Climate and environmental changes over the last 2000 years in the Serra da Estrela, Portugal

EGU22

OSPP contest

May 23rd, 2022

CL1.2.6/OS1.22

Ricardo N. Santos, Teresa Rodrigues, Enno Schefuß, Lívia G.M.S. Cordeiro, Filipa Naughton, Dulce Oliveira, Armand Hernández, and Alexandre M. Ramos

ricardo.s.16@hotmail.com
ricardo.santos@ipma.pt

FCT Fundação para a Ciência e a Tecnologia (PTDC/CTA-GEO/29029/2017)

Presentation plan

- Introduction
- Study Area
- Material and Methods
- Modern vegetation *n*-alkane signal
- Climate and environmental reconstruction
  - Major climate events
  - Forcing
- Conclusions
  - Future Works

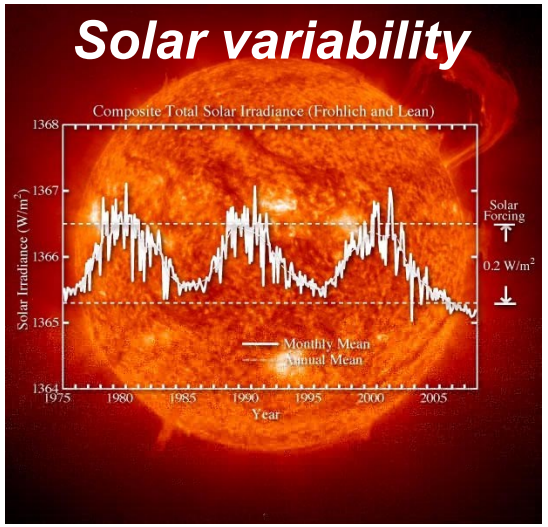
Motivation

In Iberia it is **expected** longstanding **heatwaves** and **droughts**, so it is **crucial to understand**:

- How its **hydroclimate** has changed and what the impacts over the recent times (last 2000 years).
- What are role of the main **climate drivers** in those changes.

Drought relief for Iberia over the coming days (netweather.tv)

Major natural climate forcings over the last 2000 years

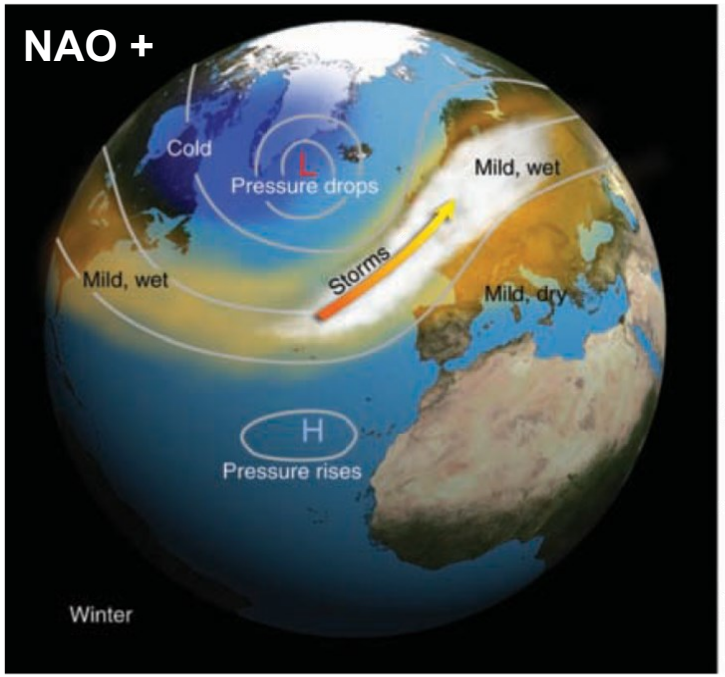


http://www.nasa.gov/audience/formedia/features/MP_Photo_Guidelines.html

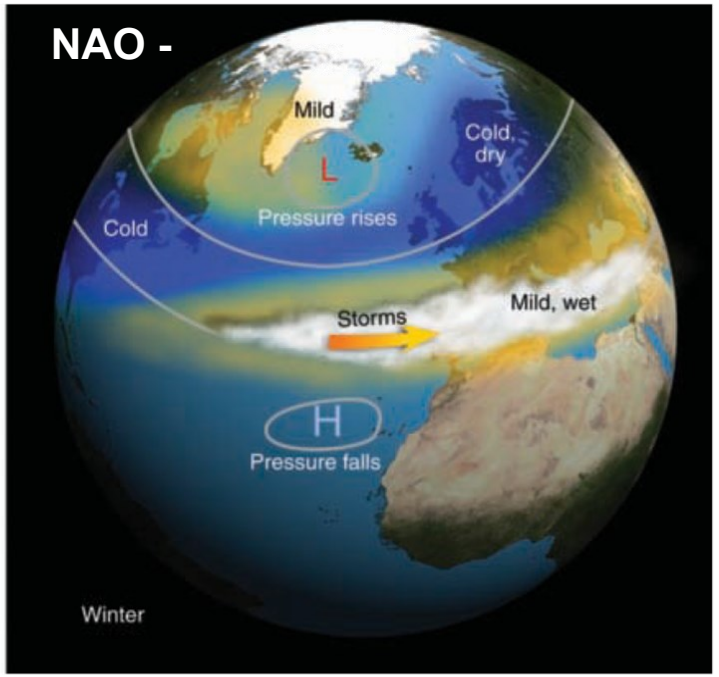
www.popsci.com

Atmospheric Patterns

North Atlantic Oscillation



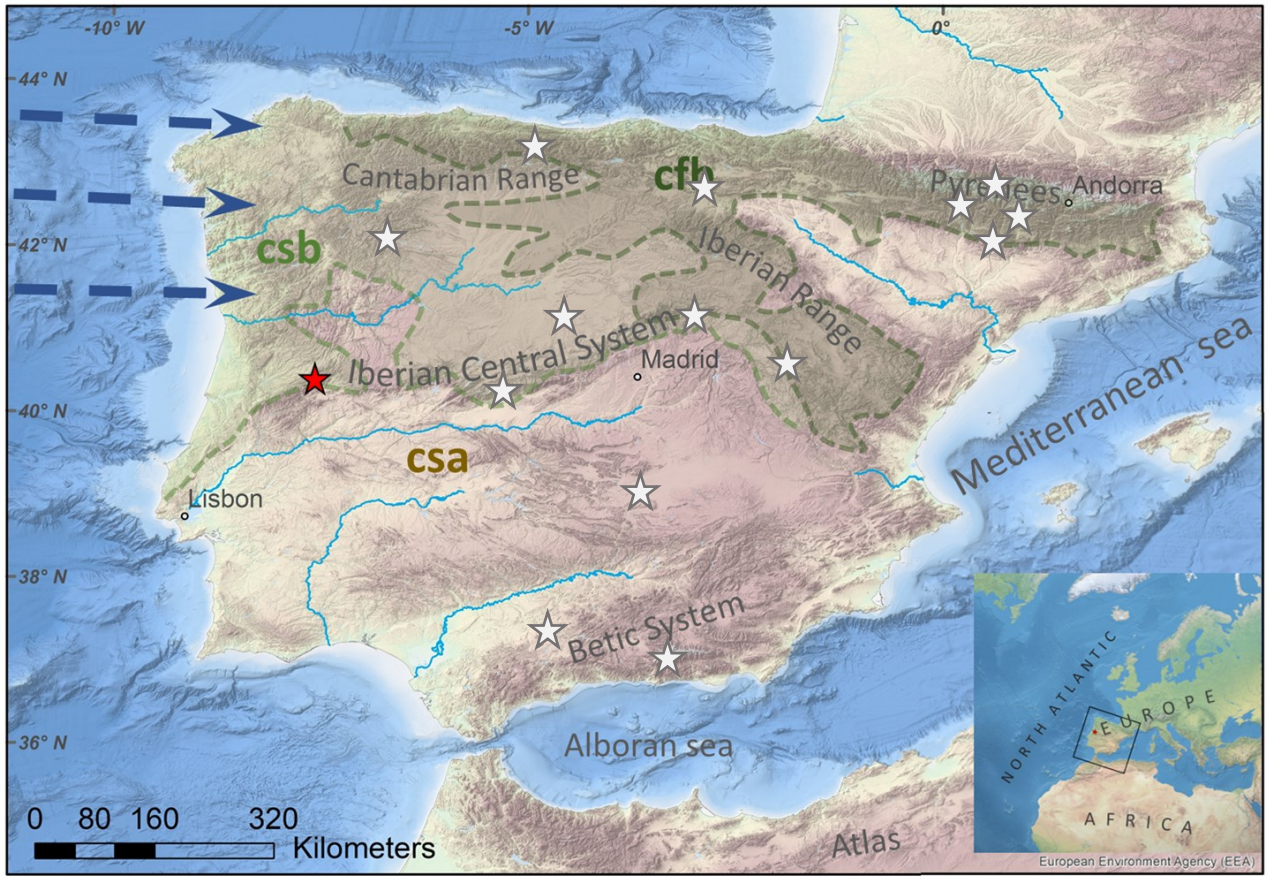
(a) Positive phase



(b) Negative phase

Petersen, J. F., Sack, D., and Gabler, R. E., 2008

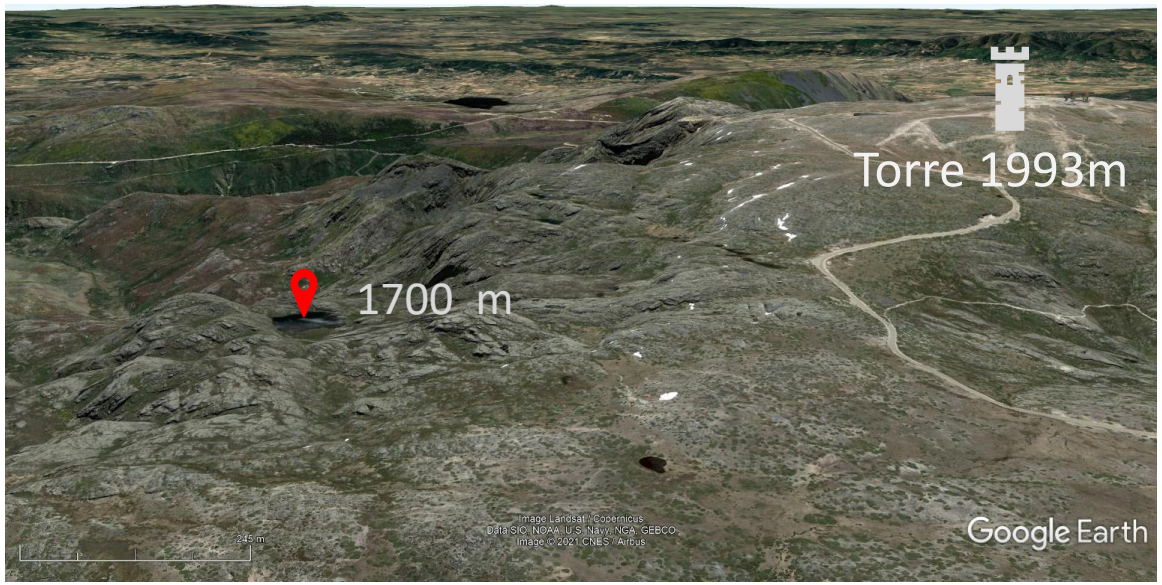
Serra da Estrela Mountain



Csb, cfb and csa -> Please see Köppen–Geiger climate classification

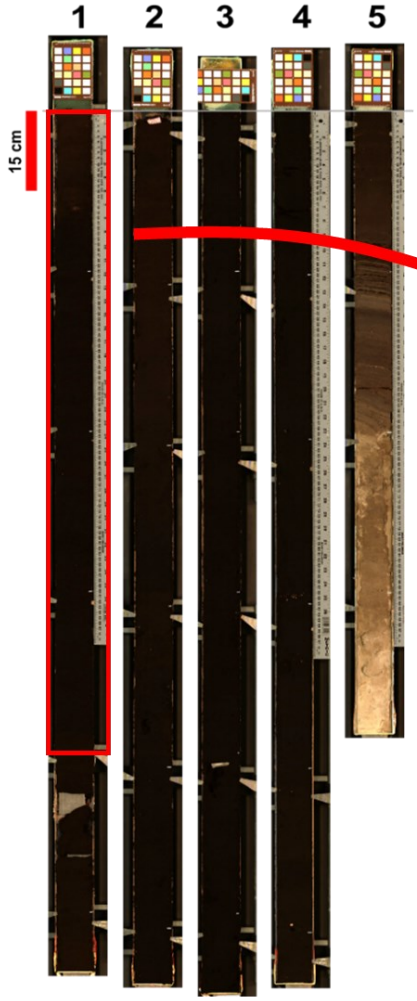
- ☆ High-mountain lake records covering the last 2ka in Iberia, see Sánchez-López et al., 2016
- ★ This study

