EGU General Assembly 2020

Flood variability in northern Spain during the last millennium recorded in lacustrine sedimentary archives

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IGE

FLOODS

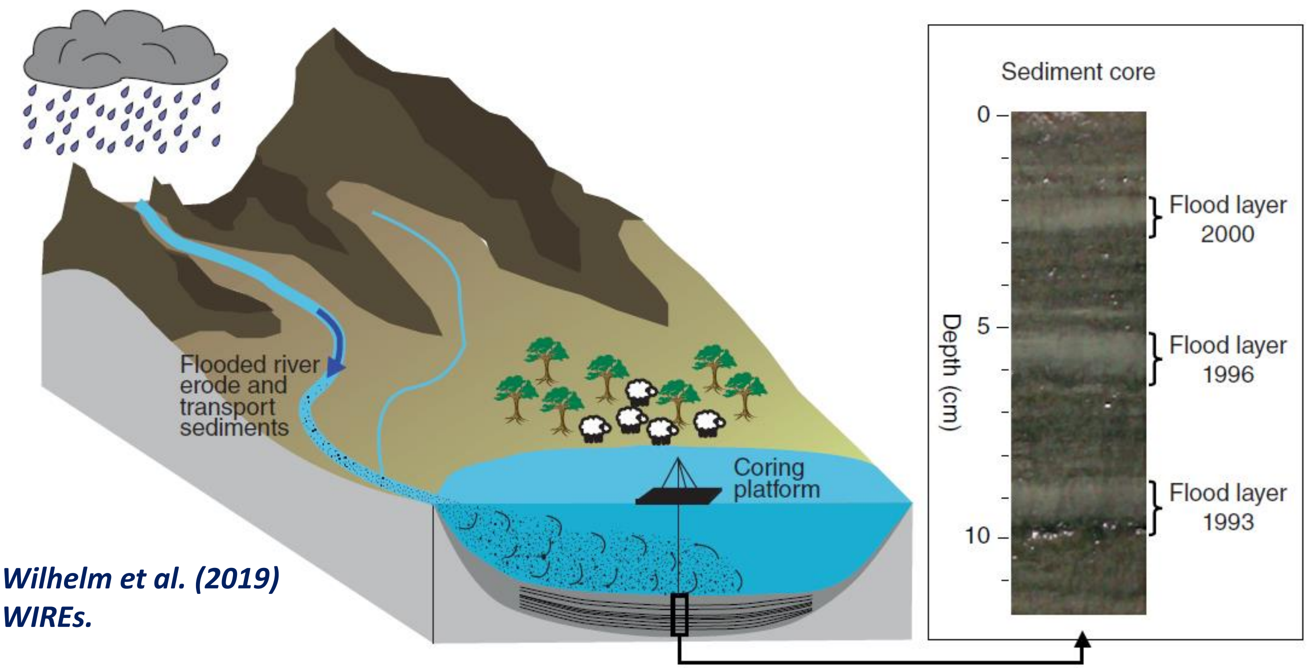
Extreme floods in the Iberian Peninsula has devastating consequences in terms of **casualties** and **economic losses**

Flood hazard ➡ *Need to understand the frequency variability of extreme hydrological events*

INSTRUMENTAL RECORD -> Barely spans the last decades

Long-term proxy data series (natural archives)

Lakes sensitive to extreme hydrological events



Wilhelm et al. (2019) WIREs.

Floods are recorded as discrete **sedimentary layers**

Archives of long-term flood variability in alpine environments

FLOODARC Marie Curie action

Sediment core repositories

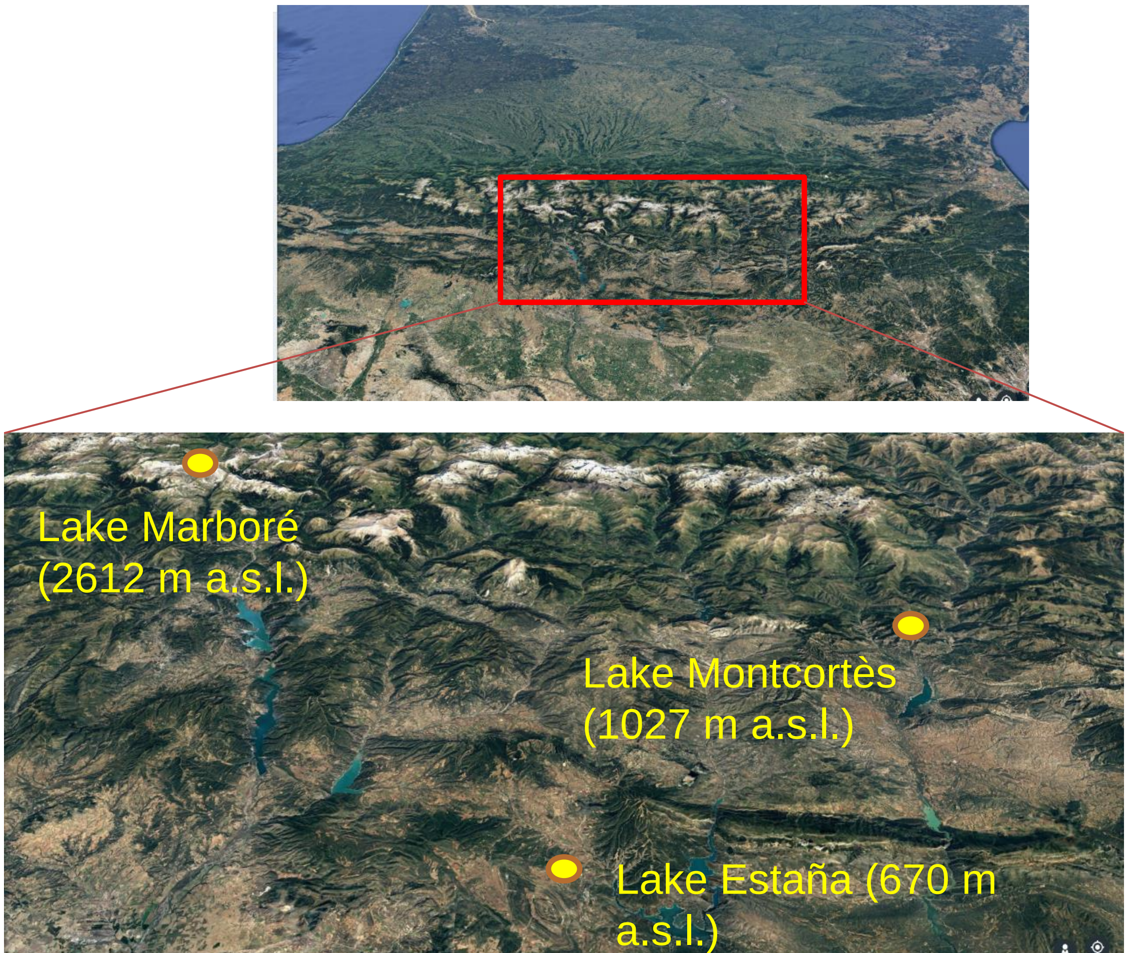
We have investigated 5 lake records in N Spain

Goal: Understand flood variability in the Iberian Península using lacustrine archives

A) Flood variability across an altitudinal transect in Southern Pyrenees

B) Flood variability across an E-W transect in Northern Spain

A) Flood variability across an altitudinal transect in Southern Pyrenees

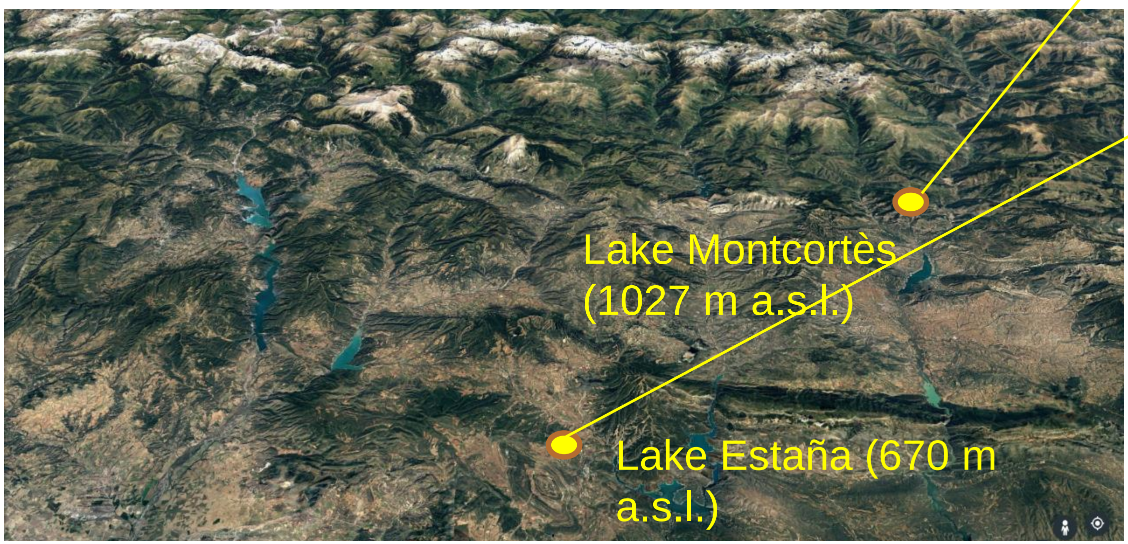


- **Small watersheds (7-18 ha)**
- **Carbonated bedrock**
- **Similar water depths (24-30 m)**

