

SNO Karst 2023 – 30/05-01/06/2023

Gramat

Seasonal pressurization of a coastal karst : the paleolithic decorated Cosquer cave (SE France)

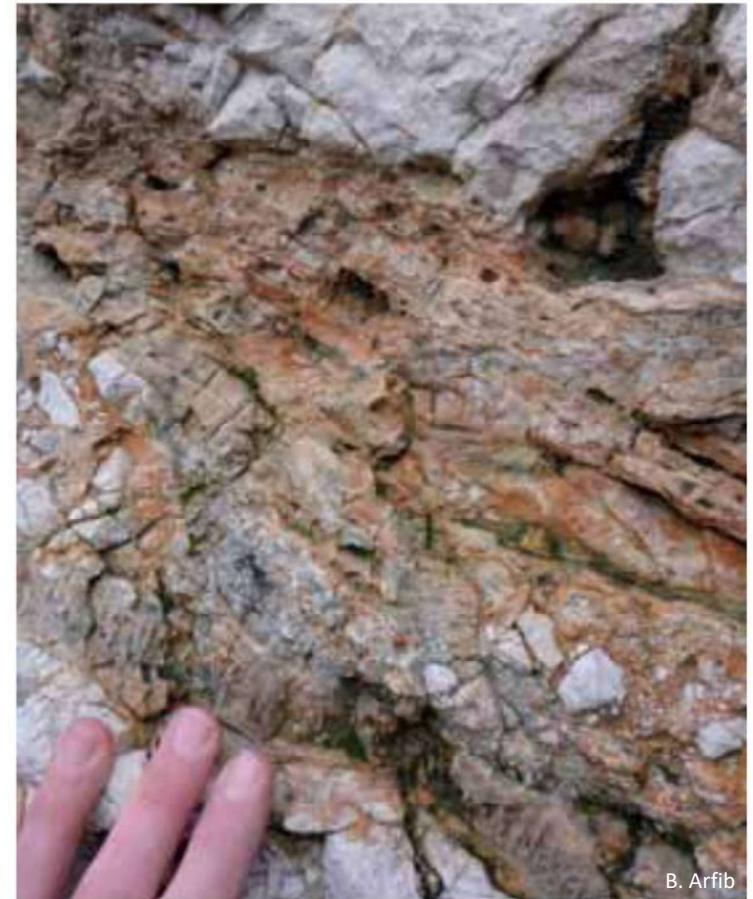
H. Pellet, P. Henry, B. Arfib, S. Touron



Context and aims

Carbonate rocks

- Heterogeneous medium with high permeability contrast
- Large range of void scales that affect air/water flow



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Coastal karst

- Sea tide
- Groundwater – Seawater exchanges



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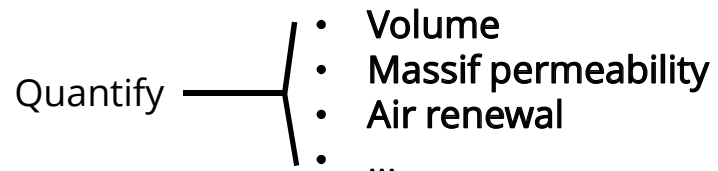
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Conservation of decorated caves



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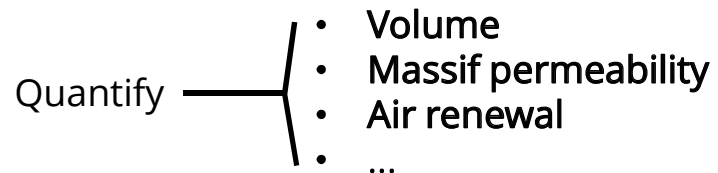
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Conservation of decorated caves



Cosquer cave : a decorated cave in a coastal karst



Study case

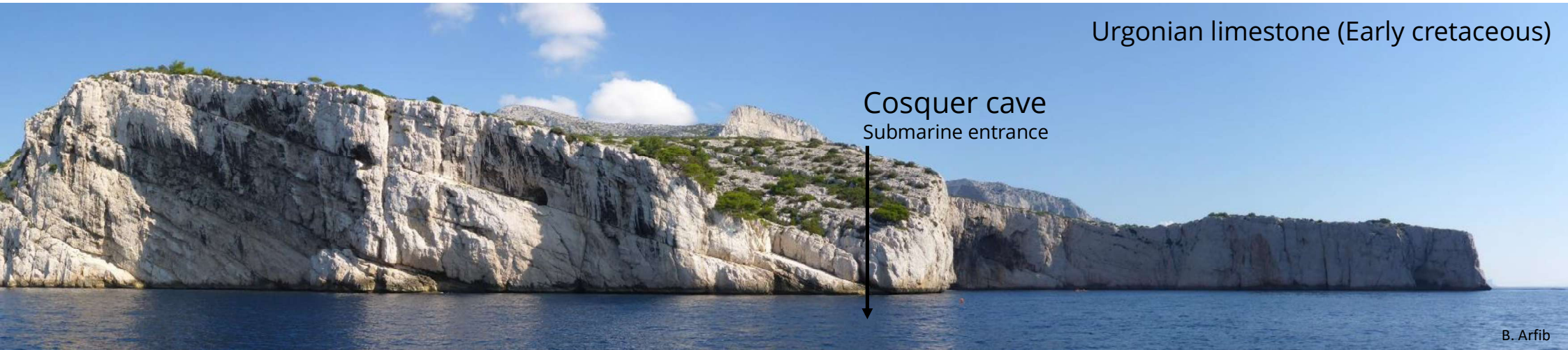


Calanques national park



https://commons.wikimedia.org/wiki/File:Europe_blank_map.png

Study case



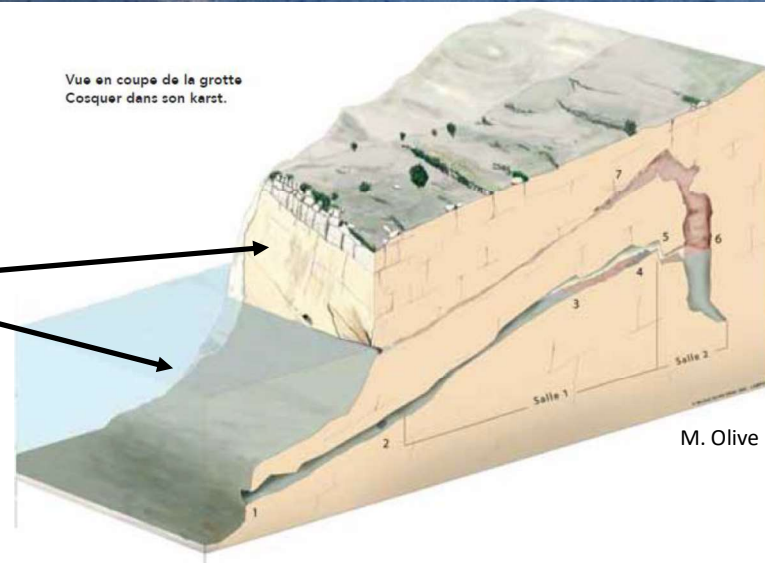
Urgonian limestone (Early cretaceous)

Cosquer cave
Submarine entrance

B. Arfib

Low permeability limestone massif above sea level

Isolated from outside air by the sea and the rock



Vue en coupe de la grotte
Cosquer dans son karst.

