Another side of the Anthropocene: humans increased ecosystem vulnerability to climate variability

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Introduction

Climate

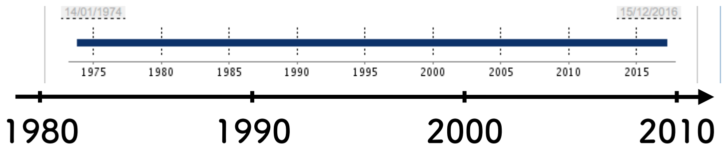
?

Lake ecological responses

→ Long-term data are needed

➜ **Monitoring program**

biovolume de l'espèce dans l'échantillon



measurements

< 70 years

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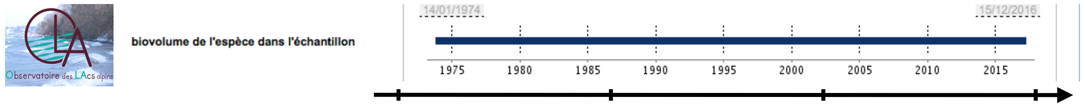
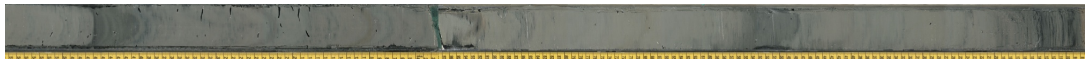


1980 1990 2000 2010

➜ Paleo-sciences



1000 1500 2000

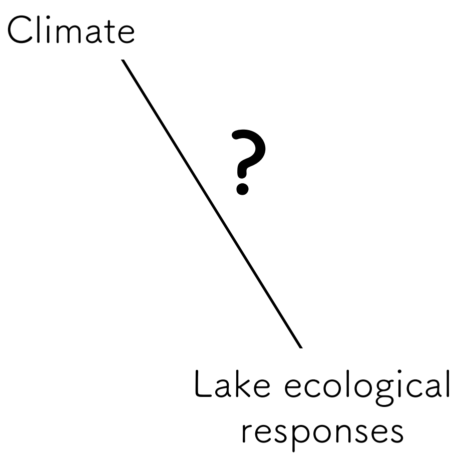
measurements

proxy

< 70 years

>1000 years

Introduction



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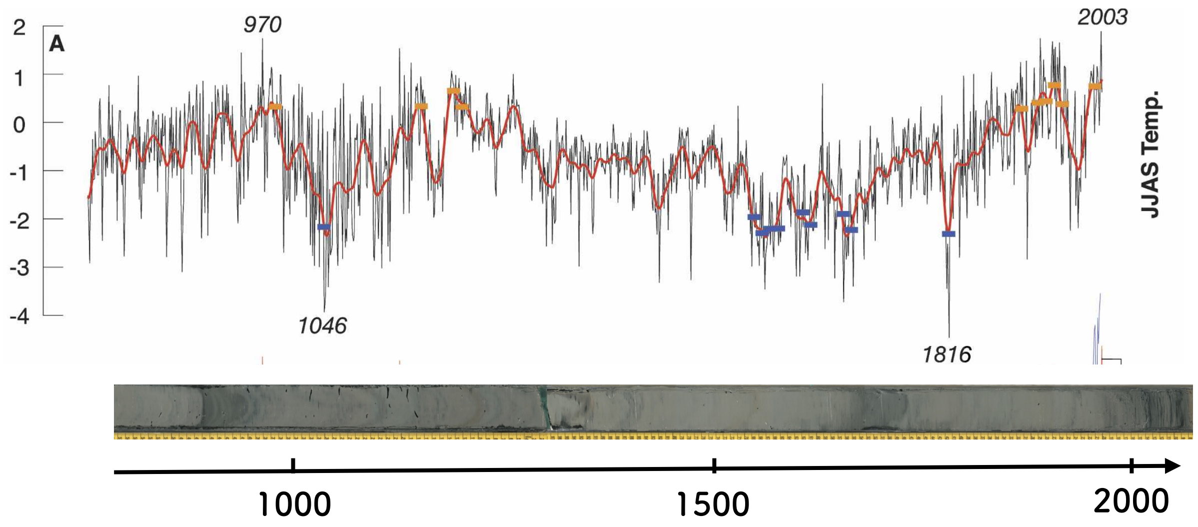

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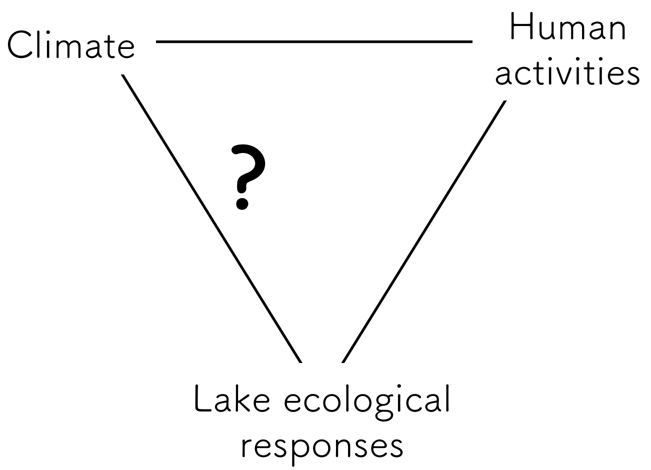

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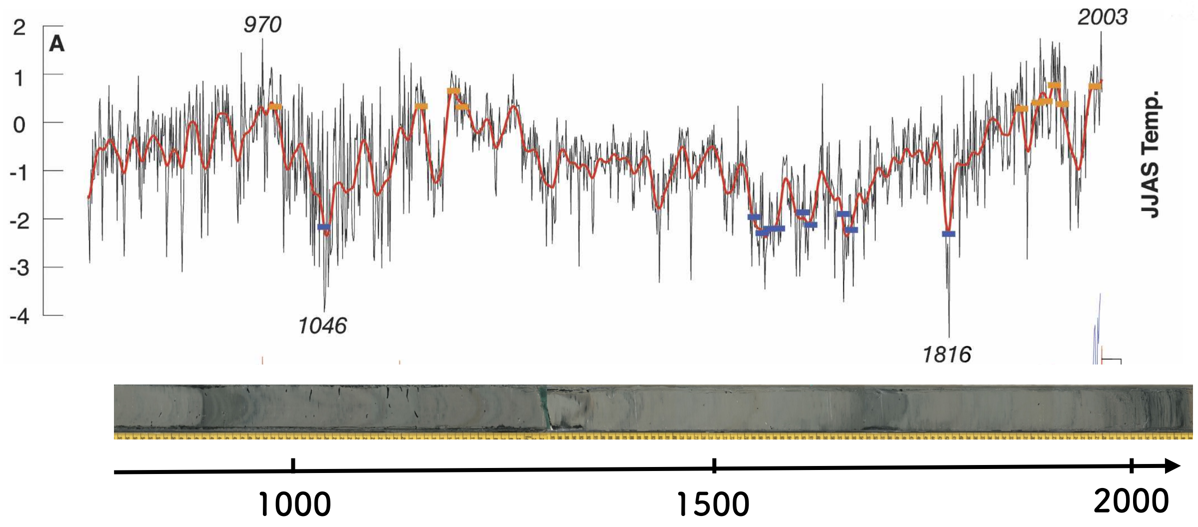

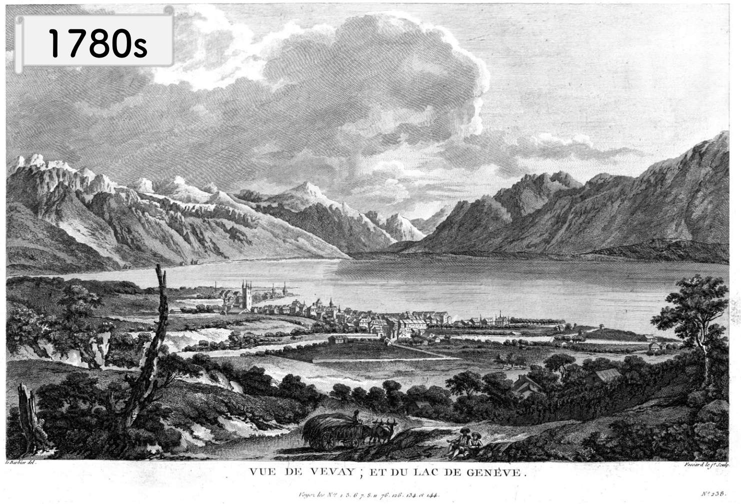

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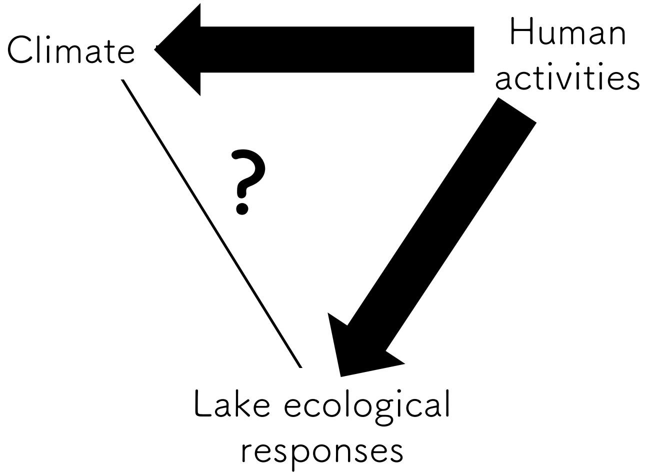

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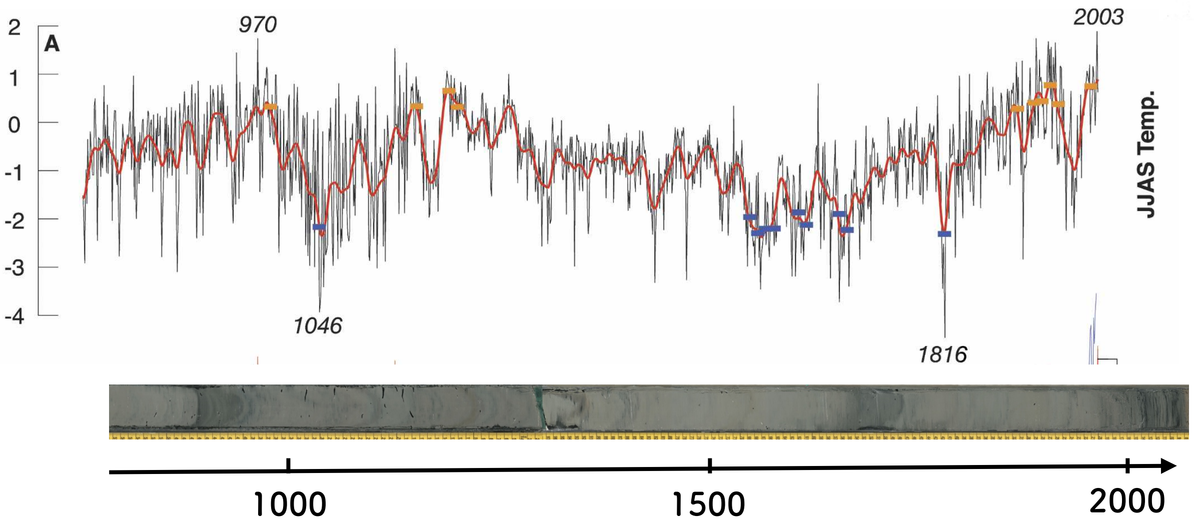

