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Intermittent water transfer: A wettability model for porous media

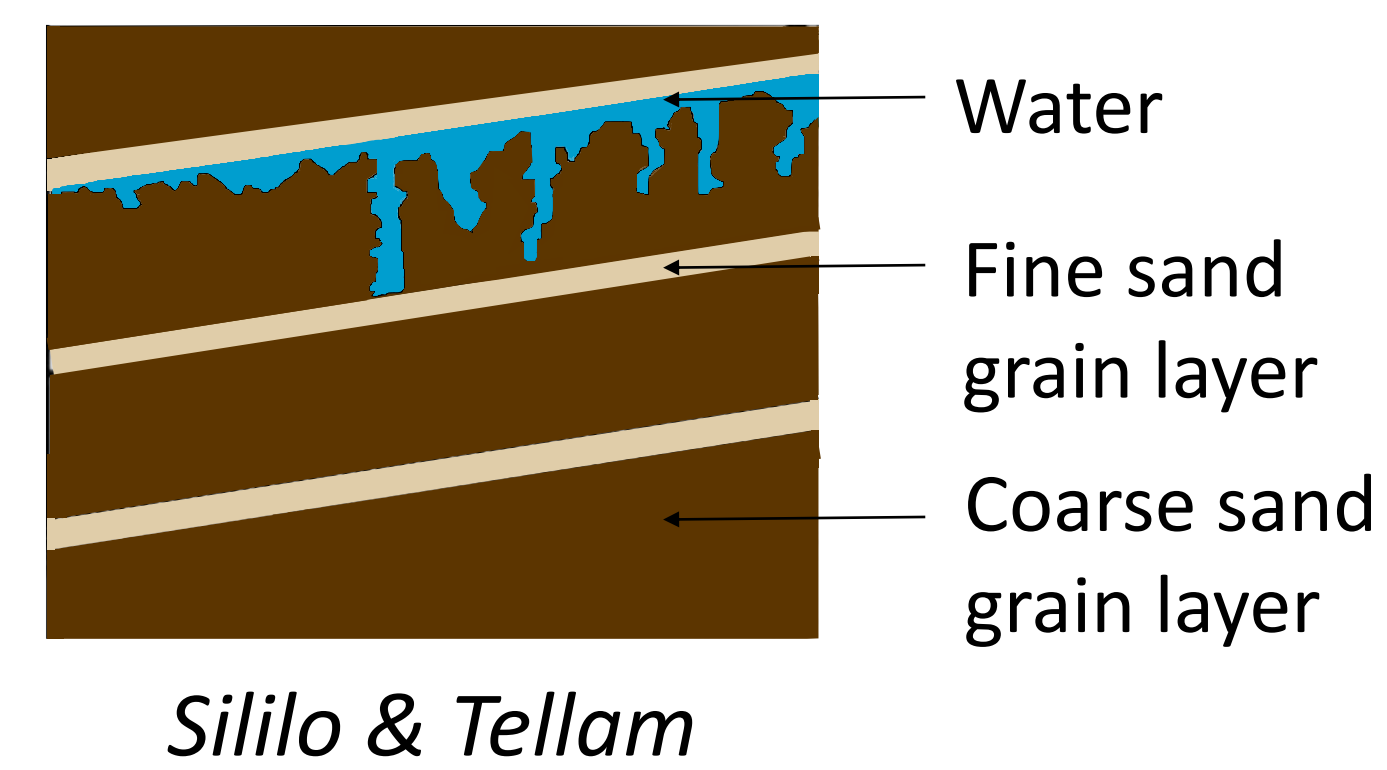
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Introduction

In stratified soil, there are spontaneous preferential flows as fingering or intermittency (flow cycle). But the Darcy/Richards model can not modeled them. By adding wettability in our model, we are able to represent these phenomena.



Wettability

Wettability is the fluid capacity to be spread on/in a surface.