M. Olive

Study case

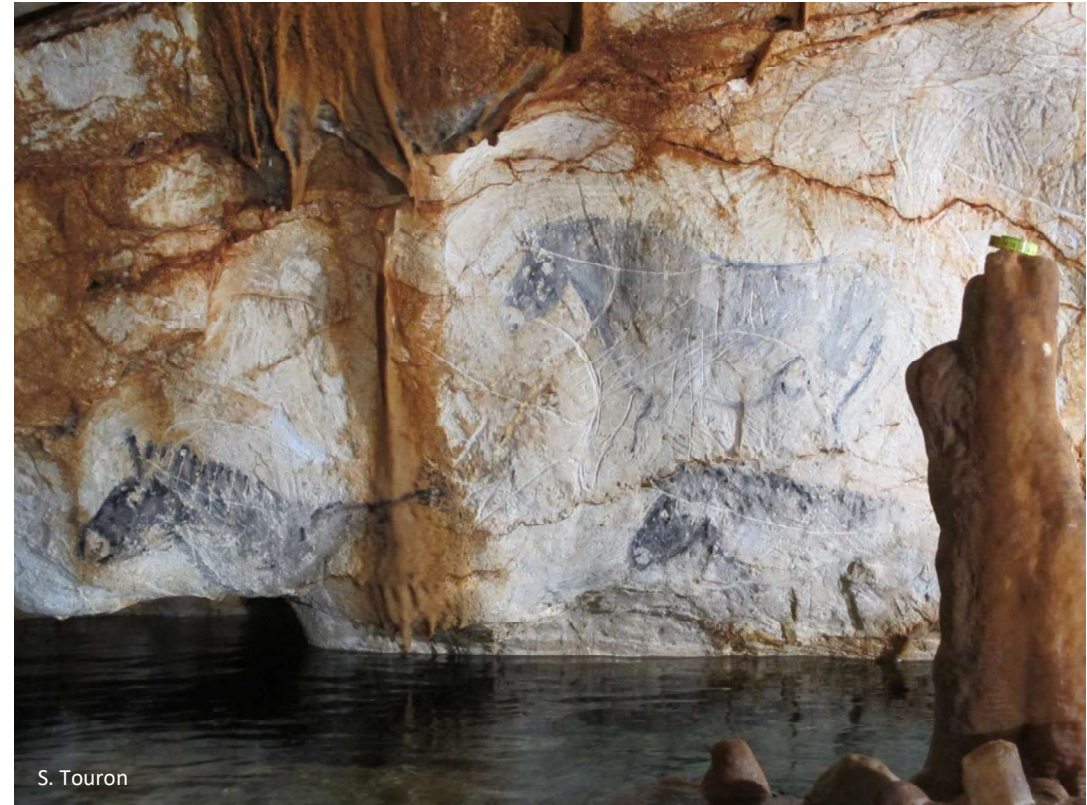


water level connected to the sea and emerged parts

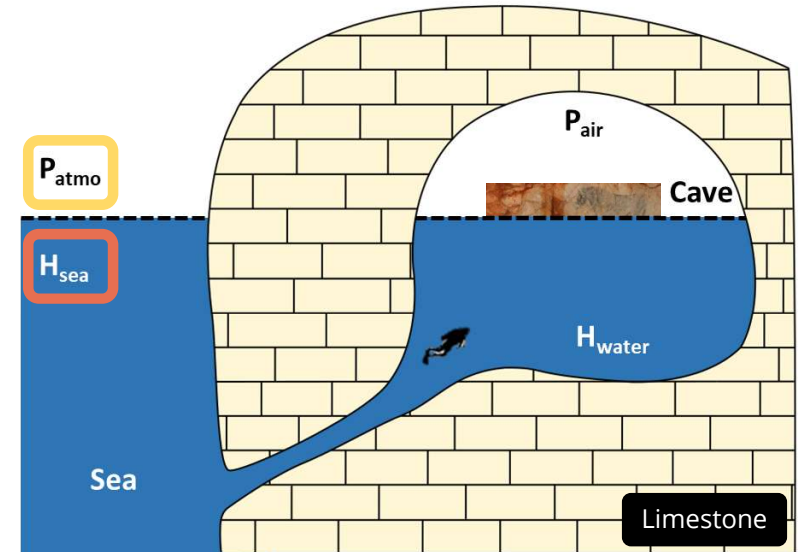
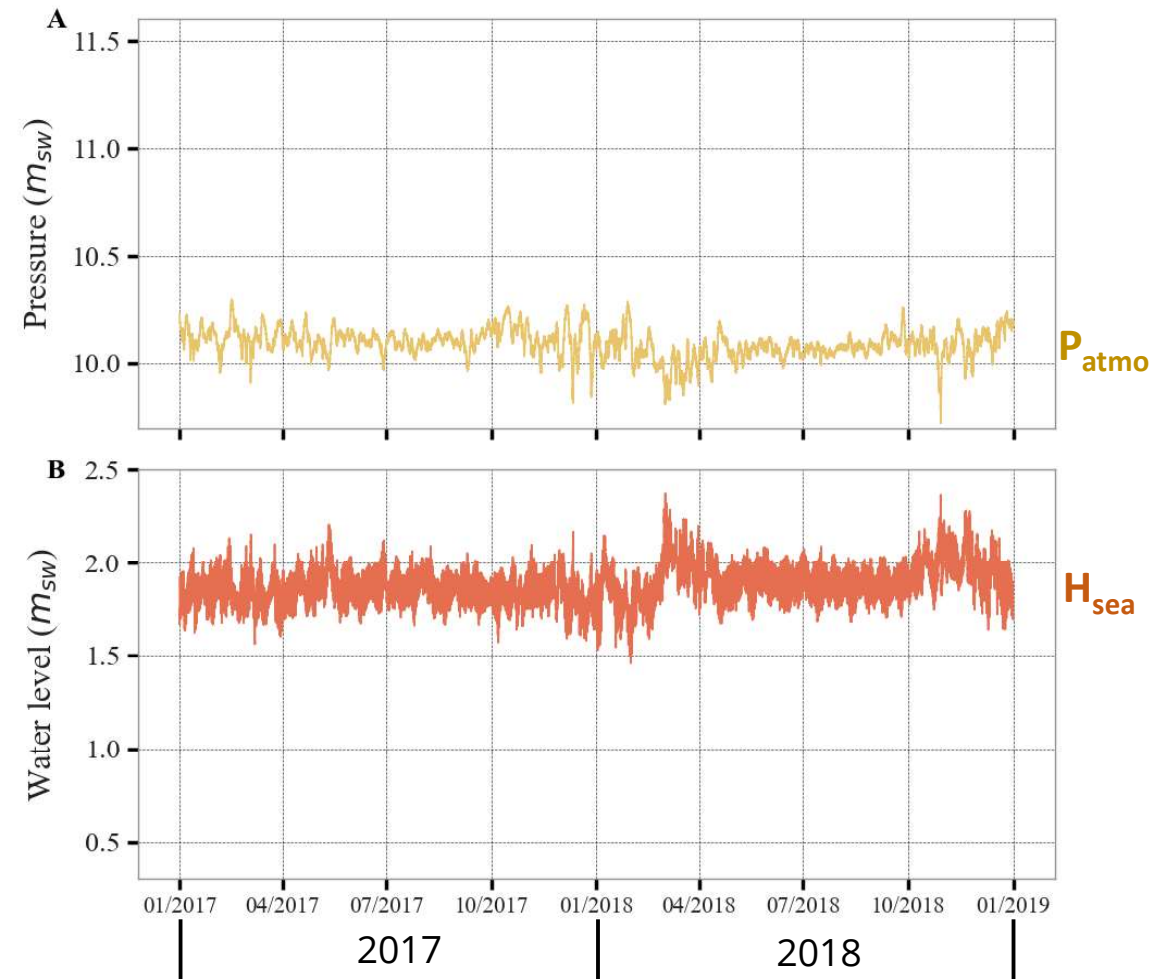


Cave surface $\approx 2000 \text{ m}^2$
Water surface $\approx 850 \text{ m}^2$

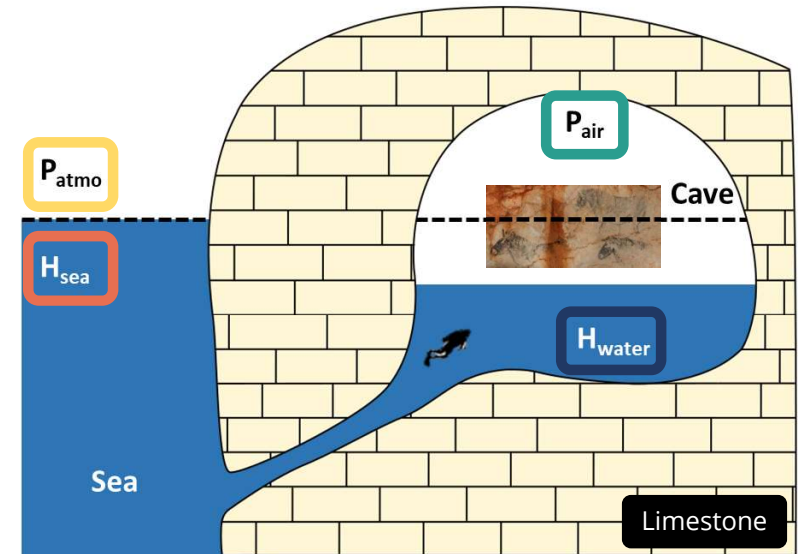
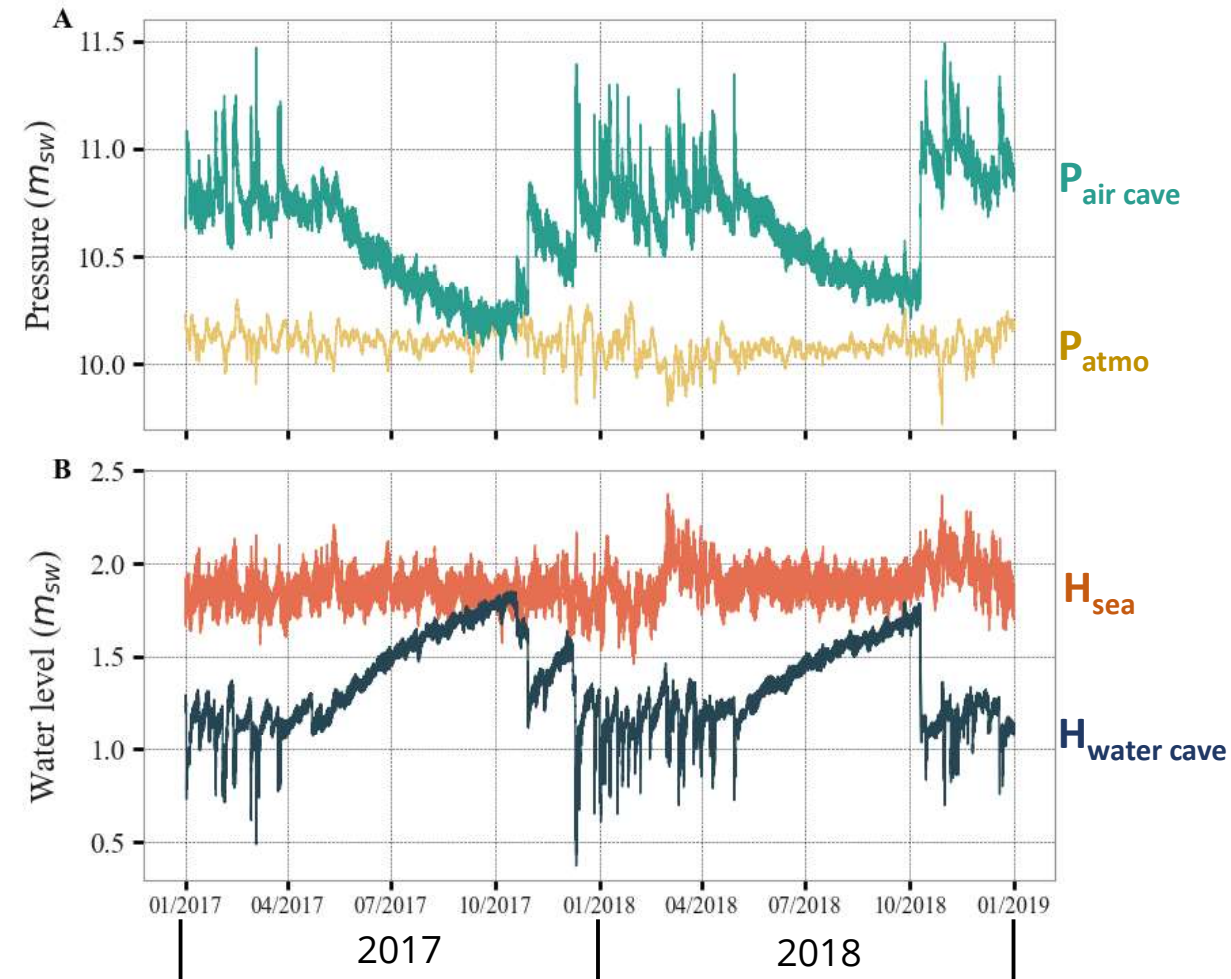
Work of art close water surface