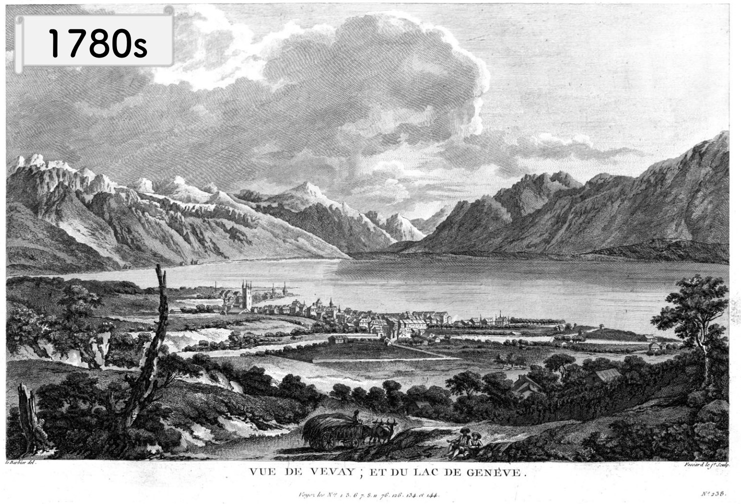

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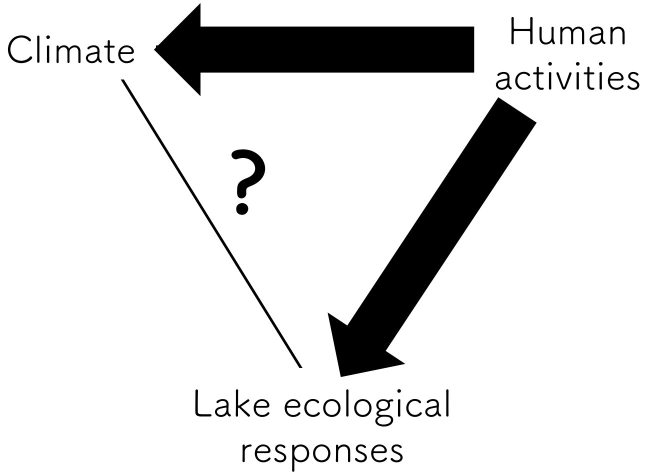
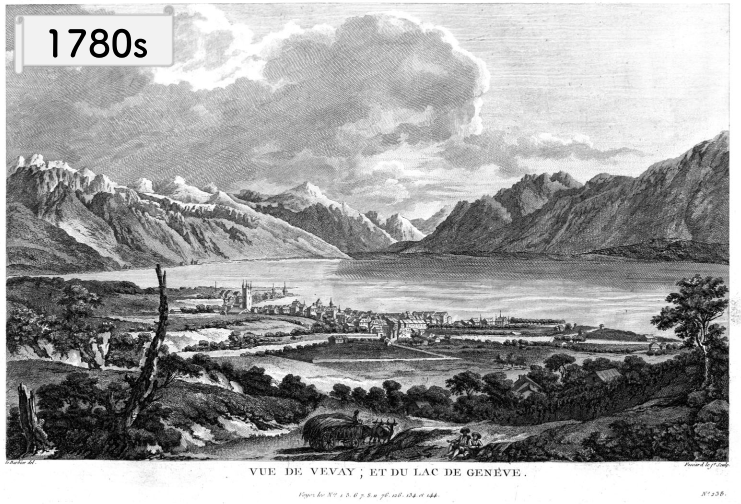


Tacit hypothesis: ecosystems vulnerability to climate fluctuations have been constant and independent from local human disturbances



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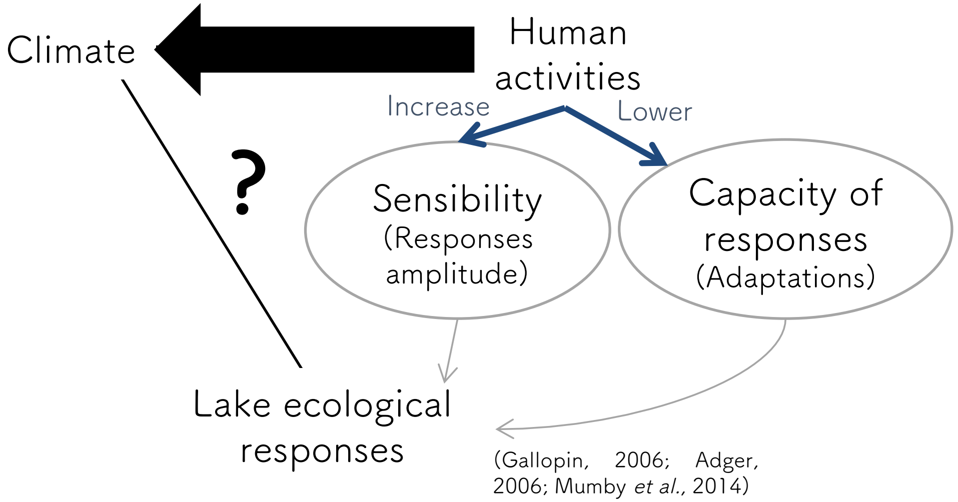

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1) Local human impacts reduce ecosystem resilience (Gallopin, 2006; Adger, 2006; Mumby *et al.*, 2014; e.g. Perga *et al.*, 2015)

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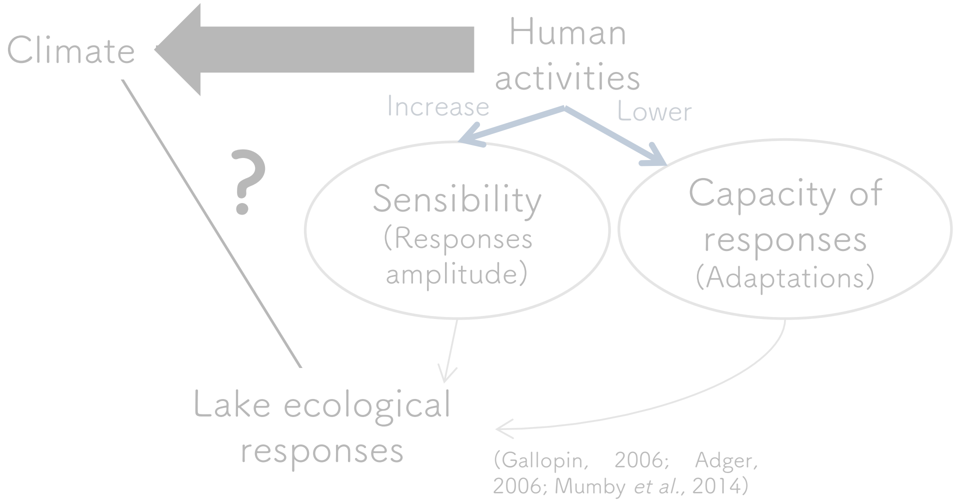

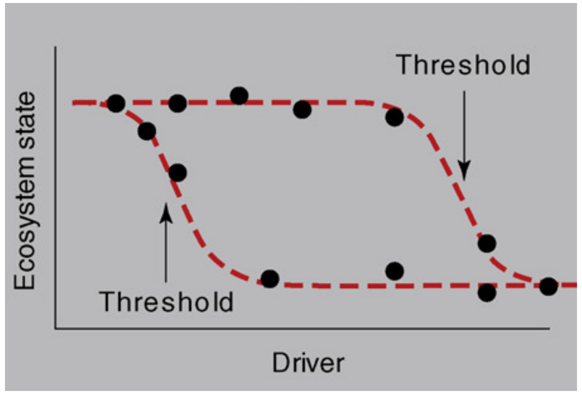

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2) Ecosystems can respond in a non-linear way to perturbations (i.e. regime shift trajectory) (Andersen *et al.*, 2009; Scheffer *et al.*, 2003)

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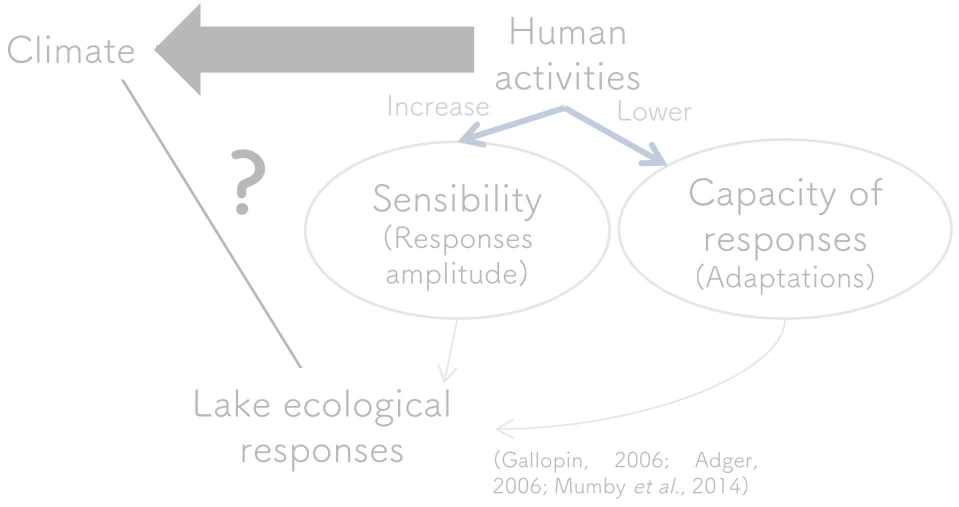

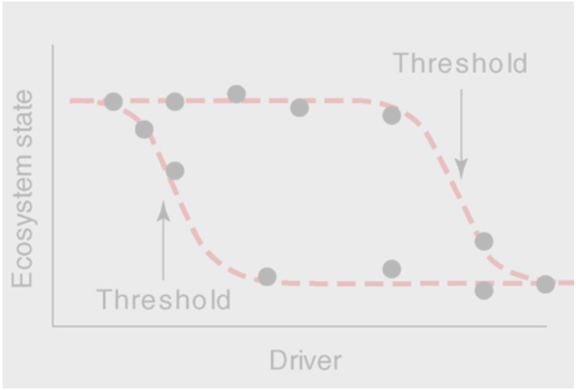

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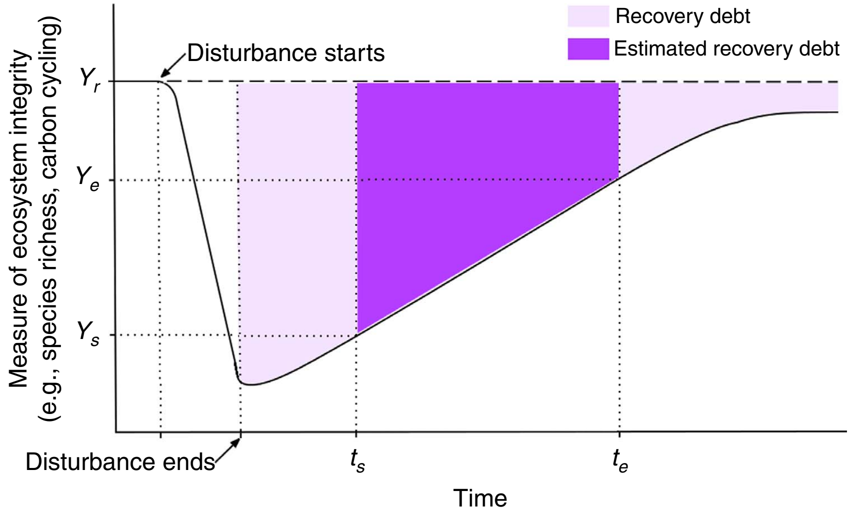
3) There is a recovery debt for ecosystems even years after they have been restore (Moreno-Mateos *et al.*, 2017)



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Has local human impact increased ecosystem vulnerability to climate variability?

