

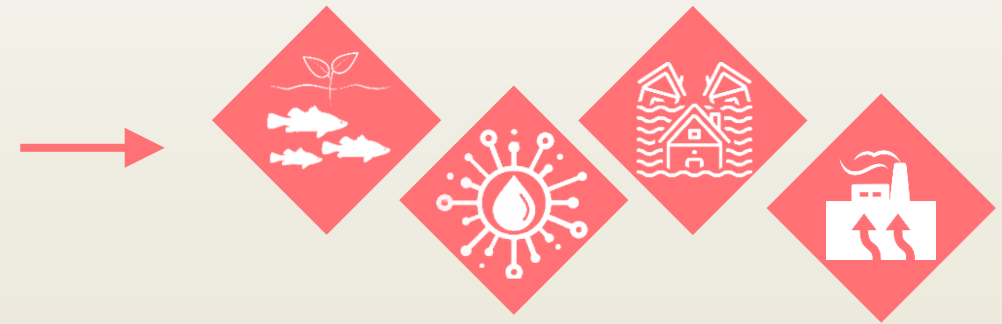
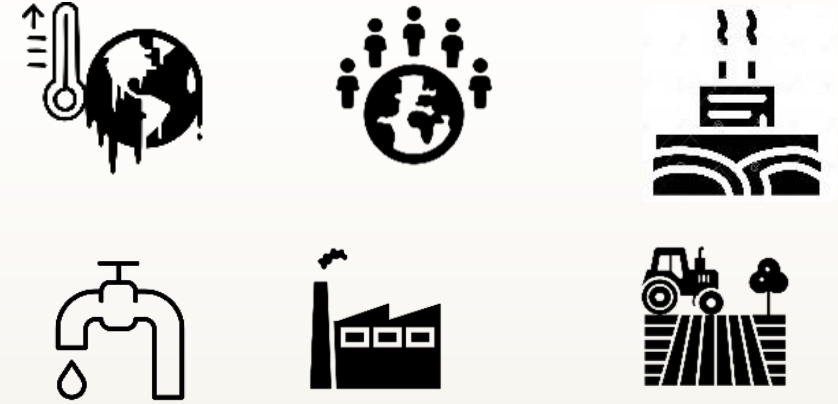
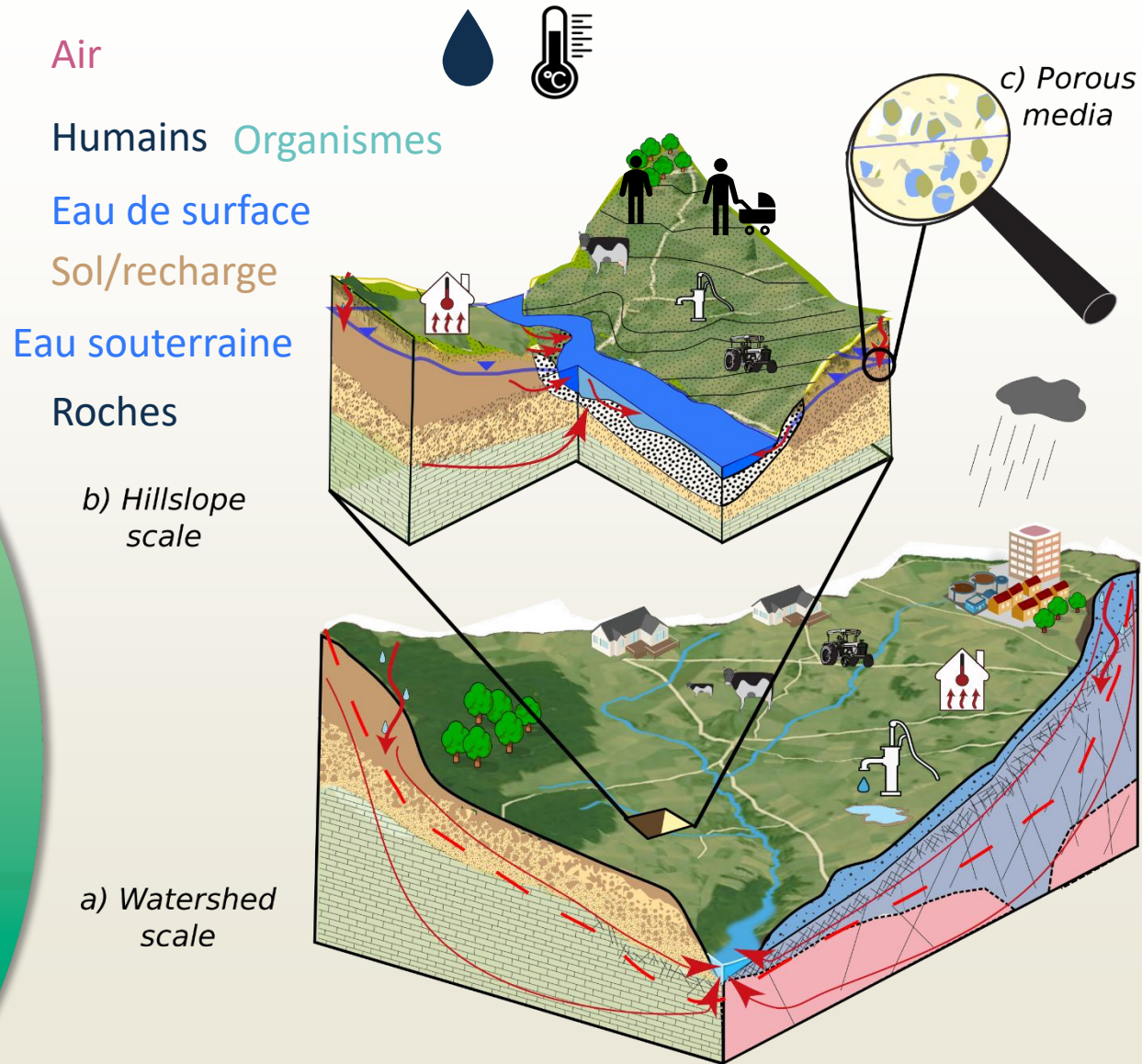


Nappes phréatiques : comment mesurer l'eau invisible ?



Agnès Rivière, Maxime Gautier, Nicolas Radic, Bénédicte Perret, Alexandrine Gesret, Sylvain Pasquet, Roland Martin, Didier Renard, Ludovic Bodet, Aurélien Baudin, Romane Nespoulet, Nicolas Loget

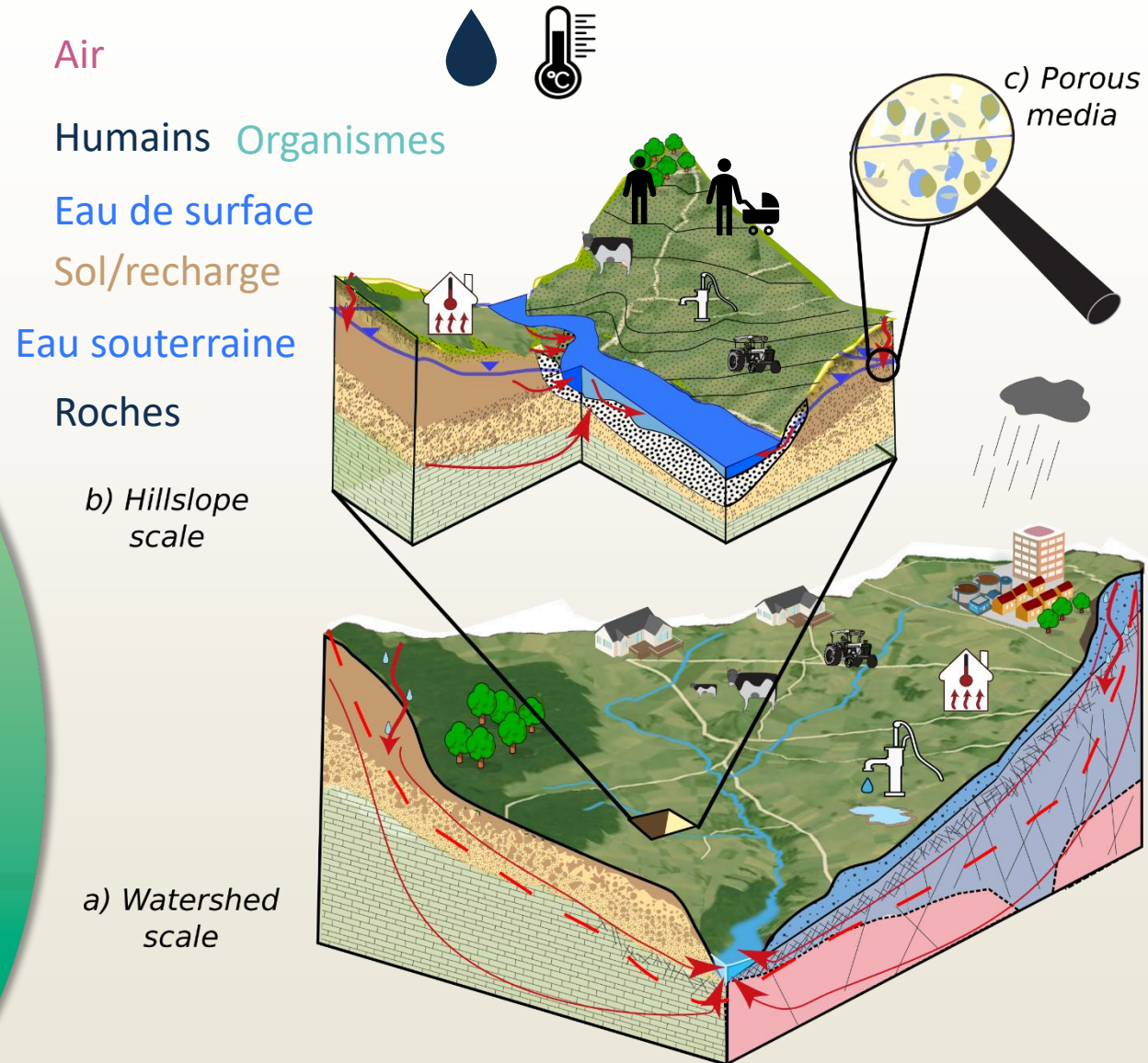
L'eau dans la zone critique



Mieux caractériser les flux d'eau souterrains ?

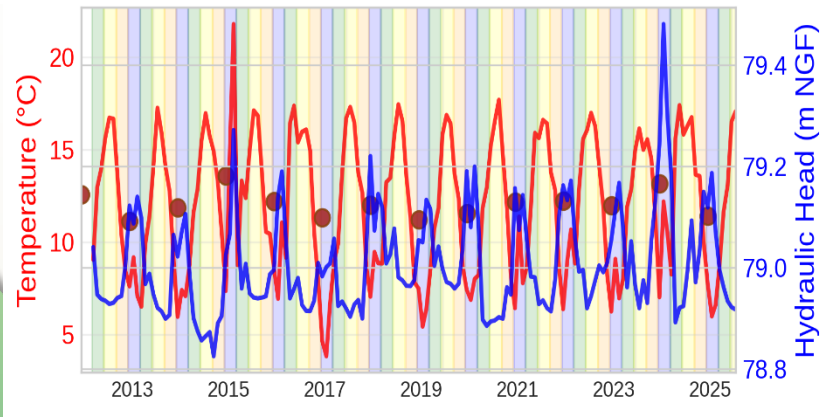


L'eau dans la zone critique

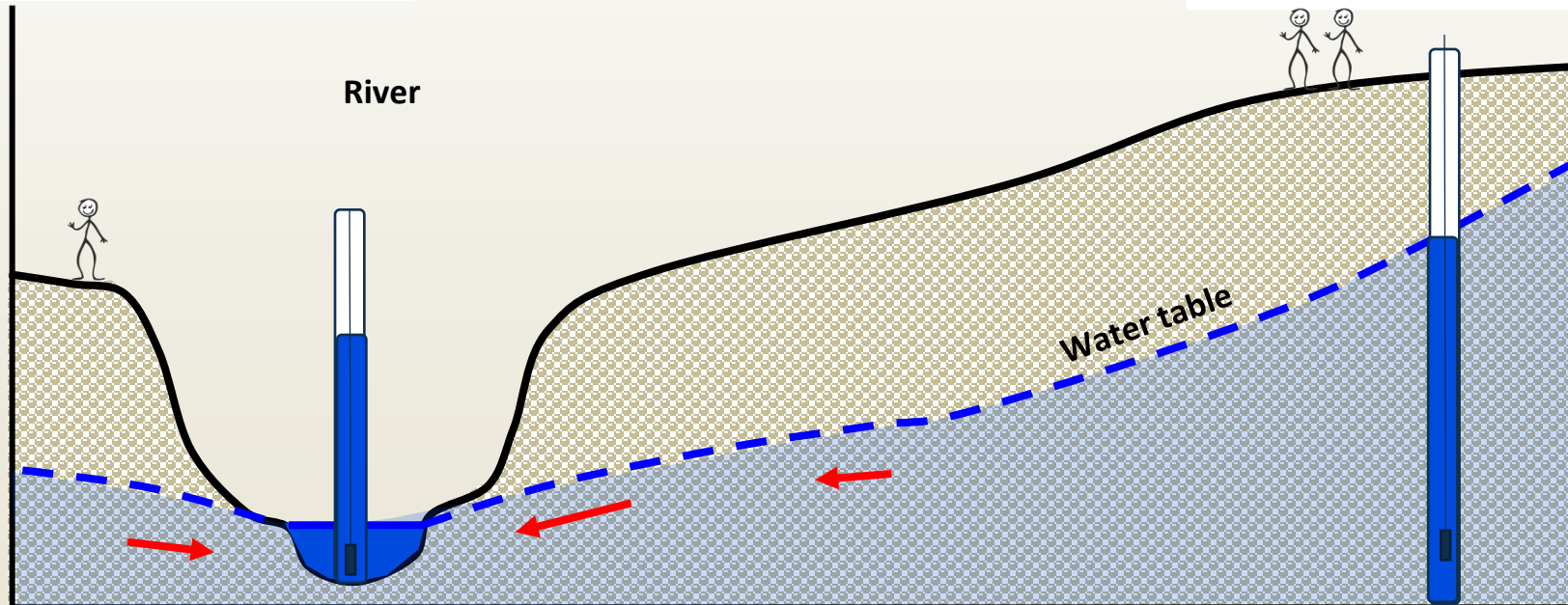
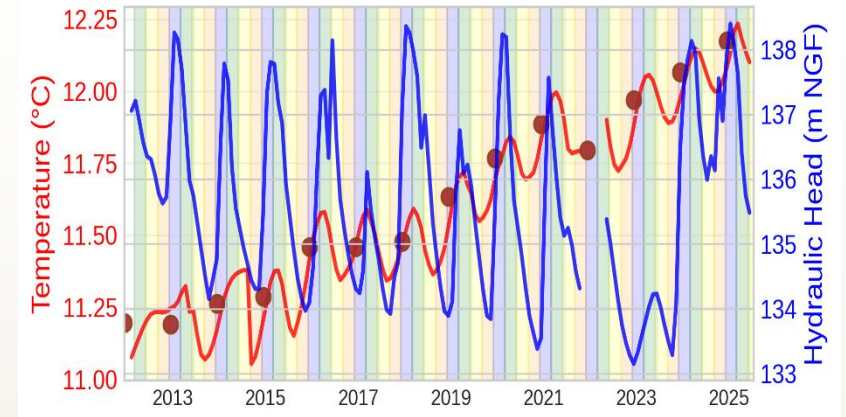


Interface nappe-rivière en milieu homogène

Rivière

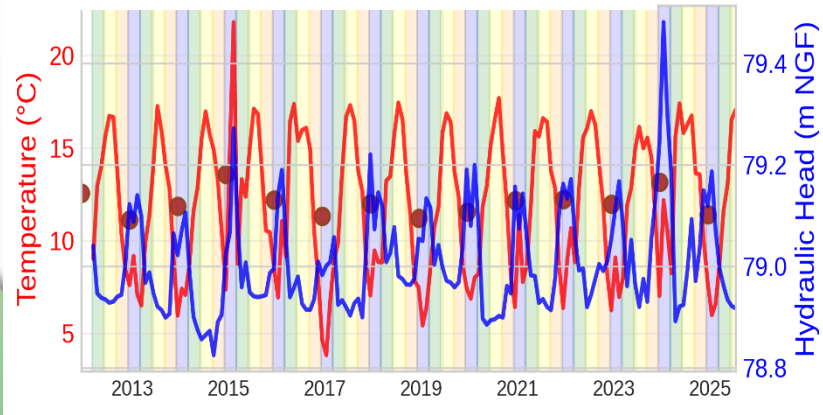


Souterrain



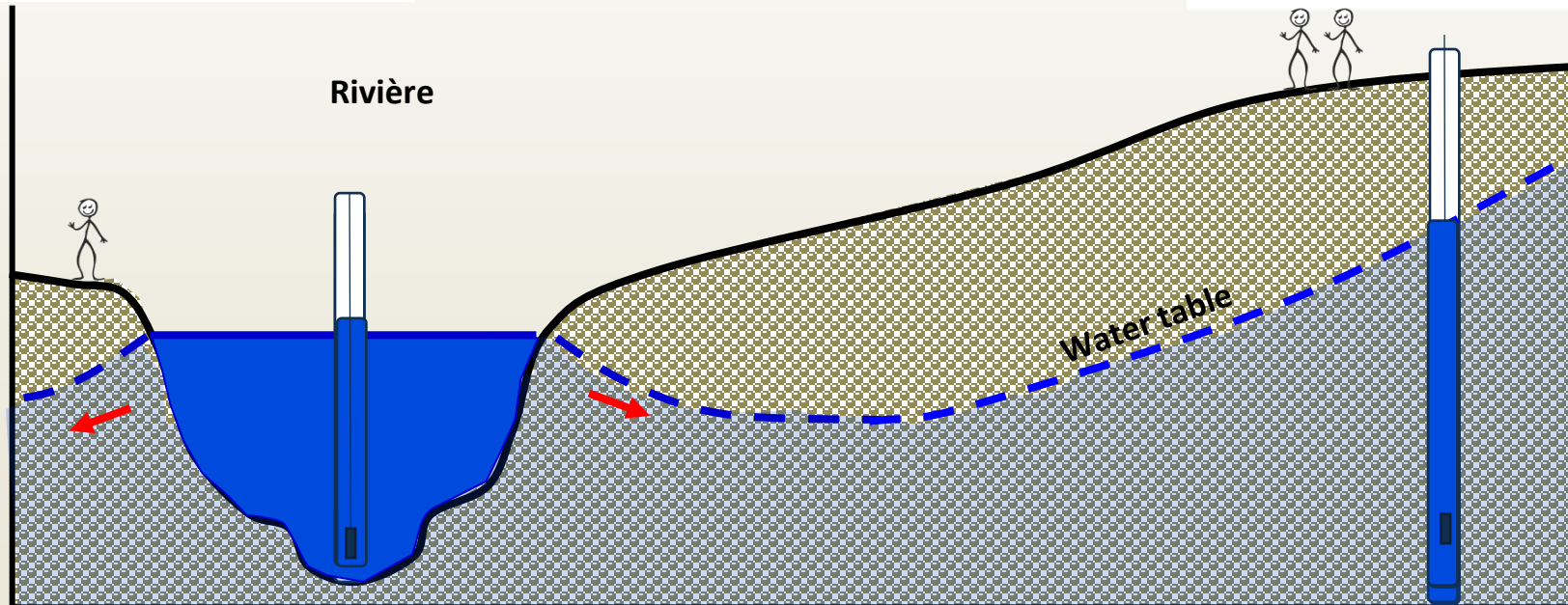
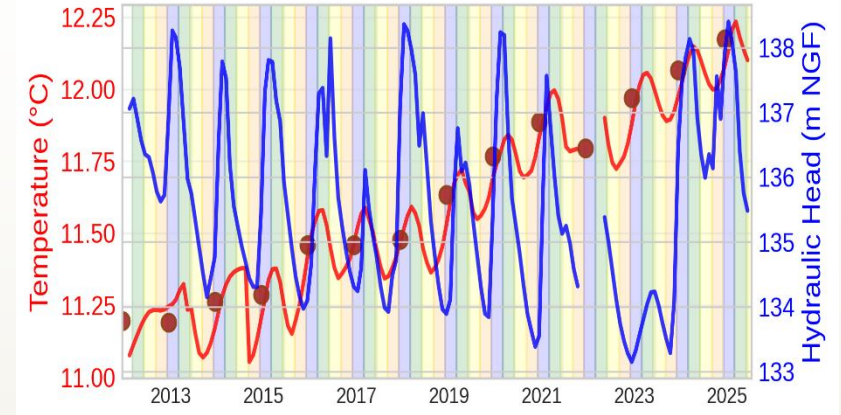
Interface nappe-rivière en milieu homogène