Data



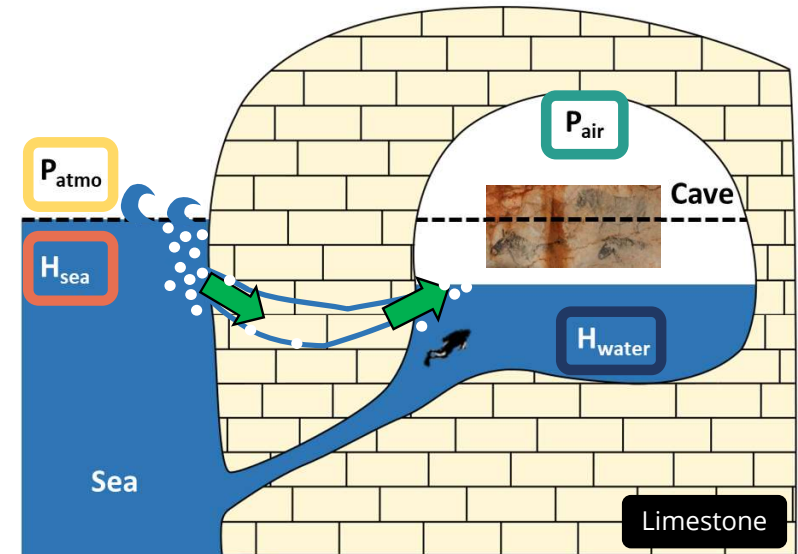
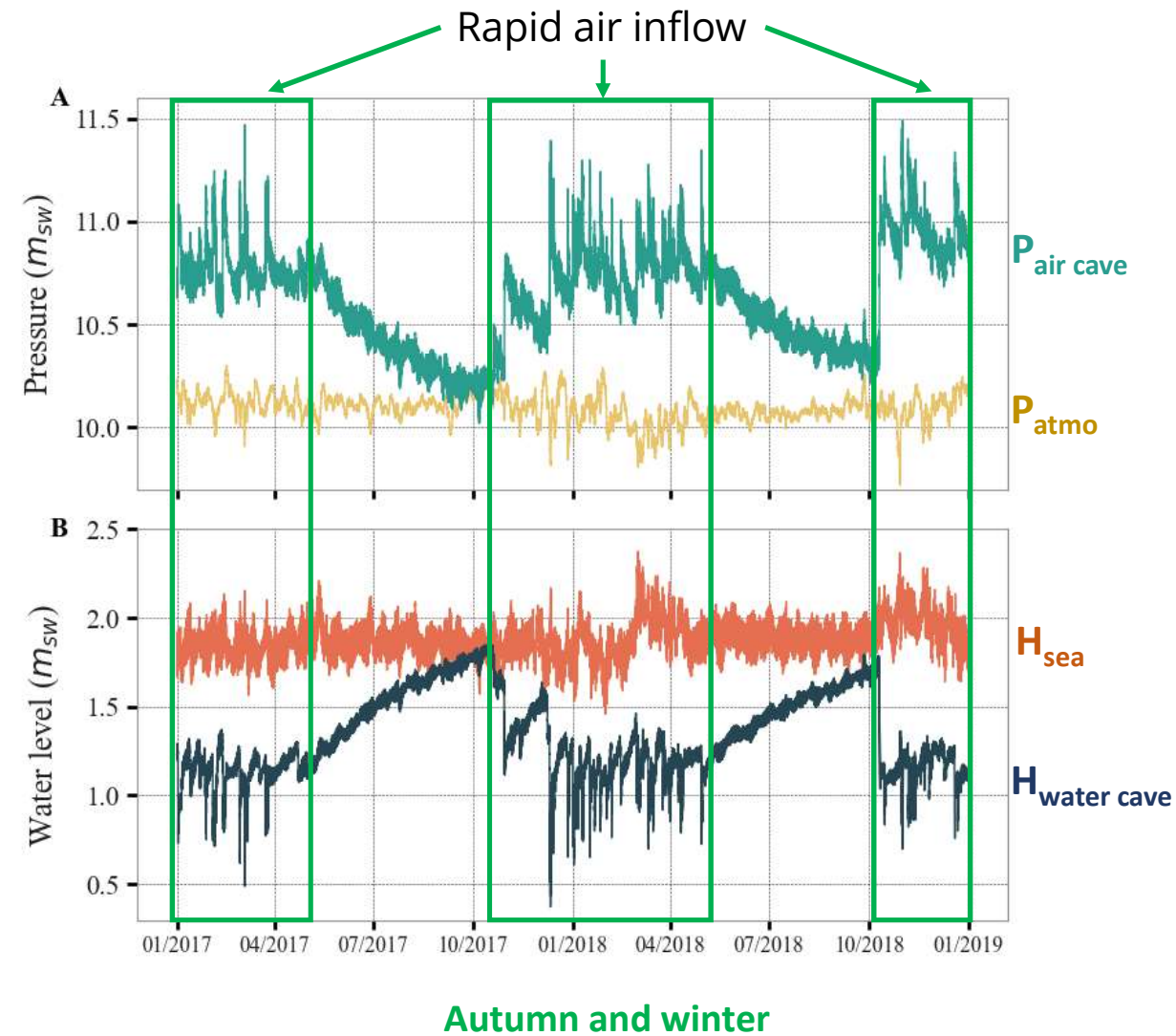
Data



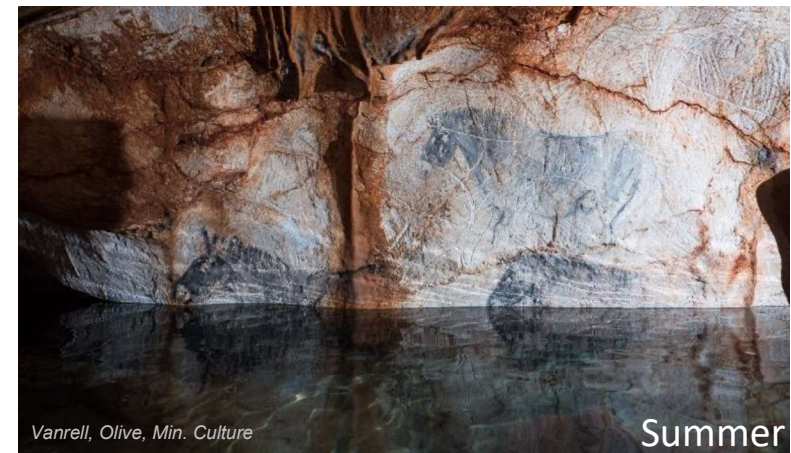
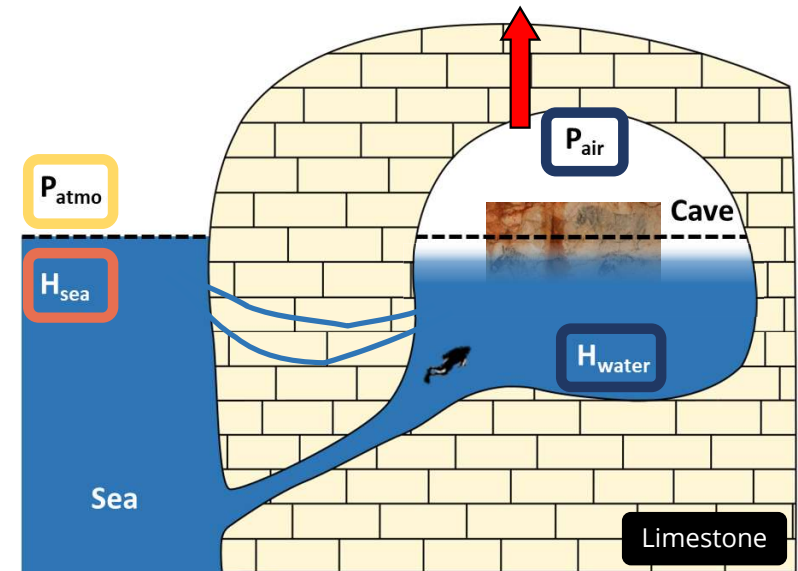
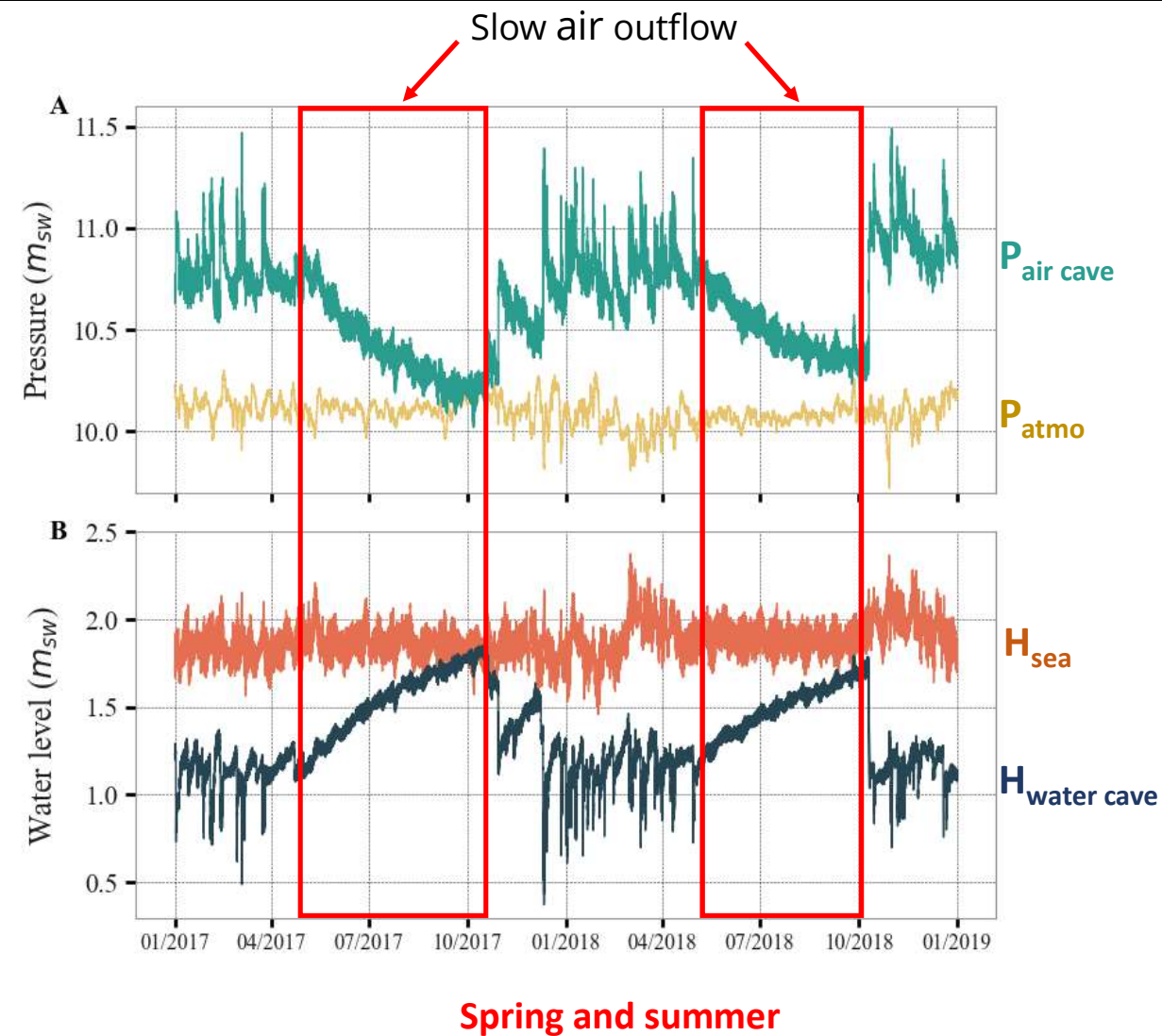
$$P_{air} > P_{atmo}$$

