Dating the Incision of the Lower Amazon River using geomorphic markers and cosmogenic nuclides

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1. Motivation

Rivers in the northern margin of the Lower Amazon River are rife with waterfalls (see the *Main Map*). In this stuy, we are interested in answering the question: ***When and why did they form?***

Background

- Between 10 and 9 Ma, uplift of the Andes caused the formation of Amazon's transcontinental river (Fig.1);
- The Amazon Fan records multiple sediment pulses after 9 Ma;
- The Pleistocene Amazon Fan records show a drastic sedimentation increase

Knowledge gap:

- Sedimentary records of incision of the Amazon River are scarce - there are little onshore deposits that record these past environmental changes.

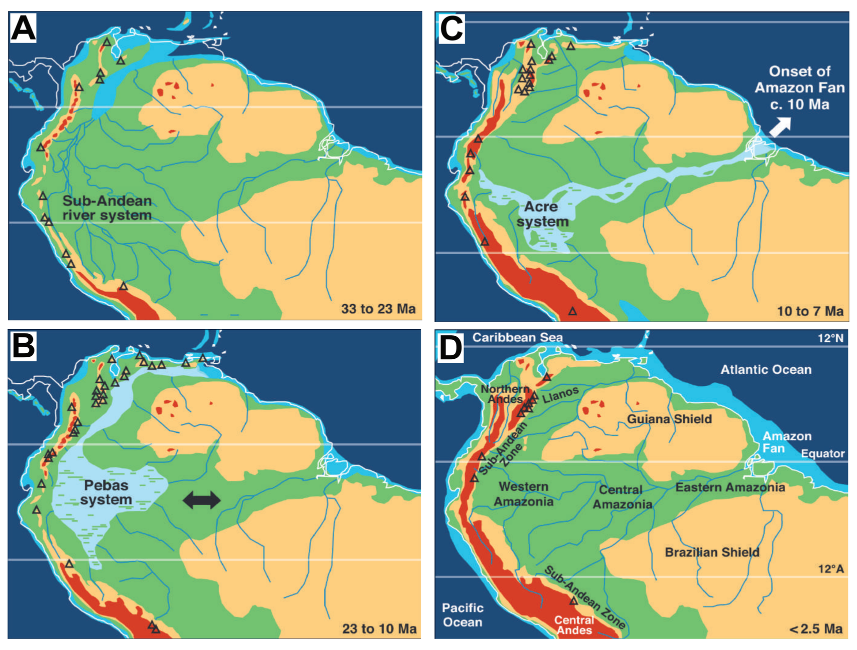
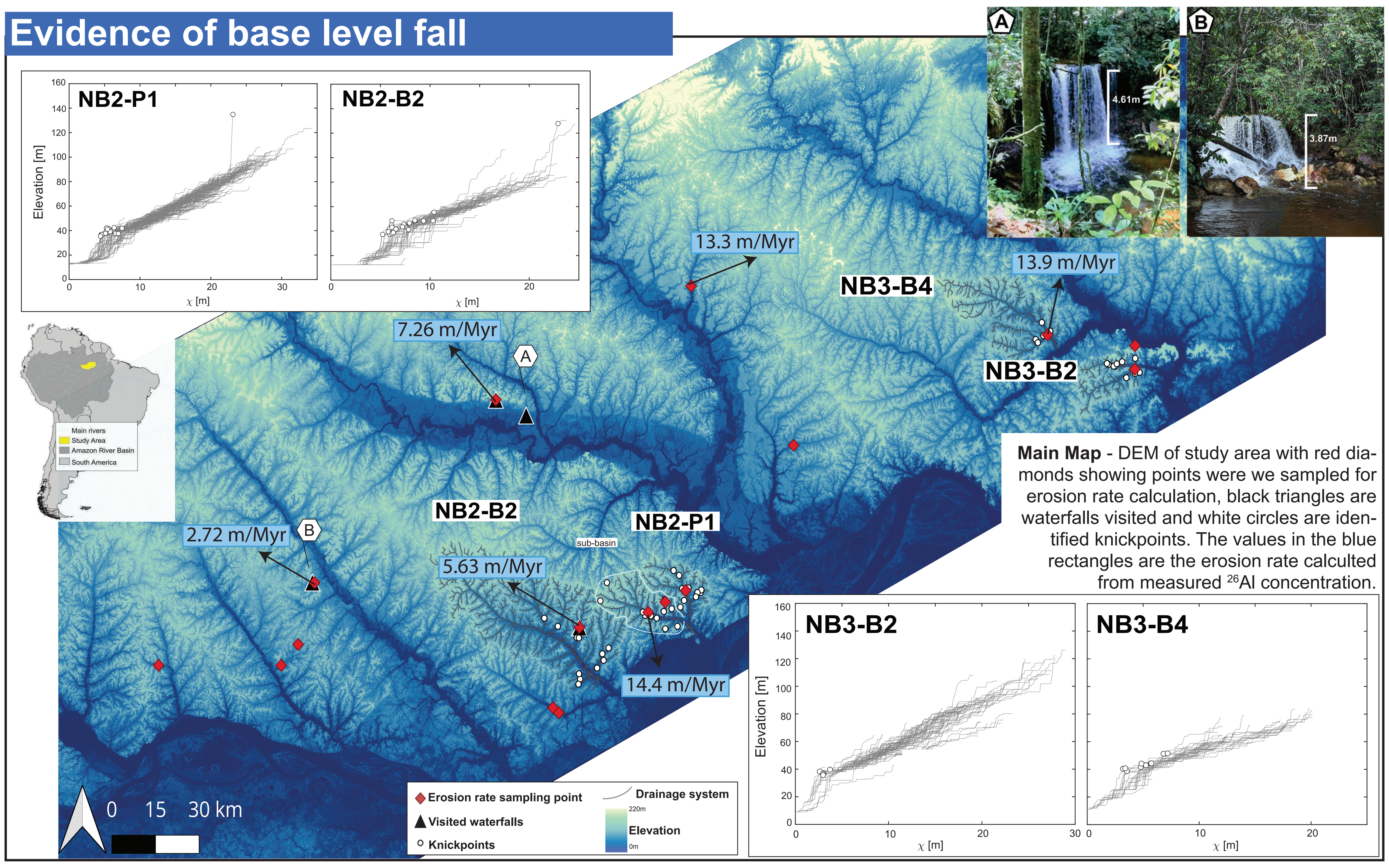


