



Flow reversal and saltwater intrusion at the submarine spring of a Mediterranean karst aquifer: explanation and modelling

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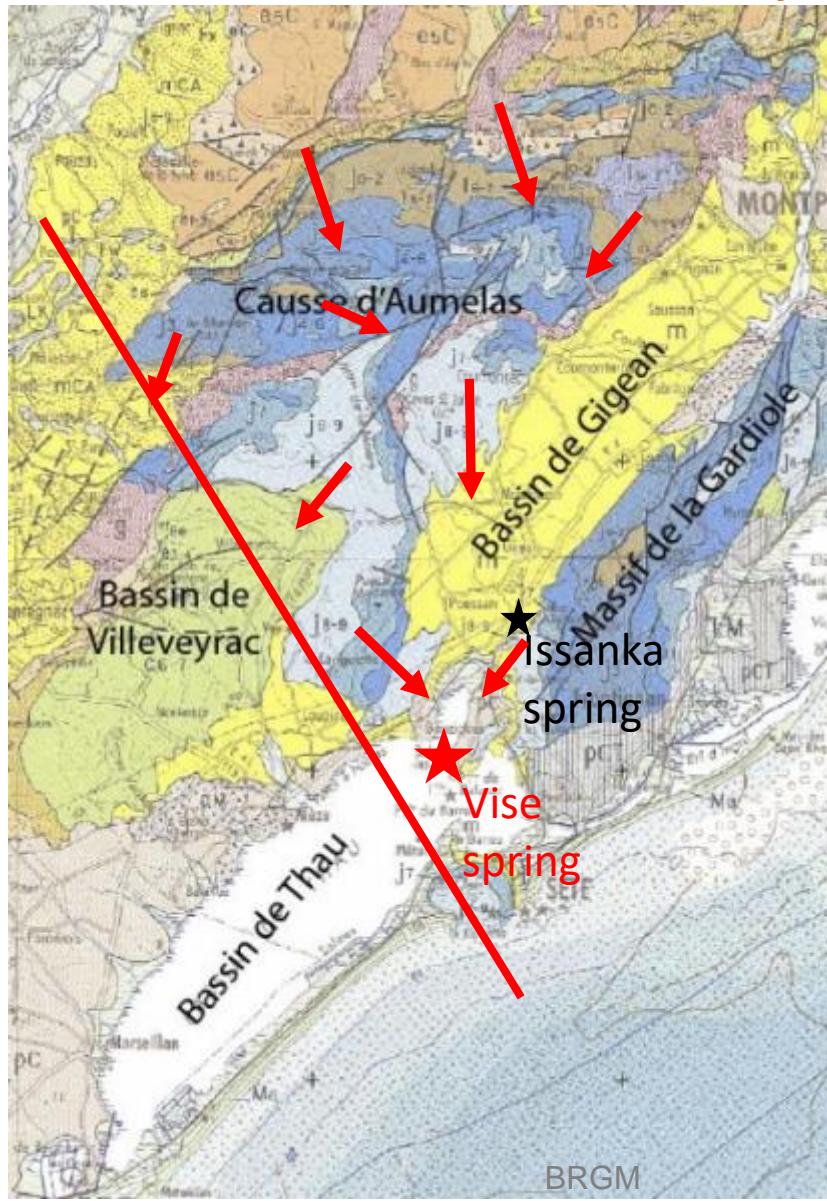
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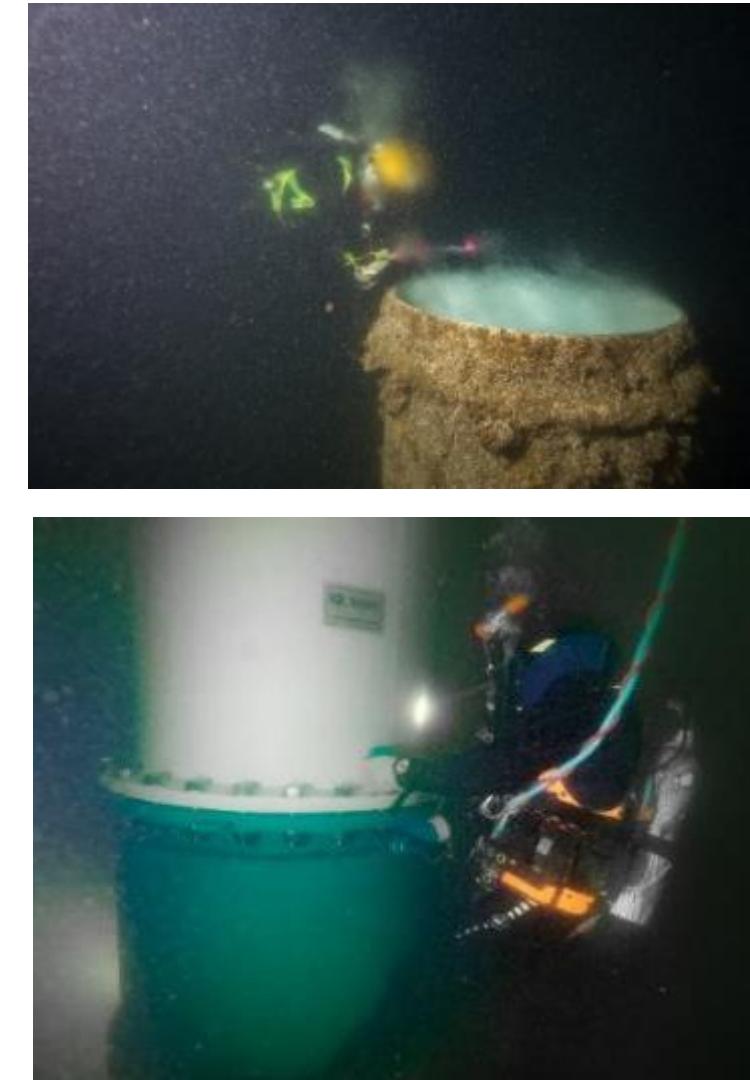
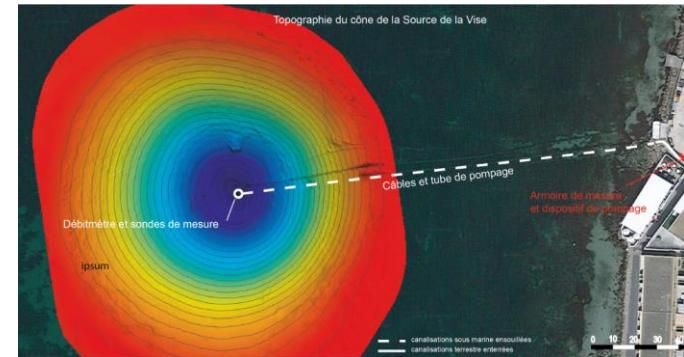
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The Aumelas-Issanka-Vise karst hydro system



