

# Cross-border cooperation in the Pyrenees for the development of a green hydrogen economy & adaptation to climate change

**NEXT  
GEN  
EU**



**EU GREEN DEAL**

**MAKE IT  
REAL**

**PARTNER EVENT  
#EUGREENWEEK  
30 MAY – 5 JUNE 2022**



3rd June 2022



# Observation of the impact of climate change on the cryosphere: lakes, glaciers and permafrost

**NEXT  
GEN  
EU**

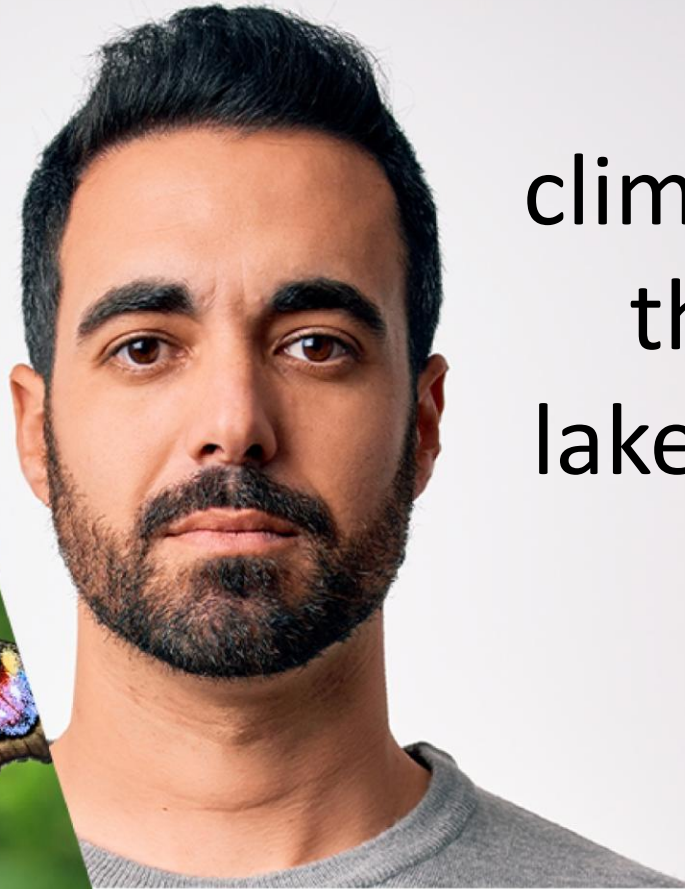


**EU GREEN DEAL**

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**BIODIVERSITY**

**PARTNER EVENT  
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# Something is changing



## What is the cryosphere?

The cryosphere is the frozen water part of the Earth system

# The Pyrenean Range



A dynamic mountain

- Atlantic and Mediterranean climate variability
- Long human history
- Recent warming & socioeconomic changes

# What we know

## Present

- Climate
  - Warming
  - Irregular Precipitation
  - Strong dust input in southern Pyrenees
- Watersheds
  - Some alpine plants shift
  - Increasing human pressure
  - Glacier/permafrost retreat
- Lakes
  - Thermal regimes
  - Ecological status
  - Biological changes
  - Pollution

## Past

- Paleoclimate
  - Temp.
  - Precipitation
  - Saharan Dust
- Watershed
  - Vegetation evolution
  - Neolithic, Medieval human impact
  - Neoglacial, Iron Age, LIA glacier advances
- Lakes
  - Depositional environments
  - Paleotemperatures
  - Bioproductivity and OM
  - Heavy metal stratigraphies

# What we do not know yet

- How past and current global changes compare?
- Interactions, synergies and feedbacks





# Cryosphere Sentinels of Climate Change





**REPLIM  
OPCC**

Réseau d'Observatoires des  
Ecosystèmes Sensibles (Lacs,  
Tourbières) au Changement  
Climatique dans les Pyrénées

Red de Observatorios de Ecosistemas  
Sensibles (Lagos, Turberas)  
al Cambio Climático  
en el Pirineo

Pyrenean Network of Climate Change  
Observatories in Sensitive  
Ecosystems (Lakes, Peatlands)

Xarxa d'Observatoris d'Ecosistemes  
Sensibles (Llacs, Torberes)  
al Canvi Climàtic al Pirineu

Klima Aldaketarekiko Sentikorrek diren  
Pirinioetako Ekosistemen  
(Aintziren, Zohikaztegien)  
Behatokiaren Sarea

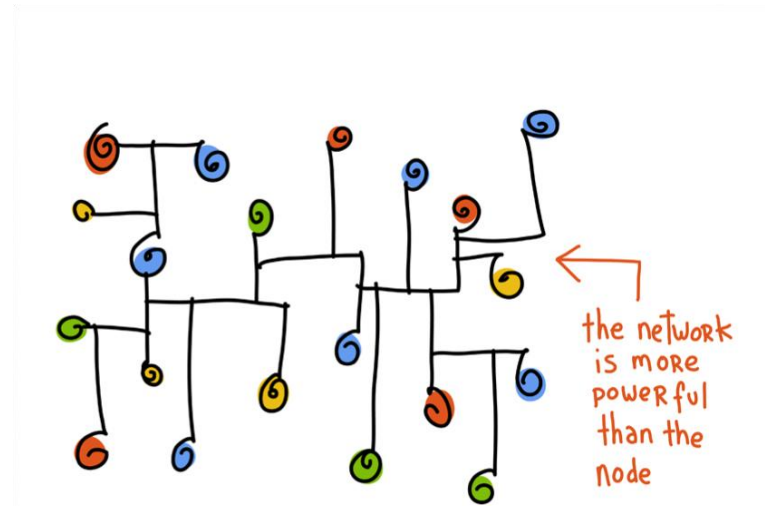
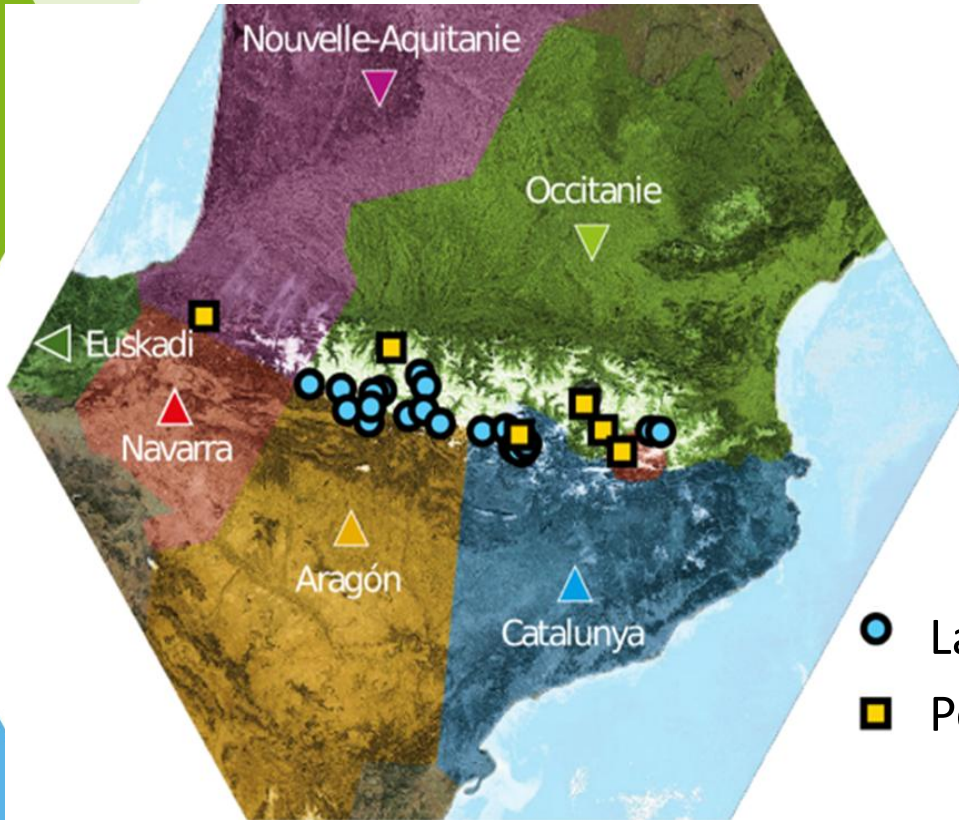
[www.opcc-ctp.org/replim](http://www.opcc-ctp.org/replim)

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Le projet REPLIM est cofinancé par le Fonds Européen de Développement  
Économique Régional (FEDER) dans le cadre du programme  
POCTEFA 2014-2020



