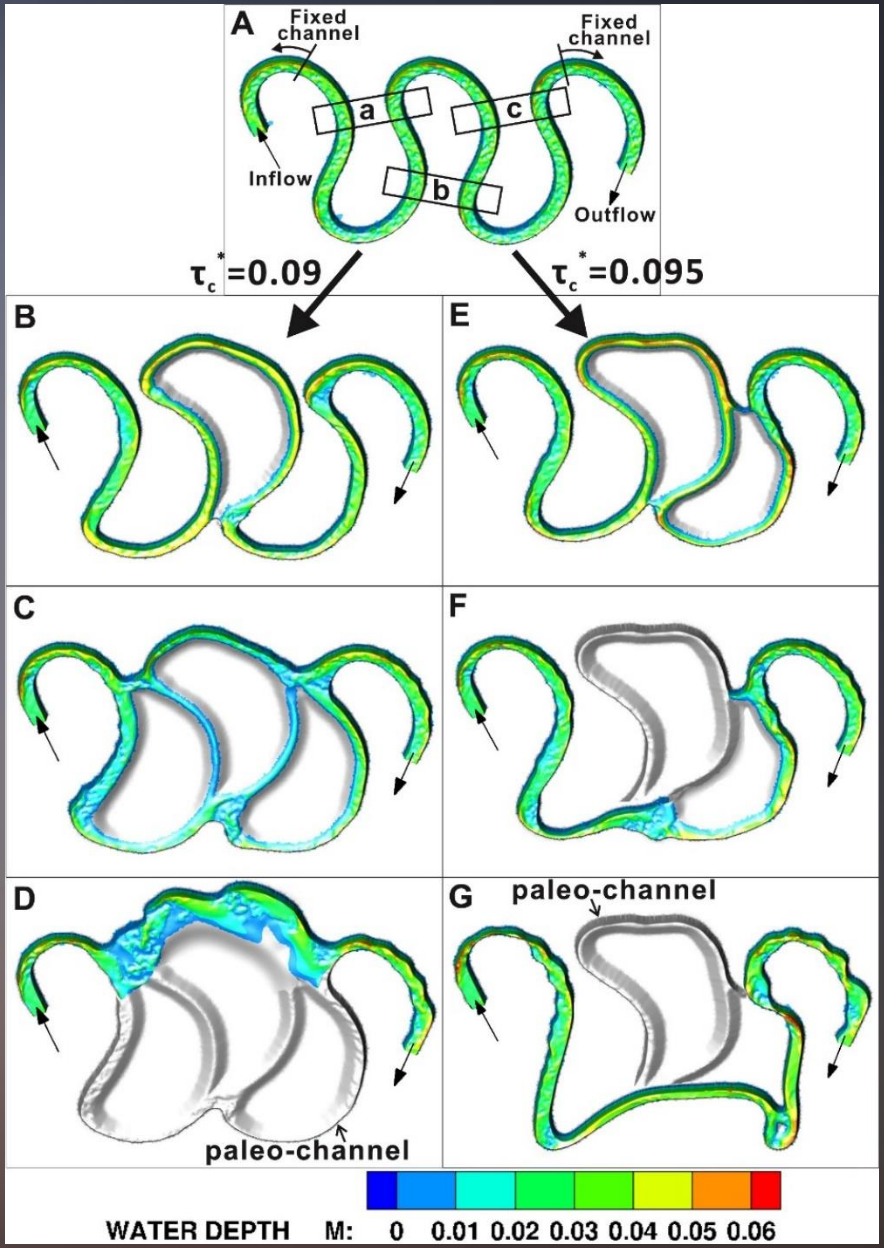
Erosional/Depositional Waves:





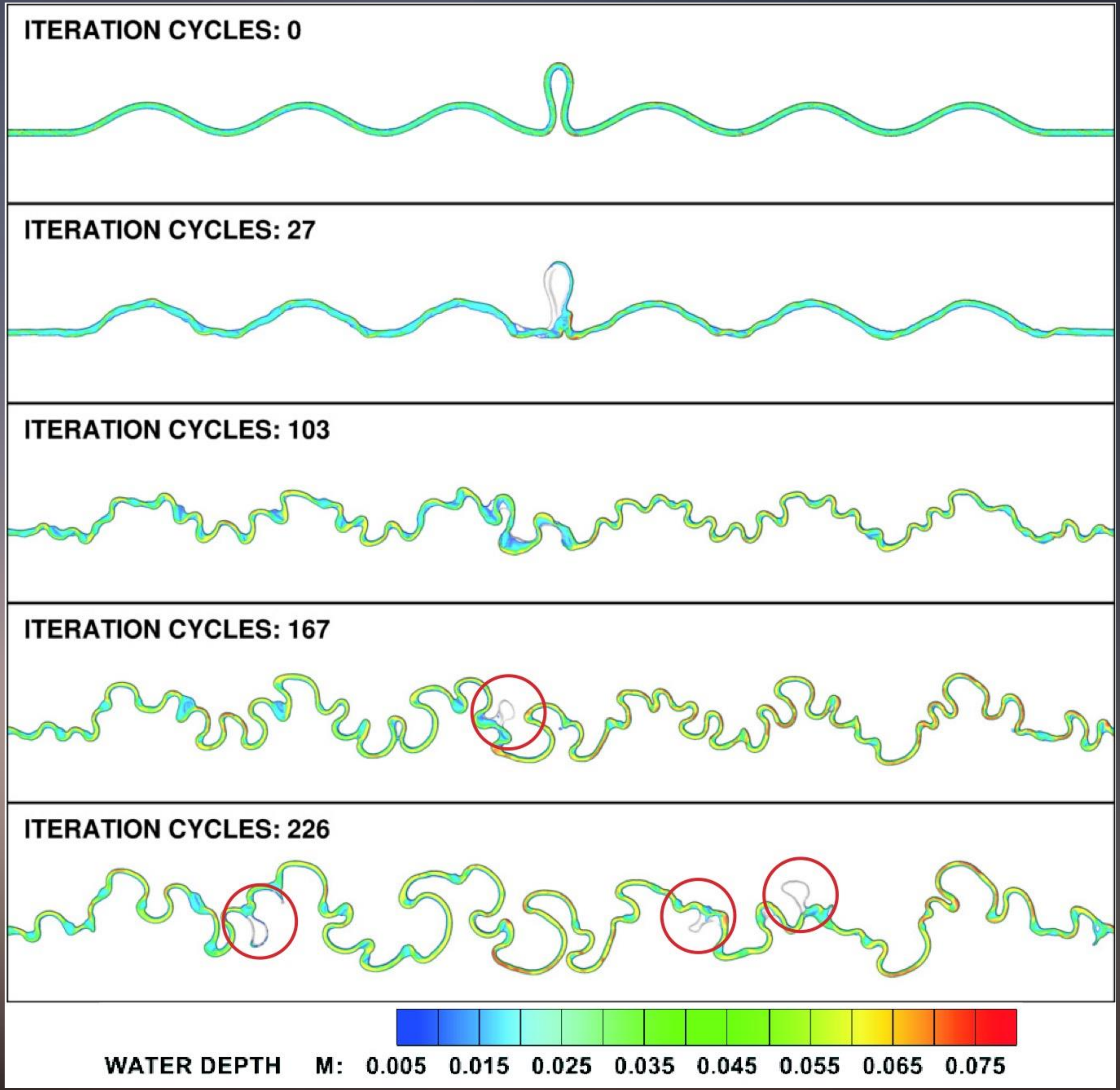
(2) Test cases based on Kinoshita channels

a. Sensitivity of τ_c



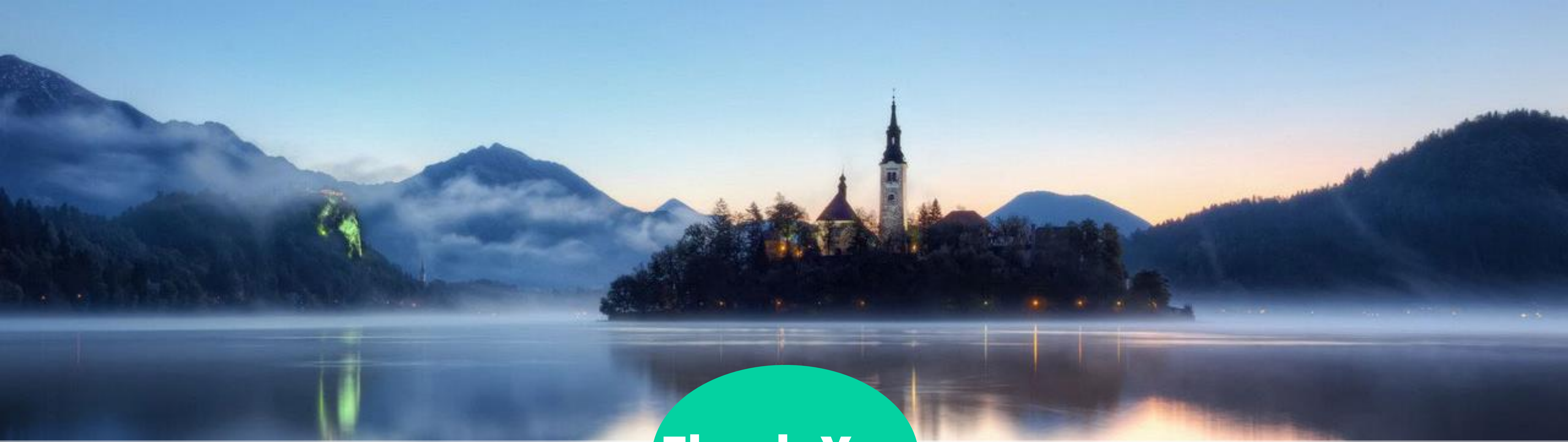
It was shown that by slightly changing the resistance of the soil, different planform shapes after cutoff are observed, thus, there is a modulation of floodplain heterogeneity due to the preservation of paleo-channels.

b. Quasi- long term simulation



The results of this integrated model suggest that this is a reliable model to simulate cutoffs, producing full records of relatively complete details during the cutoff events. It improved than treating cutoff only an adjunctive process of river meandering and dealing with them inaccurately.

Future research will extend to the improvements of the current Meandre to be more physical, and multi-time-scale modeling of the Ucayali River, a large and typical meandering river in Peru.



Thank You