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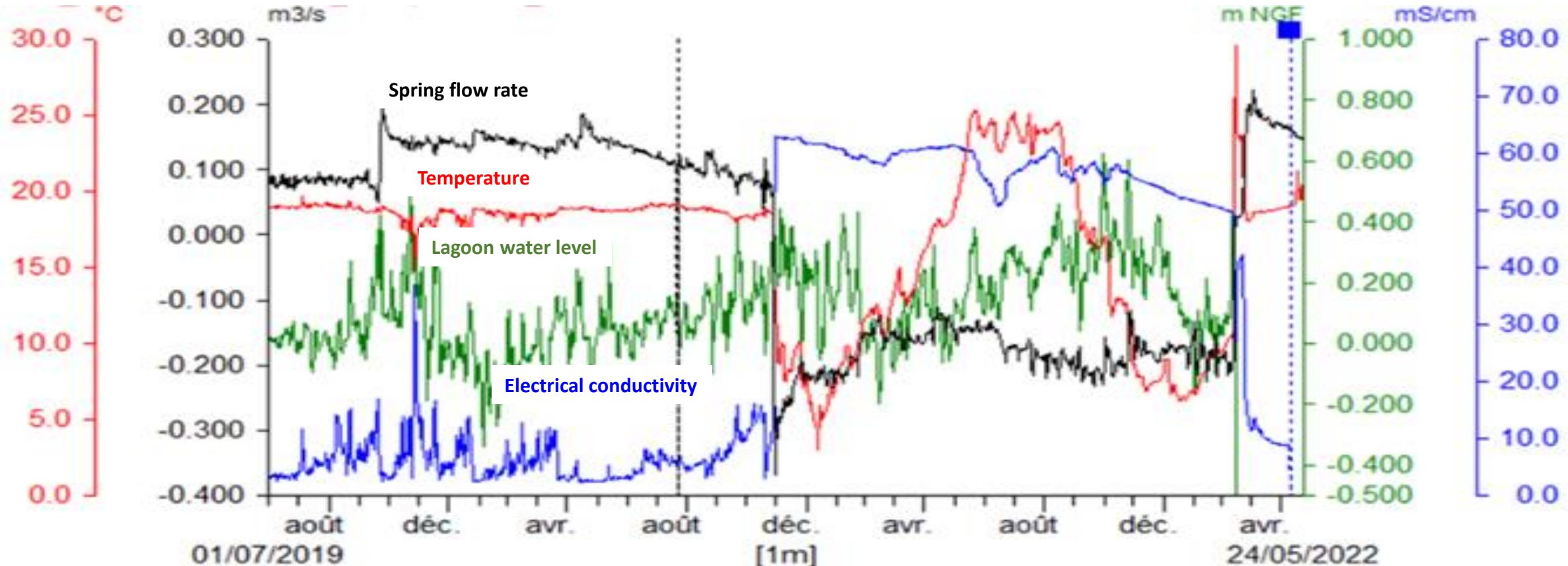
PHENOMENON DESCRIPTION

The image shows a panoramic view of a coastal city, likely Montpellier, France. The foreground is dominated by a hillside covered in green trees and shrubs. Below the hill, the city's urban sprawl is visible, with numerous modern apartment buildings and houses. The city is situated on a peninsula that extends into a large, calm body of water, which appears to be the Mediterranean Sea. In the distance, across the water, there are more coastal towns and what looks like an island or a large peninsula. The sky is a clear, vibrant blue. On the left side of the image, there is a graphic overlay for the "48th IAH Congress". It features the French national emblem (the tricolor flag) and the text "RÉPUBLIQUE FRANÇAISE" and "Liberté Egalité Fraternité". Below this is the logo for "brgm" (Bureau de Recherches Géologiques et Minières) with the tagline "Géosciences pour une Terre durable". The graphic also includes the text "48th IAH Congress" and "BRUSSELS BELGIUM 2021" along with the slogan "Inspiring Groundwater".

