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

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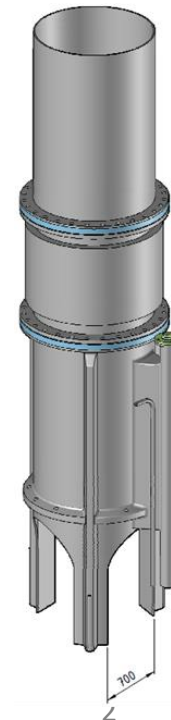
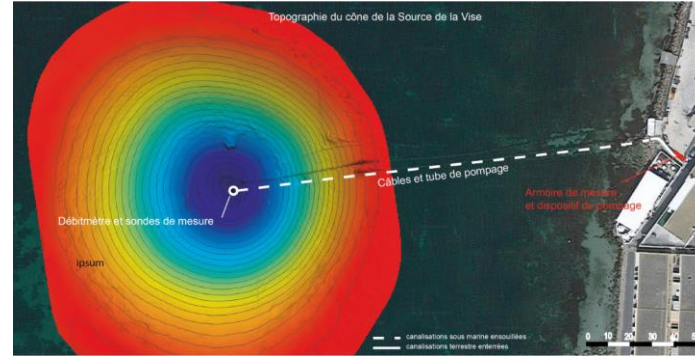
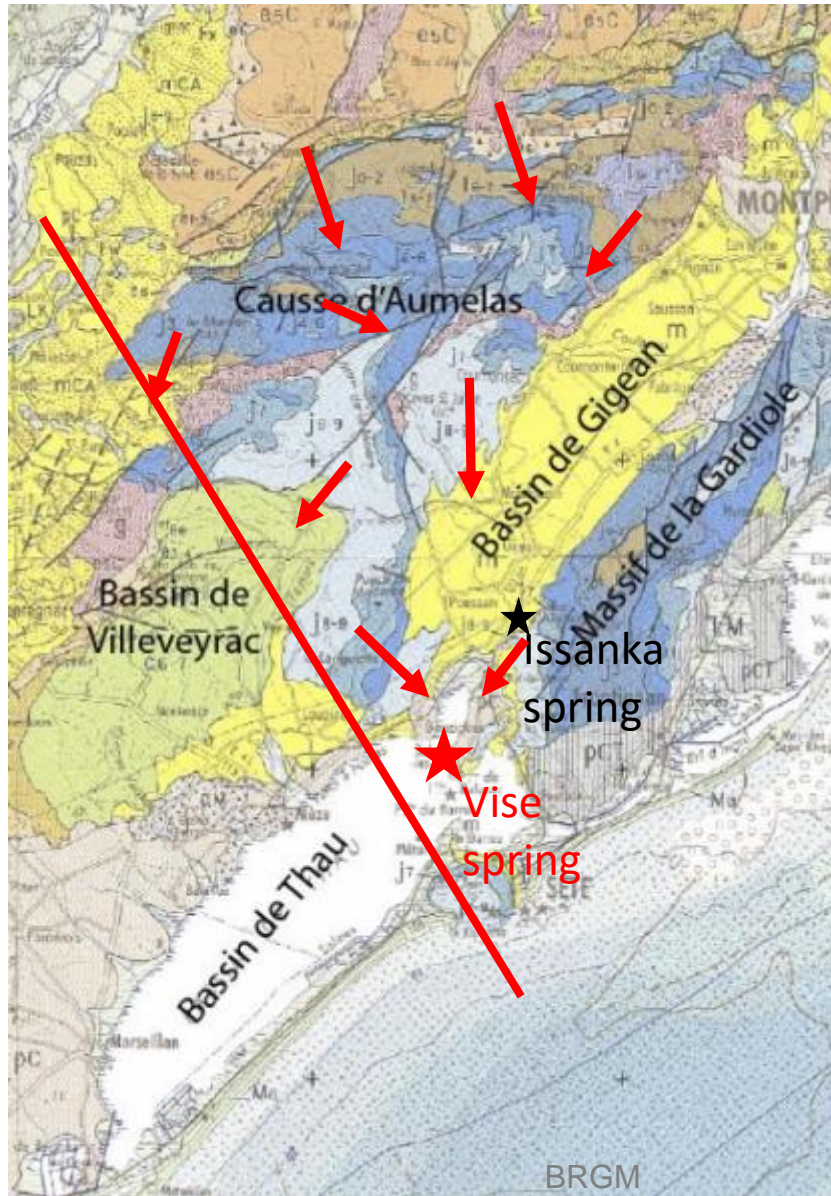
Saltwater intrusion and flow reversal at the submarine spring of a Mediterranean karst aquifer : explanation and modelling

Maréchal JC¹, Ladouche B¹, Lamotte C¹, Dewandel B¹, Hakoun V¹, Perrochet P²

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The Aumelas-Issanka-Vise karst hydrosystem





