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

Jean-Christophe Maréchal, Bernard Ladouche, Claudine Lamotte, Benoît Dewandel, Vivien Hakoun, Pierre Perrochet

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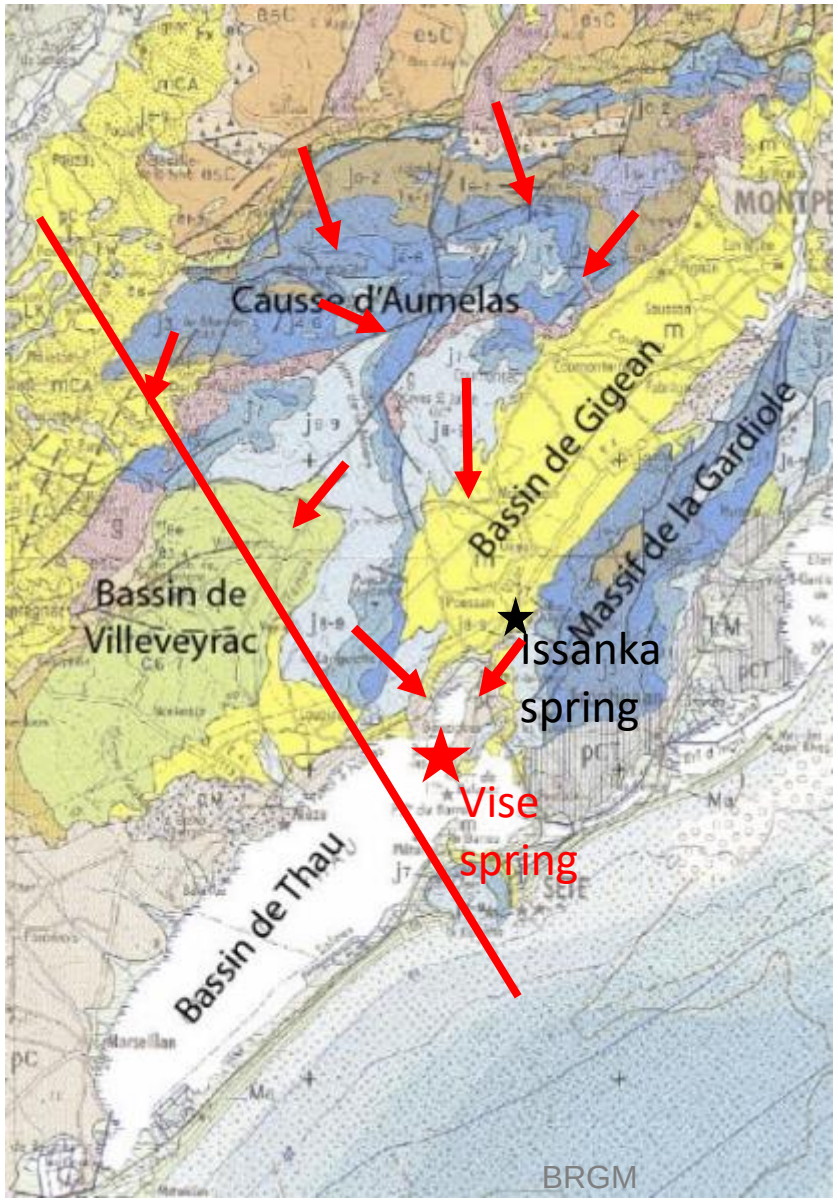
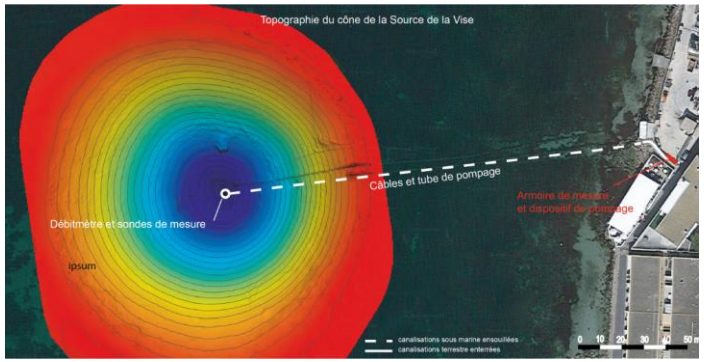
Maréchal JC [1], Ladouche B [1], Lamotte C [1], Dewandel B [1], Hakoun V [1], Perrochet P [2]

