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Long-term modelling:
why experimental evidence is hardly replicated numerically

Arianna Varrani

Summary

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A reviewer's question

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Research papers

Long-term modelling of fluvial systems at the watershed scale: Examples from three case studies

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ABSTRACT

To date, many numerical approaches are available in studying water flow and sediment dynamics along rivers from the reach to the watershed scale, based on various simplifications. The aim of the present research is to demonstrate how the so-called "morphodynamic quasi-equilibrium hypothesis" is effective in modelling riverine landscape morphodynamics evolution at the watershed scale, focussing on the long-term changes of longitudinal profile and bed grainsize composition of large alluvial rivers. A lumped 0-D, two-reach, two-grainsize model based on the Local Uniform Flow hypothesis and originally developed for reproducing fluvial changes at the historical time-scale, has been applied to three large watercourses to reproduce their long-term evolution, performing a sensitivity analysis based on the present conditions. Three morphometric parameters were analysed, aiming to describe the evolution of the longitudinal profile (concavity and aggrading) and the grainsize composition of the river bed (fining). Though the 0-D approach does not allow for a spatial distribution of the input parameters, namely the liquid and solid discharge, the modelling outcomes show reasonably good qualitative trends. At the scale of analysis (centuries to millennia) and for the chosen large sedimentary systems (thousands of kilometres long), which show high inertia to geomorphological changes likely owing to their longitudinal scale, the model can be helpful in detecting where the present conditions reflect a big disturbance to the "natural" trend. This initial detection method can provide additional insights in evaluating the capability of actual rivers to respond to the present external forcing, eventually reaching a quasi-stable configuration.

How can we trust to a very simplified long-term model?

A reviewer's question

Scientific method (as from Galileo Galilei, 15.09.1640)

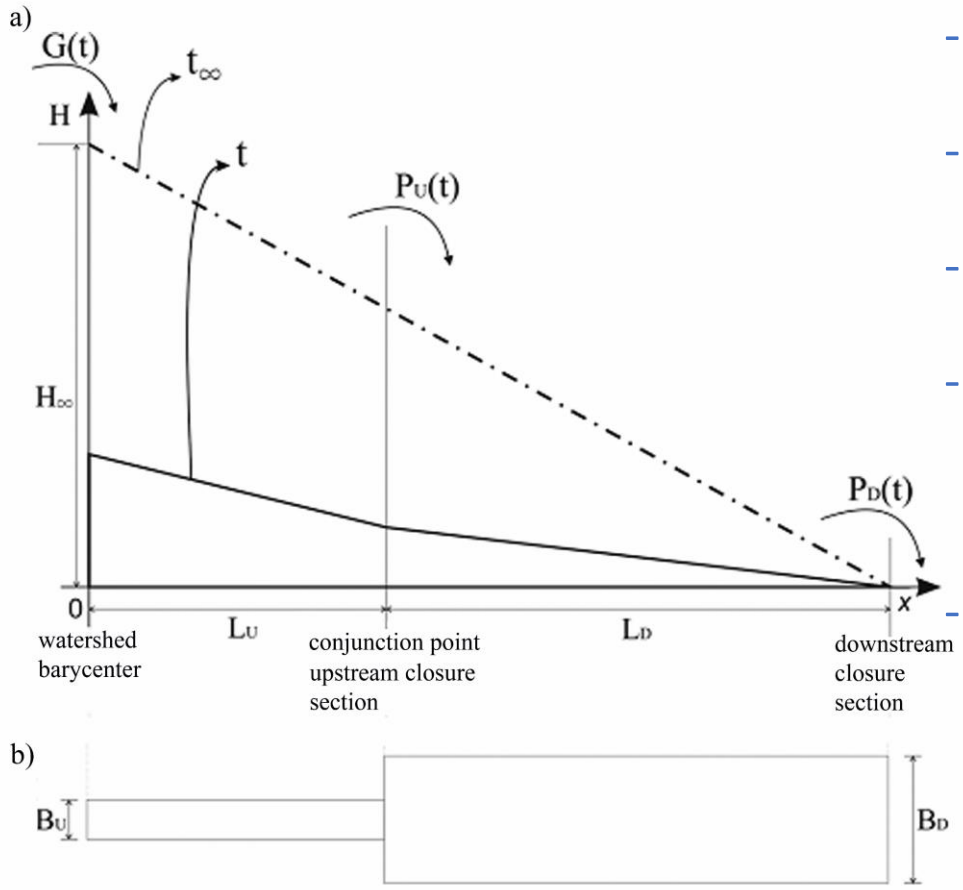
«among the unfailing ways to obtain the truth is to place experience before any discussion, not being possible the truth contradicts real experience of senses»

