THE EFFECT OF FLOW VARIABILITY ON THE RIVER MEANDERING DYNAMICS

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GM5.1 Fluvial Systems: Dynamics and Interactions Across Scales

MOTIVATION

What are the effects of discharge variability on the meander evolution?

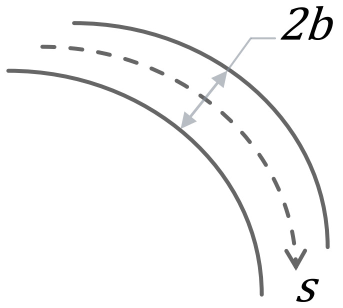
METHODS

- Numerical simulations
- Theoretical analysis

NUMERICAL MODEL

- Ikeda, Parker and Sawai fluid dynamic model
- The simulations provide the dynamics of the river axis by solving the equation:

$$v(s) = -bEU\,C(s) + bEU\,\frac{2C_F}{H}\,(P+1)\int_0^s C(t)\,e^{-\frac{2C_F}{H}(s-t)}\,dt$$

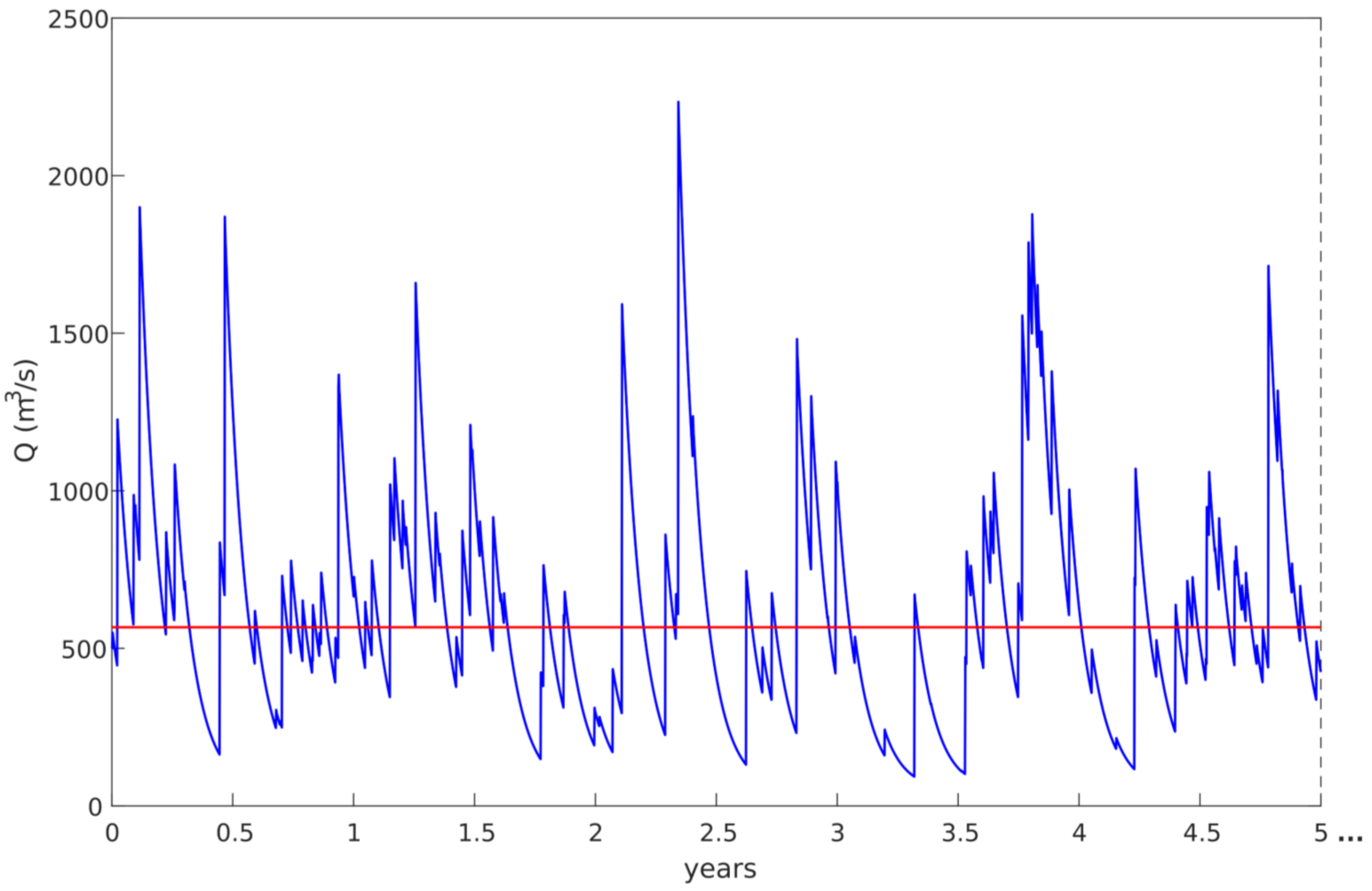


$v(s)$: migration rate along the river centerline
E: coefficient of bank erodibility, assumed equal to 10^{-6}
C: curvature
U: stream velocity
C_F: friction factor
H: flow depth
P: Parker number for sediment dynamics

→ Functions of the discharge Q

- Assumption: constant river width
- Initialization: a straight line perturbed by a weak random noise

NUMERICAL MODEL - INPUT



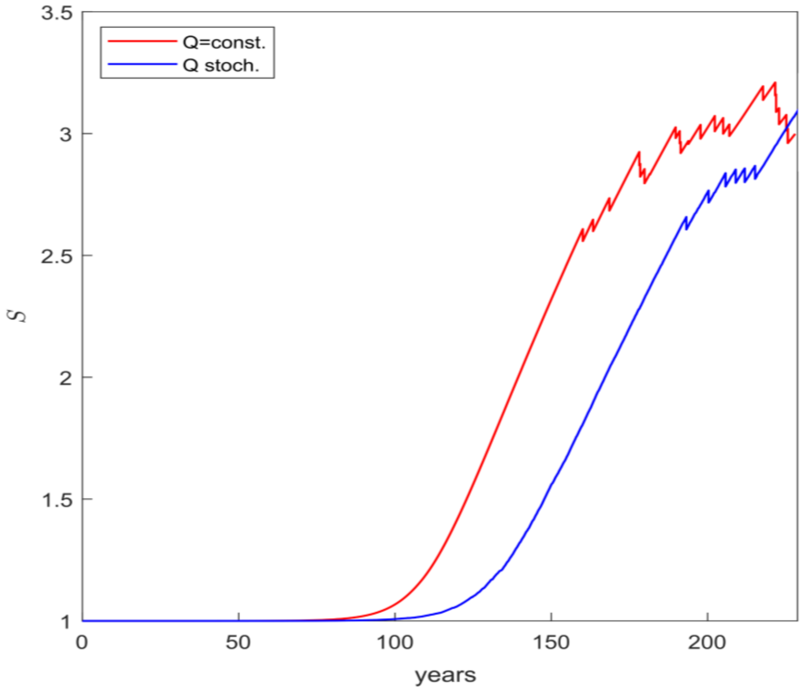
Stochastic discharge generated by a compound Poisson process

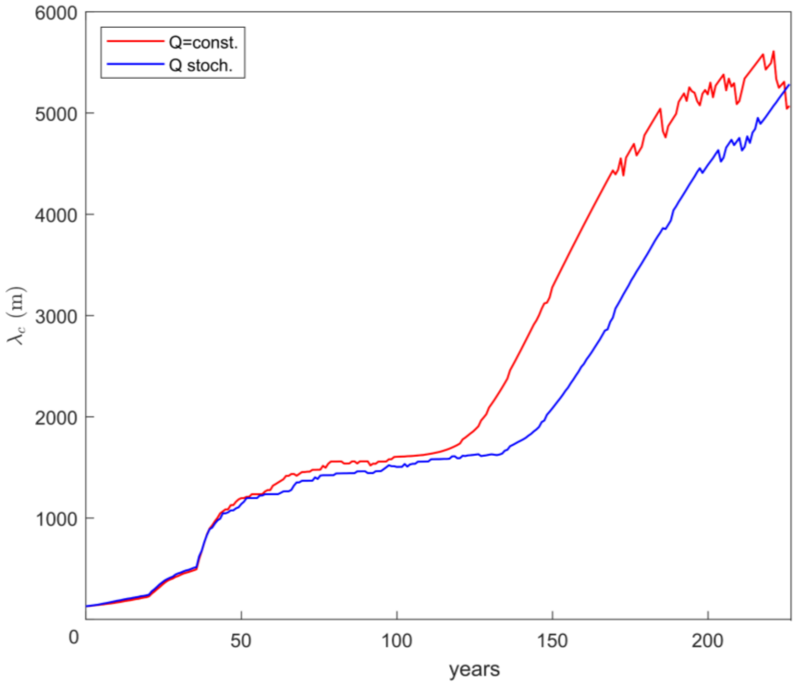
Constant discharge = mean of the stochastic process