A) Flood variability across an altitudinal transect in Southern Pyrenees

Sub-alpine lakes

- *Mid-montane areas*
- *Non connected with main fluvial systems*
- *Not affected by snowmelt and ice phenology*
- *Precipitation regime controlled by spring and autumn floods*
    - *800-900 mm/yr in Lake Montcortès*
    - *500-600 mm/yr in Lake Estanya*
- *Historical land-use and vegetation changes*



Montcortès

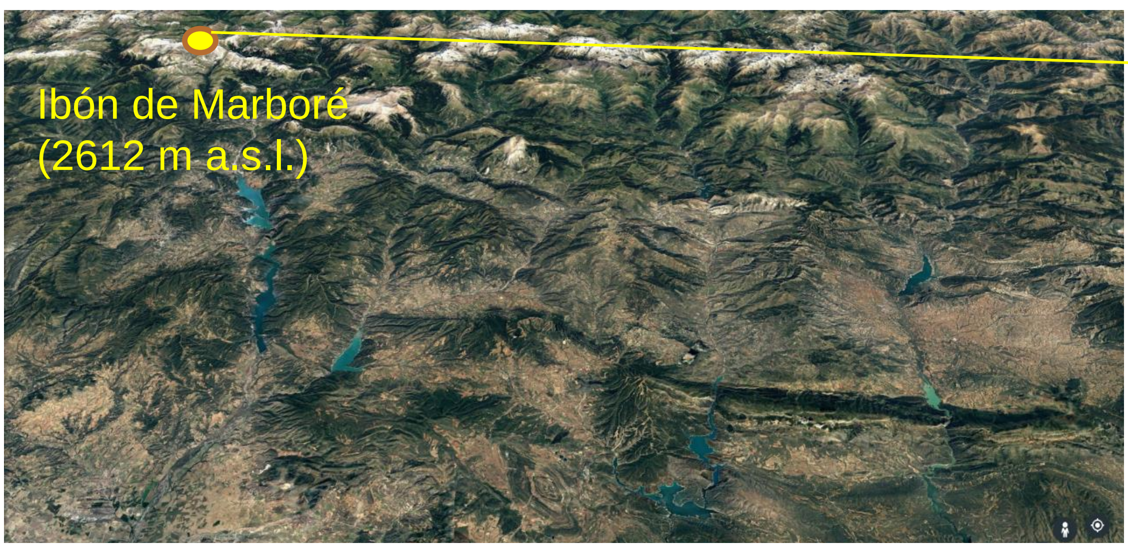
Estaña

- **Small watersheds (7-18 ha)**
- **Carbonated bedrock**
- **Similar water depths (24-30 m)**

A) Flood variability across an altitudinal transect in Southern Pyrenees

Alpine lakes

- *High-alpine environment*
- *Strongly affected by cold processes*
  - *Permafrost*
  - *Snow-melt*
  - *Ice phenology*
- *Precipitation regime controlled by summer and autumn floods*
  - *2000 mm/yr in Lake Marborè*
- *Not affected by historical land-use and vegetation changes*



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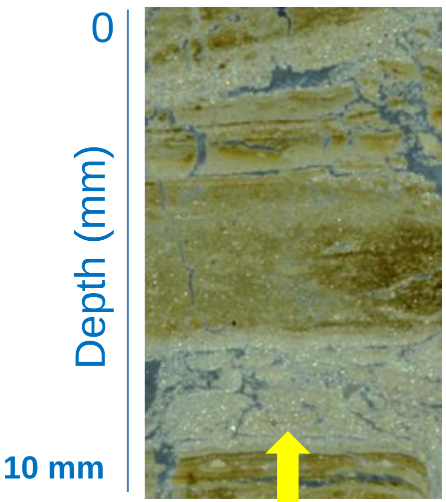
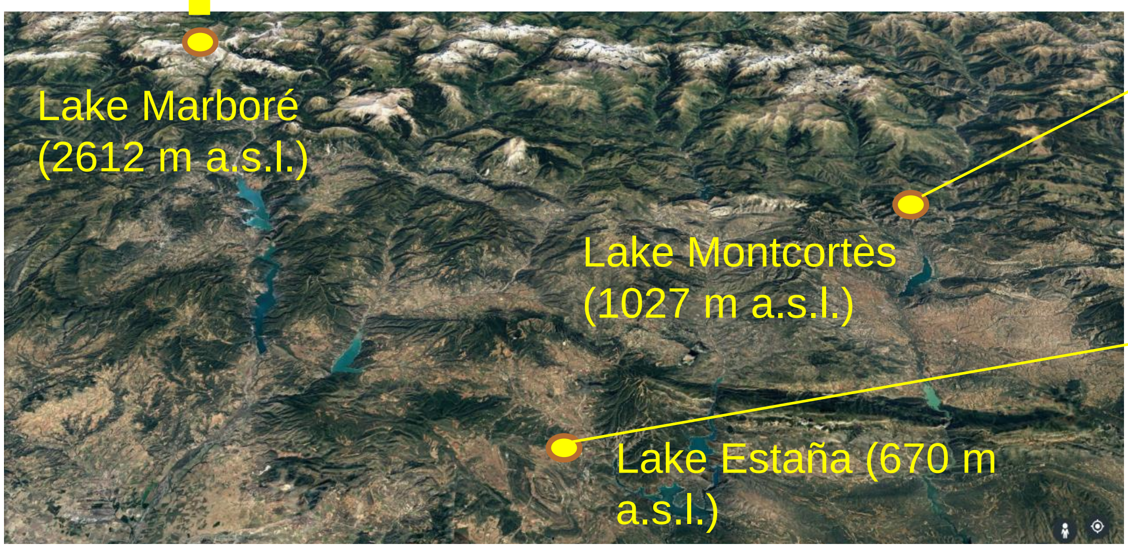
Flood layers in the Pyrenean lakes

Alpine lake (Marboré)

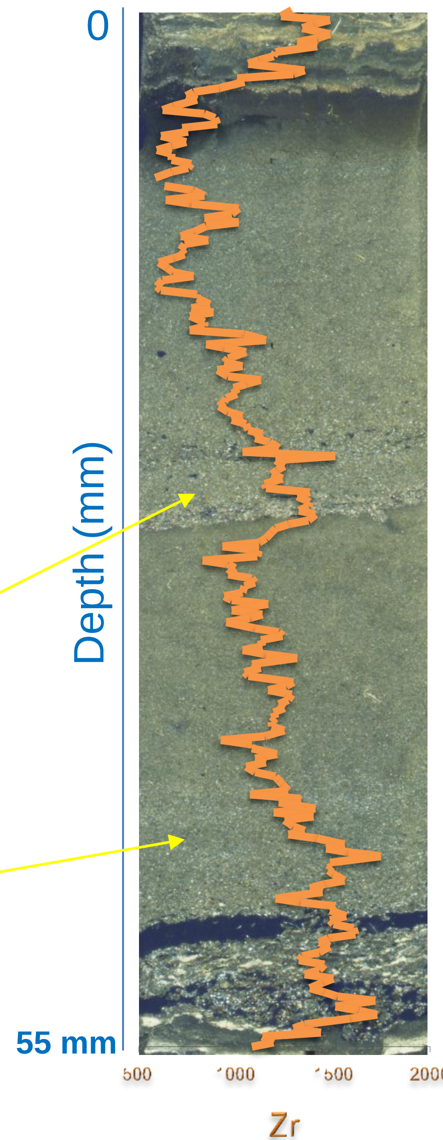


- *Finning upward sequences*
- *Coarser grain-size*
- *Variable thicknesses (mm to cm)*
- *Enriched in terrigenous elements*

Zr, Ti, K, Si, Al… grouped in eigenvectors (PC1)



Sub-alpine lakes (Montcortès and Estaña)