Flow reversal ('Inversac') event of 2020/2021

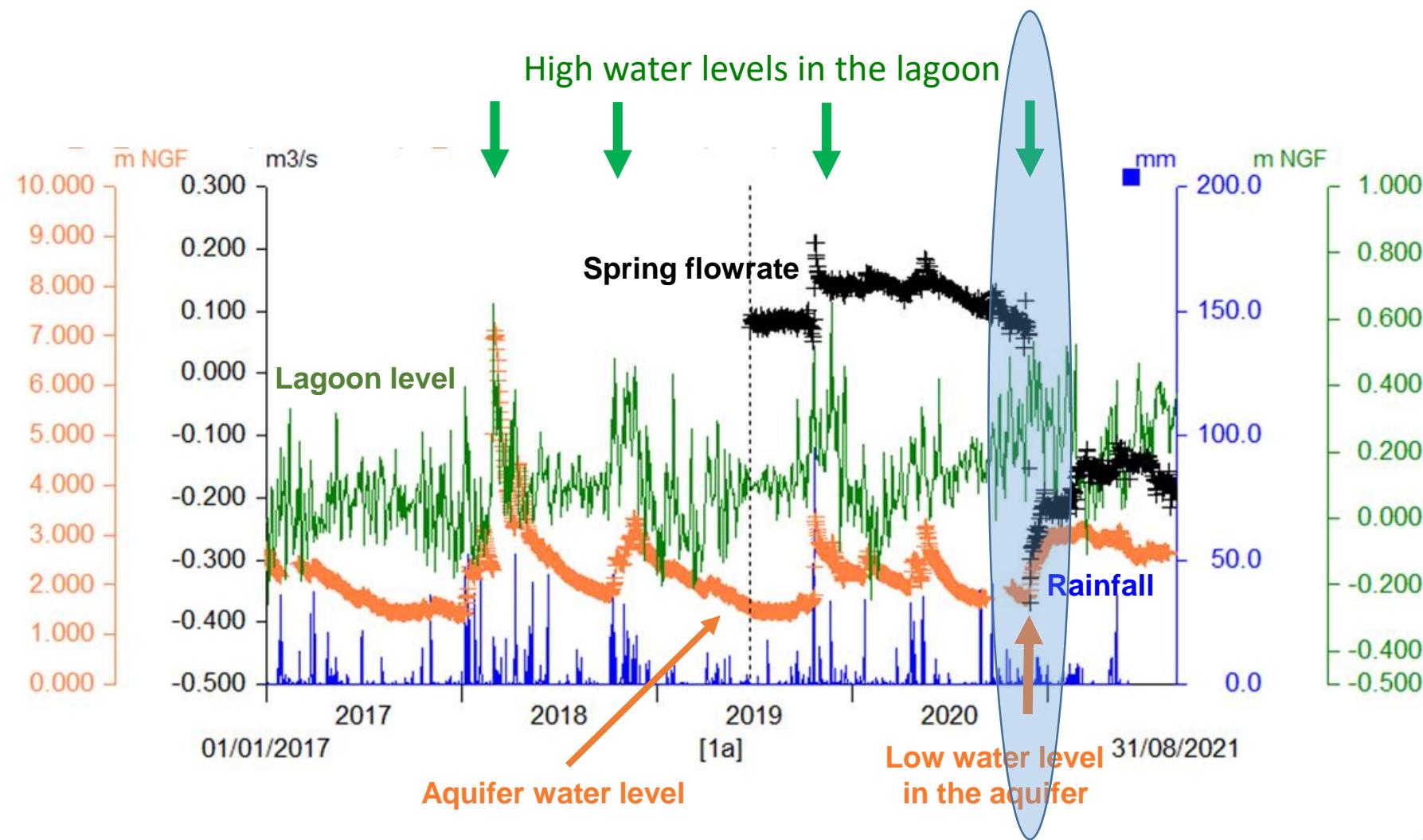
Preliminary results at the Vise spring

- Start of the phenomenon: 28/11/2020 at 09:40 AM
- Triggering factors: the lagoon's high water level in a hydrogeological context of very low water
- End of the phenomenon: 14/03/2022 at 08:35 AM (471 days later)
- Infiltration flowrate (Lagoon to Vise spring) : up to 350 l/s at the beginning of the event, decreasing later