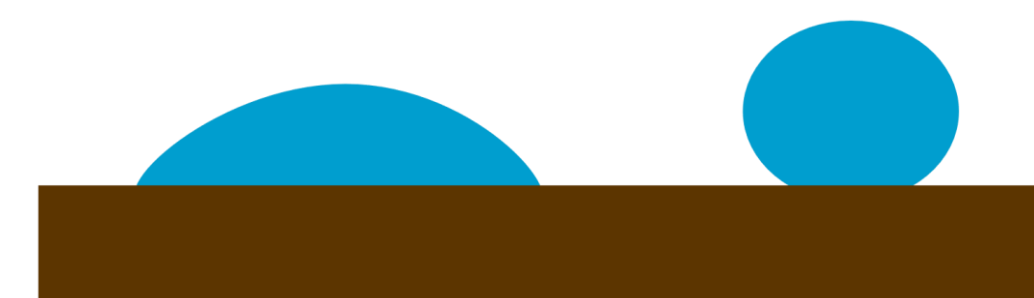
Plan substrat

Distinguish two cases :

Complete wetting



Partial wetting



Hydrophilic Hydrophobic



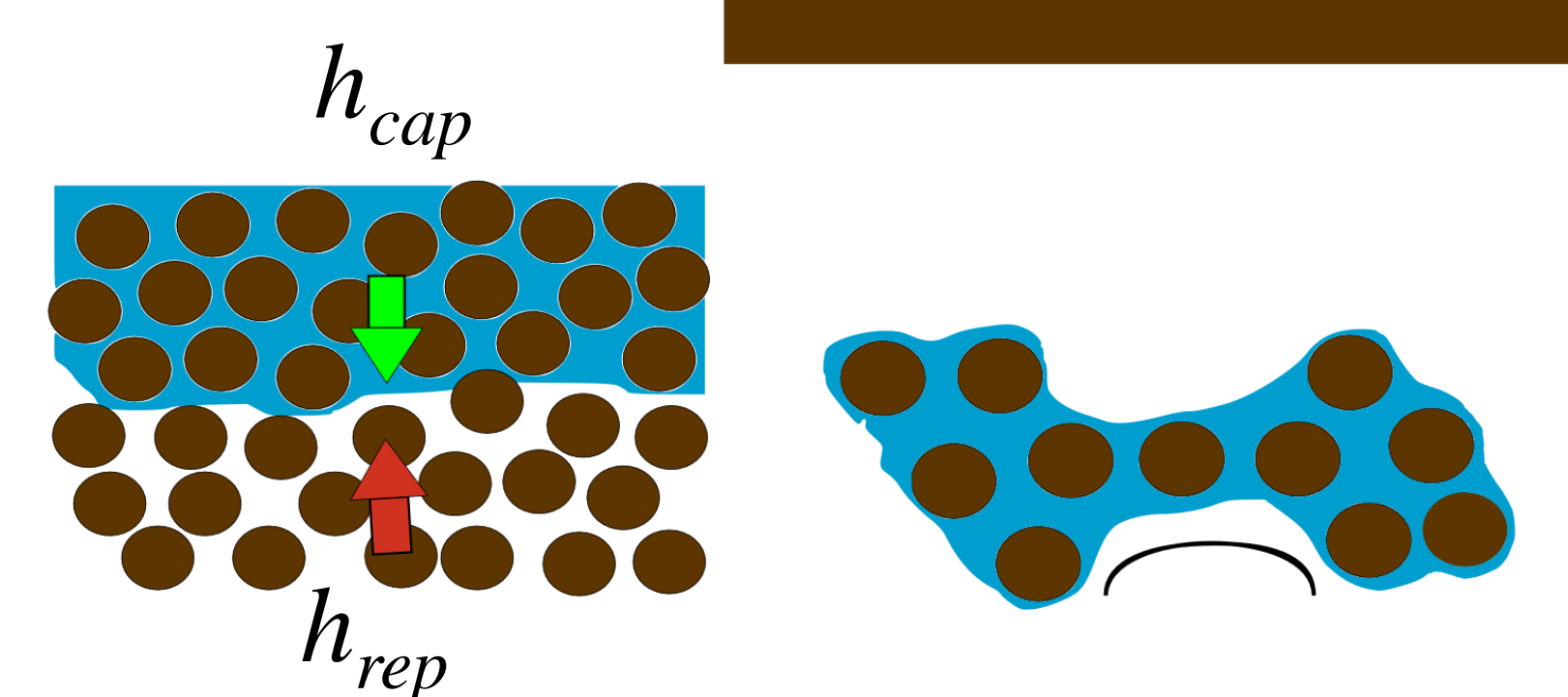
Contact angle is not easy to define in a porous medium with a dynamic