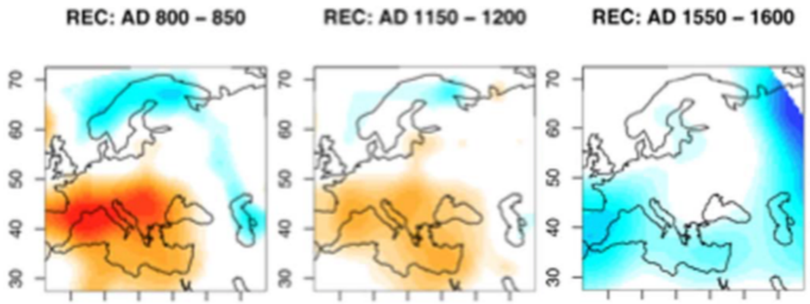
H0 Ecological vulnerability to climate variability was constant over time: by looking at the pre-Anthropocene period, we could understand which relationship exists between climate variability and ecosystem response.

H1 Local human pressures, by rearranging both the horizontal and vertical diversity of ecosystems, may have modified their resistance, resilience and therefore vulnerability to successive perturbations since entering the Anthropocene.

Strategy

<u>Study site:</u> Lake Geneva (CH, FR)

- Alps: Warming x2 /global average (Beniston, 2005)
- Good local climatic data (beware of the offsets in the reconstruction e.g. Guiot *et al.*, 2010)



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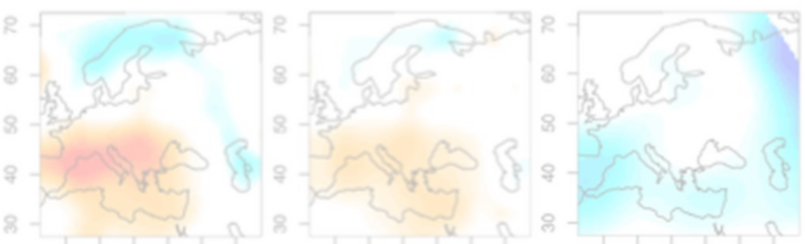


- Close to Aletsch glacier (Goehring *et al.*, 2012; Joerin *et al.*, 2006)
- Summer Air Temperature reconstructed by Buntgen *et al.*, 2006

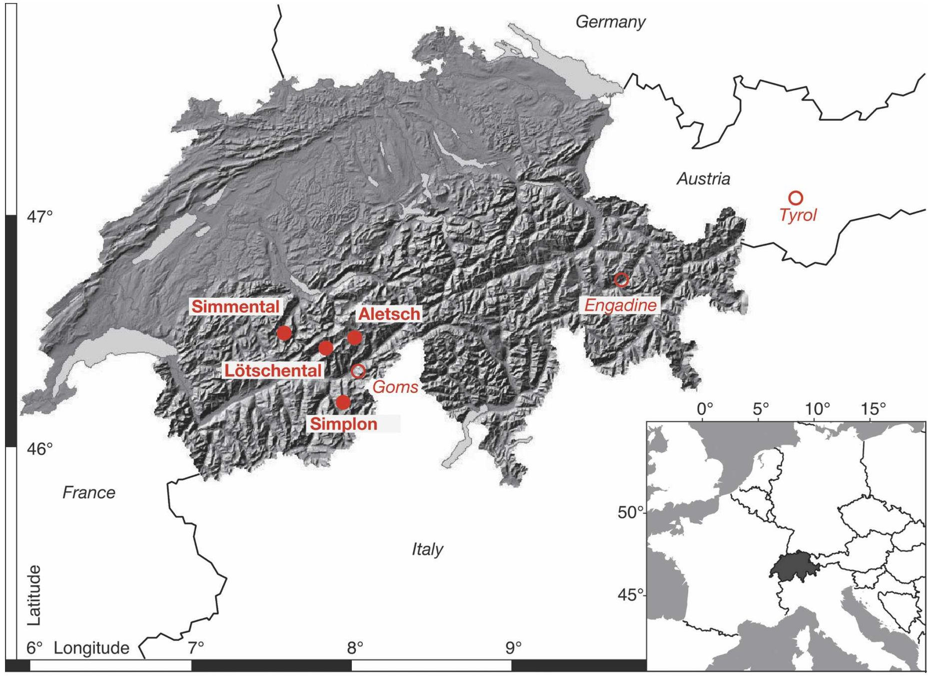
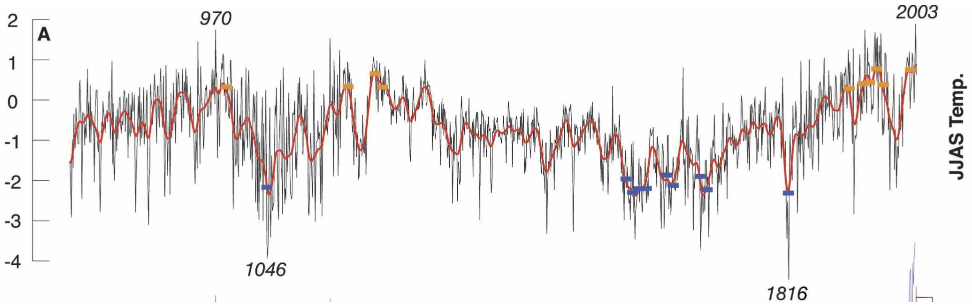
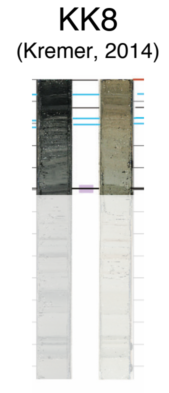
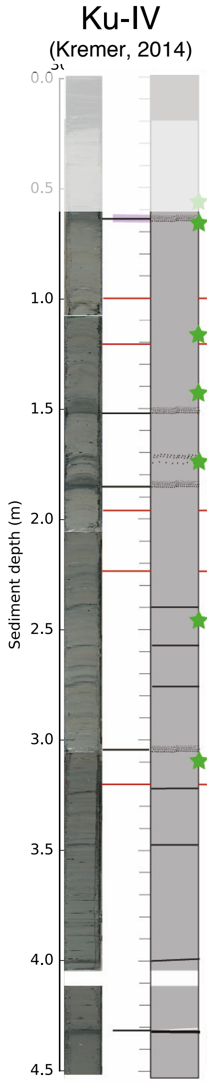


FIG. 1. Location of the four MXD tree-ring sites (red dots, bold) within the Swiss Alps, and the additional Alpine RW sites (red circles, italic) used by Büntgen et al. (2005a).



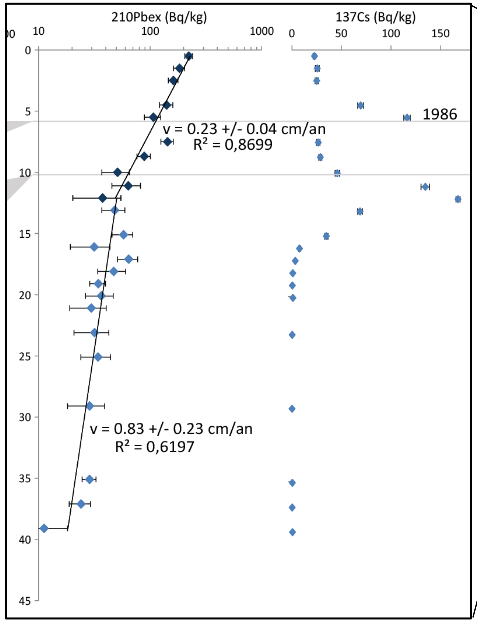
Strategy


KK8
(Kremer, 2014)


Ku-IV
(Kremer, 2014)
Sediment depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5

Strategy

- Radioelements (surface)



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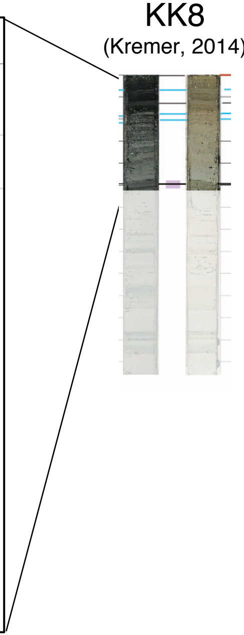

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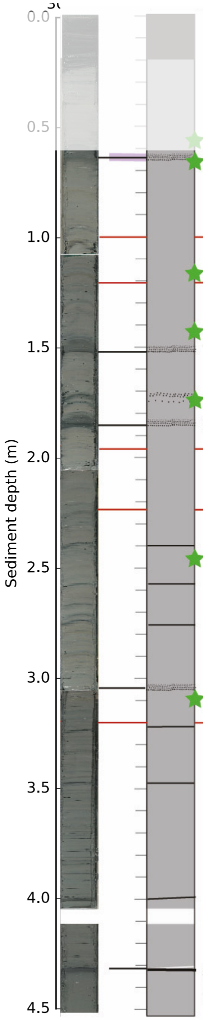

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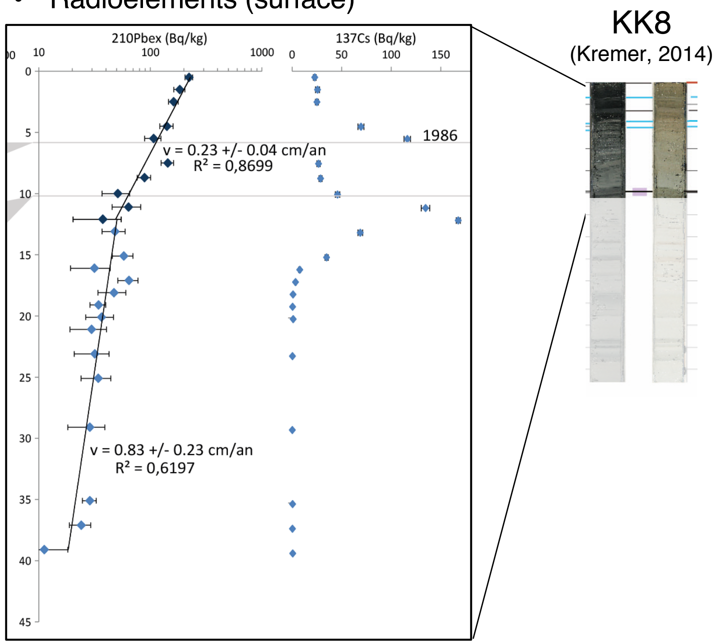
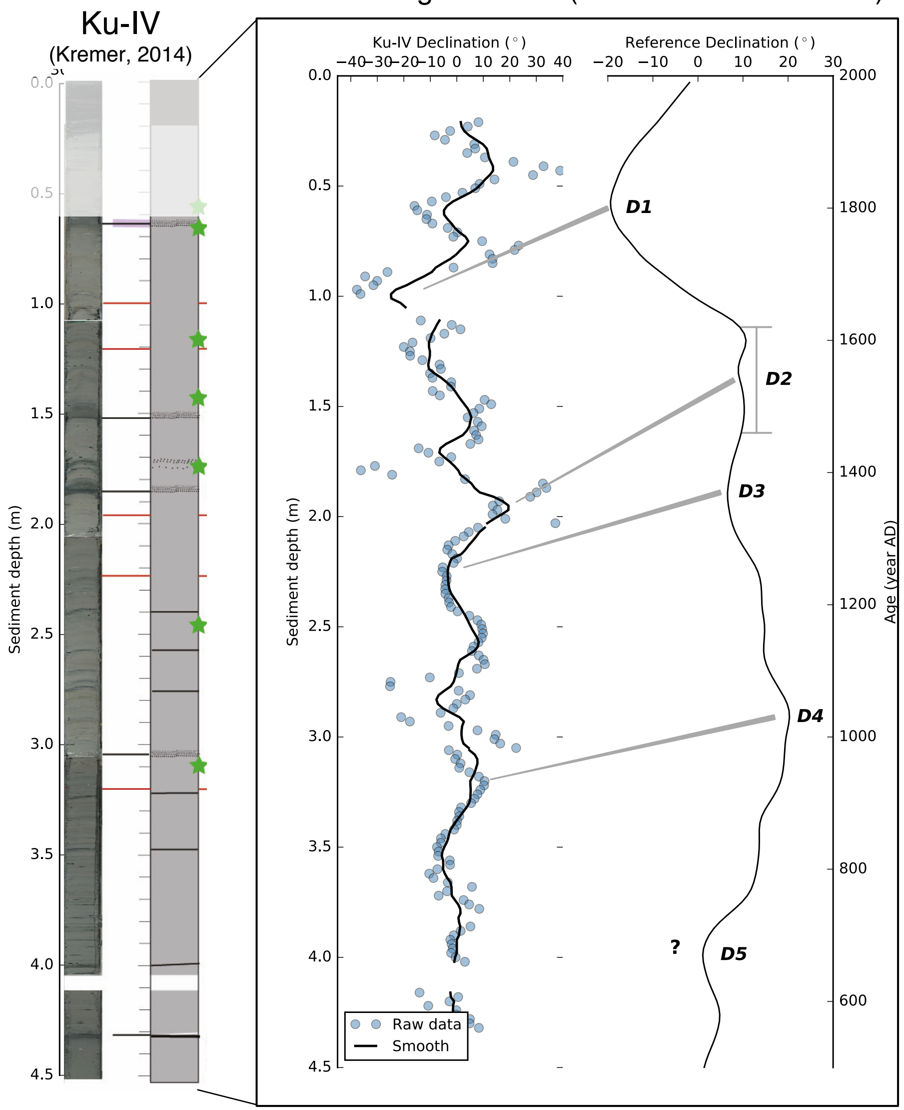