Flow reversal ('Inversac') event of 2020/2021

Hydrogeological context





United Nations
Educational, Scientific and
Cultural Organization

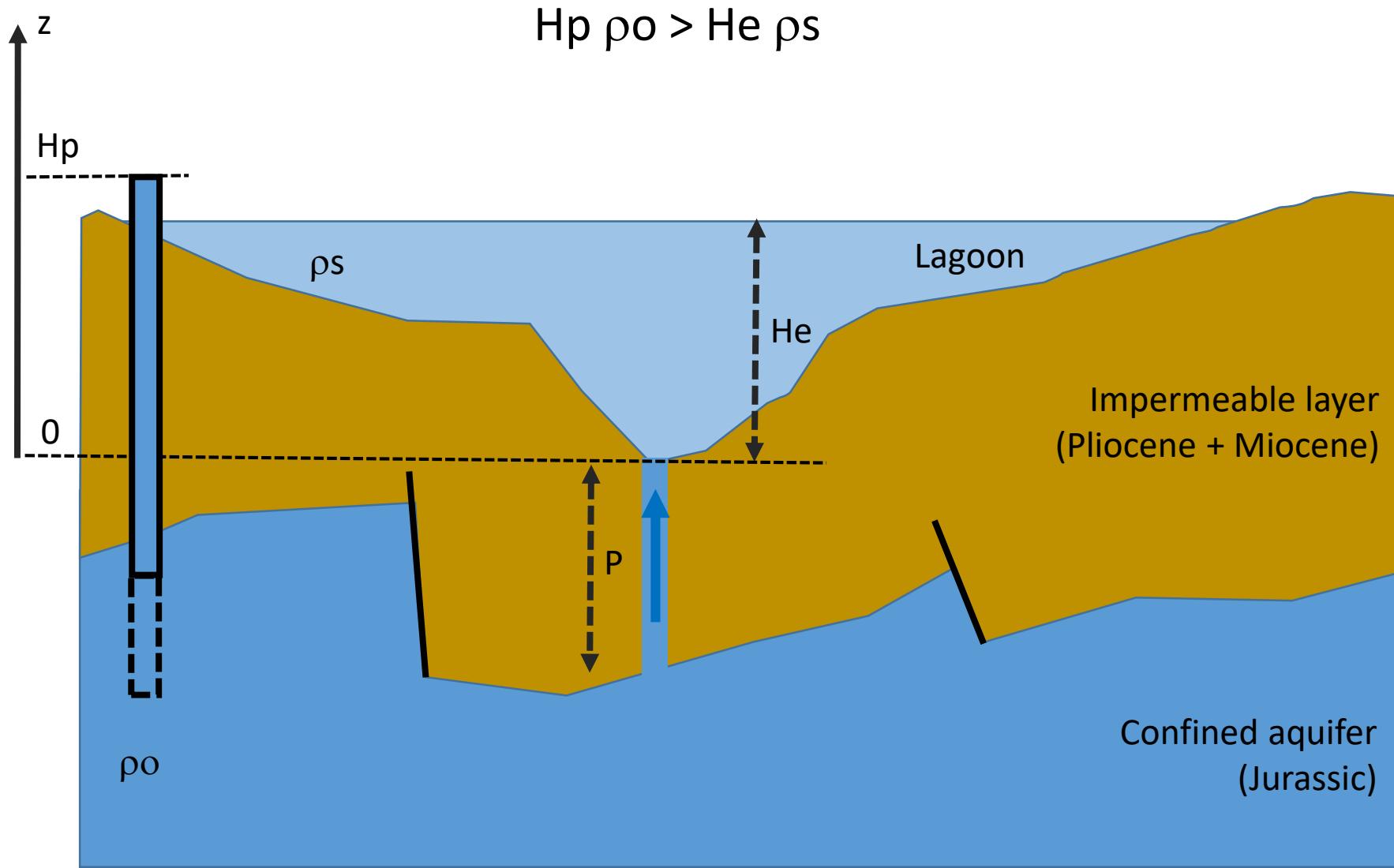


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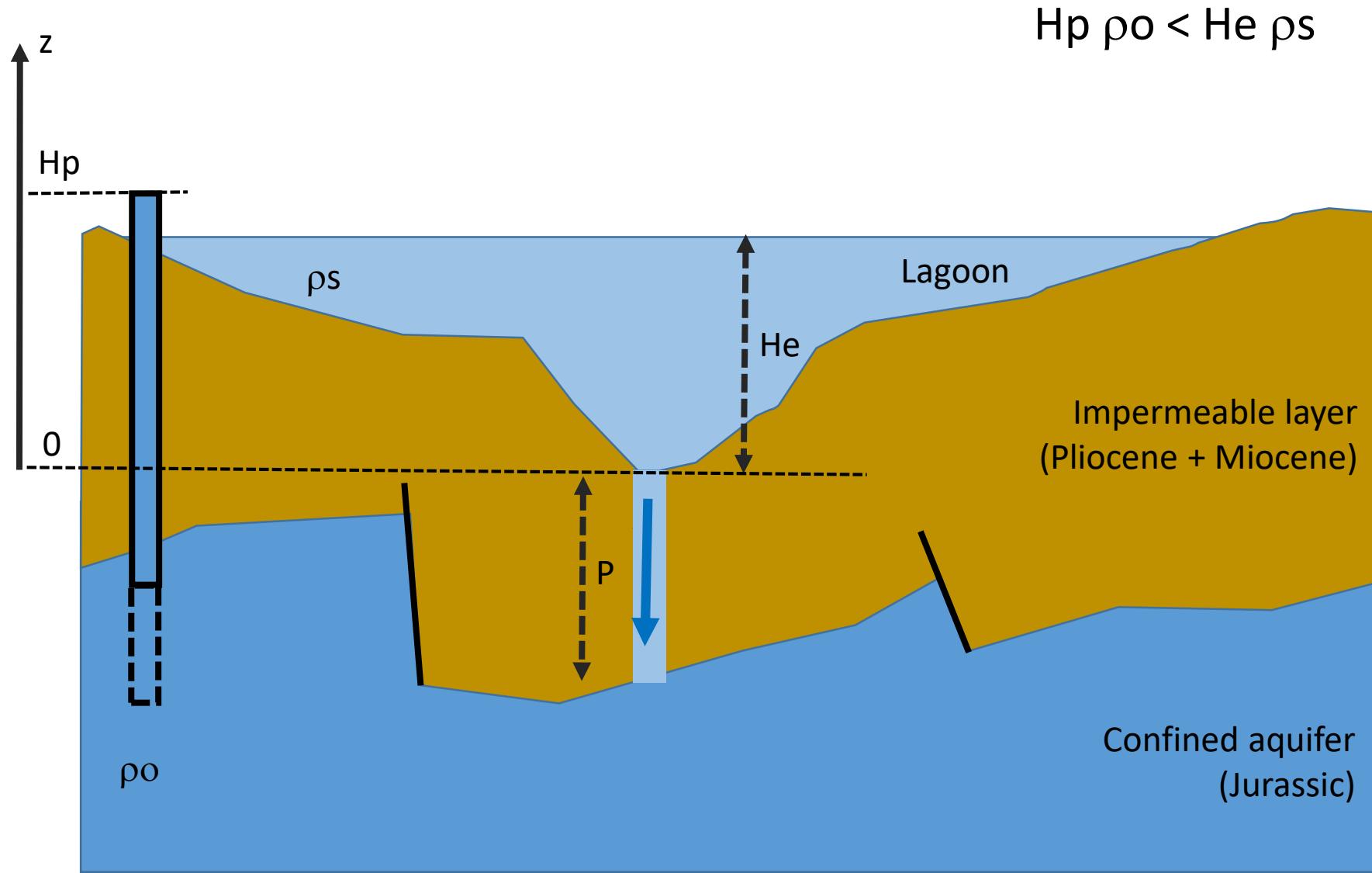


Géosciences pour une Terre durable

Inversac explanation: focus on the Vise spring (as-usual situation)



Inversac explanation: focus on the Vise spring (inversac situation)