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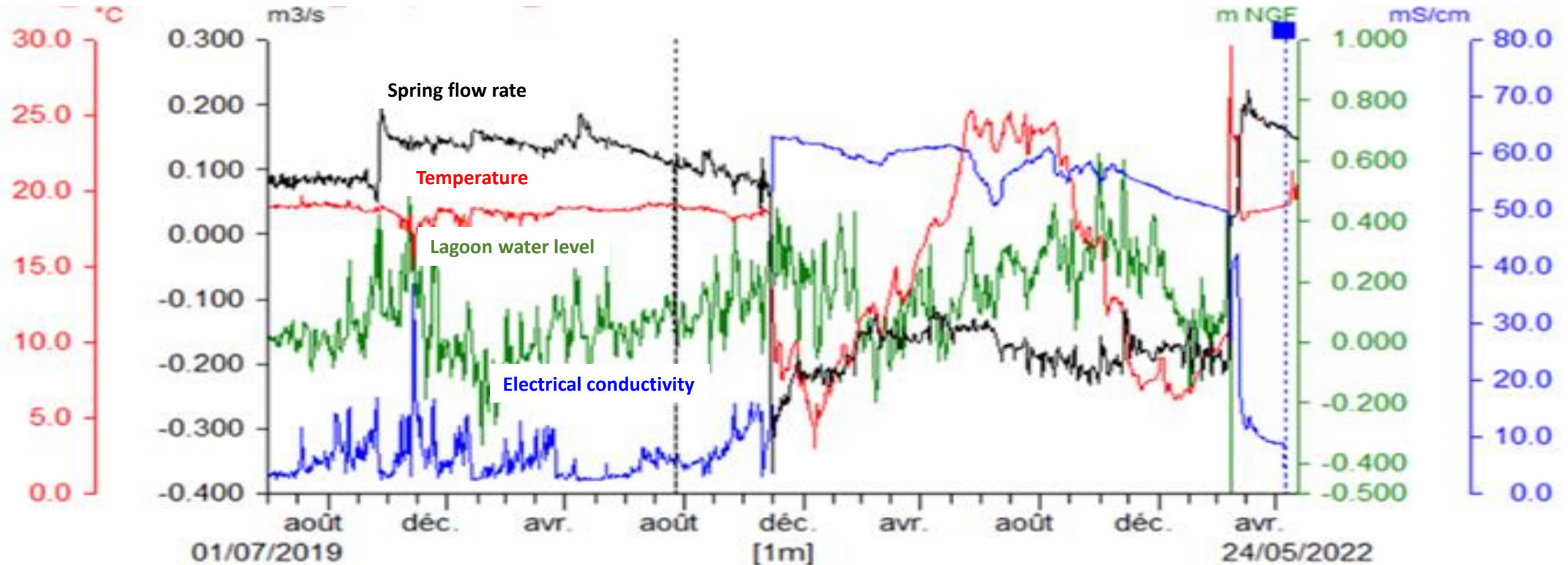
48th IAH Congress
BRUSSELS BELGIUM 2021
Inspiring Groundwater