# A network strategy



@gapingvoid

- Lakes
- Peatlands
- Monitoring
- Paleo

<https://opcc-ctp.org/en/replim>





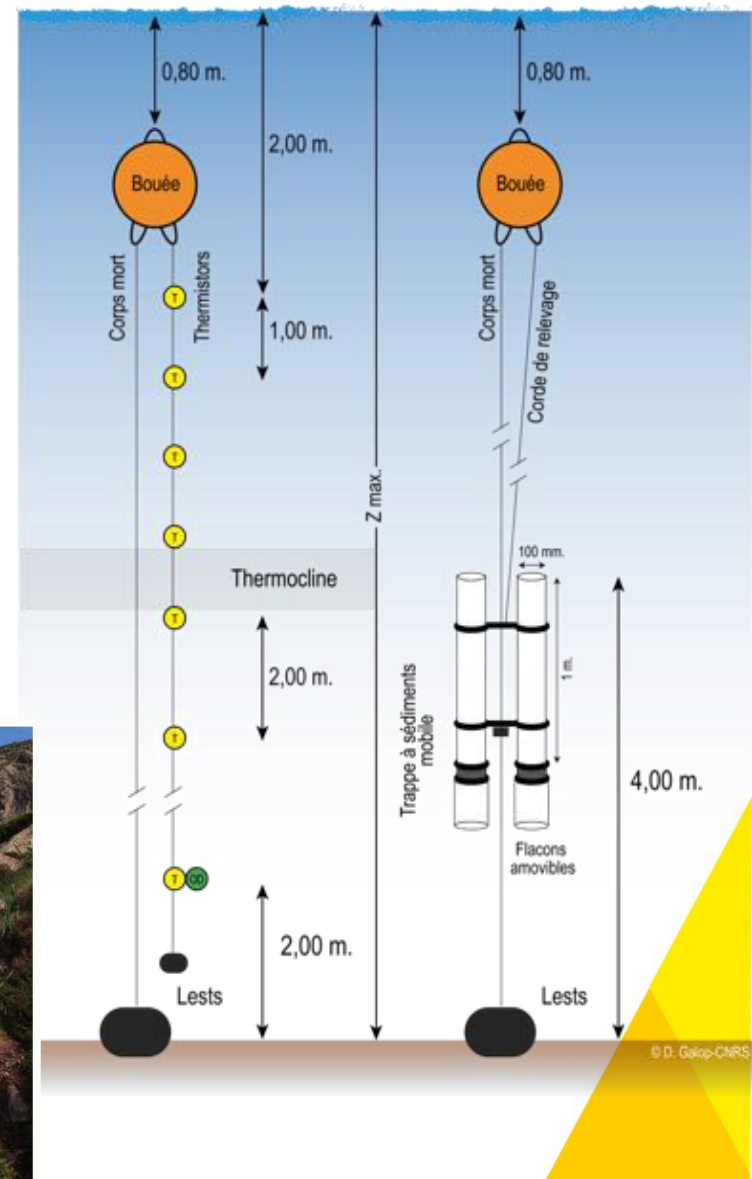
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# Monitoring

- Weather stations
- Sediment traps
- Temperature sensors
- Water and sediment sampling (annual, seasonal)
- Multiparameter probe:
  - T, conductivity, pH, Oxygen
- Sediment cores: multiproxy,  $^{137}\text{Cs}$ ,  $^{210}\text{Pb}$ ,  $^{14}\text{C}$





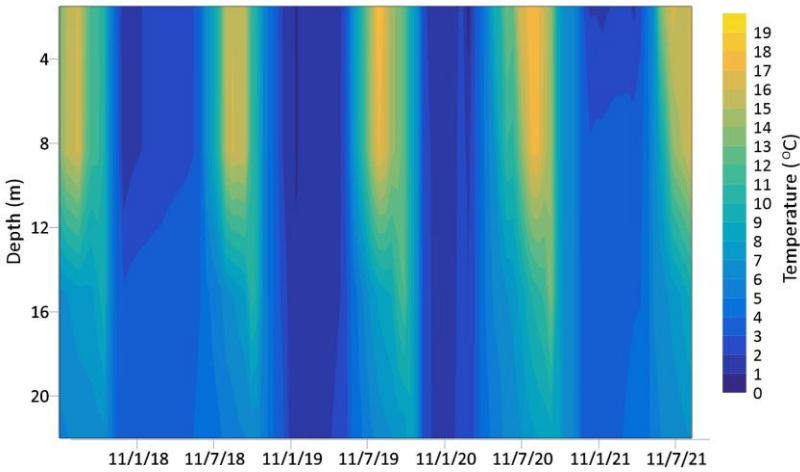
Lakes are warming



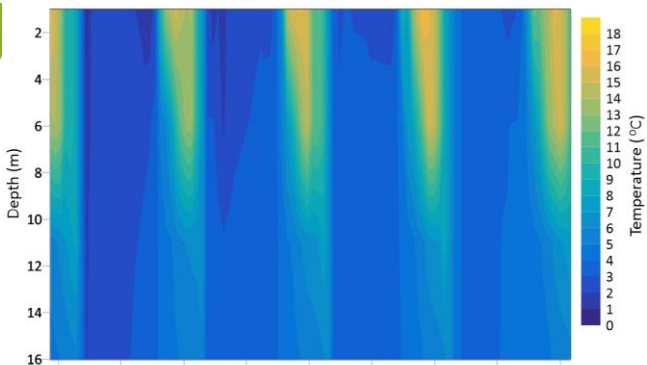


# Thermal regimes

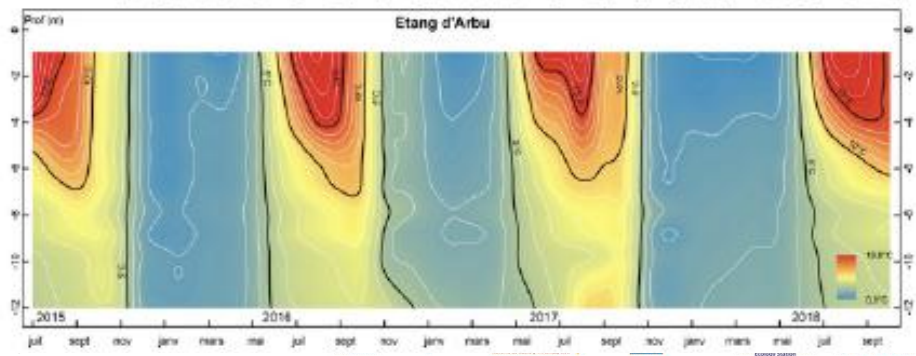
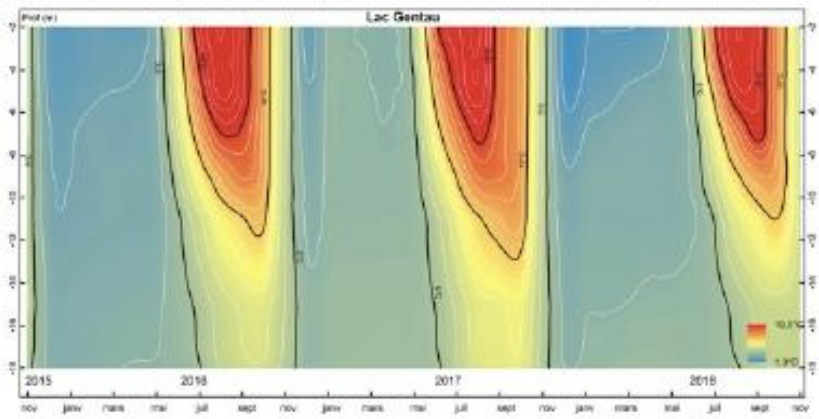
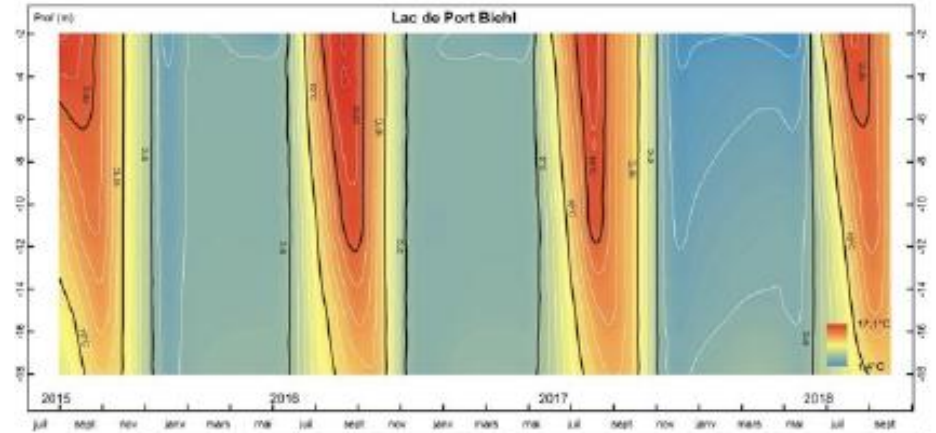
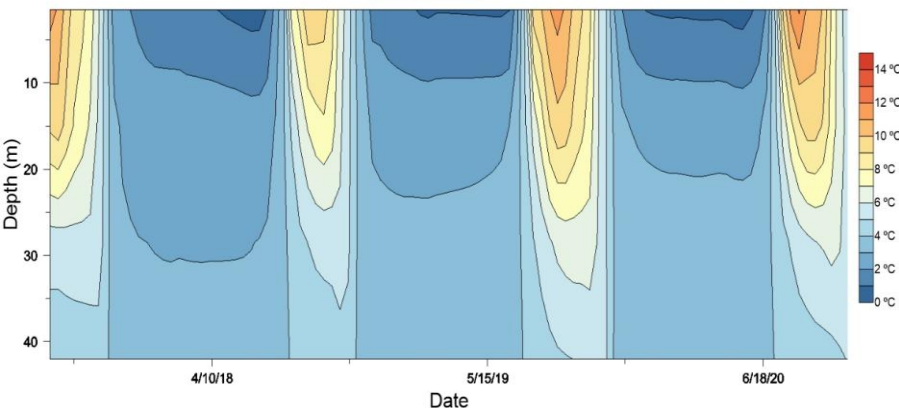
Acherito