Lake Peixão

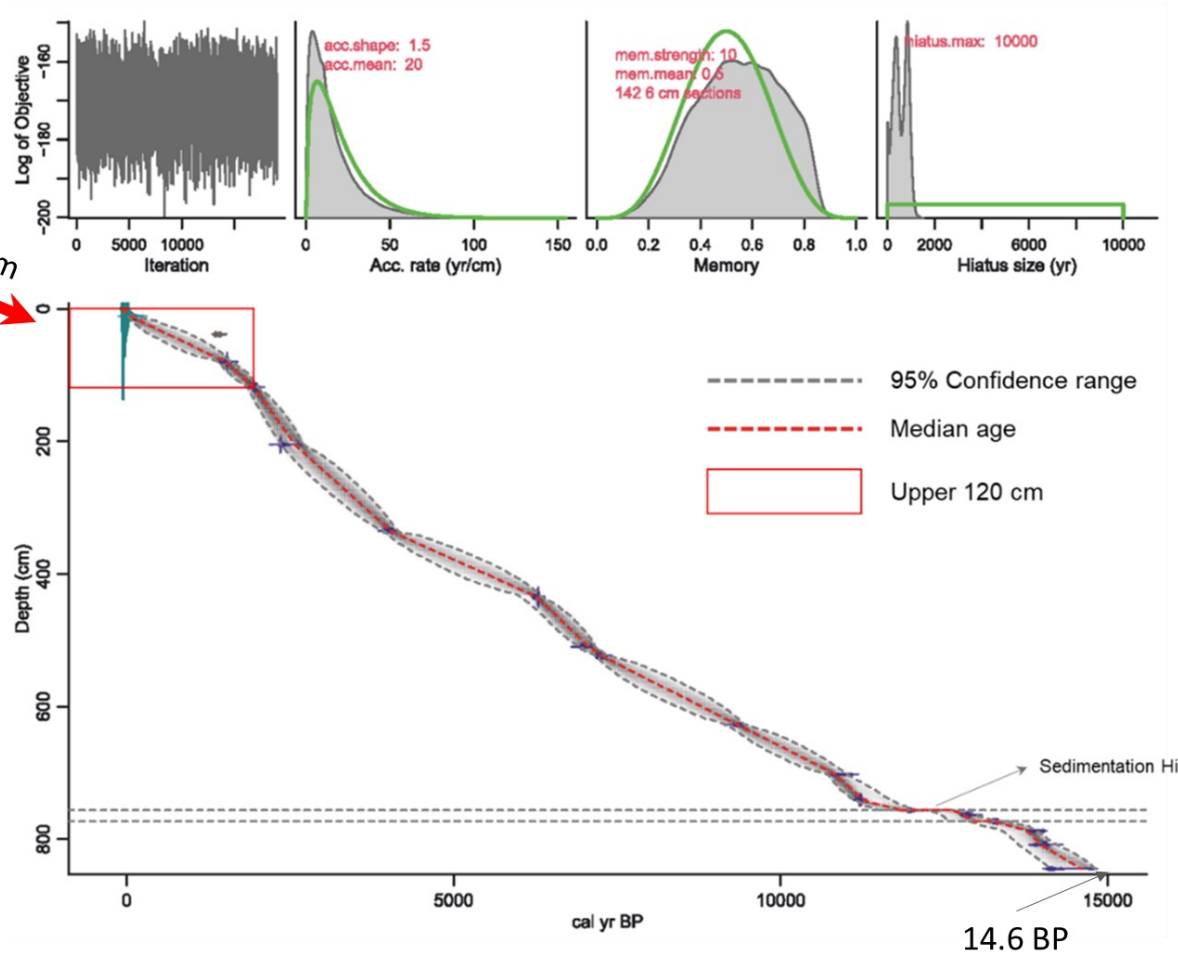


- ~ **100 Km** from the Atlantic Ocean
- **Key-location** to study **ocean-atmosphere-land** changes
- **Major barrier** to the Atlantic moister
- Defines a **boundary** between two **climate zone**
- Lake Peixão, one of the few **high-lake records**

Coring campaign, summer 2019



UWITEC core system



Leaf wax n-alkanes

Click to see a short Youtube vídeo about the methodology ☺

$H_3C\text{-}[CH_2]_n\text{-}CH_3$

Number of carbons

Trees/shrubs  $C_{27} - C_{31}$

Grasses  $C_{31} - C_{33}$

Aquatic plants  $C_{23} - C_{25}$

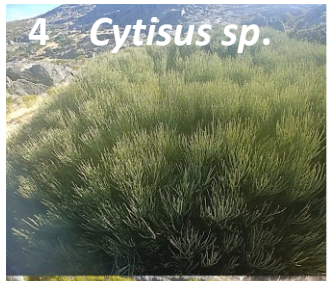
- Persist **unchanged** for extend periods in the sediments
- Compound specific isotopic analysis, **δD and $\delta^{13}C$**
- **Strong** and consistent **relationship** with **precipitation**
- Used to infer past **hydroclimate** and organic matter **sources**

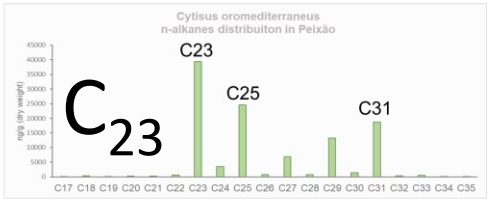
Examples of Indexes used to characterize *n*-alkanes in a sample:

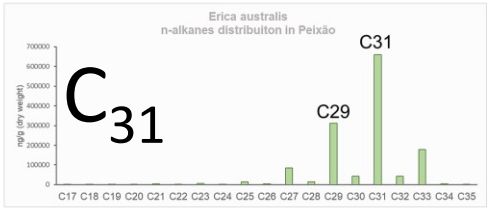
$$\text{ACL}: \frac{(\sum c_i \times i)}{\sum c_i}$$

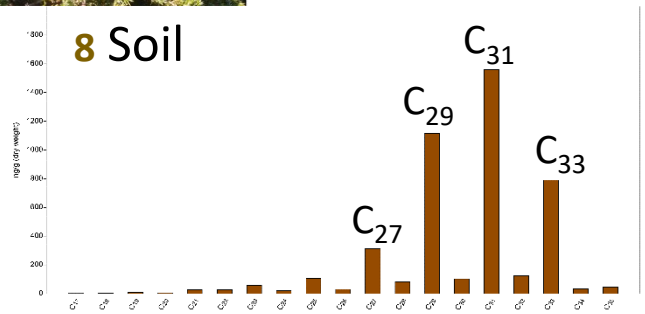
$$\text{PAQ}: \frac{C_{23}+C_{25}}{C_{23}+C_{25}+C_{29}+C_{31}}$$

