Coupling soil erosion model and lake sediment records reveals the importance of Alpine erosion crisis in total sediment exports during the Holocene

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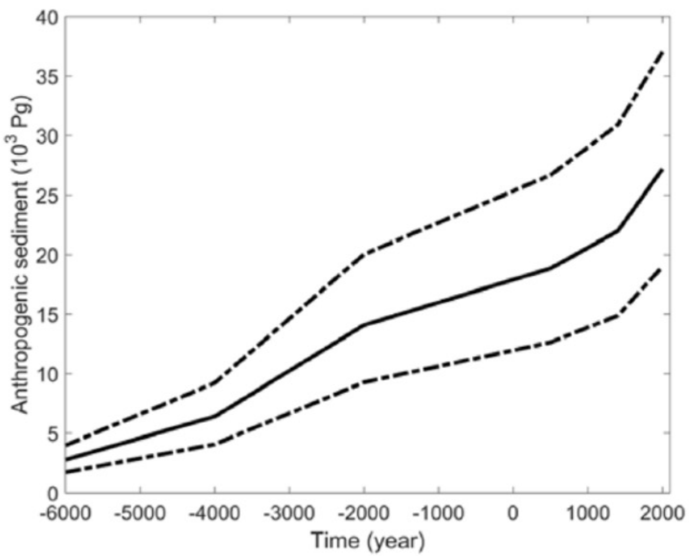
Picture : Jean-Marie Thomas

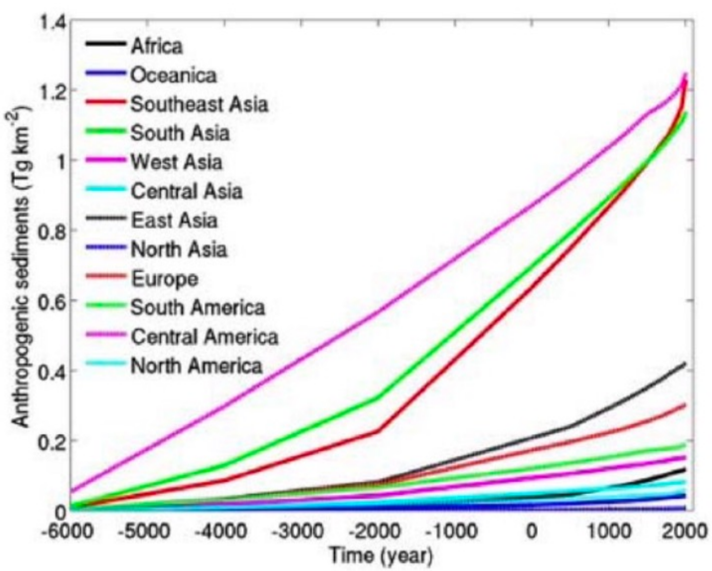
I. Context & objectives

Reconstruct long-term soil erosion dynamics

Long-term erosion reconstructions

Model reconstructions





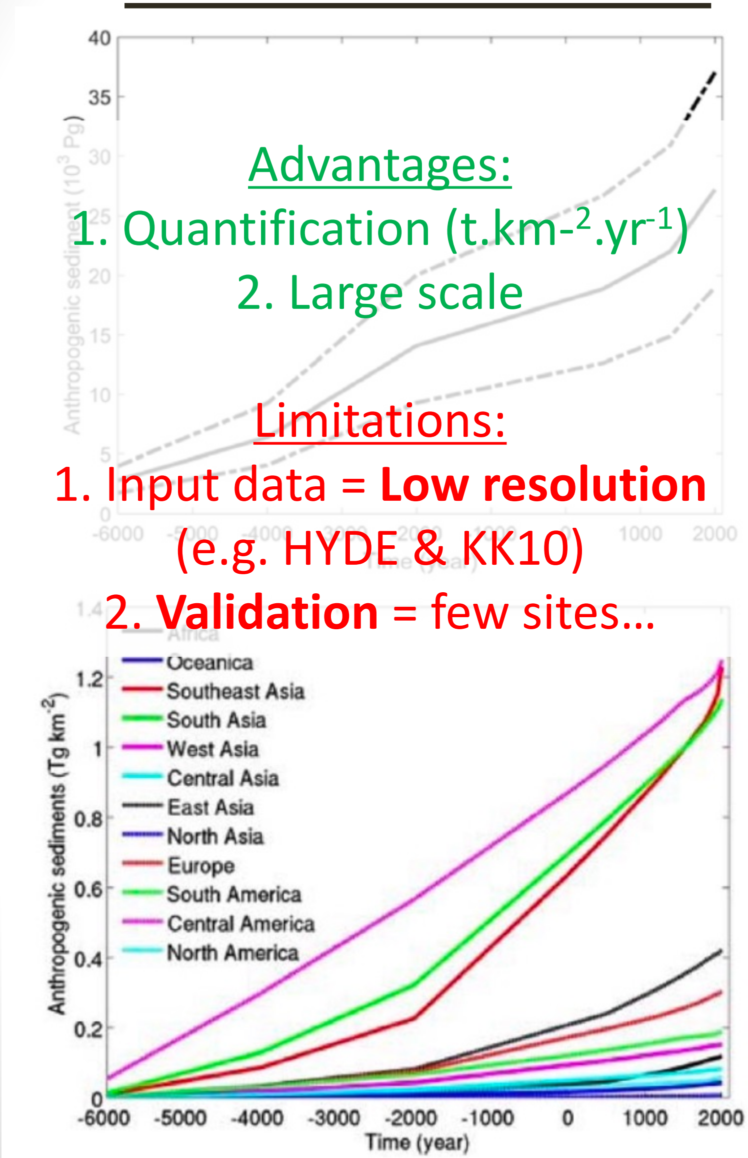
Wang et al., 2019

Long-term erosion reconstructions

Model reconstructions

Advantages:
1. Quantification (t.km-²^{2}.yr^{-1})
2. Large scale

Limitations:
1. Input data = **Low resolution** (e.g. HYDE & KK10)
2. **Validation** = few sites…



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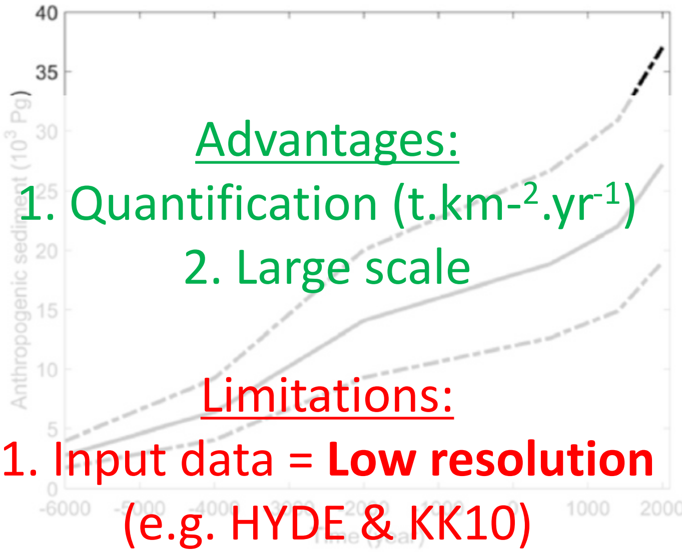
Long-term erosion reconstructions

Model reconstructions



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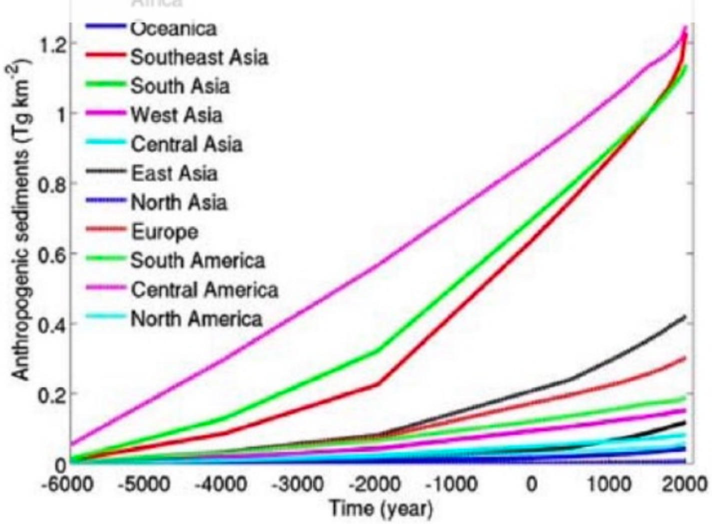
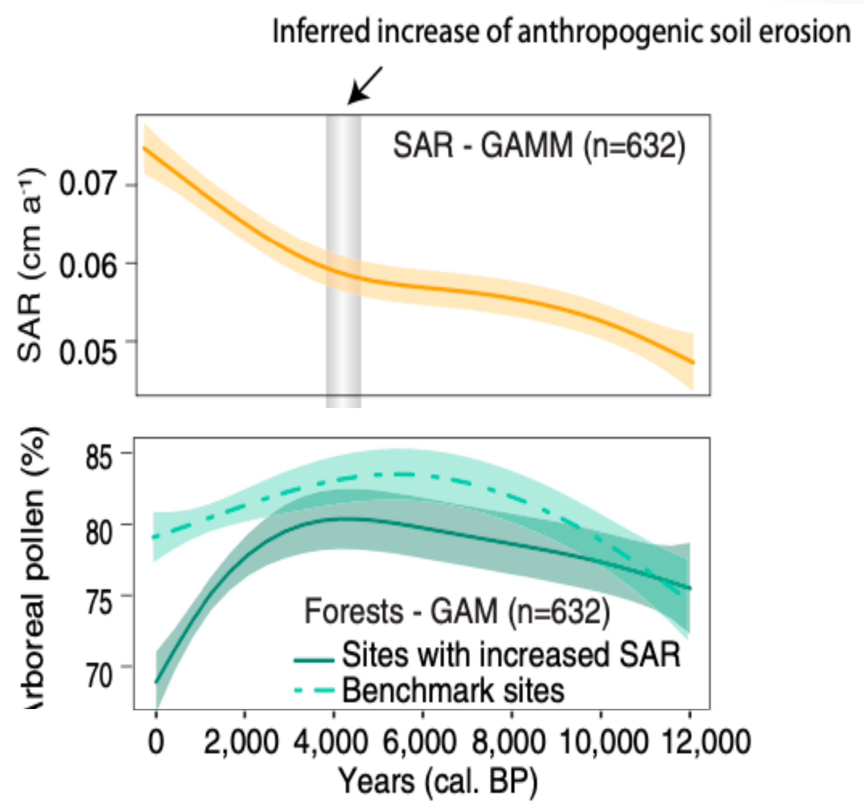