Rivière

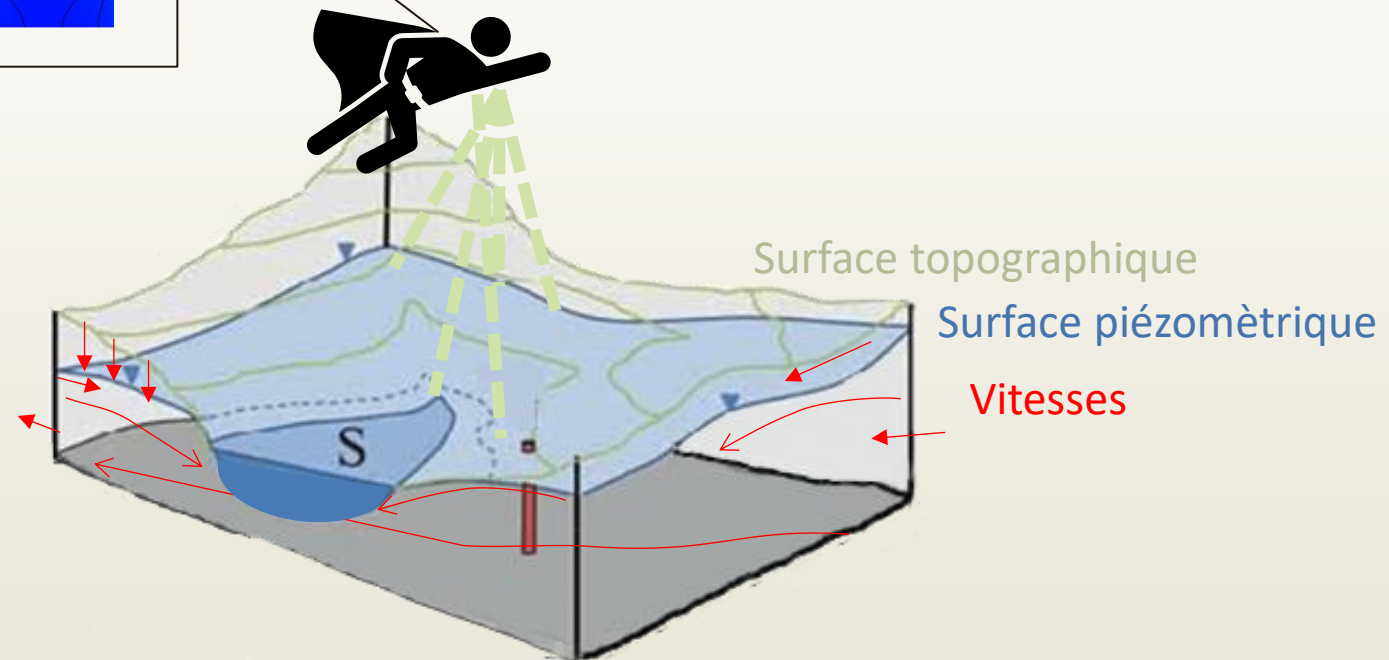
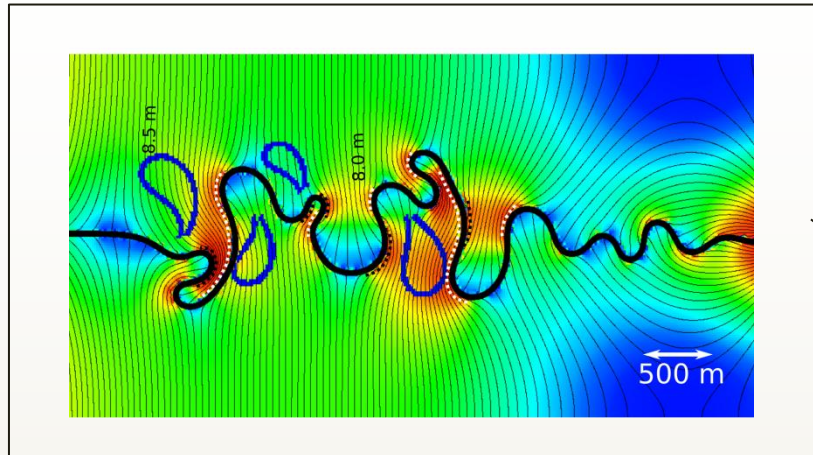


→ Orientation des échanges nappe rivière variable dans le temps et forme de la nappe

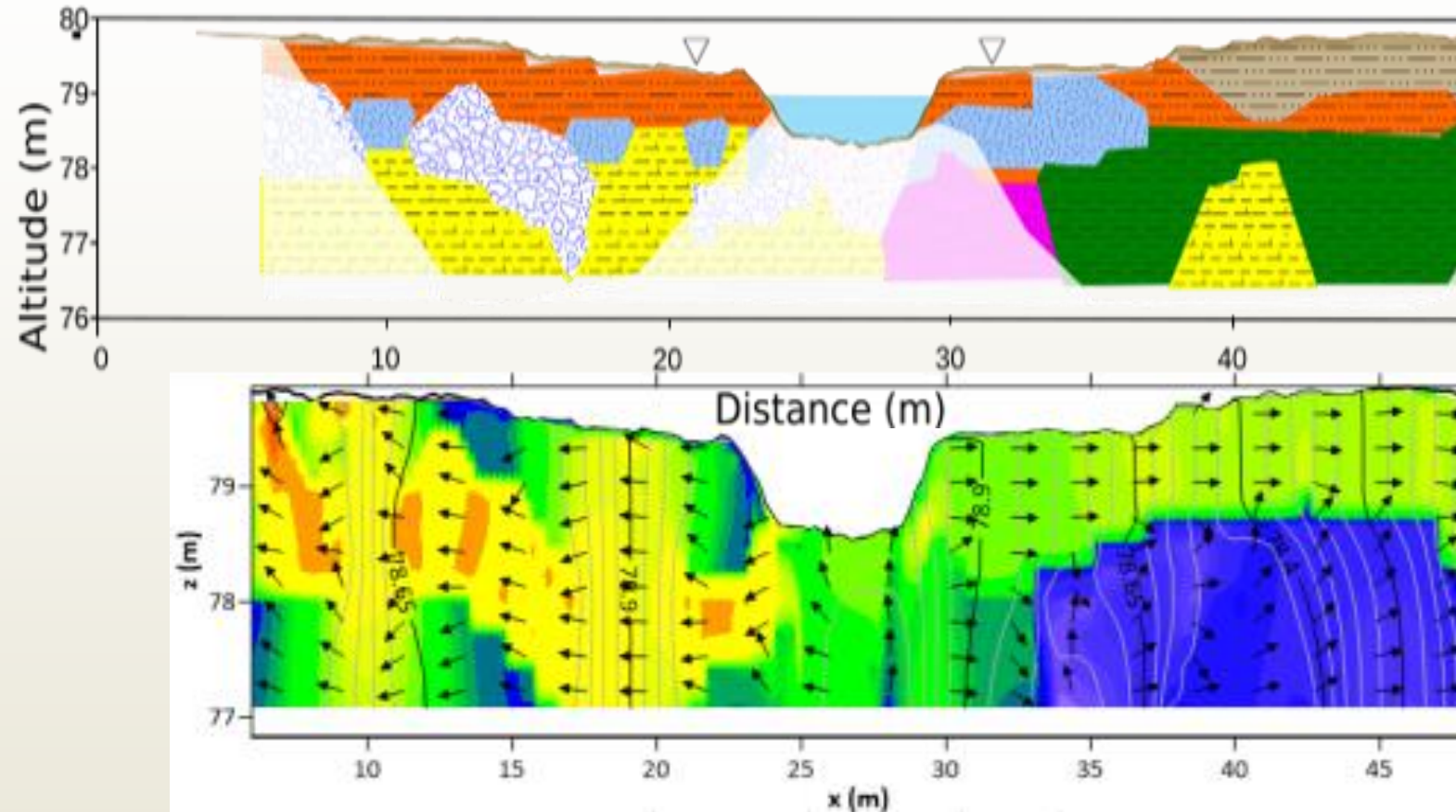
Souterrain



Hydrogéophysique : Imager le souterrain et sa dynamique



Interface nappe-rivière en milieu hétérogène



→ Flux d'eau variable dans l'espace et dans le temps

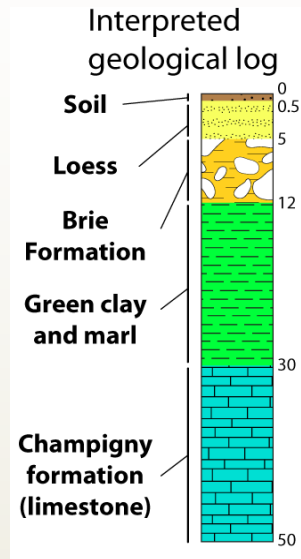
Agricultural soil (1) Silt(2) Overbank(3) Channel lag deposit(4)
Levee(5) Marls (6) Green clay(7) Streambed(8)

→ Flow direction
-78.6- Hydraulic head (m)

Flow velocity (m/s)
1E-10 1E-09 1E-08 1E-07 1E-06 1E-05

Hydrogéophysique : Imager le souterrain et sa dynamique

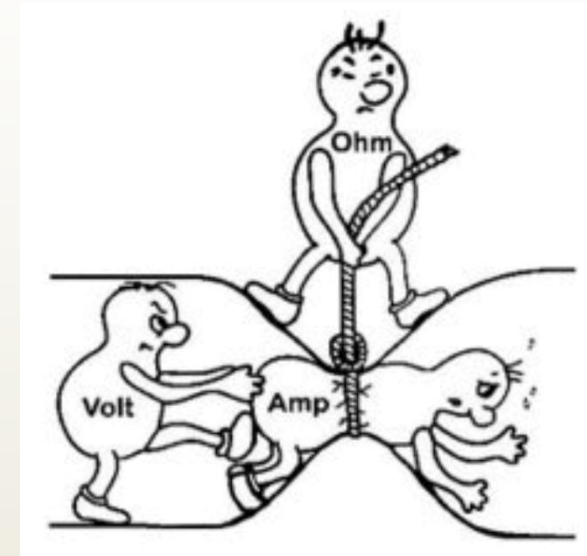
- Considérons le faciès comme une résistance au courant électrique



=



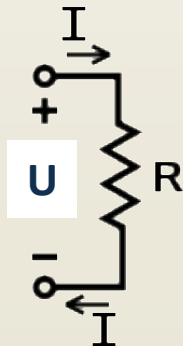
Resistance [Ω]



Voltage [V]

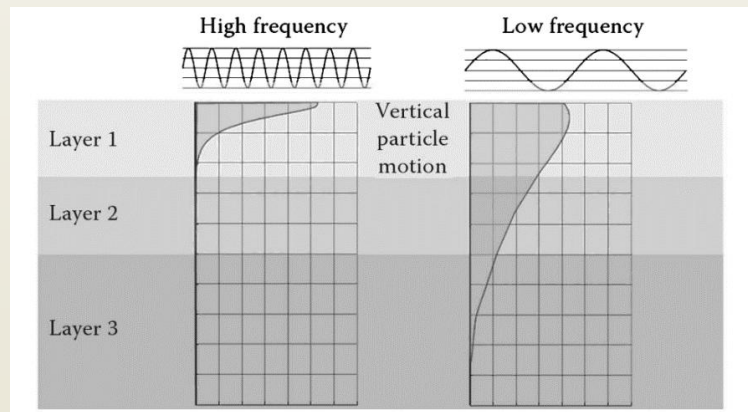
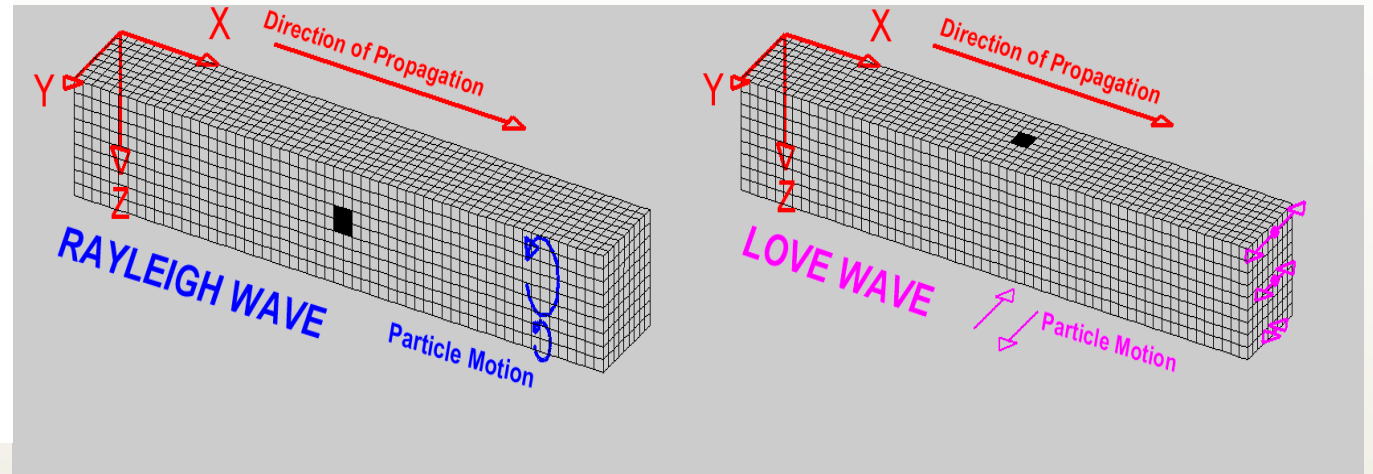
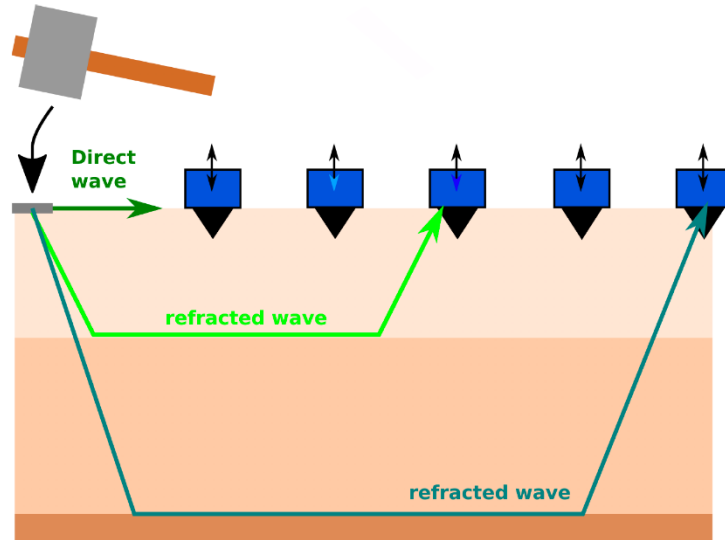
Intensity [A]

Ohm's law:



$$U = R I \longrightarrow R = U / I$$

Propagation des ondes sismiques



Propagation d'ondes de Rayleigh et Love. Tiré de Geophysics for Practicing Geoscientists

Mouvement particulaire vertical de l'onde de Rayleigh. Tiré Foti et al. (2017)

Hydrogéophysique : Imager le souterrain et sa dynamique

► Complémentarité entre les méthodes géophysiques :

Tomographie de résistivité
électrique (ERT)