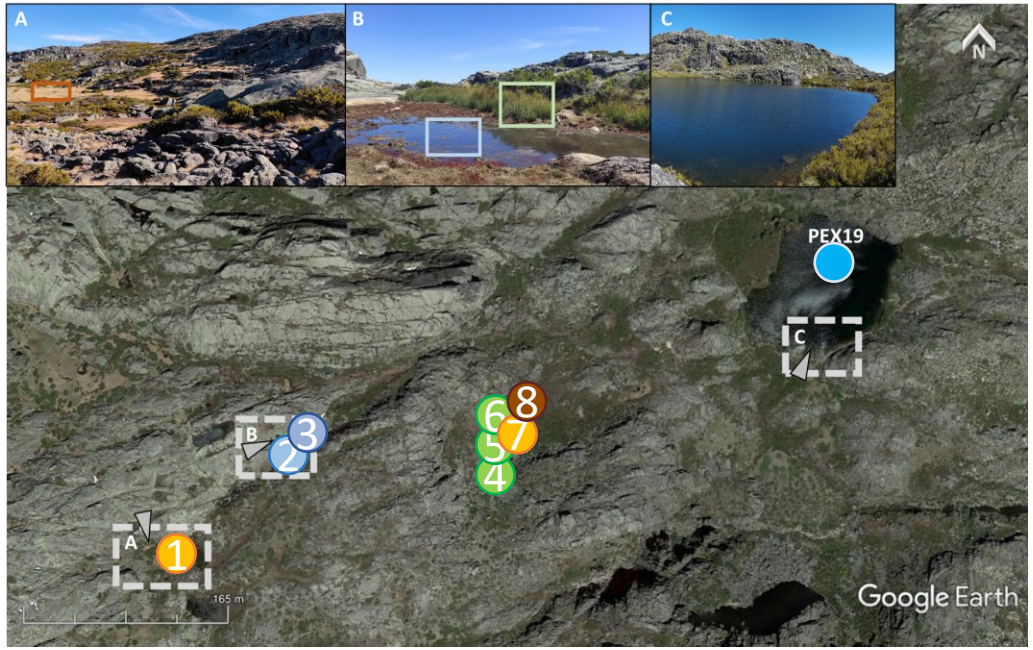
Modern *n*-alkane signal

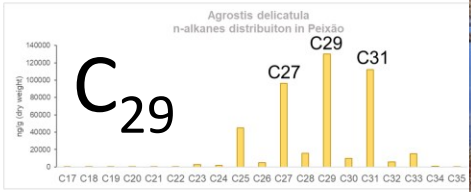


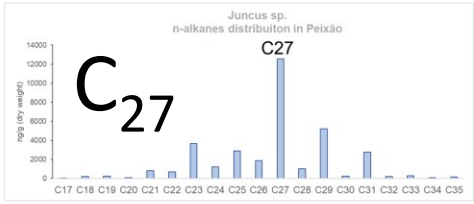


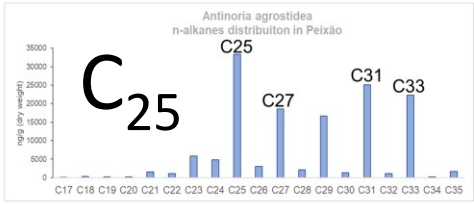




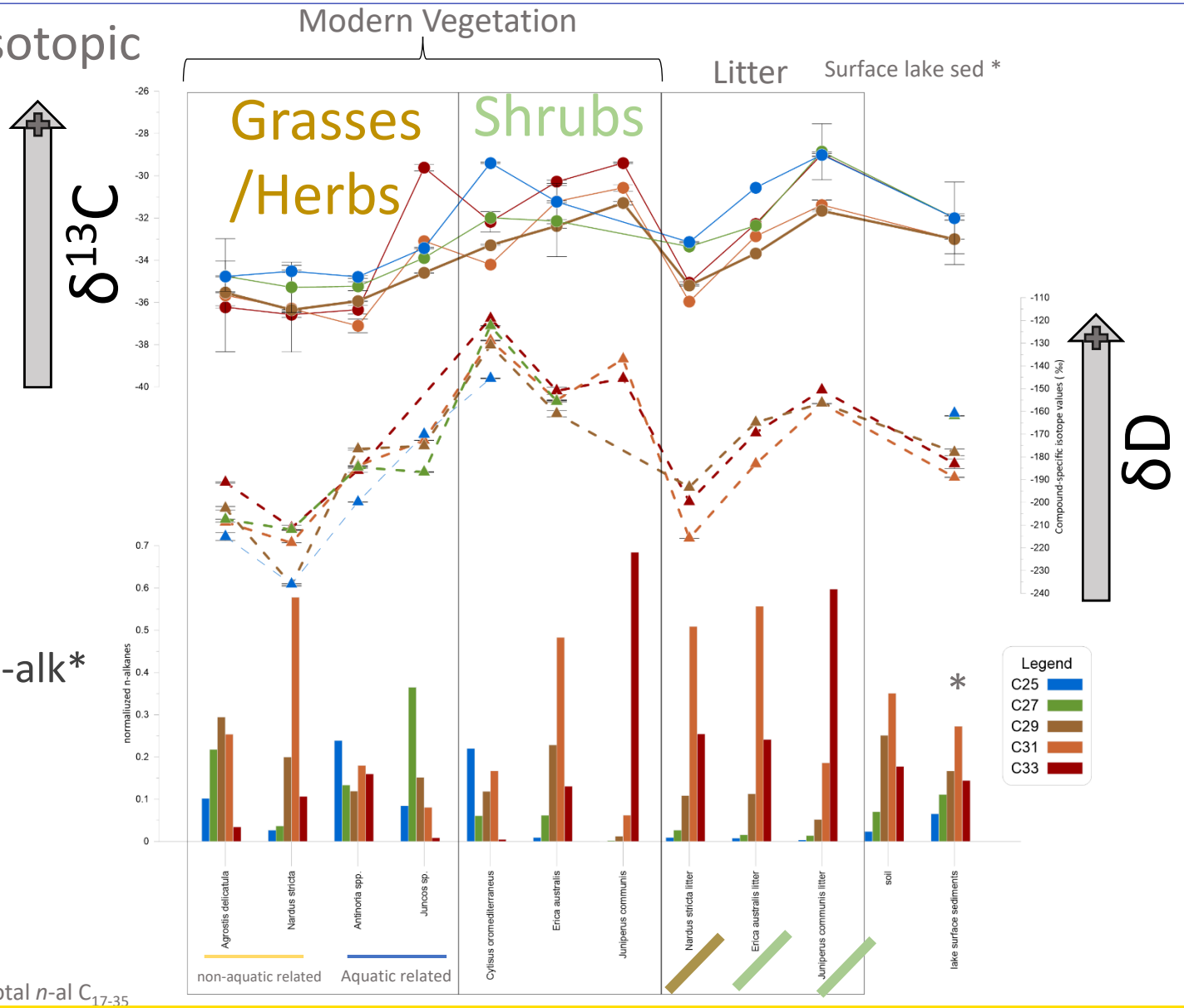




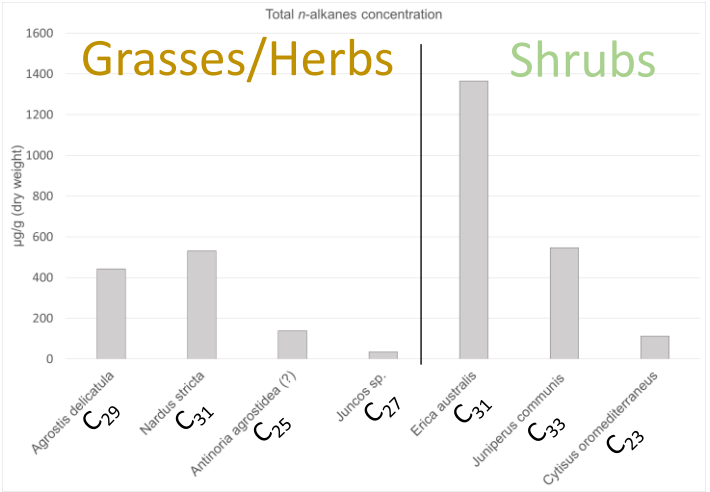




n-alkane isotopic signal



Total *n*-alk

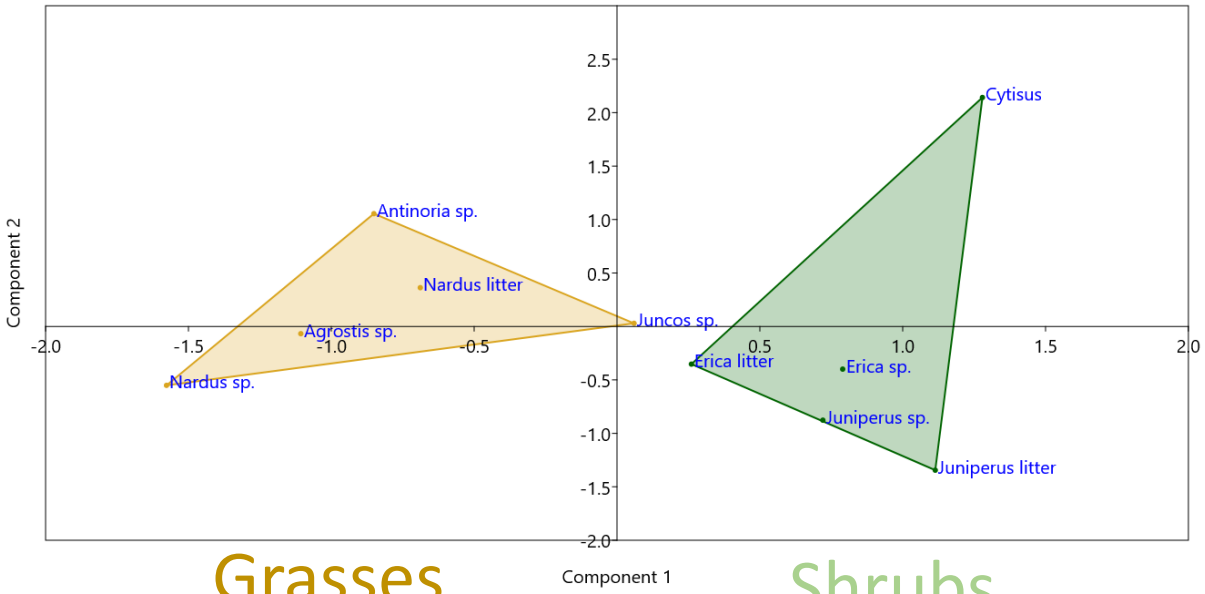


Normalized *n*-alk*

*Normalized against total *n*-al C_{17-35}

Ecological forms clustering using PCA (corr)

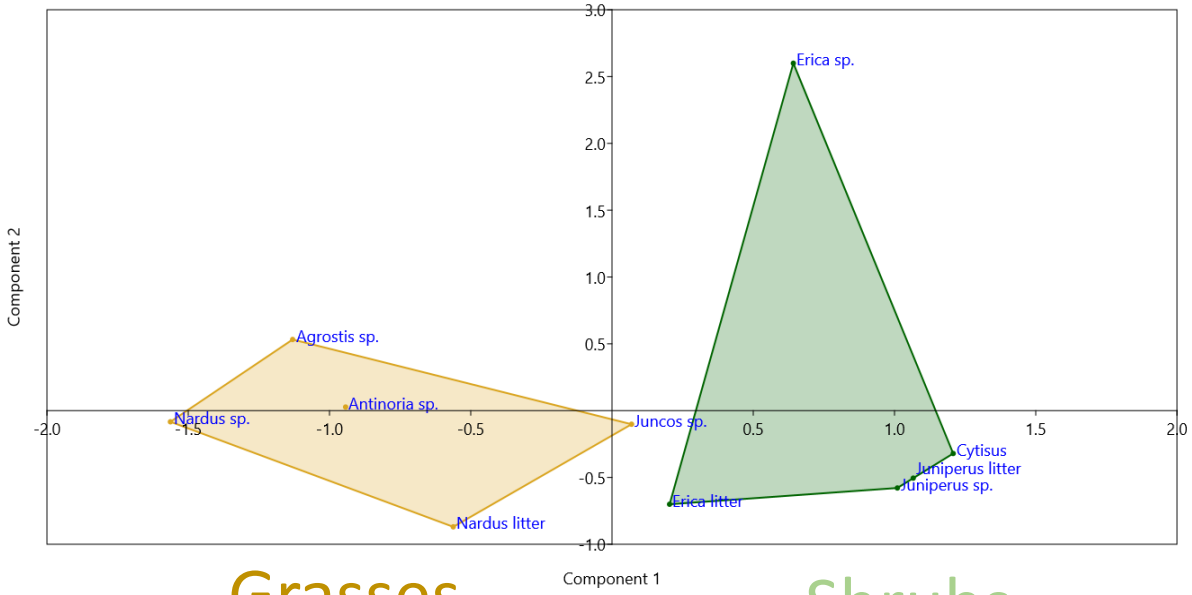
δD and $\delta^{13}C$



Grasses /Herbs

Shrubs

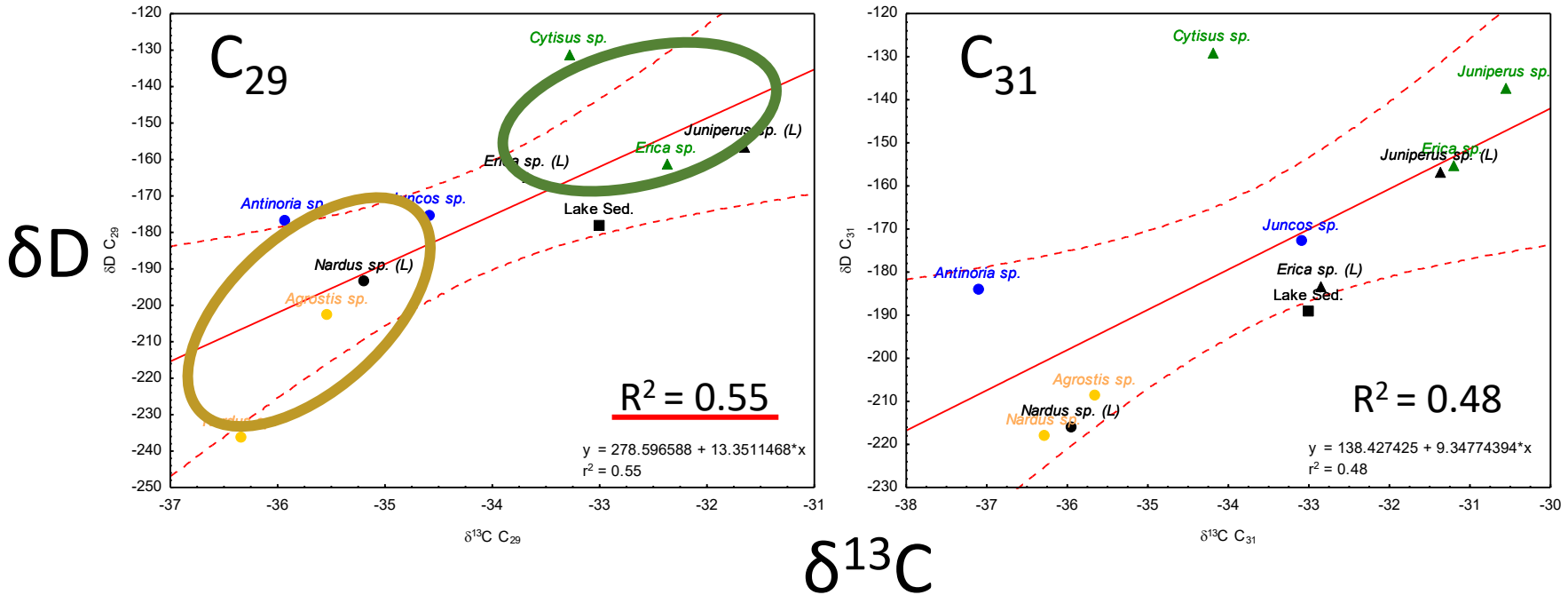
odd chain *n*-alk cond + δD and $\delta^{13}C$