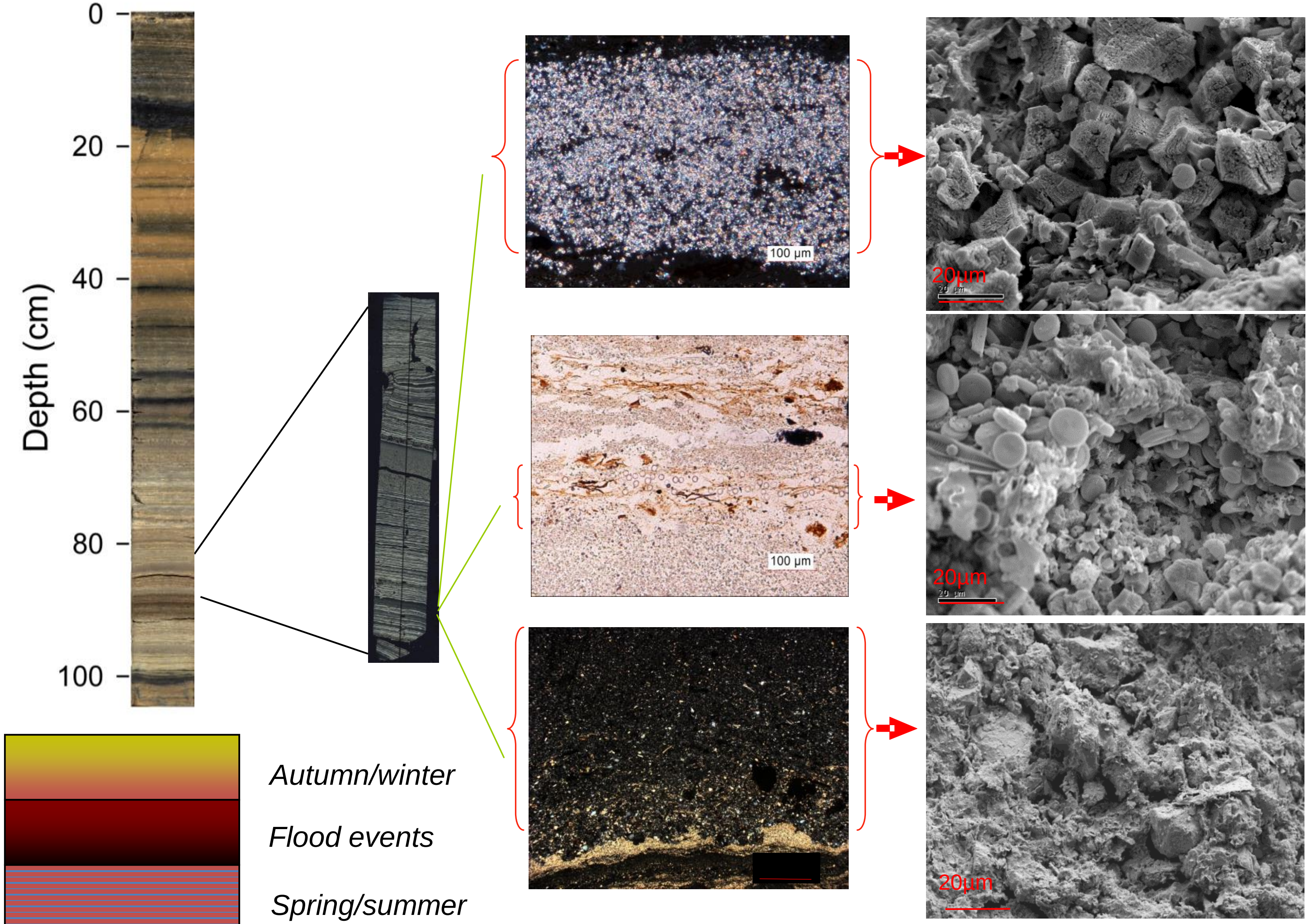
Lake Montcortès

Unique annually-laminated “varved” record
in Southern Europe

Flood record with seasonal resolution for the last 2800 years

Biogenic varves

Corella et al. (2012). Quat. Res.



Calcite layer

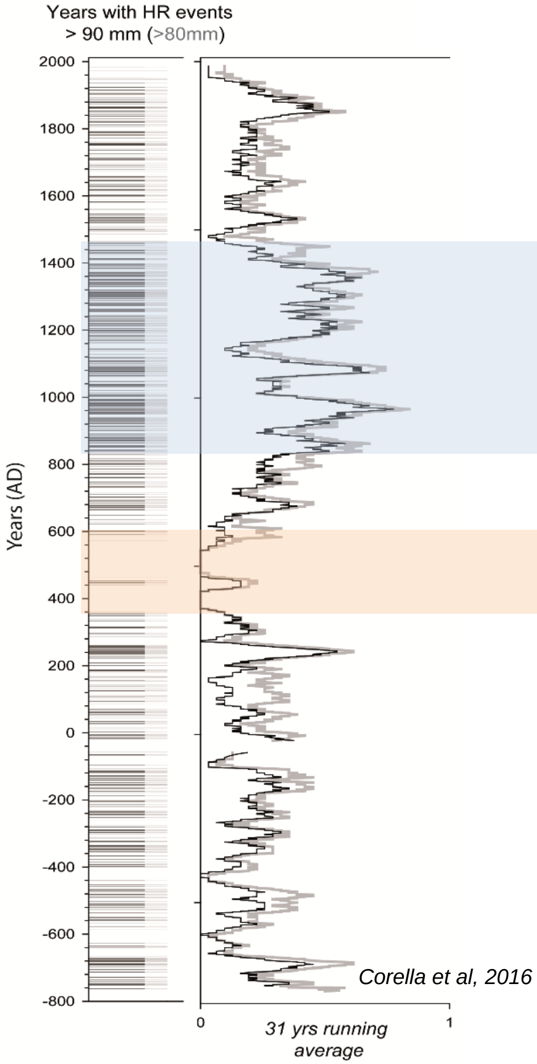
Organic layer

Detrital layers and turbidites

- Detrital mud
- Organic matter
- Endogenic calcite

Flood layers

Flood reconstruction during the Late Holocene



Medieval Climate Anomaly

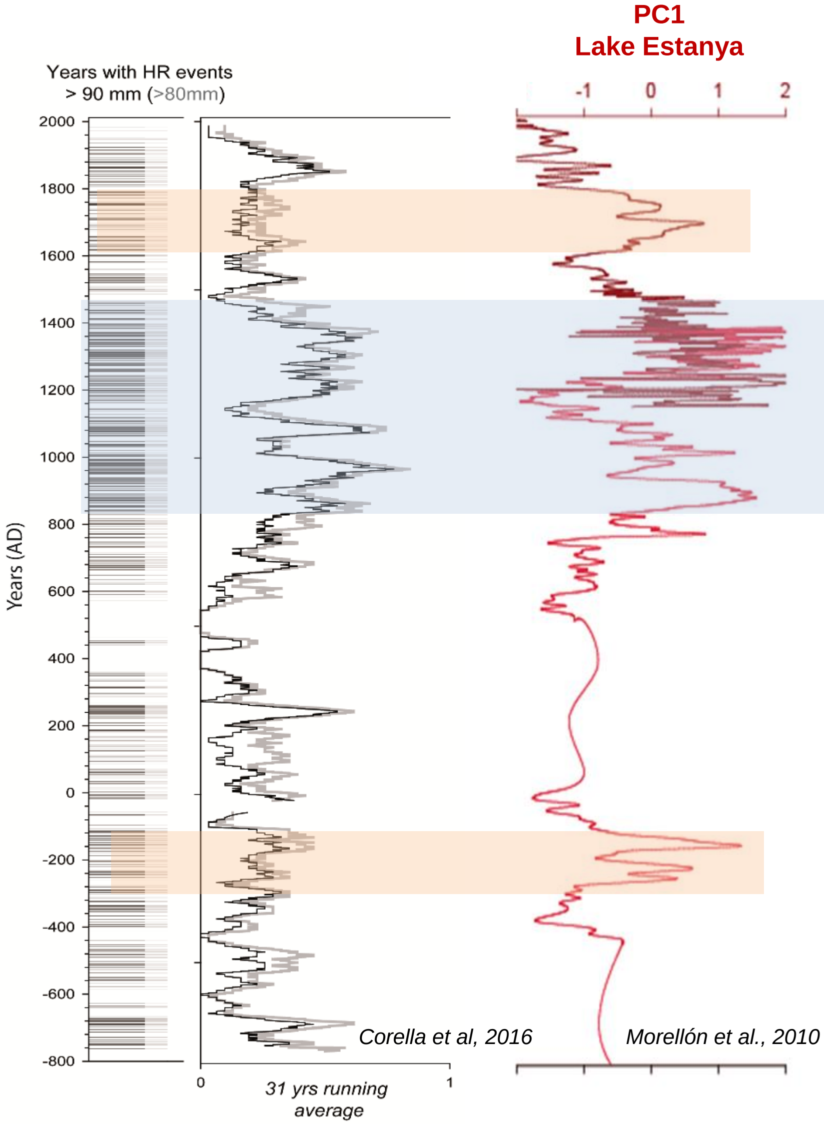
Largest hydrometeorological variability during the MCA