«tra le sicure maniere di conseguire la verità è l'anteporre l'esperienza a qualsivoglia discorso, non sendo possibile che una sensata esperienza sia contraria al vero»

Can we prove numerical result of millennial evolution to be wrong?

Numerical vs experimental modelling

Long-term evolution 0-D model:



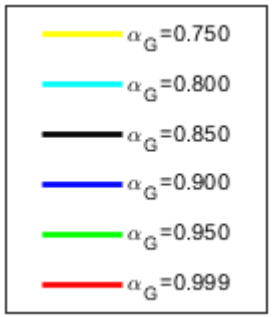
- Two reaches (mountain and lowland part)
- Constant width available for river wandering
- Two grainsizes (fine and coarse)
- Local Uniform Flow conditions (liquid phase)
- Constant solid and liquid discharge (BC upstream)
- Selective transport (no abrasion)

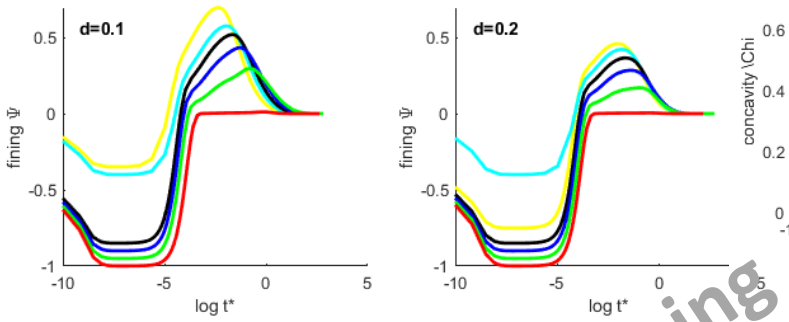
Kinematic wave hypothesis (liquid phase)

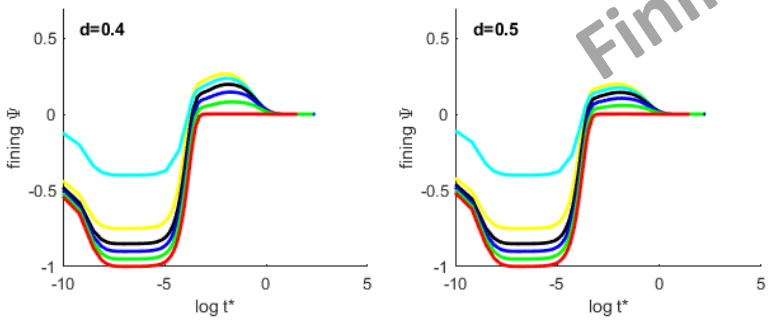
Sediment rating curve (solid phase) $P(t) = M(t)Q(t)^m$