Grasses /Herbs

Shrubs

Modern *n*-alkane isotopic signal



- ◯ Grasses/Herbs
- △ Shrubs
- □ Lake Surface Sediments
- (L) Vegetation litter

Ecological forms

- ● Aquatic related
- ● Non-aquatic

} Grasses/Herbs

- ● **Shrubs**

- **Strong linear** δD *vs* $\delta^{13}C$ relation

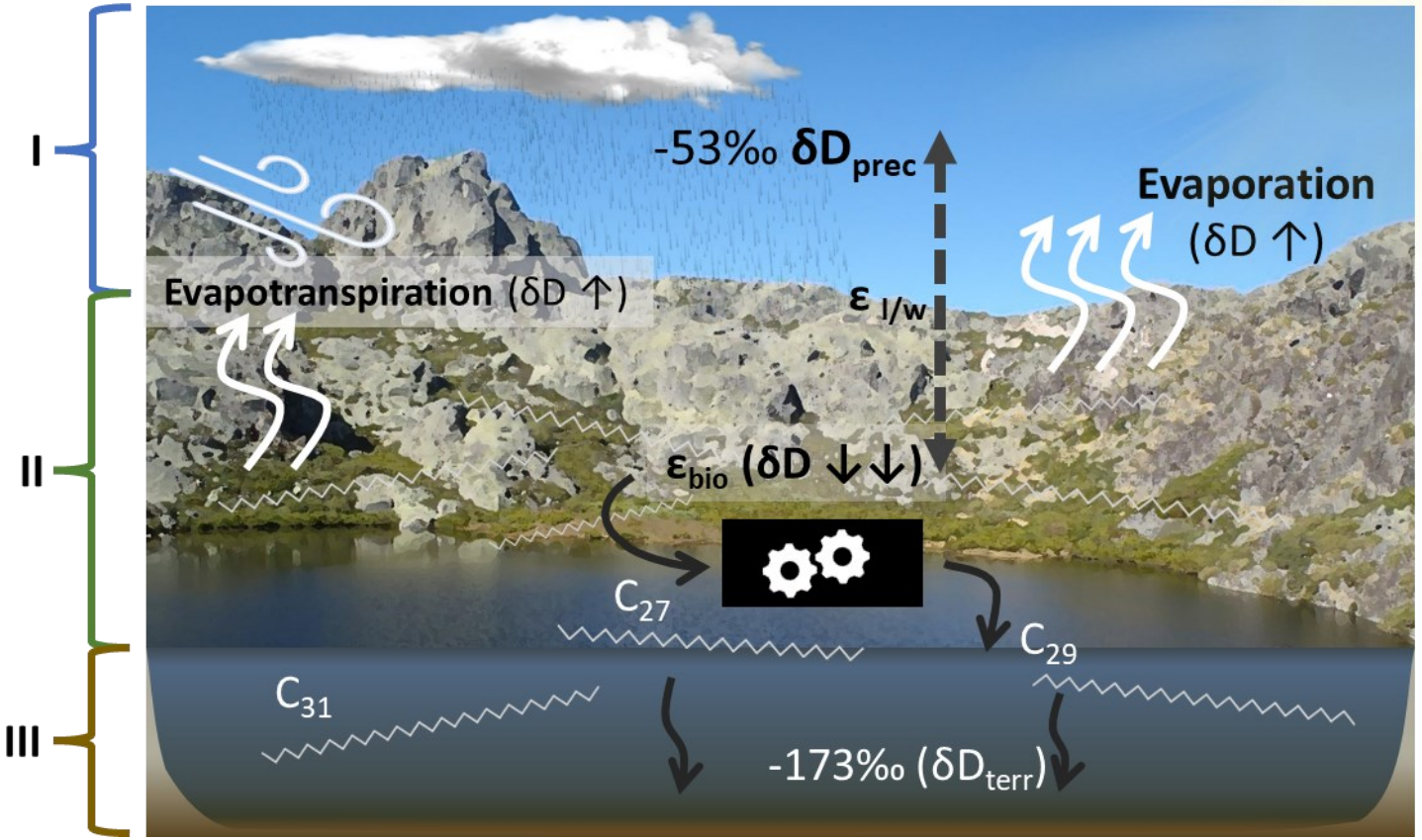
Suggesting:

common environmental factors like:

precipitation, temperature, humidity, soil and water source

- **Linear response** of **C_{29}** to differentiate terrestrial ecological forms
- Higher ε_{app} in grasses than shrubs

Lake Peixão as a climatic sentinel



I – Prevailing climatic factors;
II – Lake Peixão as a climatic "sentinel";
III – Lake sediments archive

Estimated δD_{prec}

Online Isotopes in Precipitation Calculator:

-56±5‰ (annual); **-53 ‰** (Spring months)

Near by (~ 1km) water spring:

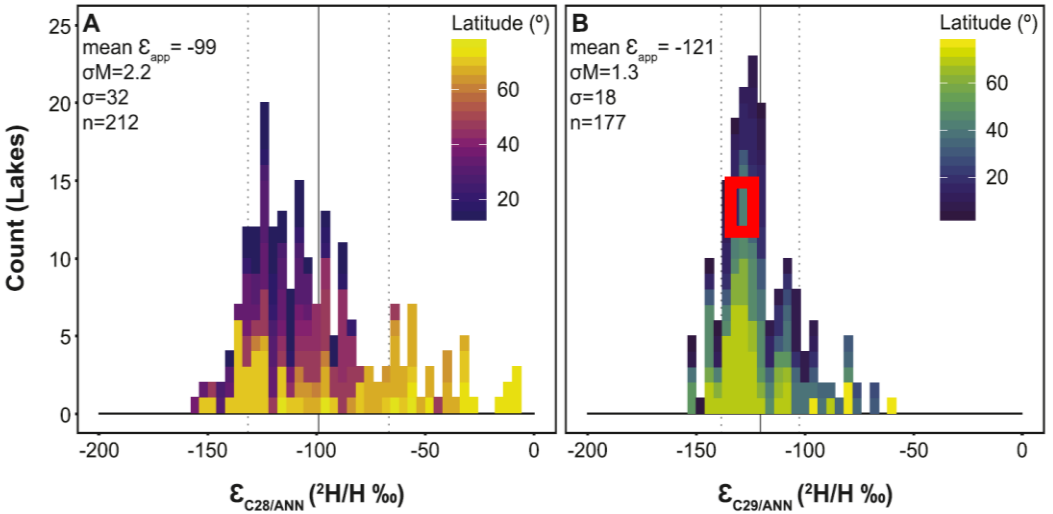
-51±2‰ (tri-monthly)

E_{app} :