$$H_{water} < H_{sea}$$

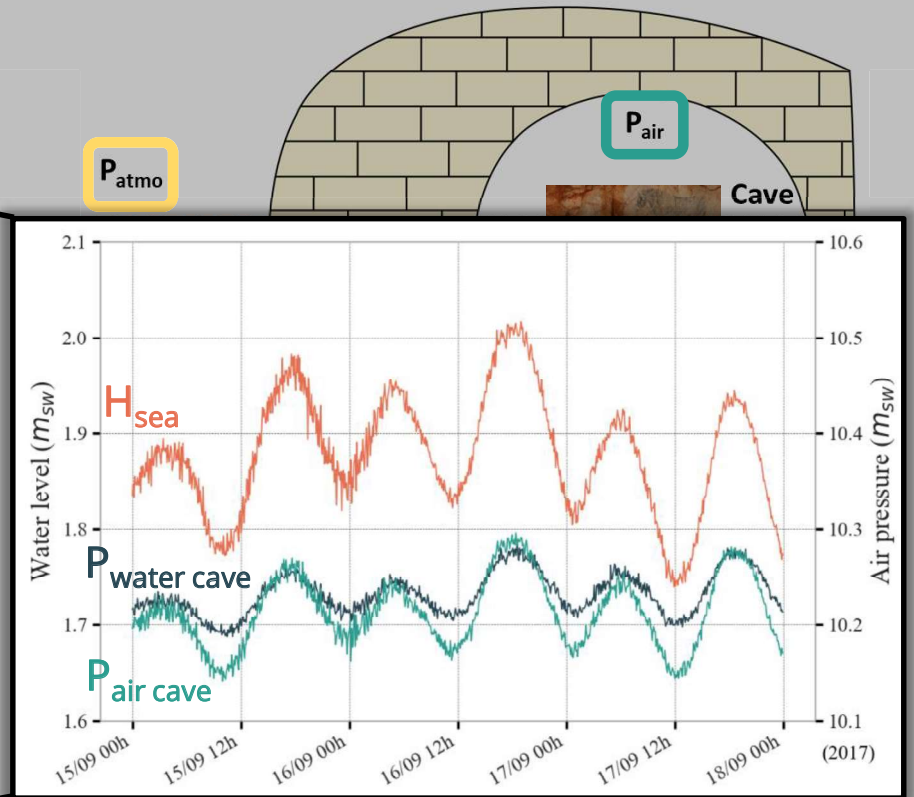
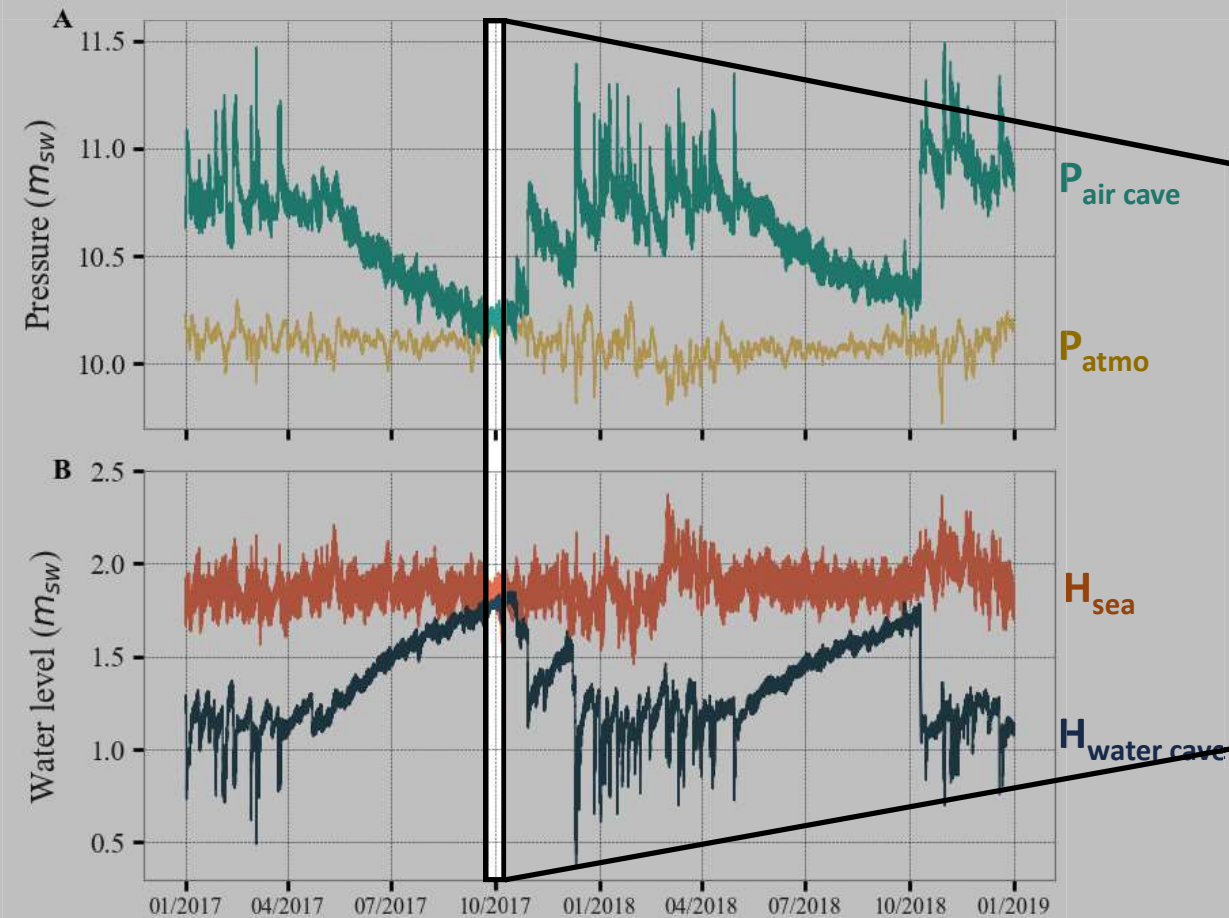
Seasonal pressurization...



... and depressurization

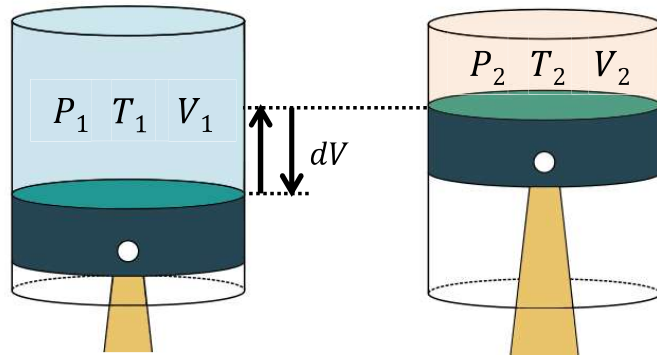


Daily variations



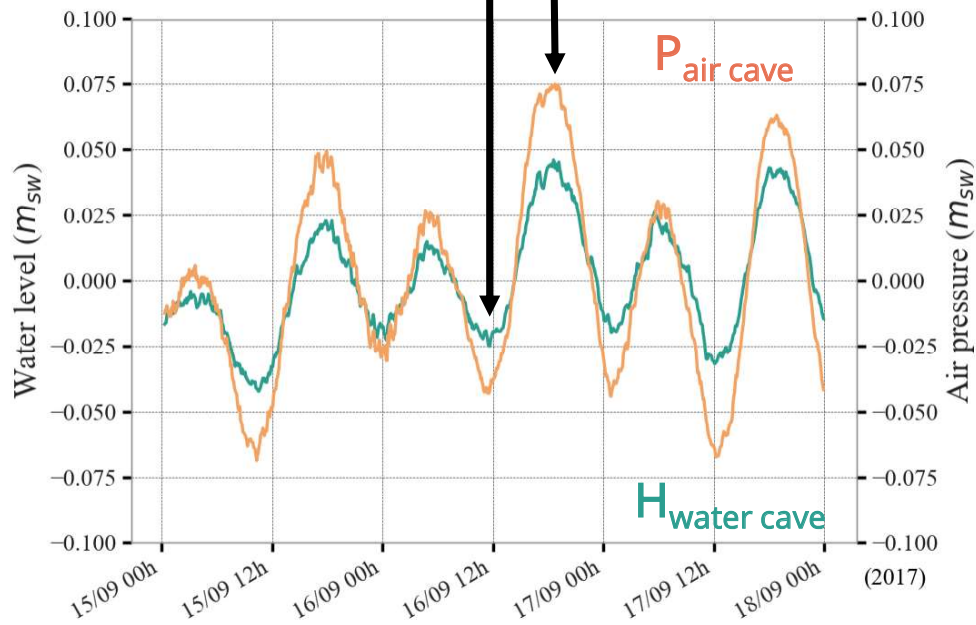
- Tide propagates into the karst
- Confined cave air

Cave volume



1: Low tide

2: High tide



Ideal gas law between low and high tide :

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_1 = V_2 + dV$$



Cave volume at each tide
(4 tides/day = 4 results/day)

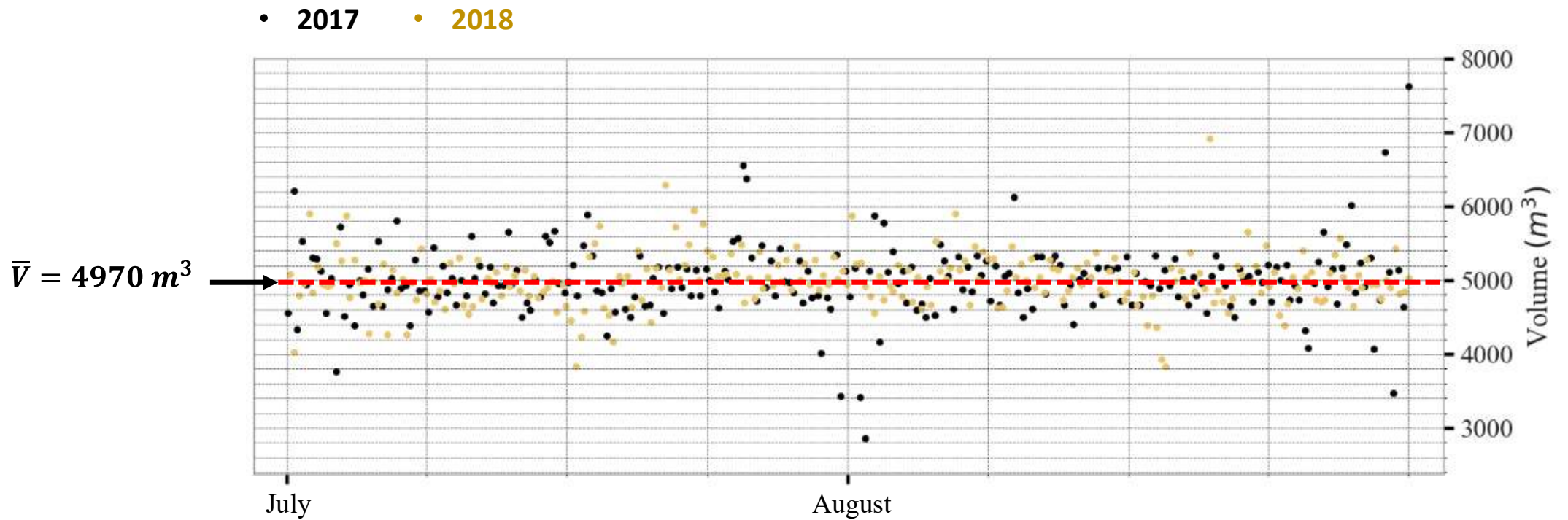
Assuming :