Numerical vs experimental modelling

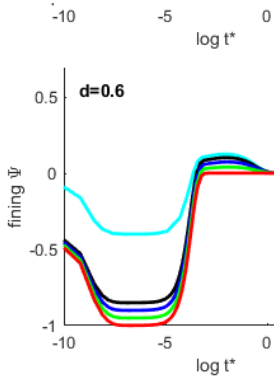
Long-term evolution: Ganges River

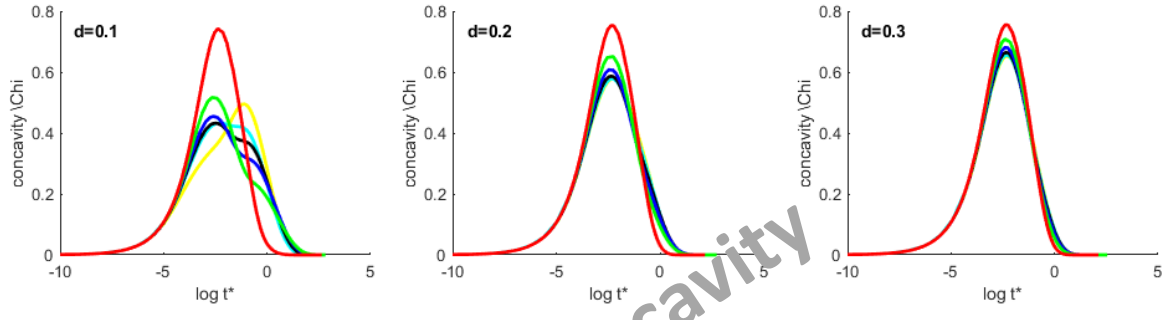




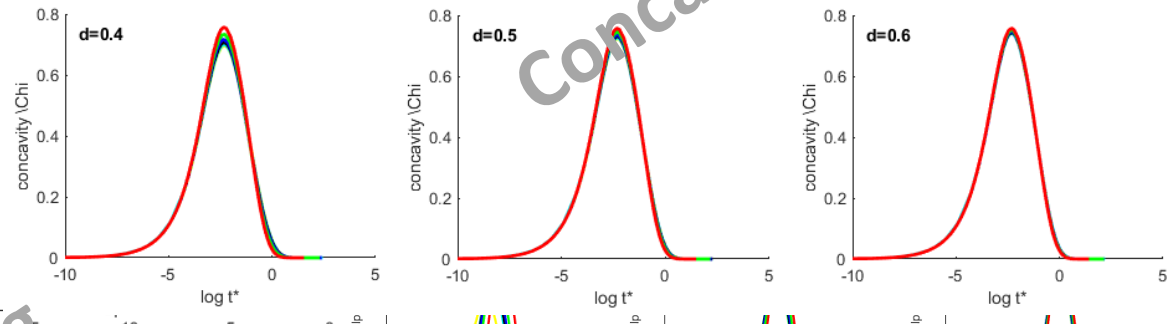


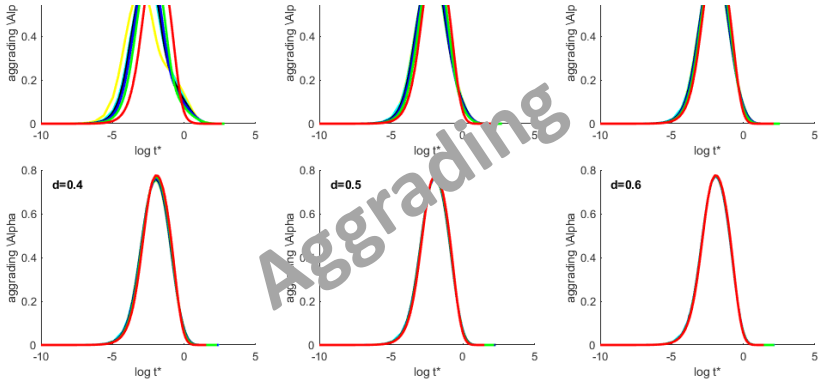
Fining





Concavity

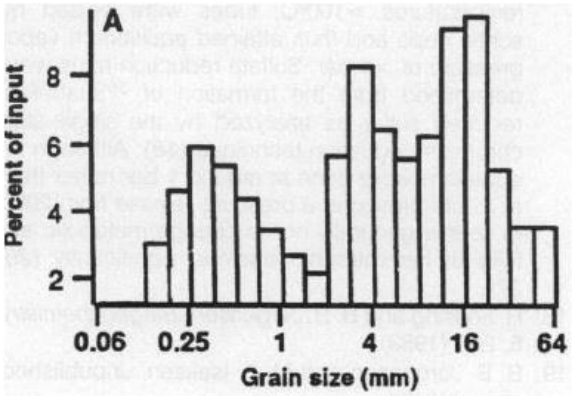




Aggrading