↓
Distribution de la
résistivité ρ

↓
Hétérogénéités

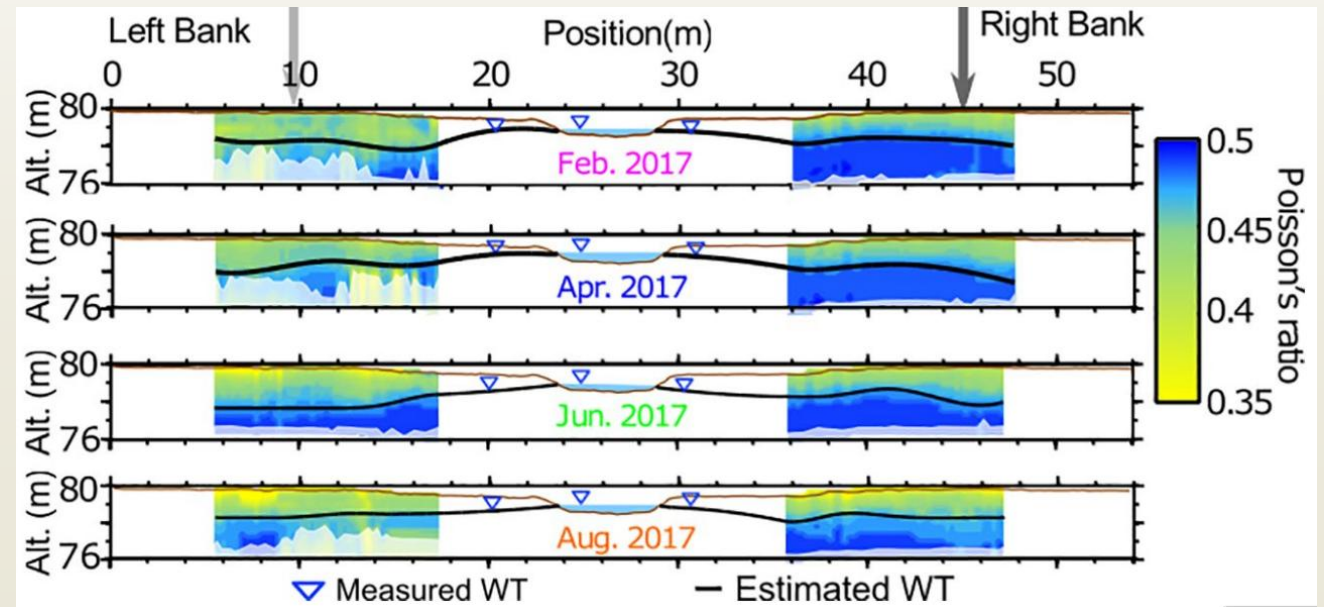
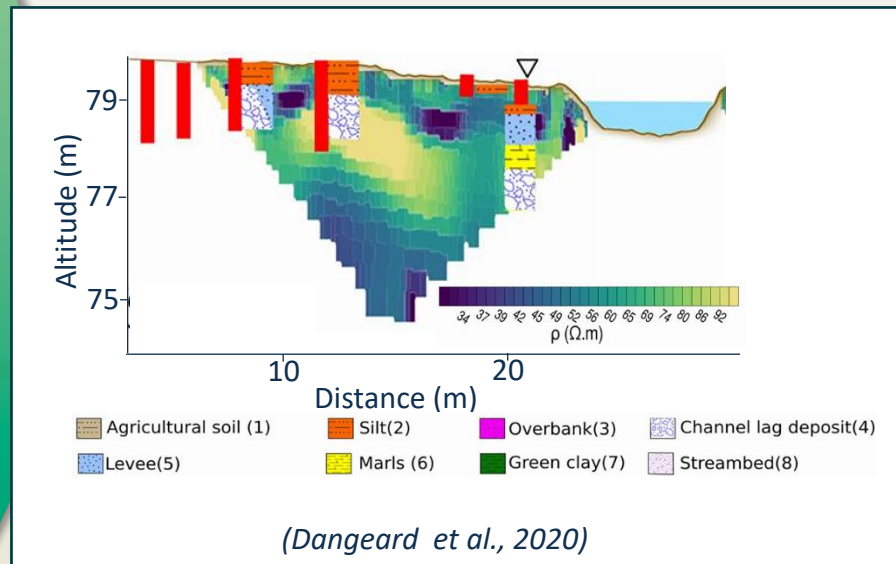
Tomographie par sismique
réfraction (SRT)

↓
Distribution de
la vitesse V_P

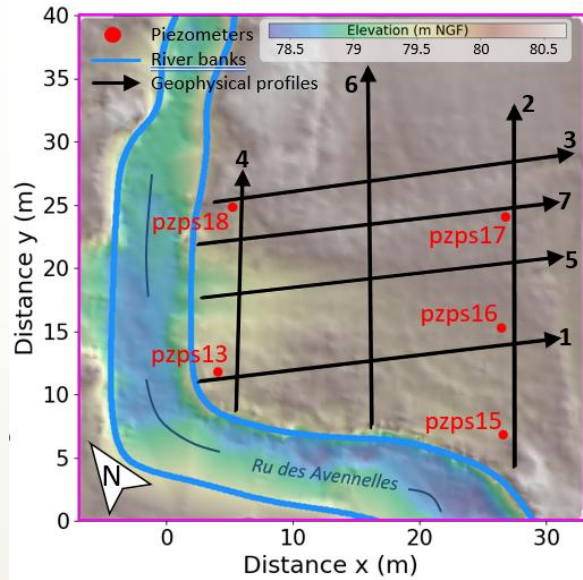
Analyse des ondes de
surface (MASW)

↓
Distribution de
la vitesse V_S

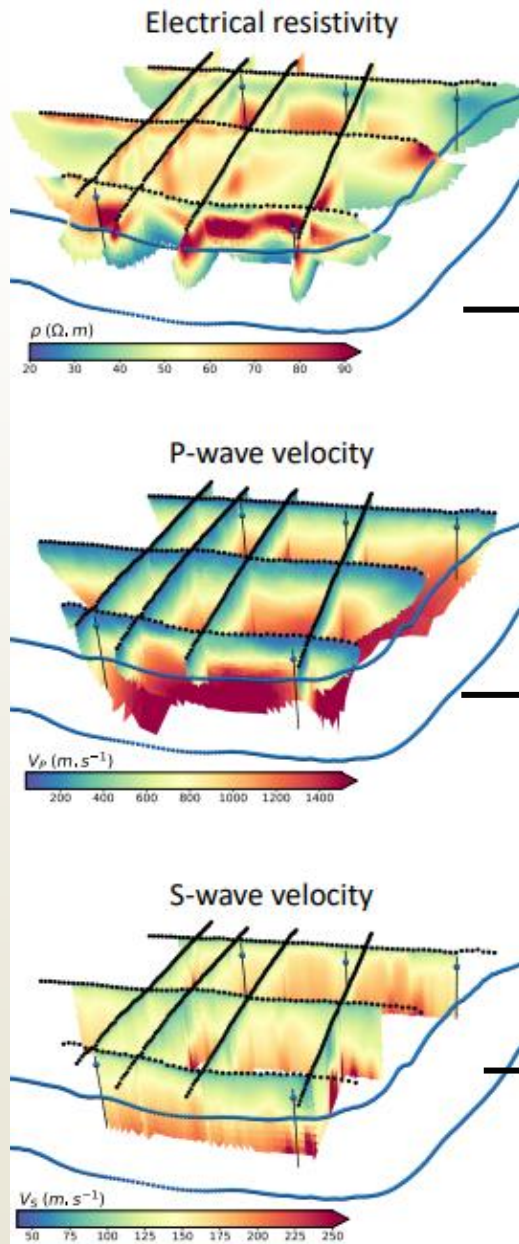
Coeficient de Poisson $\nu \Rightarrow$ Zones saturées



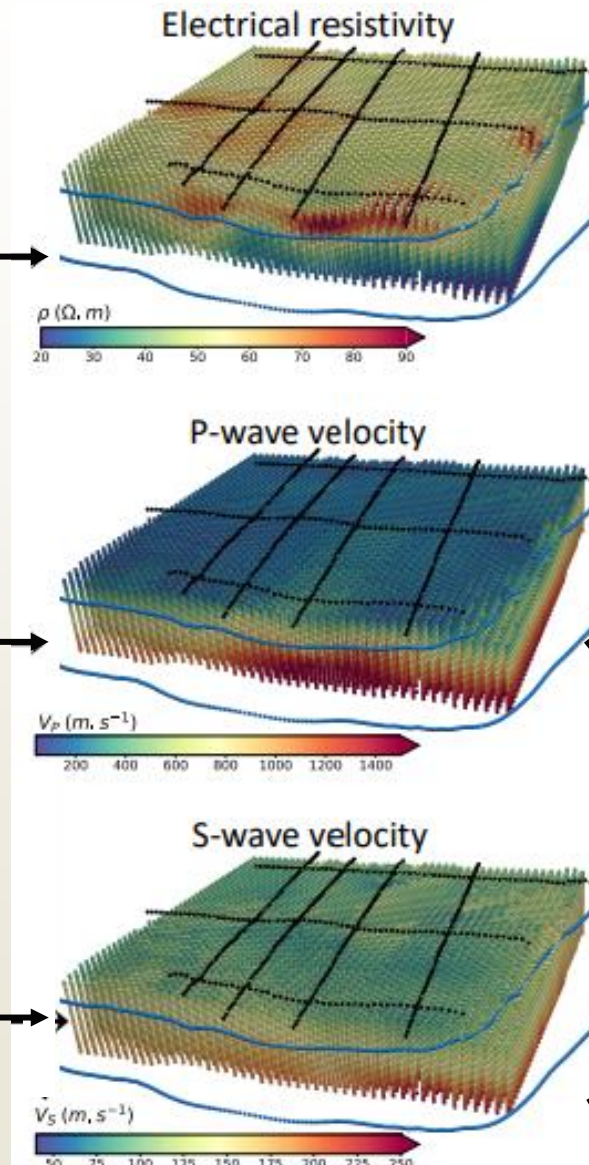
Acquisitions et suivi temporel tous les 3 mois



Vers une vue 3D du sous-sol

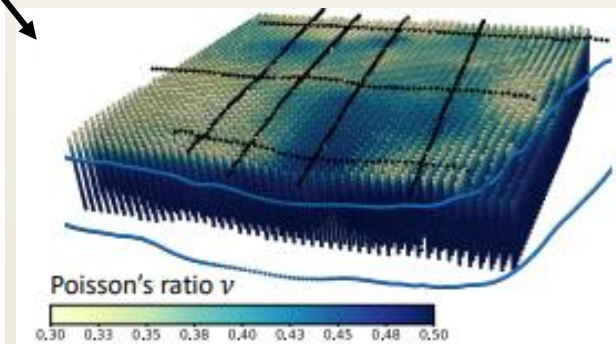


Géostatistiques

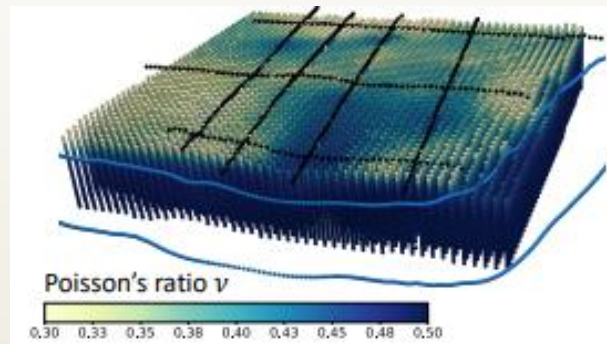


Structures

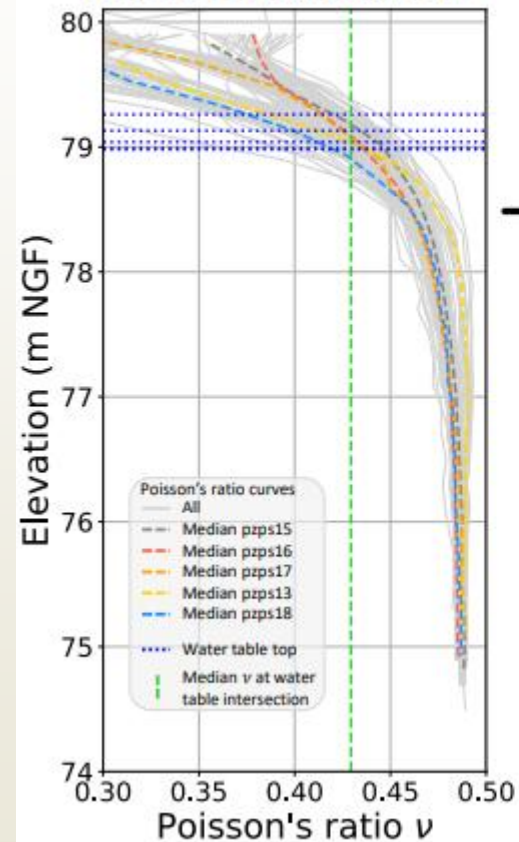
Zone saturée



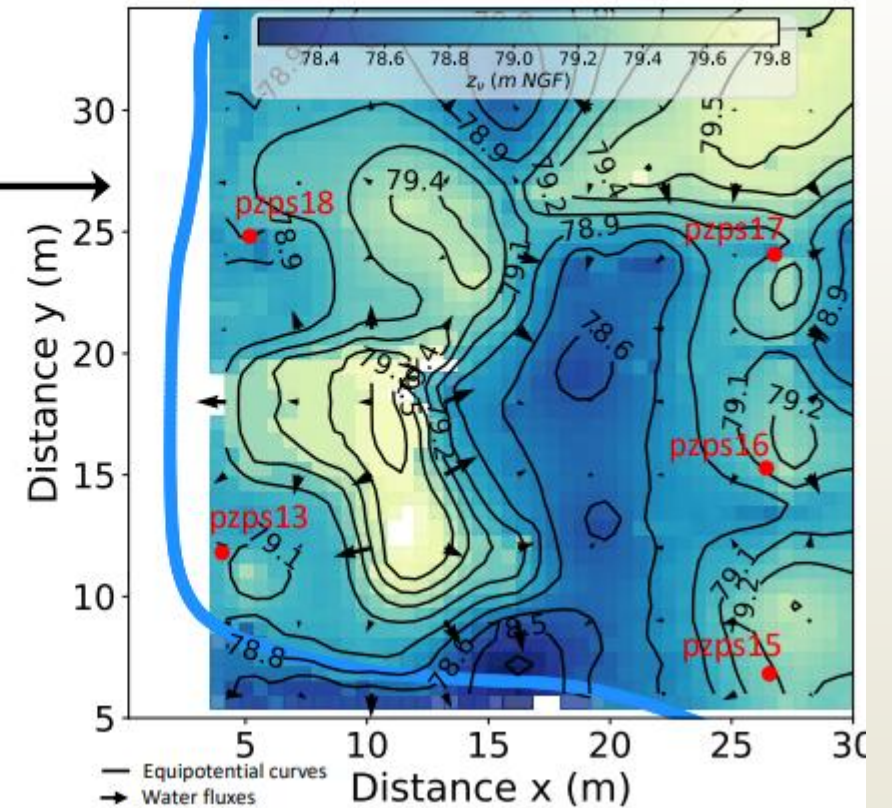
Visualiser le toit de la nappe



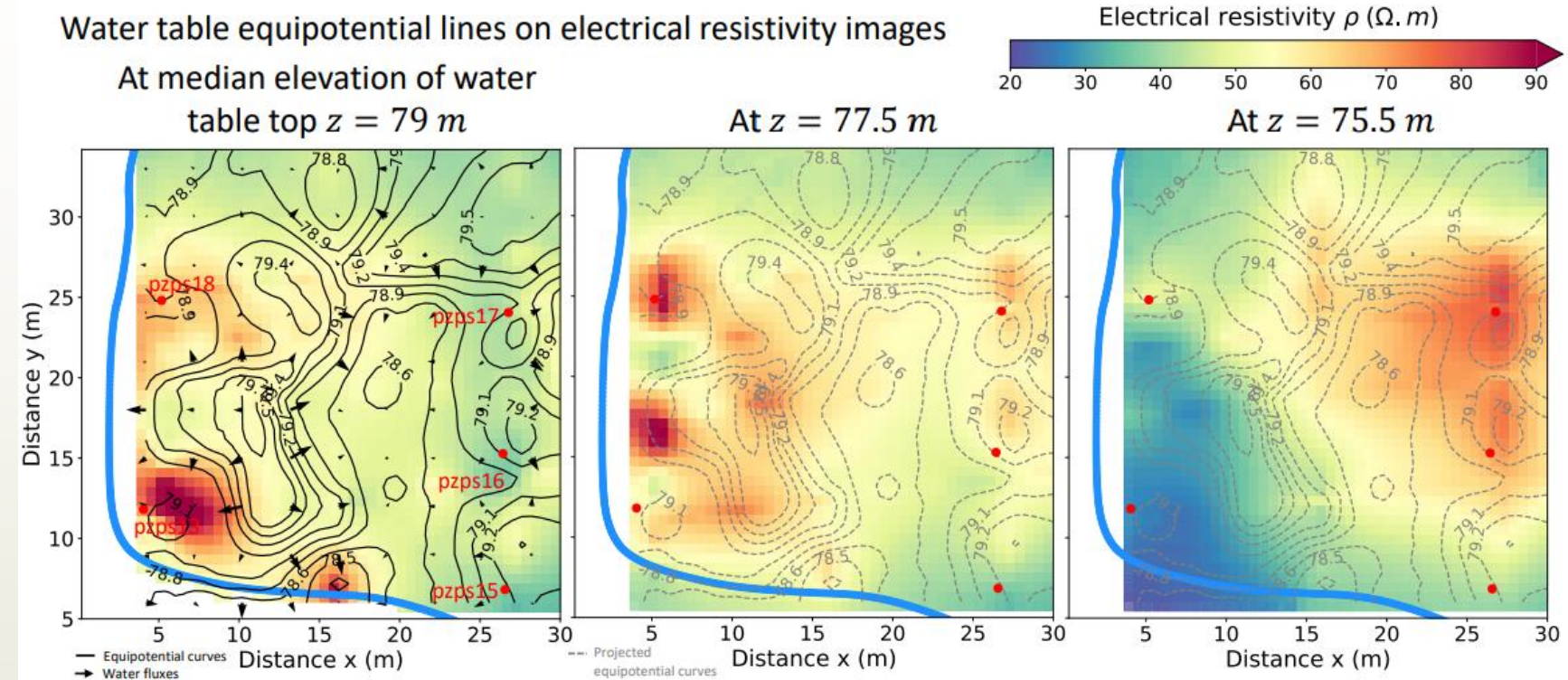
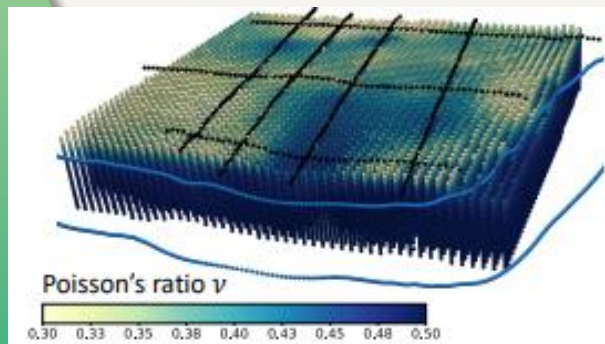
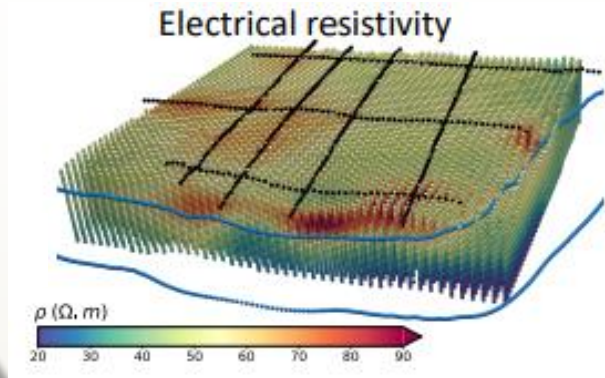
Poisson's ratio at water table intersection