RESULTS

- S is the sinuosity (the ratio of the river length to the linear distance between its endpoints)
- λ_c is the mean curvilinear wavelength

Compared with the case of constant flow (red lines), the discharge variability (blue lines) slows down the formation of the meanders and induces lower λ_c. It also delays the occurrence of cutoff events, identified by the sinuosity saturation.

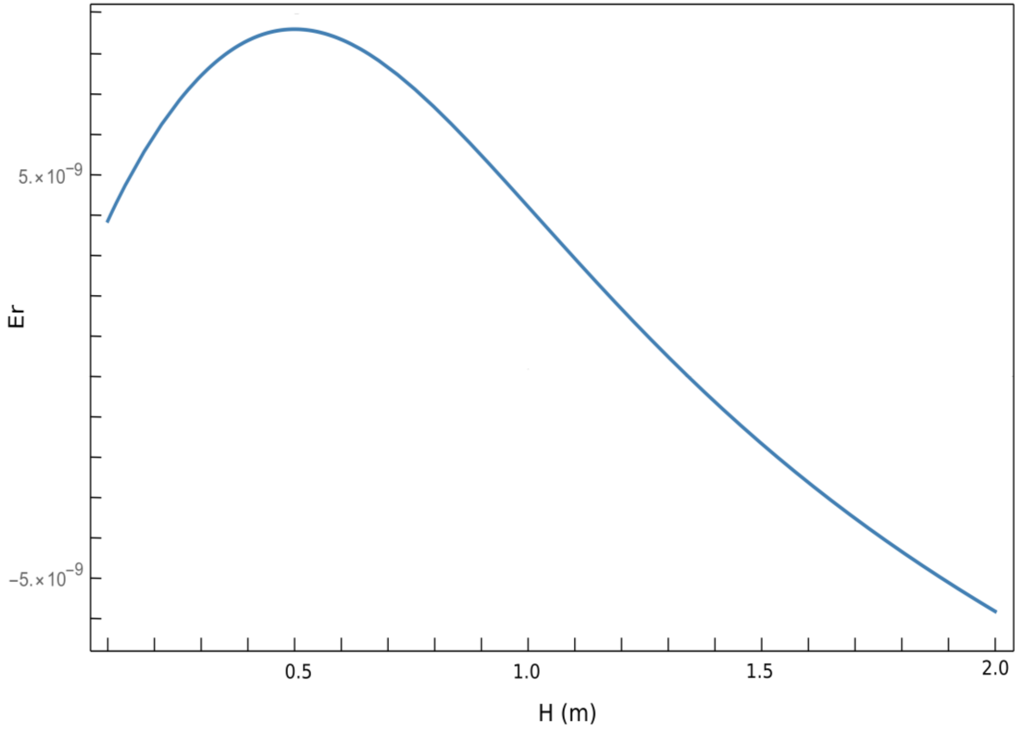




THEORETICAL VERIFICATION

Why does discharge variability slows down meanders evolution?

- Solution of the meandering equation $v(s)$ for the Kinoshita curve $C(s)$
- Channel erosion rate E_r averaged over one wavelength $(\lambda = 2\pi/q)$: $E_r = \frac{q}{2\pi}\int_0^{2\pi/q} v(s)\cdot C(s)\ ds$
- Relationship between E_r and the river depth:



The growth rate decreases for high values of $H \propto Q^{3/5}$

NUMERICAL VERIFICATION

Why does discharge variability slows down meanders evolution?