[1] BRGM
[2] University of Neuchâtel

The Aumelas-Issanka-Vise karst hydrosystem



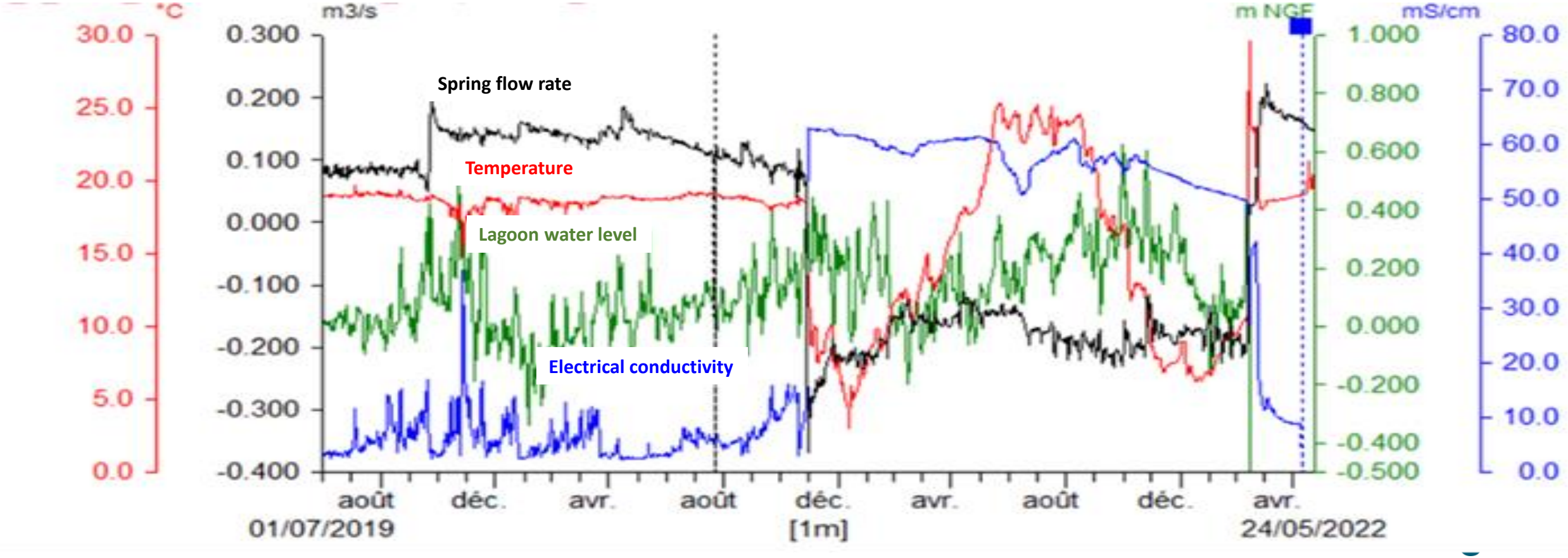


PHENOMENON DESCRIPTION

Flow reversal (‘Inversac’) event of 2020/2021

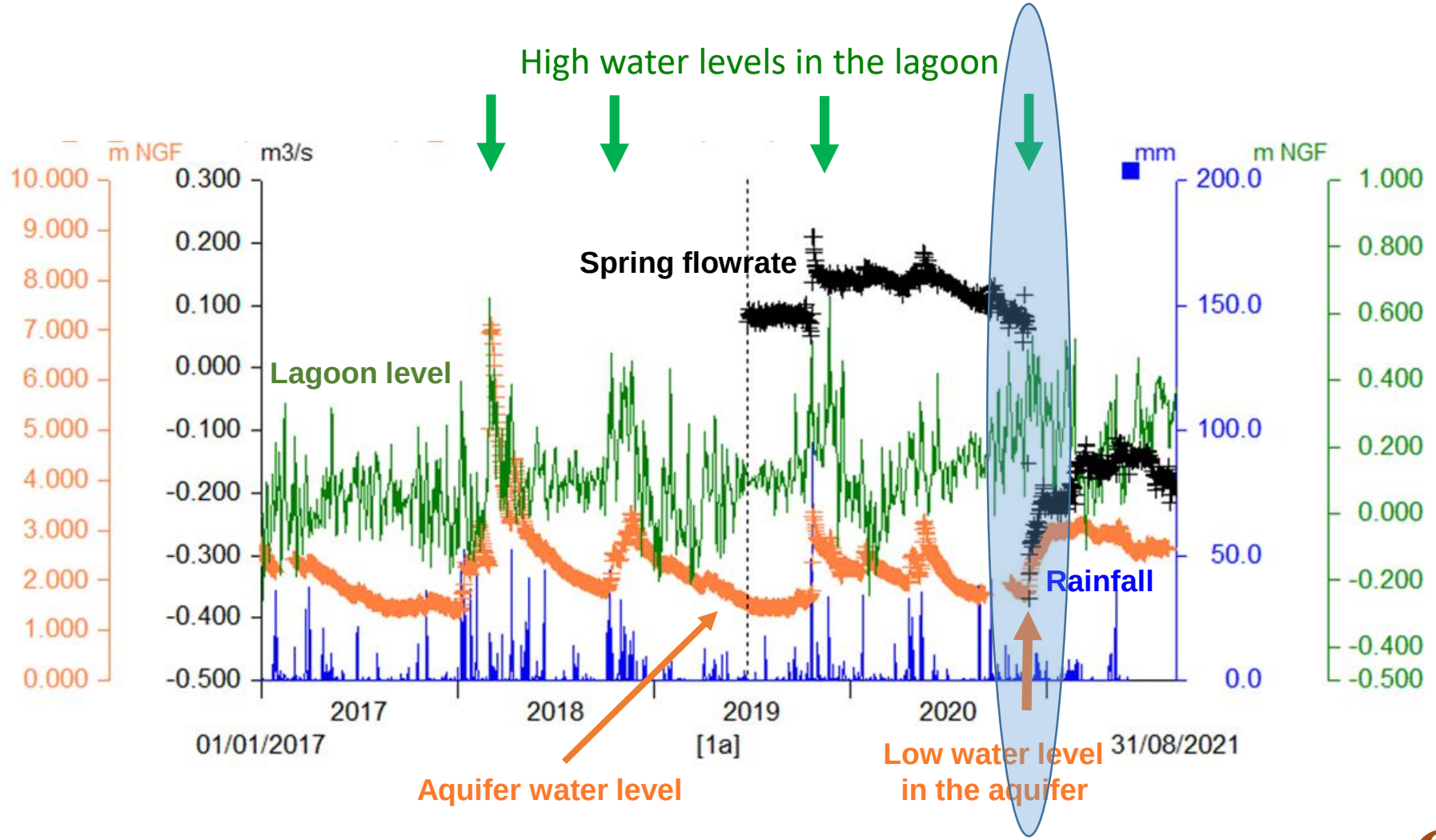