Montmalús



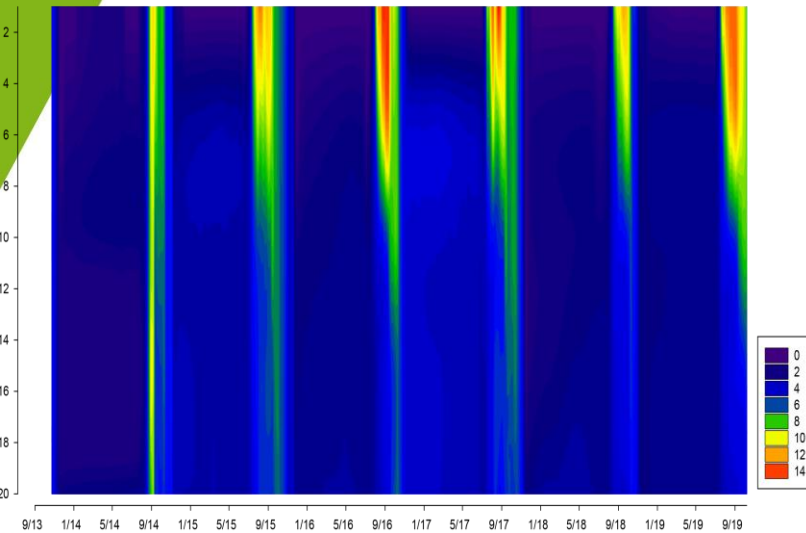
Cregüena



# Temperature evolution

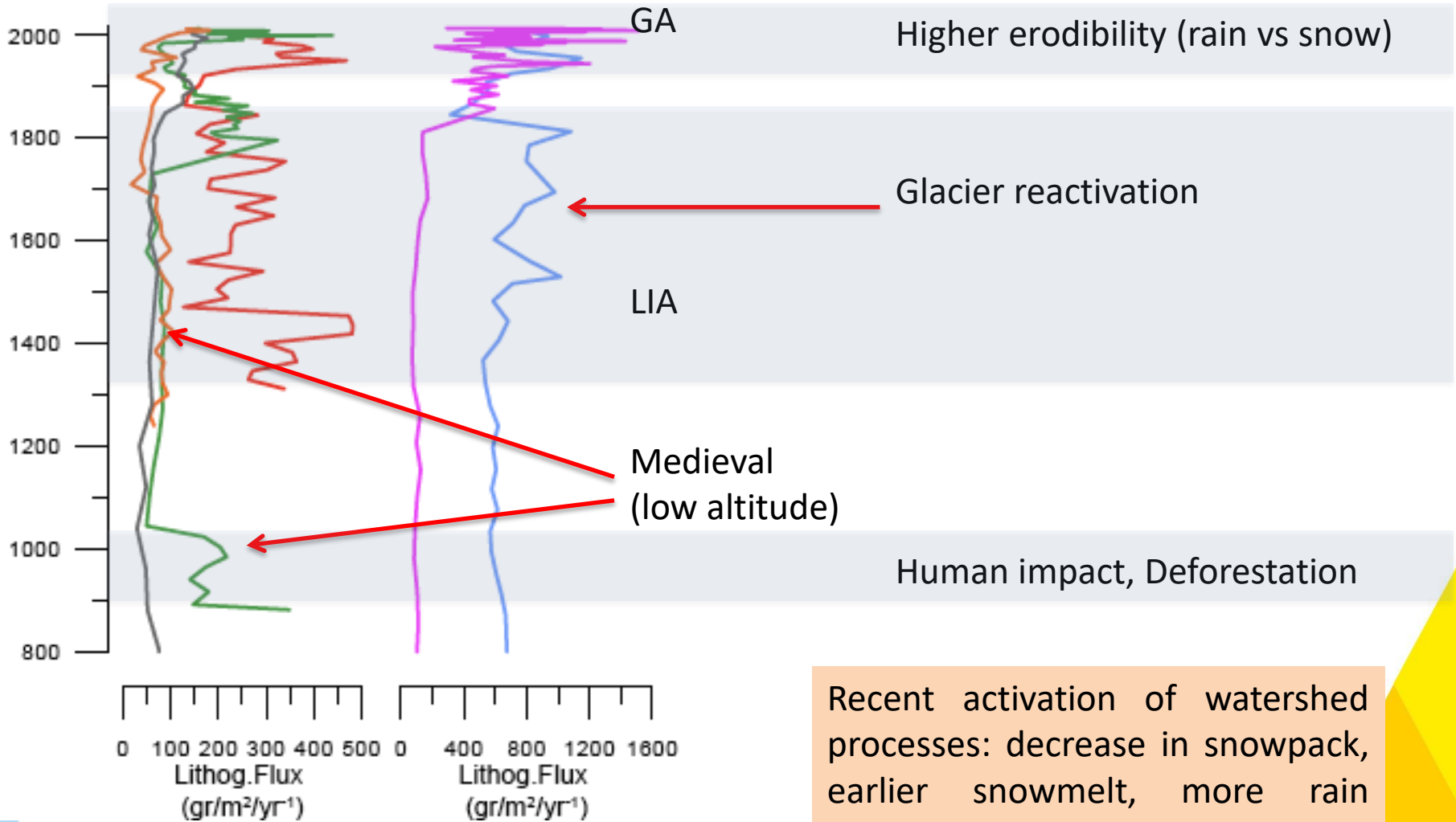
- Large interannual variability
- Geographic/seasonal variability
  - Higher in winter (northern slopes)
  - Higher in summer (southern slopes)
- Local effects, northern vs. southern slopes , seasonality?
- Shorter ice-covered season
- Increased in Summer and Fall surface T:
  - 1968 – 1970: T max (August) = 13 °C
  - 2015-2018: T max (August): > 15°C
- Smaller variability in depth