Elevation of water table top

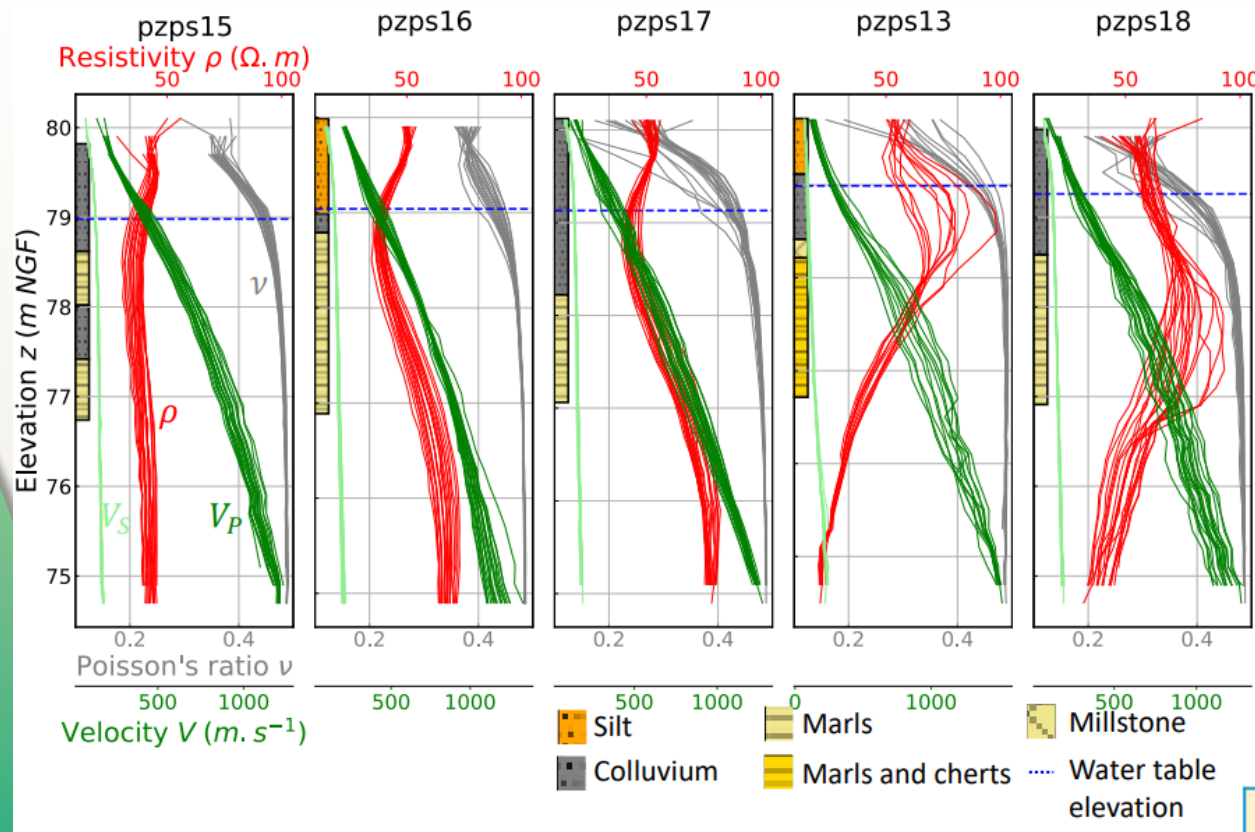


Interactions structures / écoulements



Les signaux sont liés au faciès seulement ou également à la dynamique

Interprétation des images en terme d'hydrofaciès :

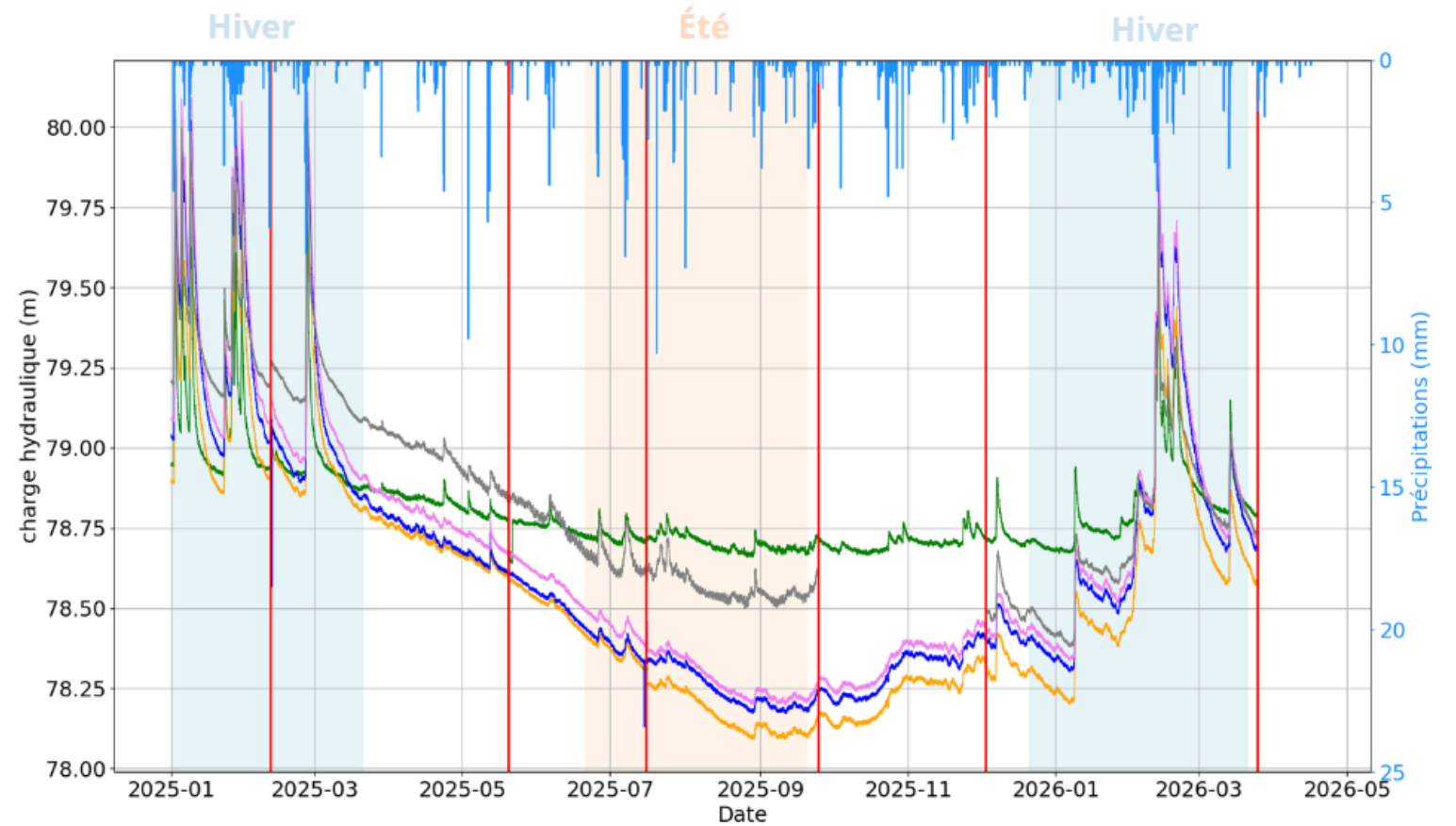
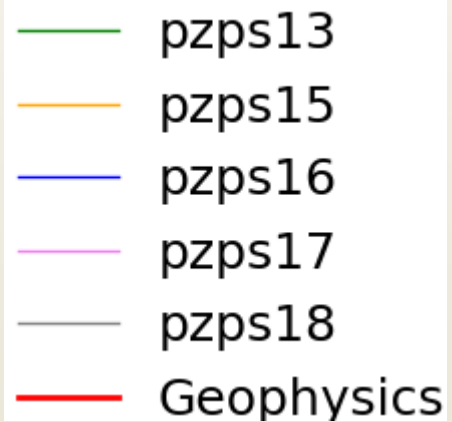
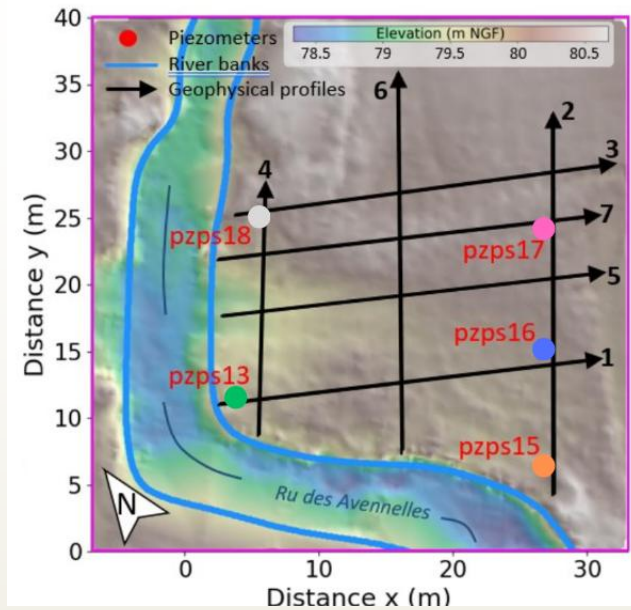


Suivi temporel

Amélioration de l'interprétation hydrogéophysique

Intégration dans des modèles hydrogéologiques 2D et 3D (conditions aux limites)