- Historical events

(e.g. Kremer *et al.*, 2012)

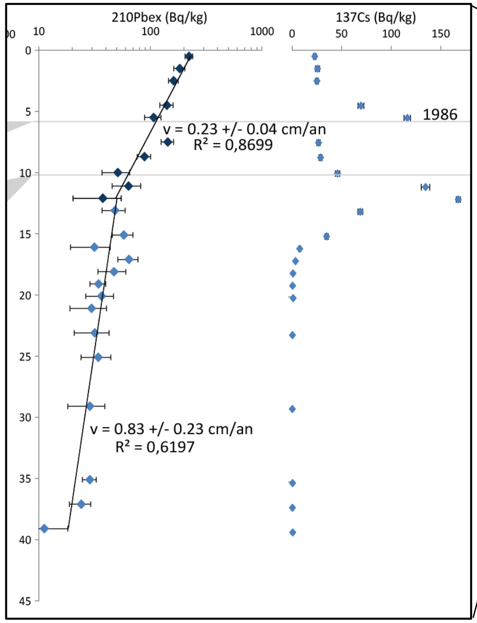
- Paleomagnetic data (Inclination + Declination)



- (Radiocarbon ★)

Strategy

- Radioelements (surface)



KK8
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Composite core
(this study)

Ku-IV
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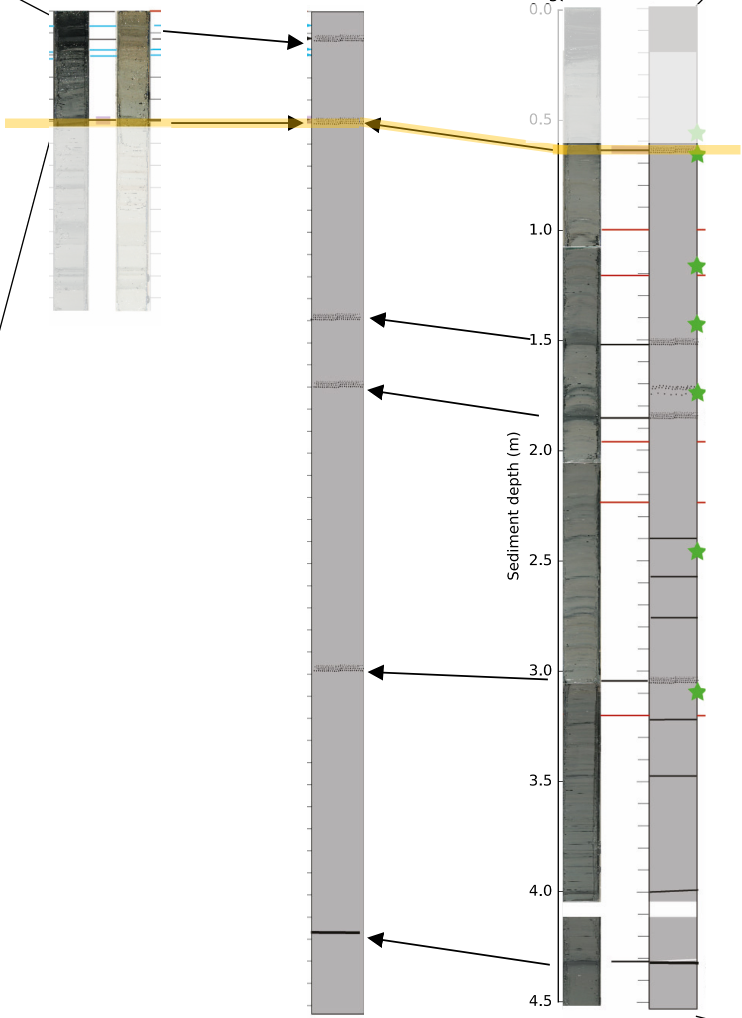

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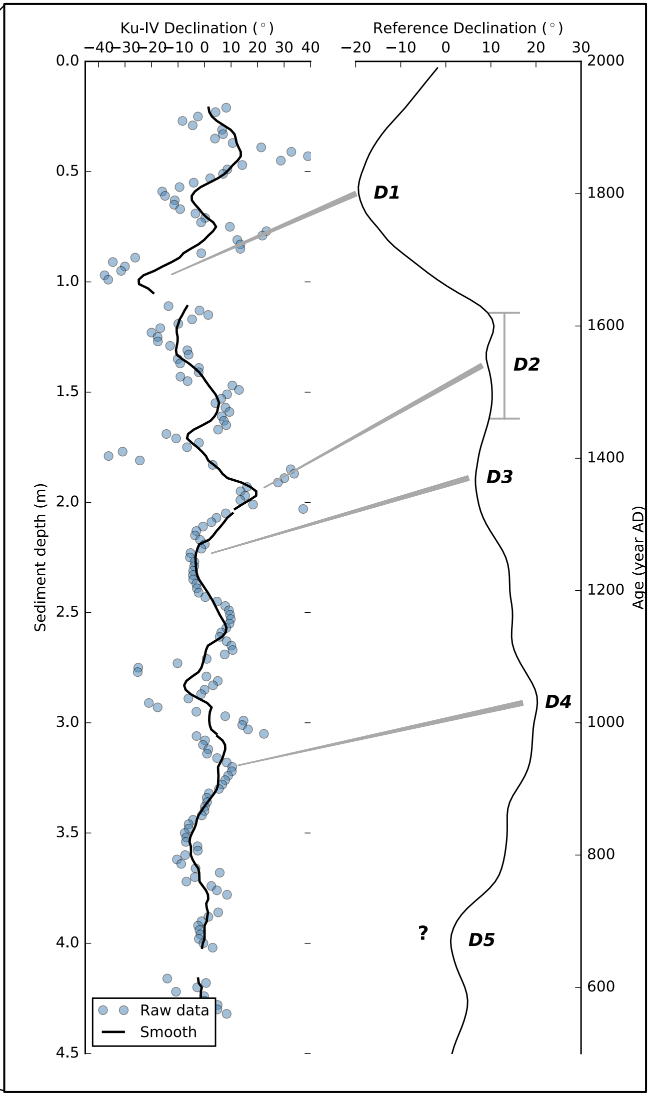
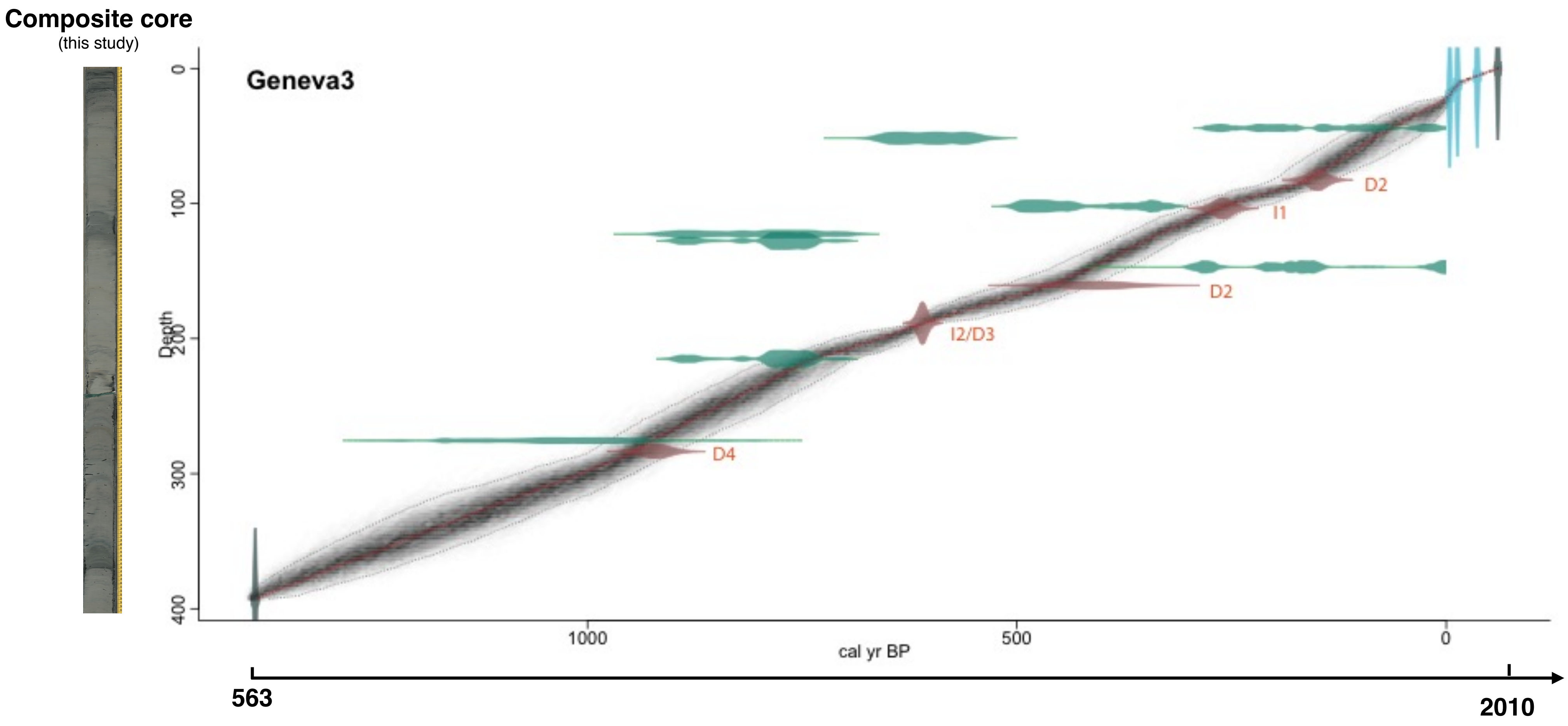