Marboré





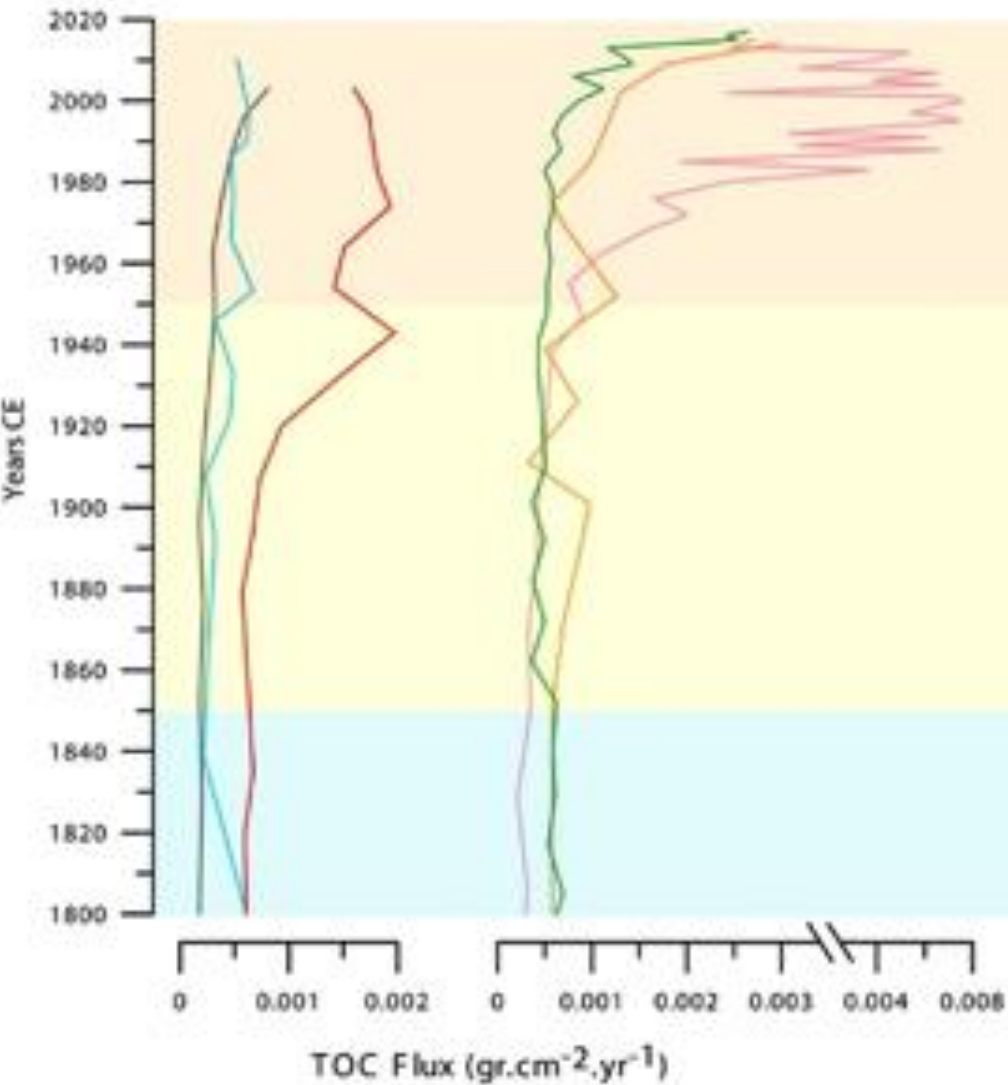
# Higher sediment fluxes



Recent activation of watershed processes: decrease in snowpack, earlier snowmelt, more rain events

- Marboré
- Acherito
- Cregüeña
- La Sierra
- Sabocos
- Urdiceto

# Higher organic carbon fluxes



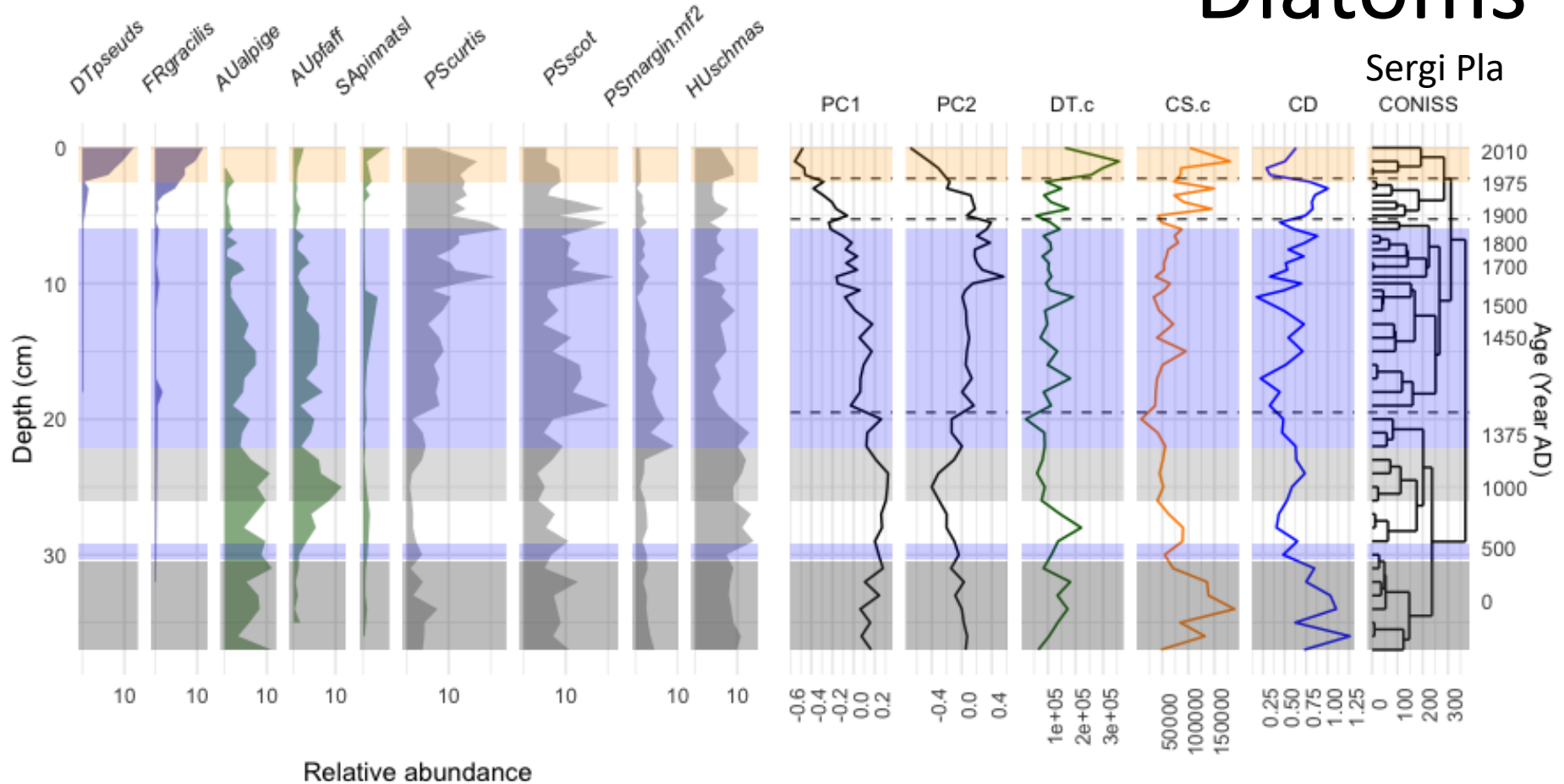
Larger changes at the end of the Little Ice Age (LIA) and during the Great Acceleration (GA)