PHENOMENON DESCRIPTION

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

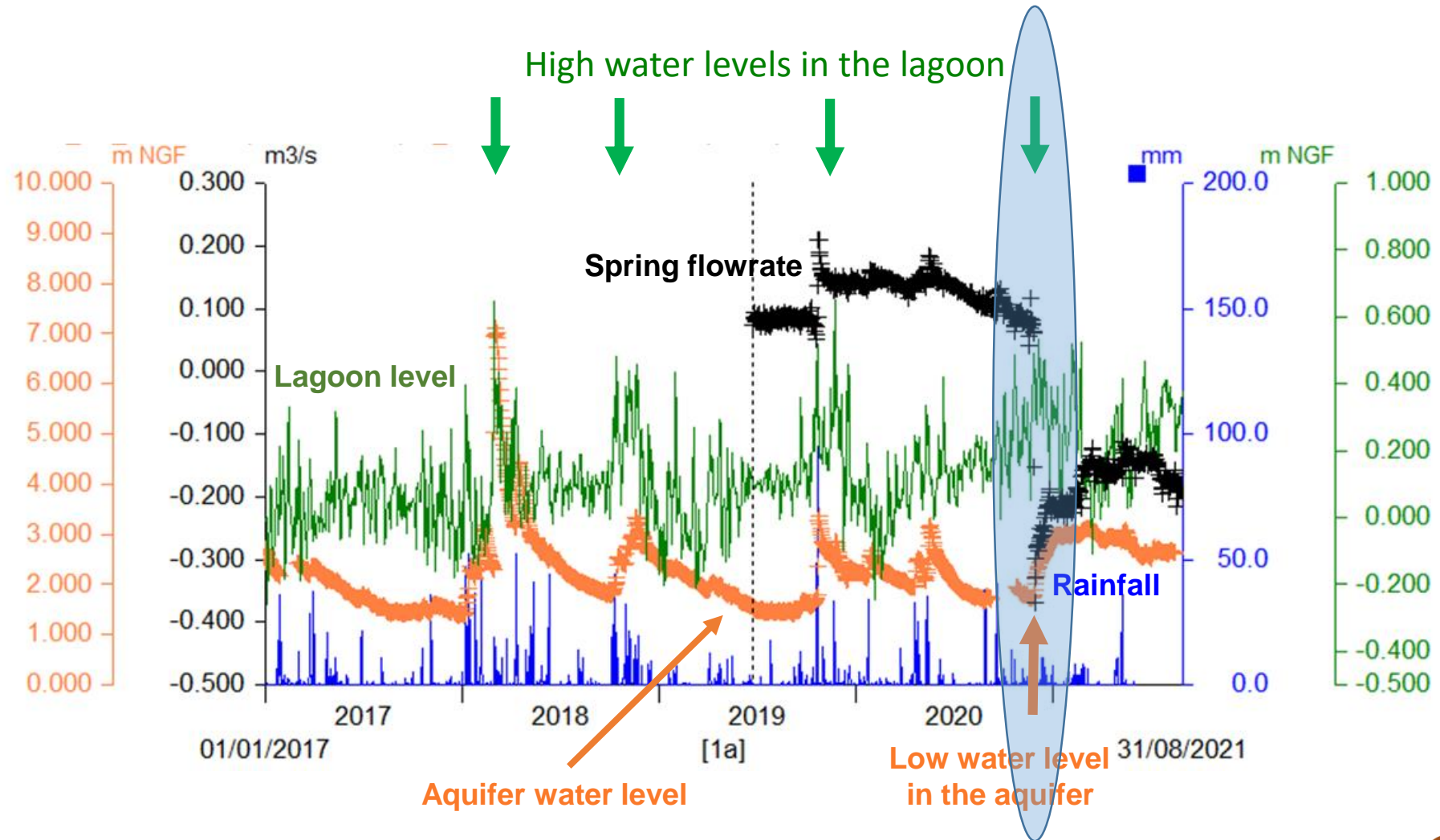
Preliminary results at the Vise spring

- 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





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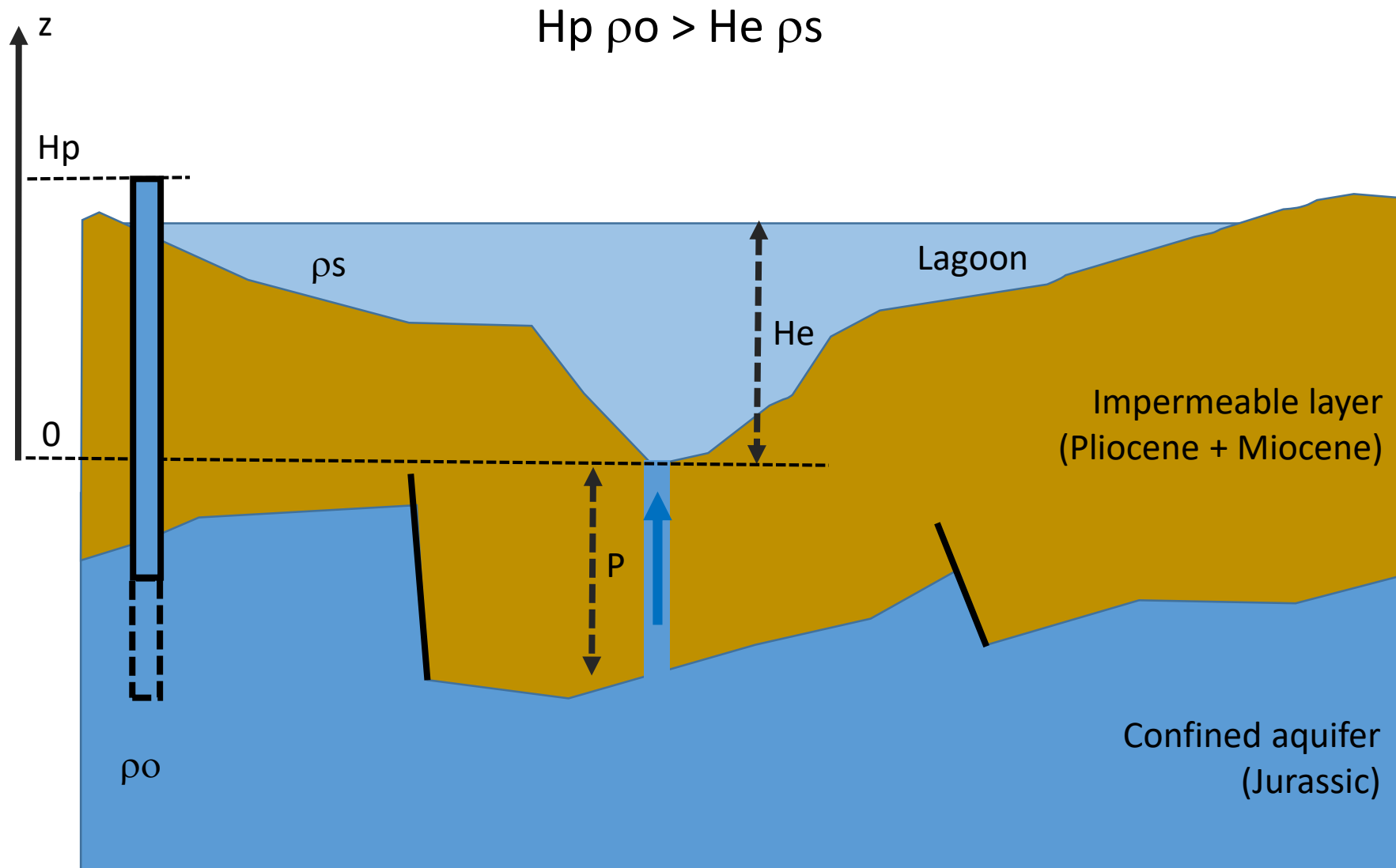
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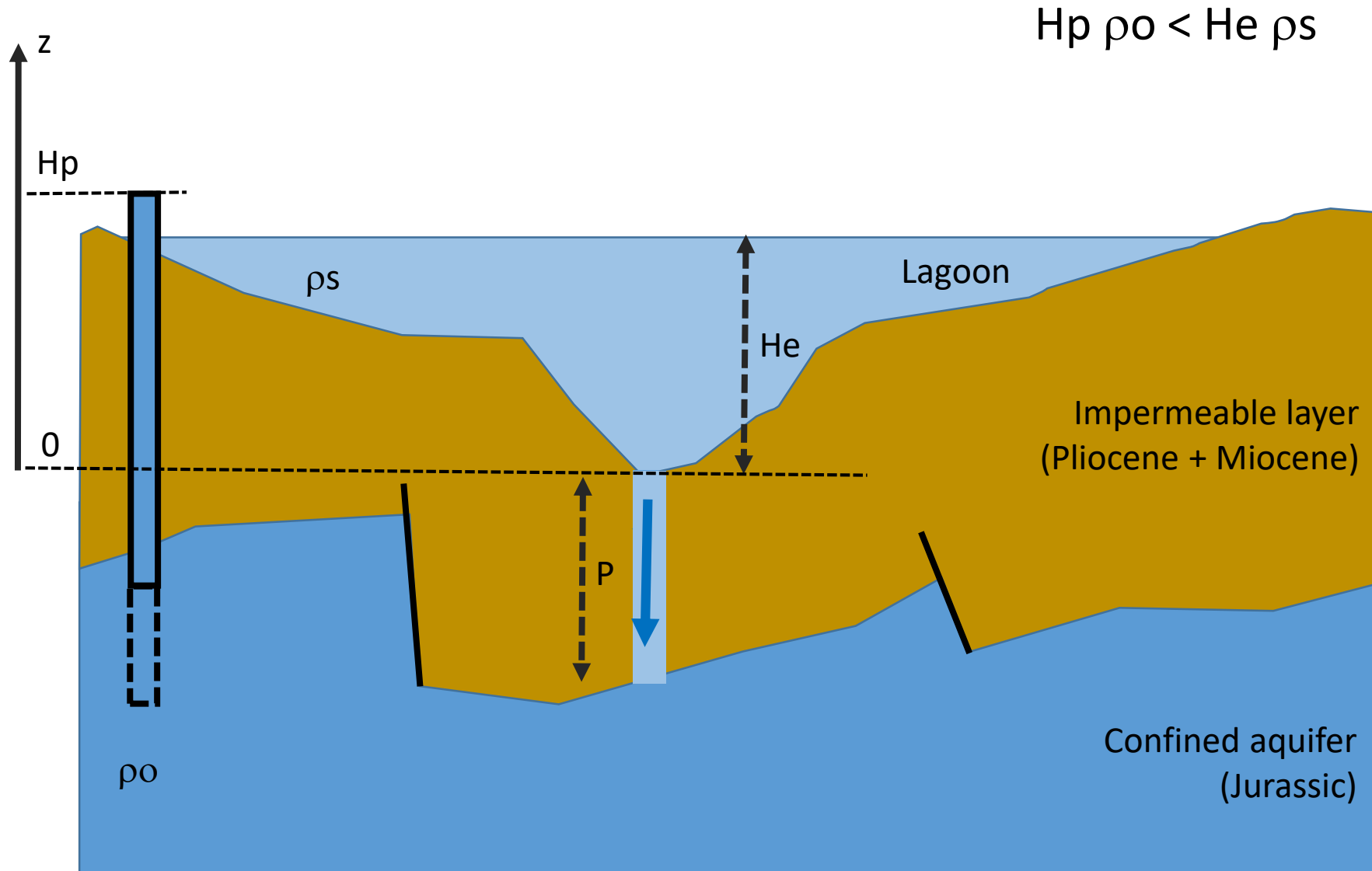
PHENOMENON EXPLANATION