- Historical events
(e.g. Kremer *et al.*, 2012)

- (Radiocarbon ★)

Strategy

Final age model



Strategy

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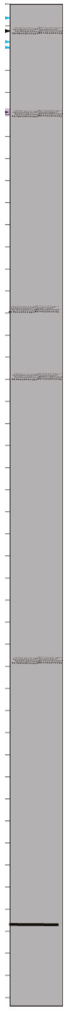

Diatoms

Local forcing: diatom-inferred total phosphorus (DI-TP)

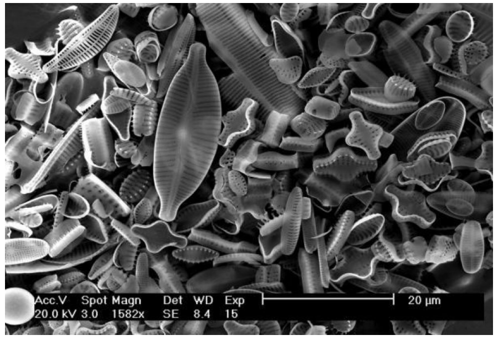

Fig 1. Diatoms in lake sediment © Swedish Research Council

Strategy

Composite core
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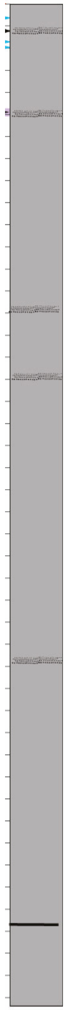

Diatoms

Local forcing: diatom-inferred total phosphorus (DI-TP)

Cladocera

Response:
Reconstitution of cladoceran communities: one of the most well represented group of aquatic invertebrates leaving subfossil remains in sediment.
Fragments of individuals exosquette allow identification to the specie level most of the time. Identification of a representative number of remains allows the reconstitution of the community at a specific time, giving information on ecological niches.

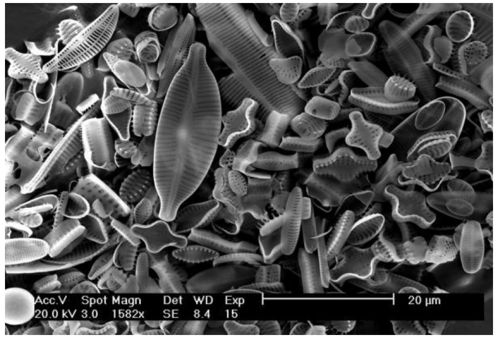

Fig 1. Diatoms in lake sediment © Swedish Research Council

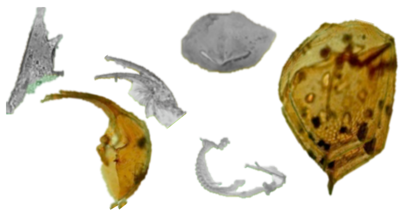

Fig 2. Cladoceran subfossils

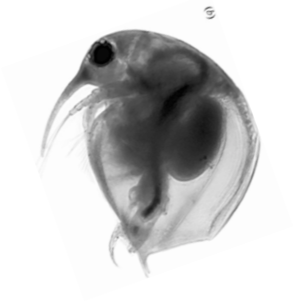

Fig 3. Identification of subfossils remains to the specie level

Strategy

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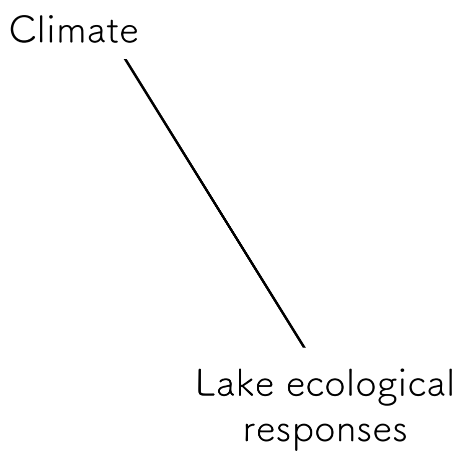

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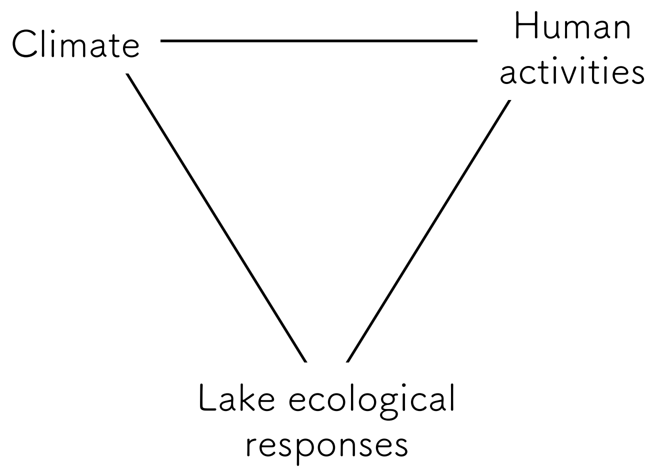

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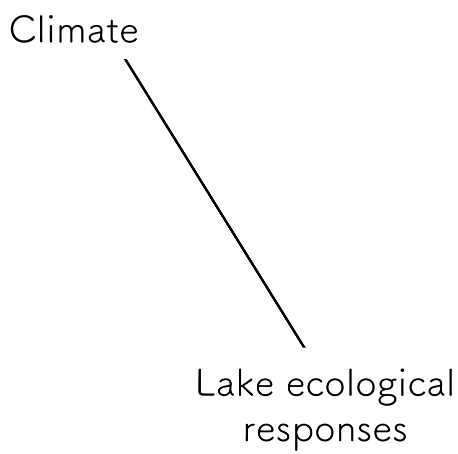

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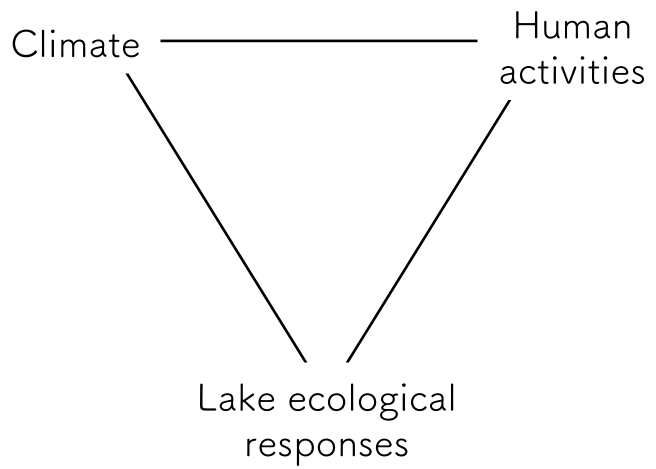


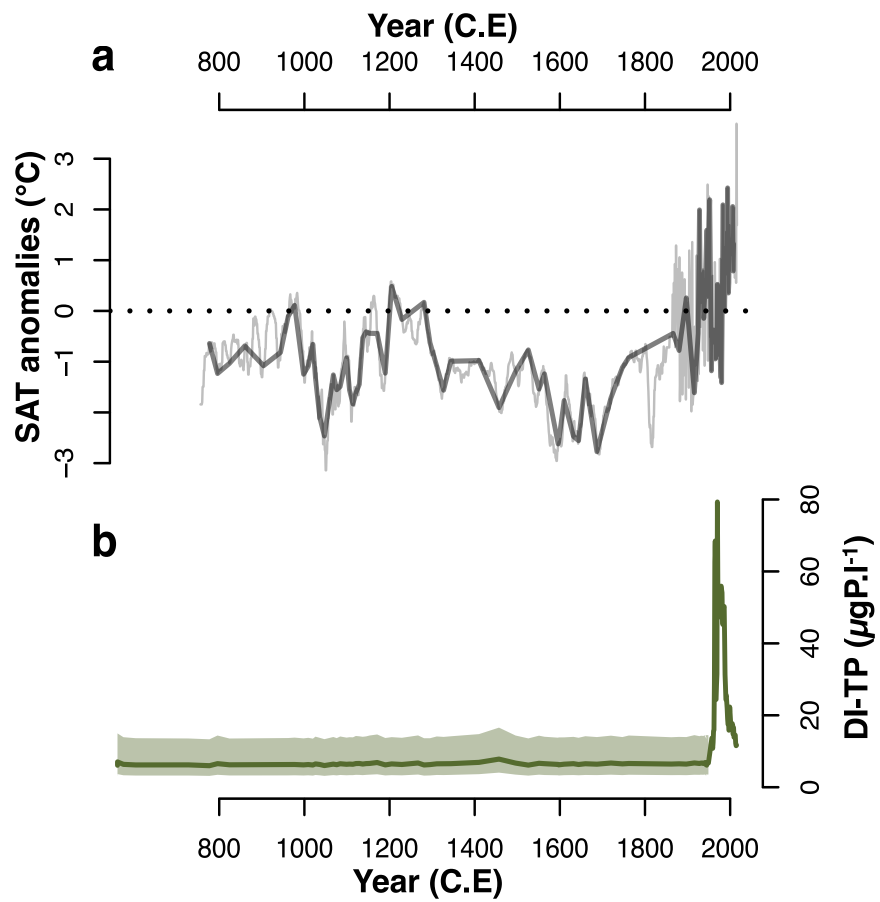
Model

Lake ecological responses = f(climatic forcing)

Lake ecological responses = f(climatic forcing + local forcing)

