Landscapes on the edge: solving the river intermittency puzzle

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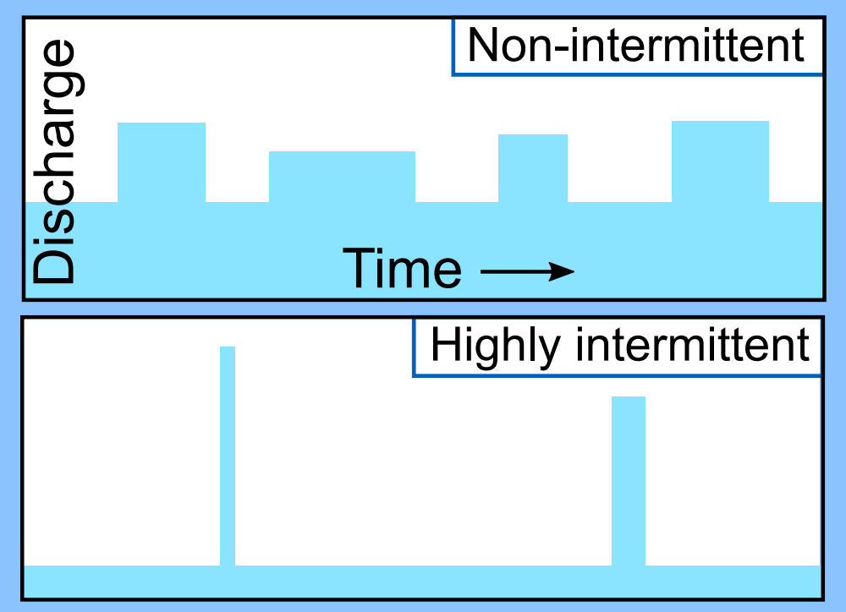
1. Context and Aims

Intermittency is the ratio between sediment or water flux actually occuring, and potential bankfull values over the same period.