Suivi temporel Hydrogéologie

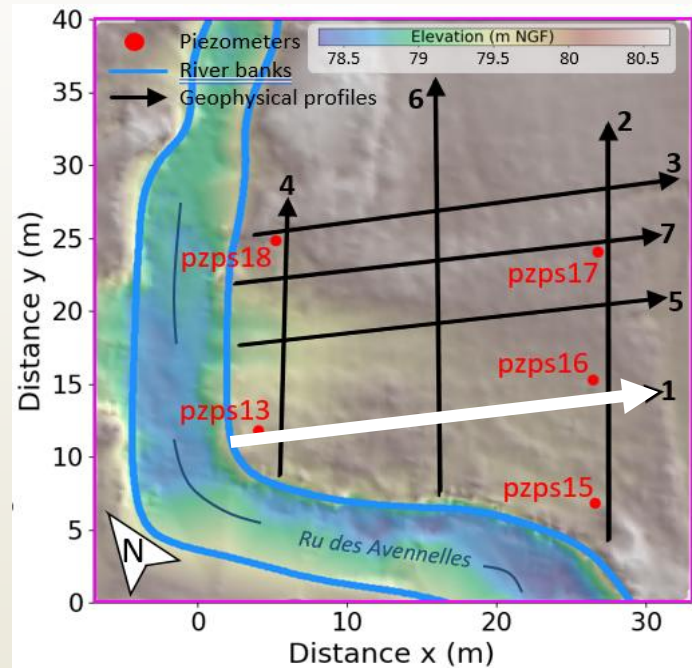


Evolution temporelle de la charge hydraulique

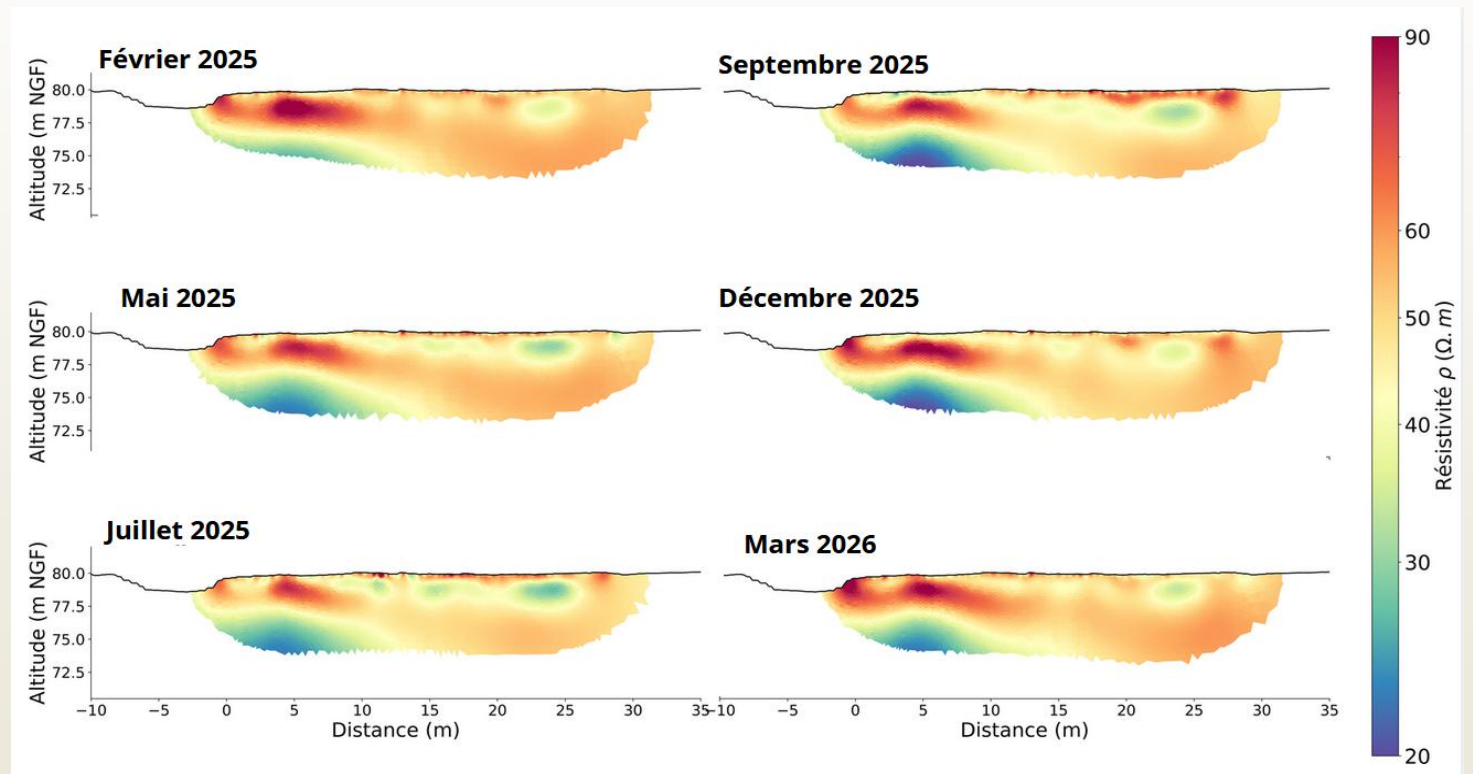
Suivi temporel Géophysique



Time-lapse



Structure commune
Difference

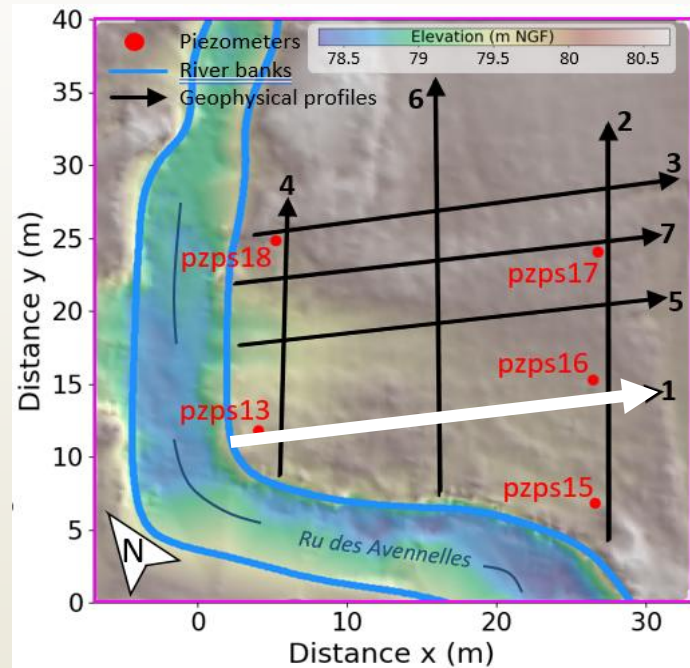


Tomographie de résistivité électrique en time-lapse – profil 1

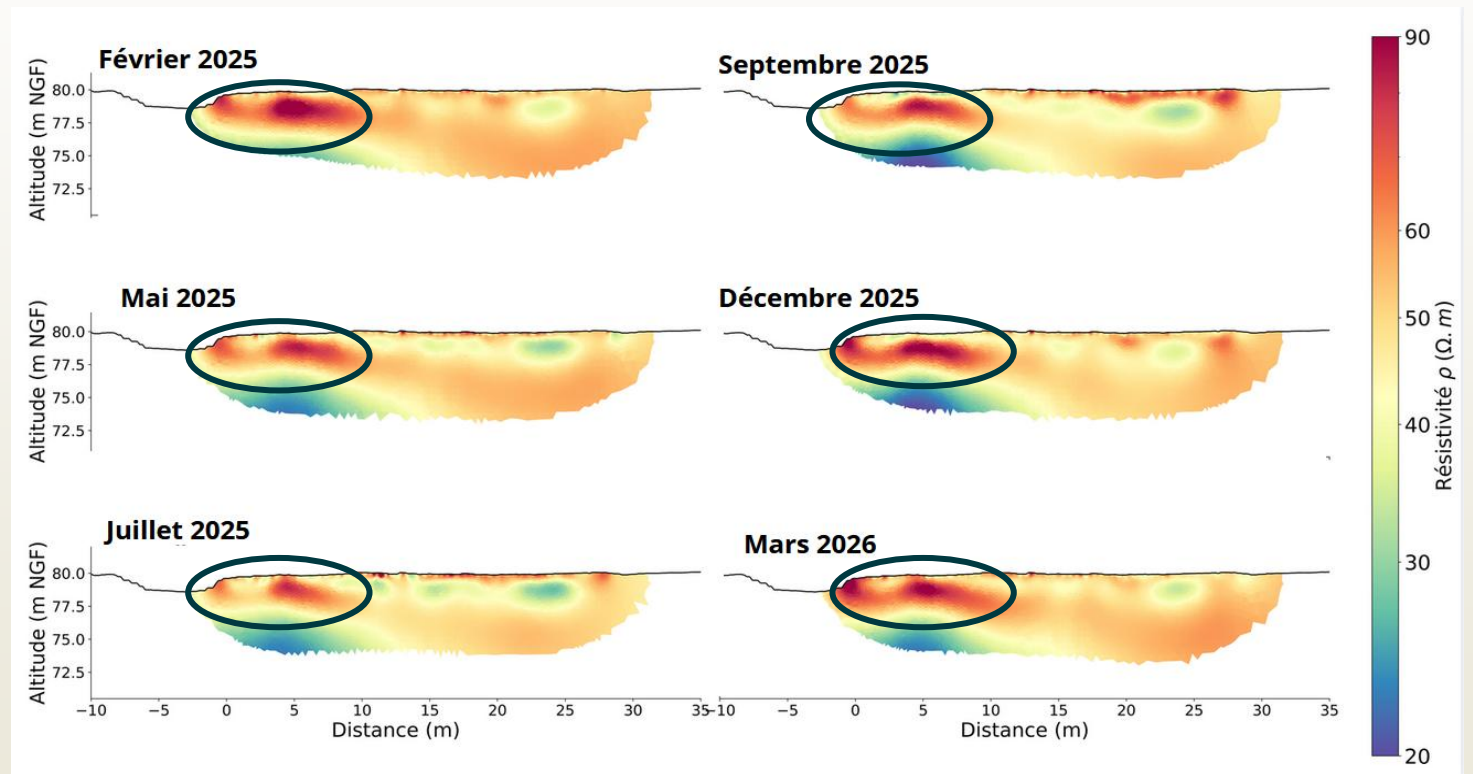
Suivi temporel Géophysique



Time-lapse



Structure commune
Difference

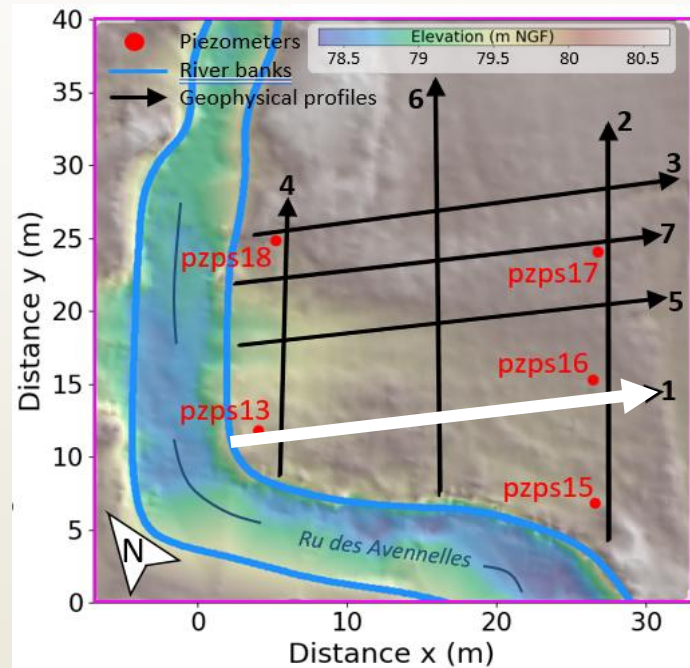


Tomographie de résistivité électrique en time-lapse – profil 1

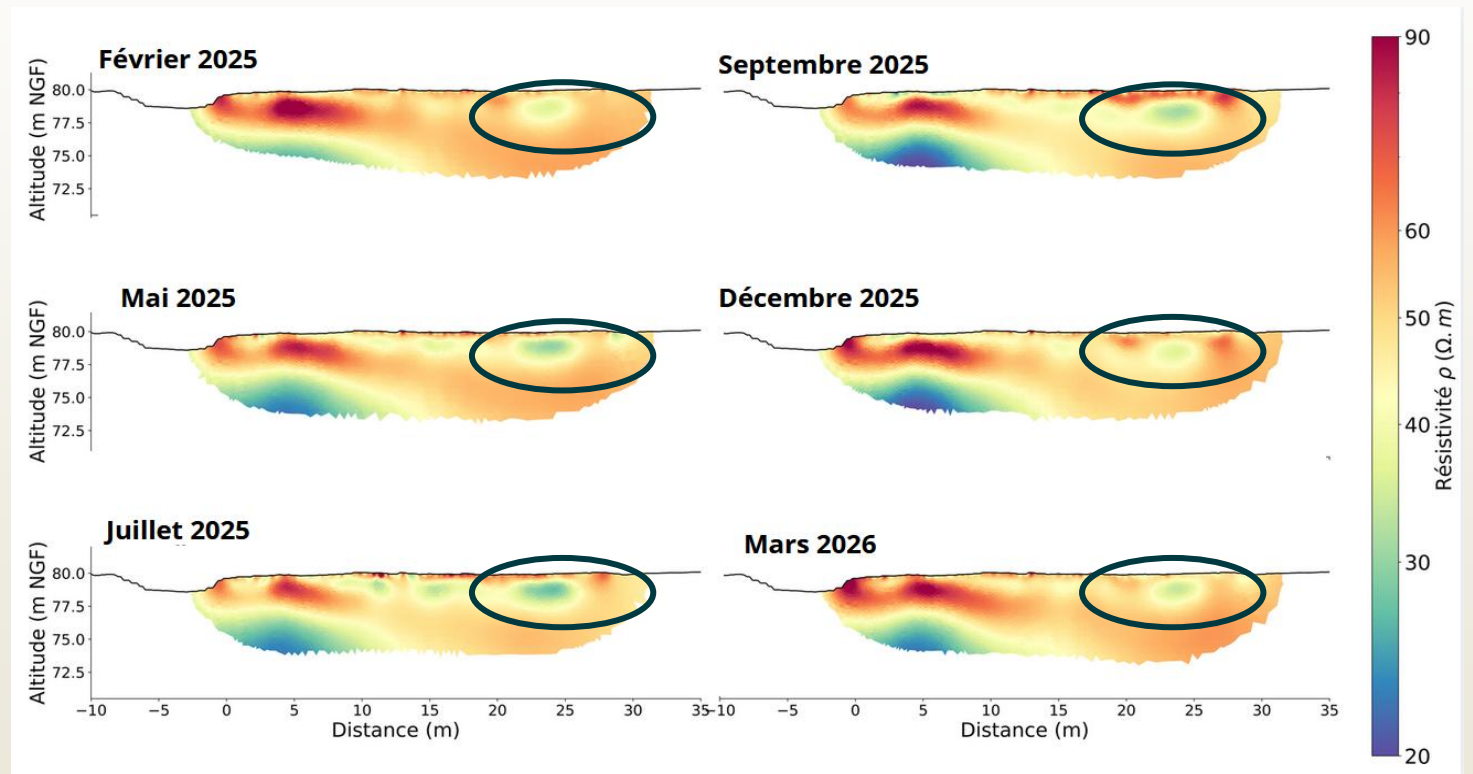
Suivi temporel Géophysique



Time-lapse

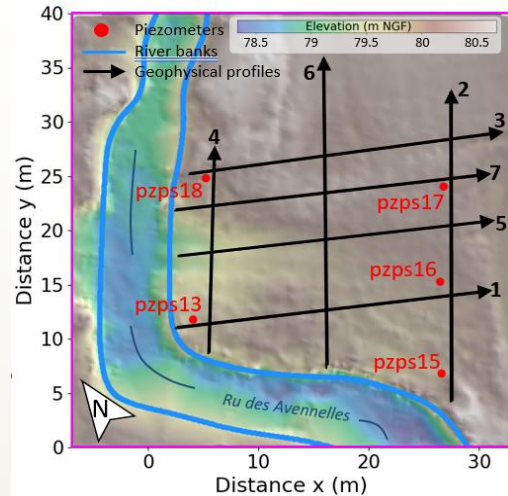


Structure commune
Difference

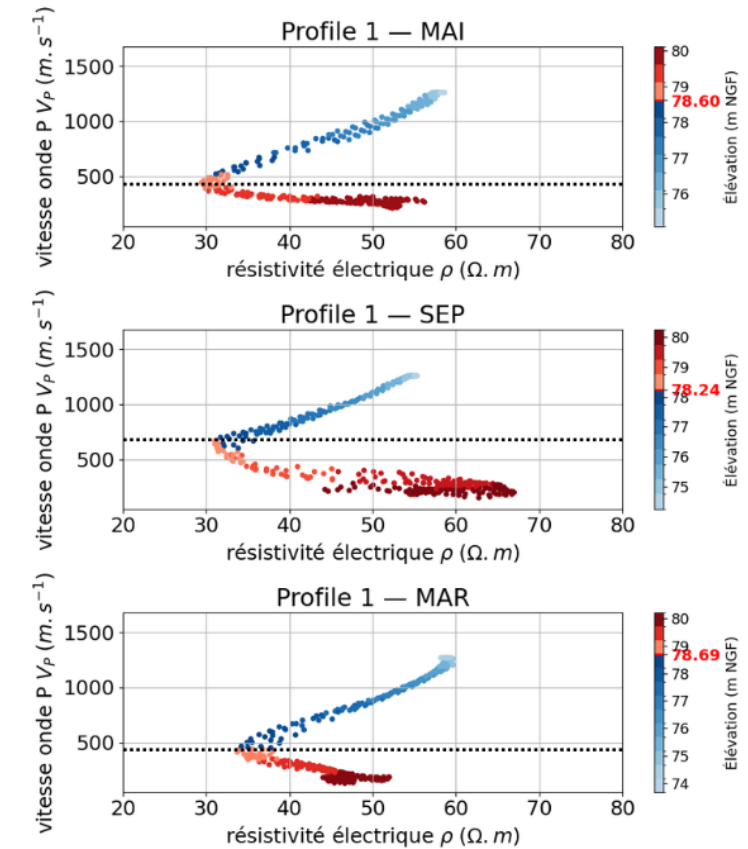
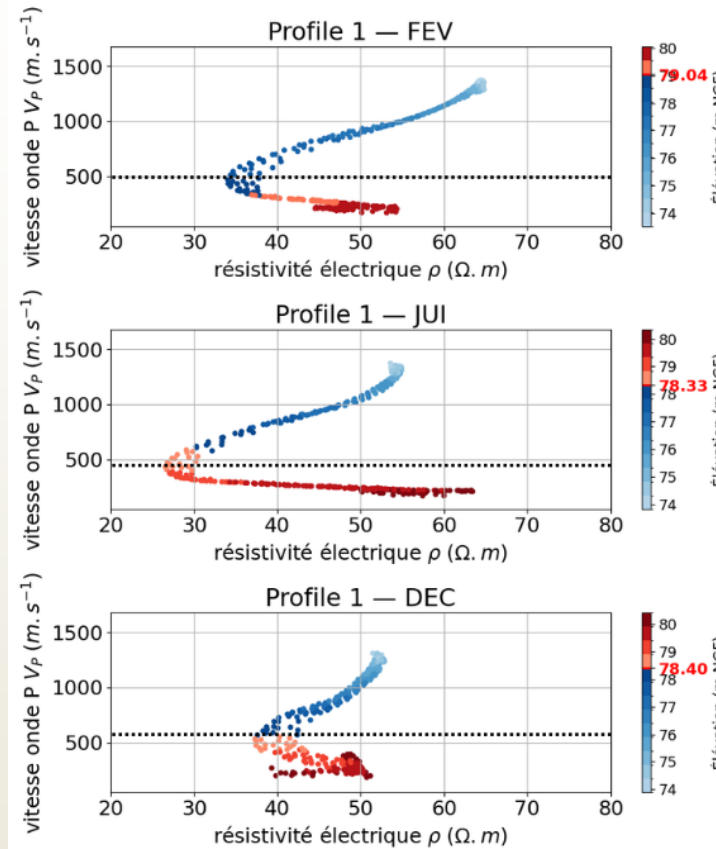


Tomographie de résistivité électrique en time-lapse – profil 1

Suivi temporel Hydrogéophysique

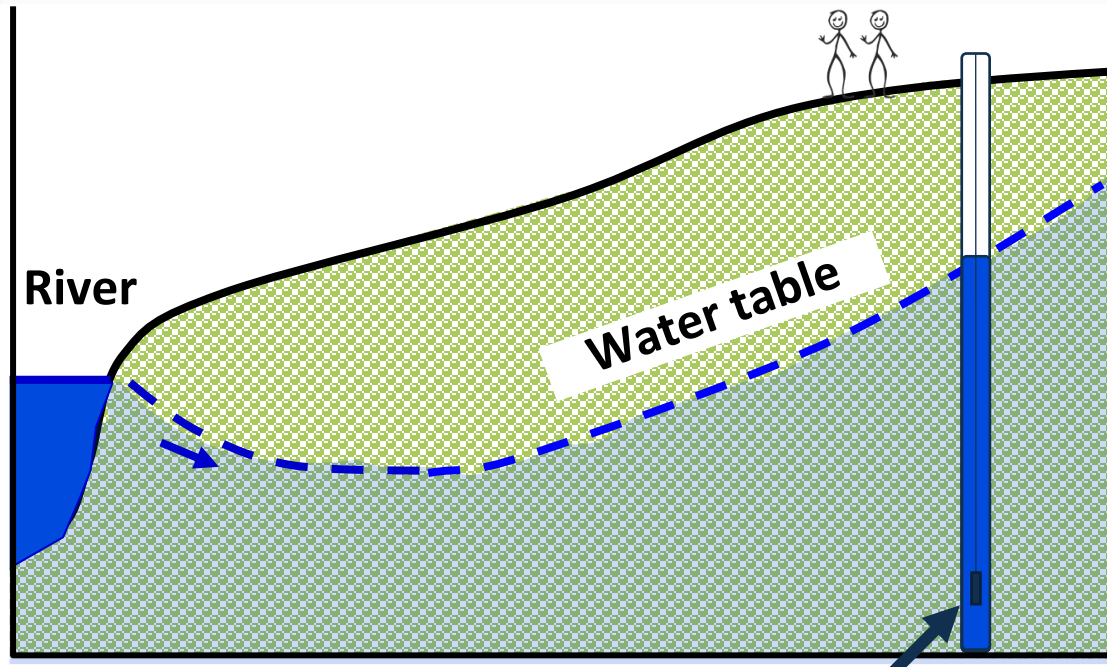


**Amélioration de
l'interprétation
hydrogéophysique
(Nicolas Radic)**

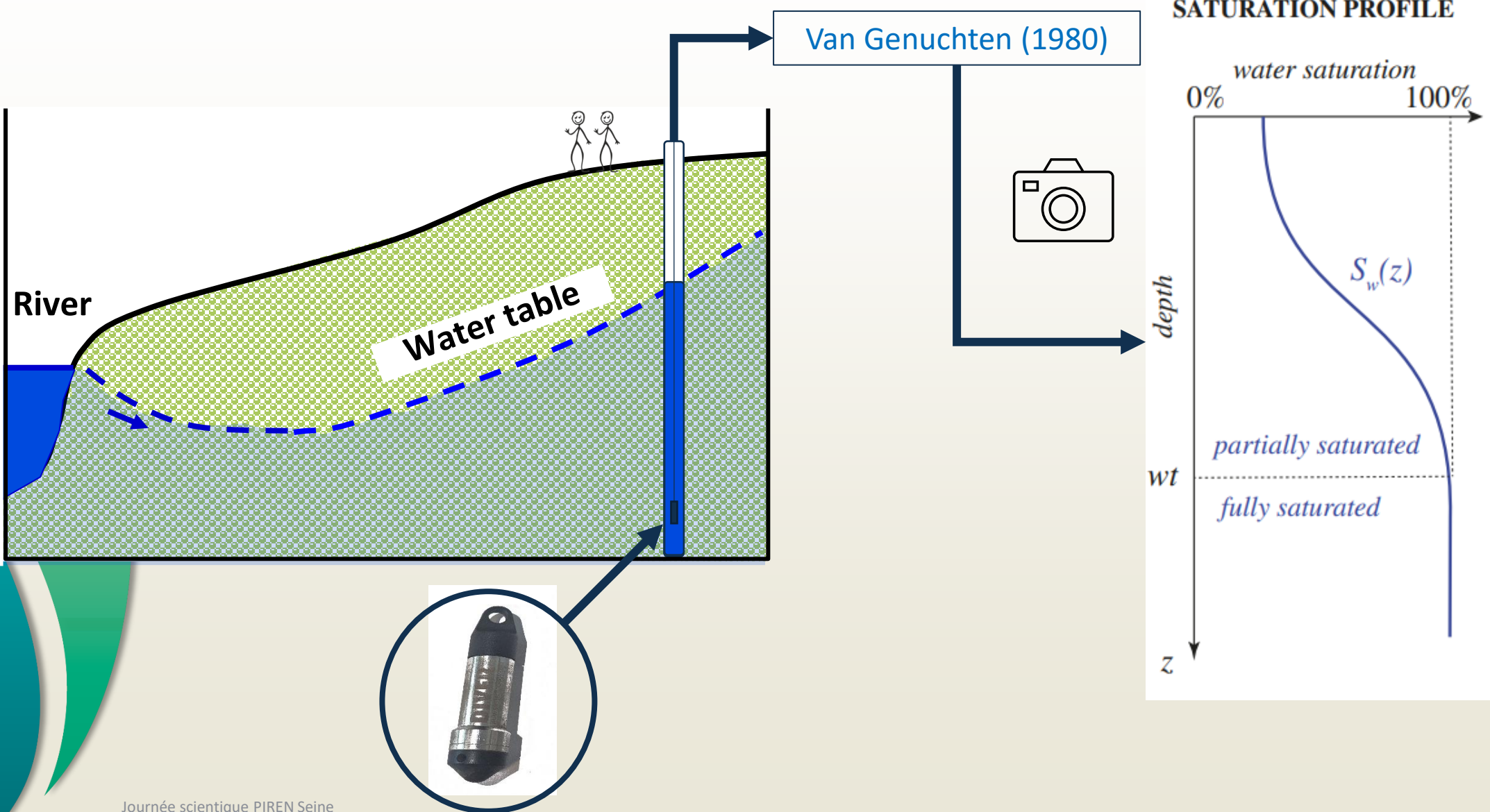


Relation entre la résistivité électrique (ρ) et la vitesse des ondes P (V_p) le long du piézomètre 16