- Marboré
- Acherito
- Cregüeña
- La Sierra
- Sabocos
- Urdiceto

## Diatoms Lake Cregueña with higher scores in PC1 or PC2

# Diatoms

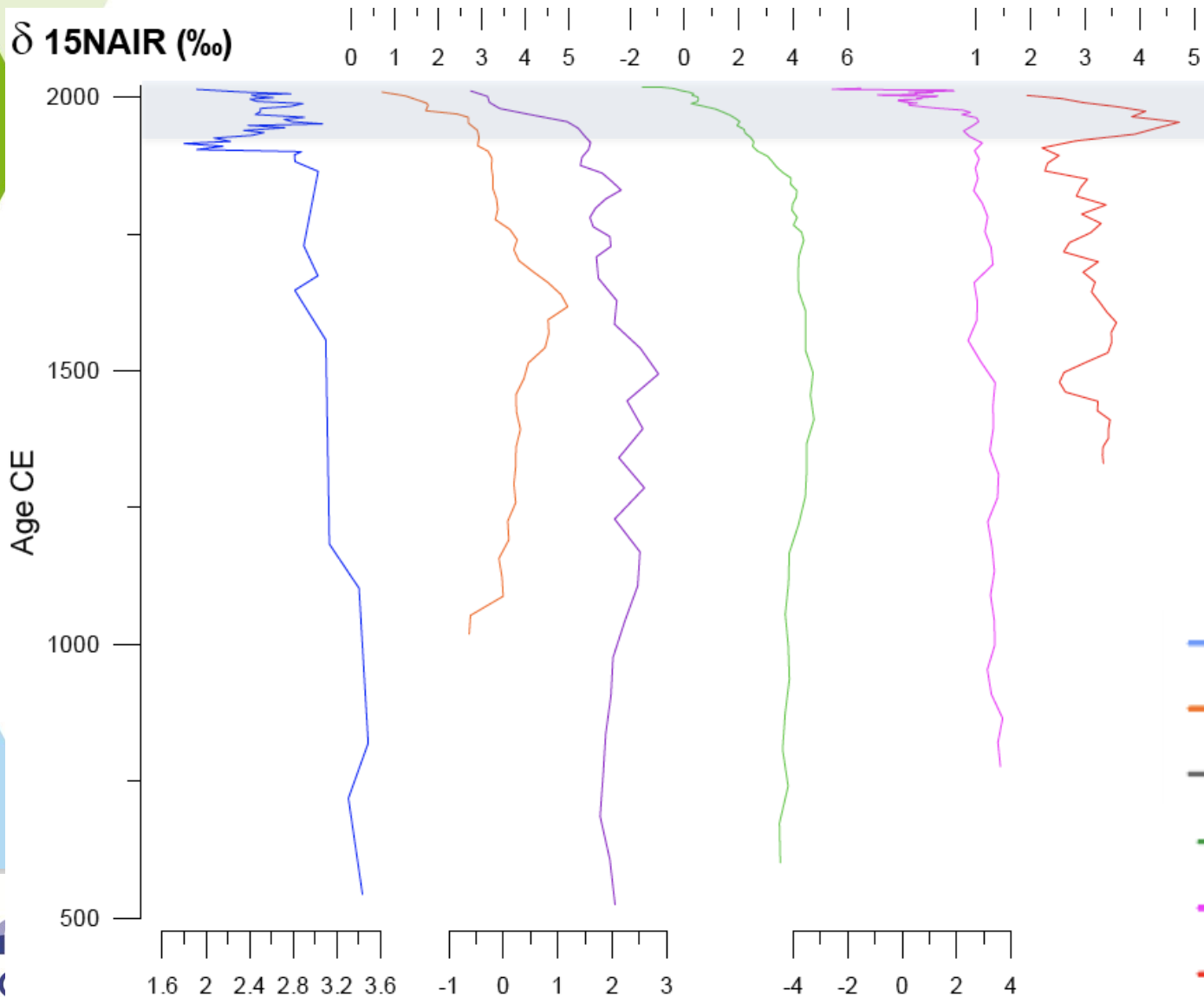
Sergi Pla



Warmer, longer ice-free season, more stable summer stratification, increase in  $L_{flux}$  favoring species of planktonic diatoms of shorter life span that bloom later in the season



# Nitrogen fluxes



Recent  
decreasing  
trend

Higher global  
anthropogenic  
N input?

- Marboré
- Acherito
- Cregüena
- La Sierra
- Sabocos
- Urdiceto

# New lakes



1876 2021

Piedrafita & San Román, 2022

## Arrablo Lakes, Ordesa – Monte Perdido National Park



# Ice Caves





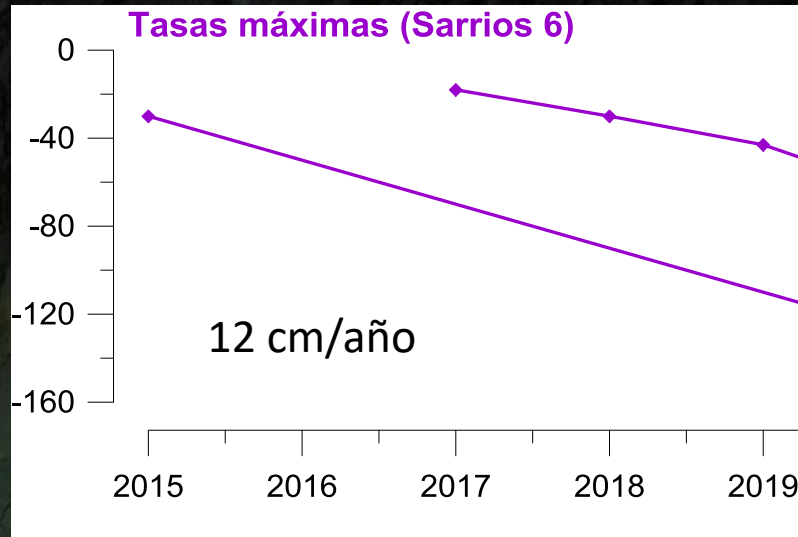
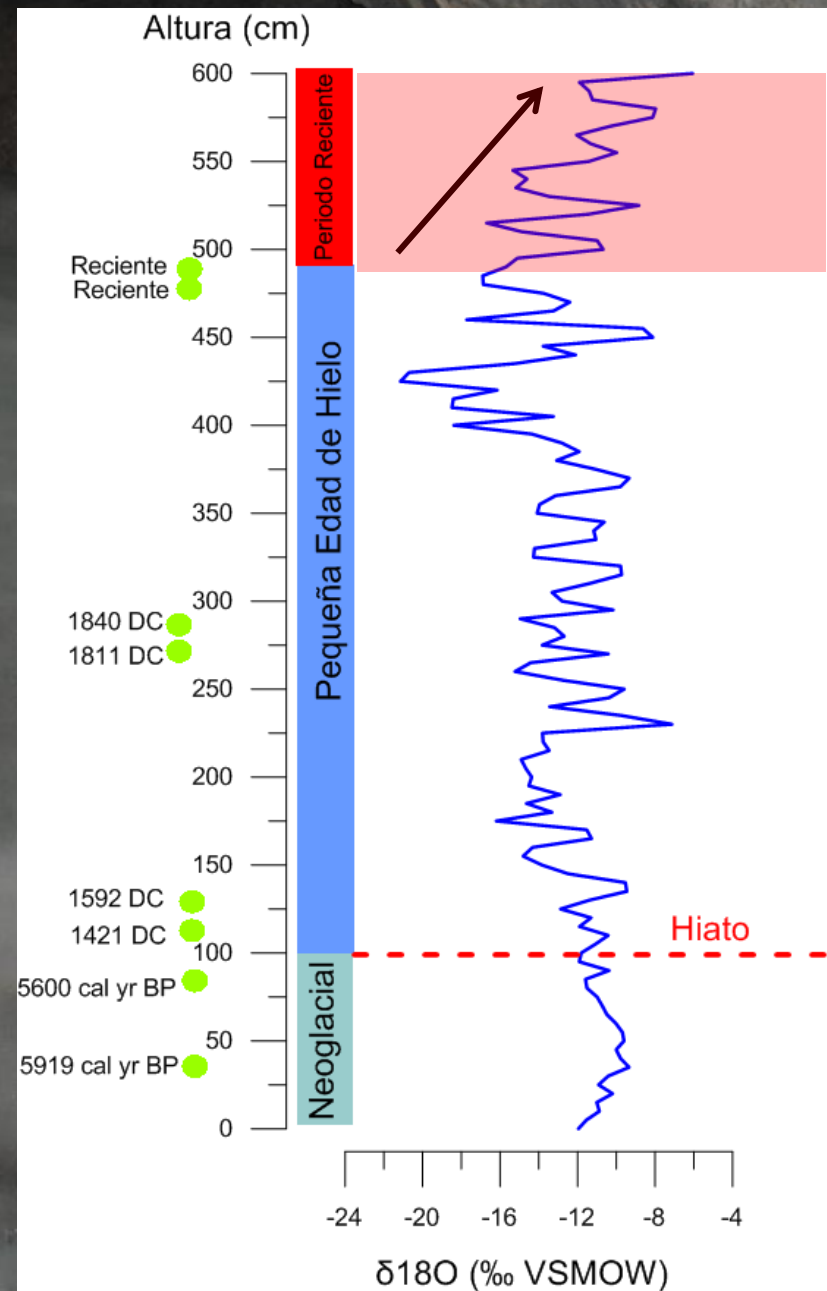


Foto: David Serrano





# Glacie







1850: 52 glaciers, 2060 hectare  
1984: 39 glaciers, 810 hectare  
2008: 22 glaciers, 306 hectare  
2016: 19 glaciers, 242 hectare

- ❑ Since 1980s, from **39 to 19 glaciers**
- ❑ **Ice loss**, 9 ha/yr during 20th century; 18 ha/yr since 1980