Preliminary results at the Vise spring

- 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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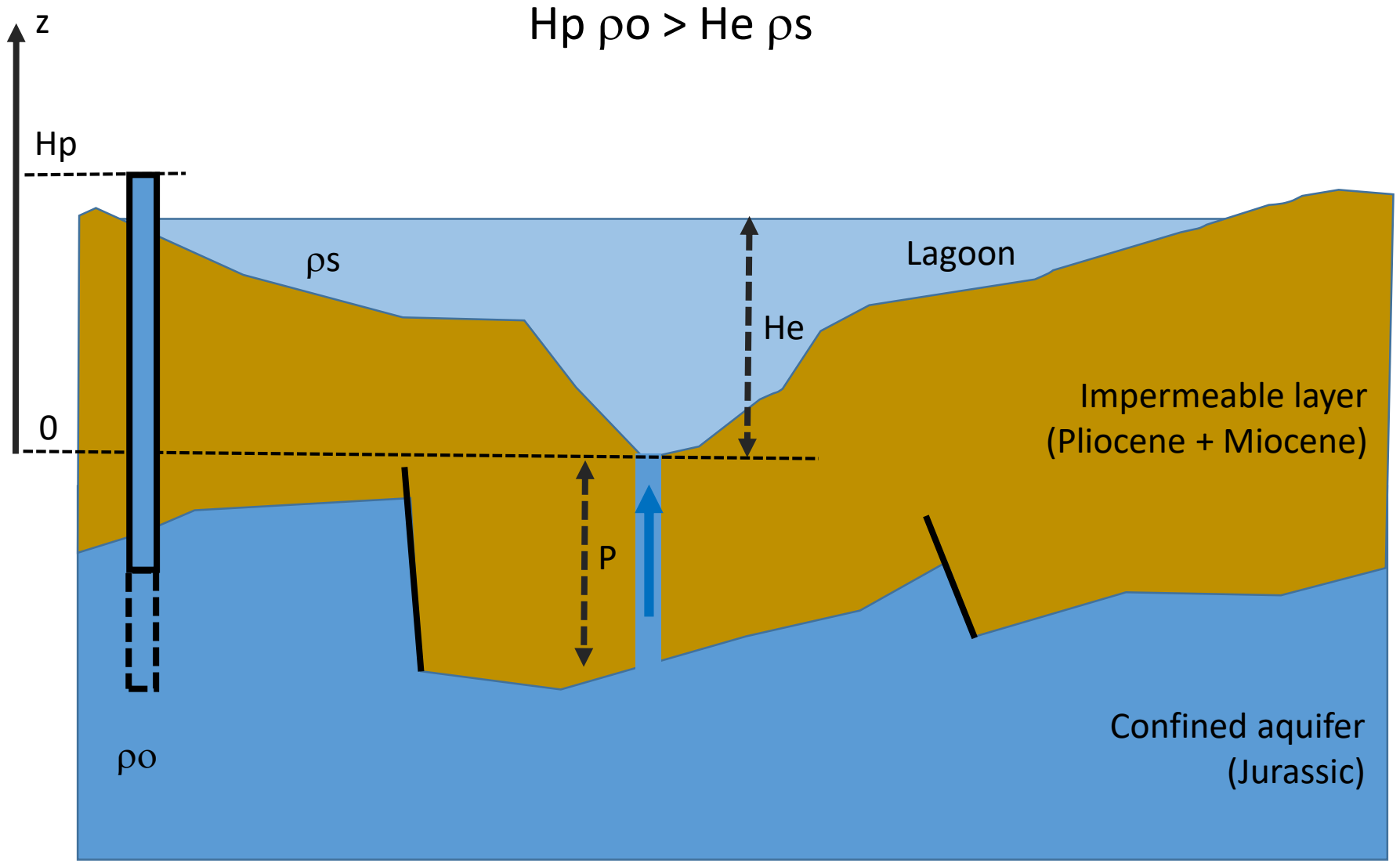
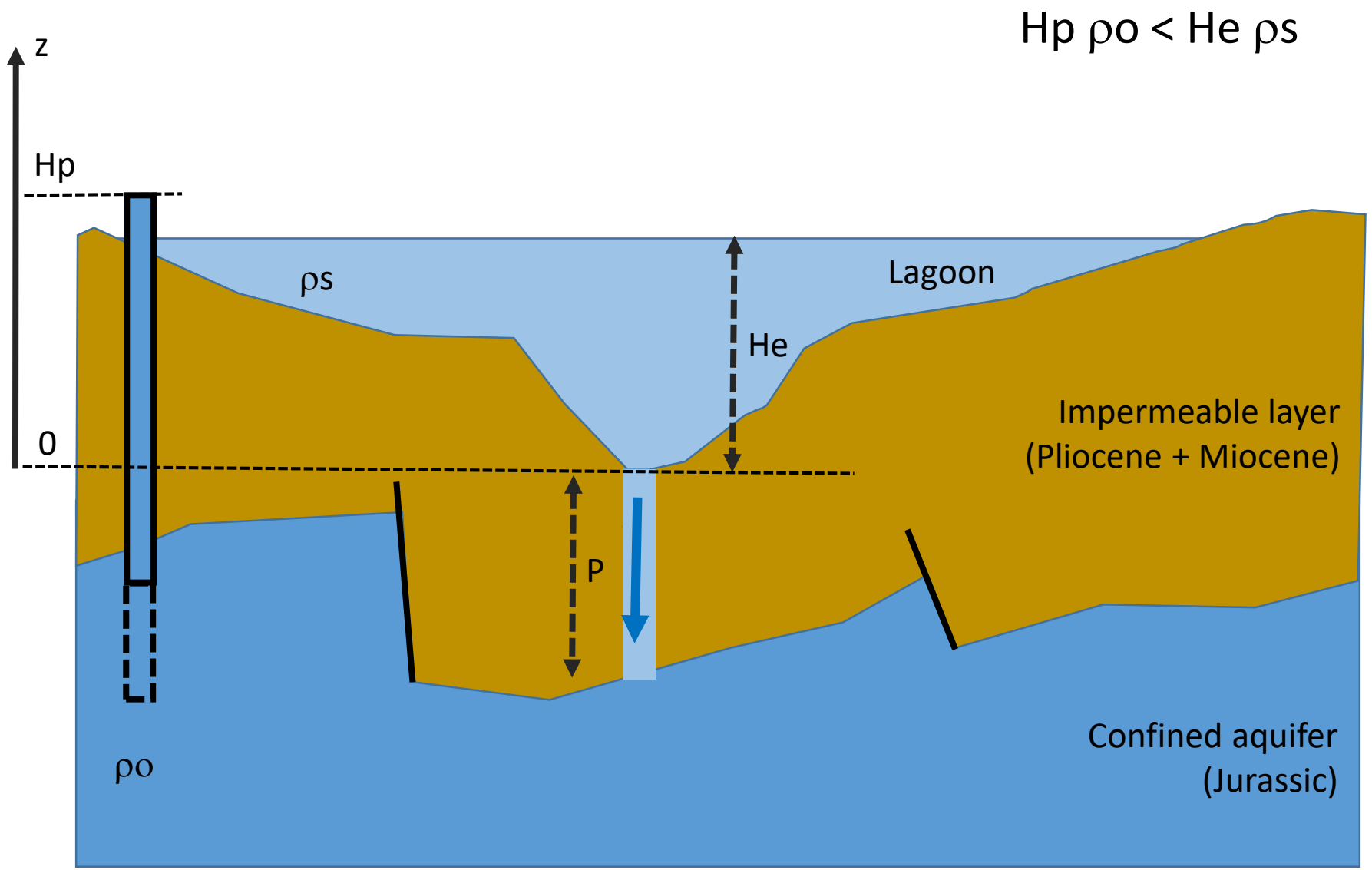
PHENOMENON EXPLANATION