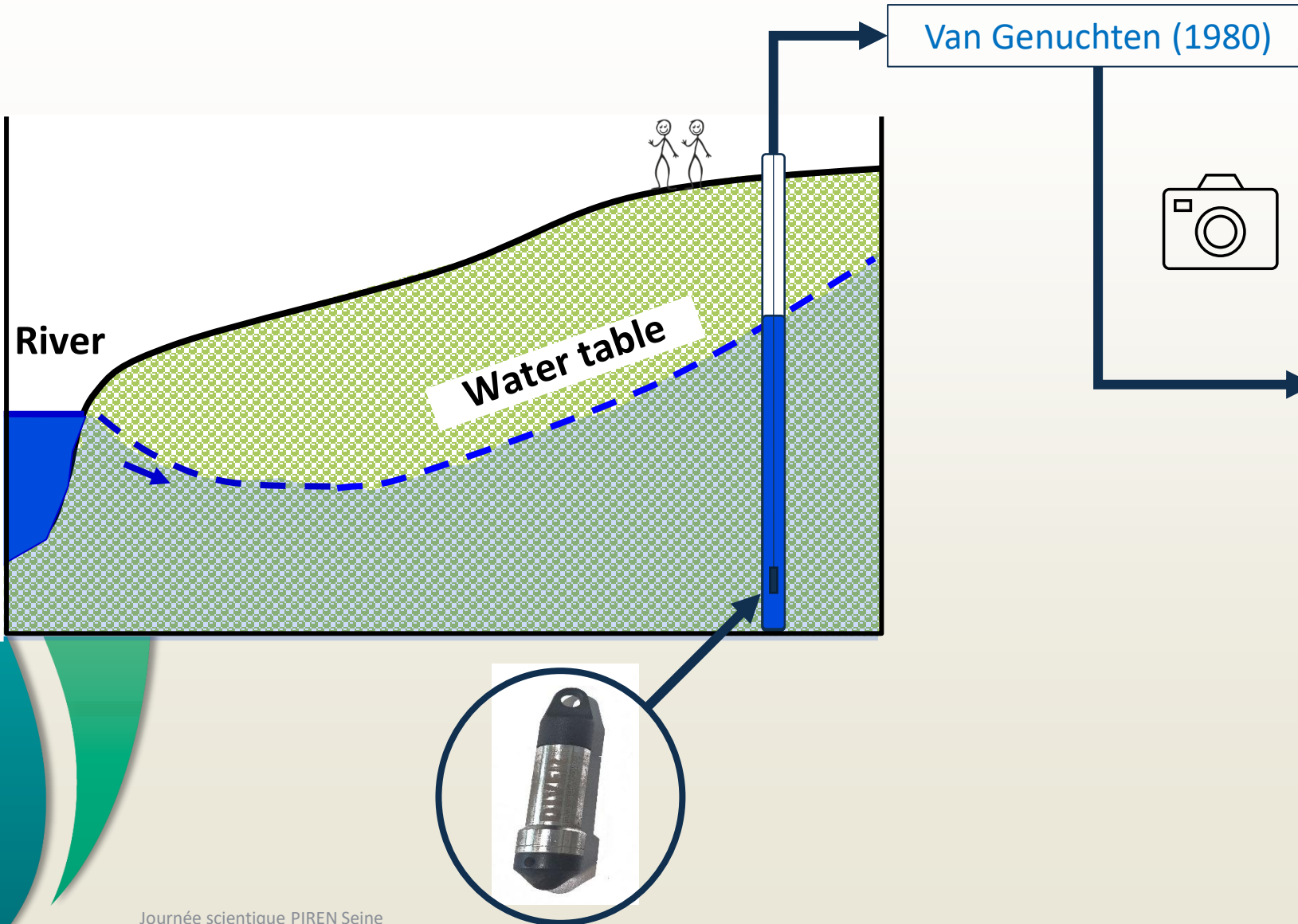
Modèle direct hydrogéophysique



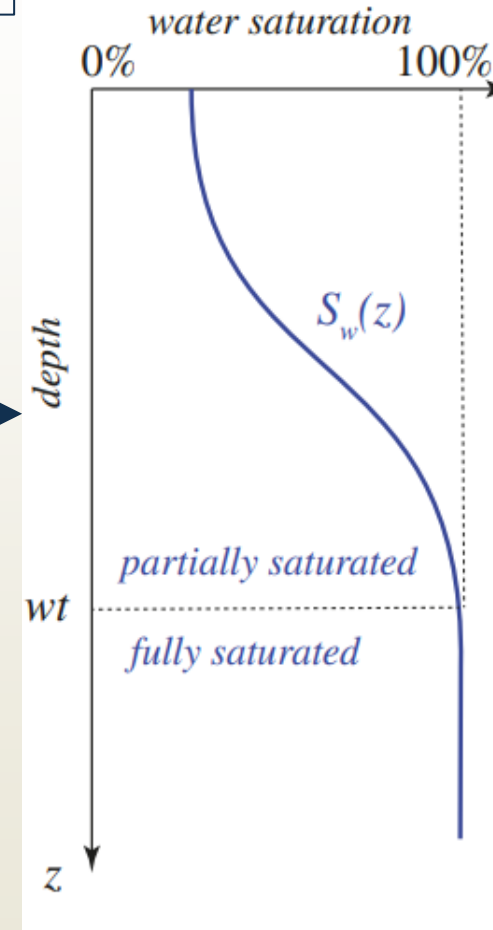
Modèle direct hydrogéophysique



Modèle direct hydrogéophysique



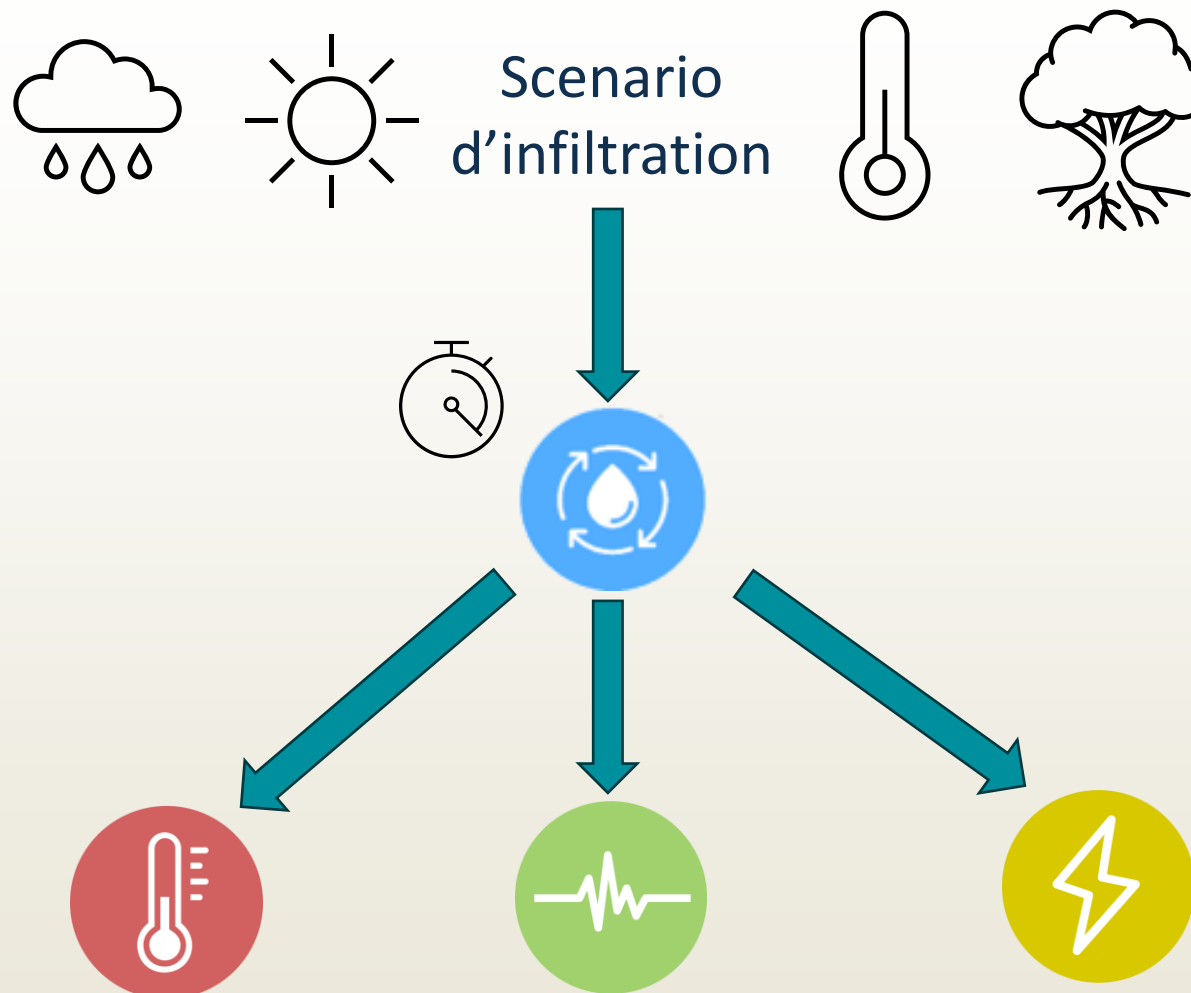
SATURATION PROFILE



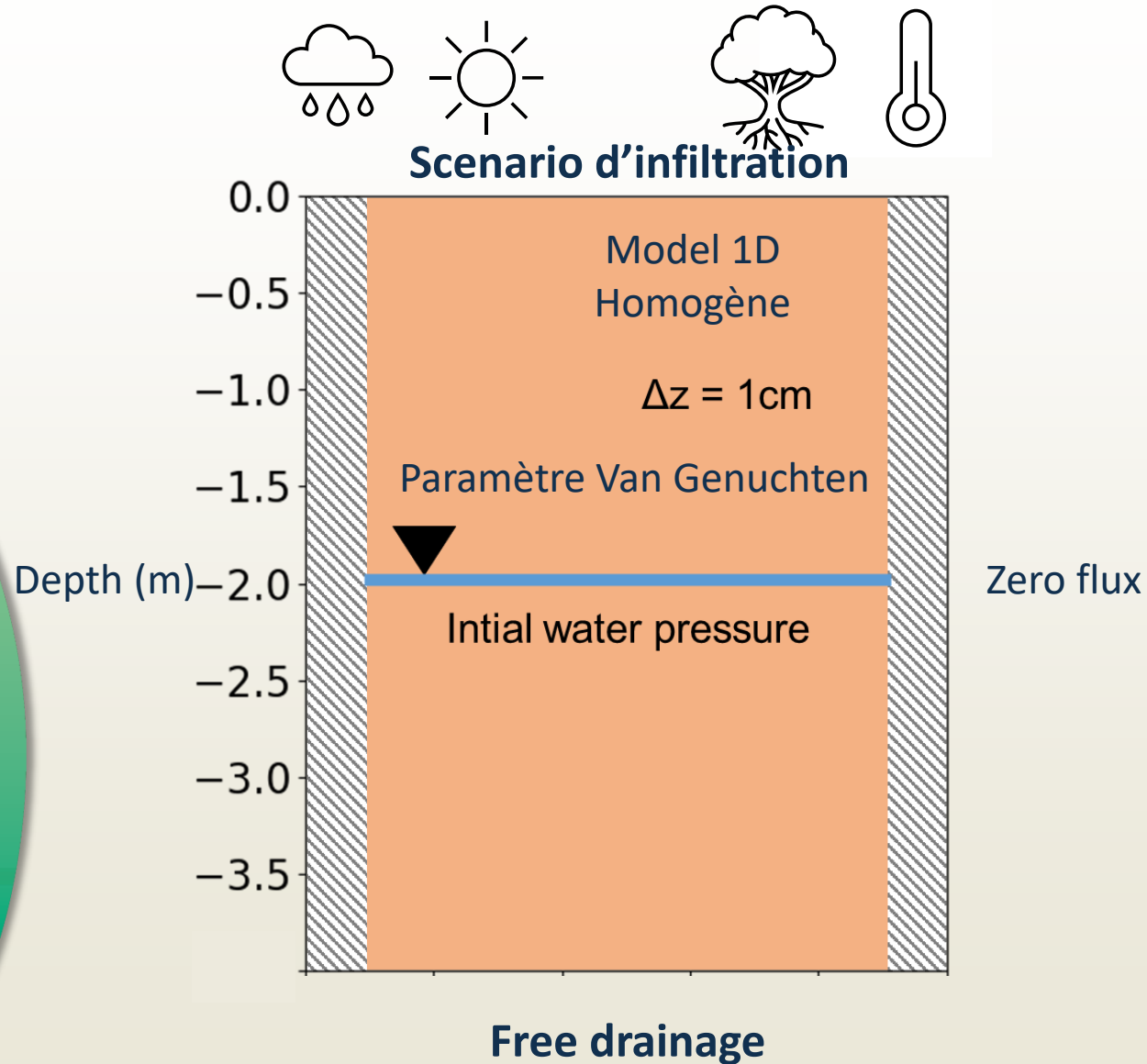
No
transient
process



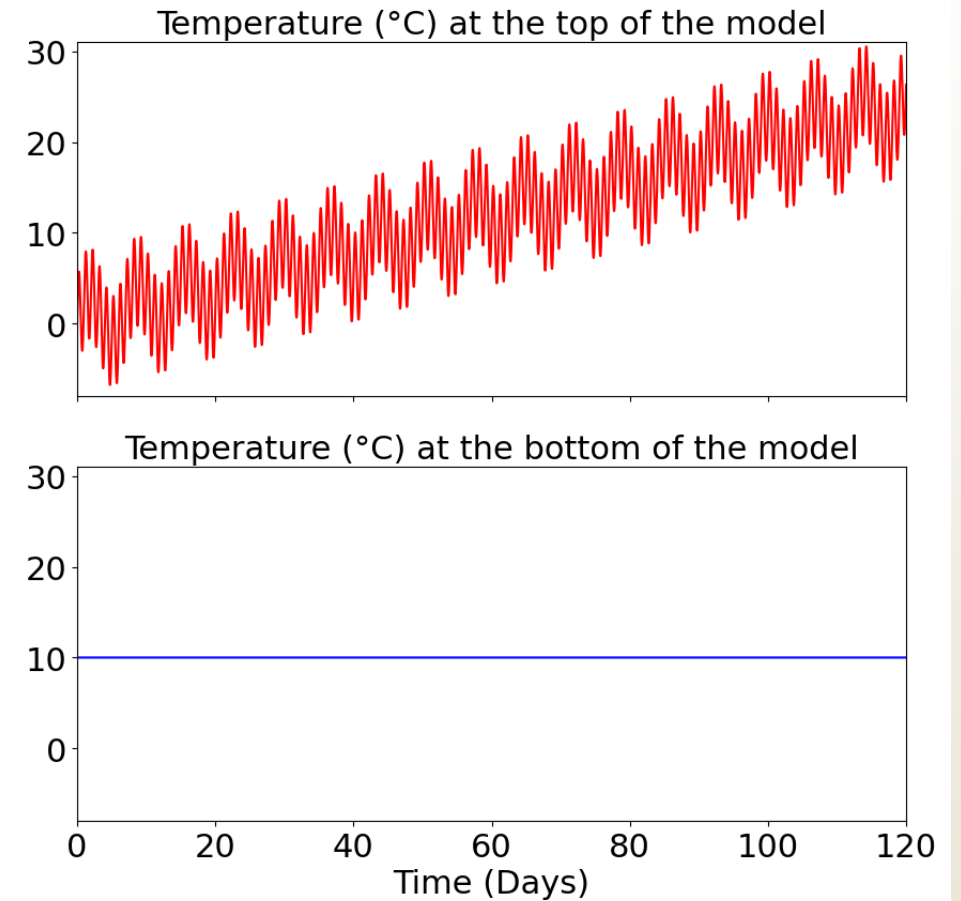
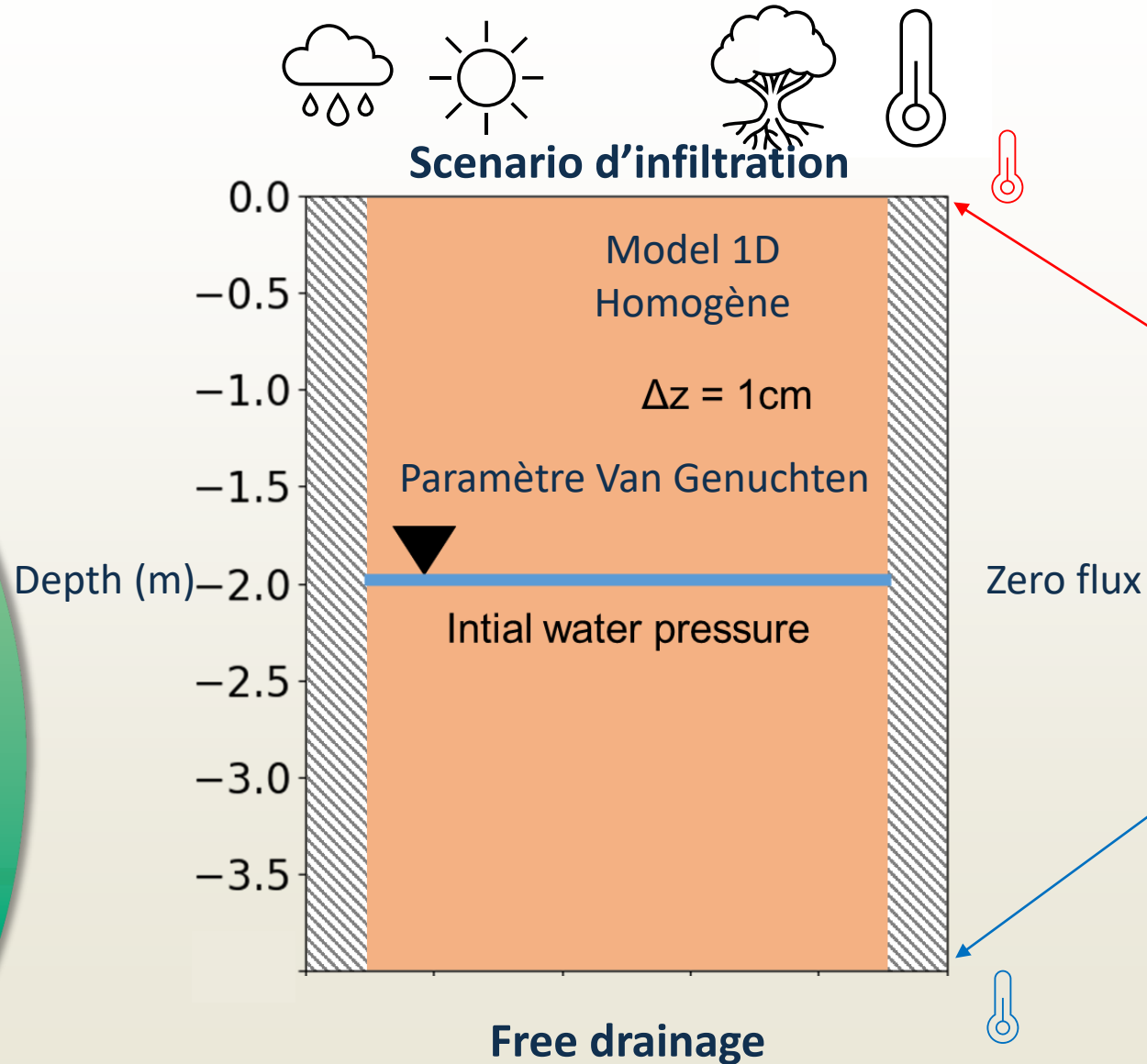
Modèle direct hydrogéophysique