Wang et al., 2019

Empirical reconstructions



Modified from Jenny et al., 2019

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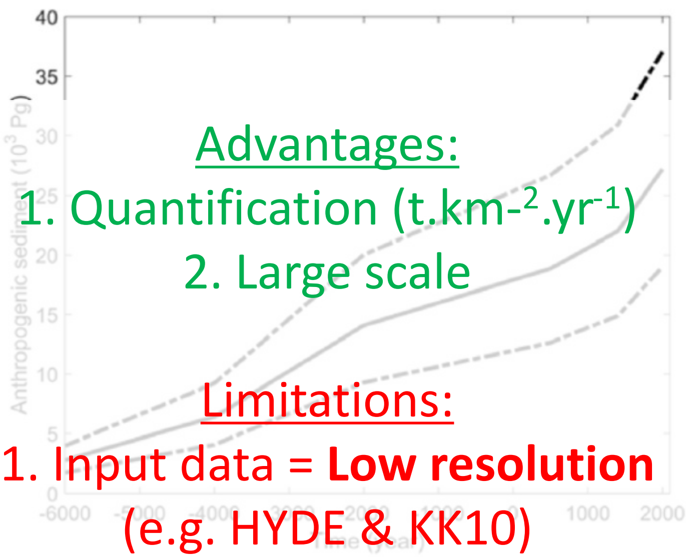

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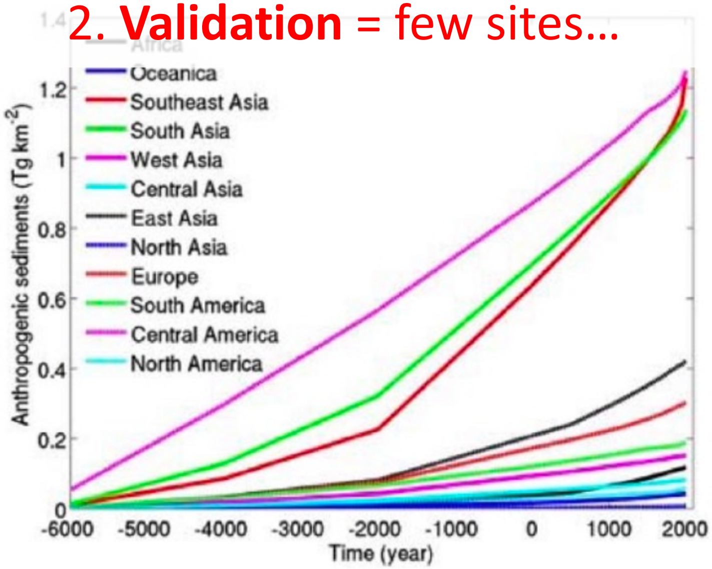

Wang et al., 2019

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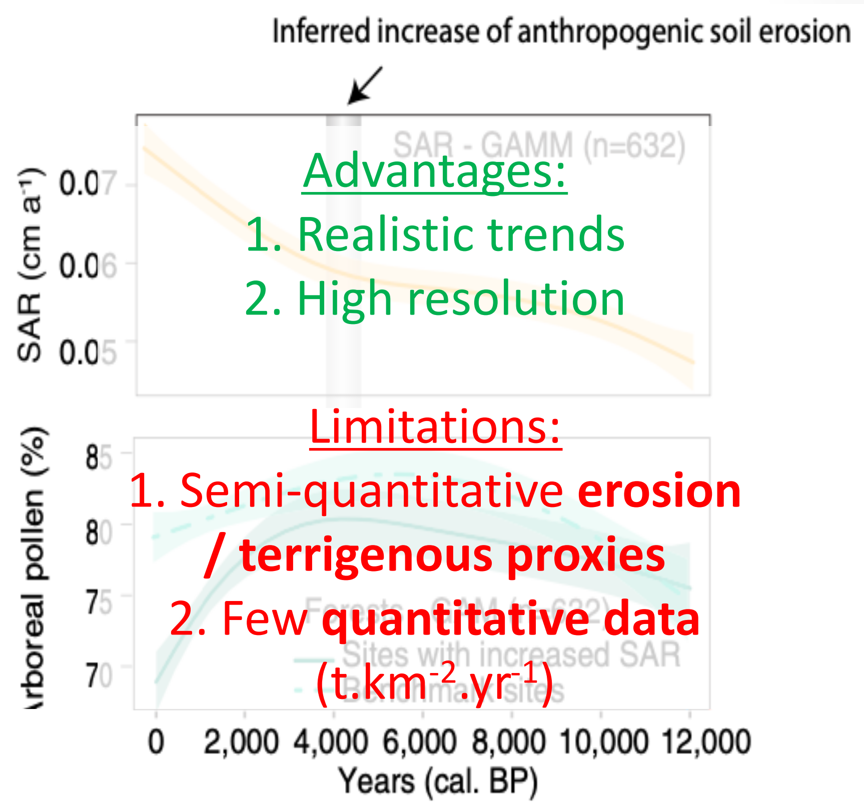

Advantages:

1. Realistic trends
2. High resolution

Limitations:

1. Semi-quantitative **erosion / terrigenous proxies**
2. Few **quantitative data** (t.km^{-2}.yr^{-1})

Modified from Jenny et al., 2019

Idea

Investigate long-term soil erosion dynamics by combining:

Quantification (model)

+

Realistic trends (paleo)

- Goals:
  1. **Methodological →** Convert soil erosion proxies into soil erosion unit ($t.km^{-2}.yr^{-1}$) by using erosion model
  2. **Thematic →** Investigate soil erosion dynamics over the Holocene period (12,000 last years)

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II. Materials and methods
Combining model & paleo data

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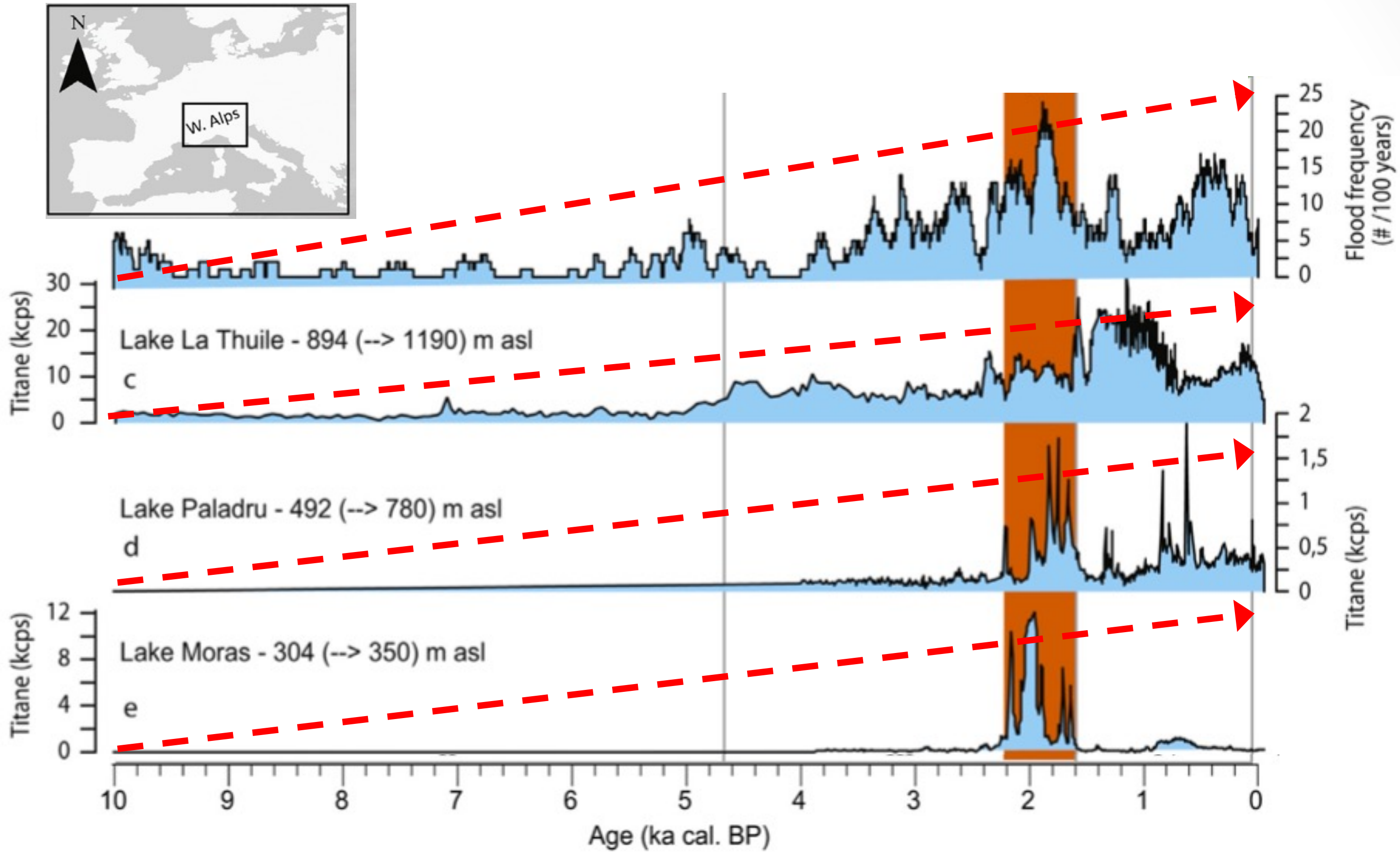
Specific region: French Northwestern-Alps