Numerical vs experimental modelling

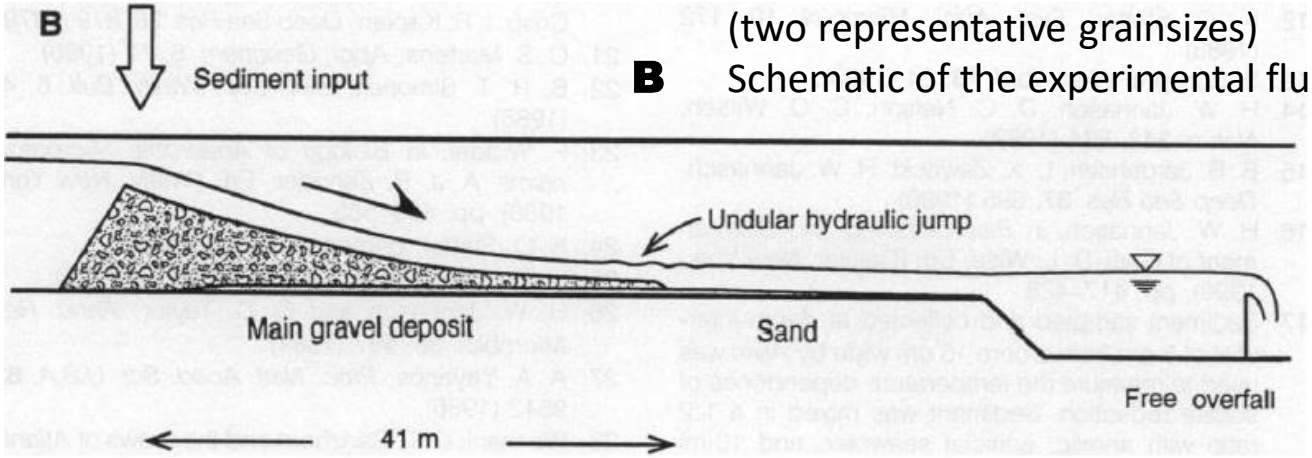
Experiment as from Paola et al., Science 1992:



- Horizontal initial surface (gravel deposits develops)
- Constant solid and liquid discharge (input from upstream)
- Selective transport (no abrasion)

A Bimodal distribution of fed sediments (two representative grainsizes)