Results

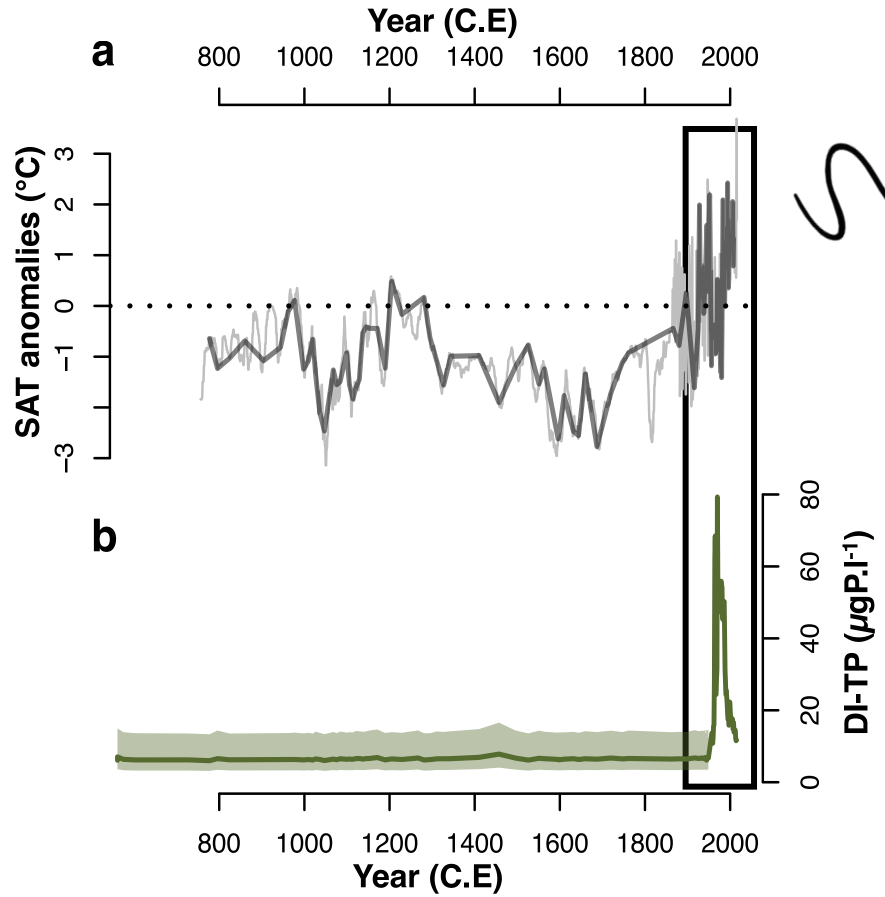
Forcings

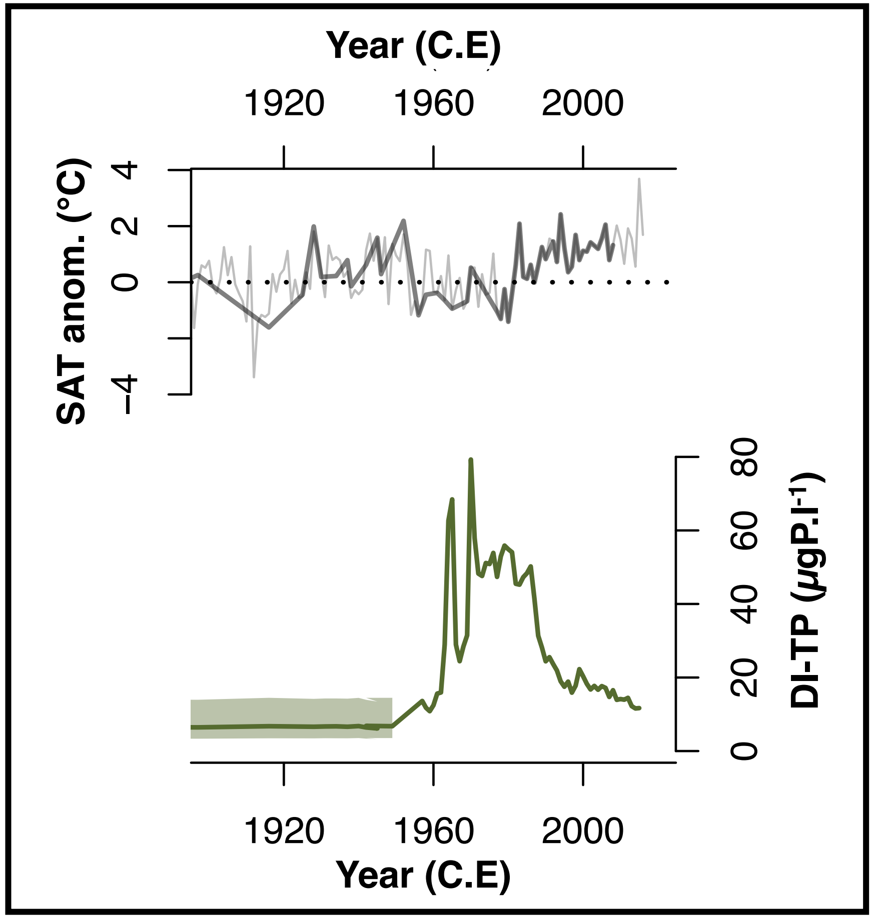


Results

Forcings

- 1960s: eutrophication
- 1980s: Climatic regime-shift (Woolway *et al.*, 2017)

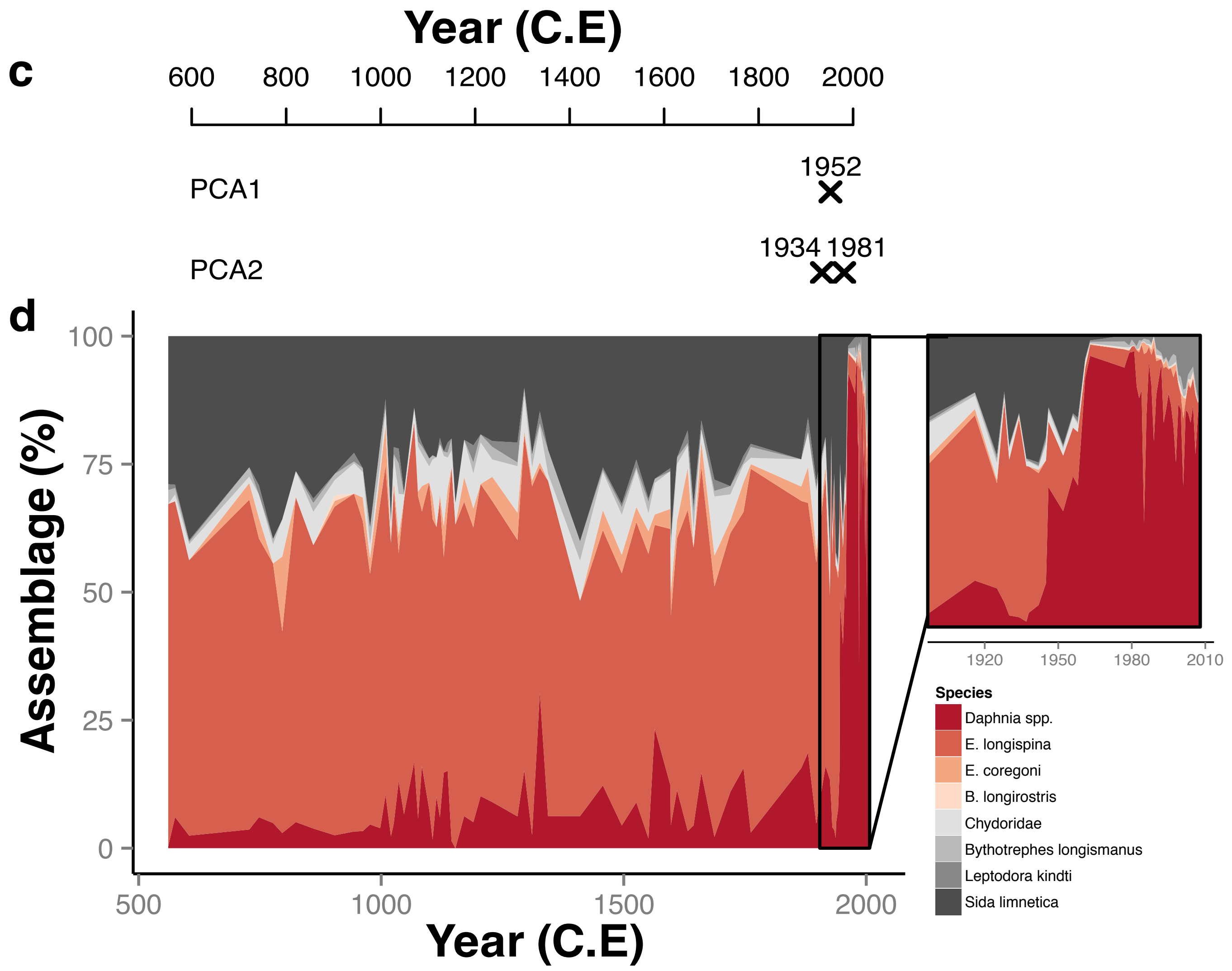




Results

Ecological responses

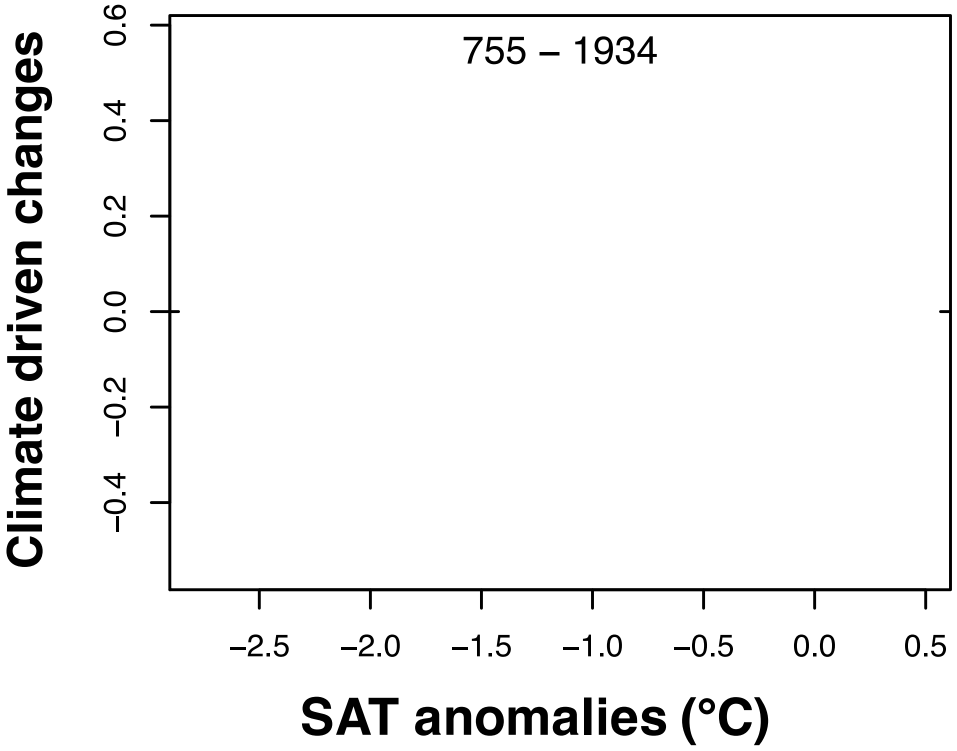
- 563-1934 C.E.: high stability
- 3 restructuration during the past century

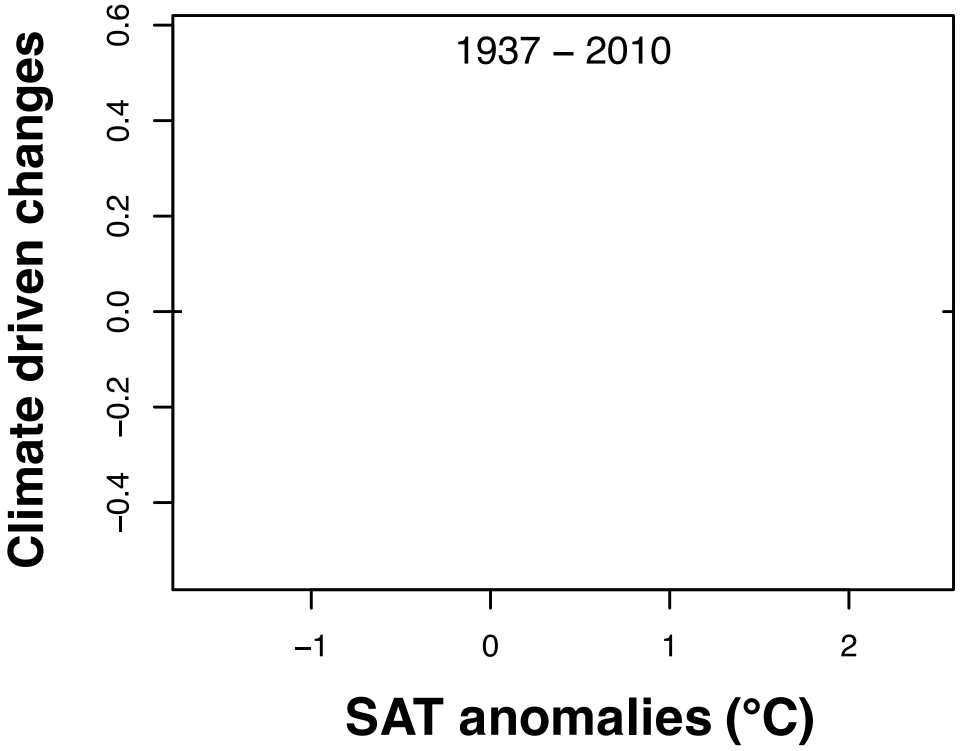


Results

Model

Method: Dataset cut in two: <1934 and >1937
Question: Are SAT anomalies significant drivers of the assemblage?