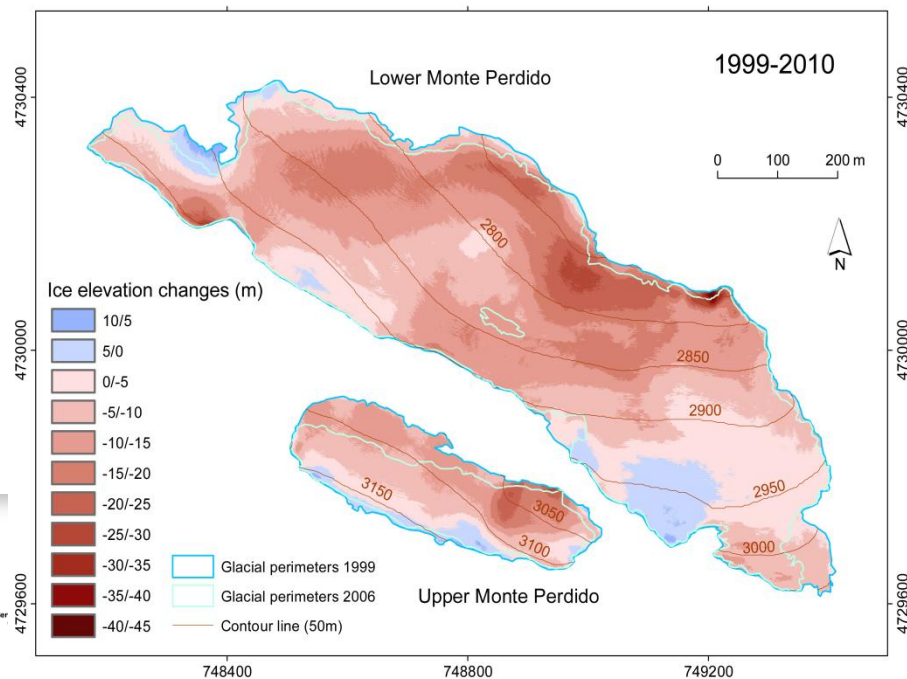
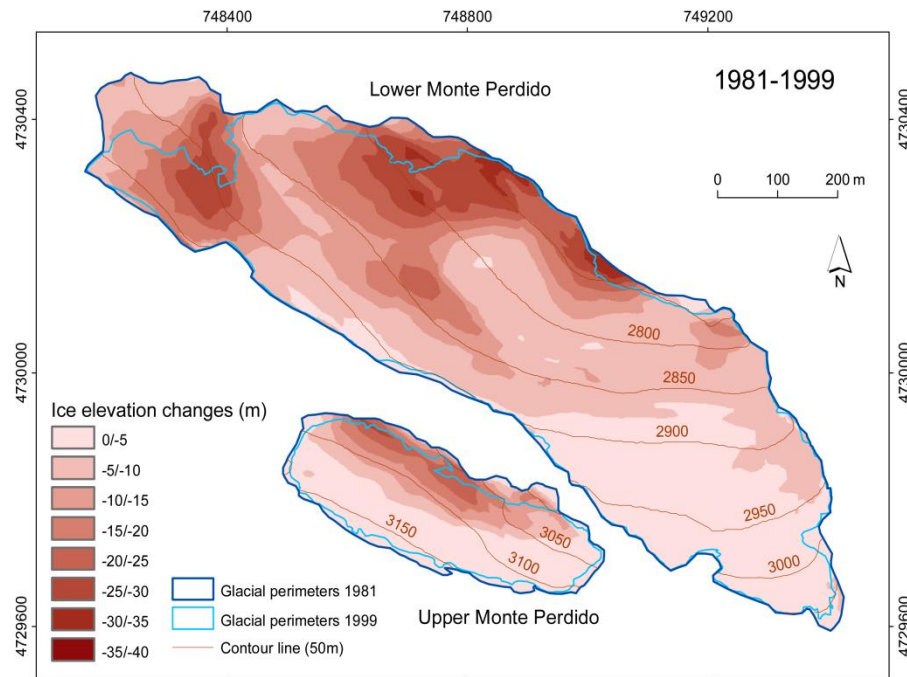
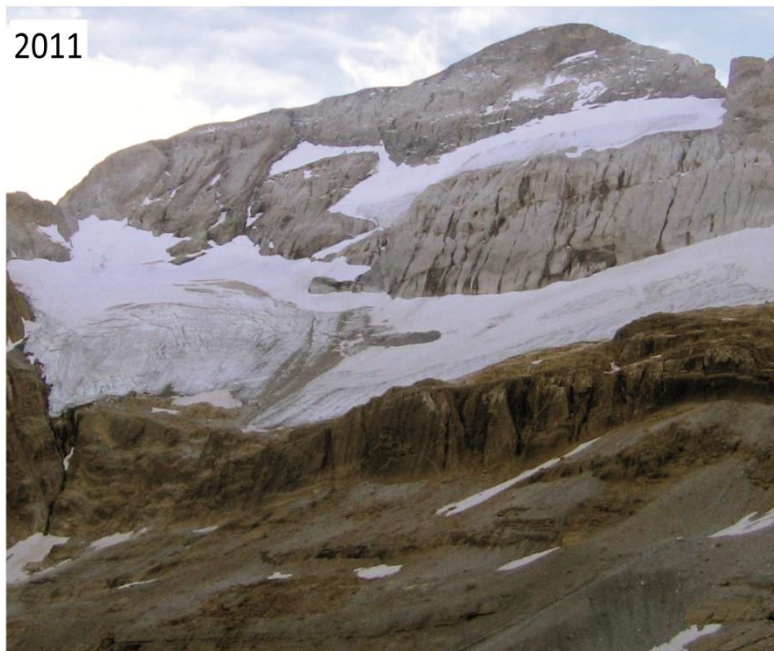
**Ossoue glacier (Vignemale),  
August 2017**

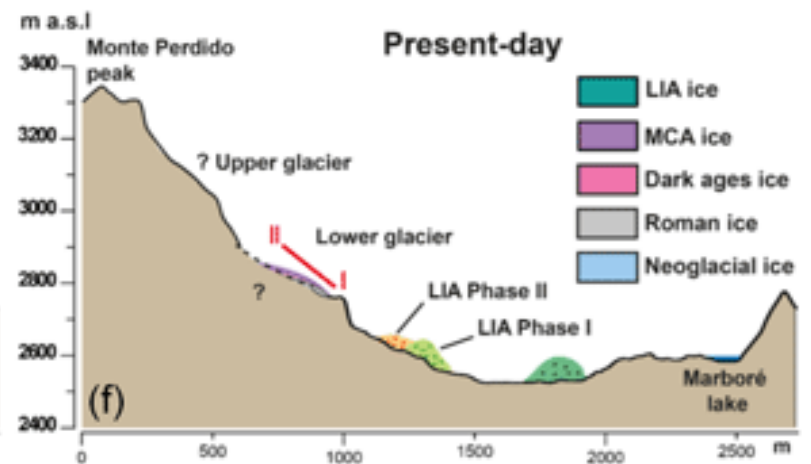
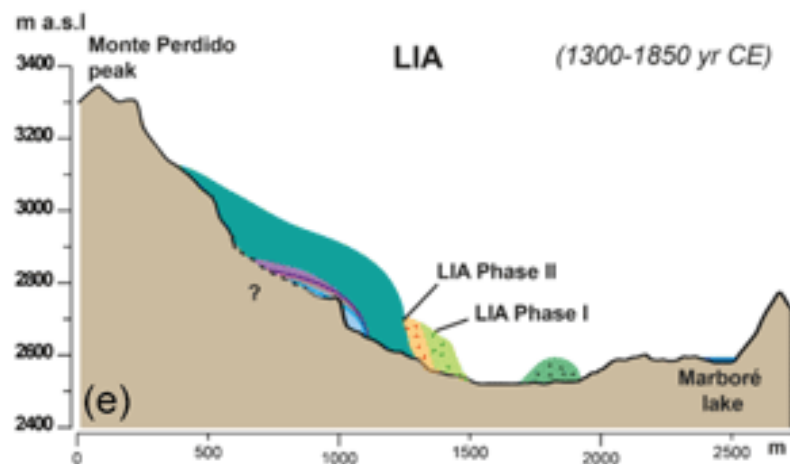
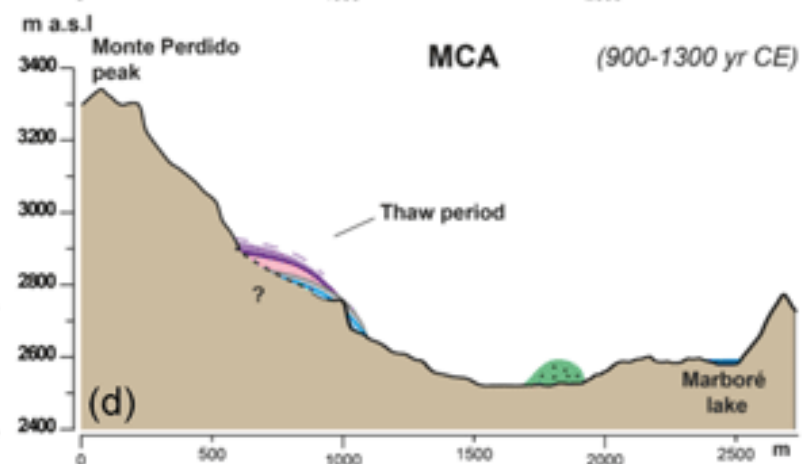
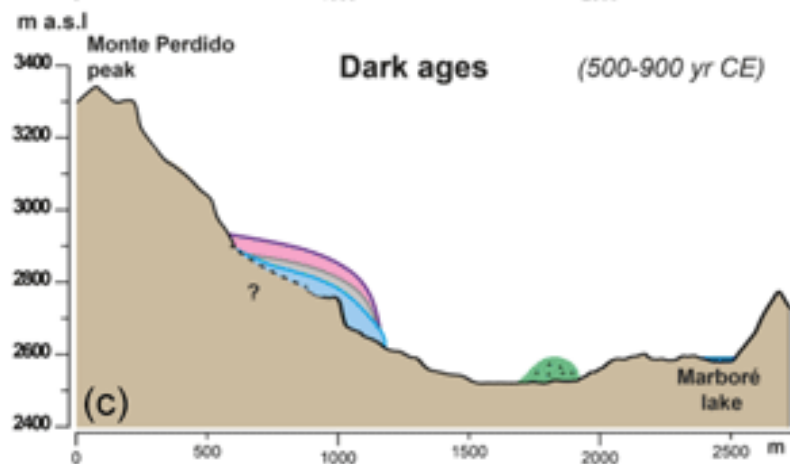
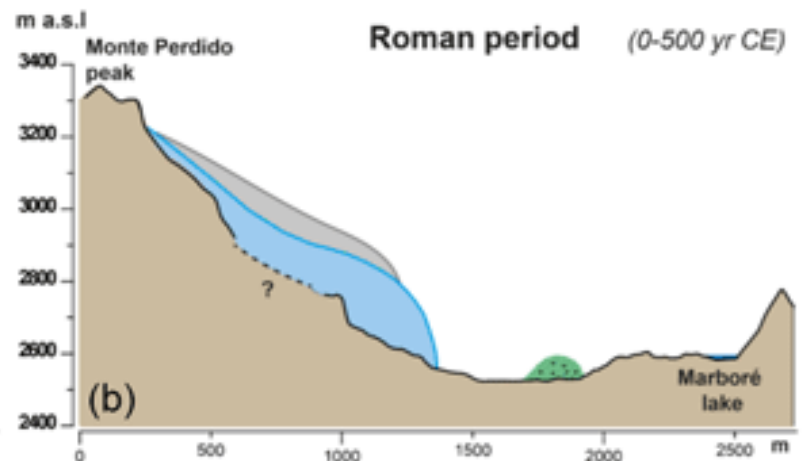
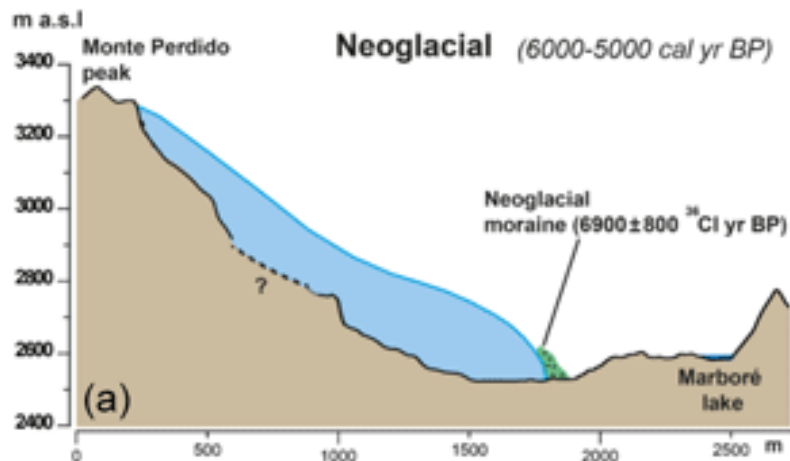
# Monte Perdido Glacier