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



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

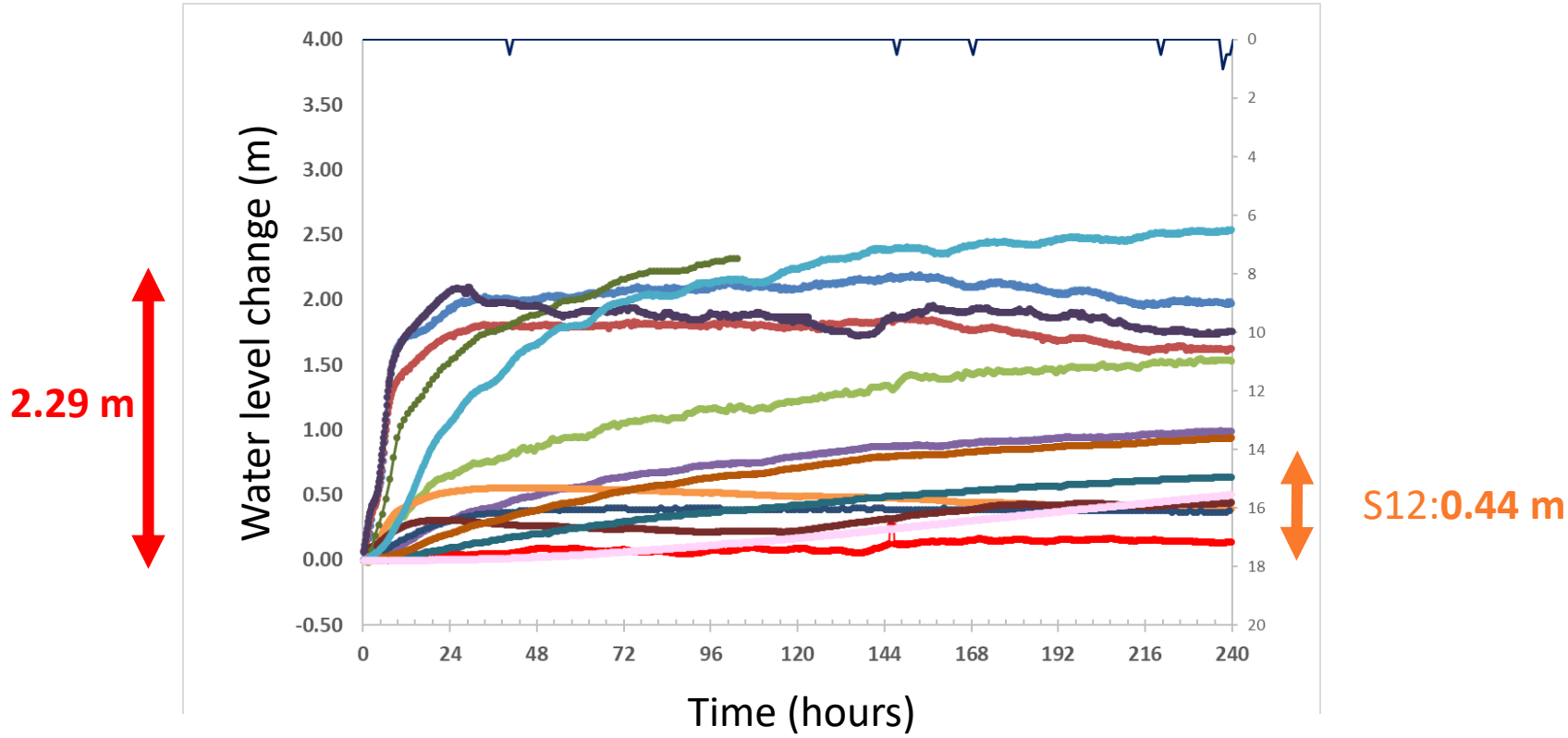


PIEZOMETRY RESPONSE

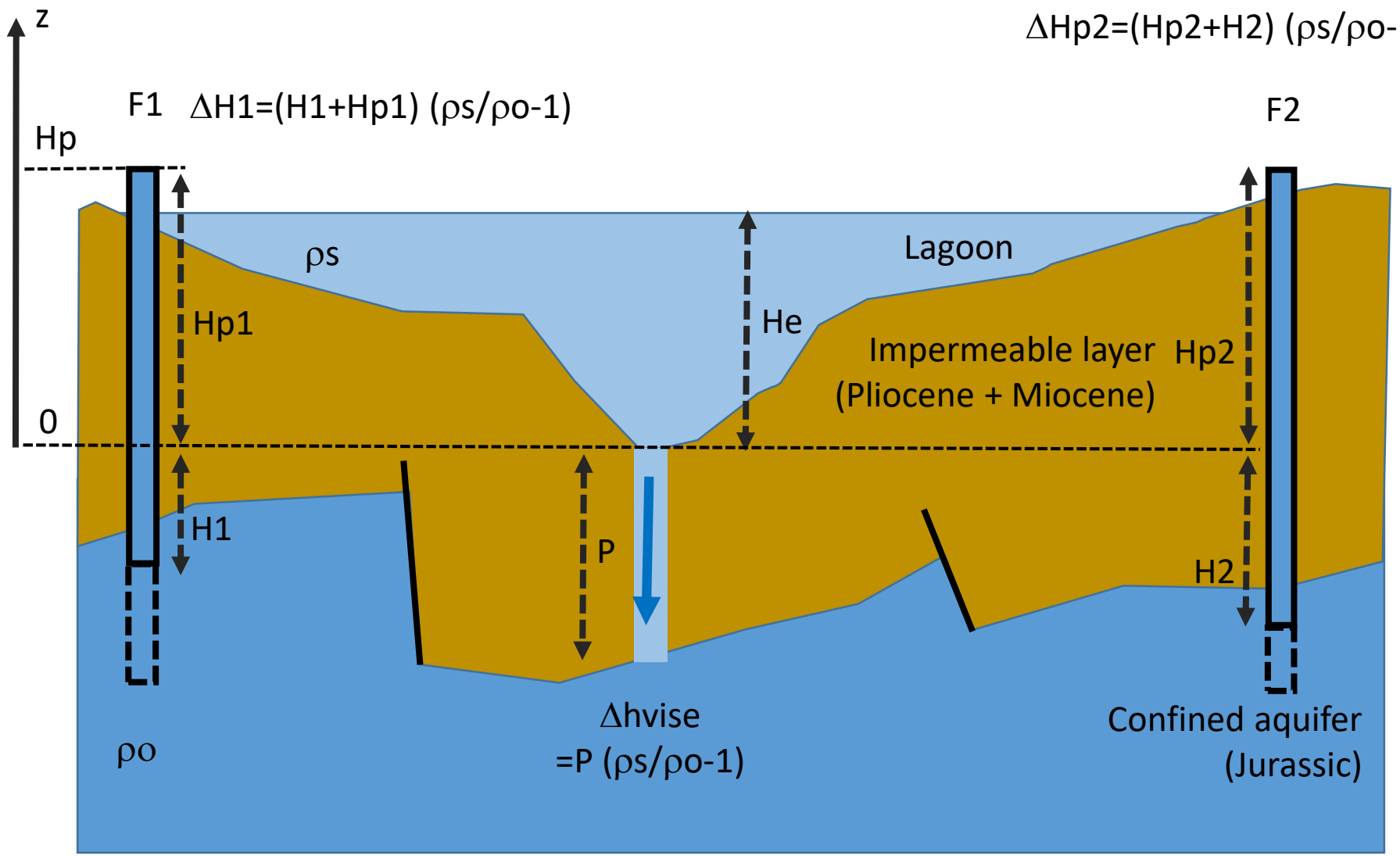