Modèle direct hydrogéophysique

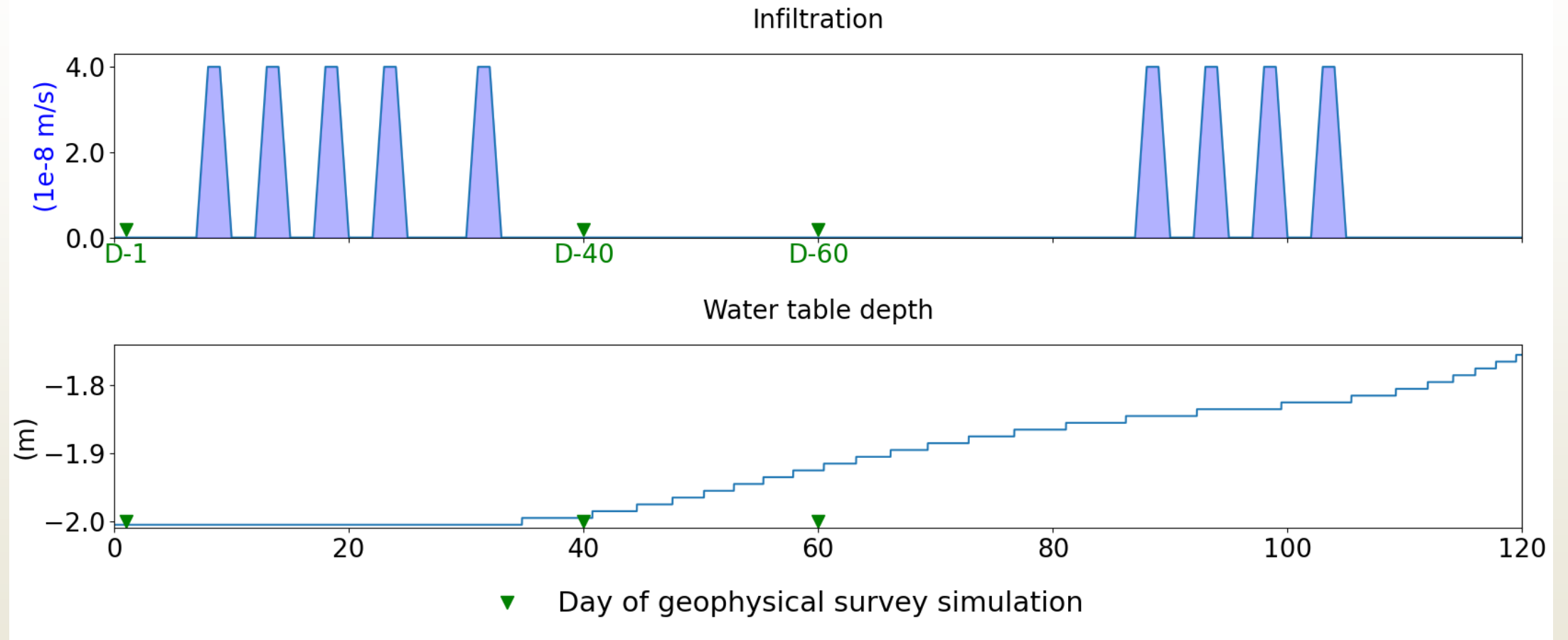


Modèle direct hydrogéophysique



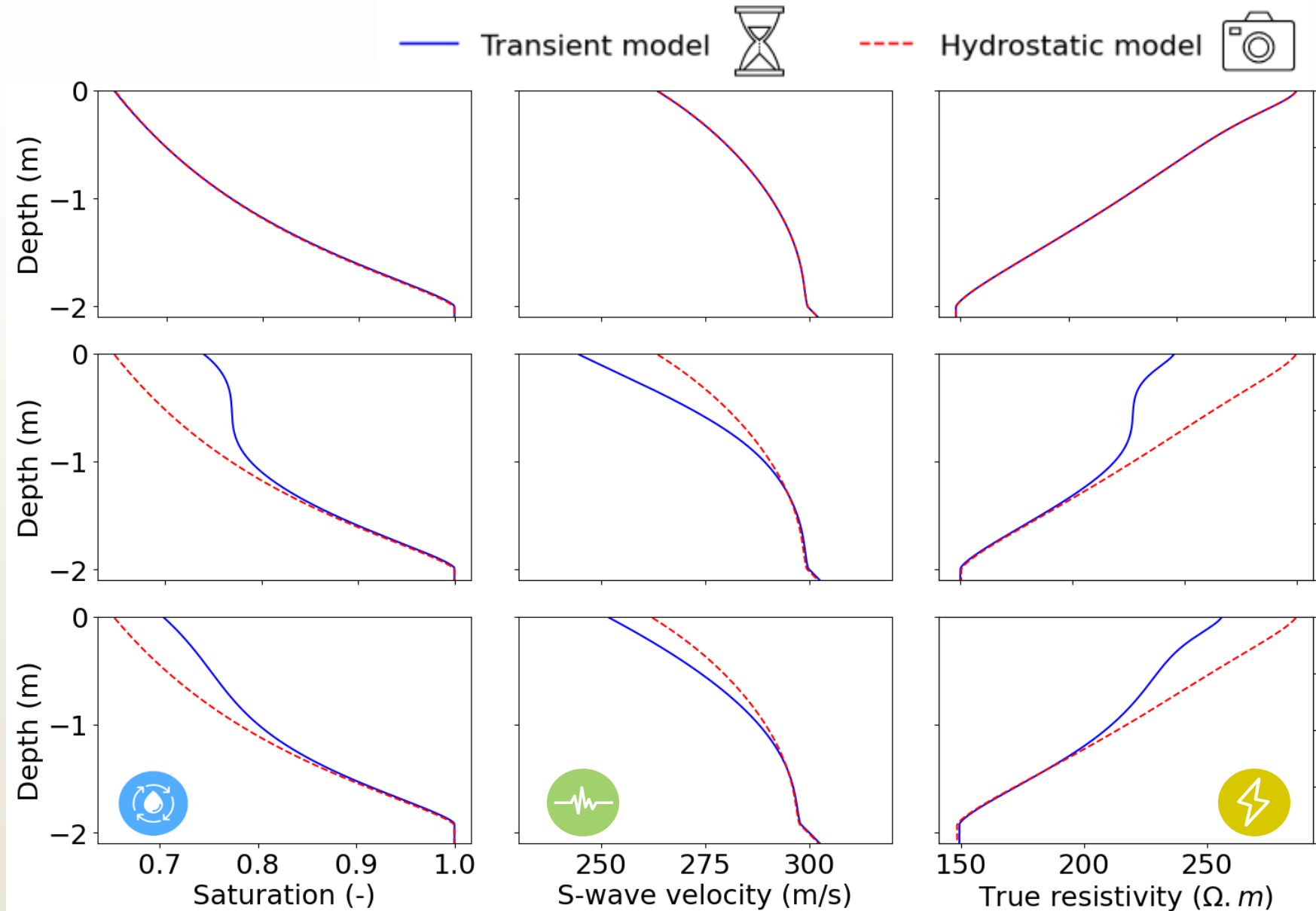


Modèle direct hydrogéophysique





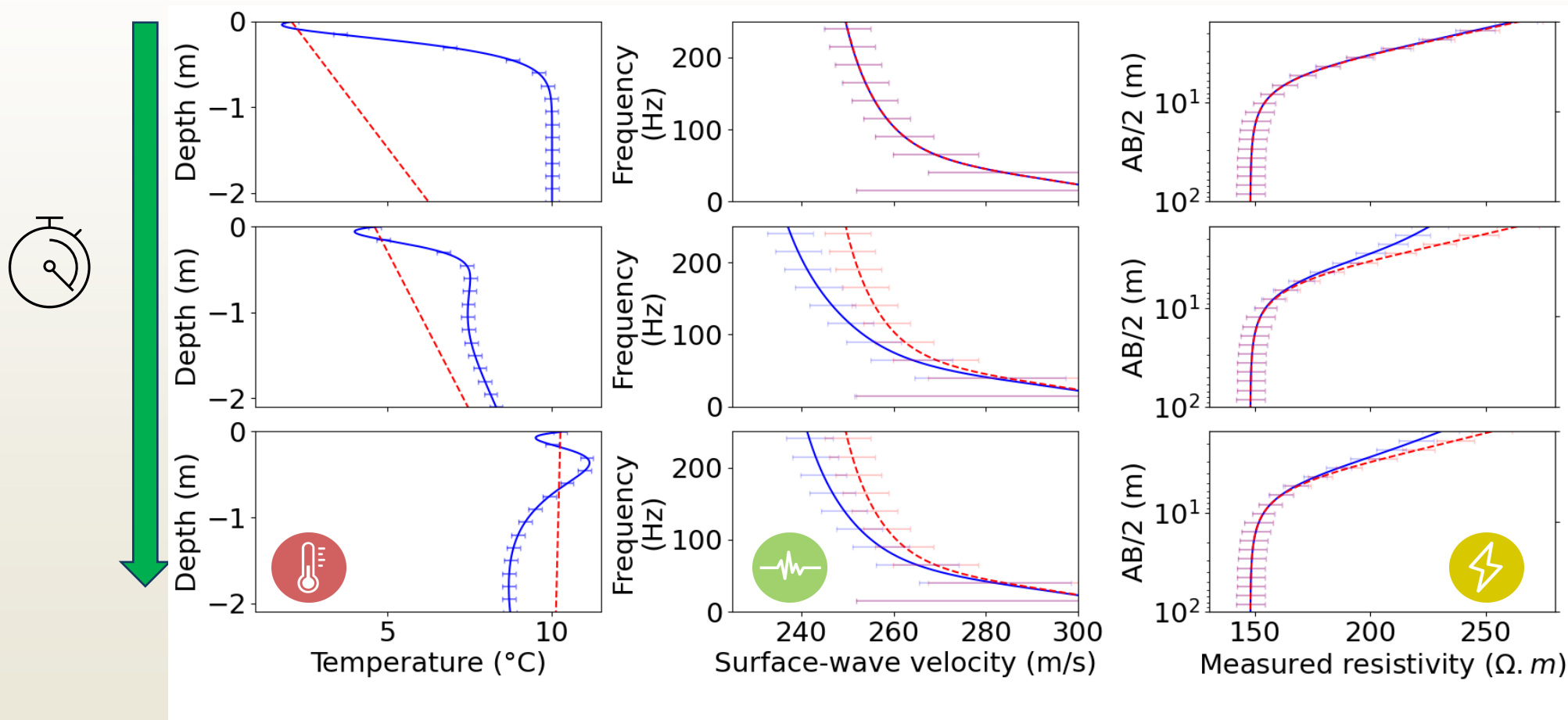
Modèle direct hydrogéophysique



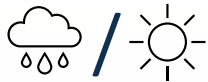


Modèle direct hydrogéophysique

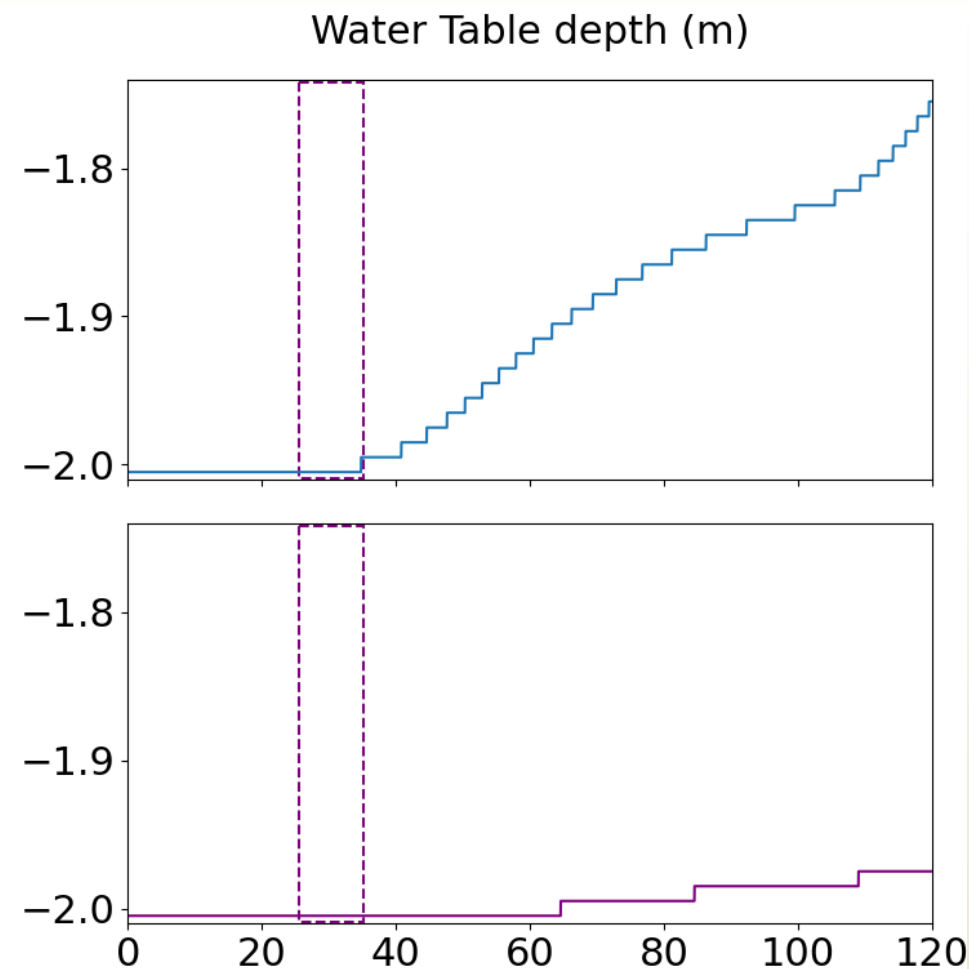
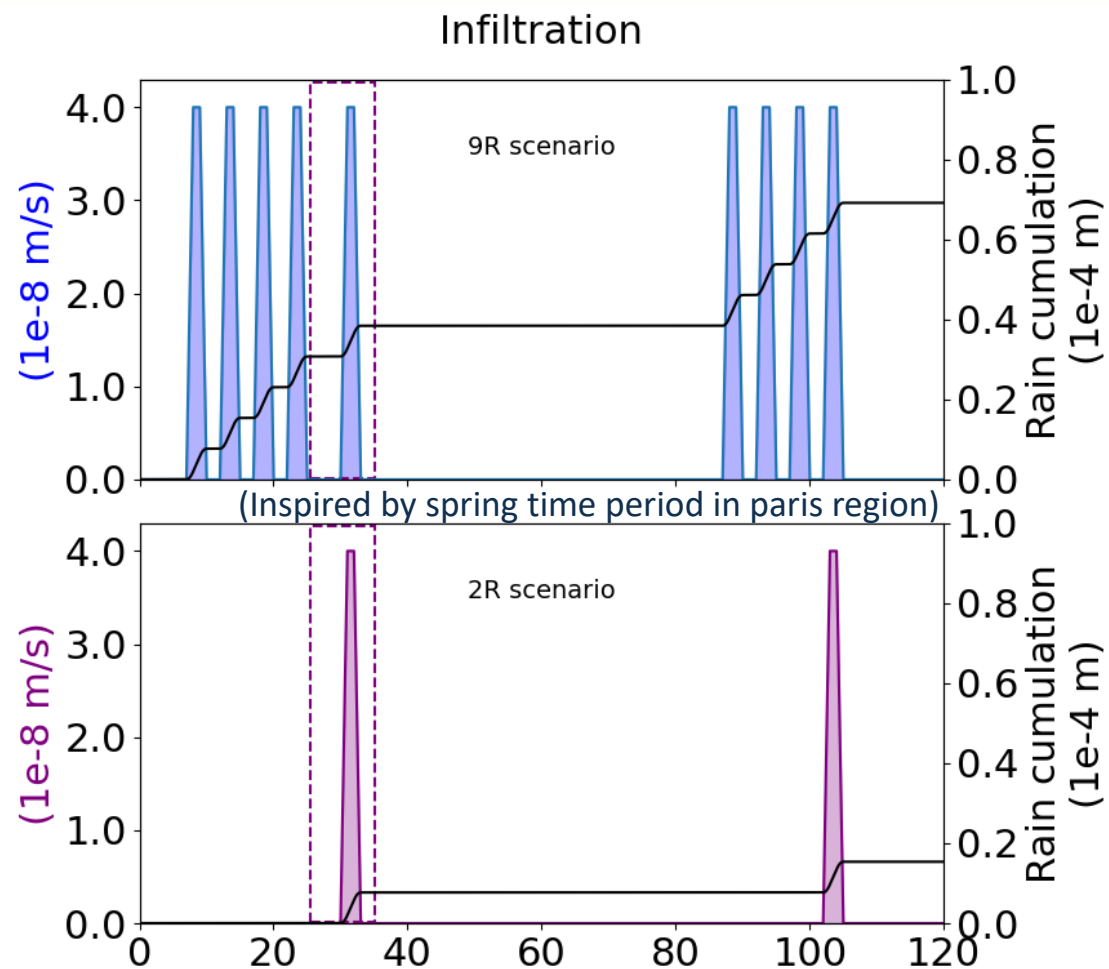
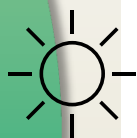
— Transient model  - - - Hydrostatic model 



→ Le front d'infiltration influence les propriétés et les observables géophysiques 29