*Lucien Briet 1898 en: Pierre René (2013).Glaciers des Pyrénées: le rechauffement climatique en images. Ed. Cairn*









# Is happening everywhere

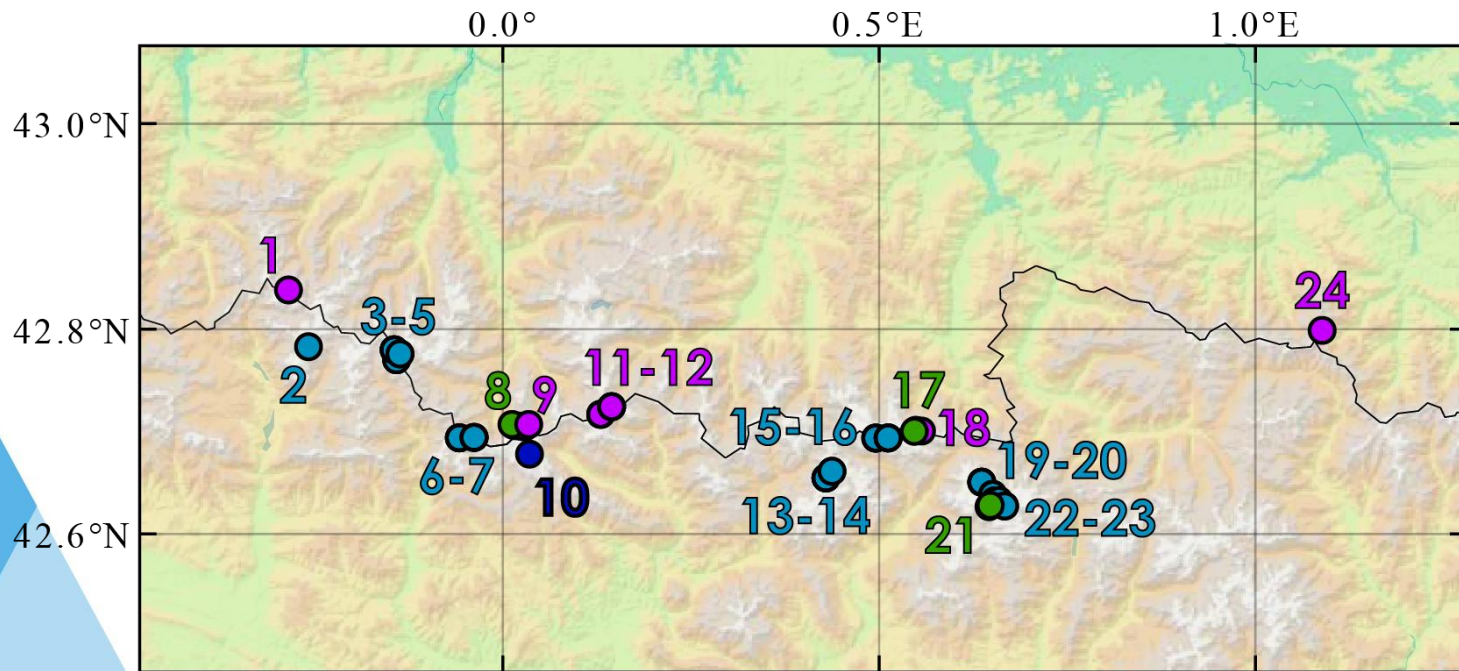


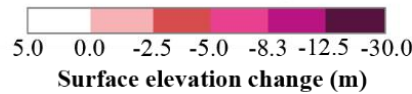
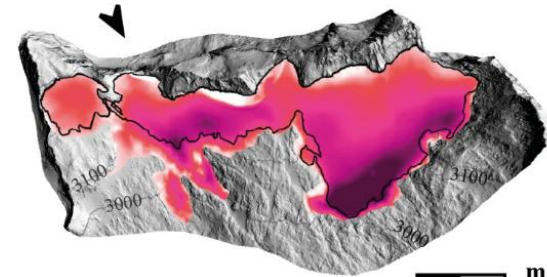
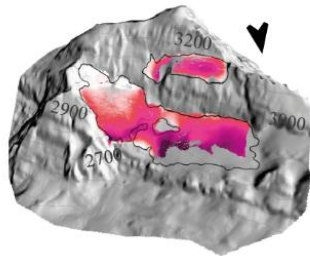
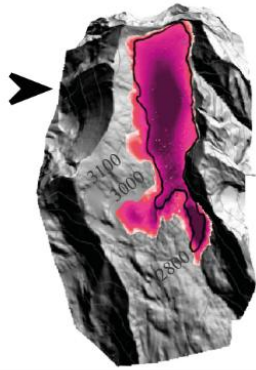
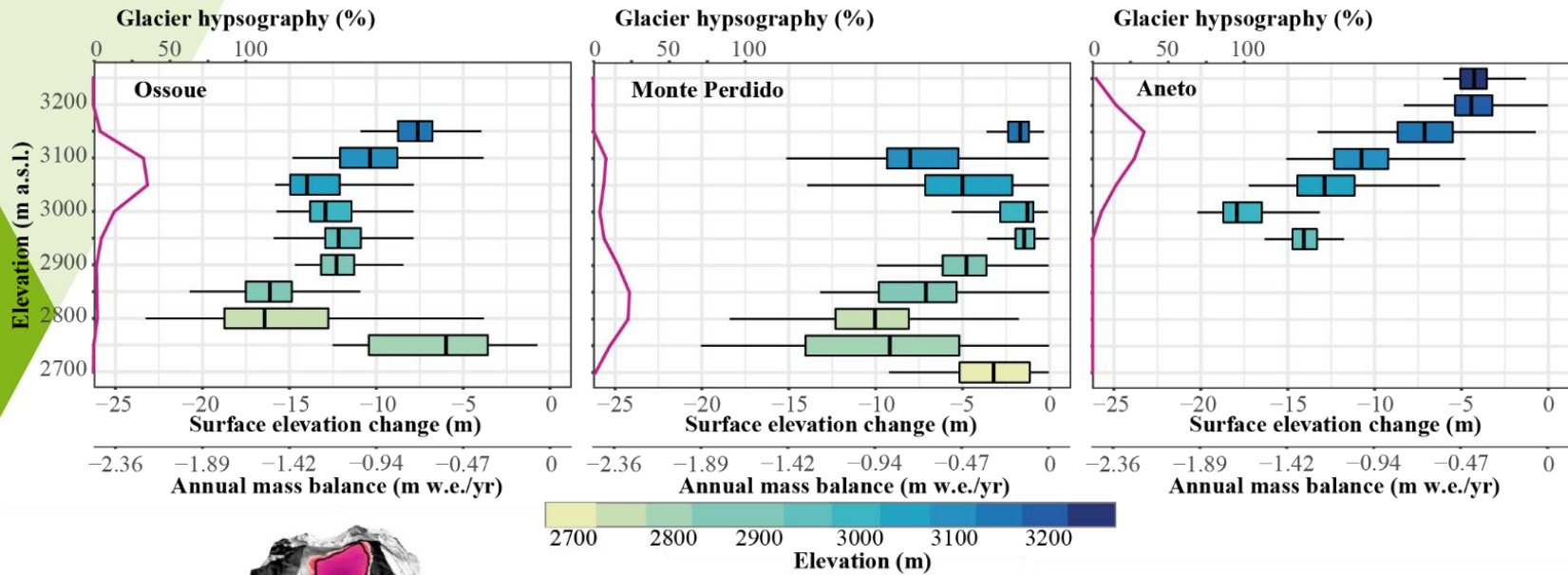
Elevation (m a.s.l.)



- Only area changes analysed
- Ice thickness change (UAV)
- Ice thickness change (TLS)
- Glaciers degraded to ice patch

- 1 Las Neus
- 2 Infierno
- 3 Oulettes
- 4 Petit Vignemale
- 5 Ossoue
- 6 Gabietous
- 7 Taillon
- 8 Paila (E and W)
- 9 Astazou
- 10 Monte Perdido
- 11 Munia
- 12 Barroude
- 13 Llardana
- 14 La Paul
- 15 Seil de la Baque
- 16 Portillon de Oô
- 17 Maupas
- 18 Boum
- 19 Maladeta (E and W)
- 20 Aneto
- 21 Coronas
- 22 Barrancs
- 23 Tempestades
- 24 Mont Valier

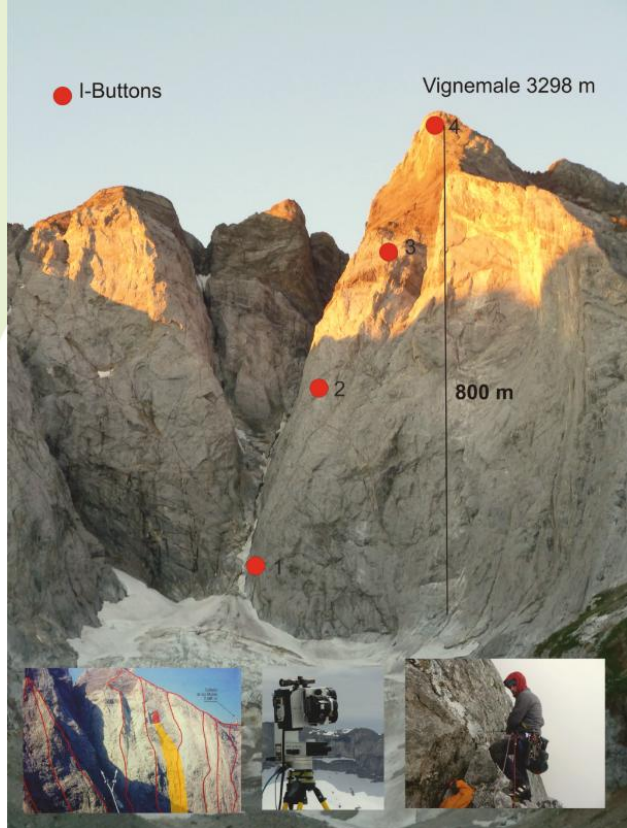




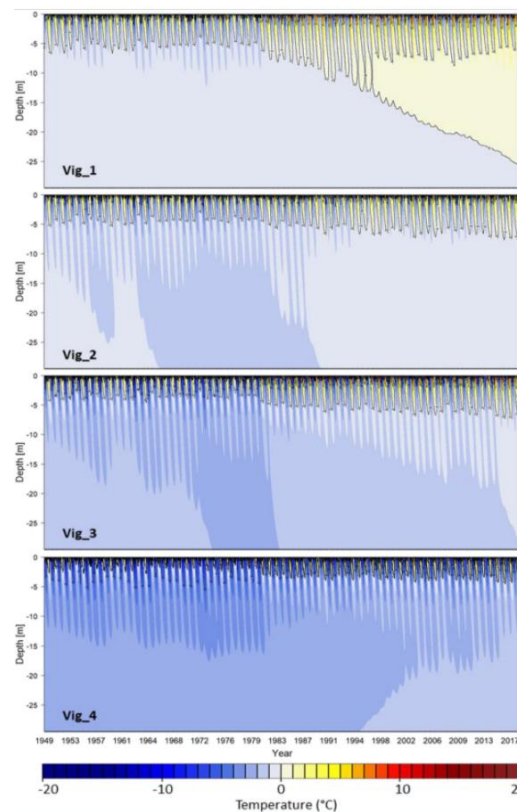
Large variability but similar picture:  
no glaciers for our grandchildren



# Permafrost



- 2900 m asl
- Northern face of Vignemale
- Ice Caves



## Permafrost and Periglacial Processes

SHORT COMMUNICATION | [Open Access](#) | [CC](#) | [BY](#) | [NC](#) | [ND](#)