- Constant air quantity
- Constant water surface

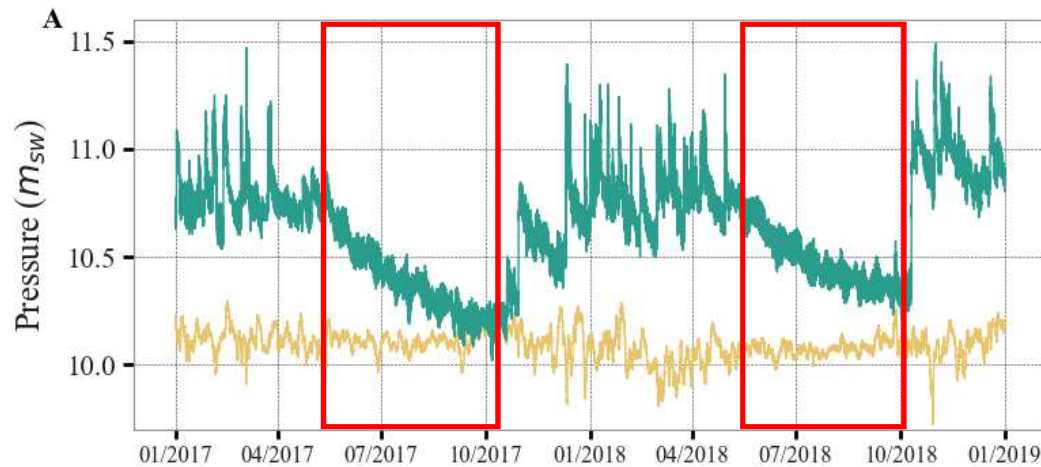
Cave volume



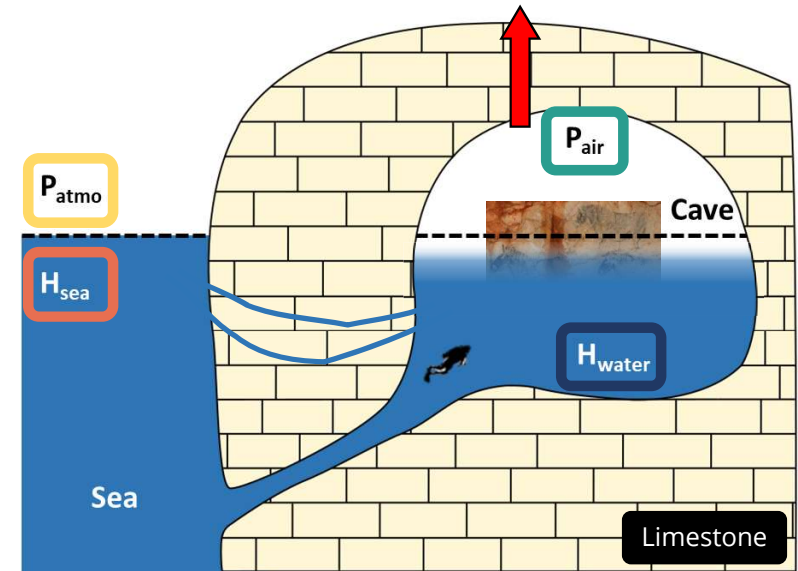
480 volume measurements between July and August for years 2017 and 2018



Permeability



slow pressure decrease periods = outflow through the rock



Darcy's law :

$$Q = \frac{k_{ea} A}{\mu L} (P_{air} - P_{atmo})$$

k_{ea} : limestone massif air effective permeability for a specific saturation¹

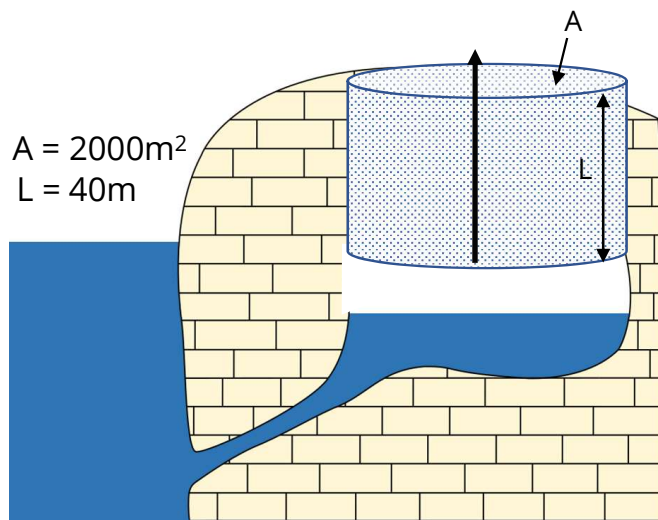
$$\text{Avec } k_{ea} = k_{ra} k_w^1$$

¹Standard handbook of petroleum & natural gas engineering, 2001

Permeability



Effective permeability of a partially saturated porous media k (Darcy)

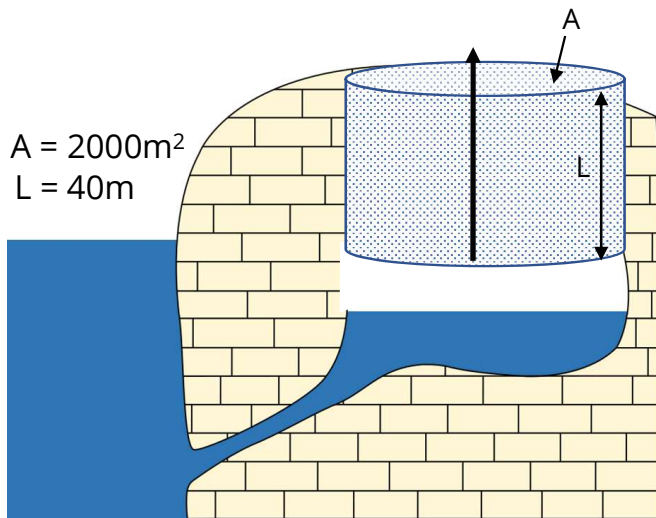


$k = 4 \text{ to } 11 \text{ mD}$ (2015 to 2020)

Permeability

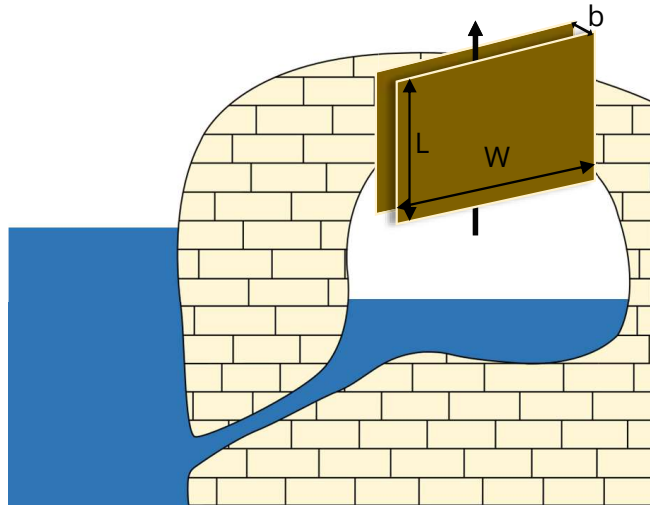


Effective permeability of a partially saturated porous media k (Darcy)



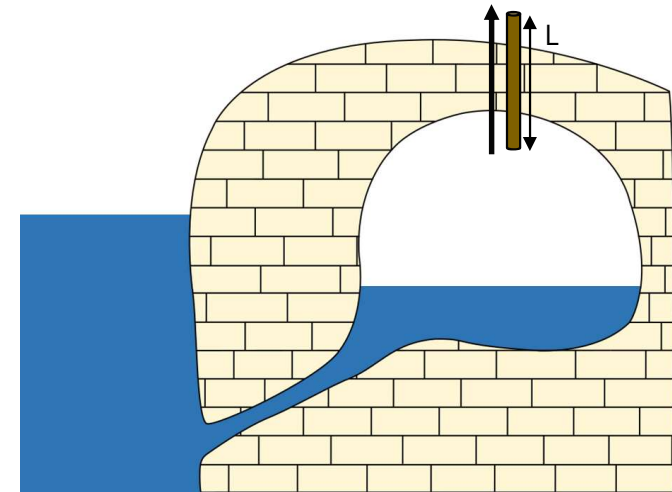
$k = 4 \text{ to } 11 \text{ mD (2015 to 2020)}$

Permeability equivalent to a fracture of b opening (Zimmerman *et al.*)



$b = 0.1 \text{ to } 0.2 \text{ mm}$

Permeability equivalent to a pipe duct of r radius (Poiseuille)