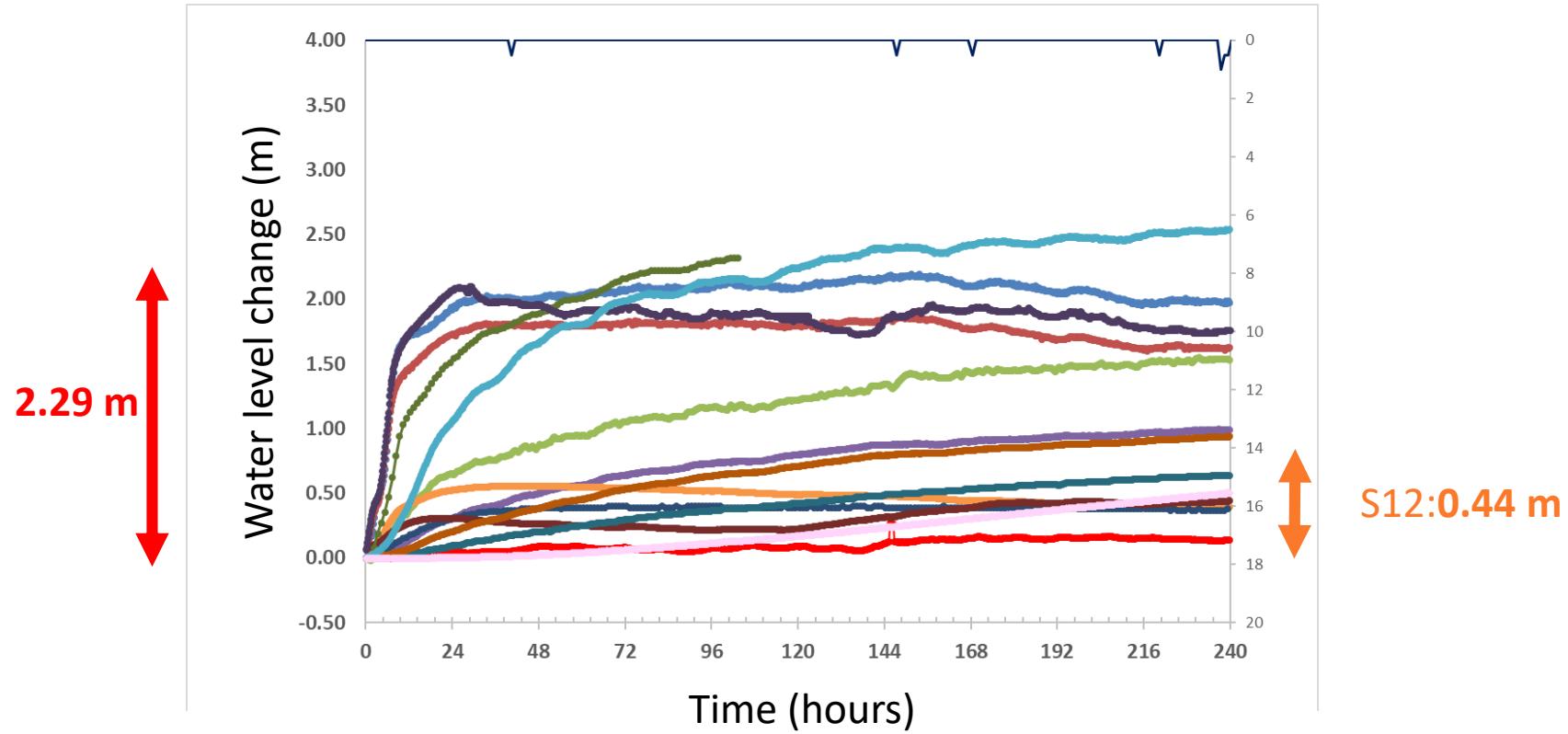




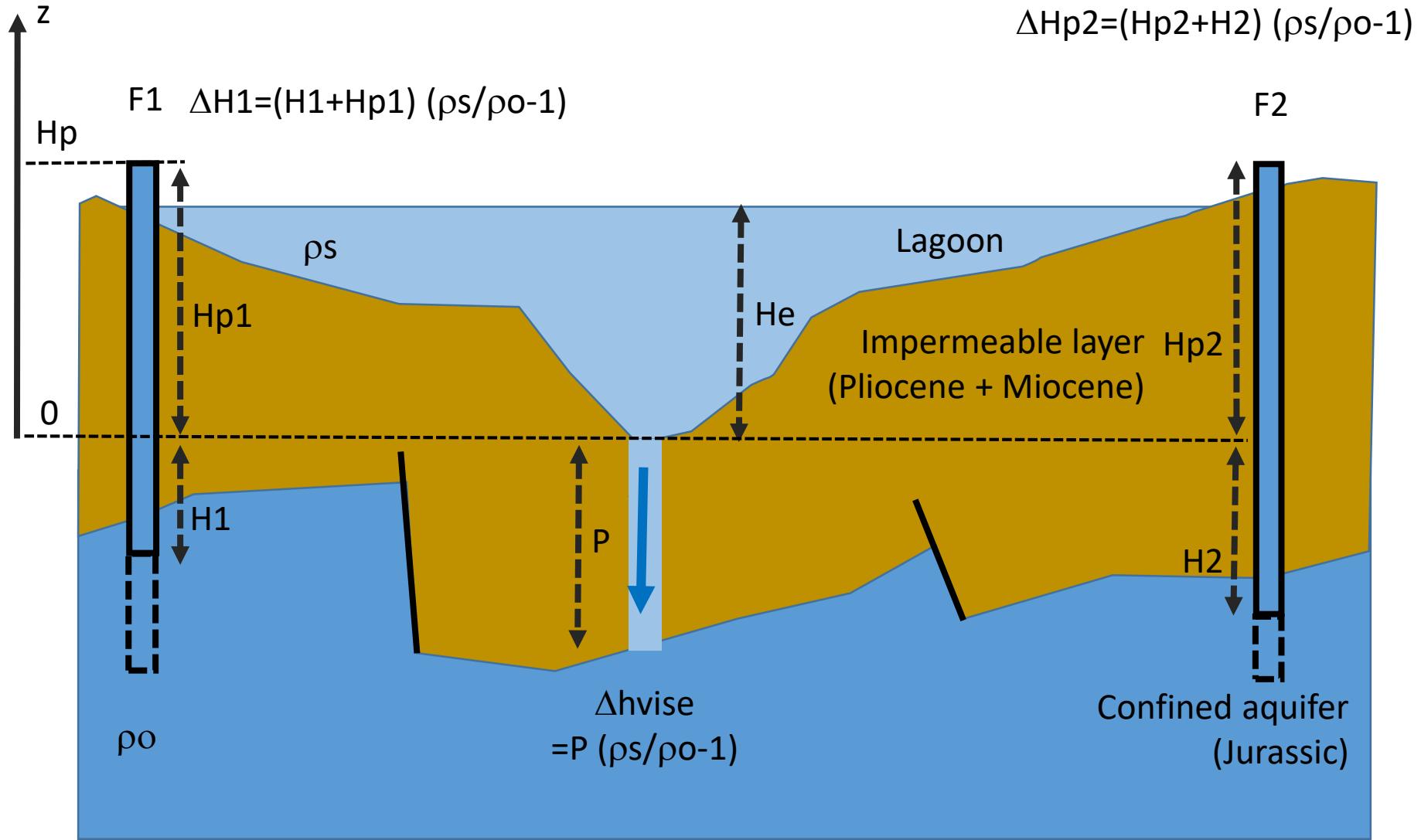
Inversac: impact on piezometry

Inversac 2020: computation of piezometry fluctuation

- High water level fluctuations in deep wells with a maximum value (2.29 m)
- Low water level fluctuations in shallow wells