$\varepsilon C_{29}/_{MAP}$: -129±12‰

Global average apparent fractionation

J.M. McFarlin et al. / Quaternary Science Reviews 225 (2019) 105978



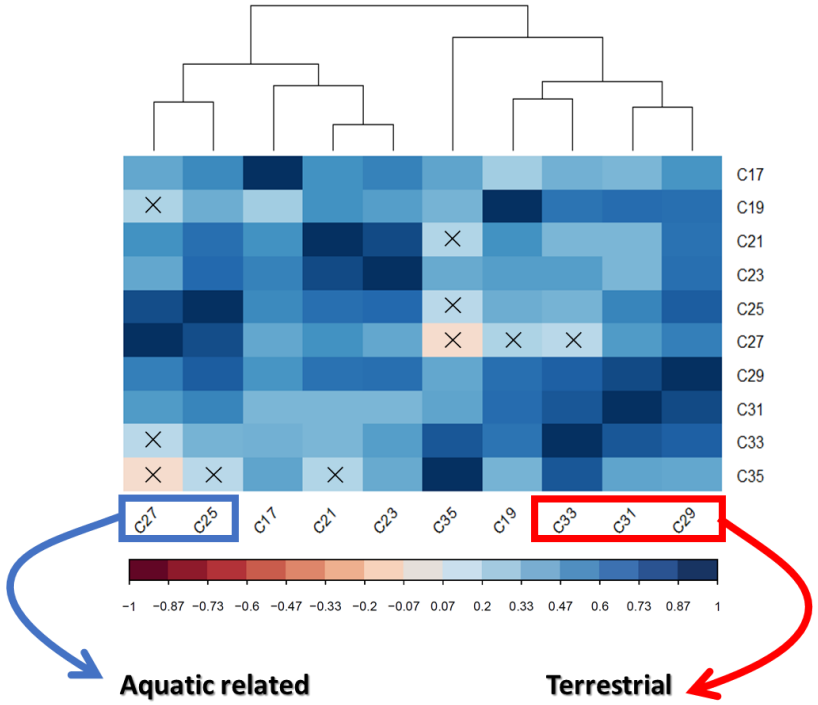
Downcore reconstruction PEX19-01

60 samples

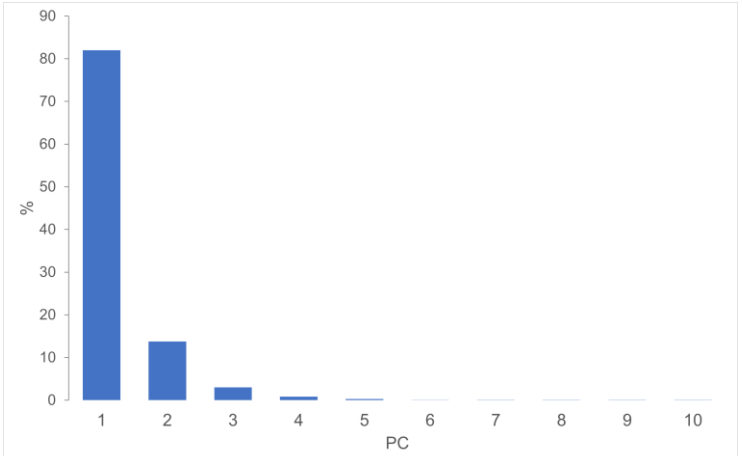
Sub- sampling each 2 cm

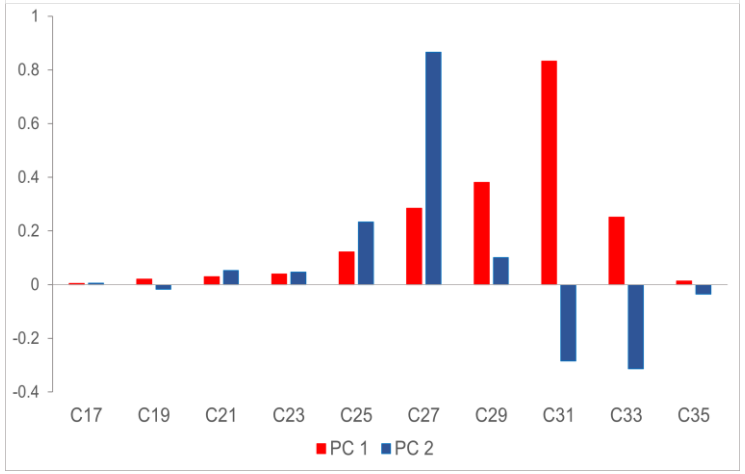
mean time resolution ~ 34 yrs

n-alk correlation analysis

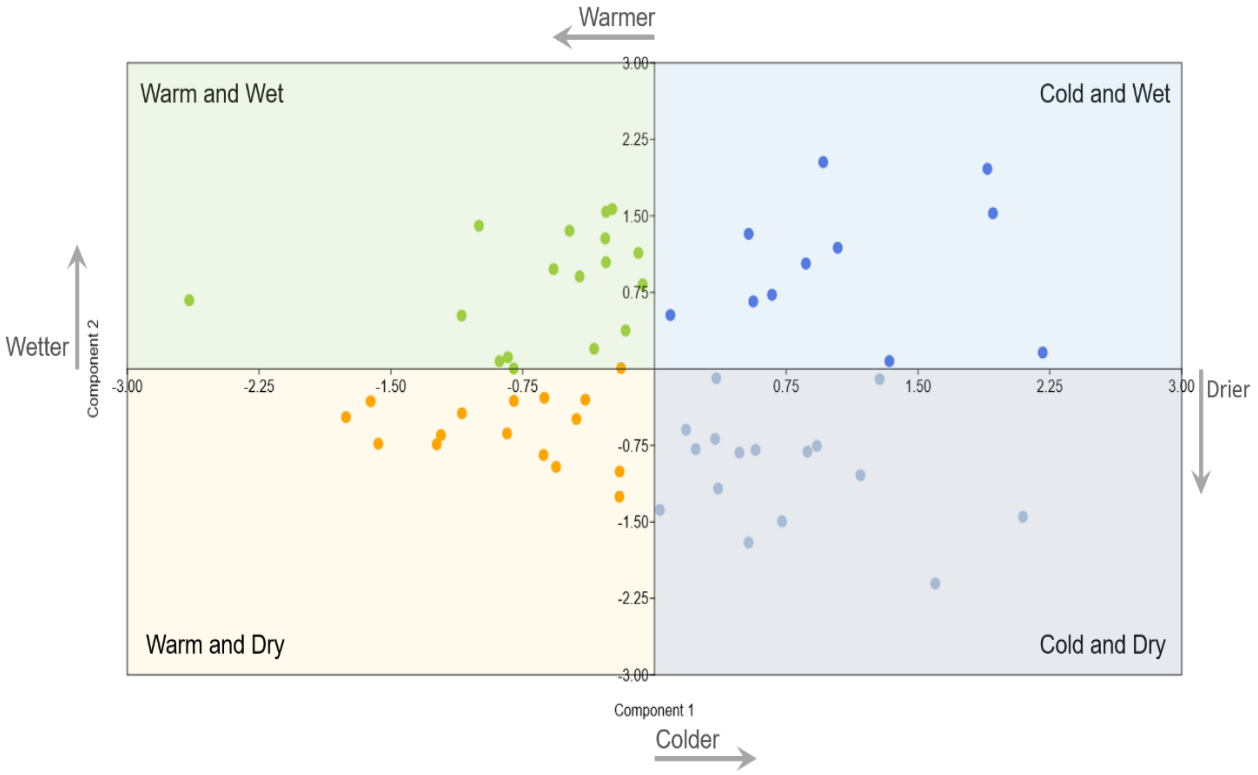


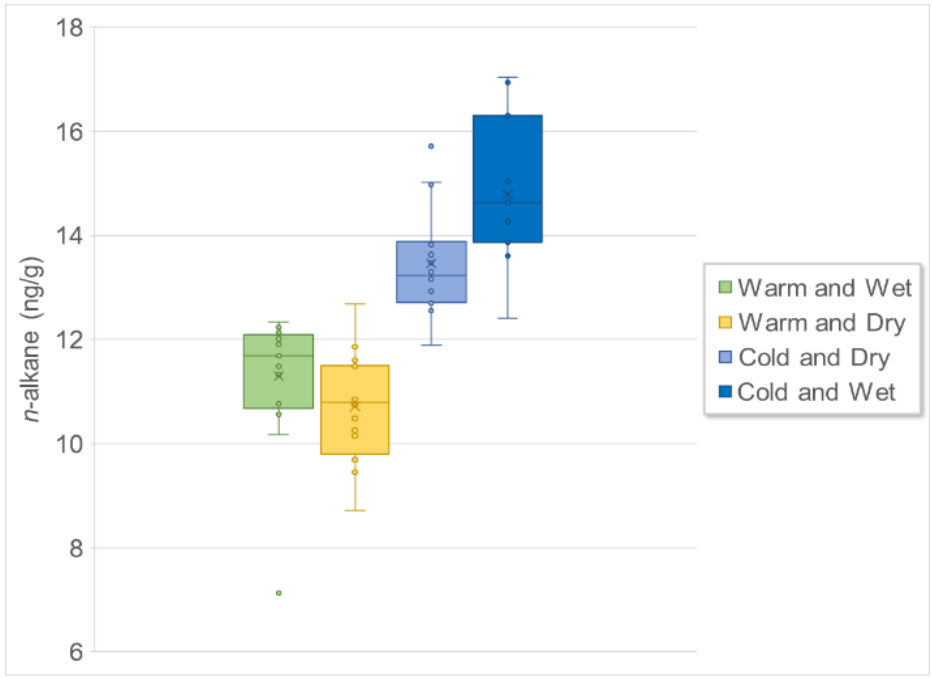
PCA – variance – covariance matrix on **odd chain *n*-alkanes of the lake sediments**





Principal component analysis model for the odd-chain compounds of the lake sediments (last 2ka)

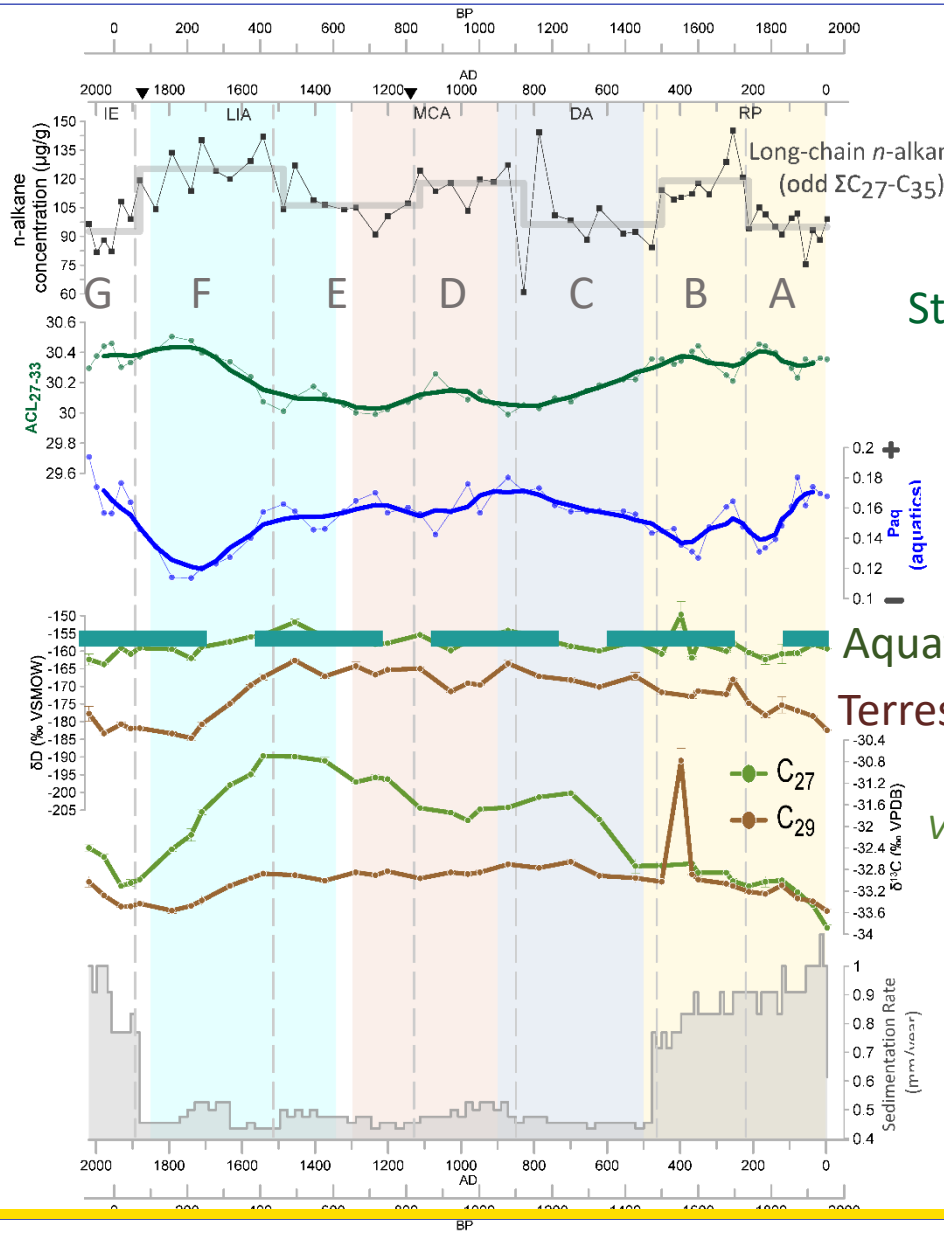




Lake Sediments

n-alkane concentration

Aquatic plants



Long-chains

Biogeochemical stages

Stable vegetation type (oro-Mediterranean) (30.2 – 30.4)

Low and variable Aquatics inputs (0.12 – 0.2)