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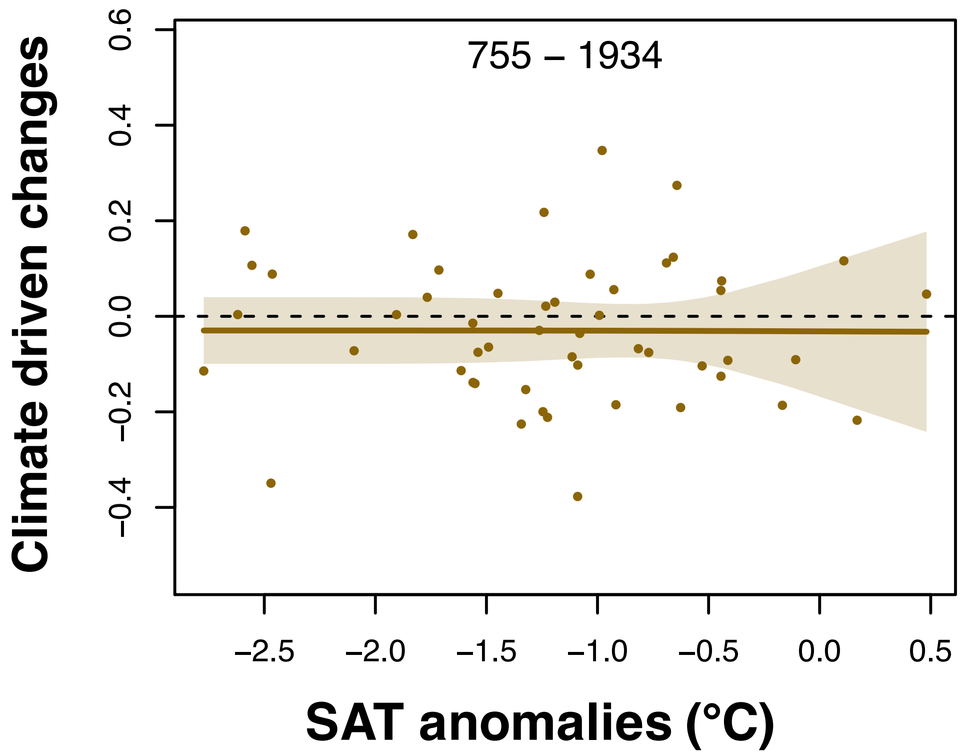

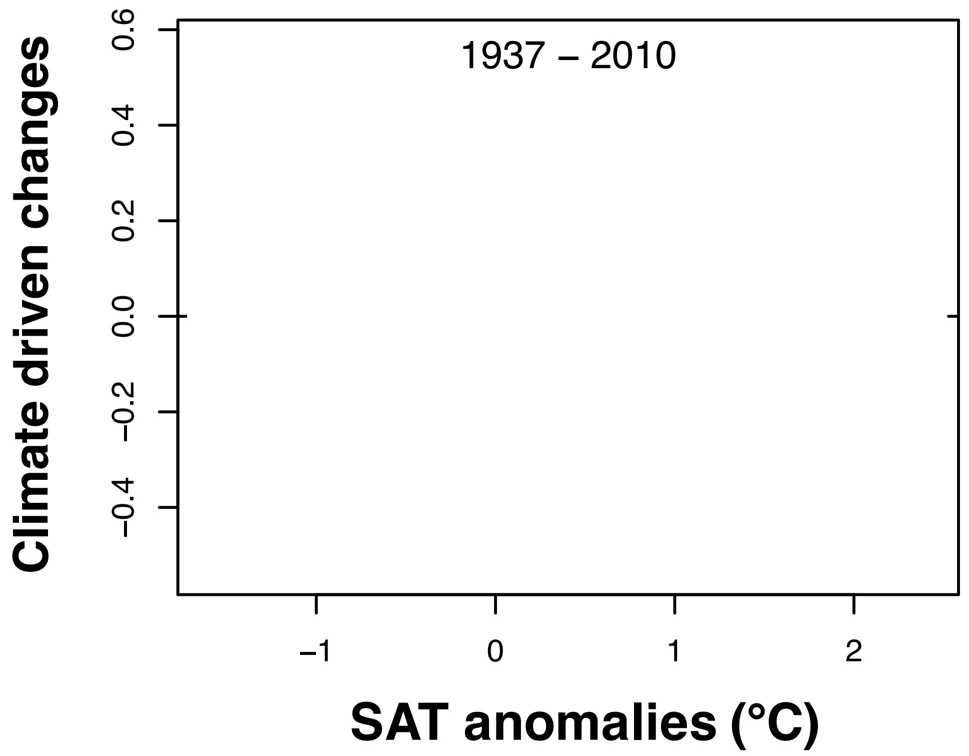

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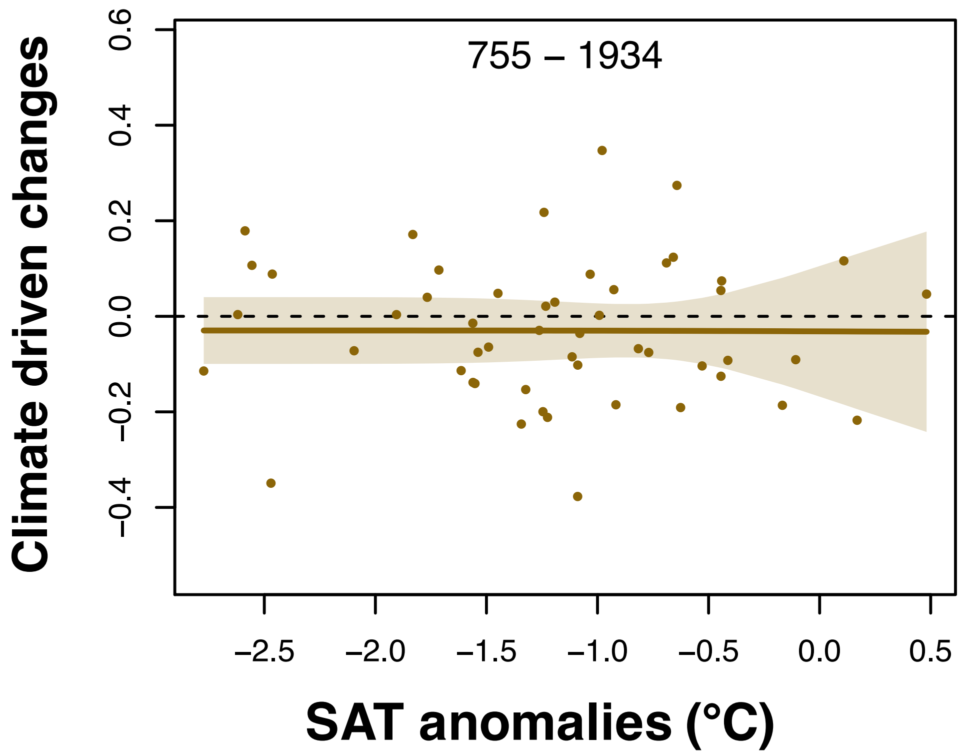
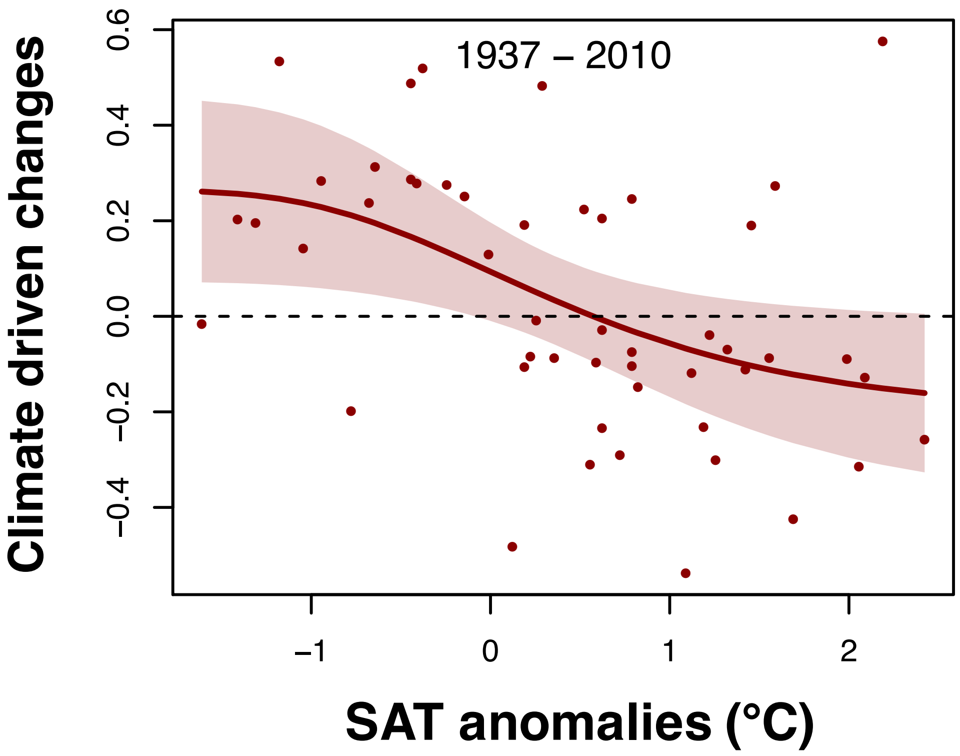
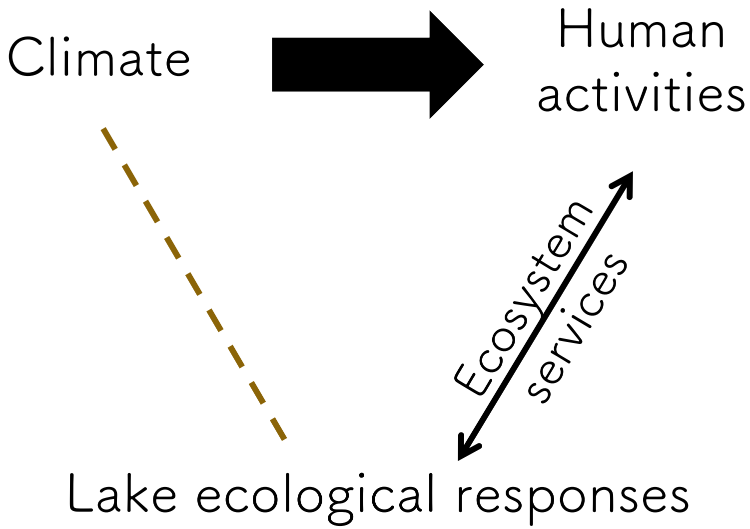