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



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





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PIEZOMETRY RESPONSE



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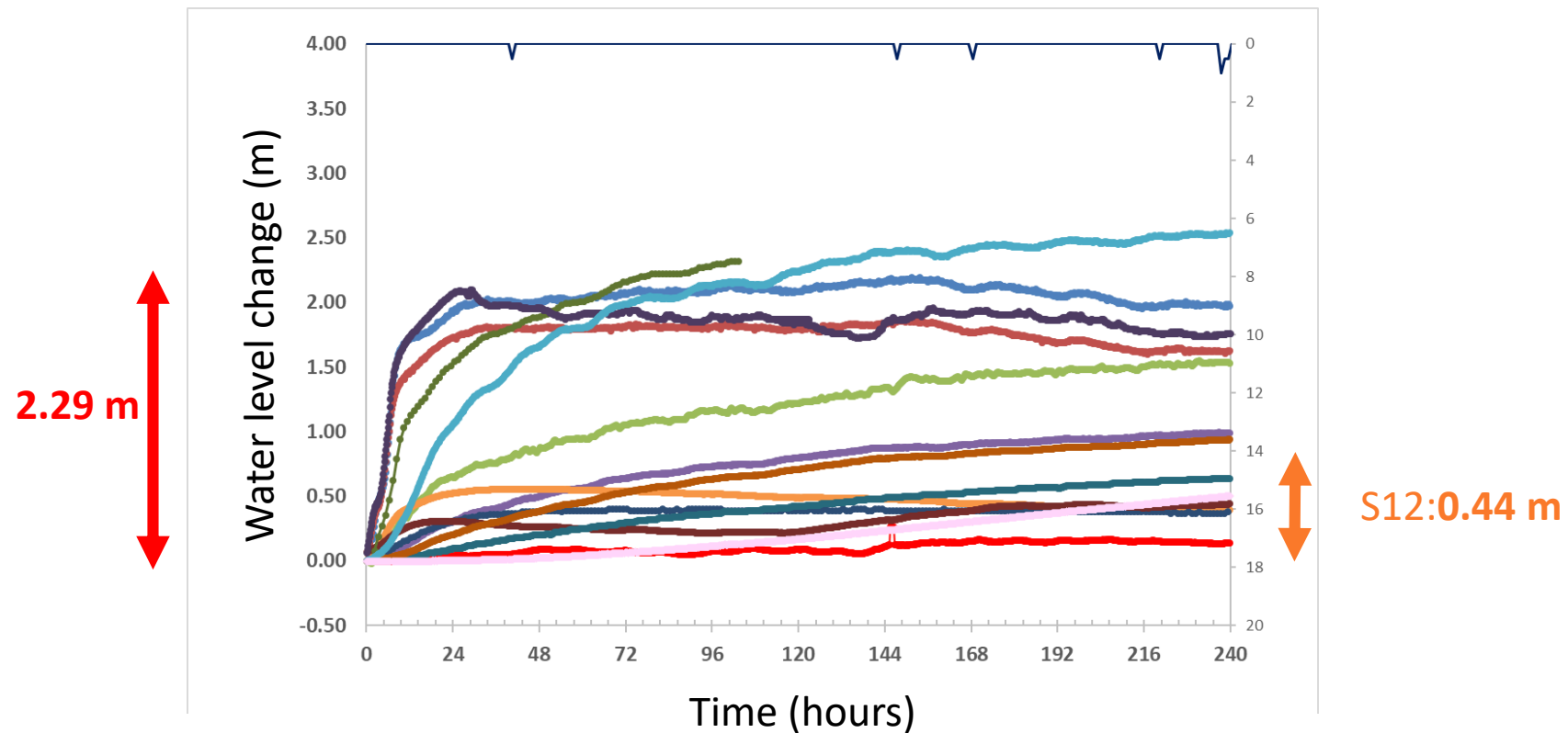
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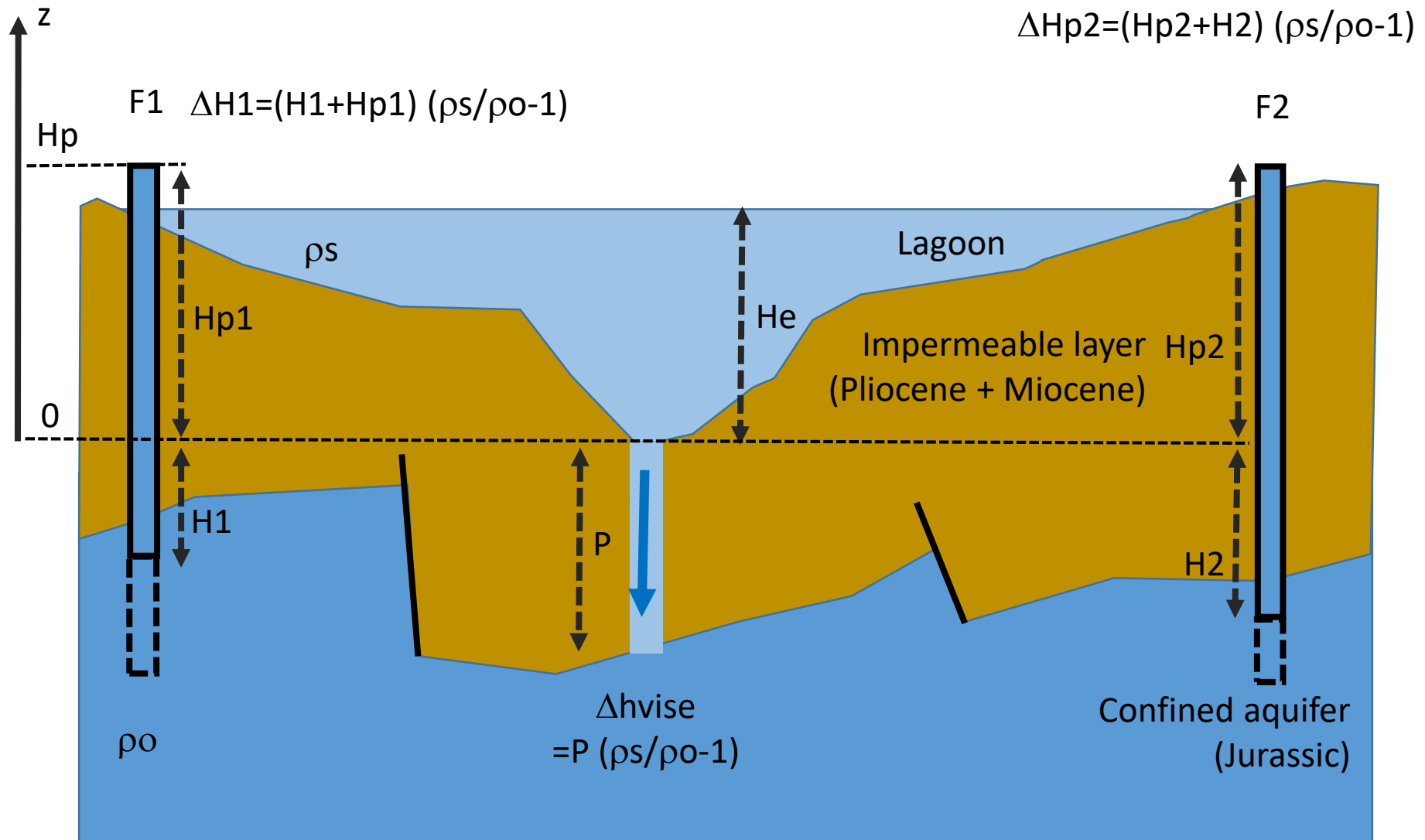
Inversac: impact on piezometry