Inversac: impact on piezometry

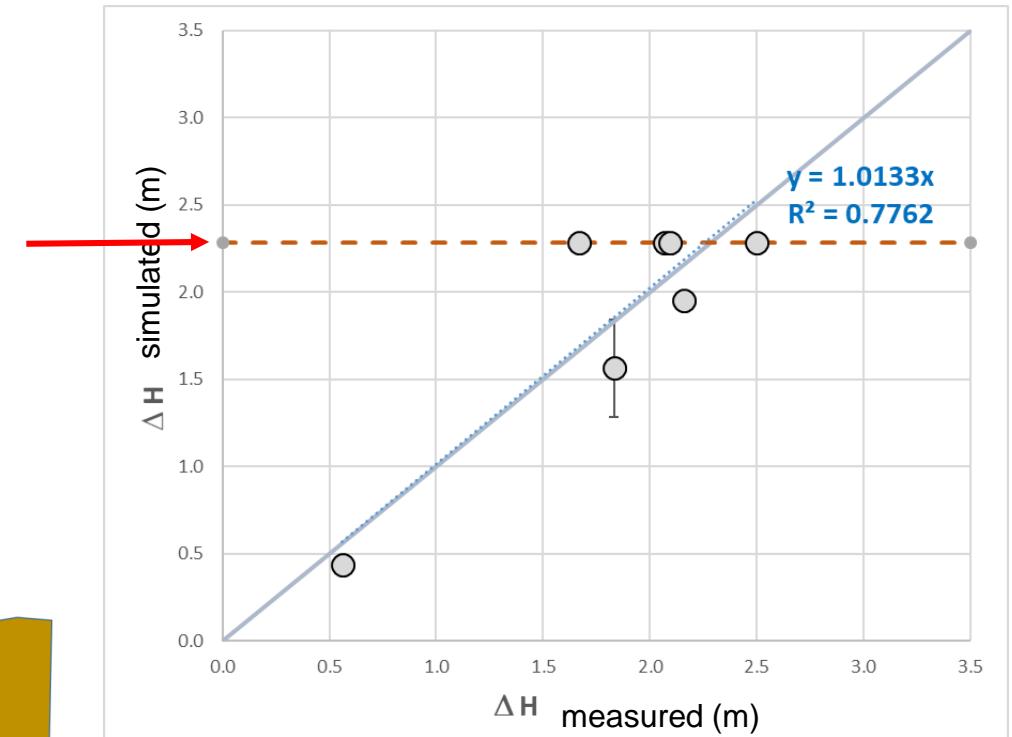
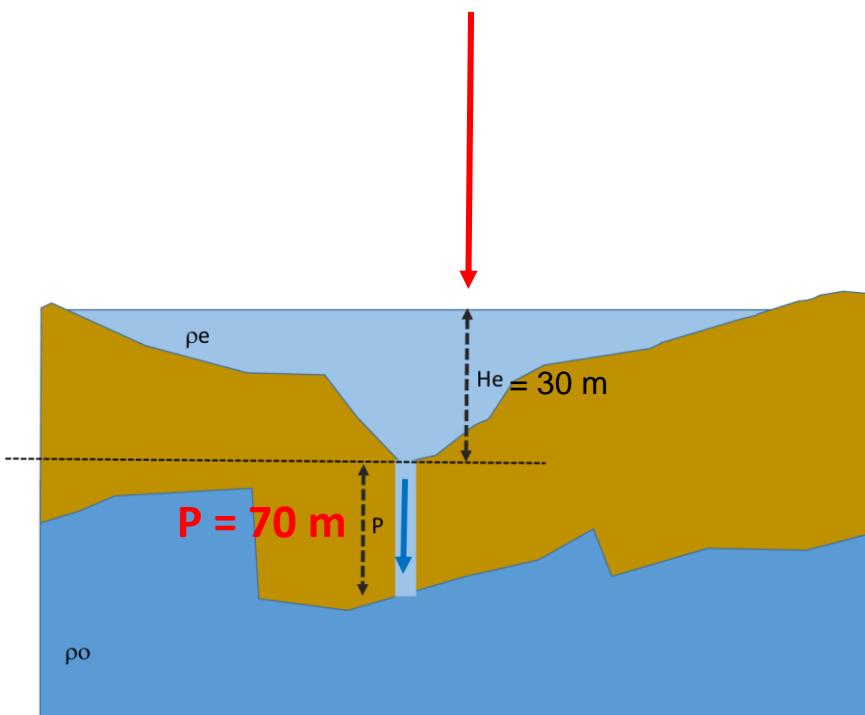


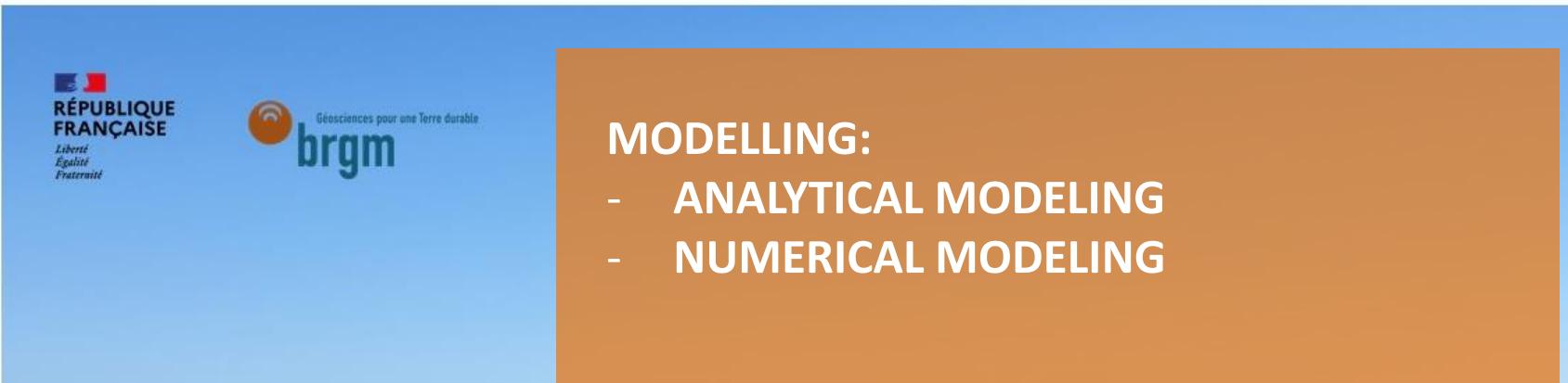
Inversac: impact on piezometry

Inversac 2020: computation of piezometry fluctuation

At well i: $\Delta H_i = (H_i + H_{pi}) (\rho_s / \rho_o - 1)$

$$\begin{aligned}\Delta h_{max} &= \Delta h_{vise} = P (\rho_s / \rho_o - 1) \\ &= 70 (1.032 / 0.999 - 1) = 2.29 \text{ m}\end{aligned}$$



