Planform as a Dominant Control on Sediment Intermittency: Global Analysis of River Transport Patterns

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1 Introduction

River intermittency (*I*) describes the ratio between long-term average and instantaneous maximum transport rates of water or sediment[1]. It is an important way of quantifying distributions of river activity through time.

$$I = \frac{\Sigma Q(t)}{Q_{(bf)}\,\Sigma t}$$

Long-term average flux

Potential bankfull flux if sustained for the same period

Motivations

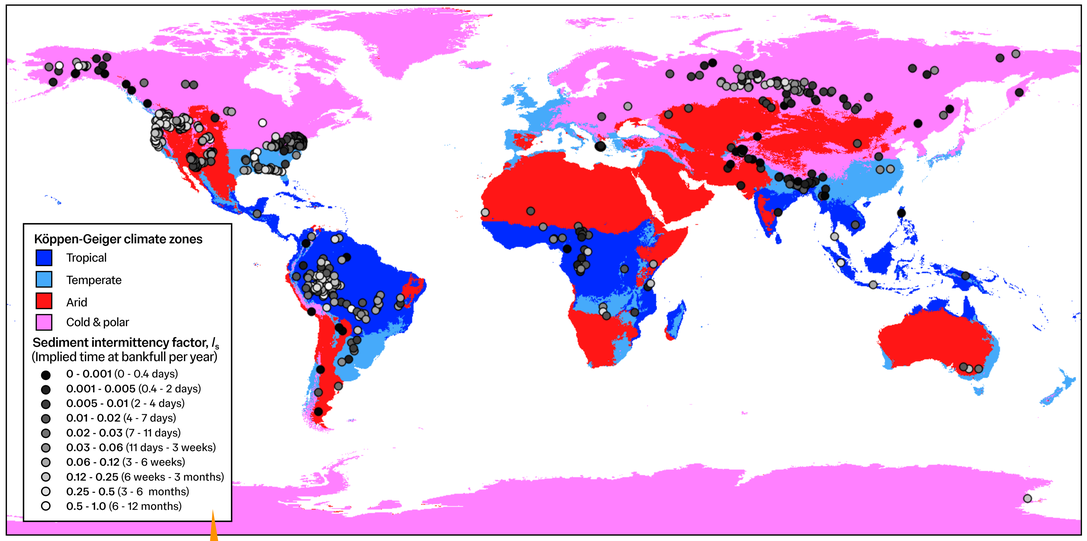
- Patterns of water and sediment flux are key to understanding geomorphic response to allogenic drivers such as climate change and tectonics[2]
- But environmental signals are buffered in river deposits
- Intermittency factors can shed light on river processes, but sediment intermittency is more challenging to estimate than water intermittency
- Interpretations of stratigraphy are limited without absolute constraints on modern-day river intermittency
- Intermittency datasets to-date are limited to restricted climate zones and planforms

Aims

- Produce a **global dataset** describing intermittency of water and sediment flux
- Investigate **river sensitivity** to a range of bounding conditions
- Link **intermittency** and other hydrologic parameters with **planform** and **climate**

Hypothesis

- Rivers transport water and sediment differently depending on planform



Based on the original concept of intermittency factors [1]

The dataset does not include strongly anthropogenically modified rivers

2 New global intermittency dataset

We present a new global dataset describing river **water and sediment transport intermittency**, in addition to a range of other parameters. Primarily, we are now able to analyse morphometry and transport dynamics in rivers across every climate zone on Earth.

Inputs

	I_s	I_w
$\Sigma Q(t)$	WBMsed model[3] BQART + Psi + WBMplus	Gauged discharge data[7]
$Q_{(bf)}$	Measured and model output grain-sizes[4] Sediment transport models[5,6]	GQBF dataset[8] GRIT FABDEM

Dataset size

N reaches	I_s	I_w	Climate	Planform
549	✓		✓	
351	✓		✓	✓
332	✓	✓	✓	✓

Methods

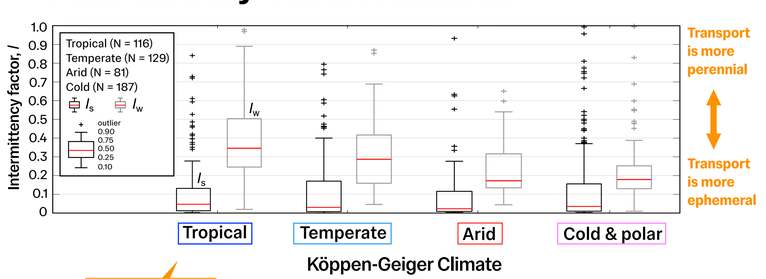
This dataset is based on compilations of published data, model outputs and empirical-theorietical transport relations.

We use the inputs outlined (left) to estimate estimates of long-term averaged water and sediment discharge, and potential bankfull water and sediment flux.

For some parameters, compiled literature datasets were used. To estimate $Q_{W(bf)}$ for each reach we used the GQBF dataset[8]. Where bankfull sediment flux was not known, we used sediment transport models to calculate $Q_{S(bf)}$. These permit us to caluclate water and sediment intermittency factors.