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

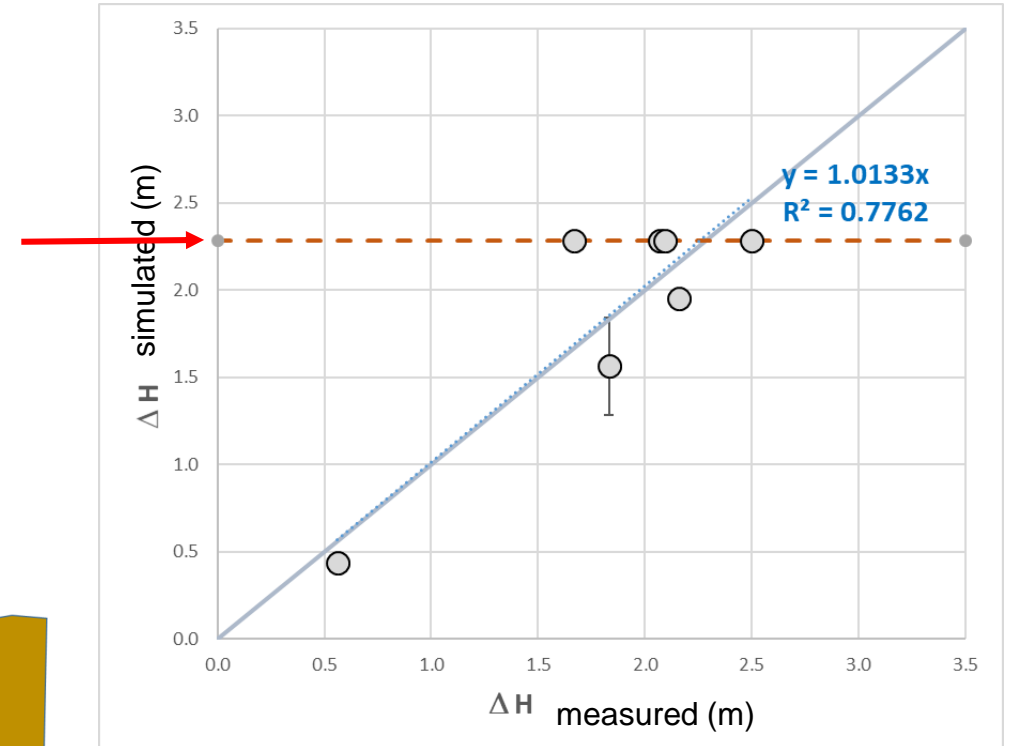
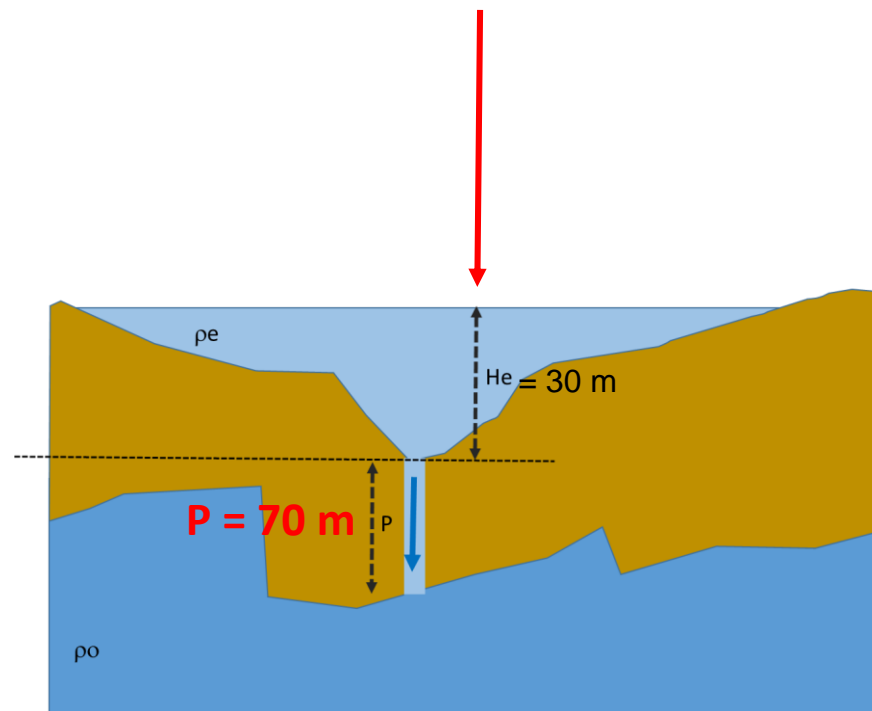