- **Plenty of paleo-reconstructions** of soil erosion
- **Inter-comparison** possible between study sites (Progressive acceleration + Erosion crisis)

Modified from Arnaud et al., 2016

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Study sites

- **Six natural lakes** with available **high resolution erosion signals** (Annecy, Anterne, Benit, Moras, Paladru, La Thuile)

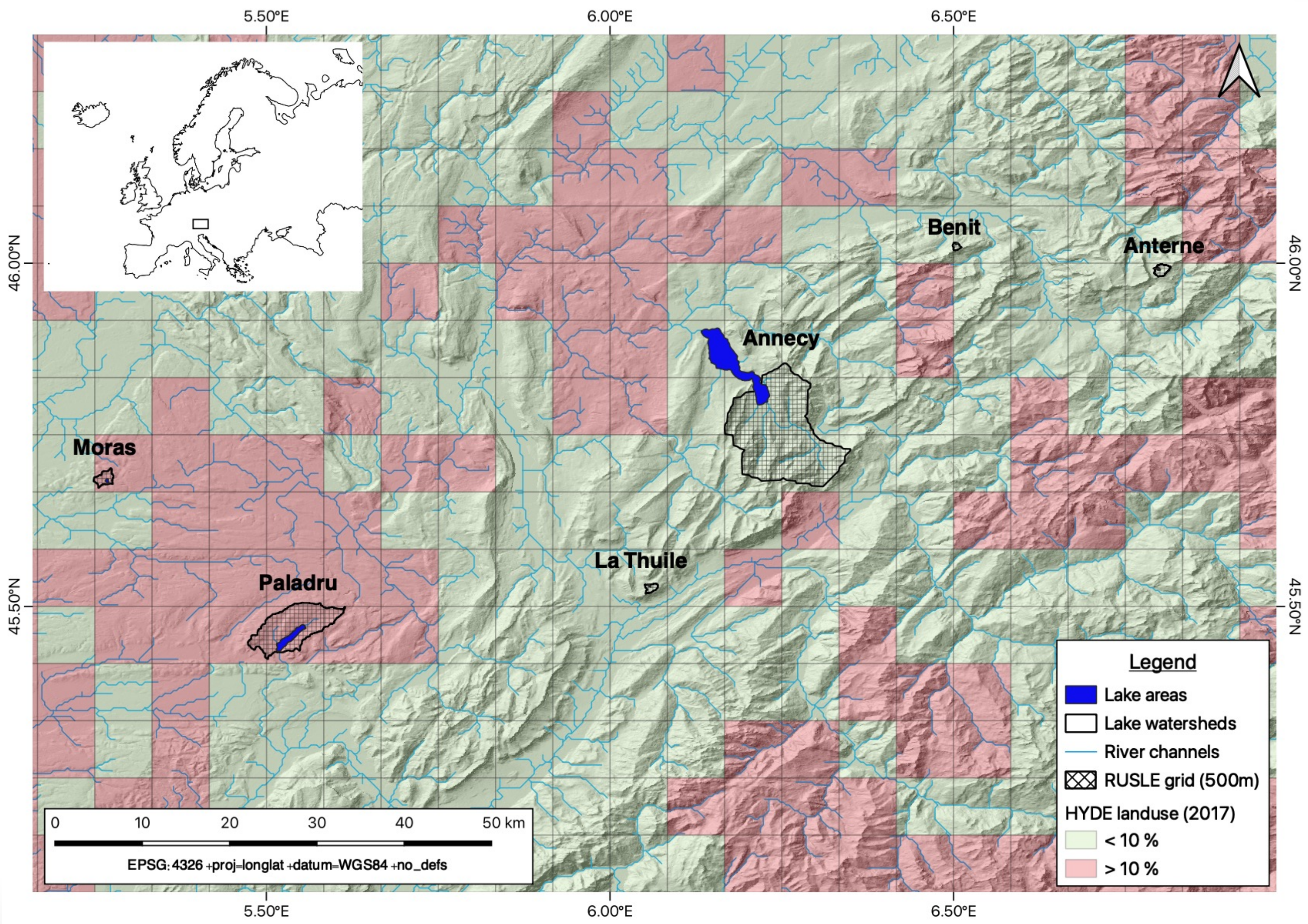

Figure: Study sites map.

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Paleo-environmental data

➢ **Long-term erosion proxies** chosen from available data in the litterature

Site	Core	Erosion proxy	Time period (cal. yr. BP)	Source
Annecy	LA13	SAR ($cm^{-2}.yr^{-1}$)	[0 ; 4350]	Jones et al., 2013
Anterne	ANT-07	SAR ($cm.yr^{-1}$)	[0 ; 9950]	Giguet-Covex et al., 2011
Benit	BEN14 & BEN16	TAR ($mg.cm^{-2}.yr^{-1}$)	[-50 ; 2110]	Bajard et al., 2018
Moras	MOR08-MC	TAR ($mg.cm^{-2}.yr^{-1}$)	[-50 ; 3950]	Doyen et al., 2013
Paladru	PAL09-MC	Ti (kcps)	[-50 ; 9950]	Doyen et al., 2016
Thuile	THU10	Erosion ($t.km-^{2}.yr^{-1}$)	[-64 ; 12010]	Bajard et al., 2017

Table: Paleo-data used in this study.