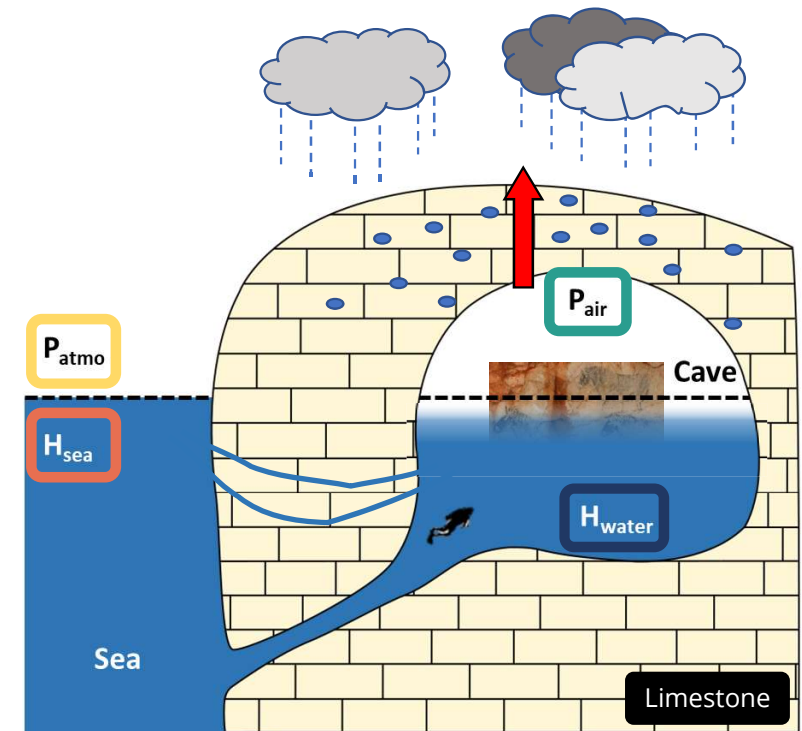
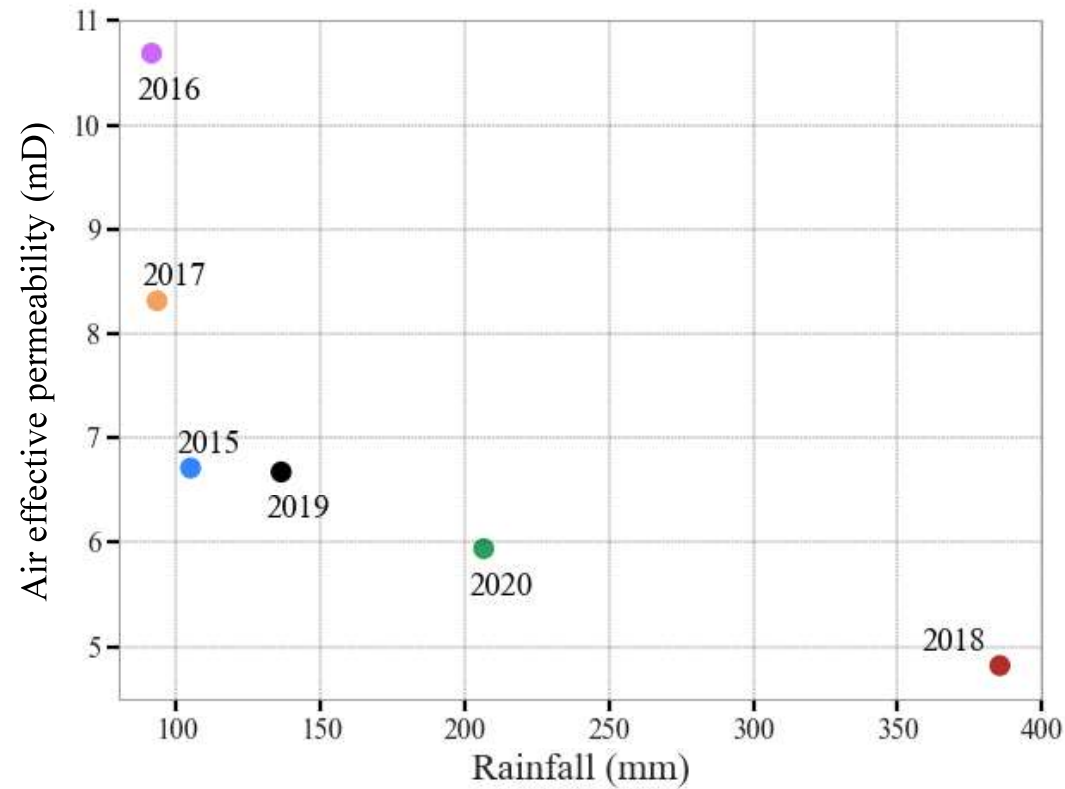


$r = 1.5 \text{ to } 1.9 \text{ mm}$

Permeability



Comparing permeability and cumulated rainfall over April to August for years 2015 to 2020 :



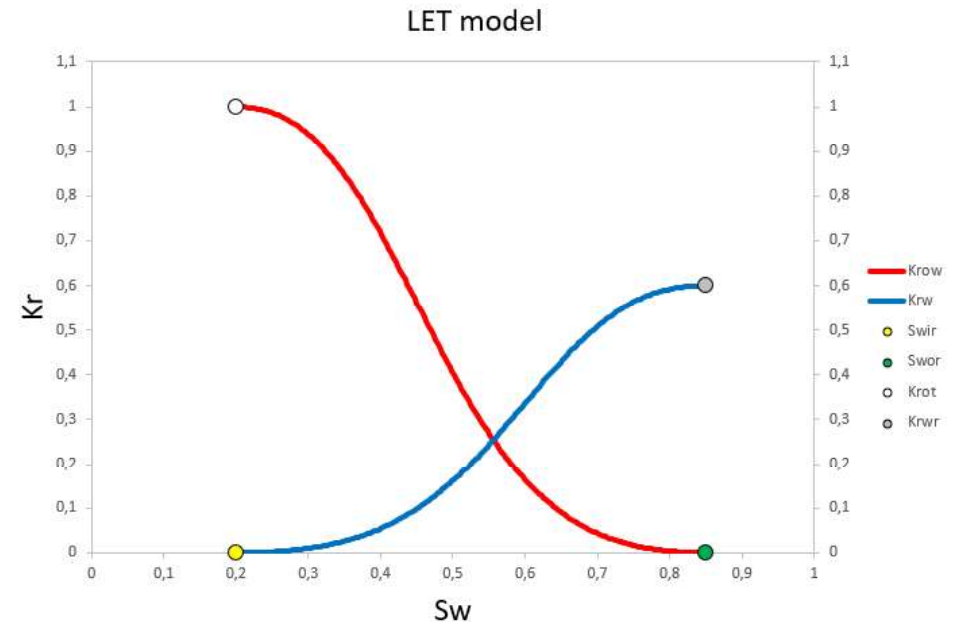
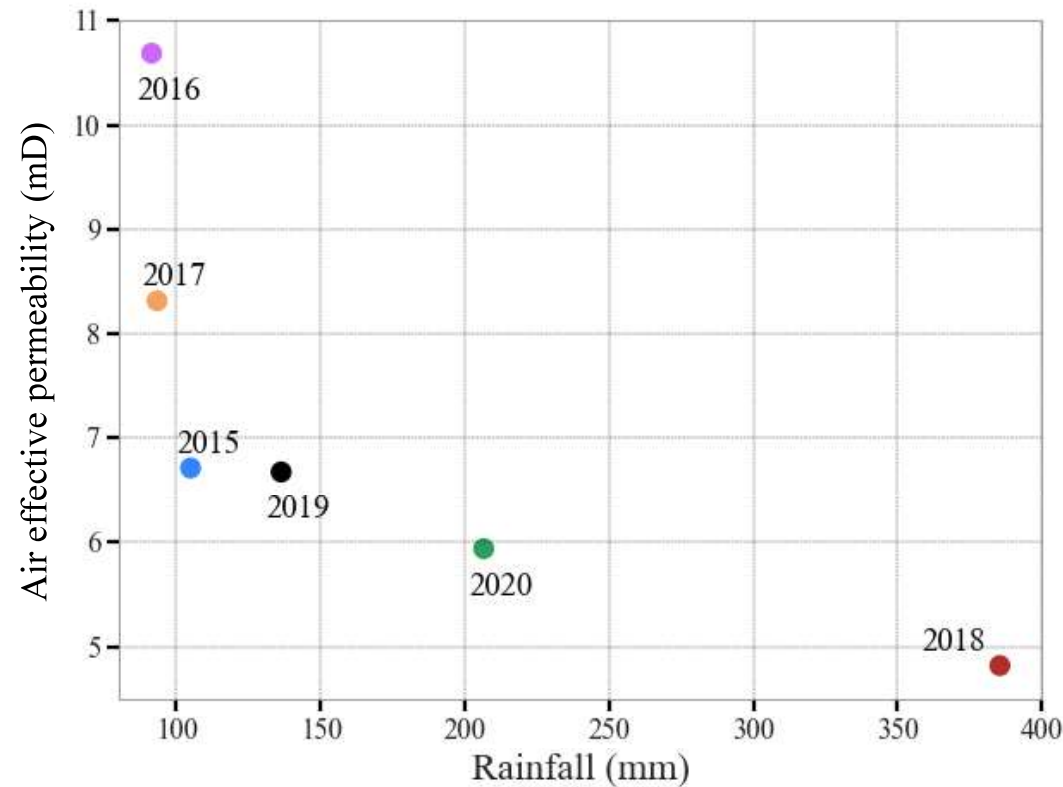
→ Decrease in rainfall leads to an increase of rock permeability

➡ Correlation between rock water saturation and rock permeability

Permeability



Comparing permeability and cumulated rainfall over April to August for years 2015 to 2020 :

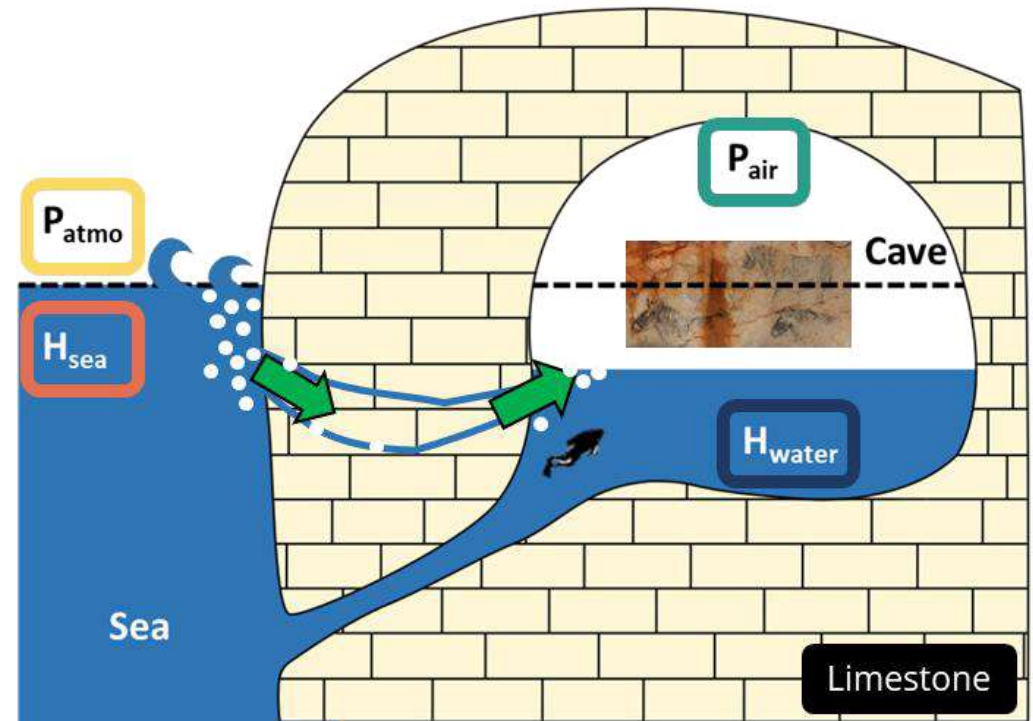


Example of LET-correlation (wikipedia.org)

→ What would be the limestone absolute permeability to air in the case water saturation falls to 0 ?