Fig. 1 - Evolution of the northern South America drainage network (Hoorn et al., 2010). Note the trans-continentalization of the Amazon River in panel (C) between 10-7 Ma.

Evidence of base level fall



Main Map - DEM of study area with red diamonds showing points were we sampled for erosion rate calculation, black triangles are visited waterfalls and white circles are identified knickpoints. The values in the blue rectangles are the erosion rate calculted from measured ^{26}Al concentration.

2. Hypothesis

The integration of the Pebas system (W) with Eastern Amazonia increased the drainage area of the eastern drainage system. **We hypothesize that the lower Amazon River adjusted its gradient in response to the E-W integration and incised its lower course (Fig. 2).**

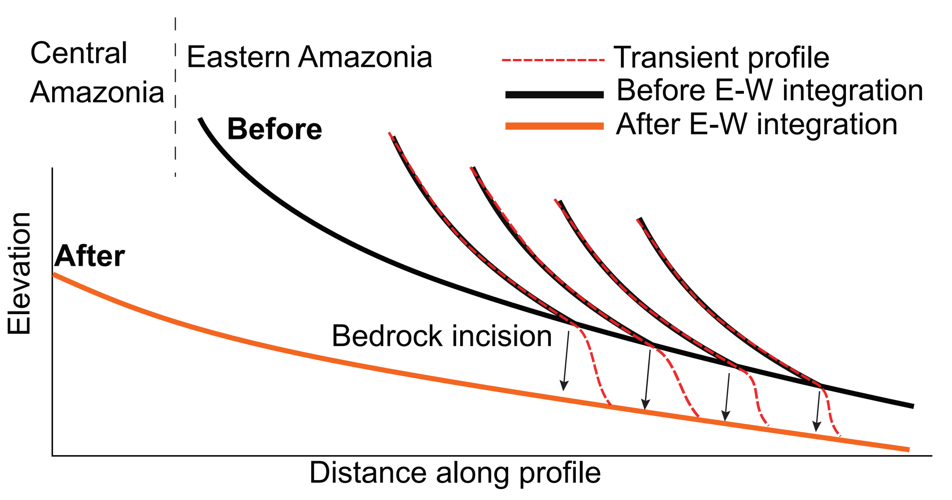


Fig. 2 – Conceptual model showing the response of a river profile to a major increase in drainage area. Note the incision of the trunk stream and formation of knickpoints in the tributaries downstream.