Adding repellency force h_{rep} in the medium in competition with the attractive force h_{cap} . This approach is analogous of dis- and con-joining pressures to characterize the wettability (De Gennes)

→ Cahn Hilliard equation (Beltrame & Thiele)

Modeling in porous media

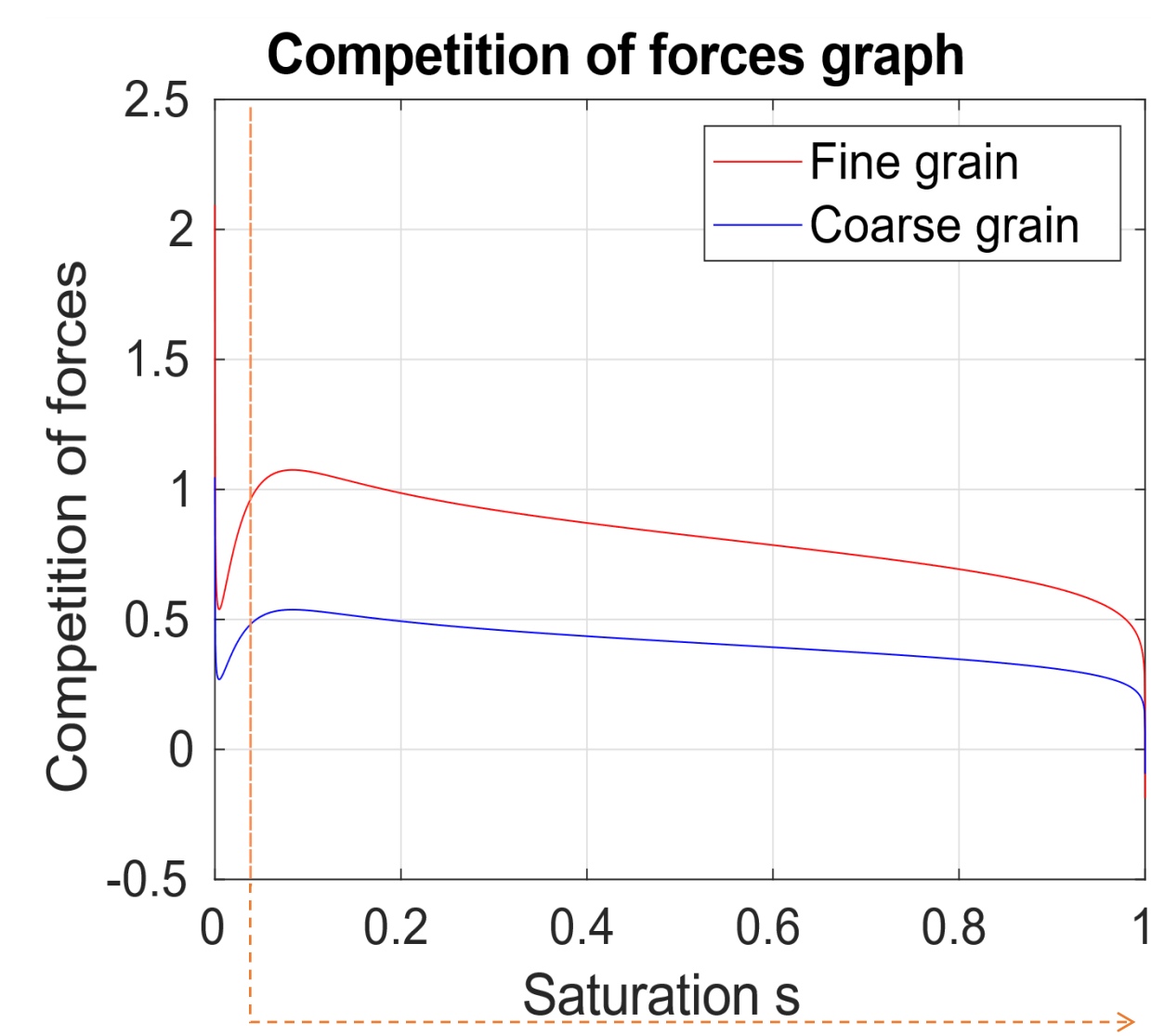


Based on this concept, adding in Richards equation : repellency term h_{rep} and regularize term which is long-range capillary effect

$$\partial_t s = -\nabla \cdot [K(s) \nabla \{ \Pi(s) + g_r z + T \Delta s \}]$$

s : saturation