Inversac: impact on piezometry

Inversac 2020: computation of piezometry fluctuation

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

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





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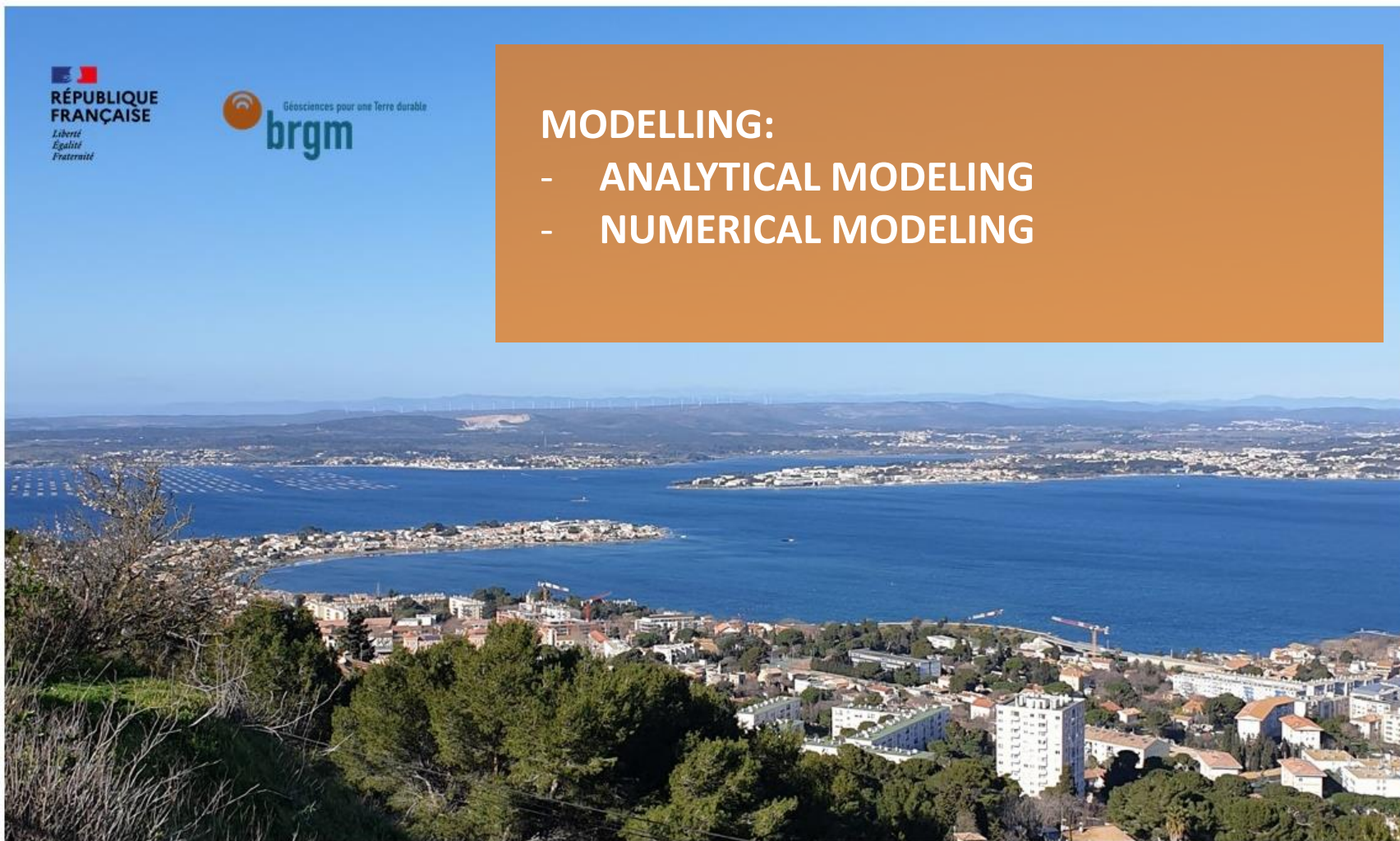


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MODELLING:

- ANALYTICAL MODELING
- NUMERICAL MODELING

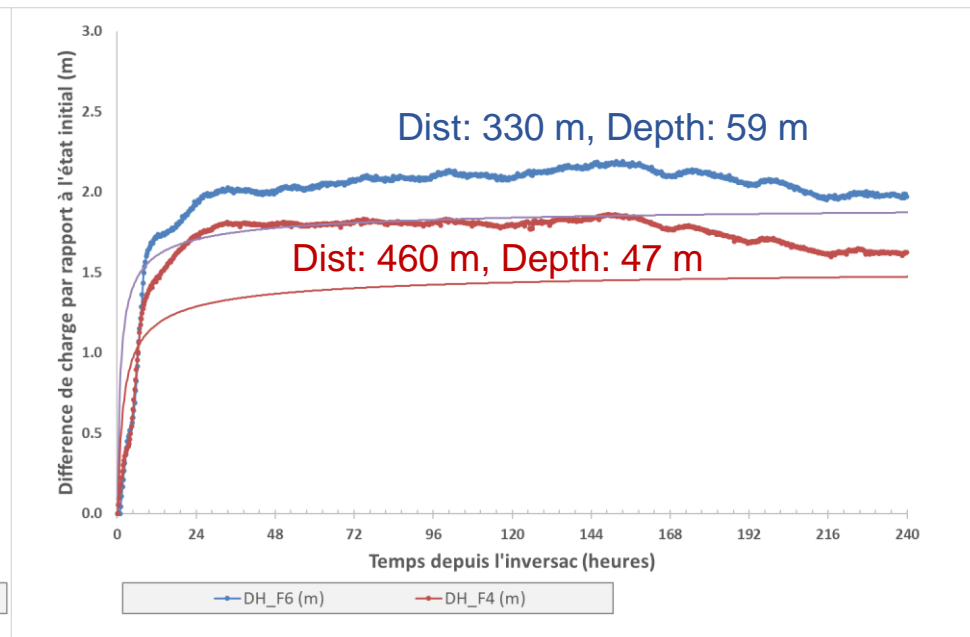
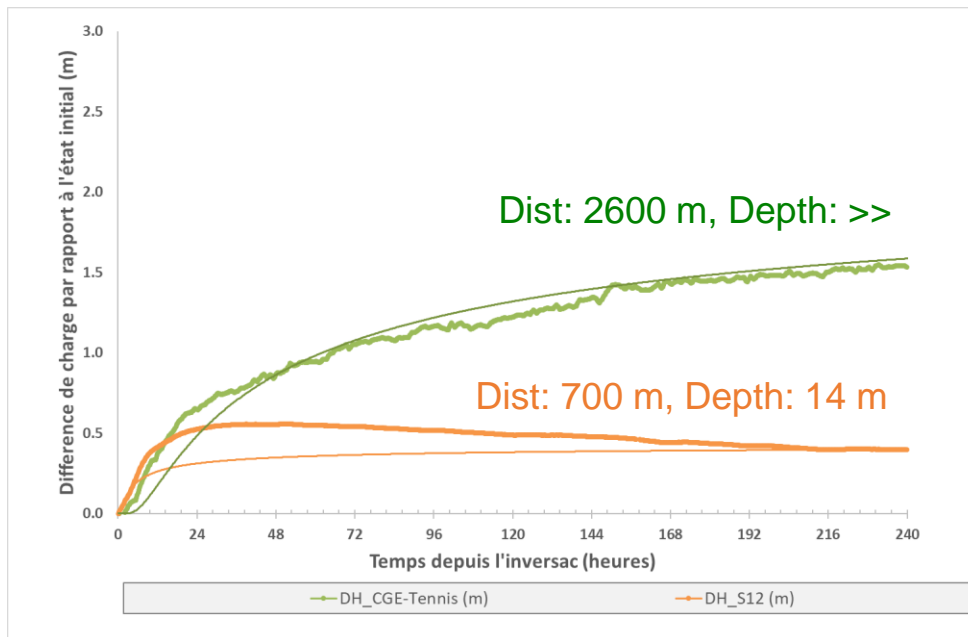


Inversac modeling

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	$H(r, t) = \Delta H_0 \frac{r_0}{r} \operatorname{erfc} \left(\frac{r - r_0}{\sqrt{4Dt}} \right)$	$H(x, t) = \Delta H_0 \operatorname{erfc} \left(\frac{x}{\sqrt{4Dt}} \right)$

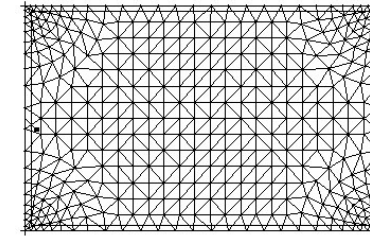
with Diffusivity $D = 25 \text{ m}^2/\text{s}$