Hypothesis evaluation

If the waterfalls in Eastern Amazonia record this base level fall, we should observe:

- Clustered knickpoints at similar elevations across the region (Main Map);
- Similar timing of knickpoint initiation everywhere in the late Miocene / early Pliocene;

3. Methods

Topographic Analysis

Using the COP30 DEM, TopoToolbox (Schwanghart & Scherler, 2014), and TopoAnalysis Kit (Forte & Whipple, 2019) we:

- Mapped knickpoints (tolerance of 12 meters);
- Computed chi-plots using a mean concavity of 0.45;

Calculating Erosion Rates

- Average erosion rates were calculated using the CRONUS Calculator (v3.0) (Balco et al.,2008) from ^{26}Al concentration data.

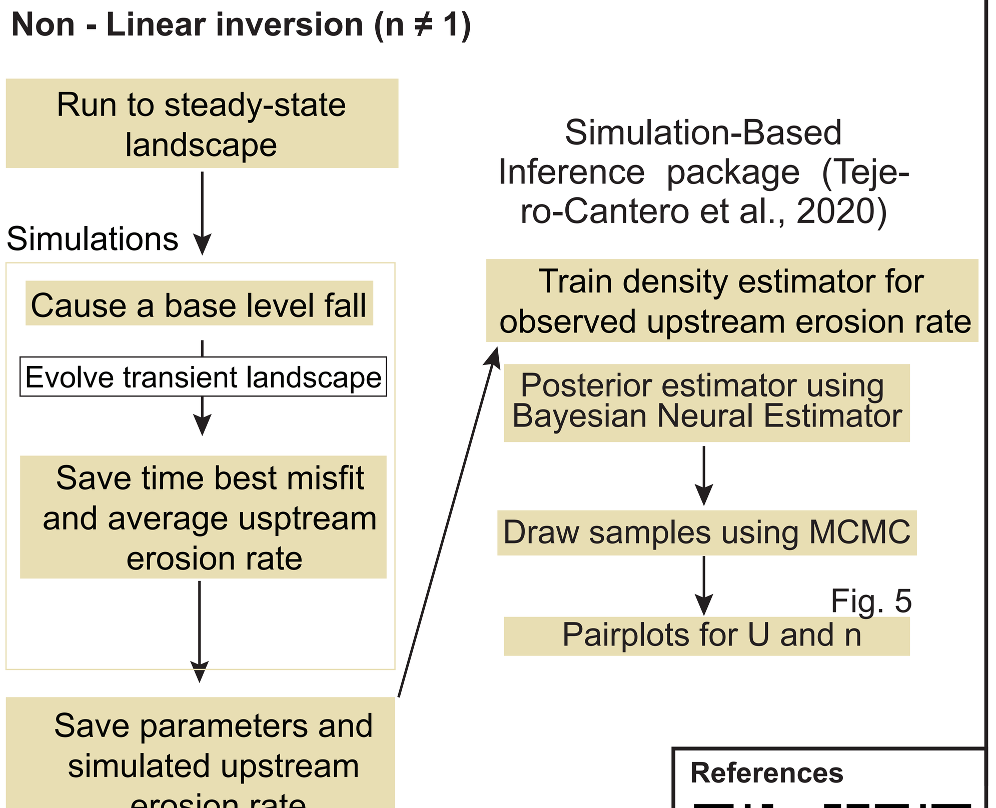
Dating base level fall

Linear inversion (n = 1)

Following Gallen (2018), we computed the age of base level fall using linear inversion (Fig. 4).

- We used the regression of ksn and erosion rates to calculate the erodibility value (i.e. K of the stream power model): $K = (E/k_{sn})$;

Non - Linear inversion (n ≠ 1)



References

4. Results: Dating the incision of the Amazon River

Linear inversion

- Possible base level fall event at a range of ages between 5 and 10 Ma;