 $K(s)$: hydraulic conductivity Genuchten/Mualem
 $\Pi(s)$: competition of forces $\Pi(s) = h_{cap}(s) - h_{rep}(s)$
 g_r : gravity term
 $T \Delta s$: surface tension / long-range capillary effect Cueto & Juanes

Under $\approx 5\%$ of saturation s , subcritical hydrophobicity can appear (Liu, Ju, Bachmann et al.)

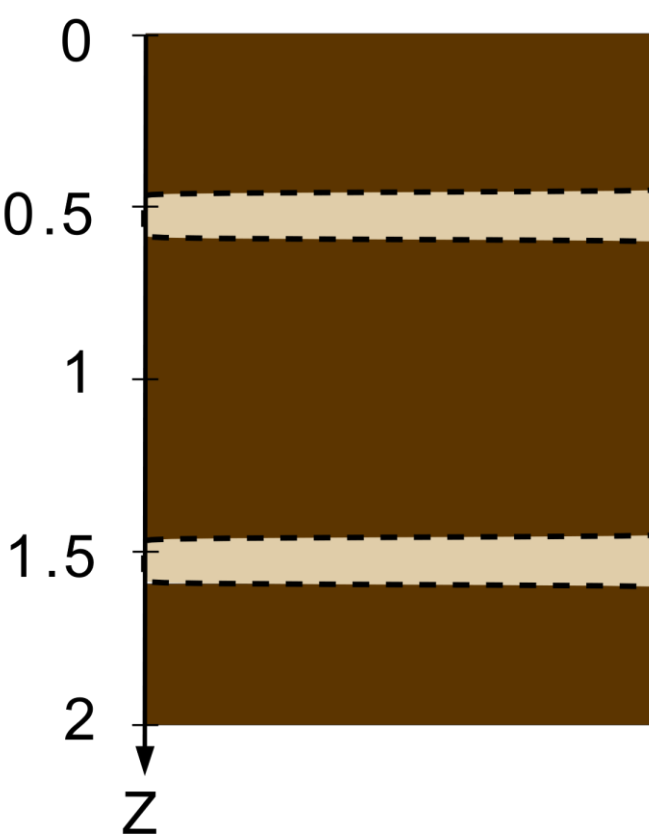


Governing equation

In a stratified medium, we must consider a contrast between each layers

$$\partial_t s = -\nabla \cdot [f_K(z) K(s) \nabla \{ f_\Pi(z) \Pi(s, z) + g_r z + T \Delta s \}]$$