$$I_f = \frac{\Sigma Q_{s(t)}}{Q_{s,bf}\,\Sigma t} \quad [1]$$

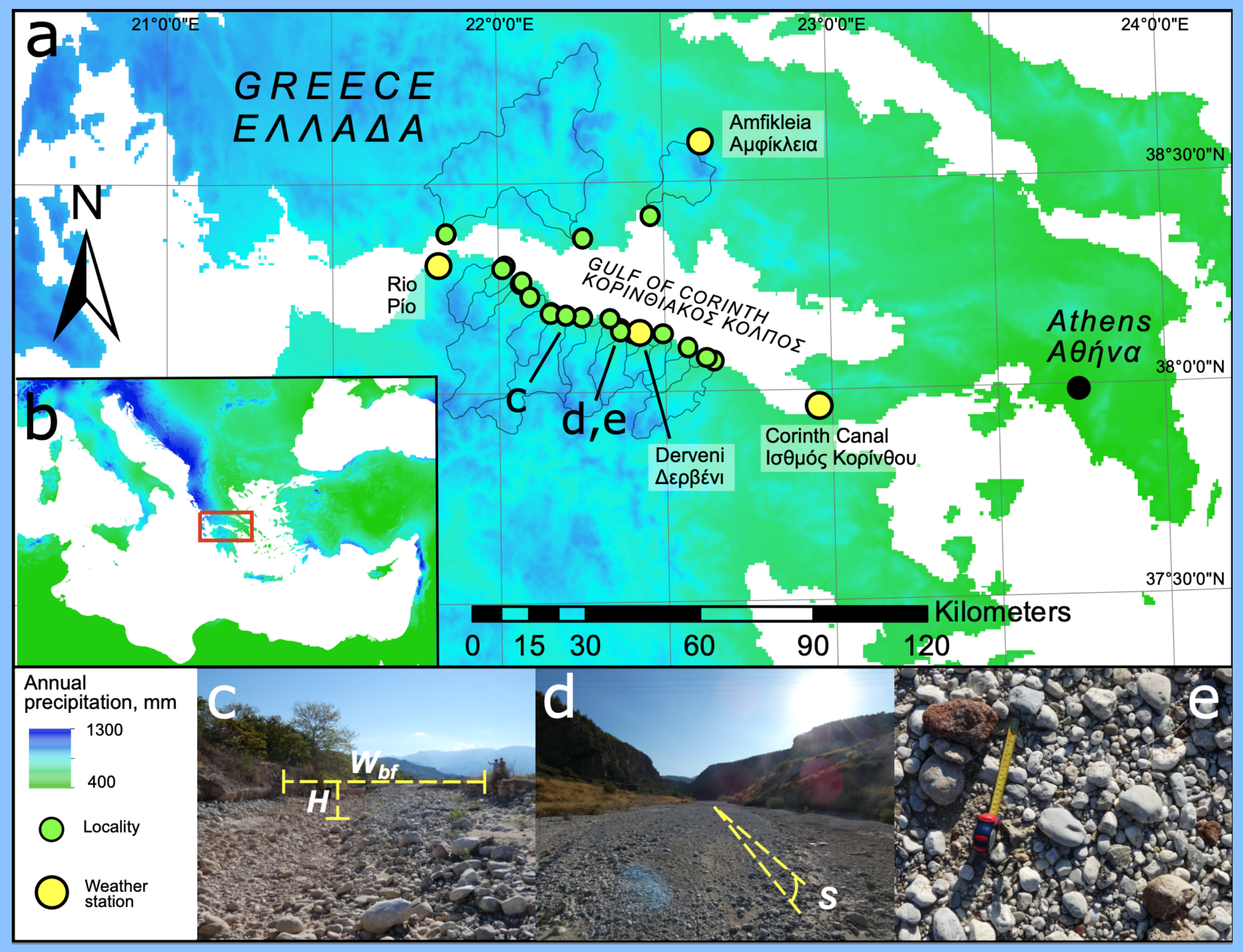


Highly intermittent systems, which only transport sediment in the most significant flow events, are particularly sensitive to changes in climate and precipitation patterns. **Climate change** will make these extreme events more frequent, and this could have **significant implications for landscapes in the future**

To assess the vulnerability of landscapes to climate change, we need to better constrain intermittency in sensitive river systems. **Therefore, our aims are to:**

1. Constrain bedload transport intermittency factors in modern rivers
2. Quantitatively link these with historical precipitation and flood records
3. Constrain the implications of a changing climate on landscapes and communities in intermittent river systems.

2. Study area and methods



To calculate the bedload intermittency factor we need to know:

a) potential bankfull bedload flux

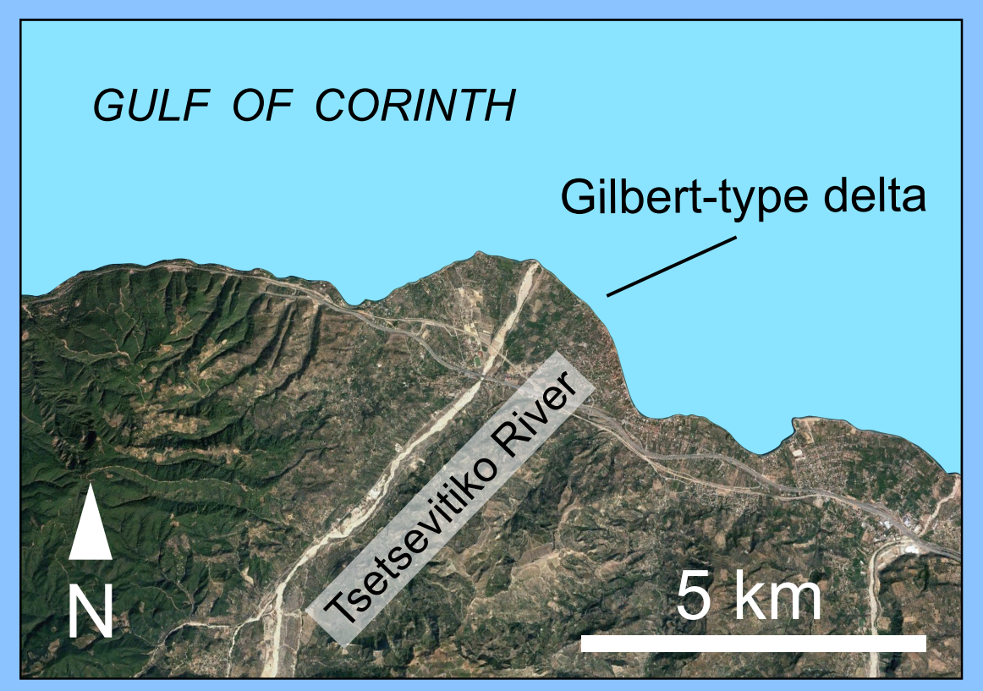
Input field data into **Meyer-Peter & Muller** formula:

$$q_S = \rho_S\,(gD_{50}\,\Delta\rho)^{0.5}C(T_b^* - T_c^*)^{\alpha}$$

b) long-term averaged bedload flux (based on published data [2])

i) Delta approach

Prominent **Gilbert-type deltas** prograde into the Gulf, representing the bedload fraction supplied by rivers. We used a simple delta volume model to estimate **Holocene-averaged bedload flux**.



ii) BQART approach

Global multi-regressional empirical model to estimate suspended flux:

$$Q_s = \omega B Q^{0.31} A^{0.5} R T$$

To get bedload flux, we need the ratio of bedload to total sediment flux, R_{bt}.

Lower bound $\boldsymbol{R_{bt}}$ **= 0.16** (from analysis of rift margin delta volumes and seismic volumes of distal basin sediment)

Upper bound $\boldsymbol{Rbt}$ **= 0.35** (from an analagous river system) [2]

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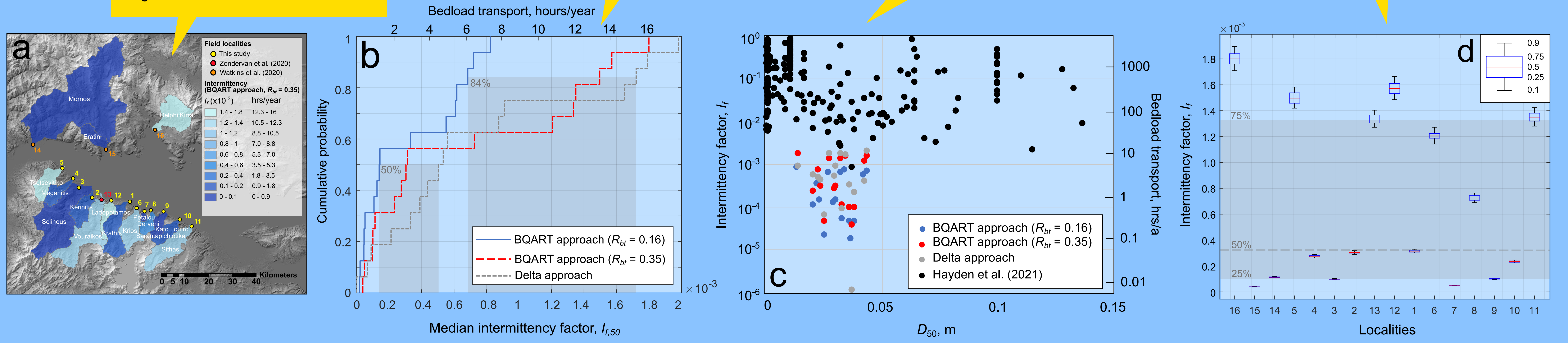
3. Intermittency results

Map view shows field localities and range of results

Median $\boldsymbol{I_f}$ **= 3.23x10^{-4}**, equivalent to 3 hrs of bedload transport per year. All approaches produce reasonable results.