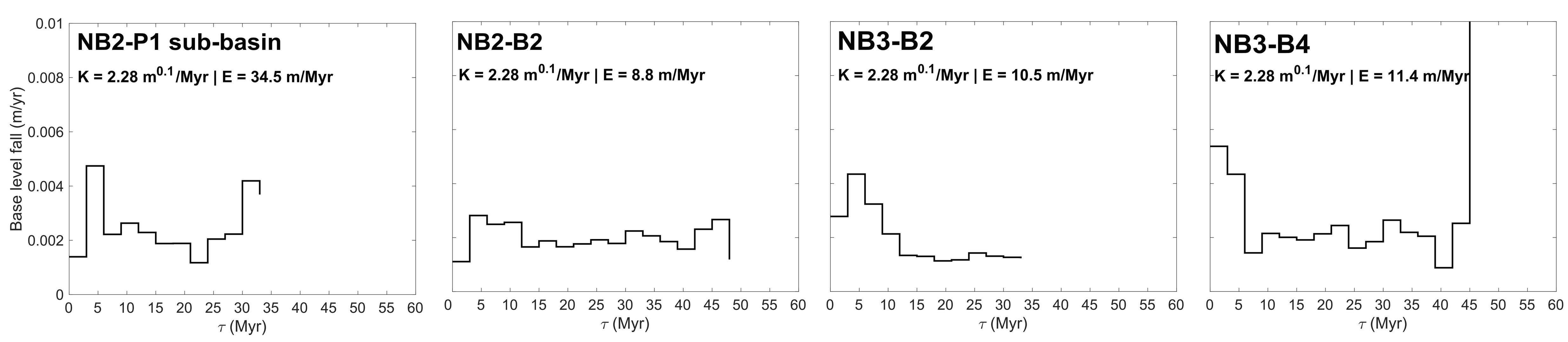


Fig. 4 – Tau-plots for four different basins showing age peak intervals of major base level fall events. The profiles were obtained with a 10^7 minimun drainage area.

Non - Linear inversion

Testing SPACE 1.0 (Shobe et al.,2017) in a synthetic landscape (Detachment-limited)

Steady-state with n = 1; U = 5x10^{-6} m/yr; θ = 0.5
Transient landscape with Umin,Umax = 2x10^{-6} m/yr,8x10^{-6} m/yr; n_min,n_max = 0.5,2

- The inversion was able to obtain the values of the paremeters used in the simulation;
- Time of the base-level fall is around 50 kyrs older than the one imposed in the simulation.