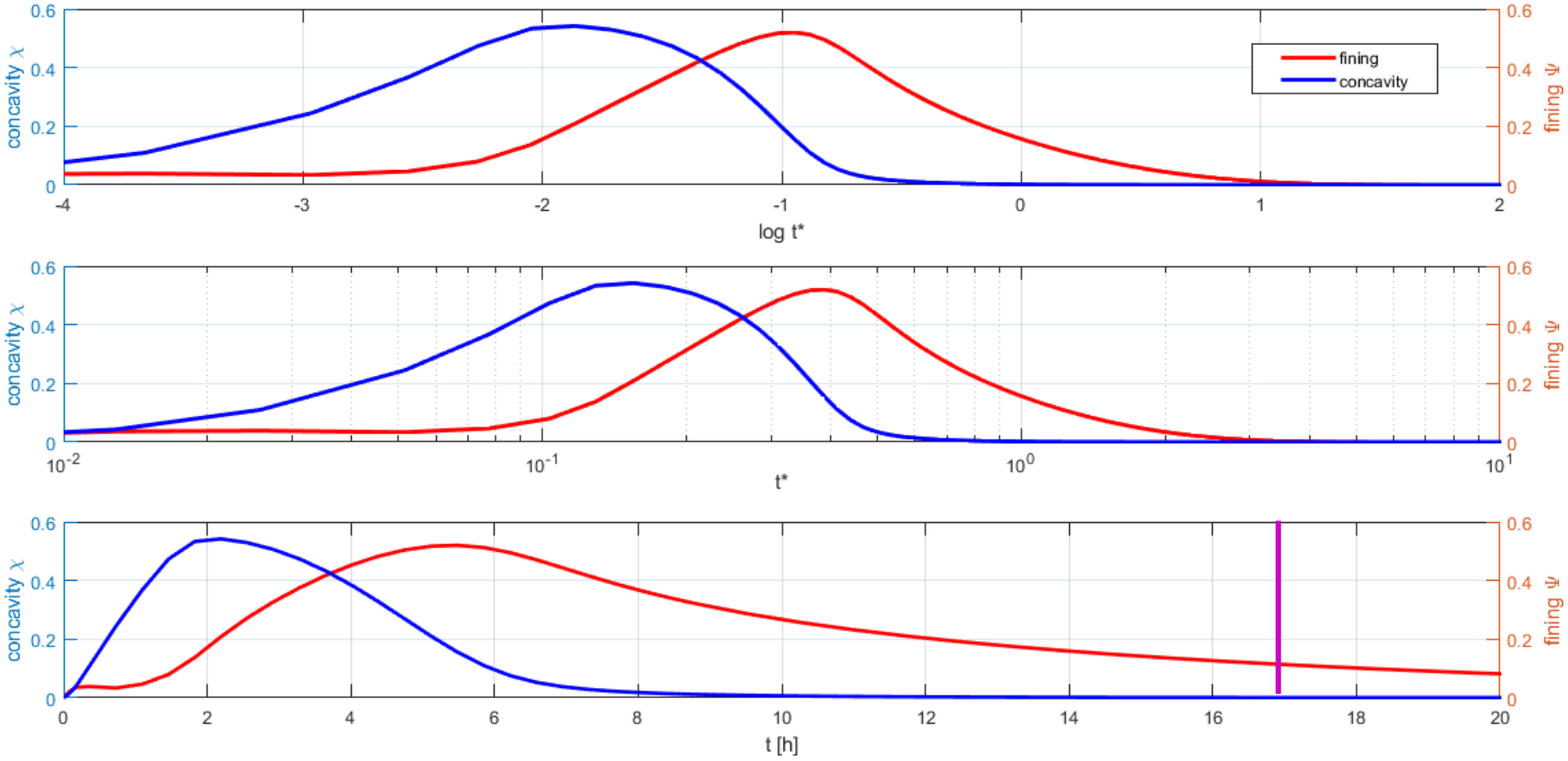
B Schematic of the experimental flume setup



Duration of the experiment: 16h 50’

Numerical vs experimental modelling

Experiment from Paola et al. 1992, numerical replication:



Validation, really?

- Long-term evolution at geological time scale:
  - numerically doable
  - field measurements or laboratory investigation cannot cover it
- Resulting values are to be considered as trend indicators (uncertainty is too high and cannot be reduced)
- Lab-scale results can highly depend on chosen IC, translated numerically this yields to a bunch of different outcomes, sensitivity analysis has been performed over some peculiar IC (Nones et al., Catena 2019)
- Modelling outcomes at short-scale show qualitative fit to experimental results

Discussion

Assumptions embedded in modelling create distortions (reality entails some chaotic component hardly handled):
“all models are wrong, but some are useful” George E.P. Box, 1976

Choice of equations, initial and boundary conditions are closely related upon the scale of analysis, short-term observation cannot prove wrong long-term results and vice versa