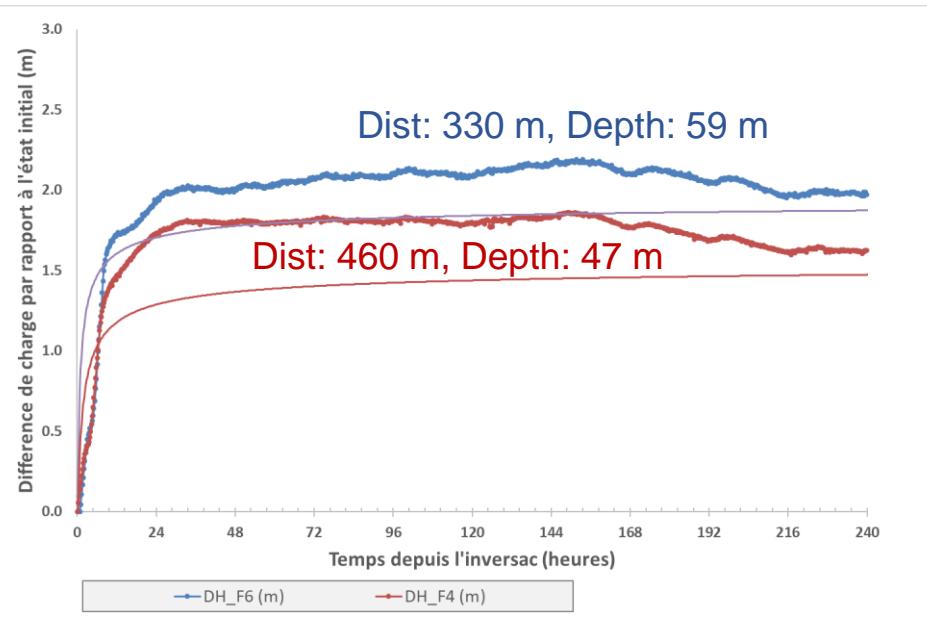
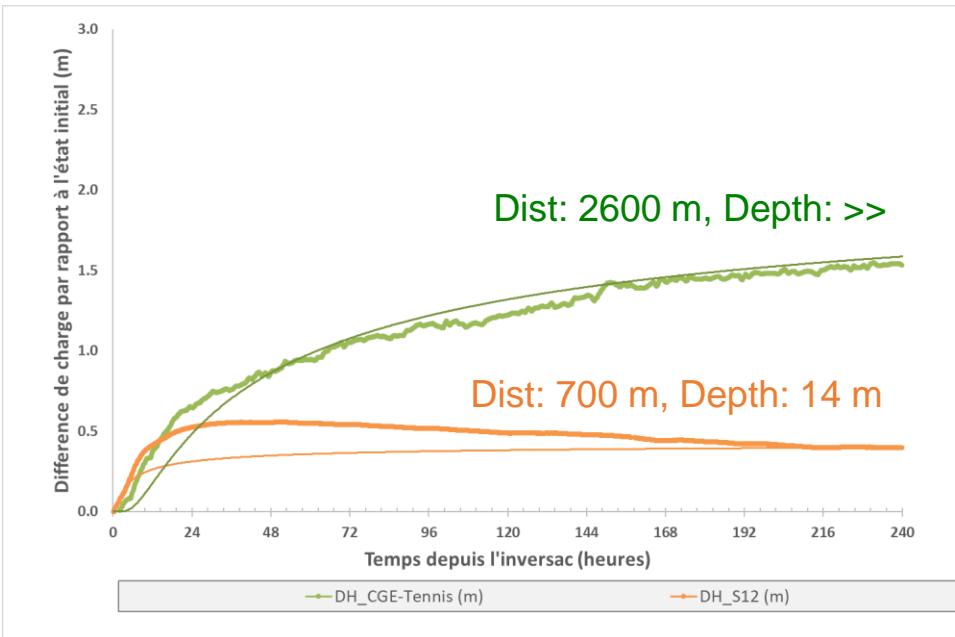


Inversac modeling

Inversac 2020: analytical modeling of piezometry

	Solution 1	Solution 2
Flow regime	Spherical	1D flow
Flow equation	$\frac{dH}{dt} = \frac{D}{r^2} \frac{d}{dr} \left(r^2 \frac{dH}{dr} \right)$	$\frac{dH}{dt} = \frac{D}{x} \frac{d}{dx} \left(x \frac{dH}{dx} \right)$
Initial condition	$H(r, 0) = 0$	$H(x, 0) = 0$
Prescribed condition	$H(r_0, t) = \Delta H_0$	$H(0, t) = \Delta H_0$
Analytical solution	$H(r, t) = \Delta H_0 \frac{r_0}{r} \operatorname{erfc} \left(\frac{r - r_0}{\sqrt{4Dt}} \right)$	$H(x, t) = \Delta H_0 \operatorname{erfc} \left(\frac{x}{\sqrt{4Dt}} \right)$

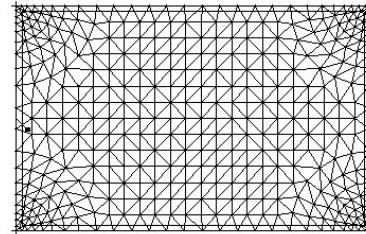
with Diffusivity $D = 25 \text{ m}^2/\text{s}$