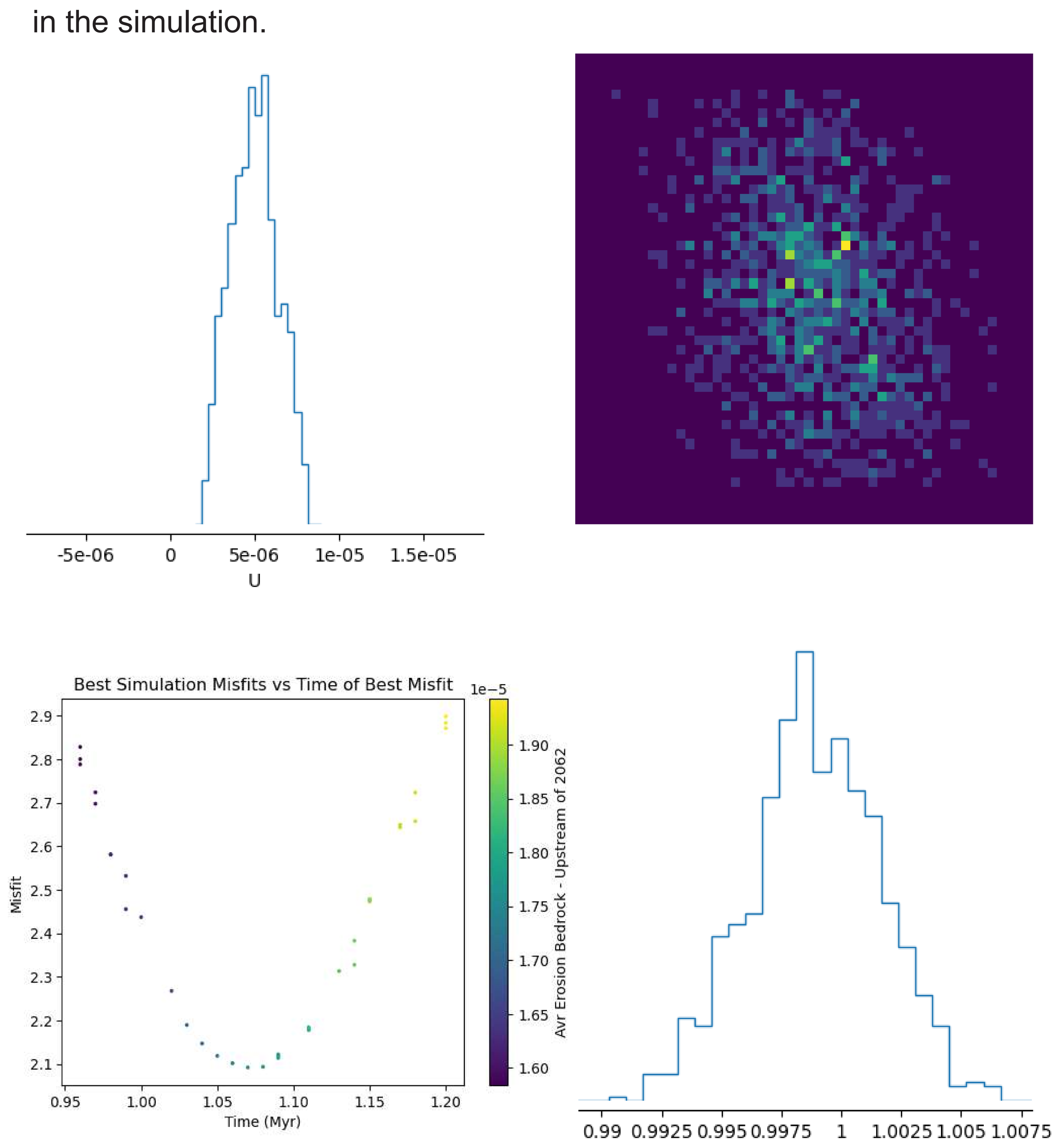


Fig. 5 –Pairplot of posterior distributions for uplift rate (U) and slope exponent (n) from MCMC. Diagonals show marginal distributions; the scatterplot shows joint distribution and correlation. Bottom left: best-fit time vs. misfit, colored by upstream average erosion rate.

FastScape Eroder to a real basin - NB2_P1 (sub-basin) (Fig. 6)
Applying FastScape Eroder to a real basin (Detachment limited)

Steady-state with n = 1; U = 8x10^{-6} m/yr; θ = 0.45

- Inversion can obtain age for knickpoint position but not a good misfit for river elevation;
- Age of base-level fall has a wide variation for different values of n and K.