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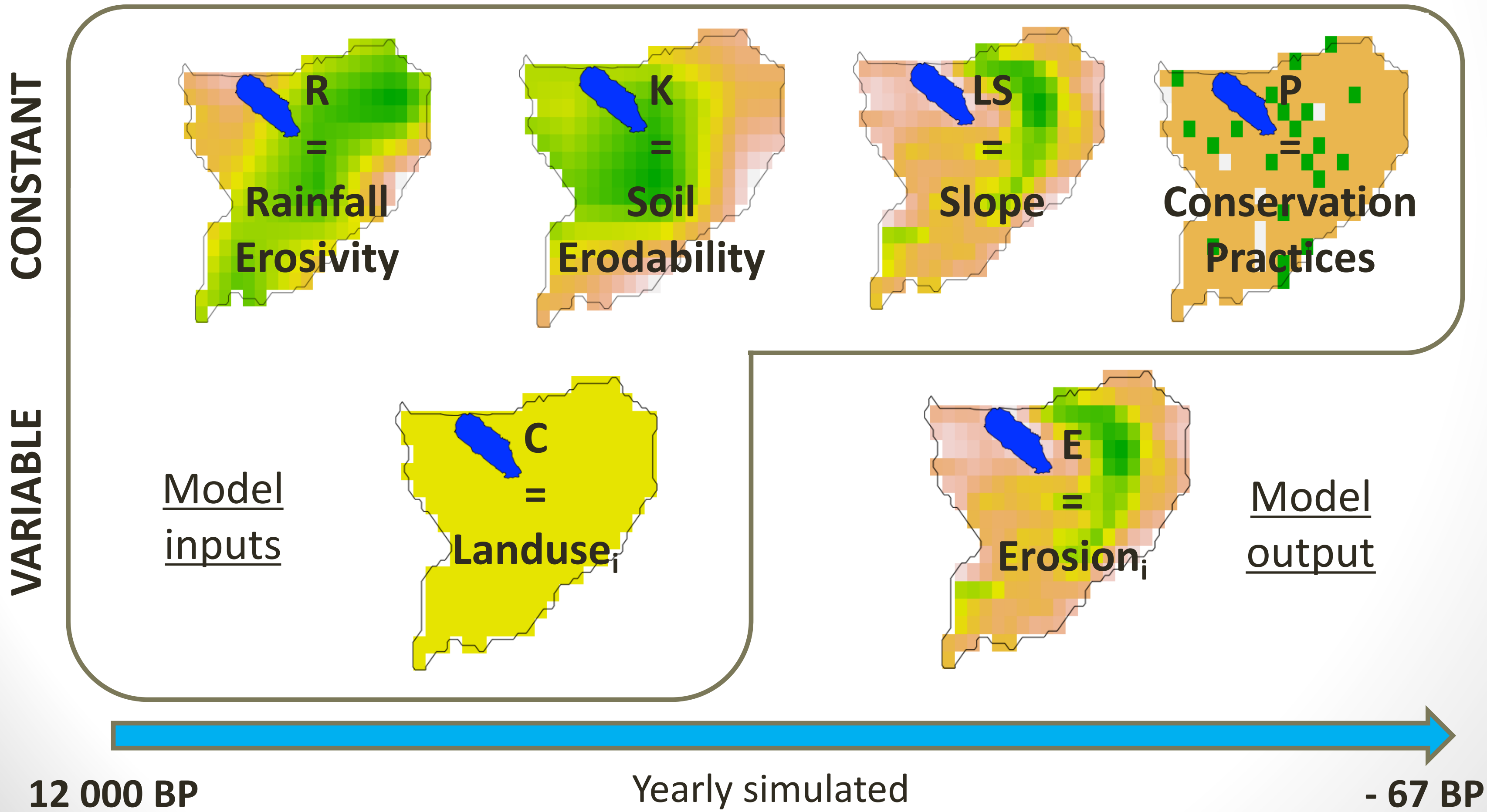
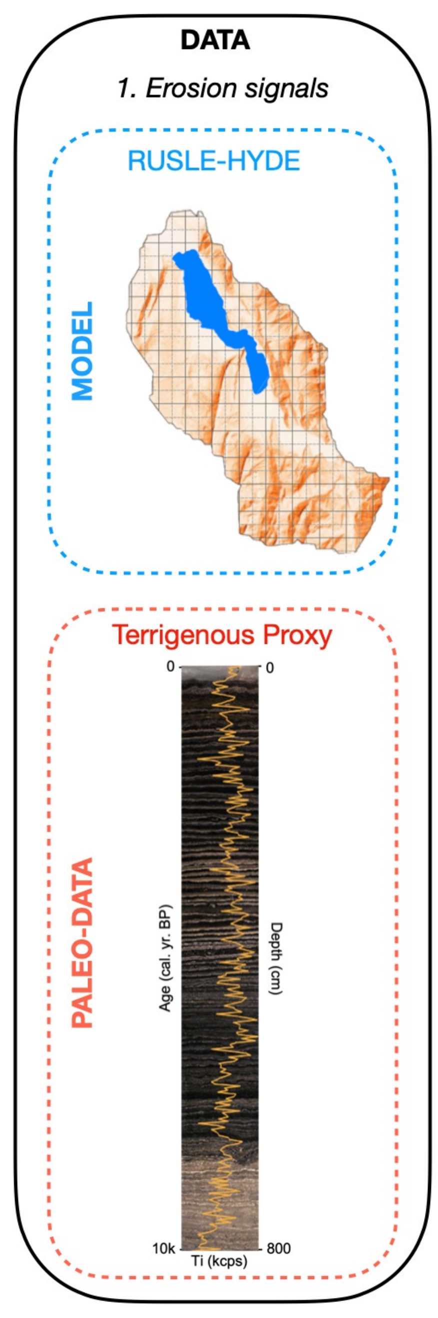
Erosion model: Revised Universal Soil Loss Equation (RUSLE)

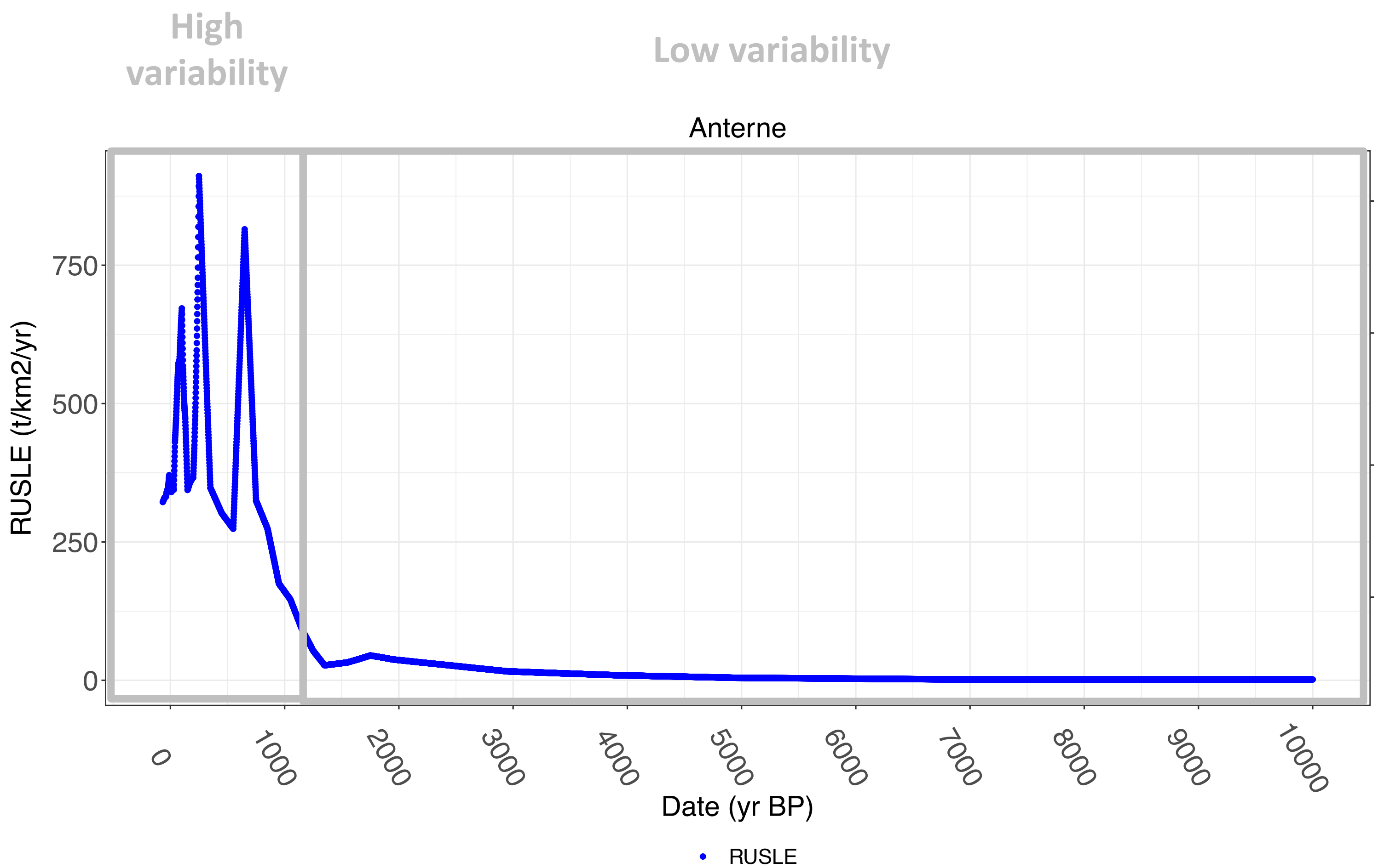
- <u>Mean soil loss rate:</u> **E = R*K*LS*C*P** (Renard et al., 1997)
  - Constant: **R, K, LS & P** (Panagos et al., 2015)
  - Variable: **HYDE 3.2** (Goldewijk et al., 2017)



Erosion data available



Model data temporal variability



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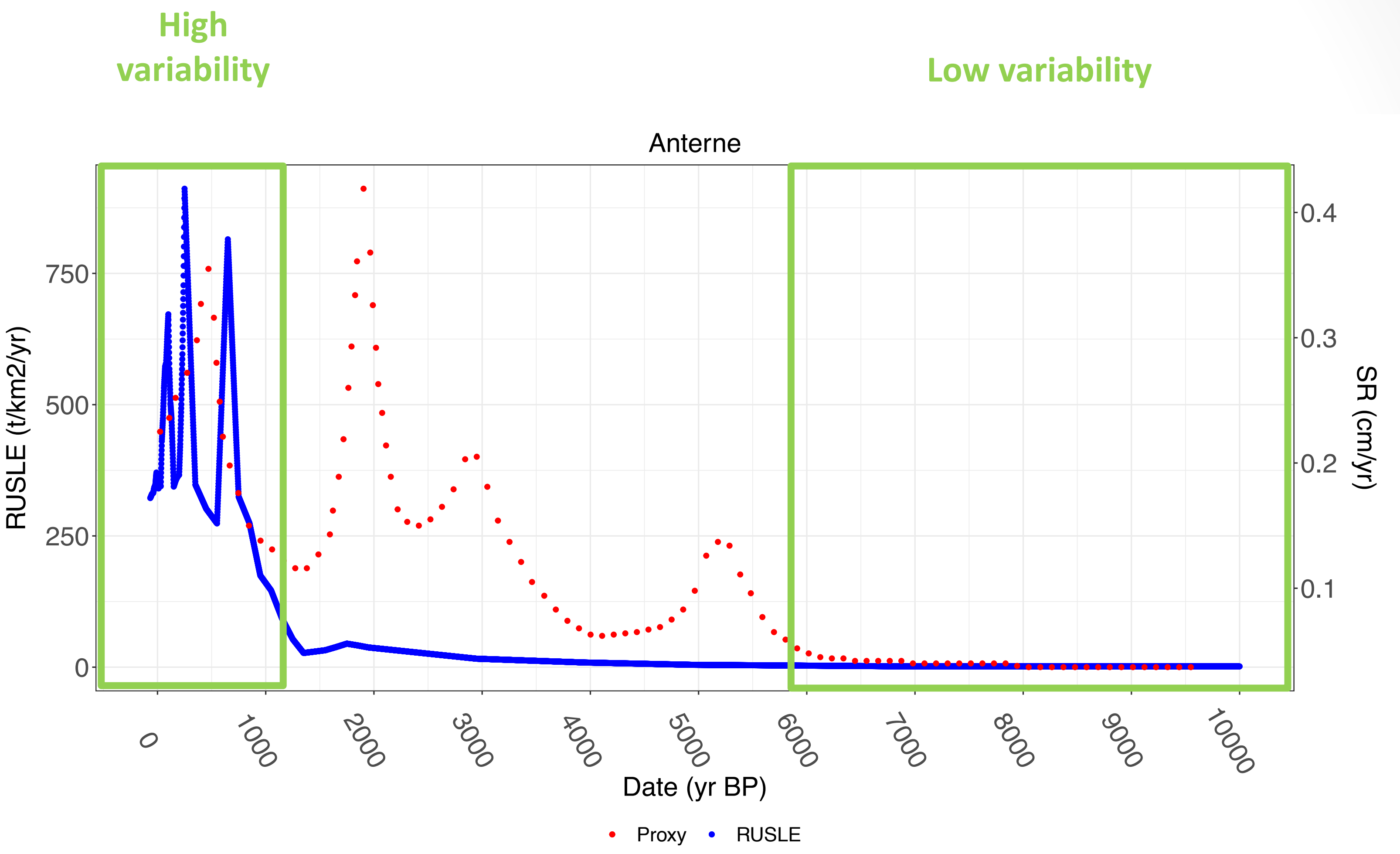
Model and Proxy data temporal variabilities