### First evidence of rock wall permafrost in the Pyrenees (Vignemale peak, 3,298 m a.s.l., 42°46'16"N/0°08'33"W)

Ibai Rico, Florence Magnin, Juan Ignacio López Moreno, Enrique Serrano, Esteban Alonso-González, Jesús Revuelto, Lara Hughes-Allen, Manuel Gómez-Lende





Foto: Argüelas Rock Glacier

José Sierra







# Increasing rock falls

## Aneto trail

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# Take home messages

- Pyrenean cryosphere is changing
- Ice is disappearing (glaciers, caves, permafrost)
- Lakes regimes are changing (diatoms, Flux<sub>OC</sub>, Flux<sub>sed</sub>)
- Watershed sedimentary processes are intensifying
- Changes during the Great Acceleration comparable to end of Little Ice Age (or even more intense)
- Early warning system
- Citizen science, educational and outreach opportunities



# Next...

- Uncertain synergies between climate (increasing Temp., wind dynamics) and global processes (higher nutrient input, pollution, Saharan dust)
- We need longer time series
- Who pays for network monitoring?

Gracias

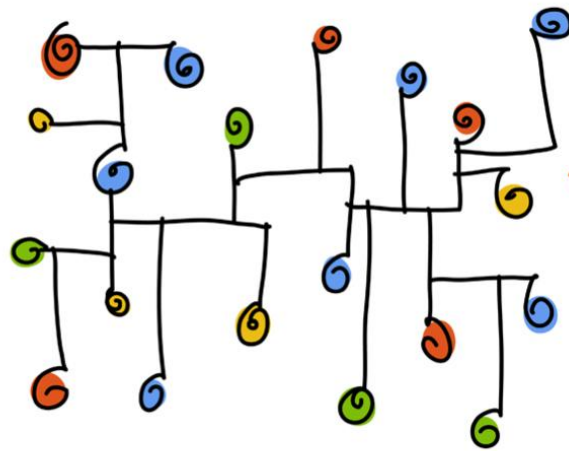
Merci

Eskerrik asko

Gràcies

Thanks

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We cannot create observers by saying 'observe', but by giving them the power and the means for these observation and these means are procured through education of the senses.

Maria Montessori