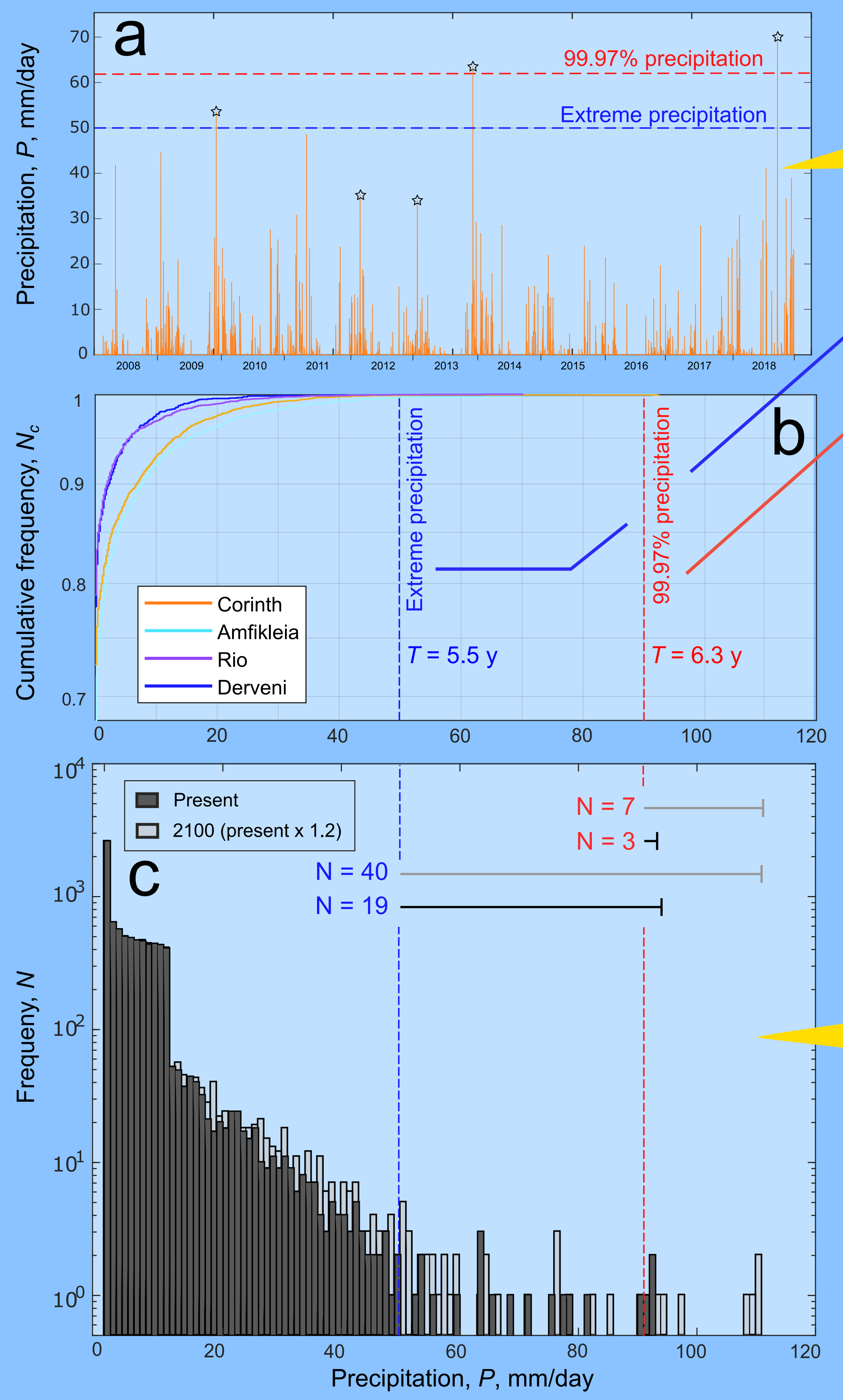
Corinth rivers are highly intermittent compared to a global dataset, meaning they are dominated by infrequent, extreme events