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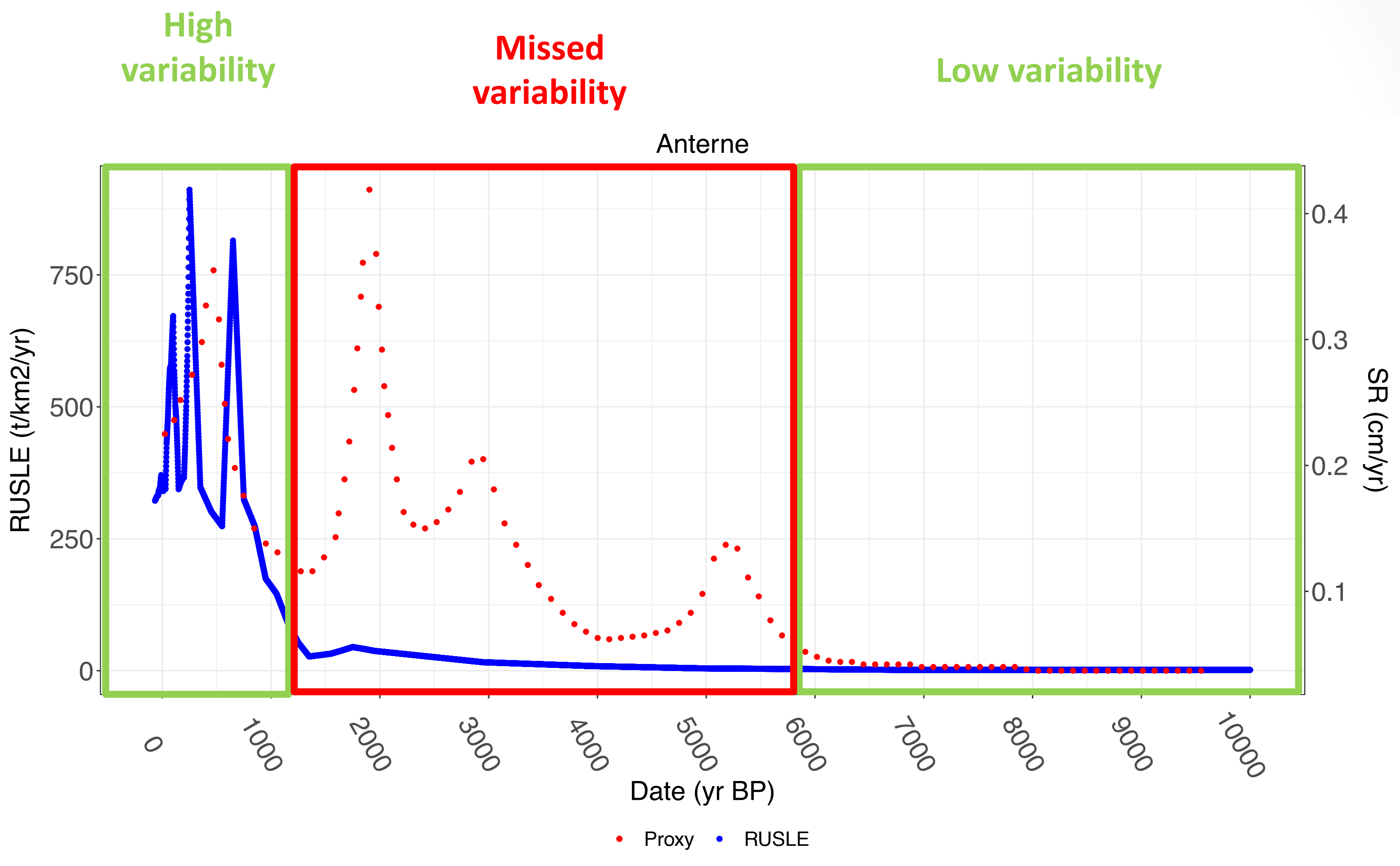
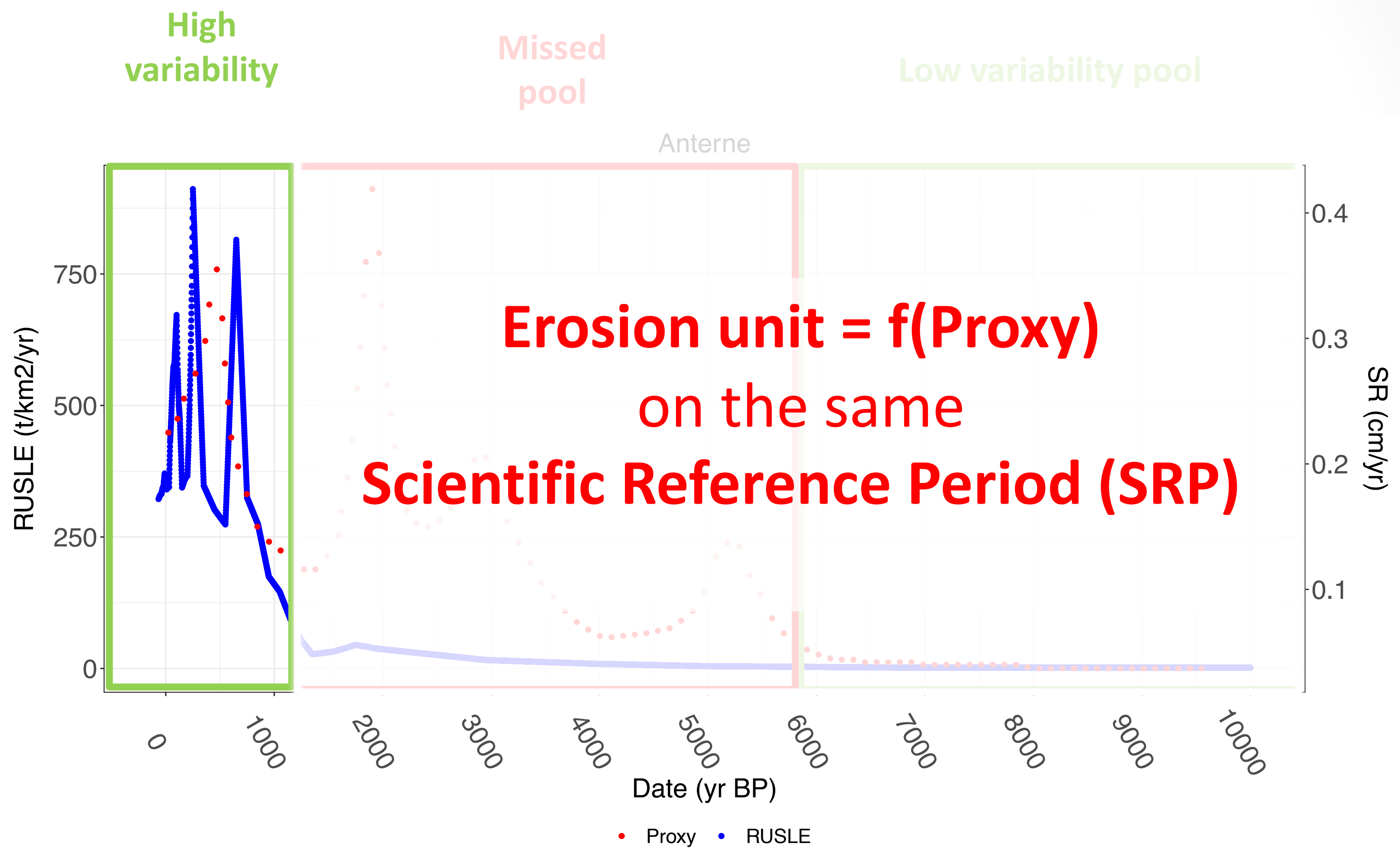