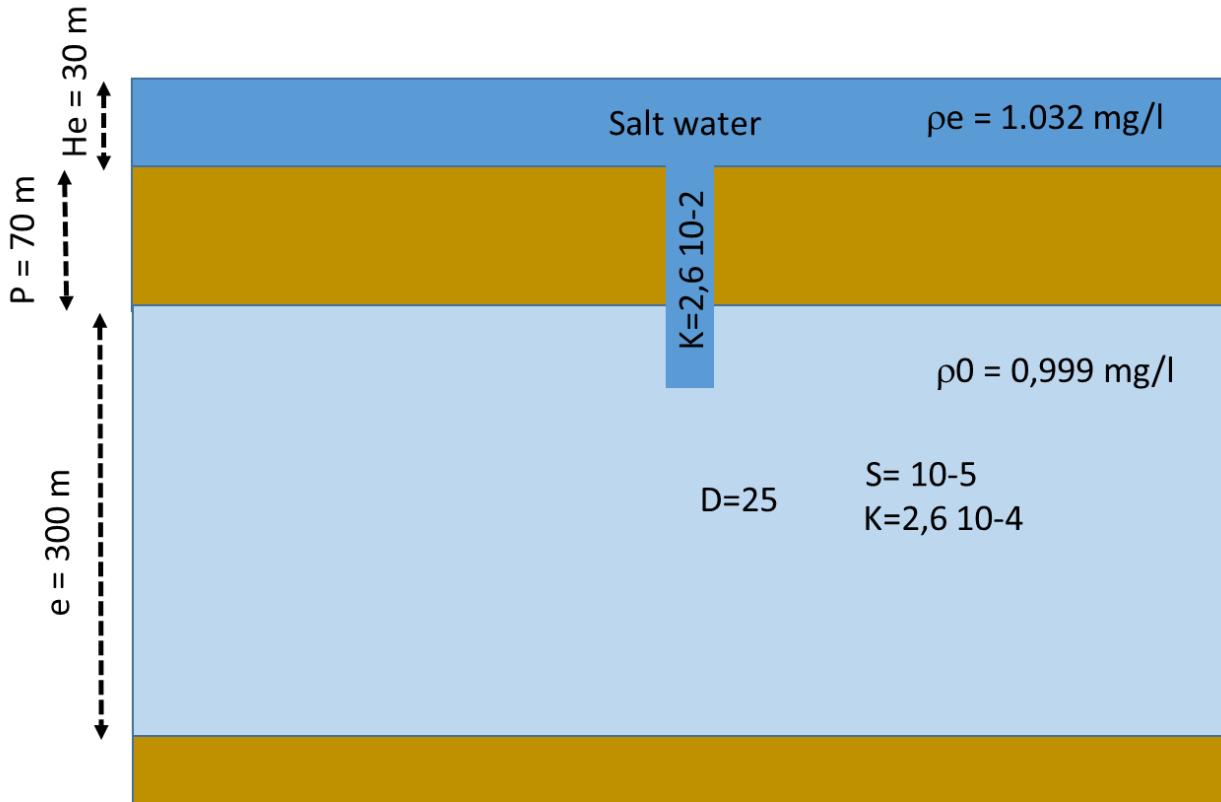
Inversac modeling

Description of the numerical model

Finite element model

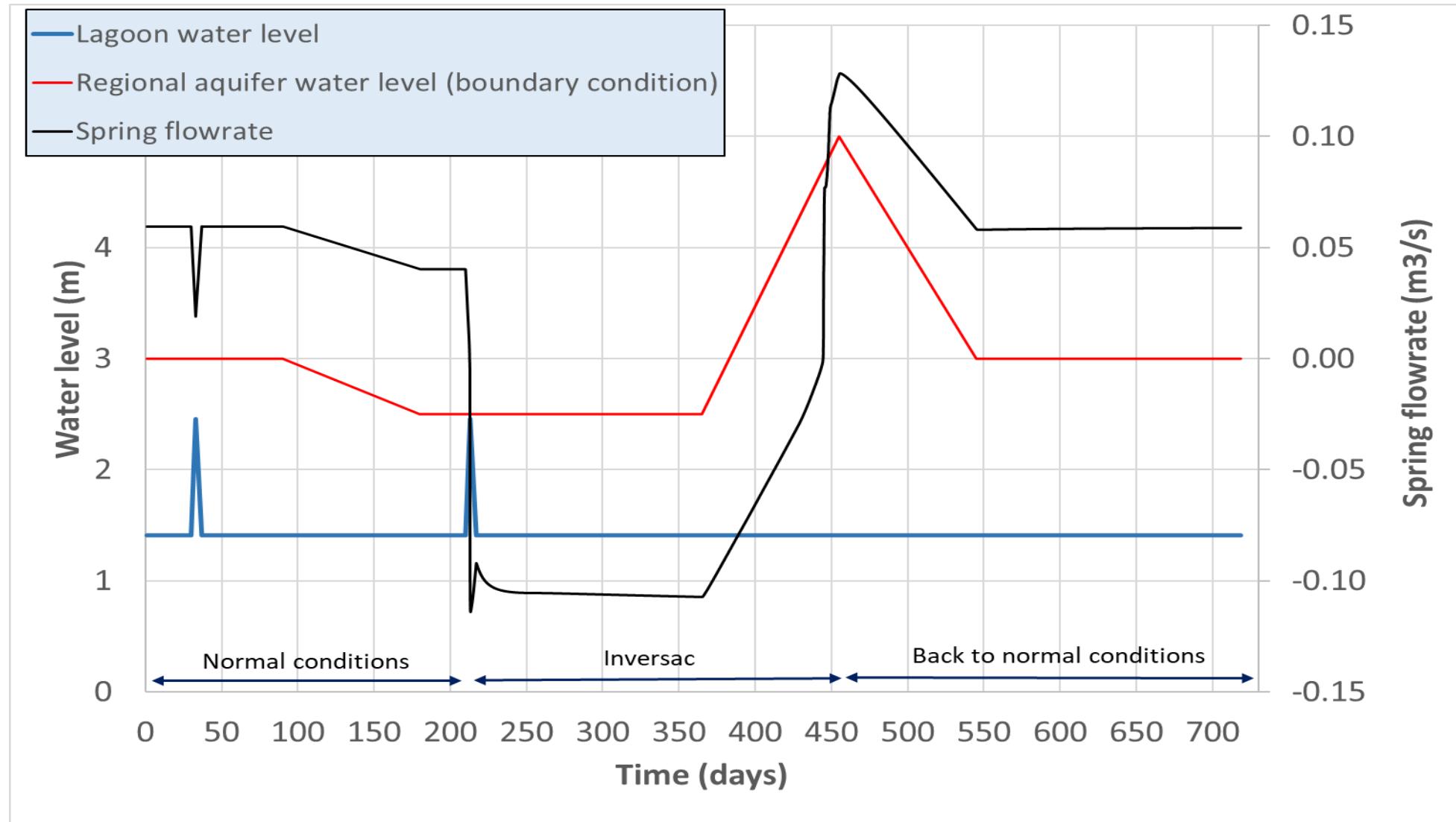


Feflow



Inversac modeling

Results of numerical simulation





Conclusion and perspectives

Conclusion

- Simple mechanism explains the observed processes
- The inversac is induced by an increase of the water level in the lagoon during low flow conditions in the aquifer
- The sudden water level increase is due to the instantaneous filling of the karst conduit
- The recovery necessitates a high water table rise able to counterbalance the hydraulic head rise due to the salt water intrusion: this is the reason why the inversac duration is very long (several months)

Perspectives

- Definition of alert indicators (lagoon water level, aquifer piezometry)
- Proposition of mitigation measures

THE END

A few figures

- Total duration of flow reverseal period: 471 days
- Total volume of salt water infiltrated : 6 700 000 m³
- Total mass of salt infiltrated : 216 000 tons



View on the lagoon when
the Vise spring flows