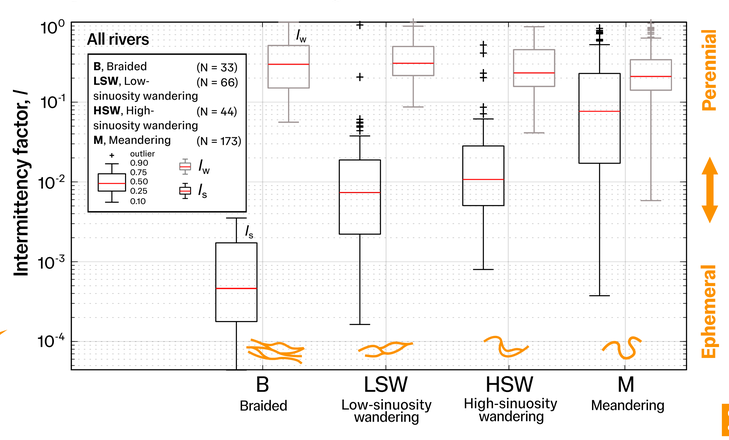
We also used a pixel masking approach to calculate planform metrics on 19 further reaches in the northwestern USA.

3 Intermittency relates to climate...



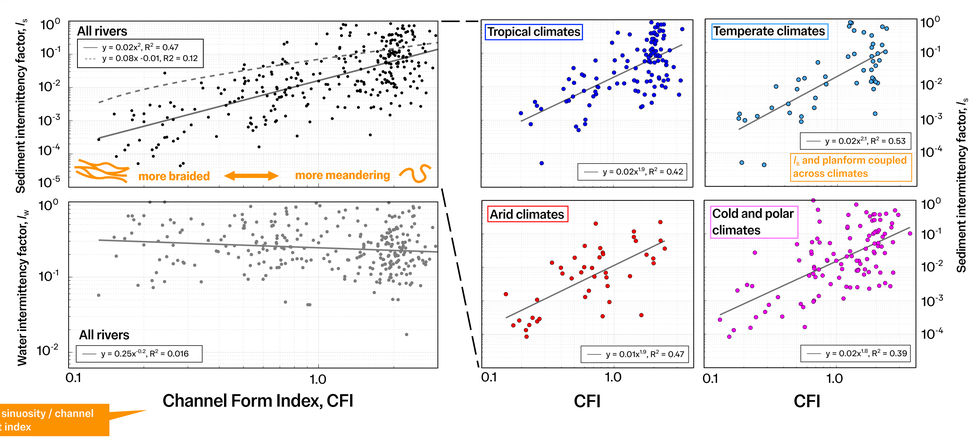
I_w varies predictably with climate. I_s trends are not as strong.

4 But river planform dominantly affects sediment intermittency...



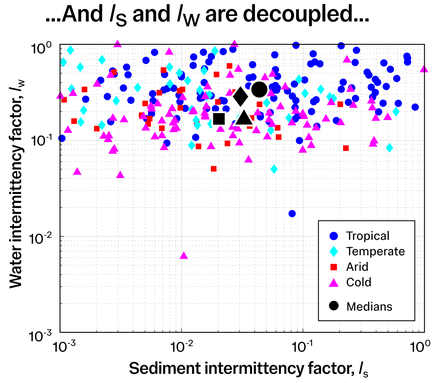
I_s inherits a strong planform signal - I_w doesn't. Could this planform signal be due to climate?

5 This is quantifiable and independent of climate.



CFI = sinuosity / channel count index

...And I_S and I_W are decoupled...



I_s more variable than I_w, with no correlation

Results

- Median I_S = 0.03 (12 days of bankfull flow would complete the annual sediment load)
- Median I_W = 0.26 (3 months per year)
- I_W responds predictably to climate, but I_S is strongly influenced by planform: I_S and I_W are completely decoupled
- Braided rivers have I_S 100 x lower than meandering rivers.
- This trend is consistent across all climate zones.

6 Implications

Planform is the dominant control on sediment intermittency. For water, climate and aspect ratio are dominant.

Results show **planform determines the thresholding of sediment transport**, in addition to channel geometry (cf. [9]). Multithreaded river geometry is thresholded to bedload transport, whereas single-threaded rivers are thresholded to bank erosion.

This implies planform should be considered another **critical filter on climate signals** into the rock record.

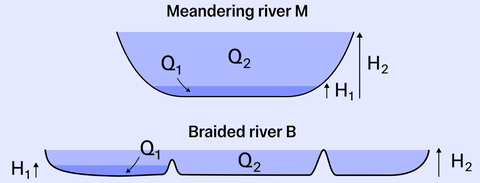
Findings suggest different river planforms can buffer/shred formative water discharge variability signals dfferently.

References

[1] Paola et al., 1992; [2] McLeod et al., 2024; [3] Cohen, 2012; [4] Hayden et al., 2021; [5] Meyer-Peter & Muller, 1948; [6]Engelund & Hansen, 1967; [7] Galeazzi et al., 2021; [8] Yinxue et al., 2024; [9] Phillips & Jerolmack, 2016

$\Delta\tau_M > \Delta\tau_B$

$\Delta\tau$ = bed shear stress differential



The shear stress differential between flow stages is higher in meandering rivers. Meandering rivers are more likely to transport sediment for a given discharge change.

Conclusions

New global datatset describes water and sediment intermittency across every climate zone.

Sediment intermittency (I_S) and planform are strongly linked, whilst I_S and I_W are decoupled.

Planform shreds climate signals from hydrology into the rock record, acting as a critical filter.