- <u>RUSLE-HYDE miss</u> « transient erosion crisis » periods in all study sites

Similar variabilities of data



⚠ **Watershed erosion** and **Lake sedimentation**

1. Not supposed to be synchronous (sediment production VS transfert, deposition…)
2. Time delay = **10^2 to 10^3 years** (Hoffmann, 2015)

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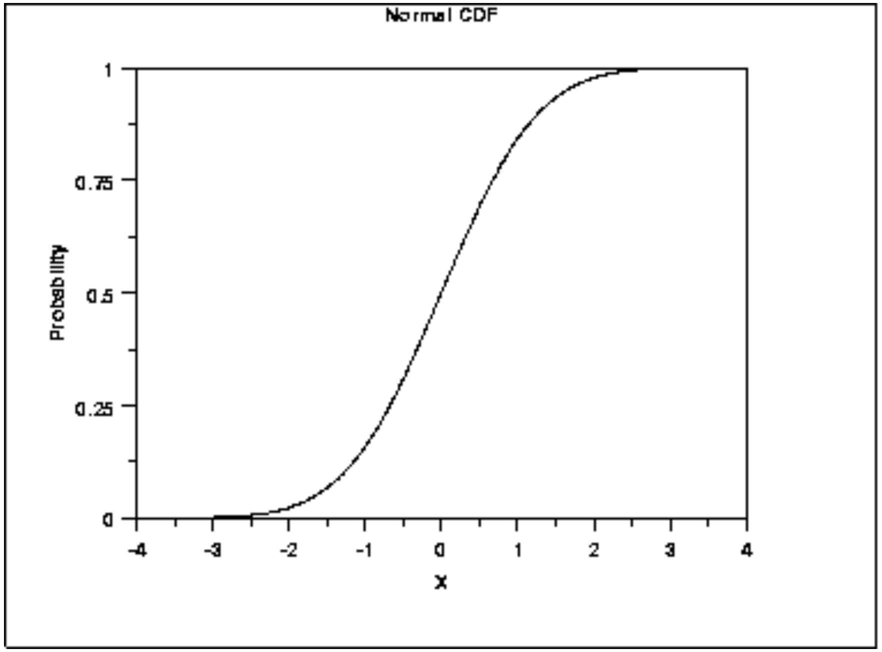
Deal with asynchronicity

- Suppress temporality between signals = **Cumulative Density Function (CDF)**



- Determine how much signals have **similar statistical variability** on the same time period

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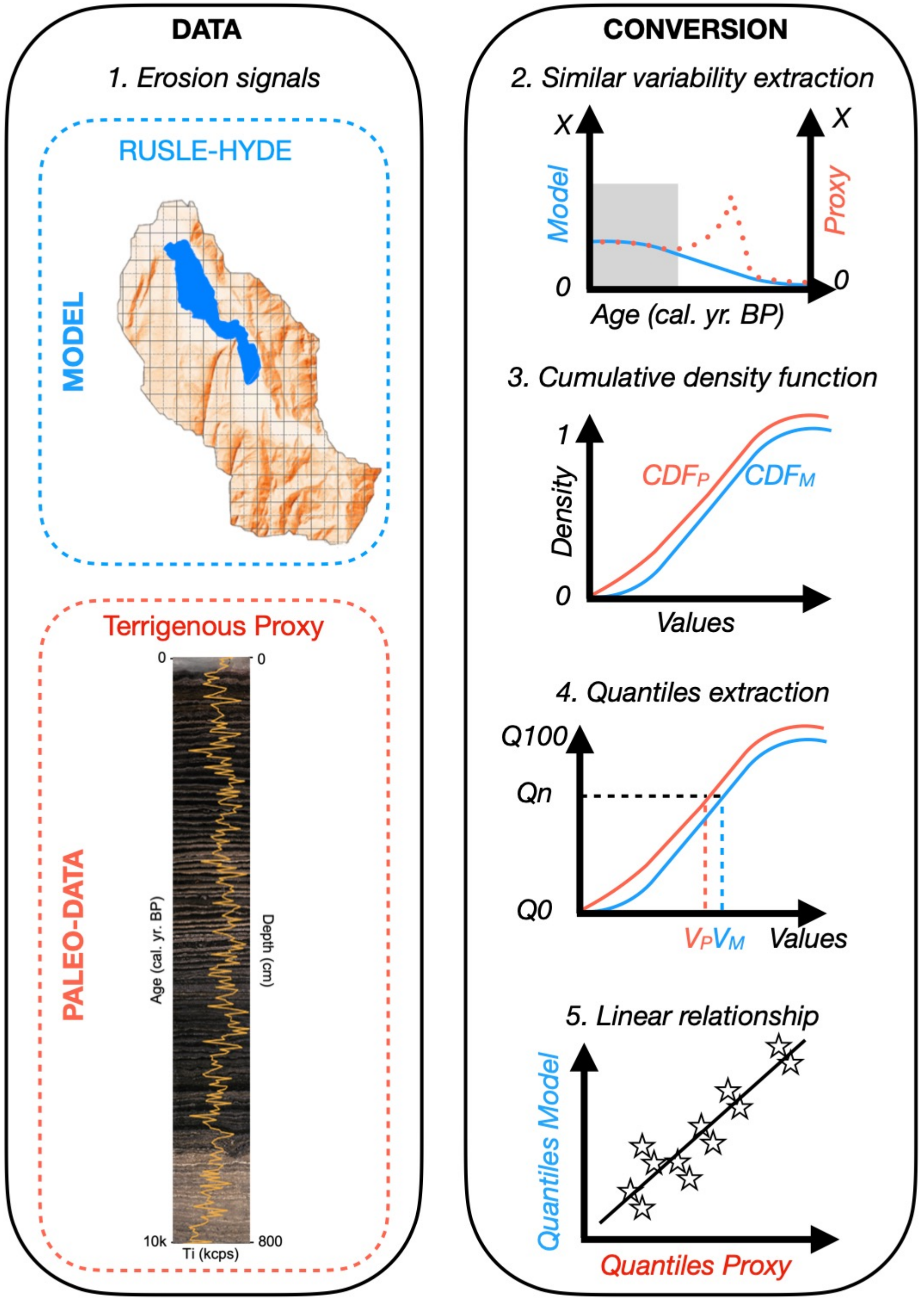
Erosion proxies conversion



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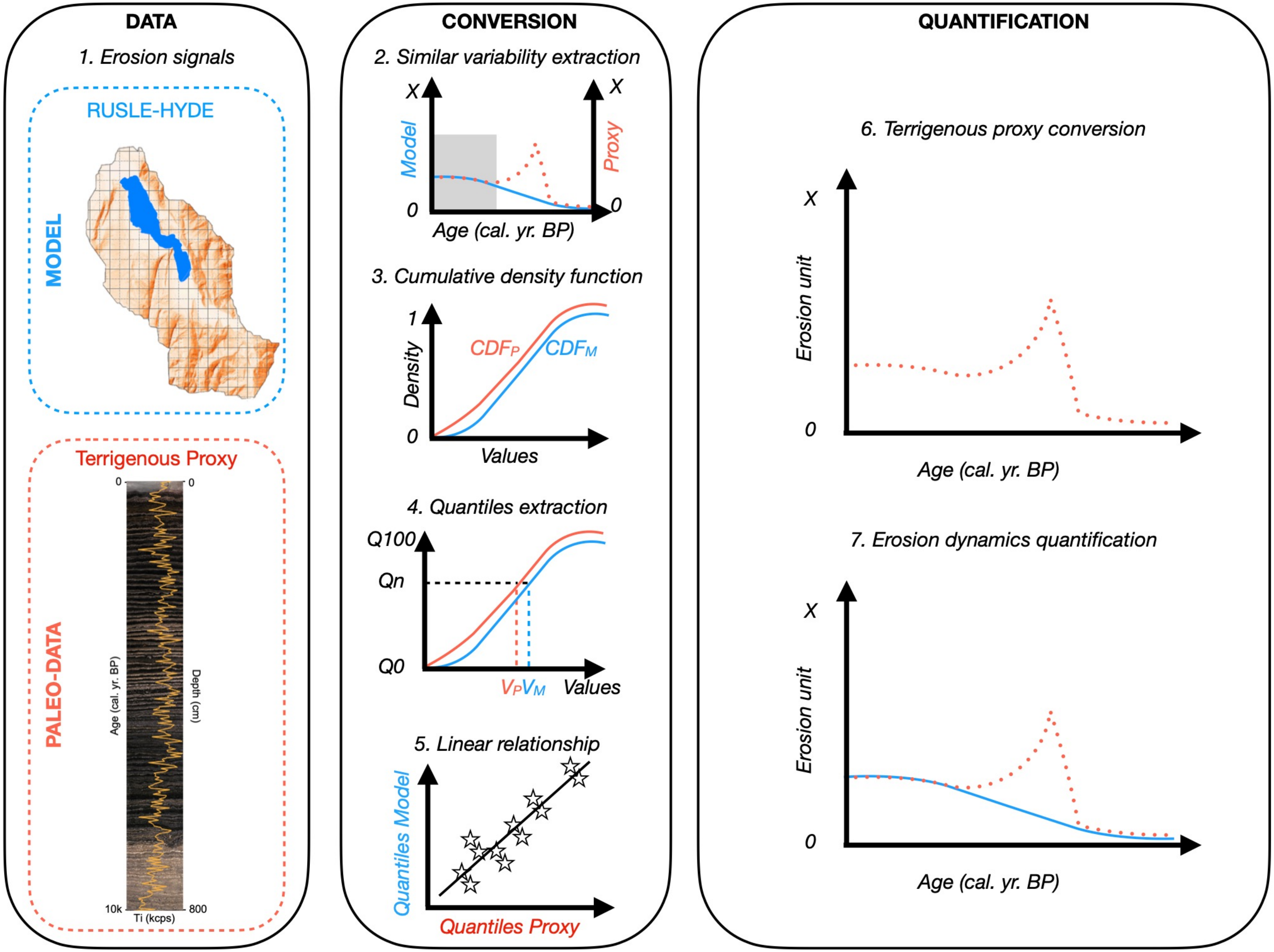