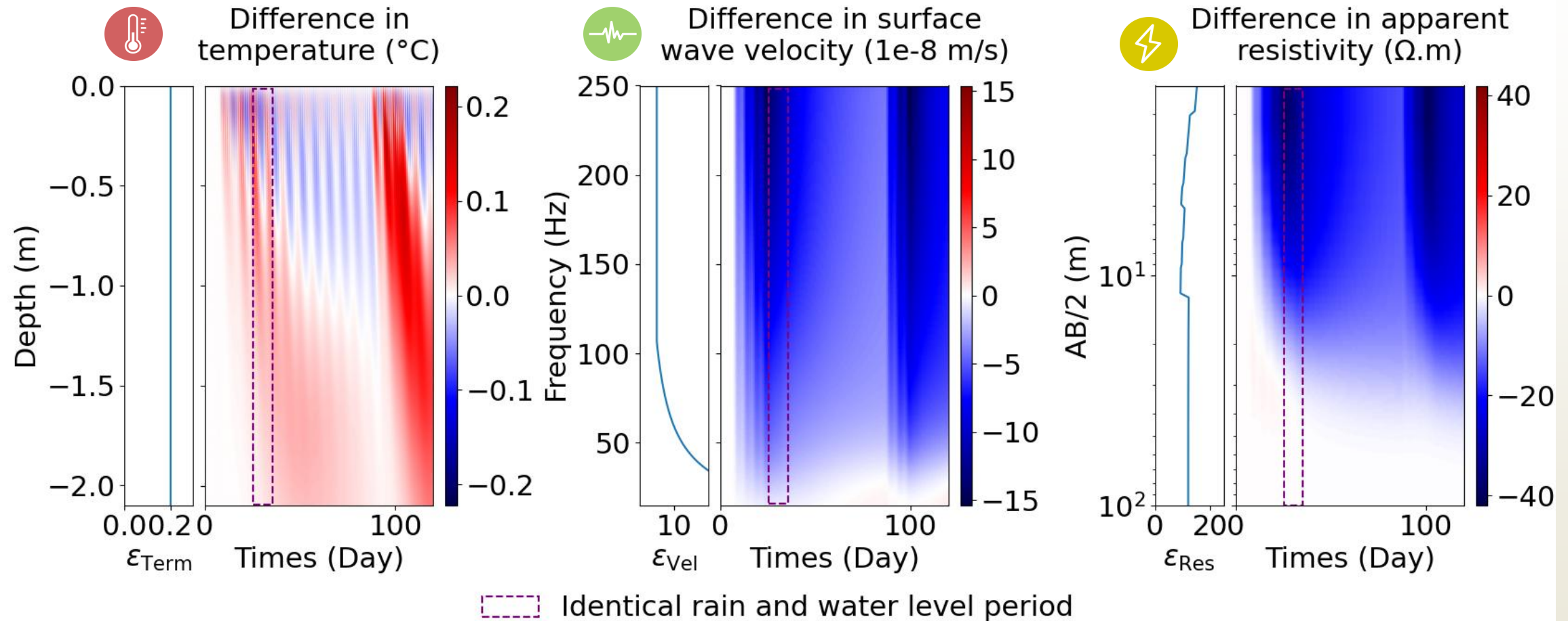
Modèle direct hydrogéophysique



Identical rain and water level period

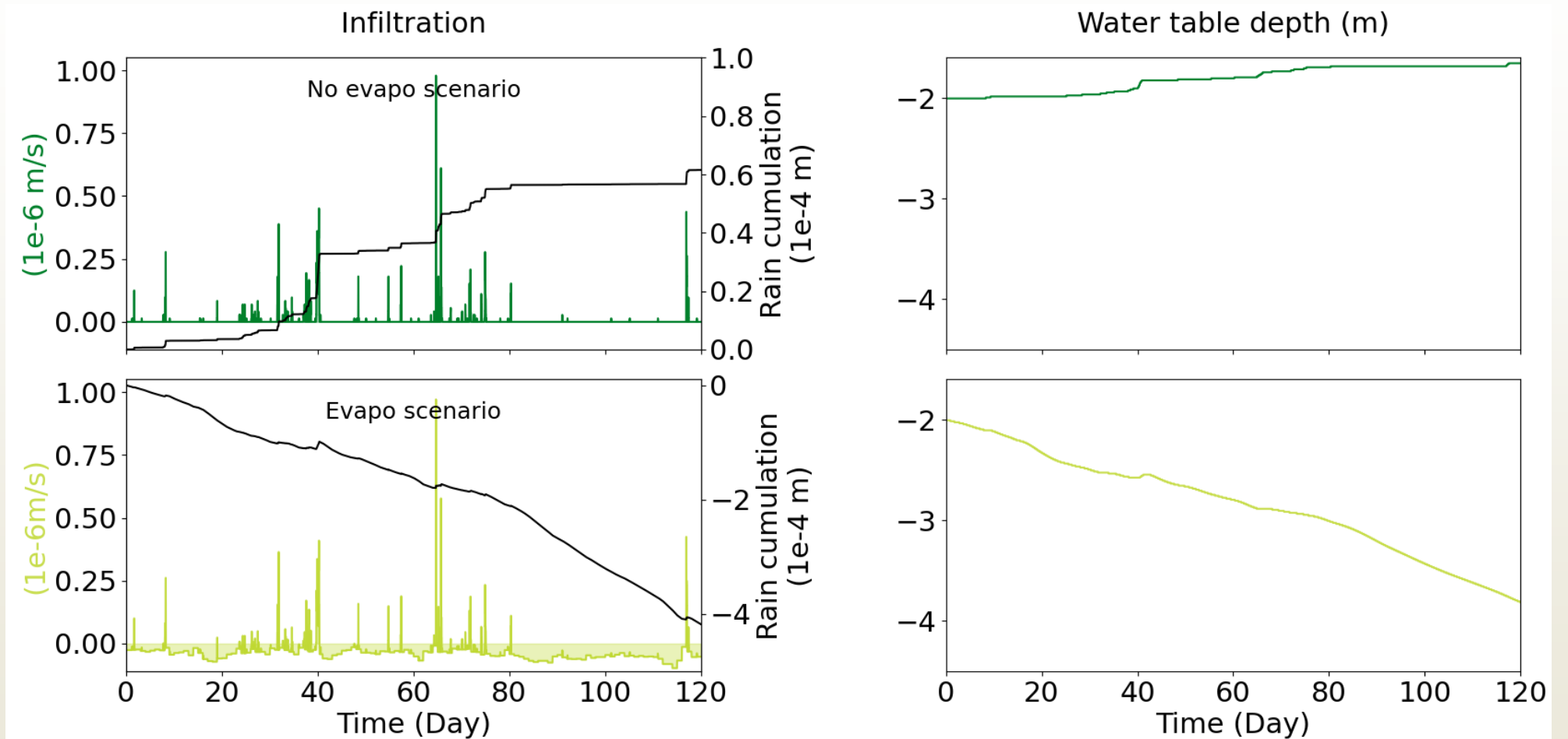


Modèle direct hydrogéophysique

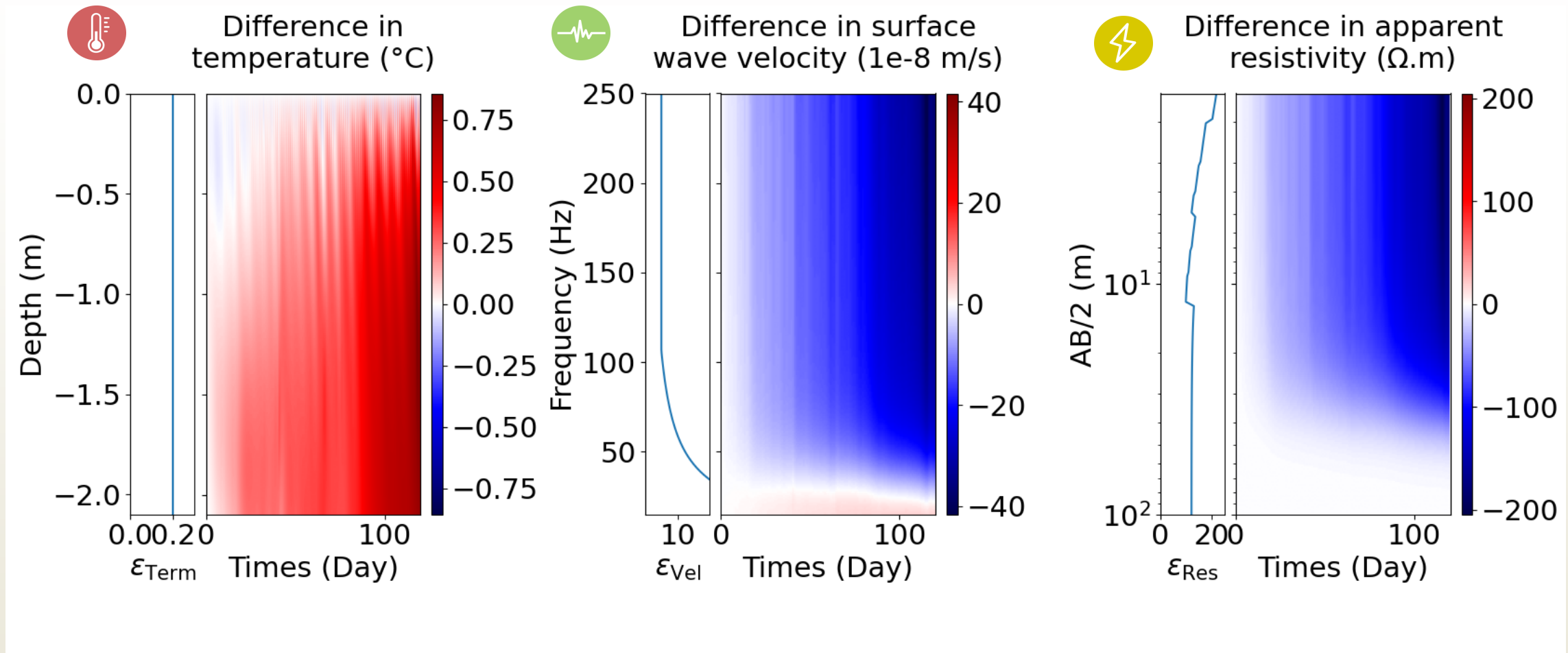


L'historique météorologique influence les observables géophysiques

Modèle direct hydrogéophysique

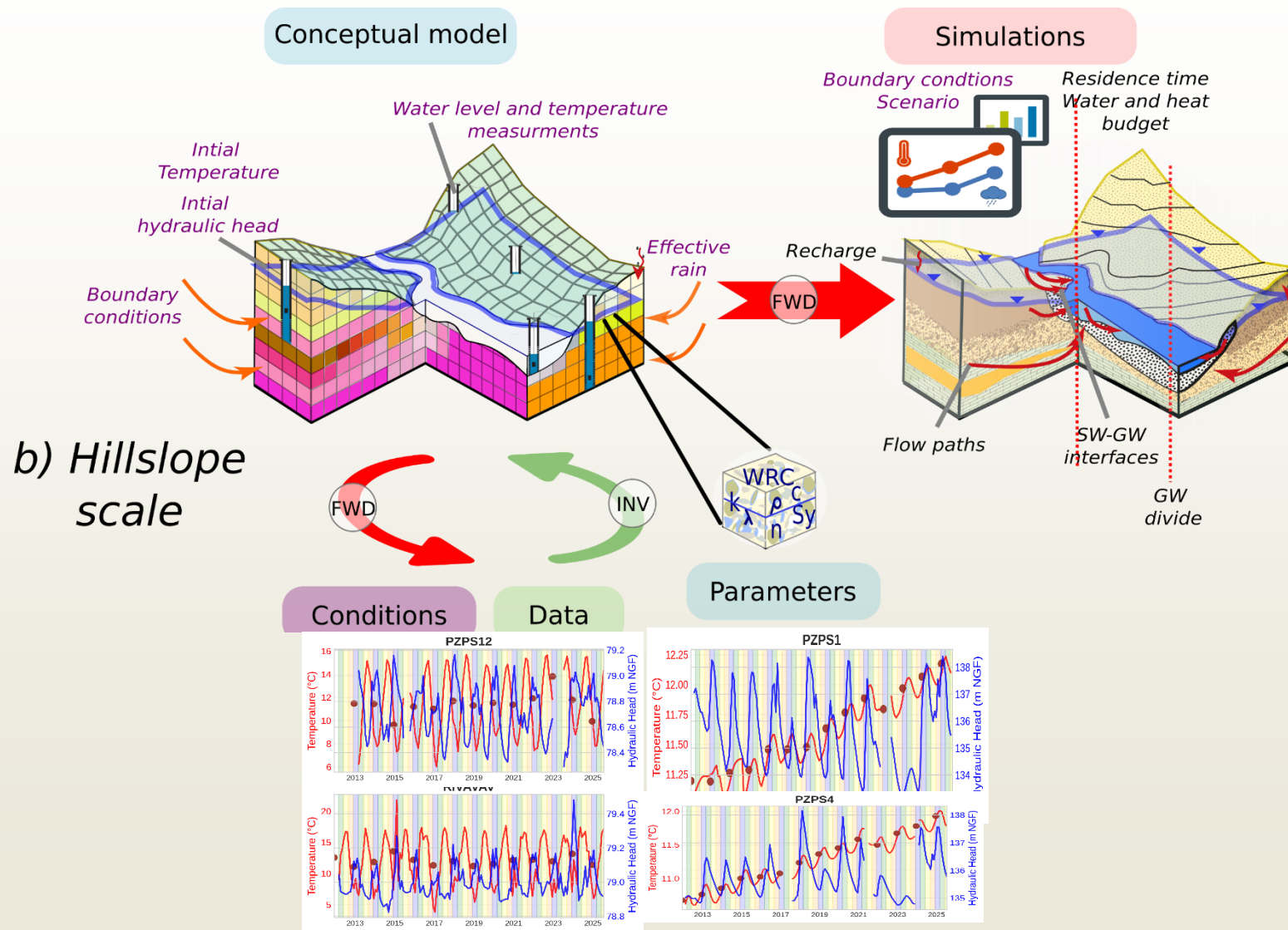


Modèle direct hydrogéophysique



➔ Evapotranspiration influence les observations géophysiques

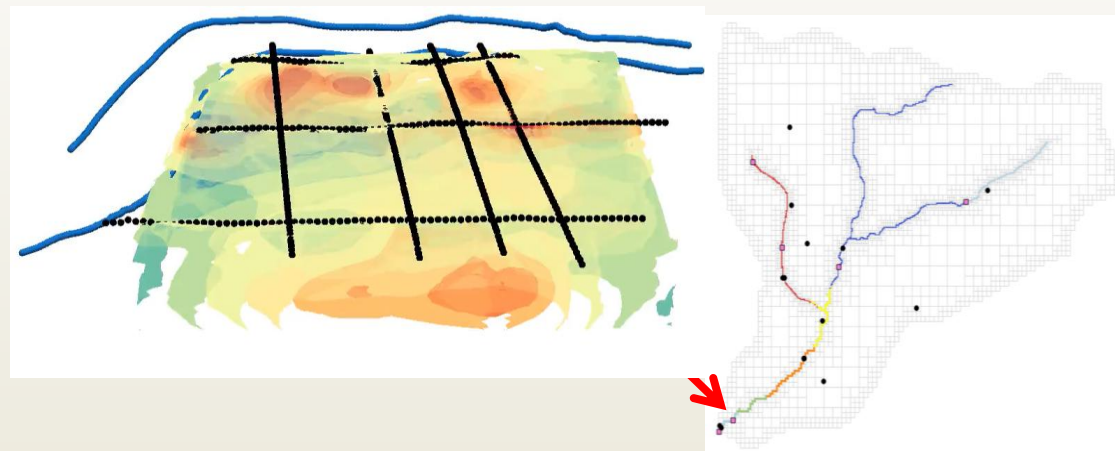
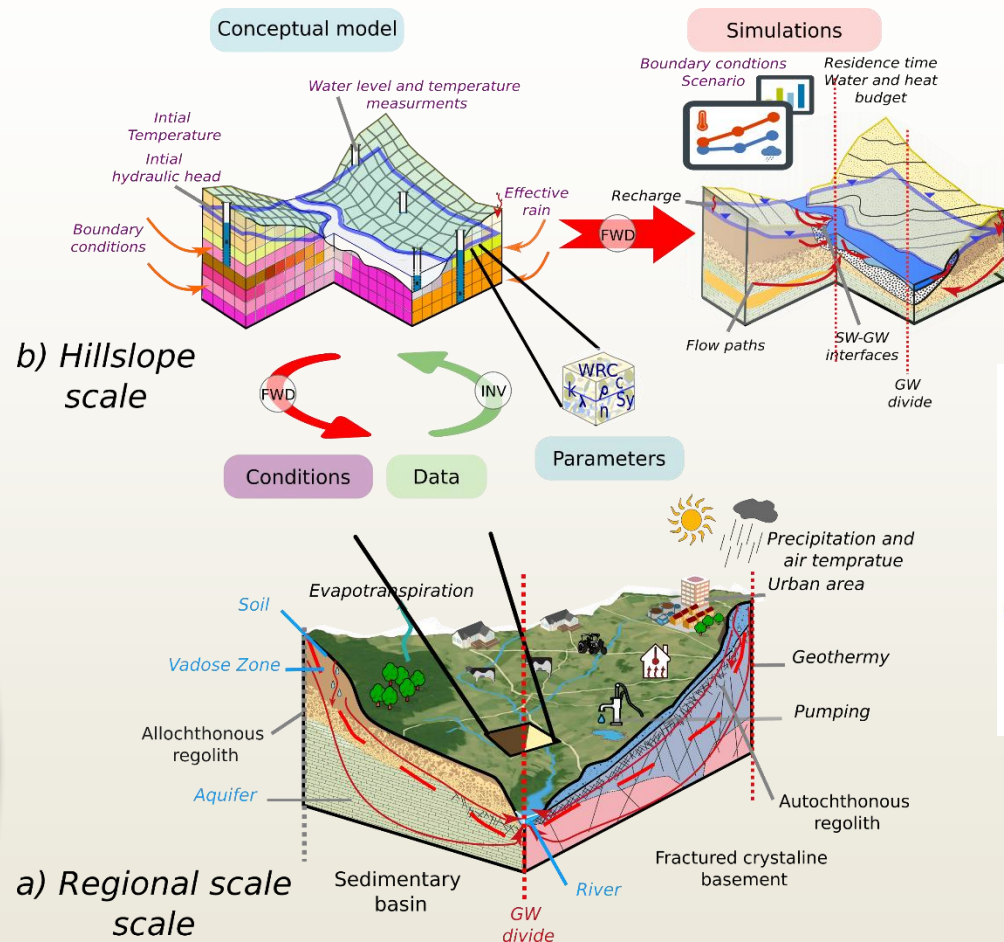
Bientôt le 4 D



Bientôt le 4 D

Objectif ?

Regrouper nos trois techniques sur notre terrain d'étude.



- Optimisation des campagnes de terrain
- Application à d'autres stations
- Changement d'échelle : Changement de support



Merci pour votre écoute