Inversac: impact on piezometry

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

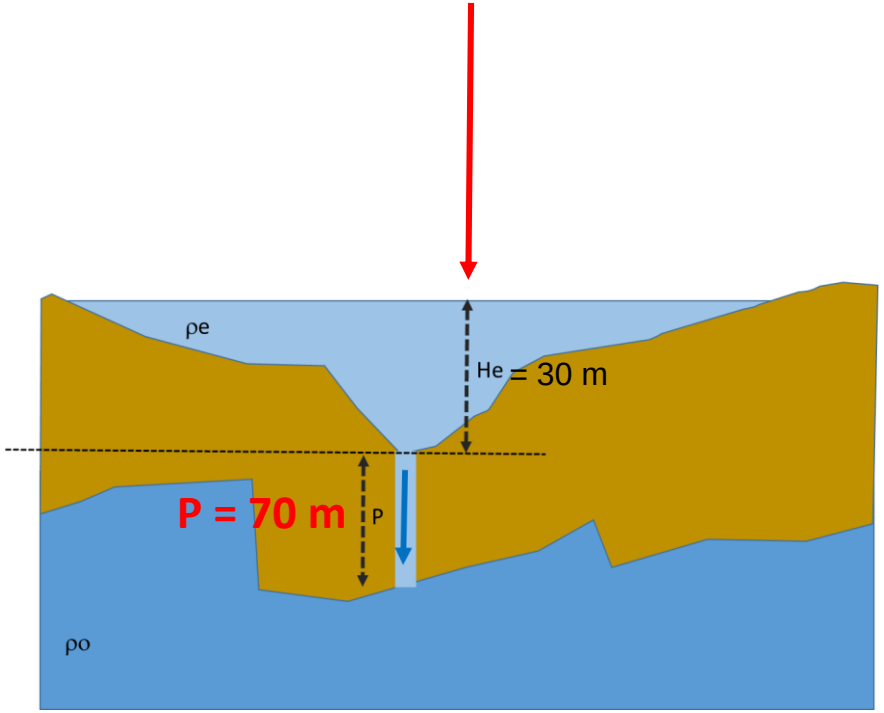


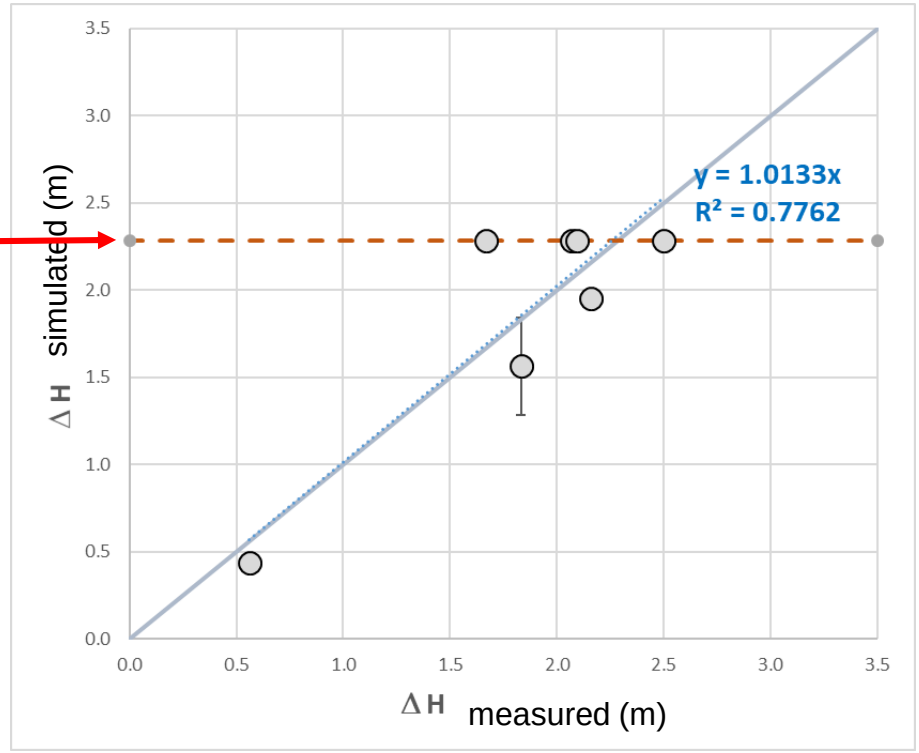
Inversac: impact on piezometry

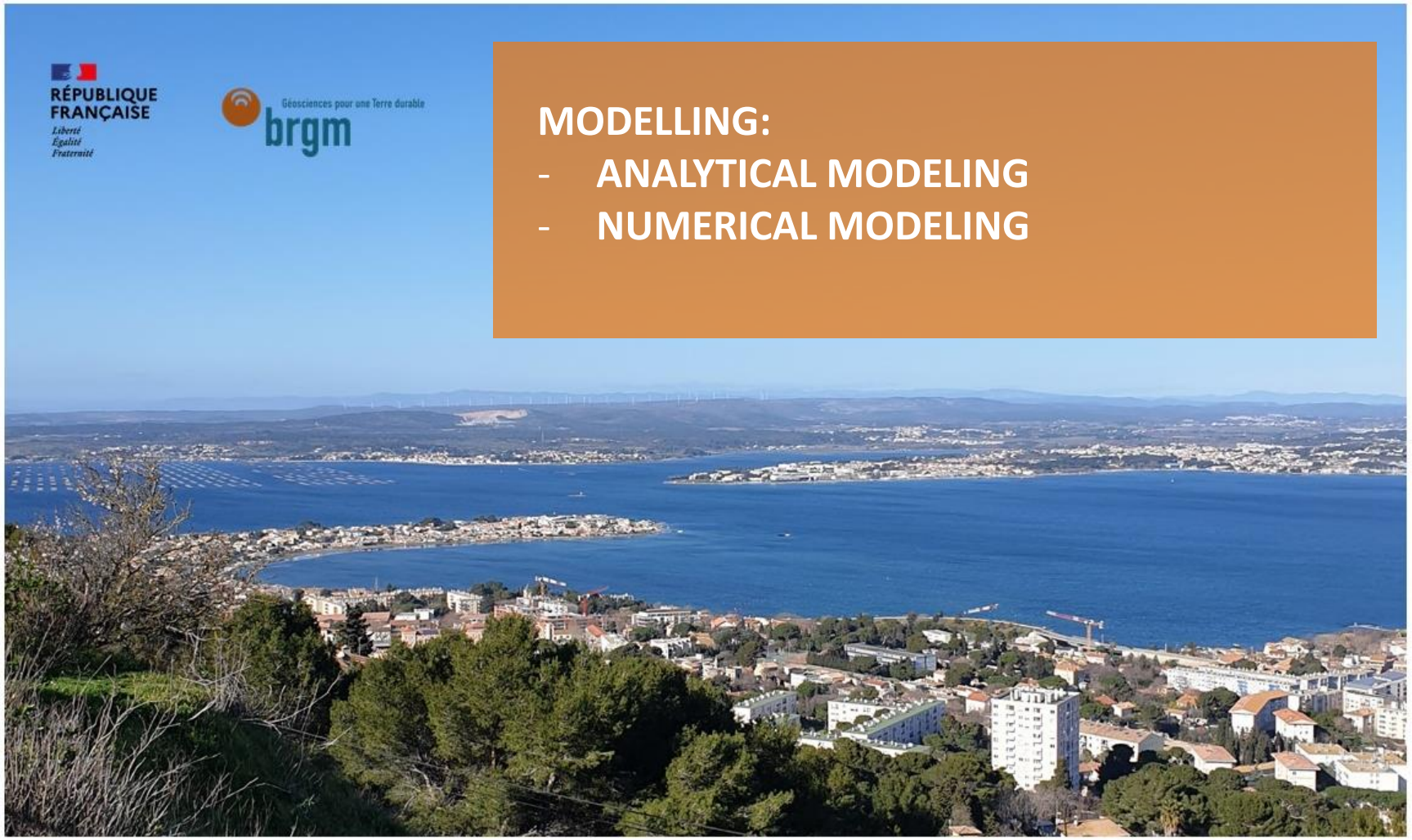
Inversac 2020: computation of piezometry fluctuation

At well i: $\Delta Hi=(Hi+Hpi)\ (\rho s/\rho o-1)$

$\Delta hmax = \Delta hvise = P\ (\rho s/\rho o-1)$
$= \mathbf{70}\ (1.032/0.999 - 1) = \mathbf{2.29\ m}$