Aquatics

Terrestrial

Water source **δD**

Vegetation sources $\delta^{13}C$

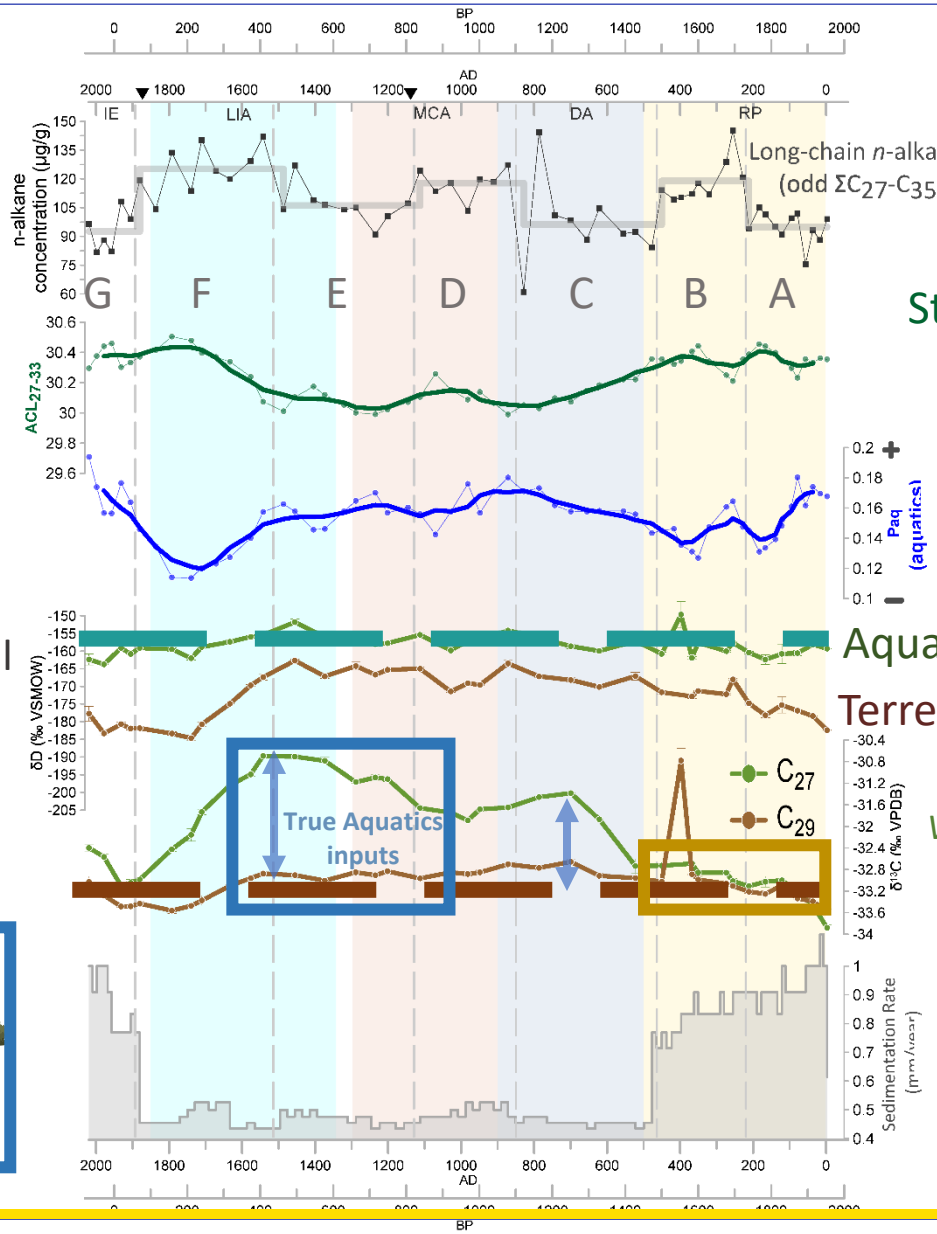
Compound-specific isotopic signal

Lake Sediments

n-alkane concentration

Aquatic plants

- δD_{prc} highly **controlled** by mean regional **temperature and precipitation amount**
- **δD of C_{29}** used as a reference to terrestrial hydrology.



Long-chains

Biogeochemical stages

Stable vegetation type (30.2 – 30.4)

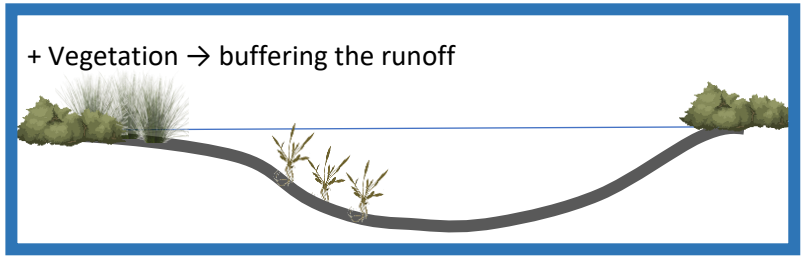
(oro-Mediterranean)

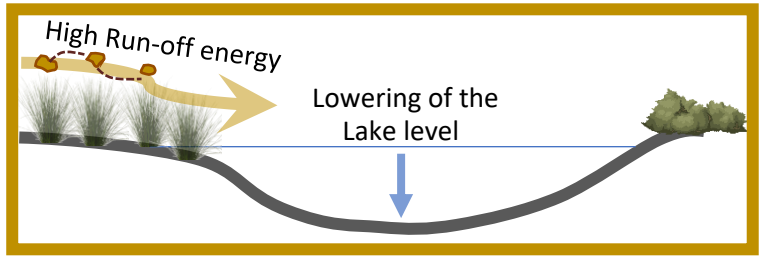
Low and variable Aquatics inputs (0.12 – 0.2)

Water source **δD**

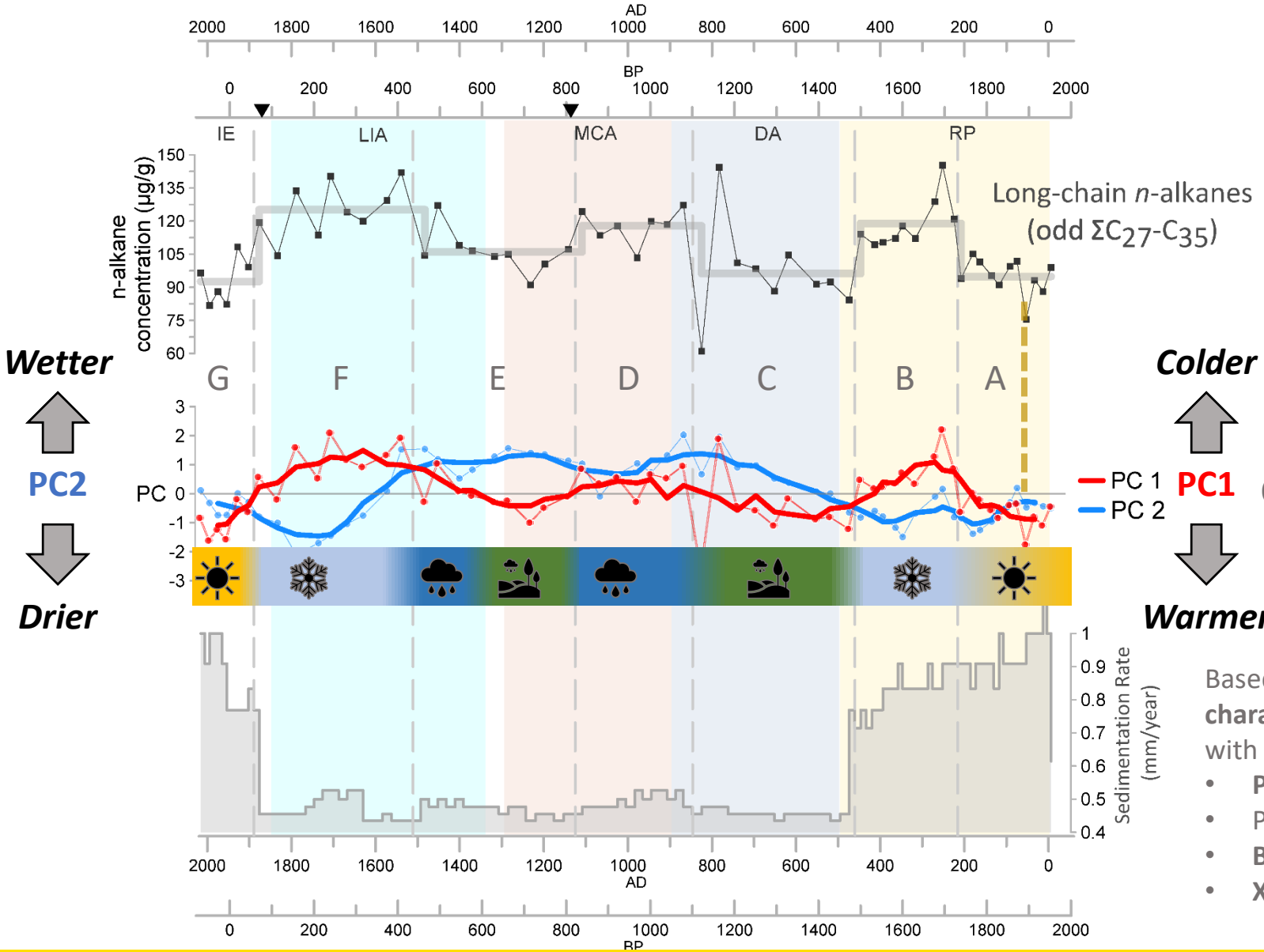
Compound-specific isotopic signal

Vegetation sources $\delta^{13}C$





PCA model

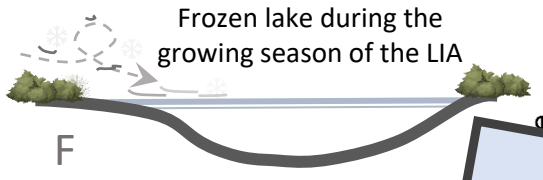


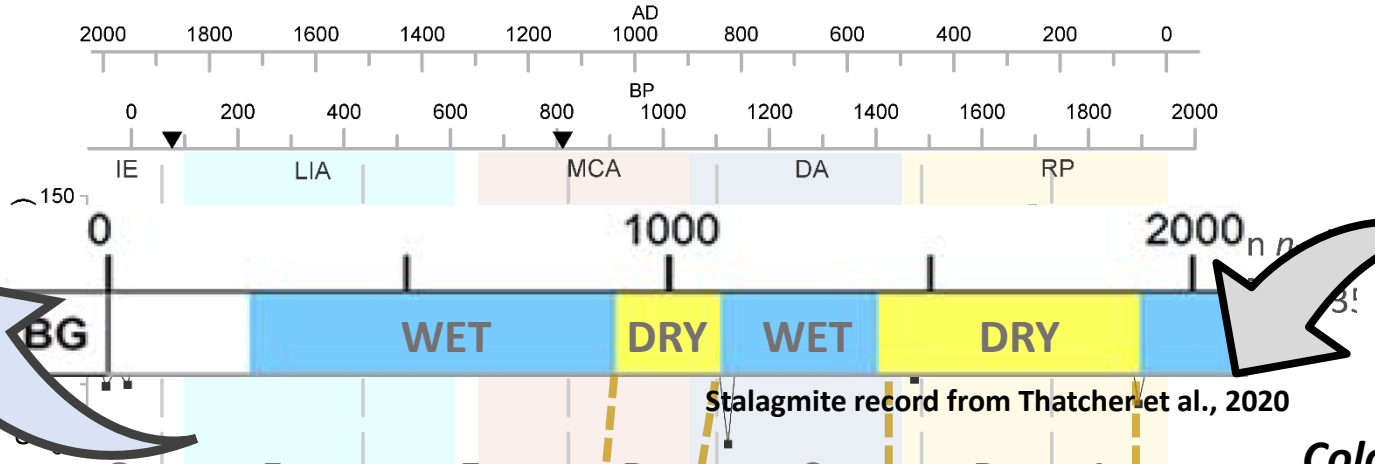
Odd chain *n*-alkanes

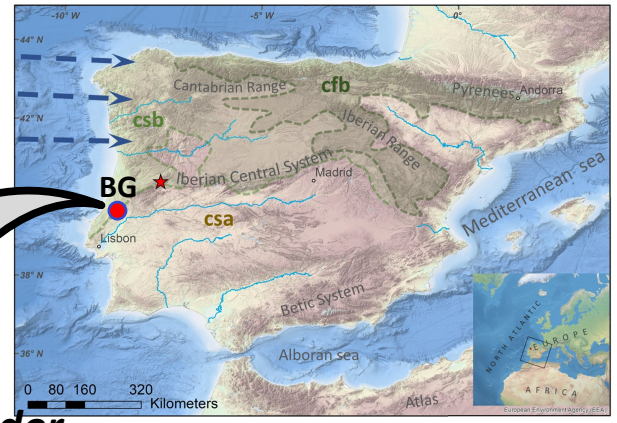
Based on **modern** *n*-alkane **characterization** and **cross-validated** with **other** independent **proxies**:

- **Pollens**
- P/B **Diatoms**
- **Bulk Organic matter**
- **X-ray fluorescence** of sediments

PCA model







Wetter

PC2

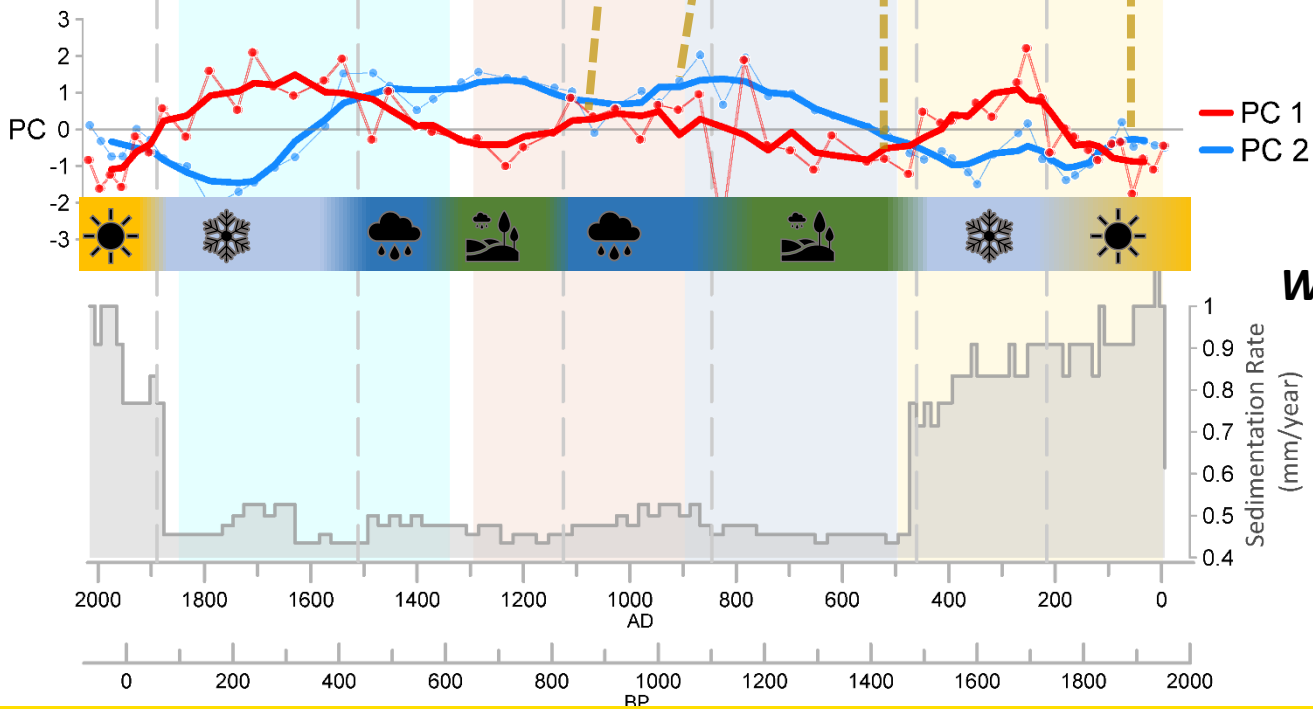
Colder

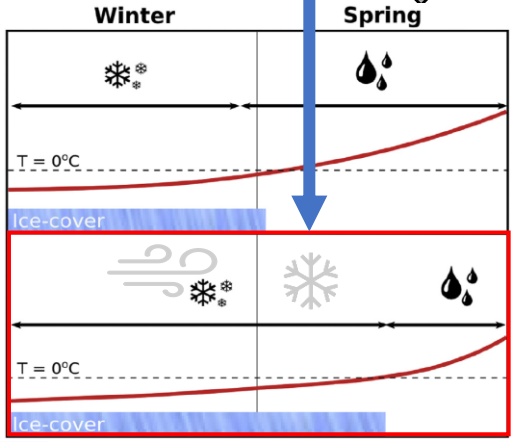
PC1

PC 1
PC 2

Odd chain *n*-alkanes

Warmer





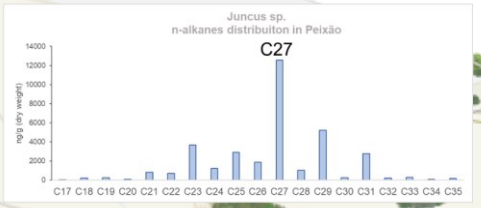
Adapted from Sánchez-López et al., 2016

Based on **modern** *n*-alkane **characterization** and **cross-validated** with **other** independent **proxies**:

- **Pollens**
- P/B **Diatoms**
- **Bulk Organic matter**
- **X-ray fluorescence** of sediments

Conceptual model

Warm and Wet conditions

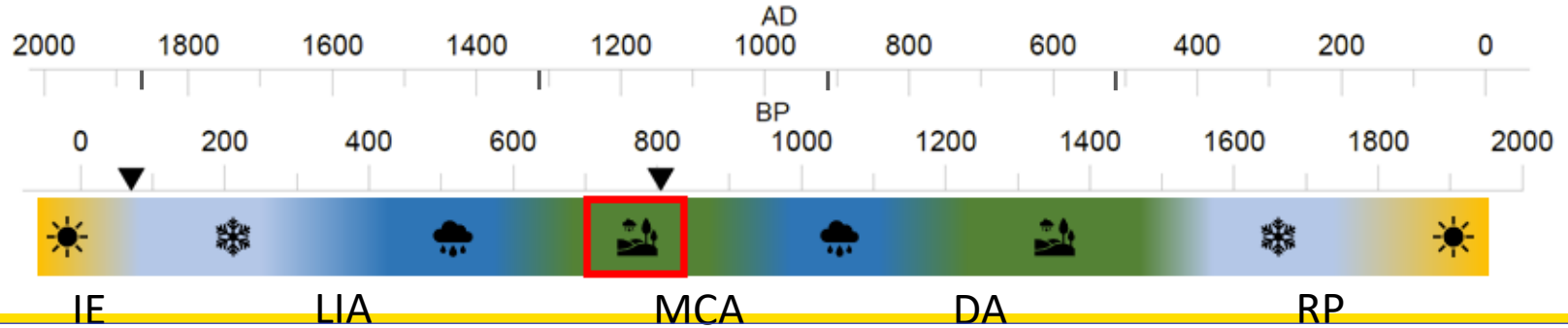


Lake Peixão - growing season

Presence of Aquatics and temperate forest

Enhanced chemical weathering

Enhanced water column stratification



Dry and Warm
Dry and Cold
Cold and Wet
Warm and Wet
Abrupt Changes

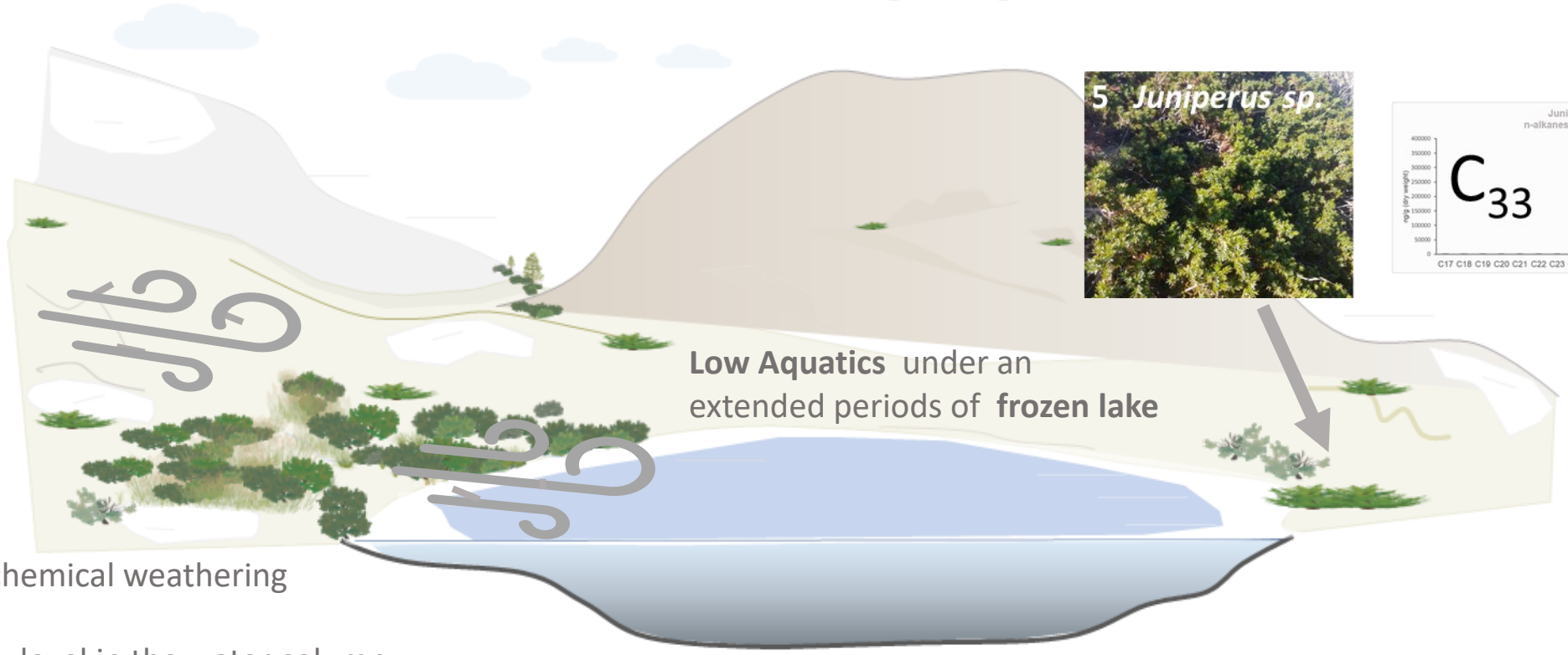
Vegetation art:
Tracey Saxby, Integration and Application Network (ian.umces.edu/media-library)
Brianne Walsh, Integration and Application Network (ian.umces.edu/media-library)