After validation the range of validity of results depends on:
- equations (related to temporal and spatial scale)
- boundary and initial conditions

Thank you for your attention

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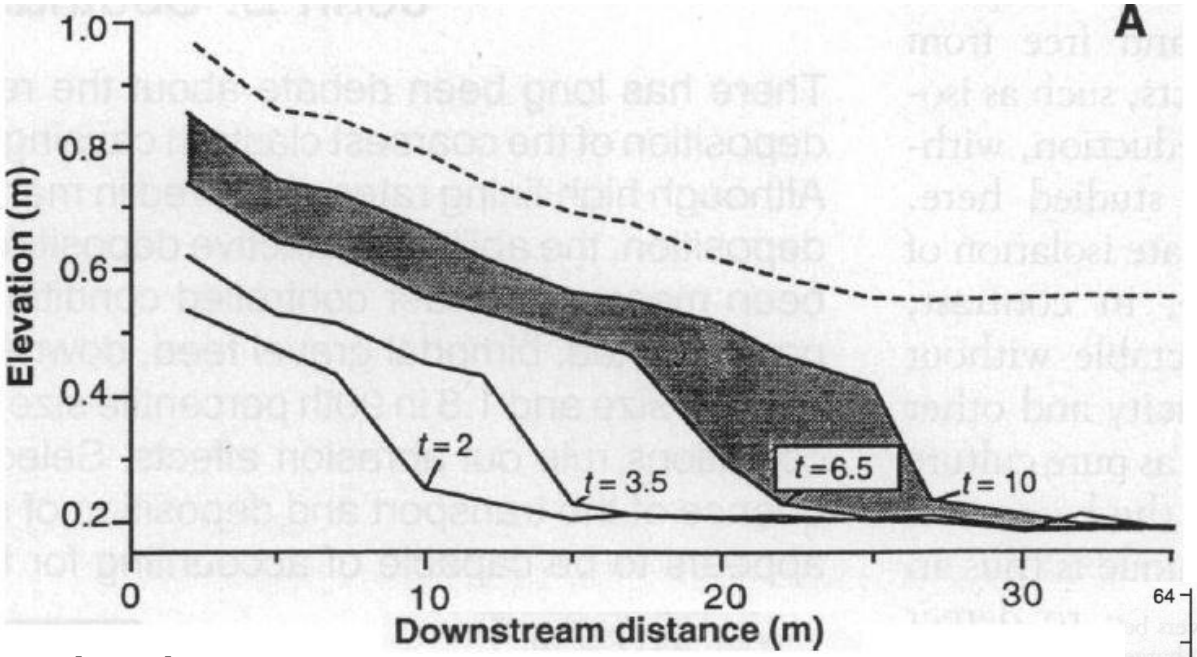
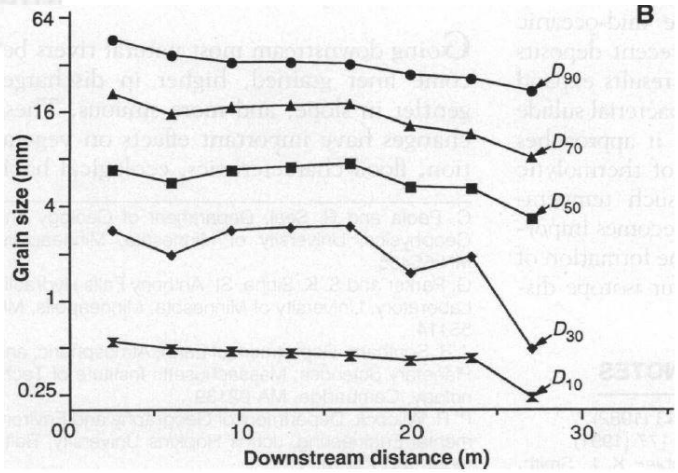
Paola et al. 1992



Paola et al., 1992, Science



Paola et al. 1992