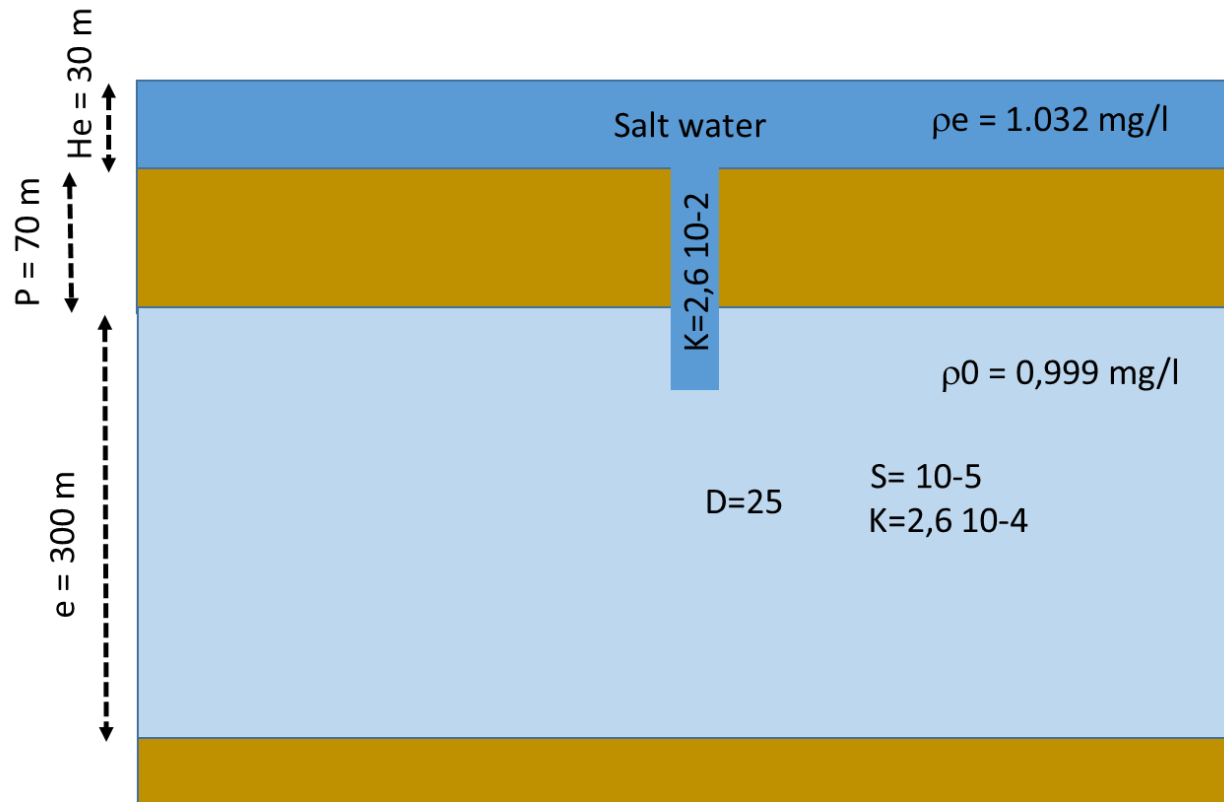
Inversac modeling

Description of the numerical model

Finite element model

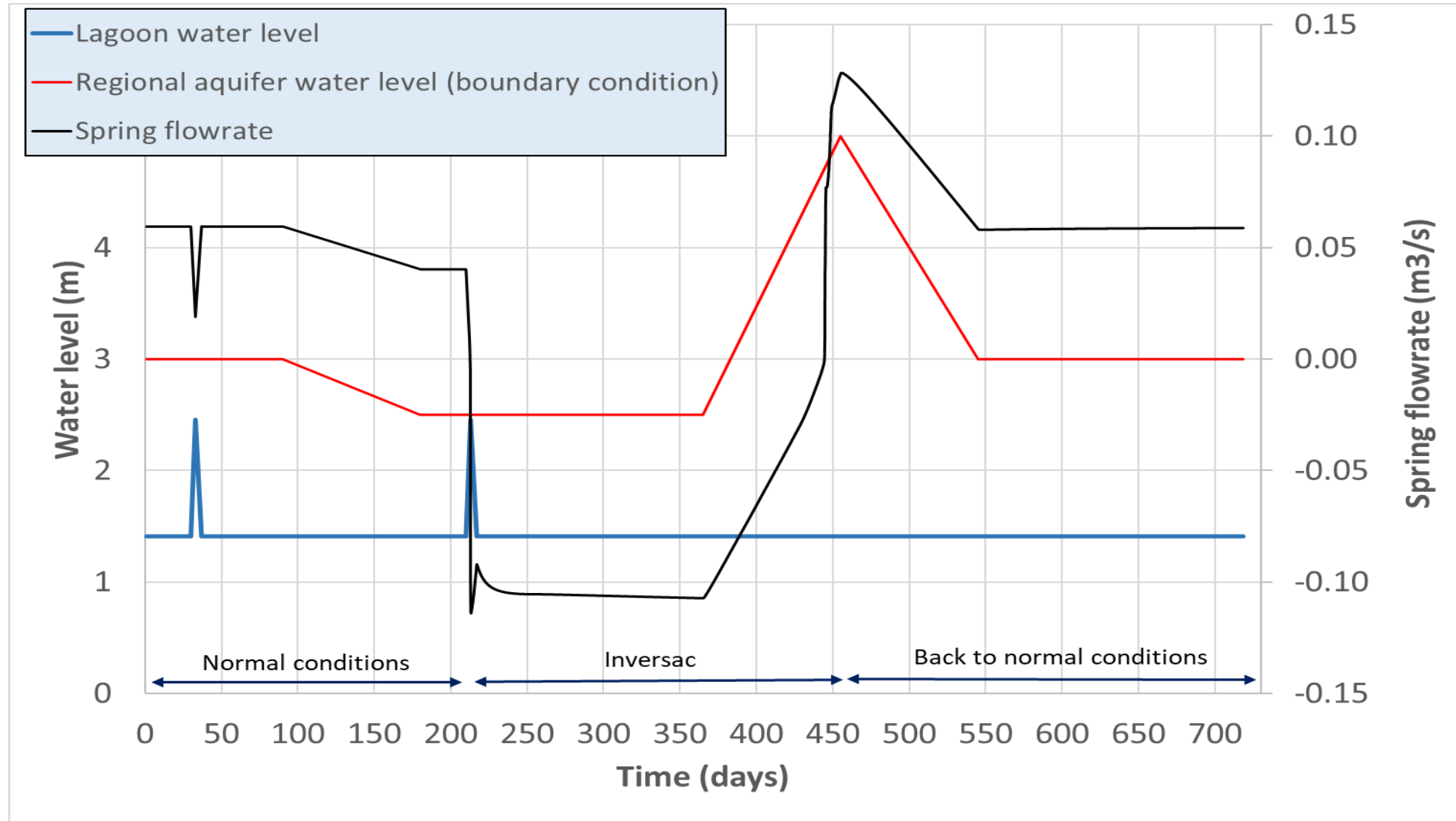


Feflow



Inversac modeling

Results of numerical simulation





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CONCLUSION



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