Migration Period

Persistent hydrological deficit
300 years with only two storm events…

Visigoths invaded Iberia in the 6th century

Flood reconstruction during the Late Holocene



Good agreement between sub-alpine lakes in the Pre-Pyrenees

Medieval Climate Anomaly

Largest hydrometeorological variability during the MCA

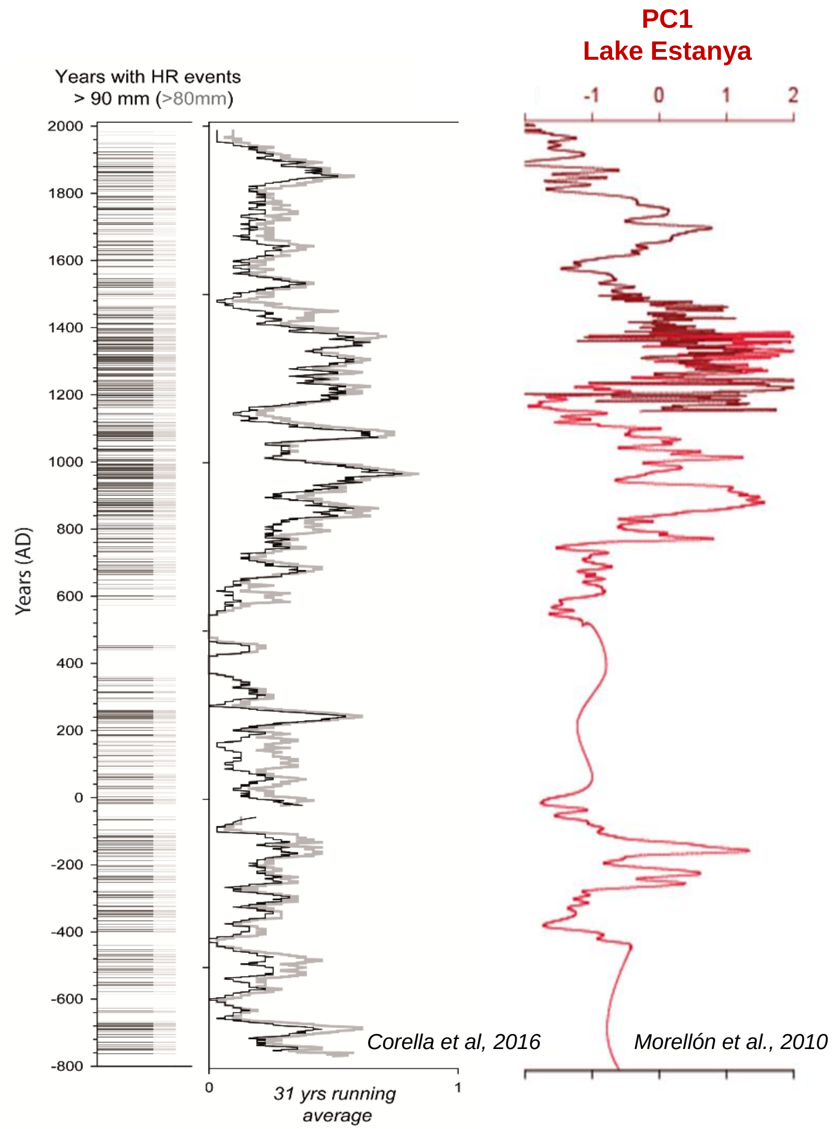
Different flood signals in specific time-intervals that can be explained by….

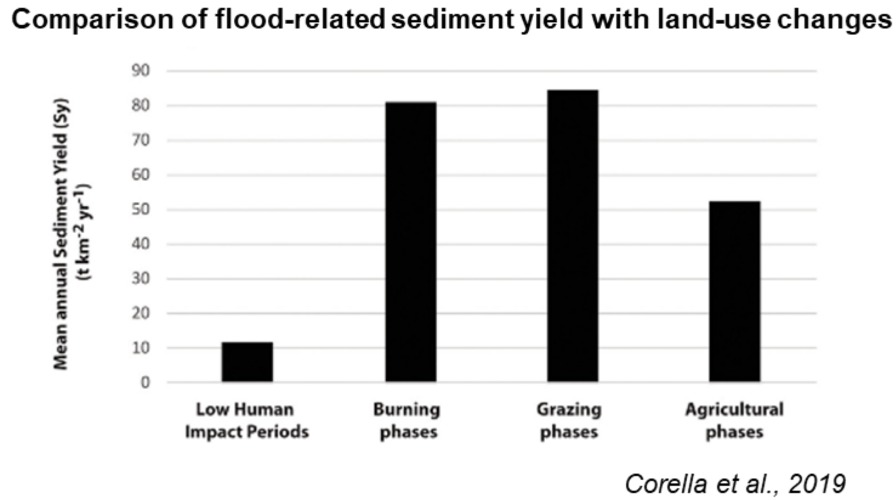
- *Spatial heterogeneity of* ***local convective storms***
- *Different* ***land use changes***

Comparison of flood layers frequency with vegetation reconstructions to evaluate the influence of land use on run-off generation at decadal to centennial time-scales

Pre-Pyrenean sub-alpine lakes

Flood reconstruction during the Late Holocene





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- *Spatial heterogeneity of **local convective storms***
- *Different **land use changes***

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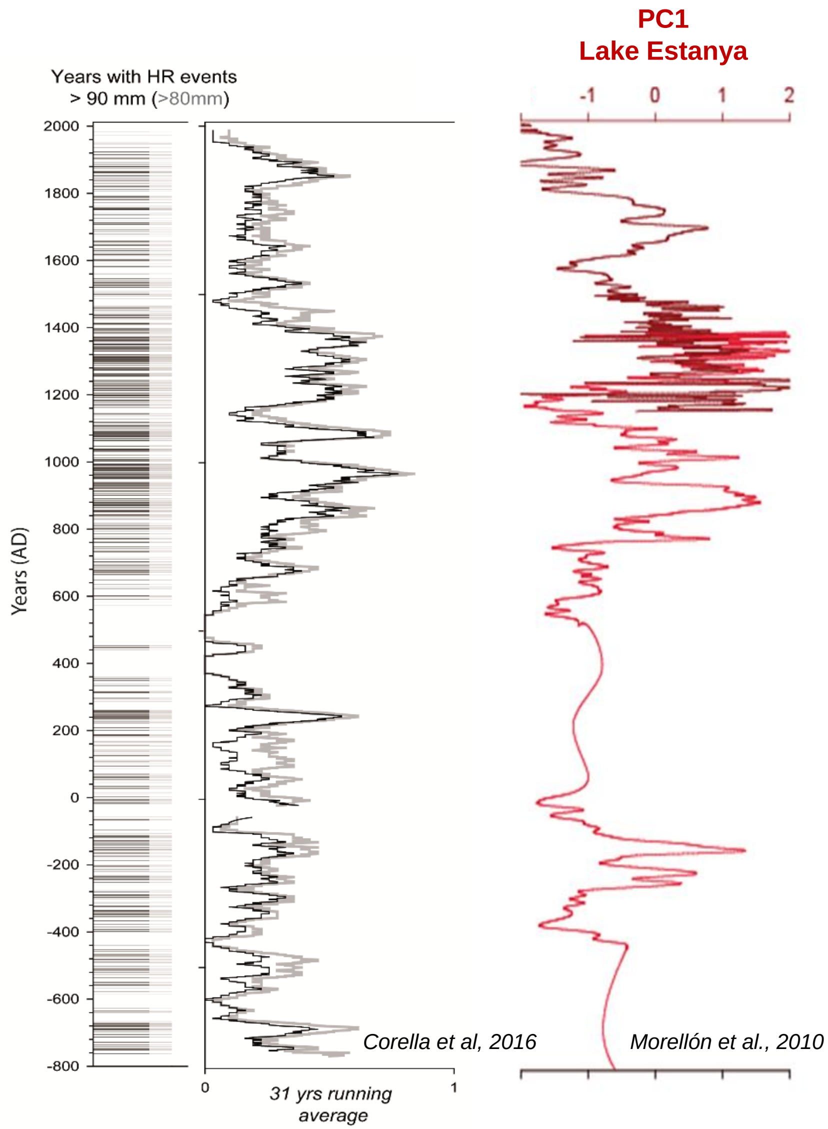
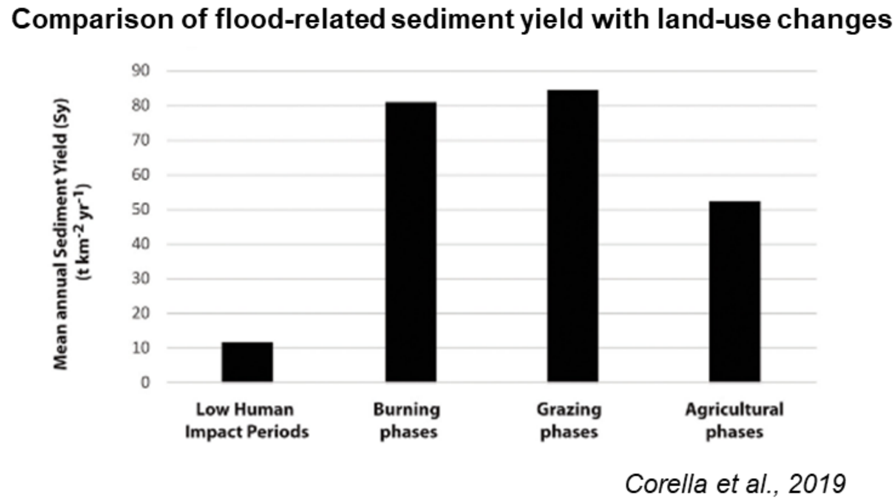
Pre-Pyrenean sub-alpine lakes