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III. Results

Conversion of erosion proxies into soil erosion unit ($t.km^{-2}.yr^{-1}$)

Method corroboration

- Method corroboration on the La Thuile watershed:
  - **Fast sediment transfer** from hillslopes to the lake
  - **Erosion proxy** already expressed as **erosion unit (t.km^{-2}.yr^{-1})**
  - We have converted it as we didn't know…

Site	Recent SRP (cal. yr. BP)	R^2 (raw data)	R^2 CDF	Slope correlation
Annecy	[0 ; 500]	0,66	0,85	1190,83
Anterne	[0 ; 1300]	0,24	0,91	2062,28
Benit	[0 ; 700]	0,02	0,96	5,93
Moras	[-50 ; 1600]	0,02	0,87	0,51
Paladru	[-50 ; 1100]	0,09	0,93	1,20
La Thuile	[-64 ; 800]	0,10	0,94	1,00

Figure: Statistical results of the conversion formula calculation (Recent SRP = Recent Scientific References Period)

Mazure et al., in review

Method performance

➢ **Good correlation** on Scientific Reference Periods (SRP)

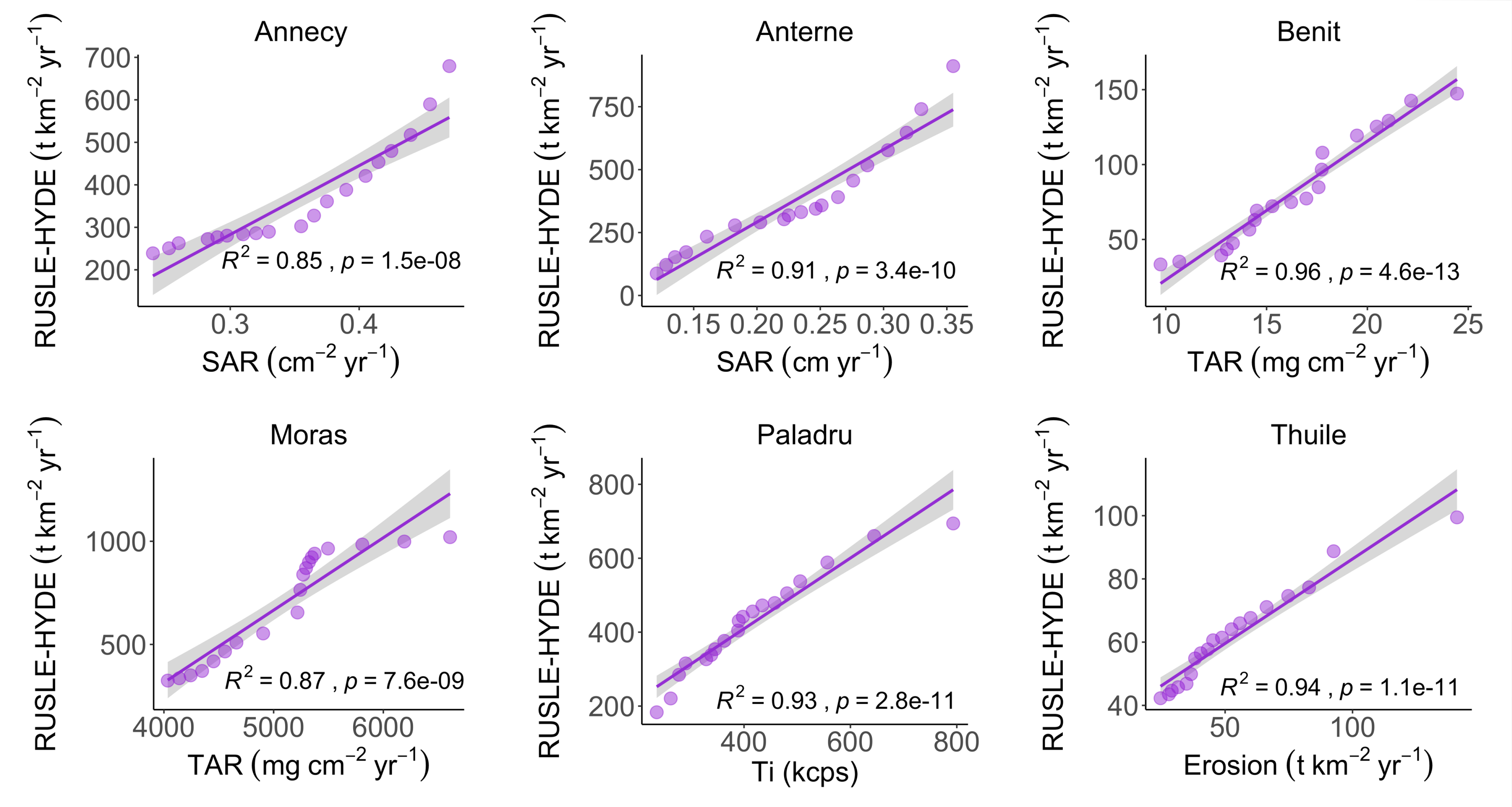

Table: Correlation between RUSLE-HYDE and proxies on SRP dates for each study site.

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Converted paleo data

- **Erosion proxies in same unit → RUSLE-PALEO** (t.km^{-2}.yr^{-1})
- **Quantitative inter-comparison** between sites possible

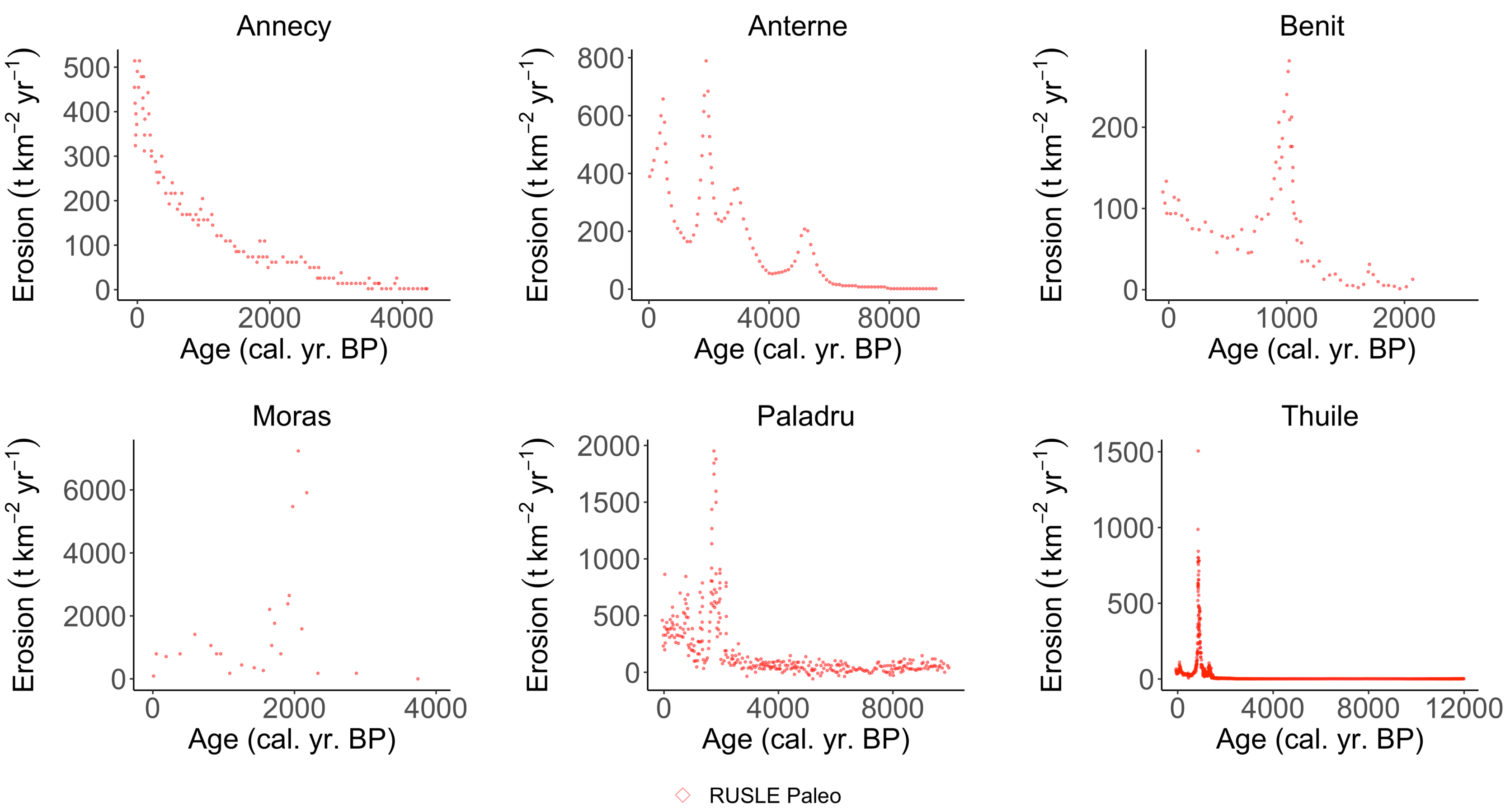

Figure: Quantified terrigenous proxies for the study sites.