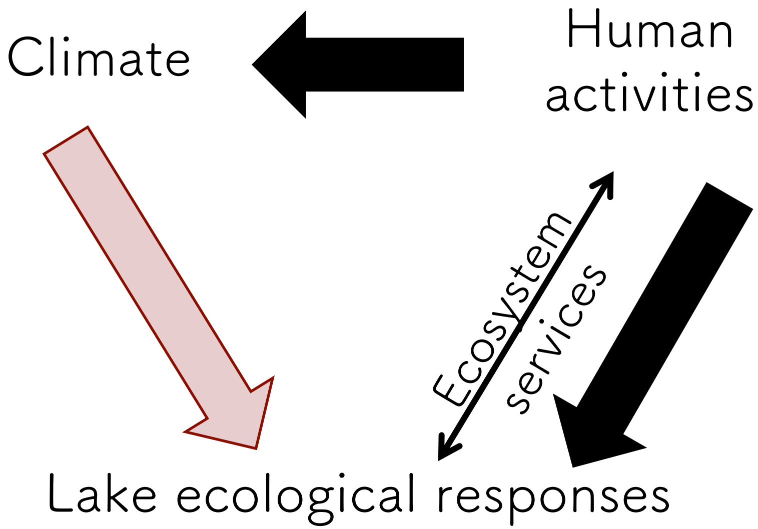


Results

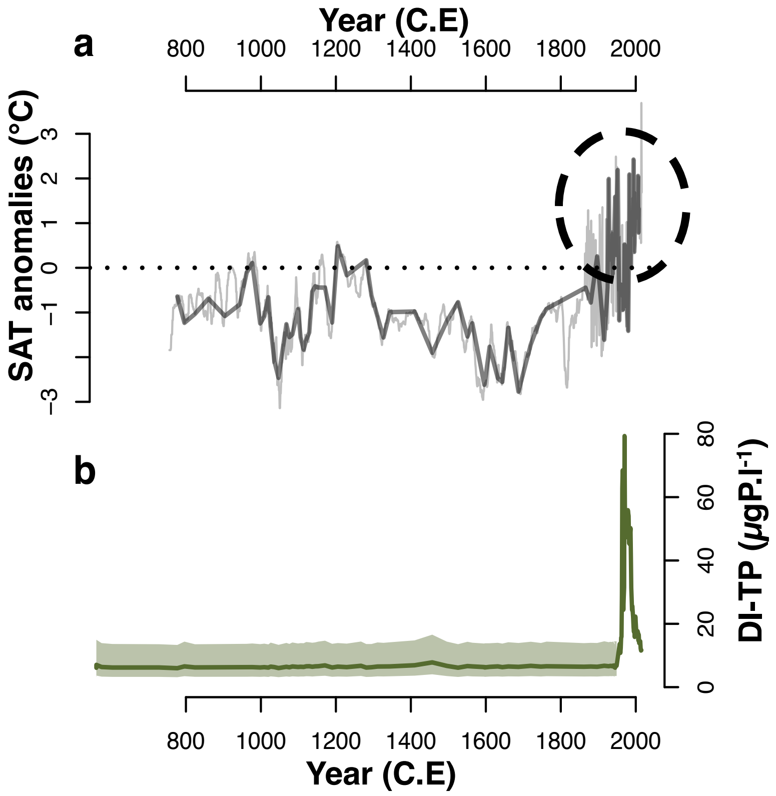
Before 1934 (the 1st restructuration in the assemblage), Lake Geneva ecological communities were **resilient** to climate variability.



Since 1937, a **relationship** could be established **between Lake Geneva ecological responses and climate variability**.



Conclusions



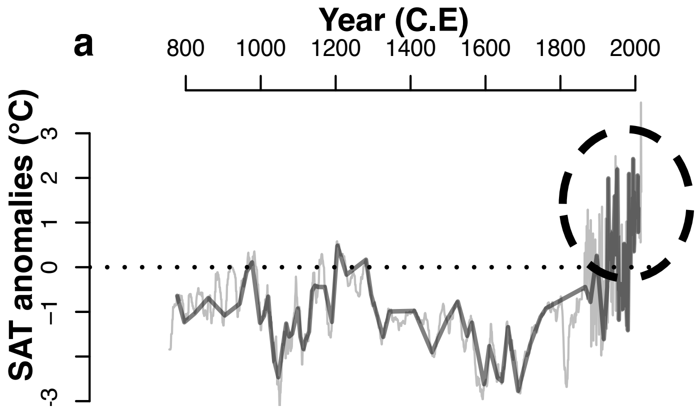
Scenario 1

There is an air temperature above which Lake Geneva cladoceran communities would have responded anyway (IPCC recommendations would need to be done by ecosystem??)

Scenario 2

Local human impact made Lake Geneva less resilient to climate variability ➔ Management implications.

Conclusions



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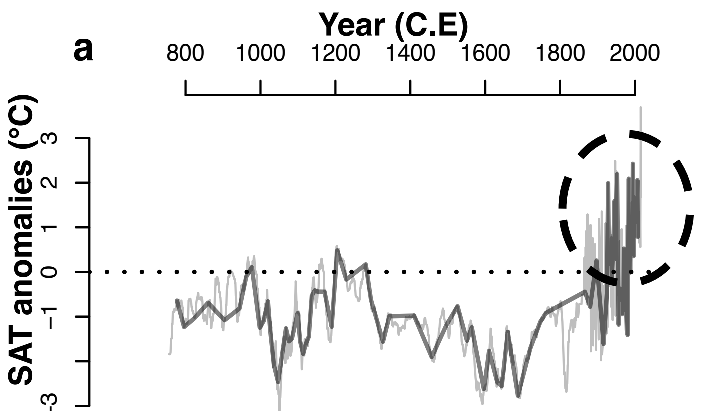
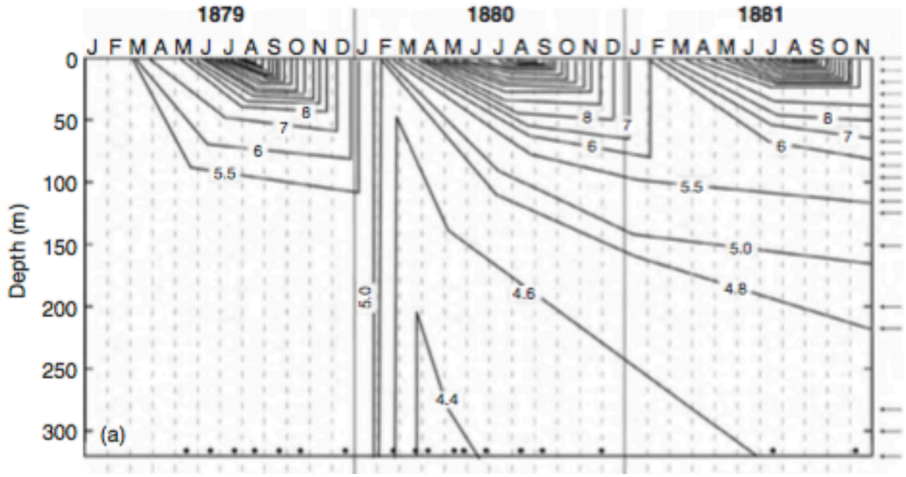


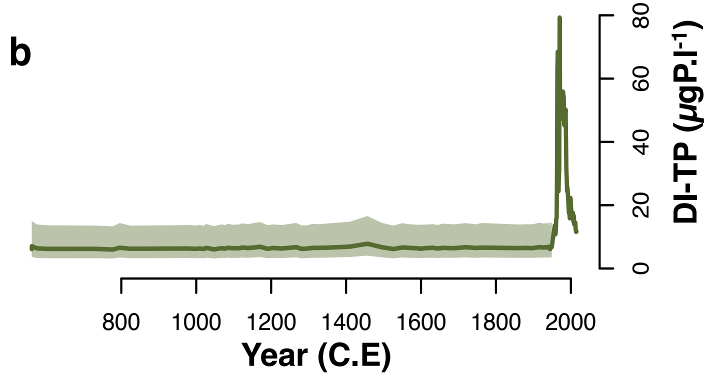


Scenario 1

There is an air temperature above which Lake Geneva cladoceran communities would have responded anyway (IPCC recommendations would need to be done by ecosystem??)

Threshold is relevant for Artic lakes (Arp *et al.*, 2016), but Lake Geneva was never dimictic (Forel, 1892).

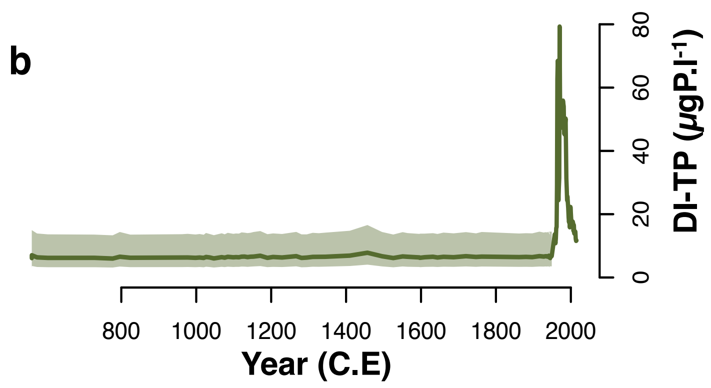
Conclusions



Scenario 2

Local human impact made Lake Geneva less resilient to climate variability ➔ Management implications.

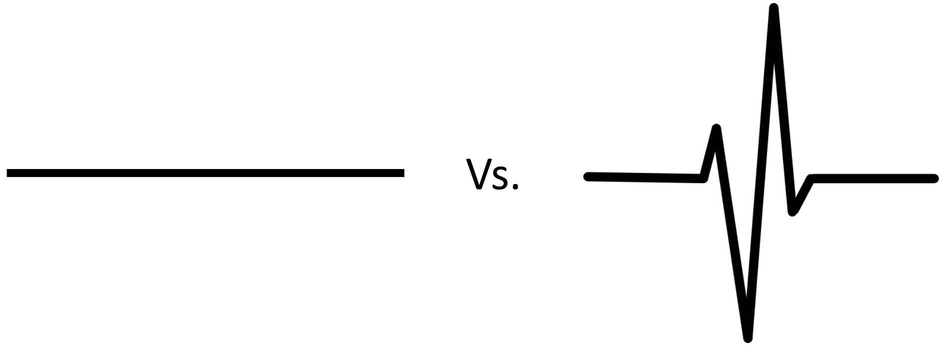
Conclusions



Scenario 2
Local human impact made Lake Geneva less resilient to climate variability ➔ Management implications.

very slow processes and small variability (driven by natural processes)

new alternative state with very high variability and unstable conditions

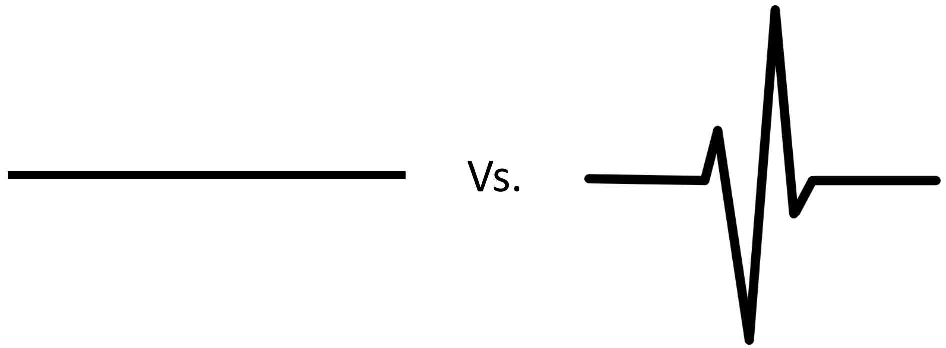


- Lake **Zabińskie,** Poland (Hernández-Almeida et al., 2017) ➔ 1600 AD
- Lake Bourget, France (Capo et al., 2016) ➔ 1950s
- Lake Garda, Italy (Milan et al., 2016) ➔ 1960s
- Lake Varese, Italy (Bruel et al., in prep) ➔ 1920s
- **Lake Geneva, CH/FR (Bruel et al., in prep) ➔ 1930s**

Conclusions

very slow processes and small variability (driven by natural processes)

new alternative state with very high variability and unstable conditions



→ **Ecologists:** ecosystems may respond to forcings in a non linear way i.e. display ≠ vulnerability over time

→ **Paleoscientists:** worth having a better time-resolution and account for internal processes when studying ecosystems responses

Thank you for your attention!
Any questions/remark?

This work would not have been possible without the contributions of:

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