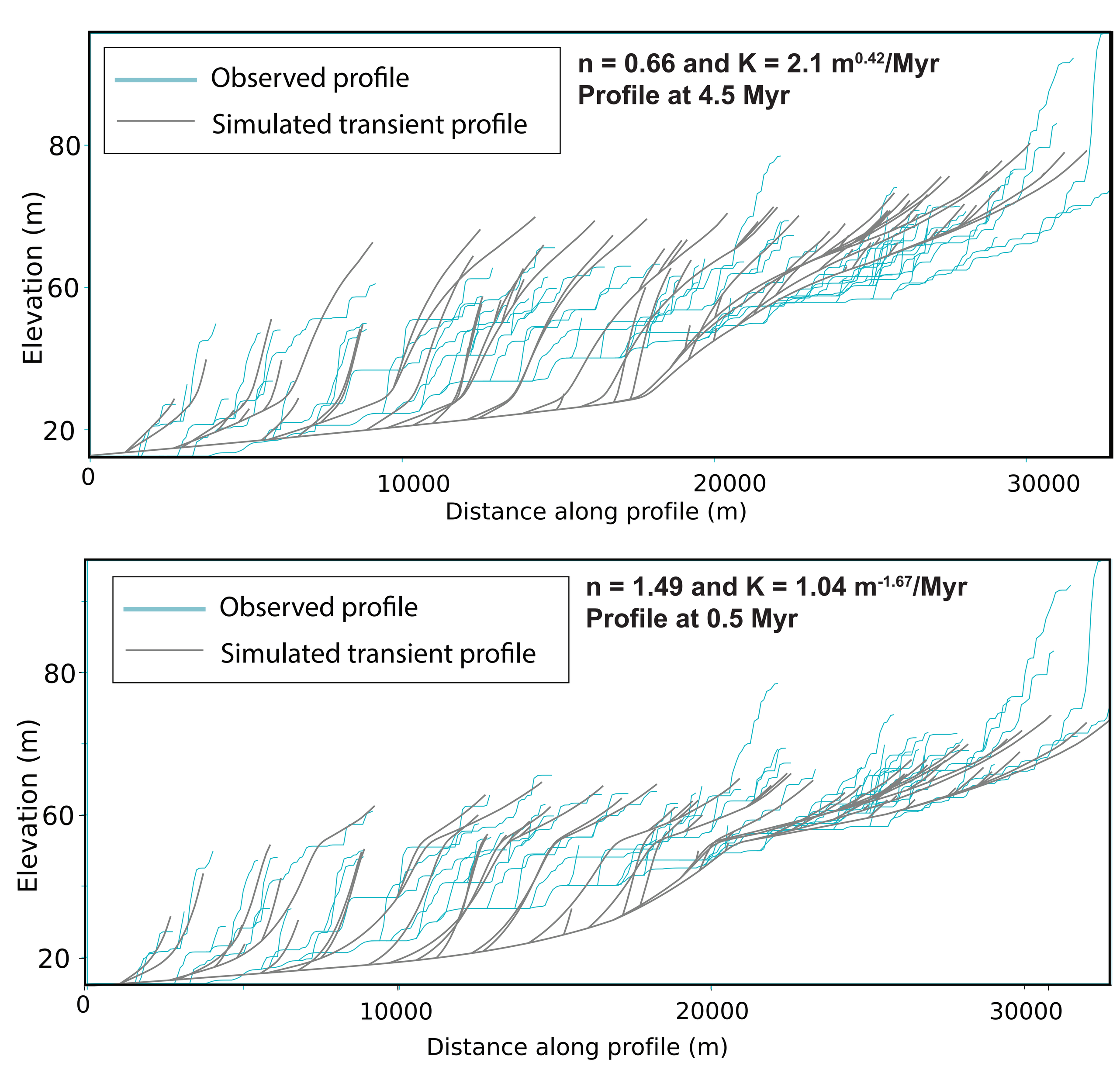


Fig. 6 – Results of transient profiles using non-linear inversion for two different scenarios. Light blue is the observed profile from the NB2_P1 Sub-basin and gray is the transient profile.

5. Future Work

- Run thousands of simulations applying the FastScape Eroder to the real basin
  - Constrain age of incision interval
  - n and K best fit and correlation using SBI - similar to Fig. 5
- Run the same simulations using SPACE 1.0 for the real basin, both as a transport-limited and detachment limited river.
- From SPACE 1.0:
  - Find relation of porosity of sediment, sediment erodibility and fraction of fine sediment, and sediment column thickness.
- Problem with SPACE 1.0
  - Multiple solutions for the age of base-level fall?

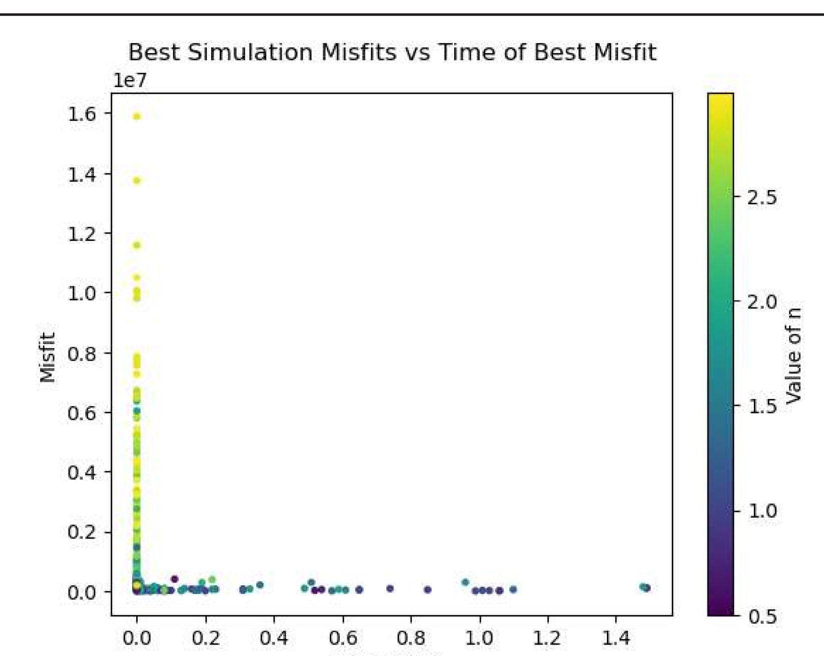


Fig. 6 – Applying SPACE using a synthetic landscape for a transport-limited river model. We observed that for similar values of n it is possible to obtain different ages.

Aknowledgments

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