Ricardo N. Santos
23 May 2022

Conceptual model

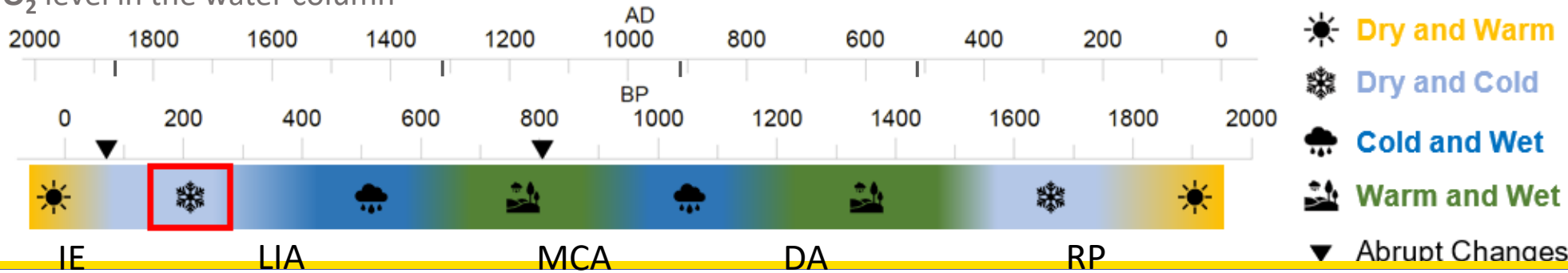
Dry and cold conditions

Lake Peixão - growing season



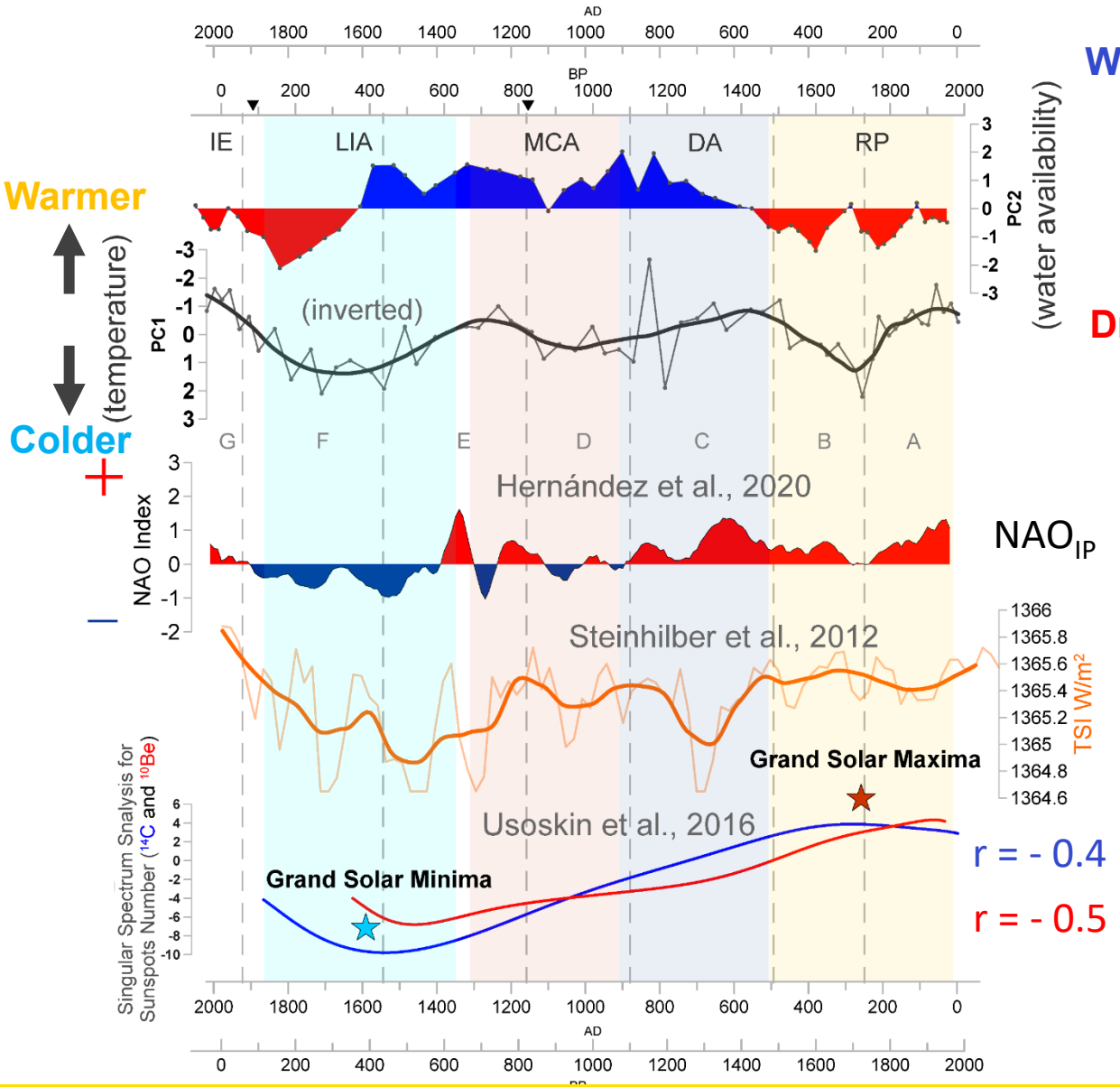
Reduce chemical weathering

Higher O_2 level in the water column

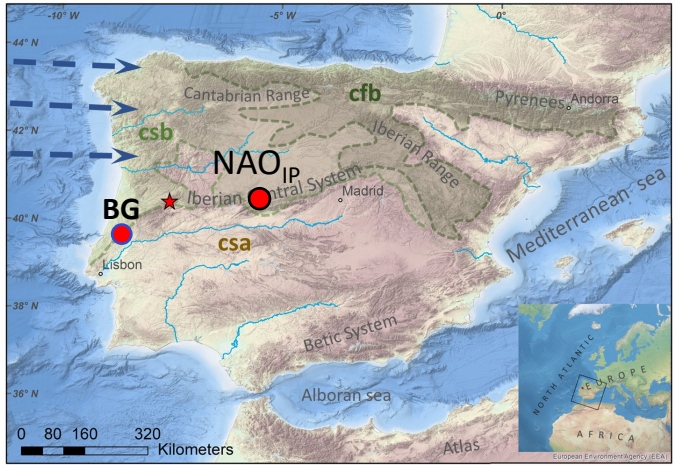


Vegetation art:
Tracey Saxby, Integration and Application Network (ian.umces.edu/media-library)
Brianne Walsh, Integration and Application Network (ian.umces.edu/media-library)

Ricardo N. Santos
23 May 2022



Climate Forcings



NAO reconstruction

Smooth lines correlation

PC1 and **NAO$_{IP}$** : **r = - 0.7** (p <0.0

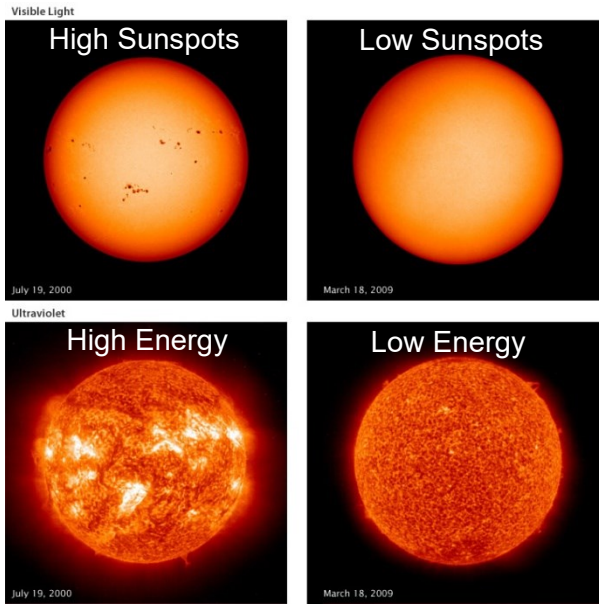
Solar Variability

Smoothed lines of PC1 and solar variability

r = - 0.4, p <0.01

Total solar irradiance

Sunspots



https://www.climate.gov/news-features/understanding-climate/climate-change-incoming-sunlight

Main conclusions

- ✓ The **vegetation type** has **not change significantly** over the last 2000 years, however the **relative proportions** of *n*-alkanes **signal** allowed to infer some significant **changes in climate and environment conditions.**

- ✓ Isotopic signals of C_{27} and C_{29} can reflect changes in the lake and terrestrial hydrology, respectively.

- ✓ **Roman Period:** generally dry climate under a prevailing **NAO+** and **Grand Solar Maxima,** with two phases, a first warm and a second cold phases.

- ✓ **Dark Ages** and **Medieval Climate Anomaly:** the climate were generally **warm and wet,** with **colder and drier** interval between the two periods, under a more variable NAO.

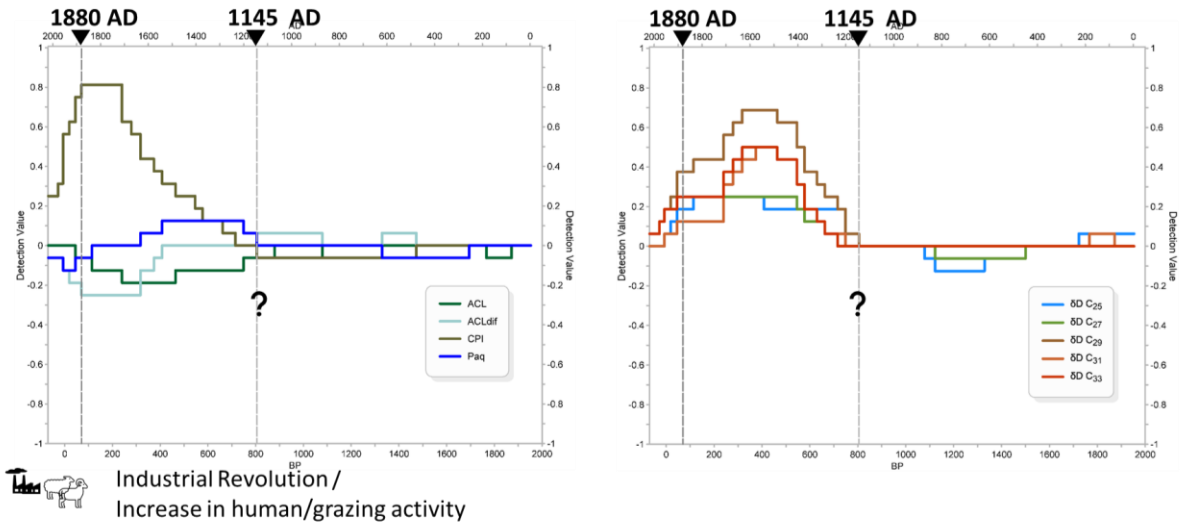
- ✓ **Little Ice Age:** Cold period under **NAO-** and **Grand Solar Minima, first** phase of **cold and wet** climate and a **second** especially **cold,** which dry conditions may be the result of a temperature **mask effect**.

- ✓ **Since 1880 AD,** with the onset of the **Industrial Era,** there is a significant shift towards **warm and dry** conditions**.**

Future Works

- **Improve** the *n*-alkane characterization of modern vegetation and topsoils in **Serra da Estrela.**

- Understand the causes of the **abrupt changes** detected in *n*-alkane signal using a new statistical approach.



- **Improve climate and environmental reconstructions** in the core such as temperature, biomass burning and anthropogenic impact using new biogeochemical tools (**PAHs** and **brGDGTs**).

The authors are grateful to FCT (Fundação para a Ciência e a Tecnologia) for the financial support of this work through the projects: HOLMODRIVE—*North Atlantic Atmospheric Patterns Influence on Western Iberia Climate*: *From the Late Glacial to the Present* (PTDC/CTA-GEO/29029/2017). WarmWorld—*Features, and lessons from Past Interglacials "warm periods" during the last 1.5 Ma* (PTDC/CTA-GEO/29897/2017). RNS´s grant supported by Ultimatum—*Understanding past climatic instabilities in the North Atlantic Region* (IF/01489/2015)

FCT Fundação para a Ciência e a Tecnologia (PTDC/CTA-GEO/29029/2017) HOLMODRIVE PROJECT INSTITUTO DOM LUIZ IPMA marum Center for Marine Environmental Sciences CCMAR POLAR2E Polar & Extreme Environments ESTRELA GEOPARK UNESCO Organização das Nações Unidas para a Educação, a Ciência e a Cultura Estrela Geoparque Mundial da UNESCO