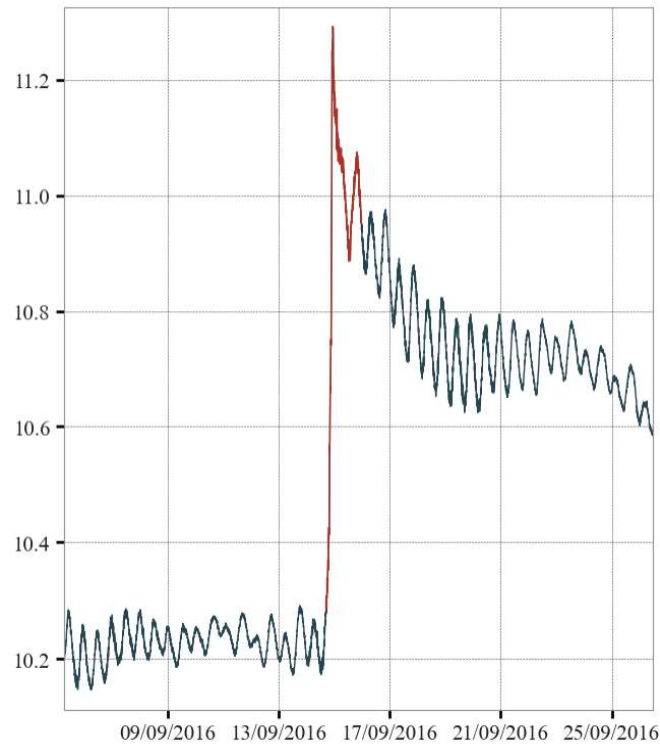
En cours : évènements de mise en pression

Définition provisoire : une seule ou une succession d'augmentations de la pression, suivie ou non d'une rapide baisse de la pression. Analogue à un phénomène de crue/décrue d'un karst.

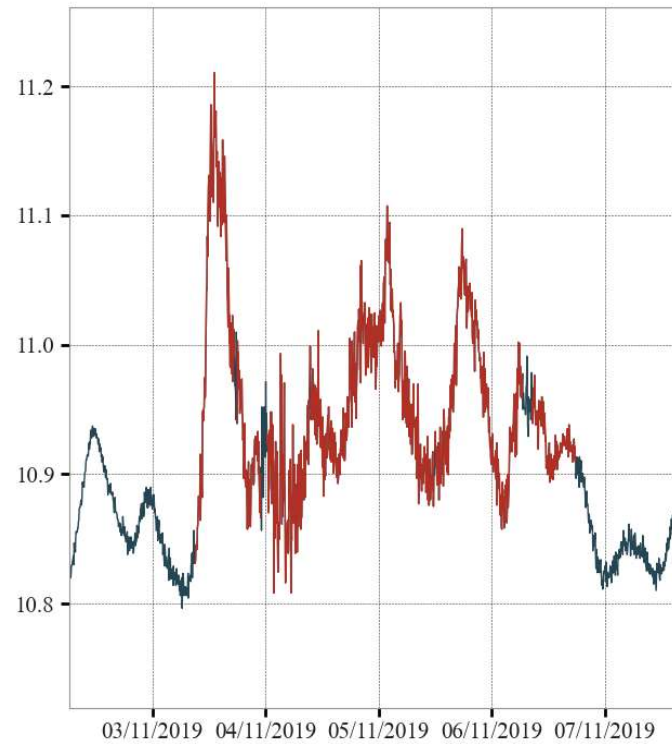


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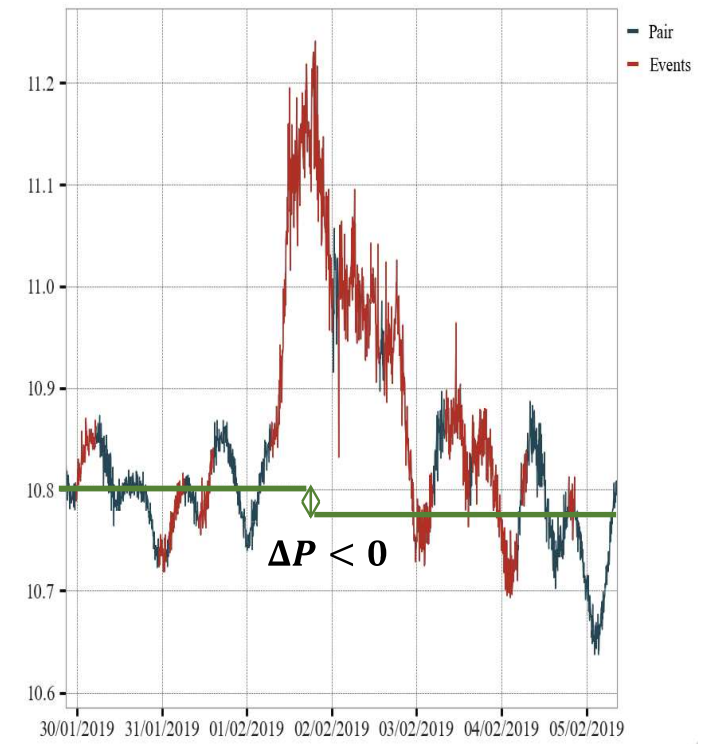
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Unique montée en pression



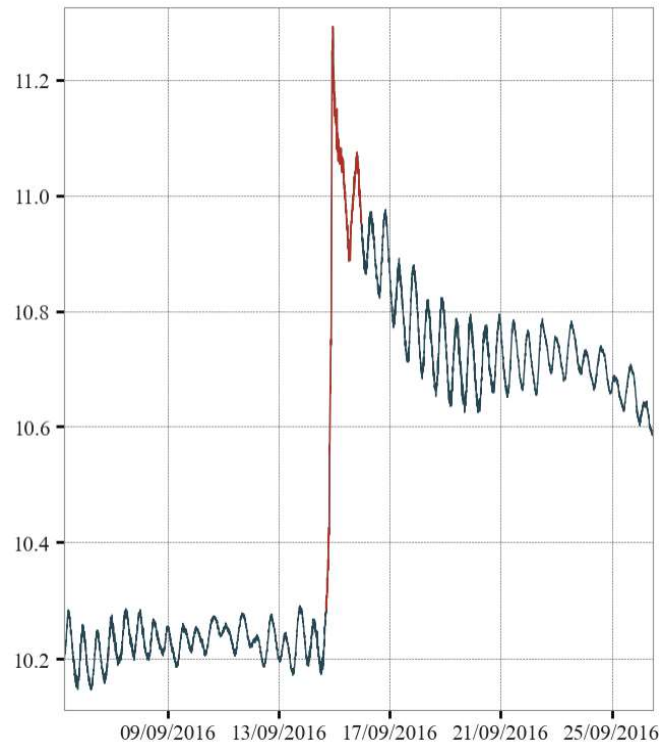
Succession de montées et baisse de la pression



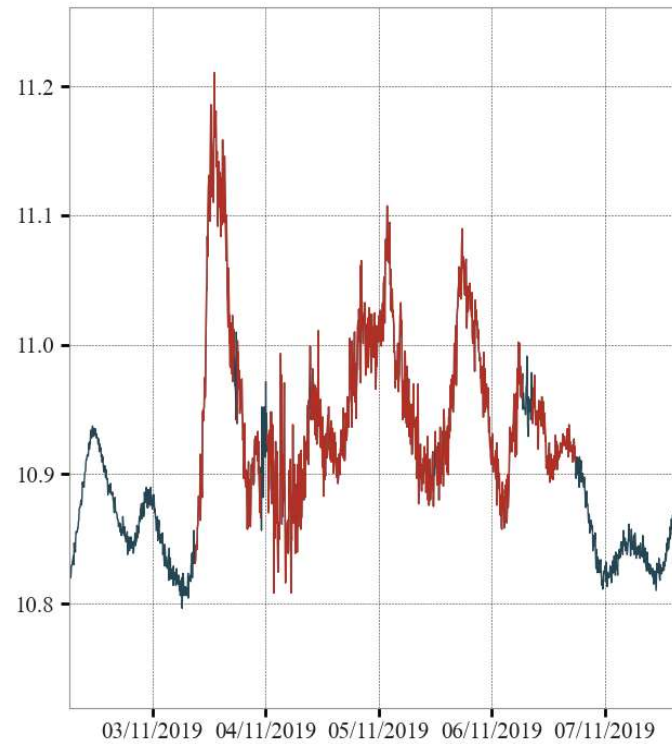
Pression inférieure à la fin de l'évènement qu'au début

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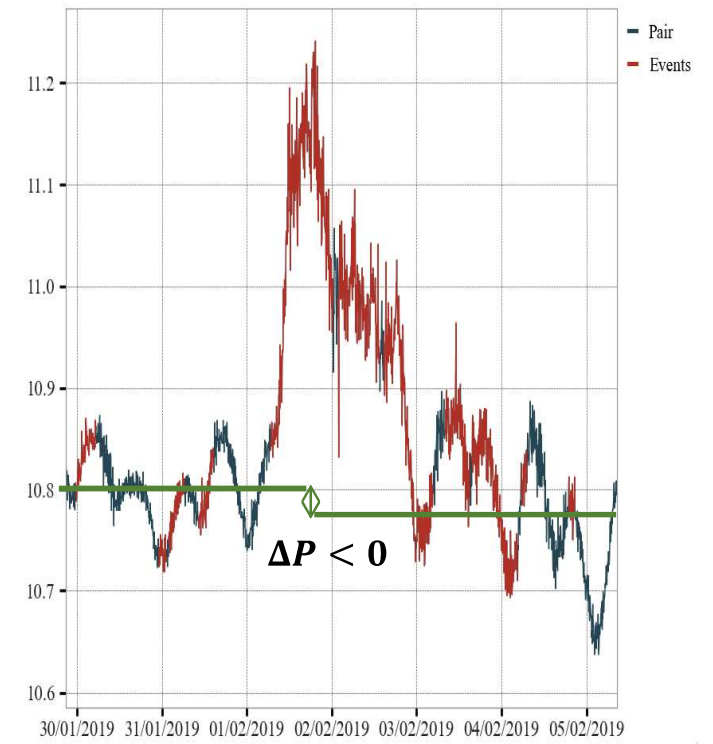
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Unique montée en pression