Intermittency boxplot with Monte Carlo uncertainty propagation (BQART, R_{bt} = 0.35) shows no spatial trend



Calculations show Corinth rivers are extremely intermittent, with median $\boldsymbol{I_f}$ **= 3.23x10^{-4}.** This implies that, on average, rivers only transport bedload sediment 0.03% of the time, and would need under **3 hours of bedload transport per year** in order to fulfil their annual budget.

4. Precipitation analysis



To investigate the role of precipitation, we analysed daily rainfall data from 4 weather stations near the study area.

Daily rainfall time series for Corinth weather station, 2008 - 2018, with floods indicated by stars

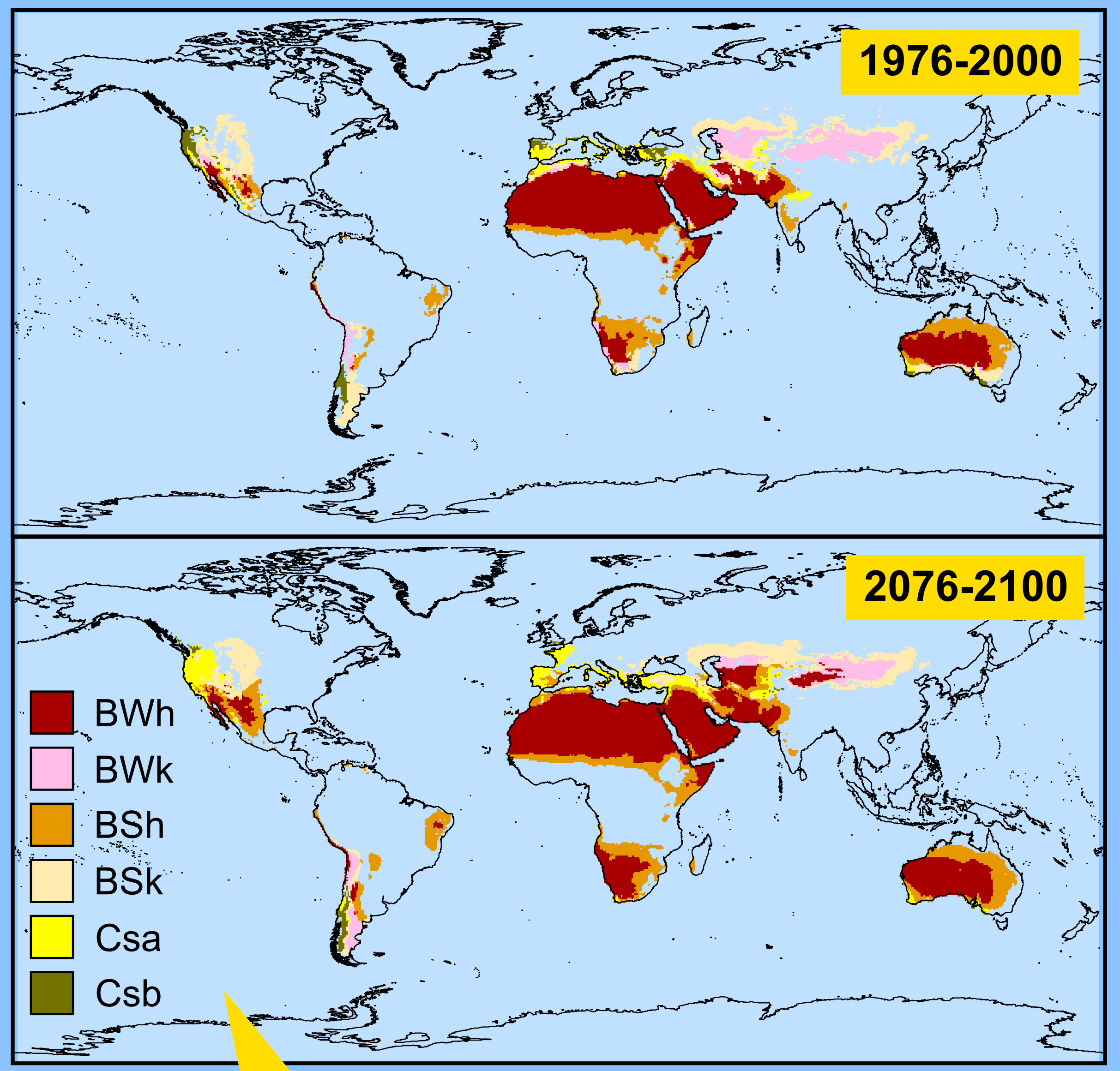
The accepted magnitude of extreme precipitation is 50 mm/day [3]. I_f calculations suggest the average precipitation probability threshold to move bedload is 99.97%, or 91 mm/day. This shows that bedload is likely only moved in extreme events.