- Same initial planimetry (**Fig. 1**)

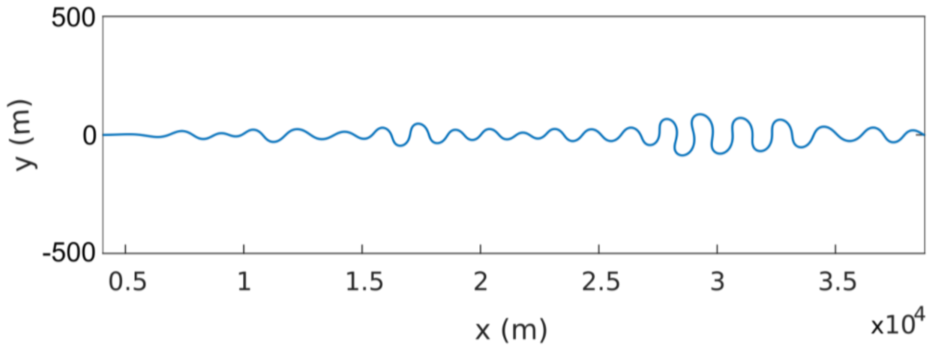


Figure 1: Initial planimetry (time=0).

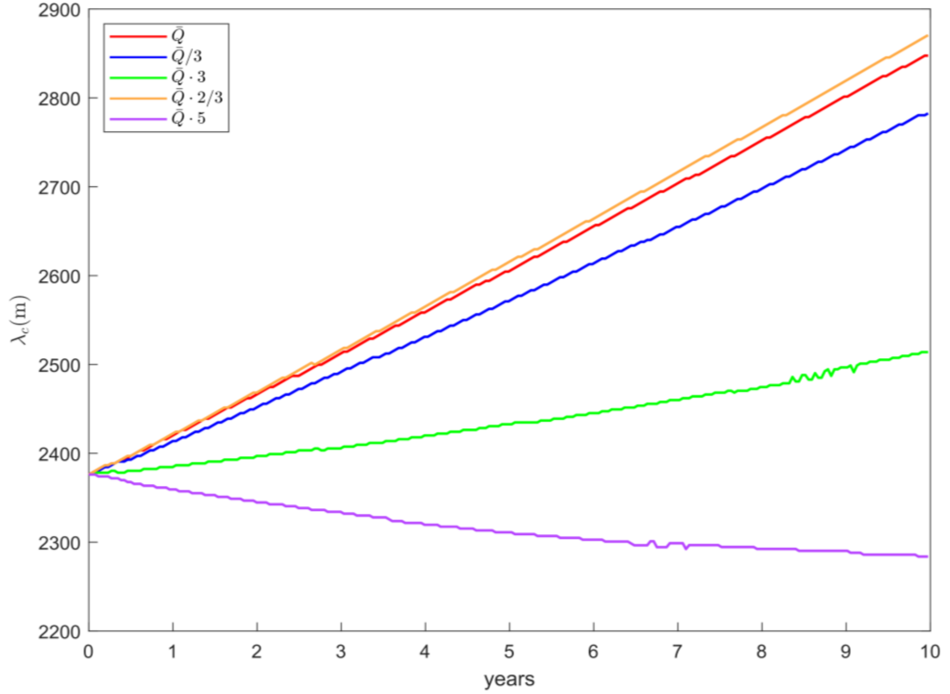


Figure 2: Mean wavelengths for different values of discharge.

- Depending on the values of the discharge, the meander grows or decreases (**Fig. 2**)

CONCLUSIONS

- Evolution of a meandering river:
  Long-term → dominated by the filtering action of cutoff events
  Short-term → strongly affected by discharges;

- With respect to the case of constant discharge:
  (i) the flow variability slows down the formation of meanders (the sinuosity increases more slowly)
  (ii) the reach elongation (induced by the local bank erosion) shows a significant delay;

- Simulations and theoretical analysis reveal that the higher the discharge, the bigger is the planimetric dilatation of the meander bend, resulting in lower curvilinear wavelengths;

- A single constant value of discharge does not yield to the same temporal and spatial scales typical of the evolution of a meander bend forced by a stochastic flow.

THANK YOU FOR YOUR ATTENTION