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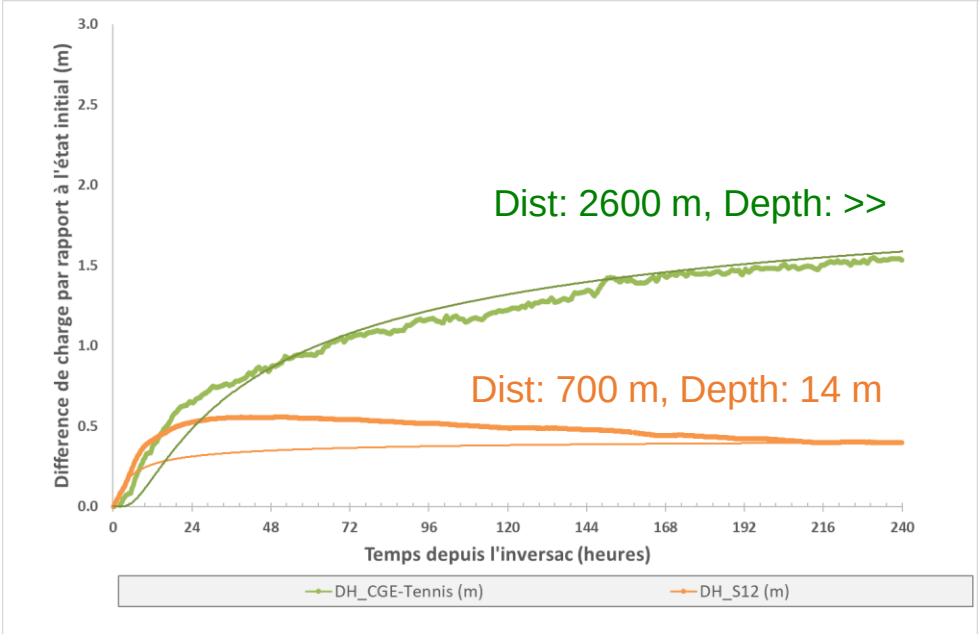
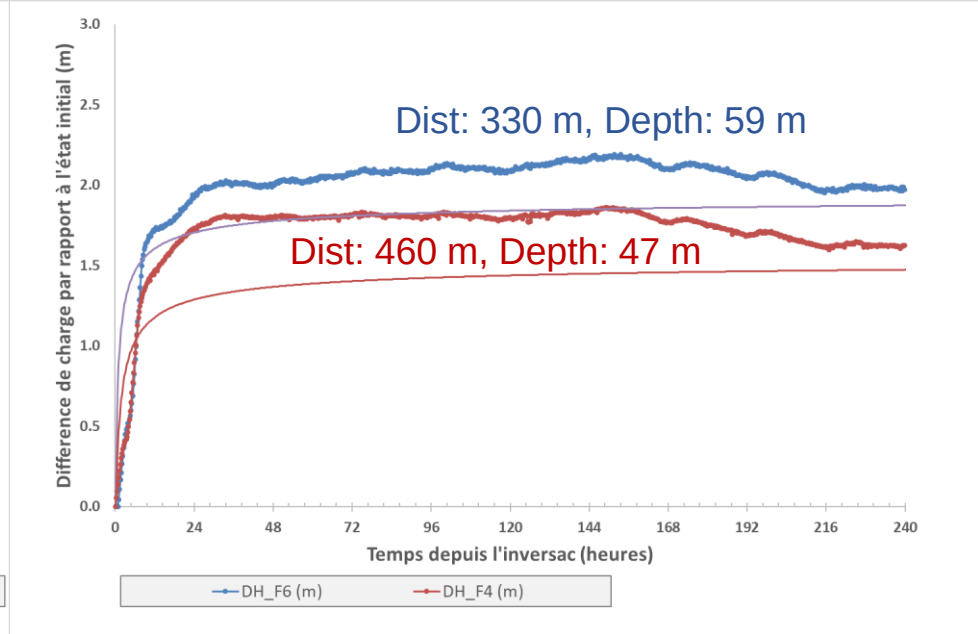
MODELLING:
- ANALYTICAL MODELING
- NUMERICAL MODELING