Flood reconstruction during the Late Holocene



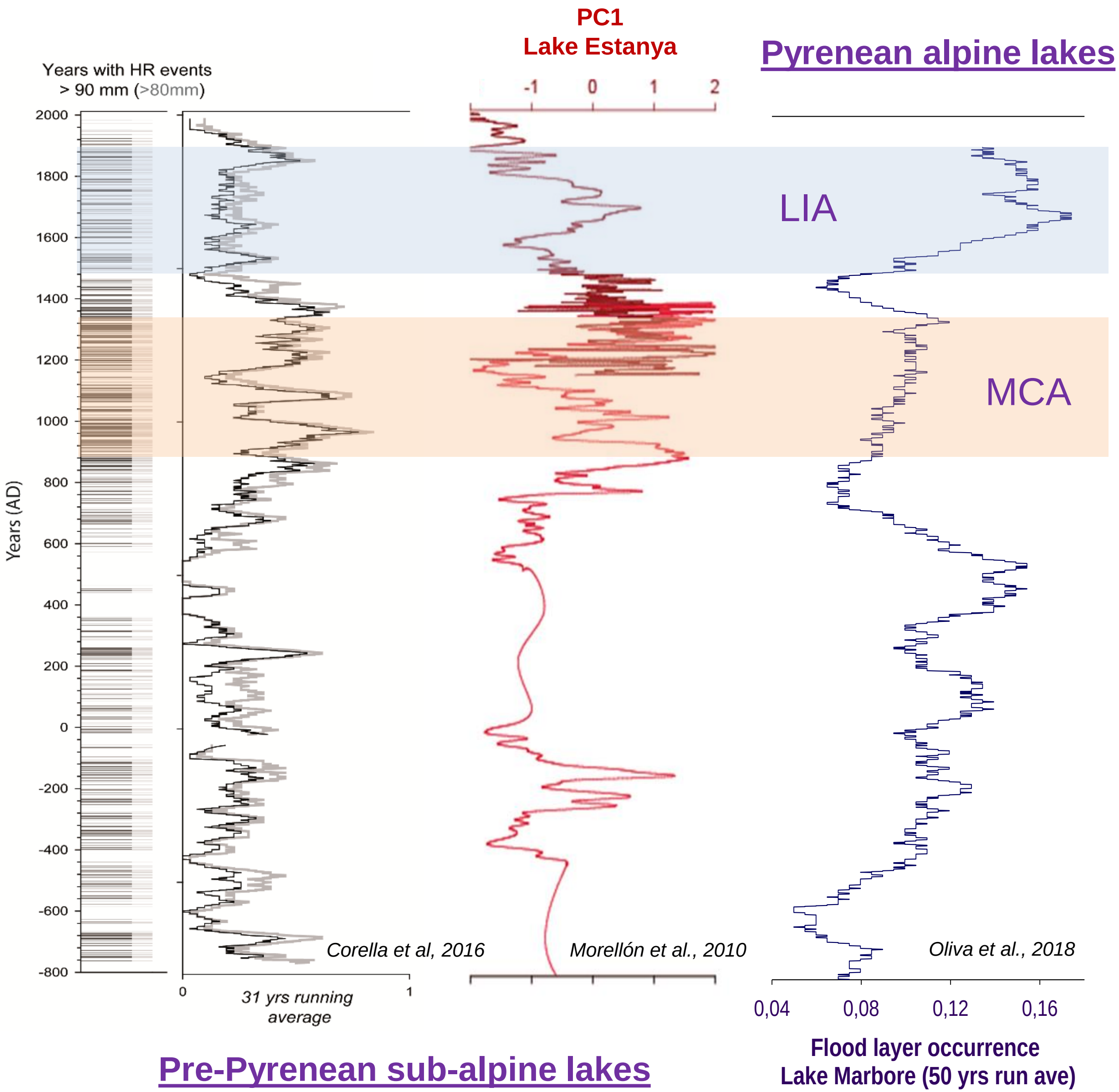


Extreme run-off events are strongly affected by land use changes in mid-montane areas

But… How was the flood and run-off variability in high-alpine environments?

Pre-Pyrenean sub-alpine lakes

Late Holocene flood variability in the Central Pyrenees



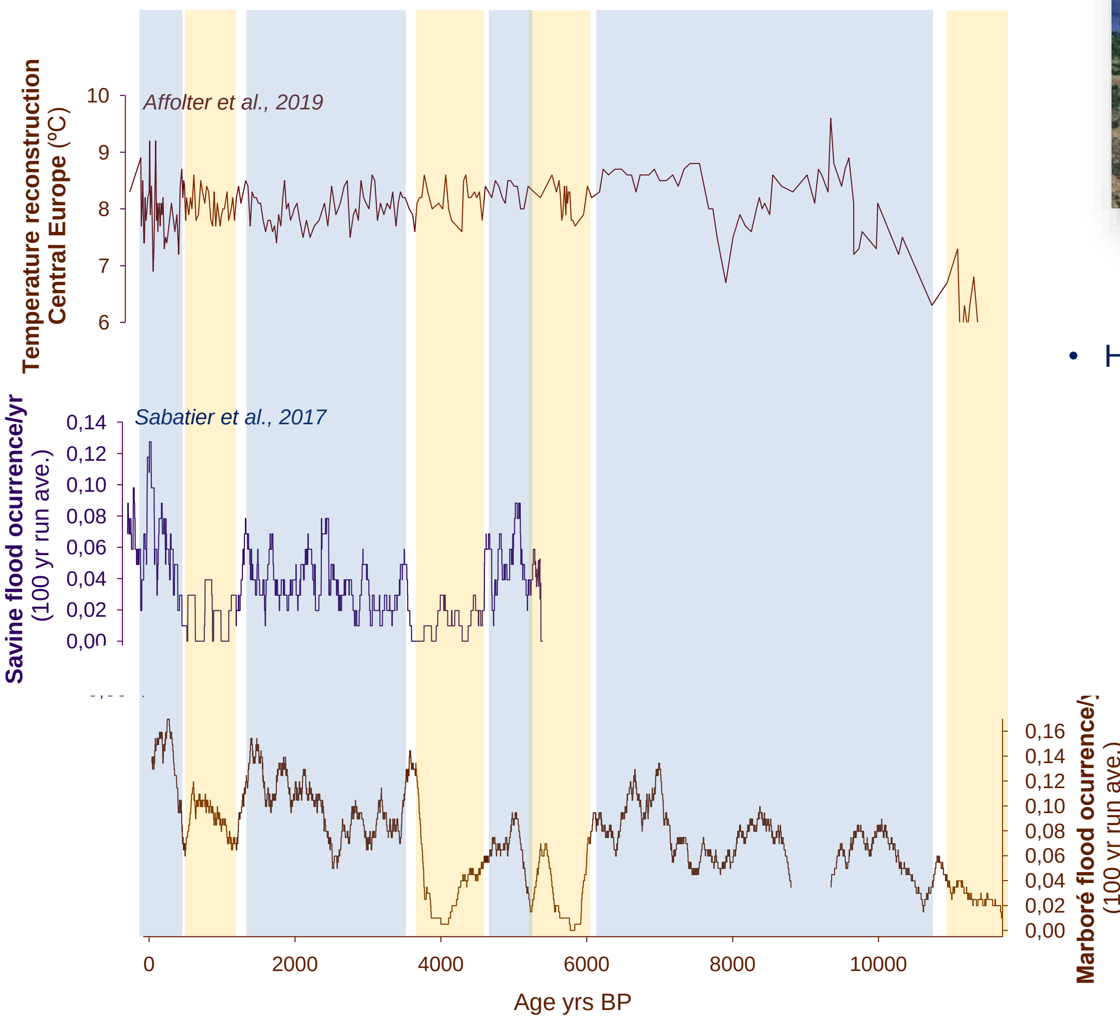
Strong flood variability across the altitudinal gradient