This is reinforced by analysis of historical flood records to understand the characteristics of real threshold-surpassing floods. From data on significant floods within 50 km of the study area (2000-2021), **the average flood duration is 14 hours.** Intermittency calculations imply the following flood return intervals:

Mean	>50 mm/day	>99.97%
4.8 y	5.5 y	6.3 y

Rainfall frequency-magnitude for all weather stations, and thresholds in present and future

But how will this change in the future? Climate models suggest a **20% increase in extreme precipitation by 2100** in the study area. The frequency-magnitude plot (left) shows the expected change in number of threshold-surpassing rain events.



World maps for 1976-2000 and 2076-2100 highlighting **arid (potentially intermittent) zones** of the Koppen-Geiger climate classification. [4]

5. Implications

A 20% increase in extreme precipitation could cause a **20-70% increase in sediment budget** across the study area, depending on the balance between changing rainfall frequency and magnitude.

Today, 30% of global land mass is arid, and can host intermittent river systems. **By 2100, this could increase by 1.6x10^6 km^2, the size of the UK, France, Spain and Italy combined.**

So climate change could cause a significant increase in sediment budgets on a global scale.

This will be associated with a range of hazards:

Flooding
Enhanced erosion (landslides)
Agricultural topsoil erosion
Pollution and disease

6. Conclusions

Rivers in the Gulf of Corinth are **extremely intermittent,** requiring only 3 hours of bedload transport per year to fulfil their annual budgets. They are driven by **1 rainfall event every 5 - 6 years**.

Rainfall events causing bedload transport are extreme (> 50 mm/day) and result in large floods.

By the year 2100 the global land area capable of hosting intermittent systems could increase by 1.6x10^6 km^2. Across this area, **sediment budgets could increase by 20 - 70% by 2100**, associated with a range of hazards.

[1] Hayden, A. T., Lamb, M. P., & McElroy, B. J. (2021). Constraining the Timespan of Fluvial Activity From the Intermittency of Sediment Transport on Earth and Mars. *Geophysical Research Letters,* 48(16). [2] Watkins, S. E. (2019). Linking source and sink in an active rift: Quantifying controls on sediment export and depositional stratigraphy in the Gulf of Corinth, central Greece. Imperial College London. [3] Nastos, P. T., & Zerefos, C. S. (2008). Decadal changes in extreme daily precipitation in Greece. *Advances in Geosciences*, 16, 55–62. [4] Rohli, R. V., Andrew Joyner, T., Reynolds, S. J., Shaw, C., & Vázquez, J. R. (2015). Globally Extended Köppen–Geiger climate classification and temporal shifts in terrestrial climatic types. *Physical Geography*, 36(2), 142–157.