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

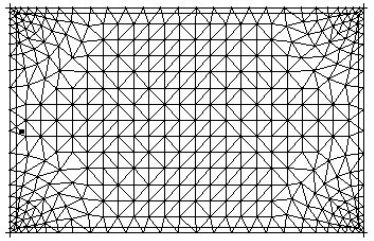
with Diffusivity *D* = 25 m²/s



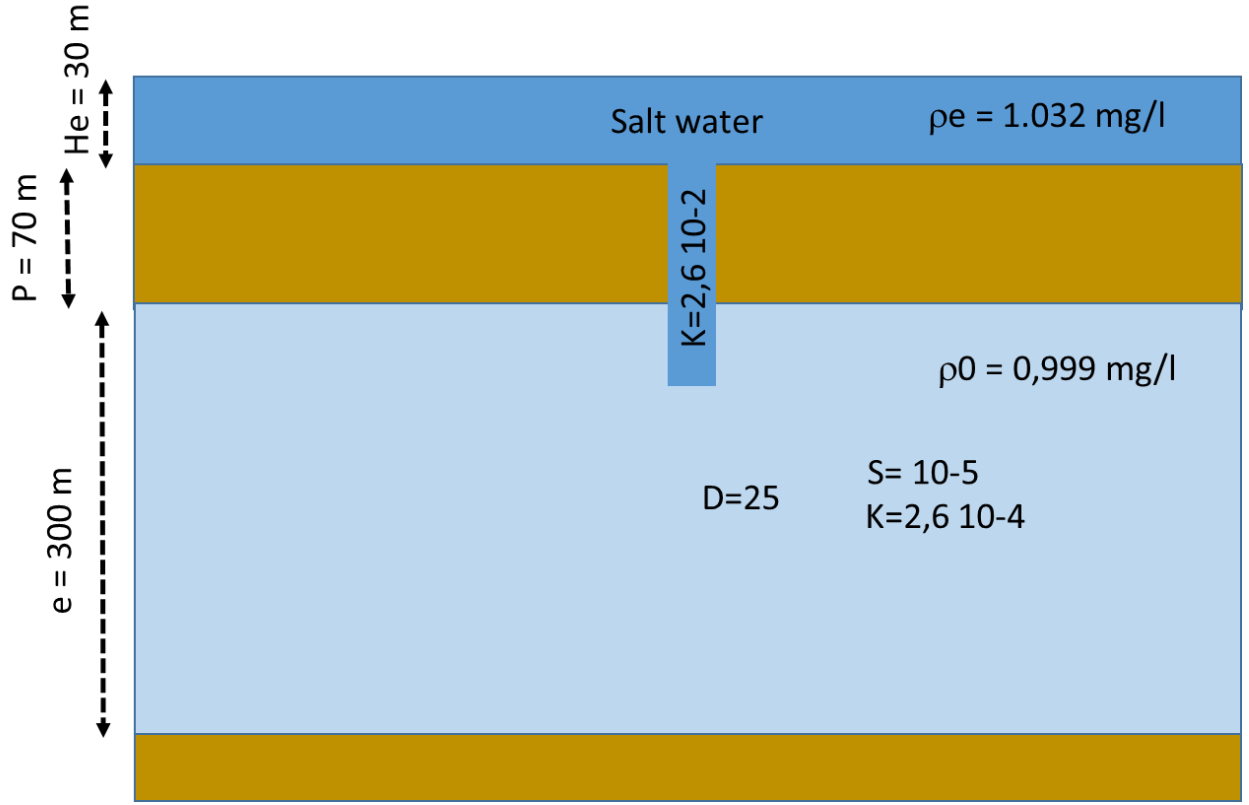


Description of the numerical model

Finite element model

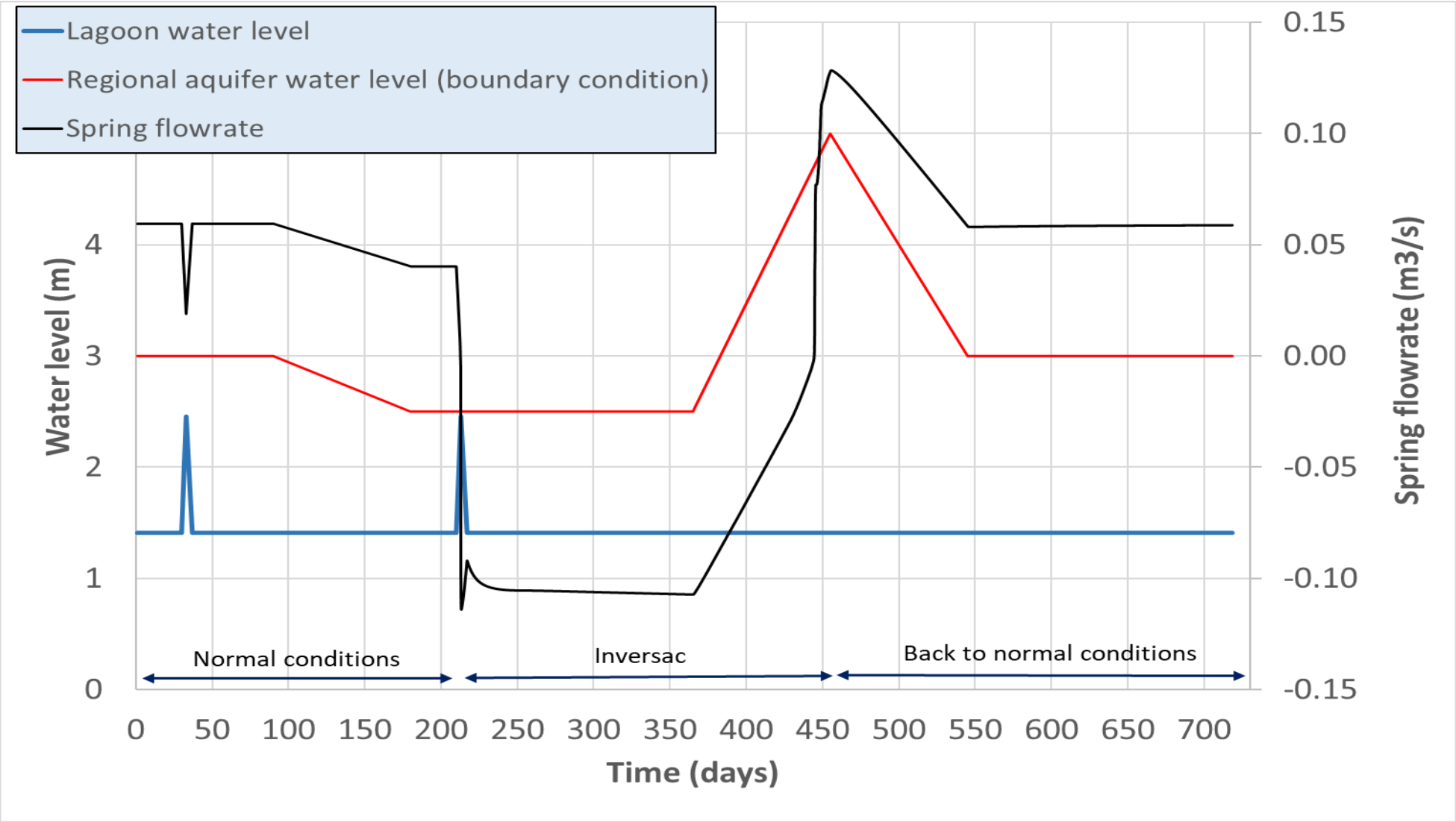


Feflow



Inversac modeling

Results of numerical simulation



CONCLUSION

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 watre 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