Different forcings controlling run-off generation

- Ice phenology - Lake Marboré only records **summer and early autumn floods**
- Not influenced by land use and vegetation changes
- Direct run-off response to storminess frequency variability

Holocene flood variability in the Central Pyrenees

Complex relation between temperature and flood variability



- Higher flood frequency
  - *10-6 ka BP*
  - *5,2-4,8 ka BP*
  - *3,7-1,6 ka BP*
  - *0.4-present ka BP*
- Lower flood frequency
  - *11,7-10 ka BP*
  - *6-5,2 ka BP*
  - *4,8-3,8 ka BP*
  - *1,6-0,4 ka BP*

*Relative good **agreement** between long-term flood variability in the Alps and the Pyrenees*

A) Flood variability across an altitudinal transect in Southern Pyrenees

To sum up…

- **First lacustrine paleoflood reconstructions in the Pyrenees during the last 11,700 years**

- **Large spatio-temporal heterogeneity in flood frequency variability across an altitudinal transect in the Central Pyrenees**

- **Low-elevation (sub-alpine) records are strongly influenced by historical land-use changes**

- **High-elevation (alpine) record (Lake Marboré) shows summer and early autumn flood frequency evolution in the Pyrenees during the Holocene**

  - ***In agreement with similar paleoflood reconstructions in Western Alps***

B) Flood variability across an E-W transect in Northern Spain

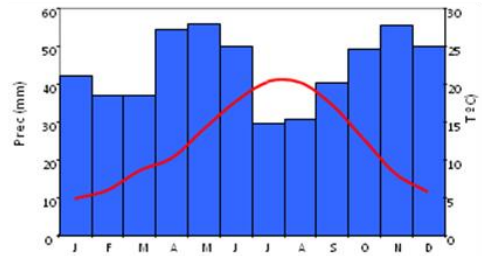
We have investigated flood variability during the last millennium in four different lake records

All of them located in mid-montane regions (600-1000 m a.s.l.)

Lake Arreo

Climate

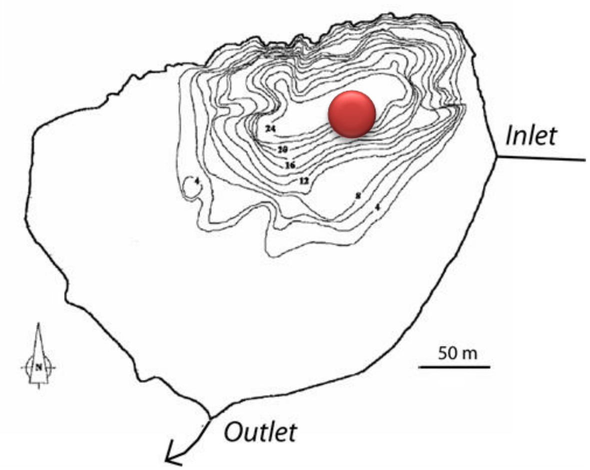
- **Atlantic-Mediterranean**
- 655 m a.sl.
- 670mm/yr
- 12ºC average
  - -20ºC (July)
  - - 5ºC (February)



Vegetation

- **Evergreen** and deciduous oak forest
- Conifers
- Cultivated lands and pastures

Sediment core ARR04-1A-1K

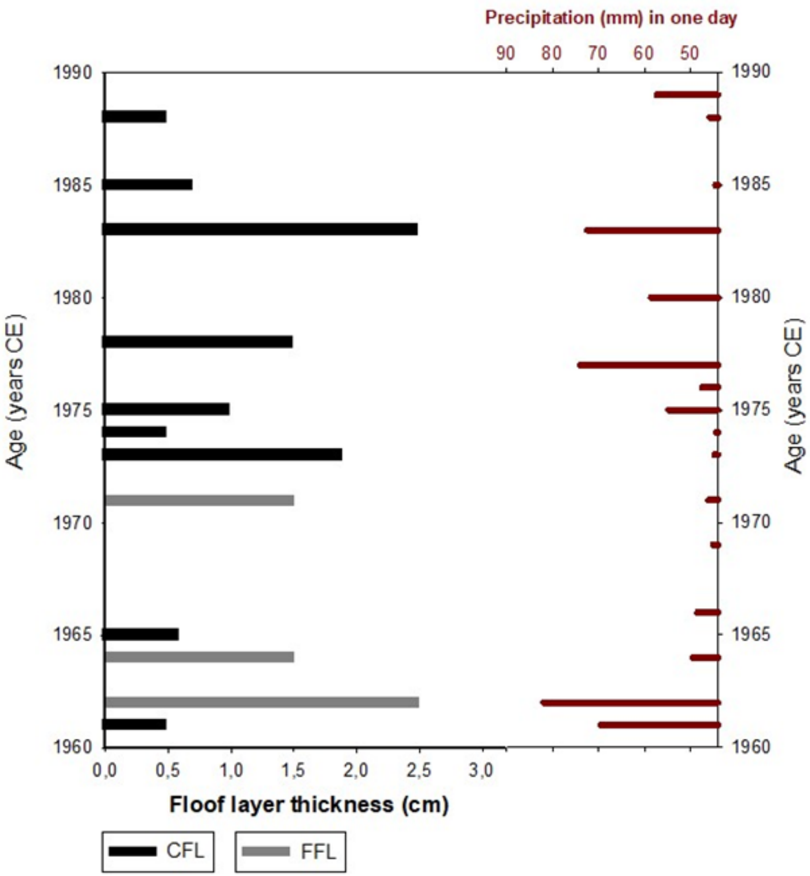


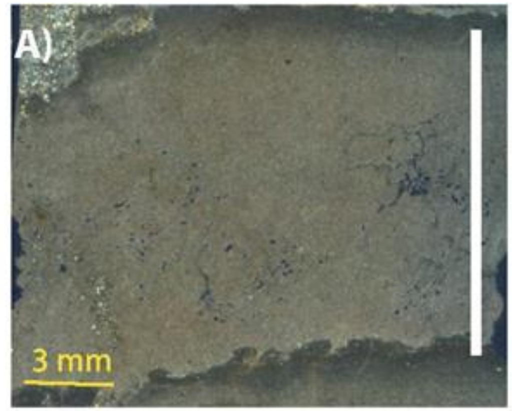
Hydrology and Limnology

- **Morphology:**
  - **Funnel-shaped**
  - **24m depth**
- **Hydrology:**
  - **Groundwater inputs**
    + **Inlet**
  - **Evaporation outputs**
    + **Outlet**
- **Water chemistry:**
  - **Subsaline**
  - Ca-(Mg)-(Na)-SO_4-HCO_3-(Cl)
- **Limnology:**
  - **Mesothropic**
  - **Holomictic (tendence to meromixis)**

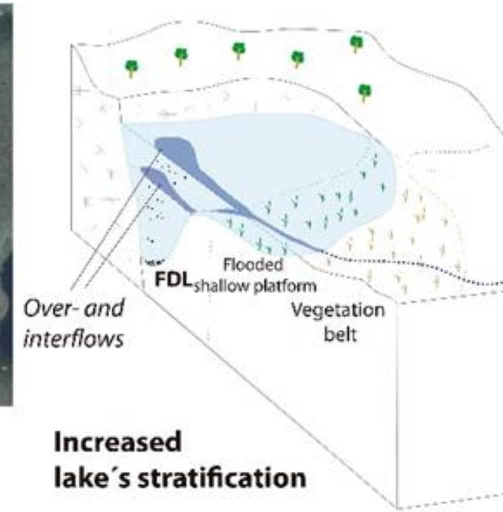
Lake Arreo

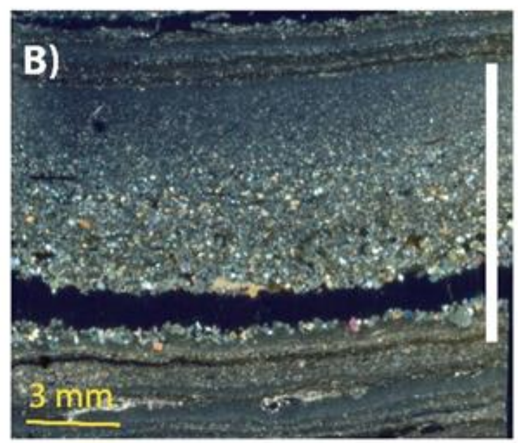
2 flood layer types correlating with regional heavy rainfall extremes



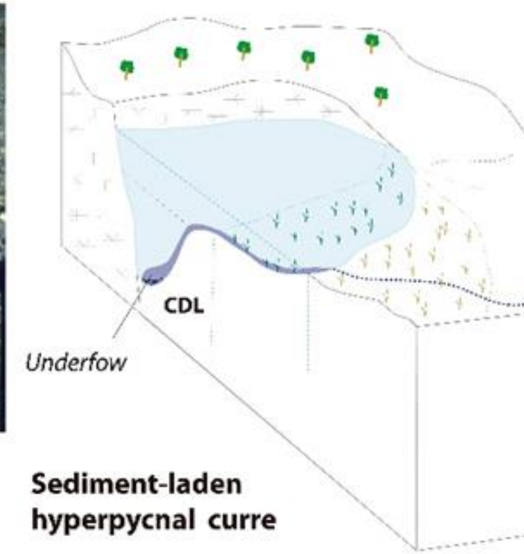


Fine Flood Layers (FFL)