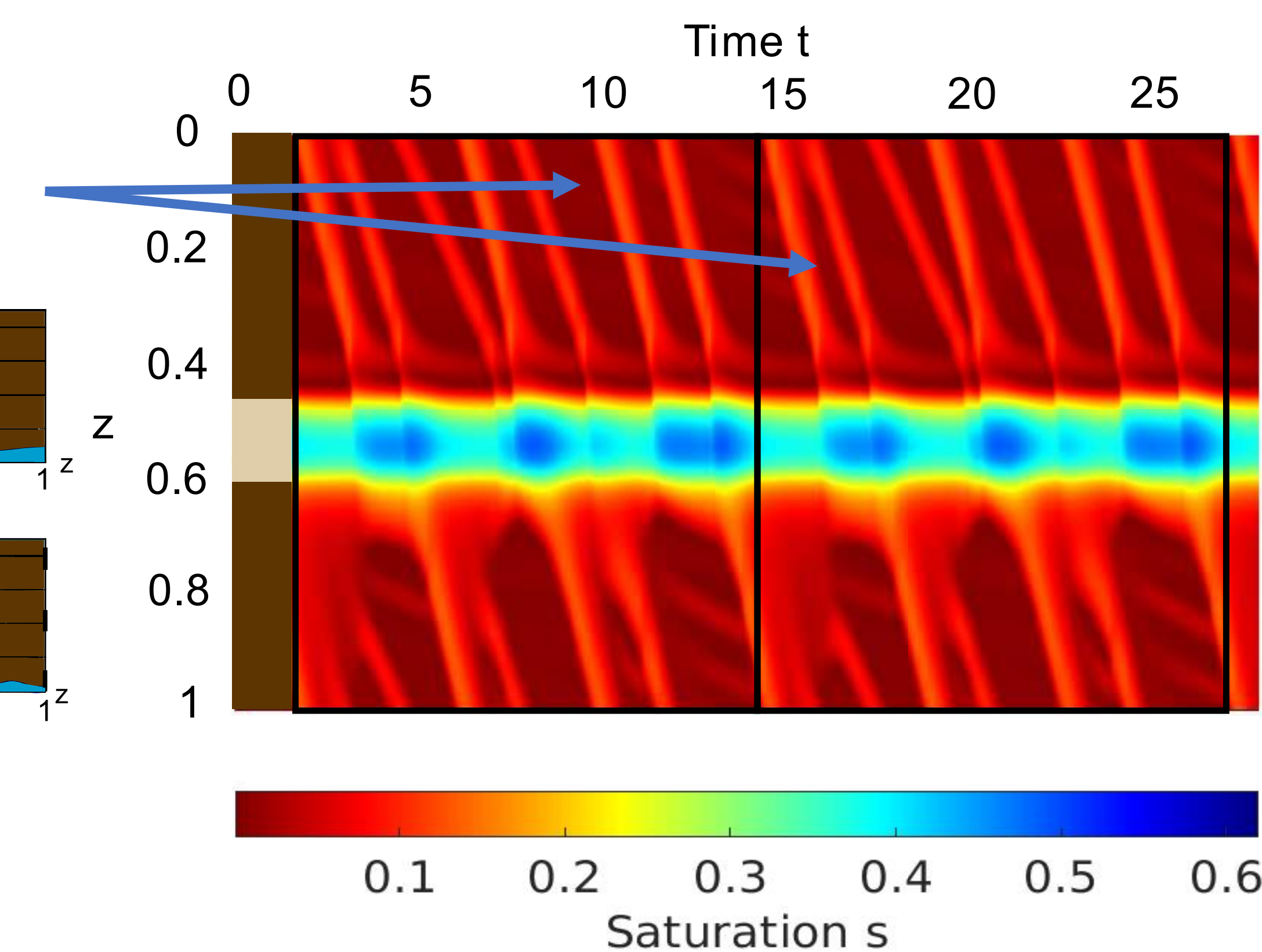
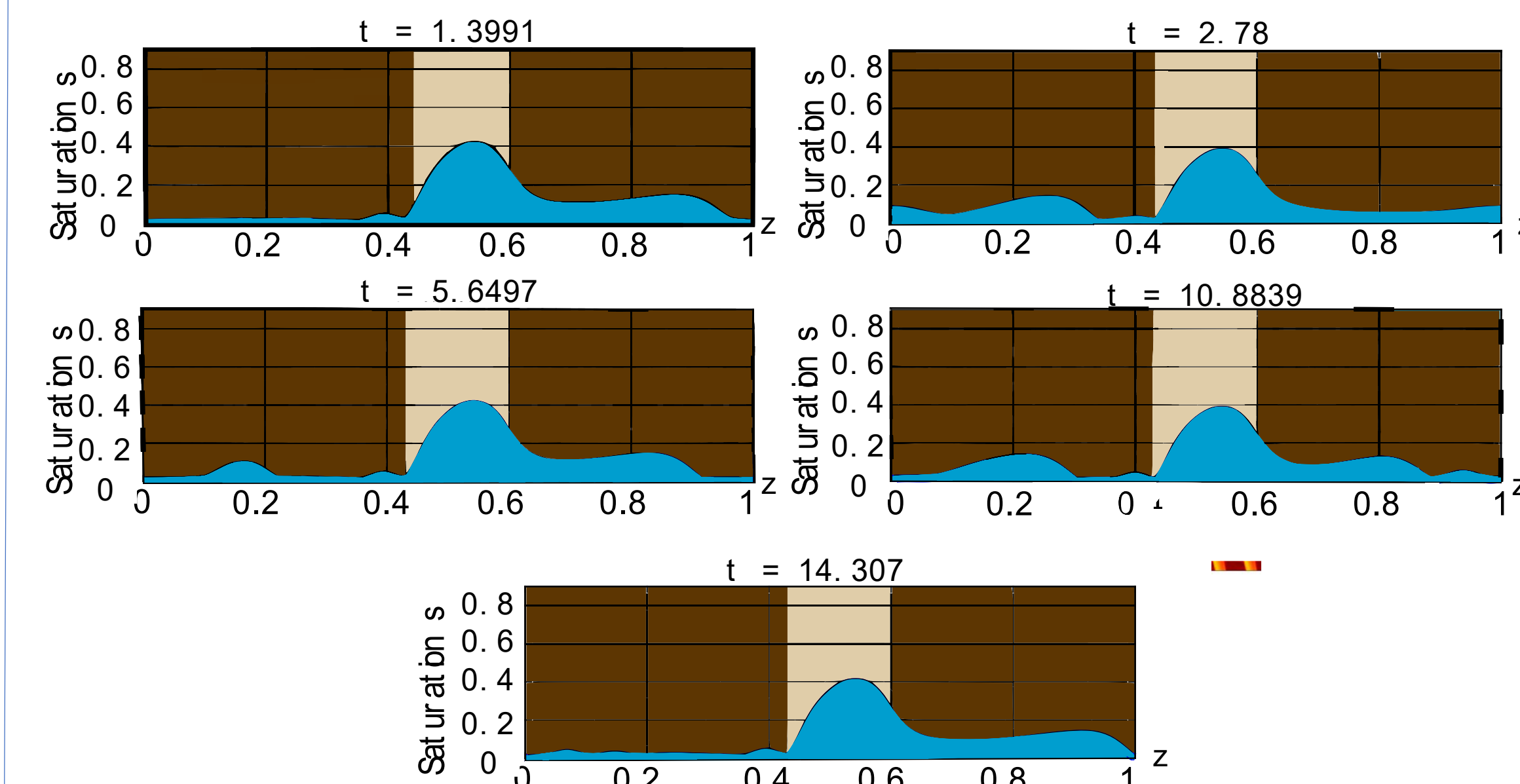
f_K : conductivity contrast
 f_Π : hydraulic contrast



We considered a situation where the coarse sand conductivity contrast is 20 and the force competition contrast is -0.5

Results

The evolutive graph show a periodic behavior in the stratified medium



It can be seen from the 1D simulation that most of the water remains in the fine grain layer. With a contrast of forces between the two layers and gravity, intermittence in the coarse-grained layer can be seen.

Conclusion

Wettability in a stratified porous media allows to illustrate hydric specific flow, in particular intermittency, which can appear.

In our further work, we will focus on hydric transfer in hydrophobic porous media and fingering in 2D.