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III. Results

Holocene soil erosion dynamics

RUSLE Paleo vs RUSLE HYDE

- **RUSLE-PALEO and RUSLE-HYDE** both expressed as **erosion unit**
- Quantification of **erosion dynamics by RUSLE-PALEO vs RUSLE-HYDE**

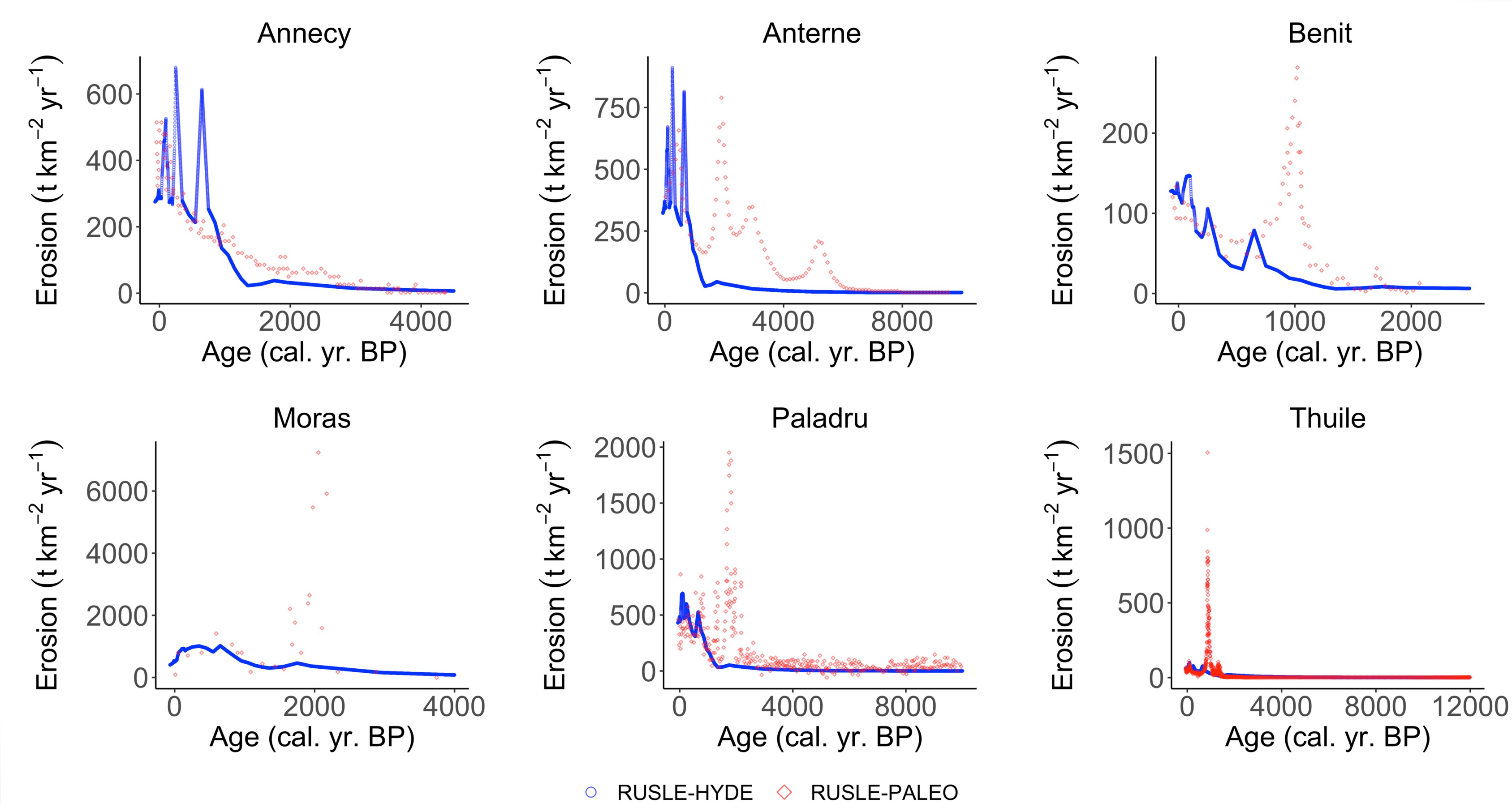

Figure: RUSLE Paleo vs RUSLE HYDE erosion fluxes.

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Cumulative Holocene erosion exports

- <u>Crisis periods exports (RUSLE-PALEO)</u> = **51 %** [+35 % ; +64 %]
- <u>RUSLE-HYDE under-estimation</u> = **48 %** [-1 % ; +60 %]

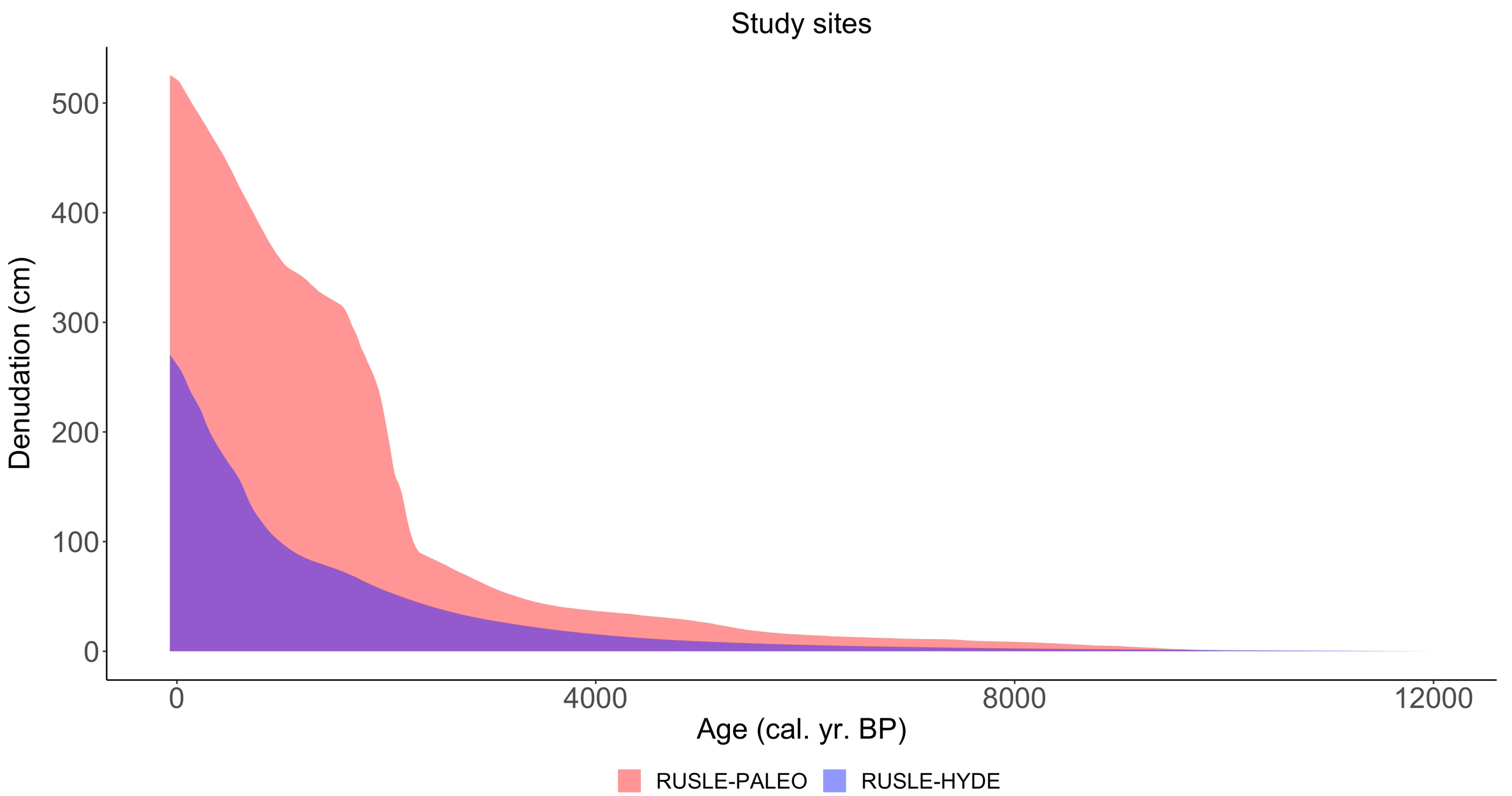

Figure: Multi-sites cumulative erosion.

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Take home messages

- **Sediment records seem to be appropriated to assess and quantify long-term erosion dynamics** at the local (or possibly even regional?) scale

- **Sediment records could potentially improve long-term erosion simulations,** which represent well **progressive erosion acceleration** but miss **transient erosion periods** (half of the total erosion exports)
  - Hypothesis: Under-estimation of the intensities of **land-use change** and of **land-use practices**

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Thank you for your attention !

https://theo-mazure.netlify.app/

Picture : Jean-Marie Thomas