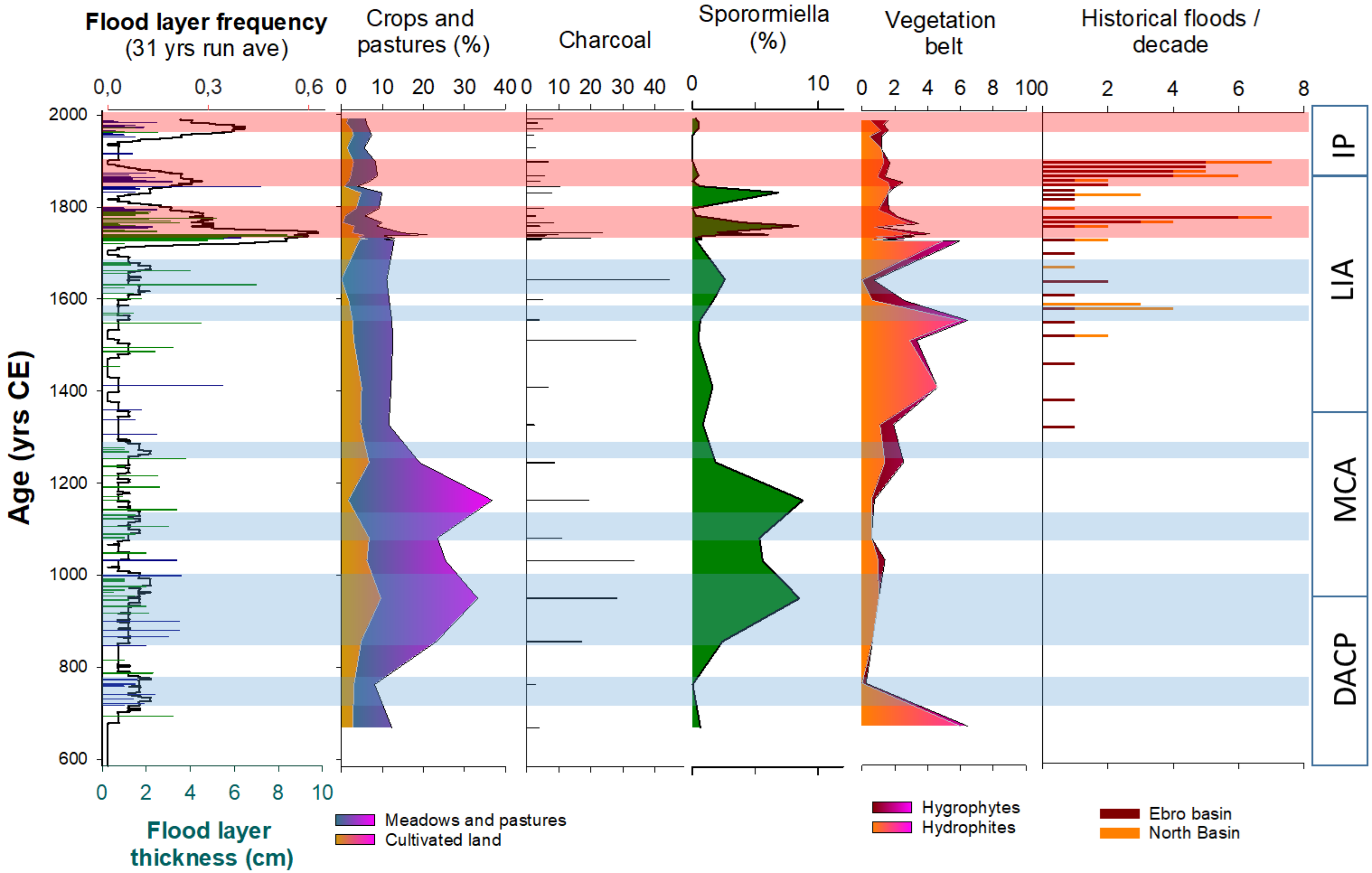




Coarse Flood Layers (CFL)



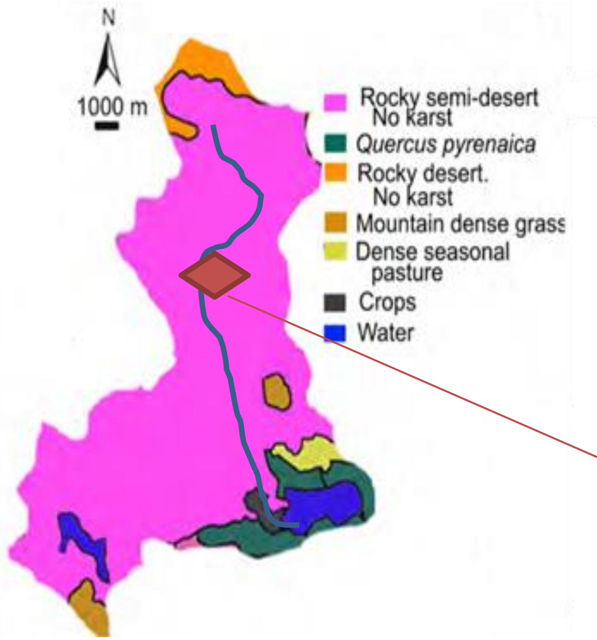
Lake Arreo



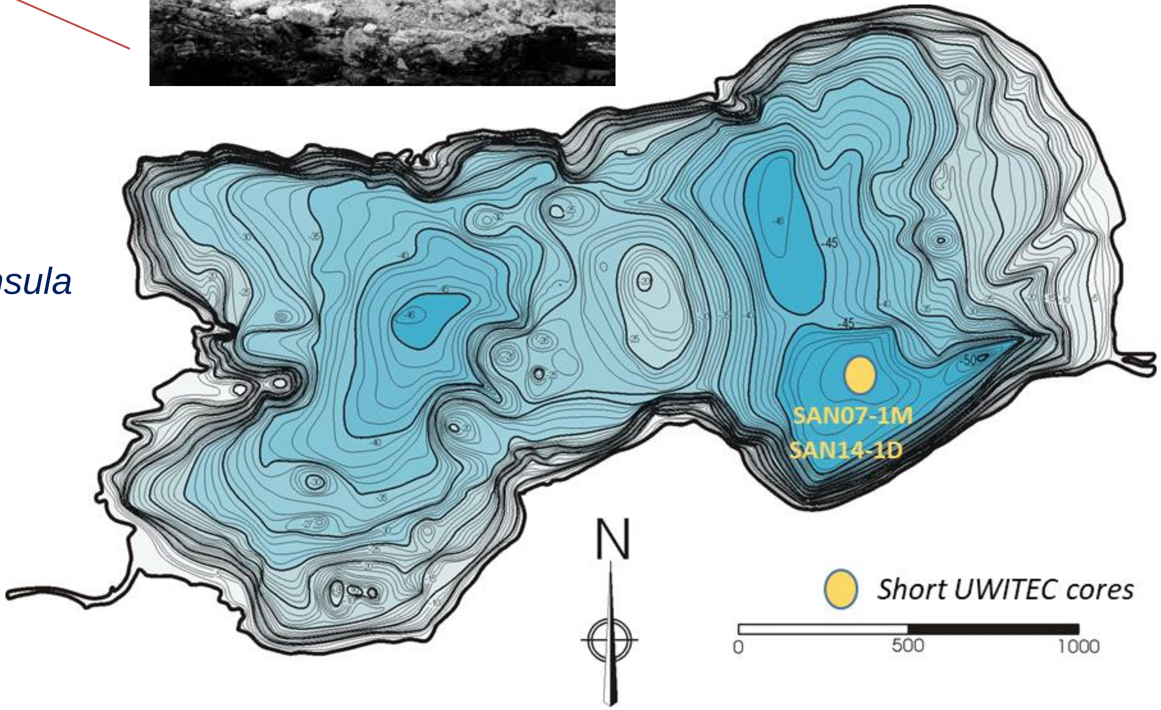
Moderate flood-rich periods: *700-780, 850-1000, 1080-1150, 1250-1290* and *1590-1670* yrs CE