Succession de montées et baisse de la pression

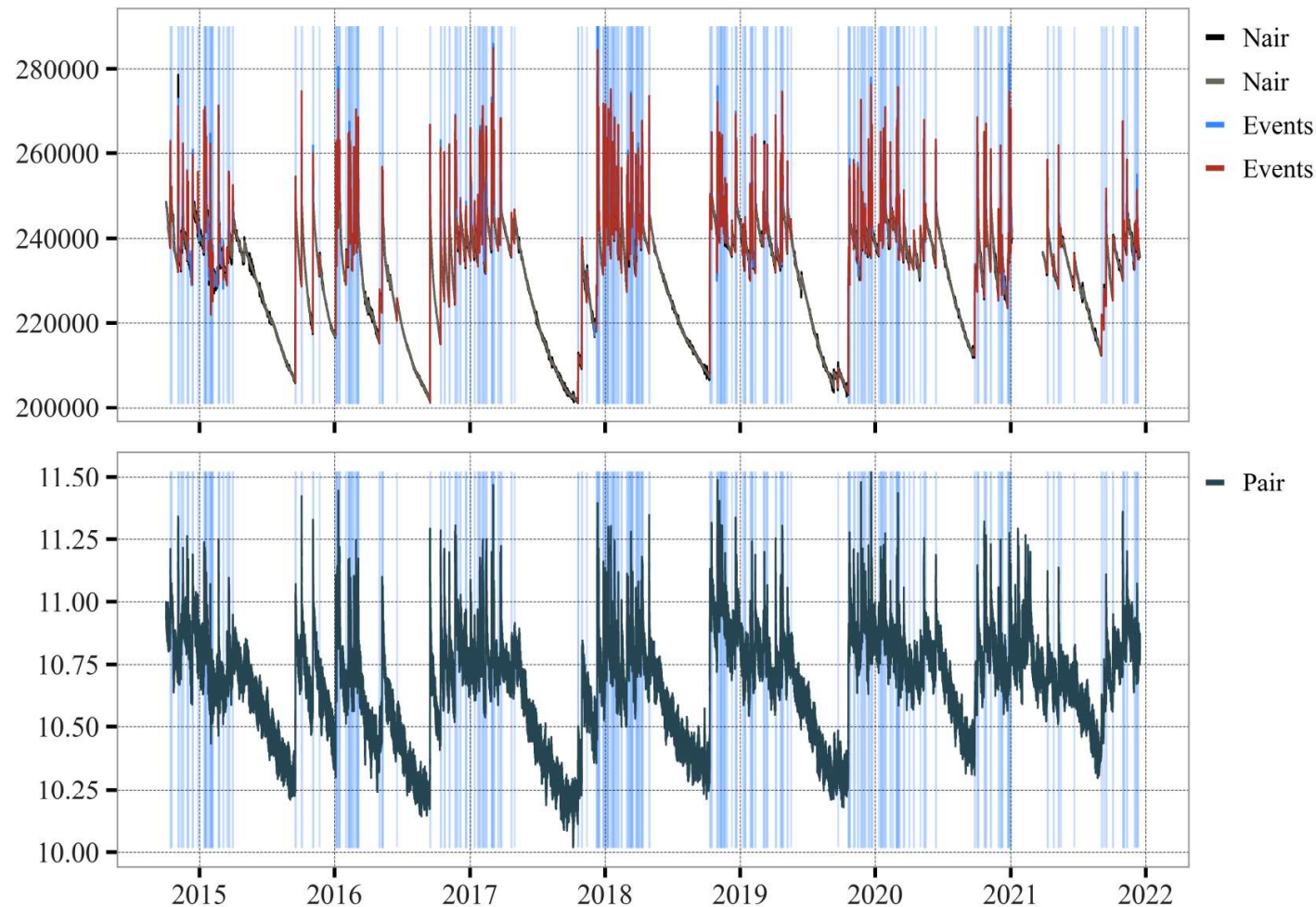


Pression inférieure à la fin de l'évènement qu'au début

Comment classer ces évènements ?

Evènements de mise en pression

Automatisation de la détection d'évènements (barres bleues)



Objectifs :

Déterminer les paramètres contrôlant les flux d'air.

- Pression de l'air dans la grotte
- Niveau d'eau
- Niveau de la mer
- Hauteur des vagues
- Direction des vagues
- Période des vagues
- Vent
- Durée
- D'autres paramètres ?...

Comment s'en sortir avec autant de paramètres ?

Possibilité de clustering pour réaliser une typologie des évènements

Conclusion

Fragile cultural heritage

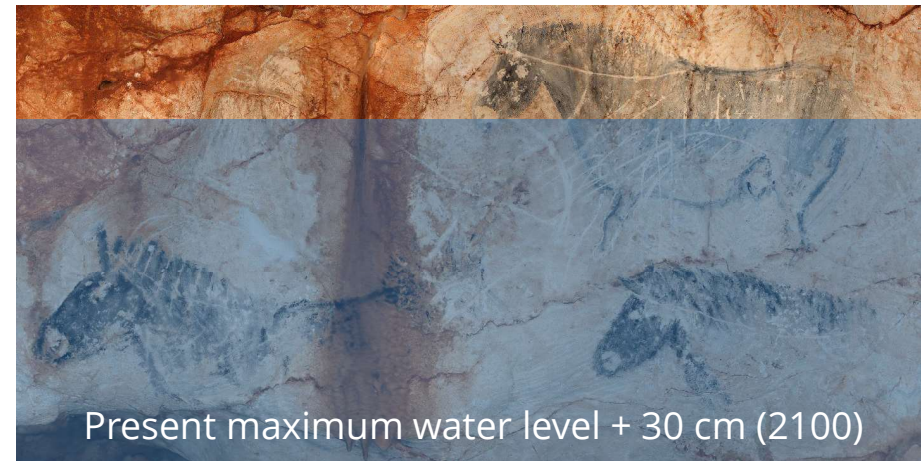
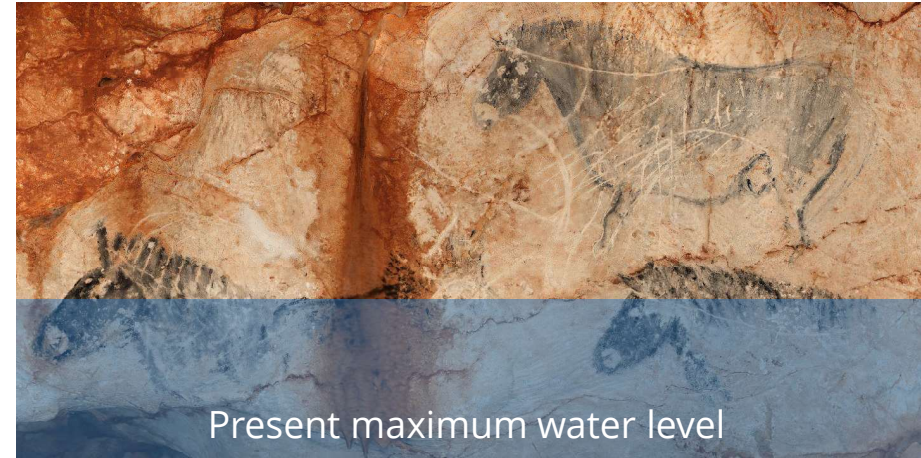
- Favorable climate conditions
- Understand the system

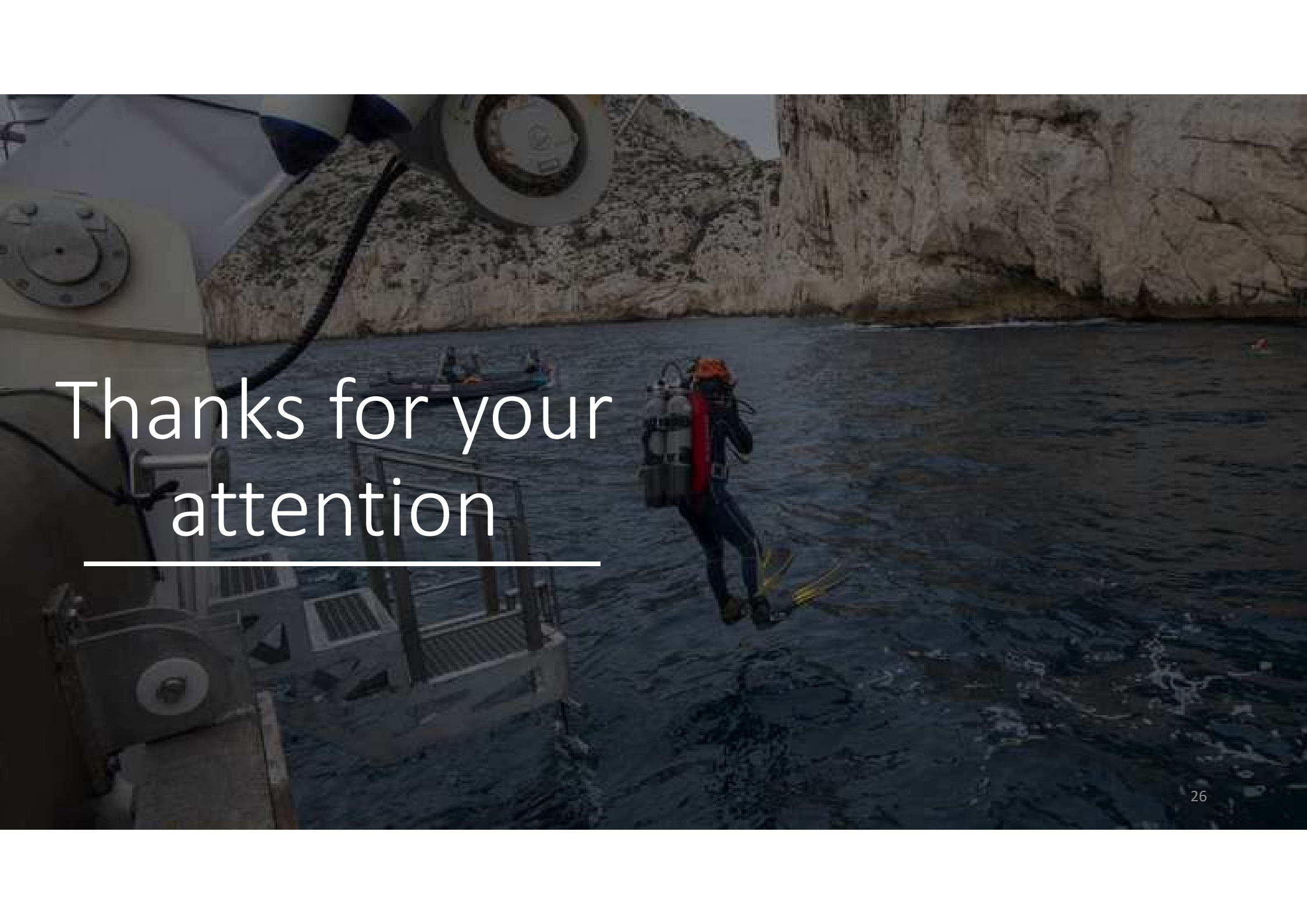
Climate changes

- Sea level rising
- Drought
- Temperature increase
- Ocean acidification...

Adapt conservation choices

- Understand the current behaviour
- Assess future changes





Thanks for your
attention