High flood-rich periods: *1720-1790, 1830-1870 and 1950-1990* yrs CE

Lake Sanabria



1959 Vega de Tera dam failure



-Largest glacial lake in the Iberia Peninsula

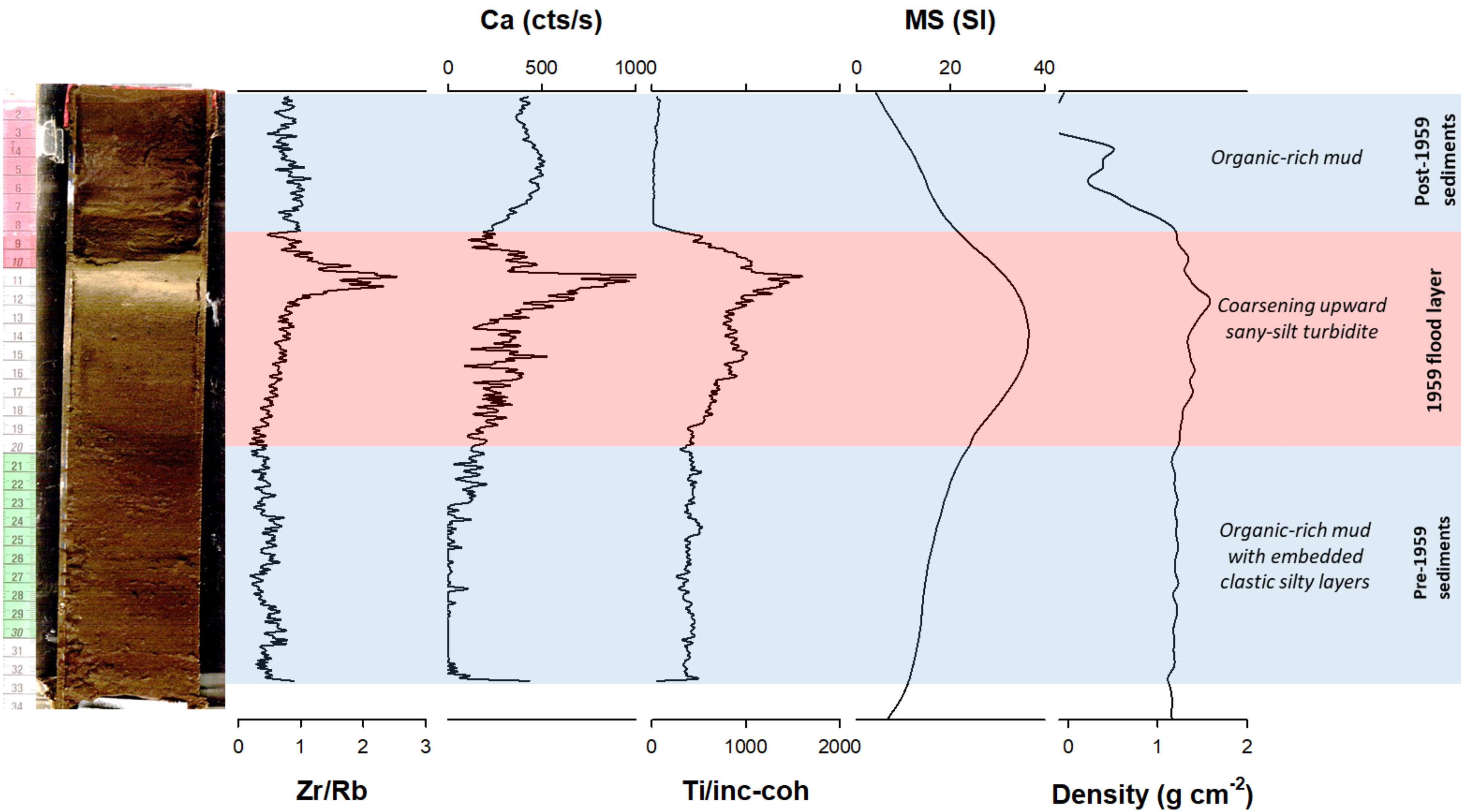
-Second largest lake in Spain (348 ha)

-1005 m a.s.l.

-Hydrologically open (Tera river)

-Large watershed (127.3 km^2)

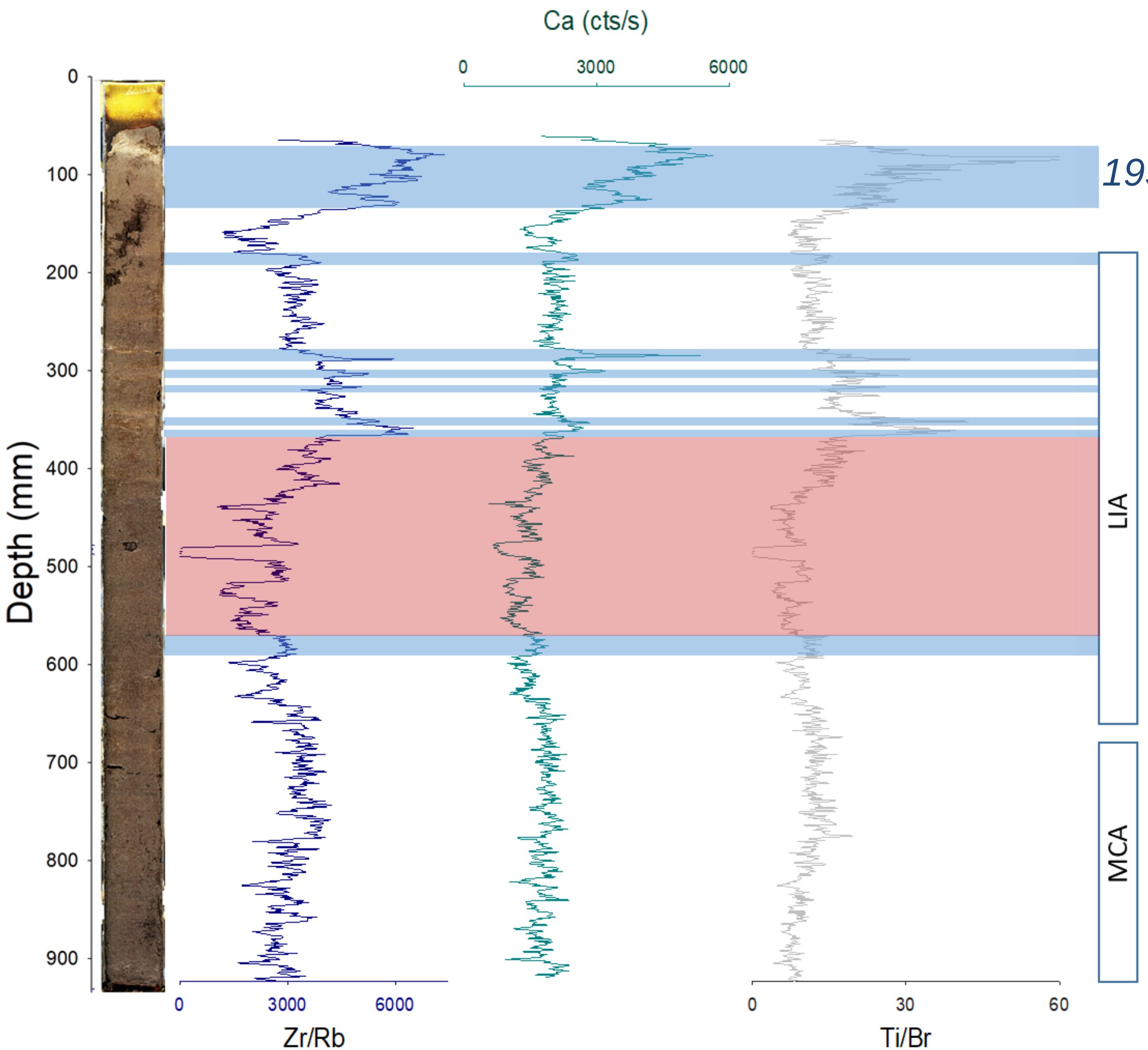
Lake Sanabria: The Vega de Tera 1959 catastrophic flood



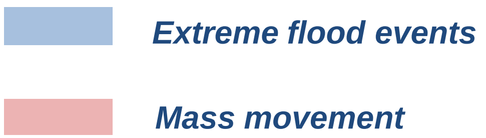
Largest flood recorded in a lake in the Iberian Peninsula

-Two orders of magnitude higher than any other flood layer recorded in Spain during the last millennium

Lake Sanabria: Extreme floods during the last millennium



- *Complex interplay between fluvial input and internal lake dynamics*
- *Increased in flooding events during the LIA*




Different flood frequency and magnitude variability in Atlantic Vs Mediterranean sites during the last millennium
MCA/LIA flood frequency variability
Mediterranean – flood-poor during the LIA
Atlantic – flood-rich during the LIA

Thanks

FLOODARC Project (2019-2021)

- **Understanding long-term FLOOD pattern variability in Western Mediterranean using natural ARChives**
- *MARIE SKŁODOWSKA-CURIE ACTION **H2020-MSCA-IF-2017***

MARIE CURIE ACTIONS

We acknowledge EU funding