

# Evaluation of the spatial variations of the hydrodynamical parameters of soils with GPR

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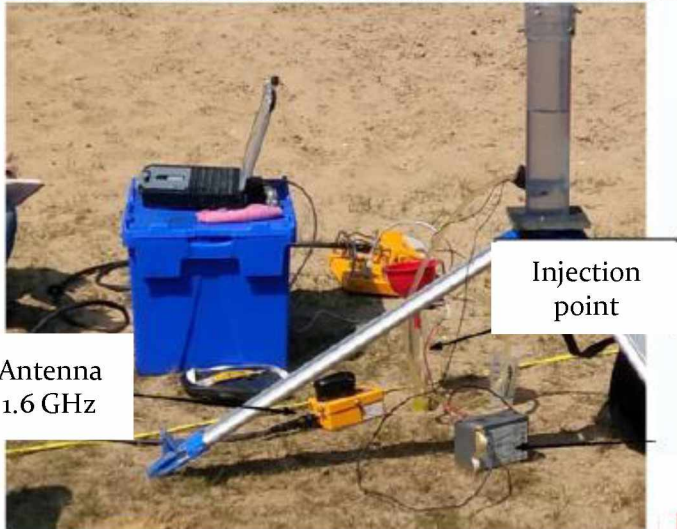


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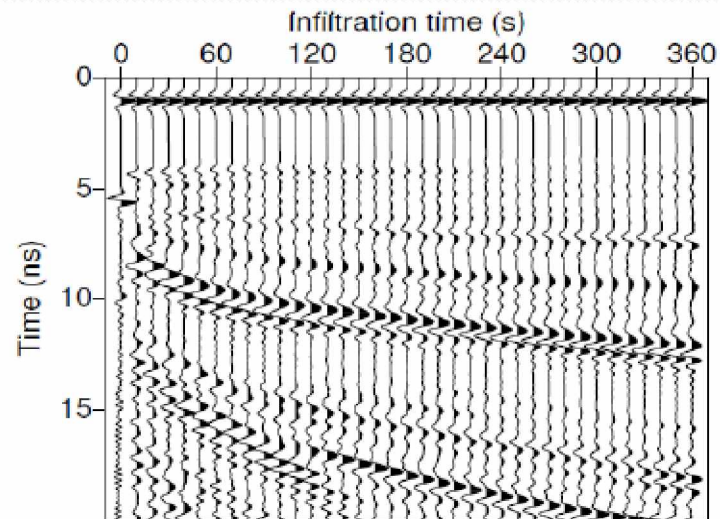
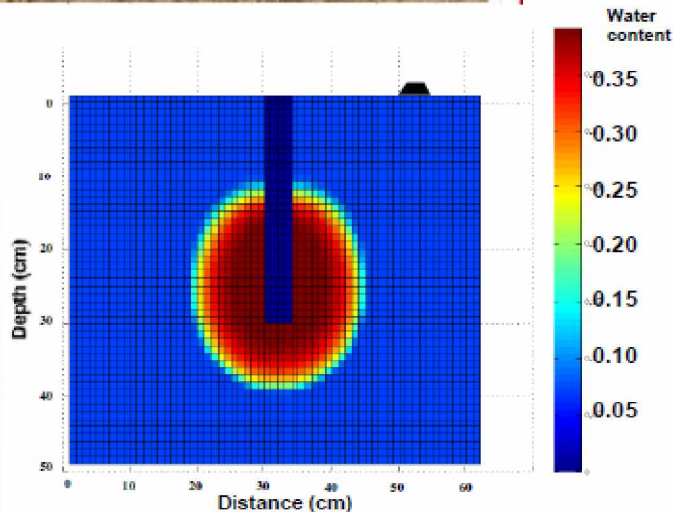




# In-situ measurements of soil hydrodynamical parameters with GPR



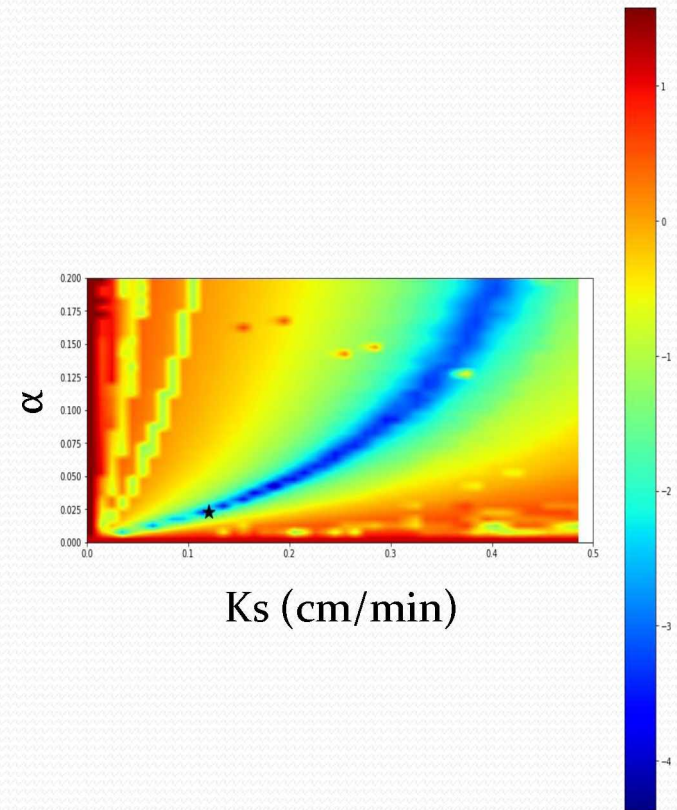
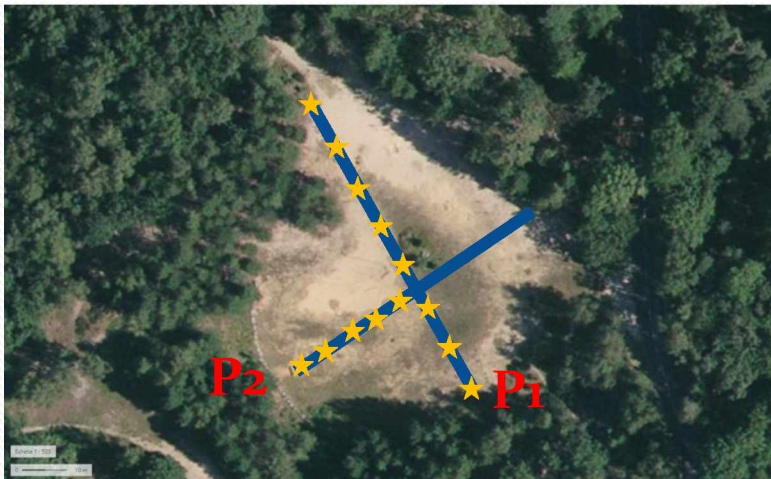
- Development of forward and inverse Python code for modelling GPR data for infiltration tests
- Monitoring of Porchet experiments with high frequency GPR antennas
- Using the last versions of Python packages dedicated to geophysics
  - gprMax
  - PyGimli





# In-situ measurements of soil hydrodynamical parameters with GPR

- Field experiments to determine the best protocol
  - Sandpits
  - Reproduction and efficiency of measurements
- Data processing and research
  - Parameters sensitivity analysis
  - Work on data fitting
    - Infiltrated water volume
    - TWT





# Bibliography

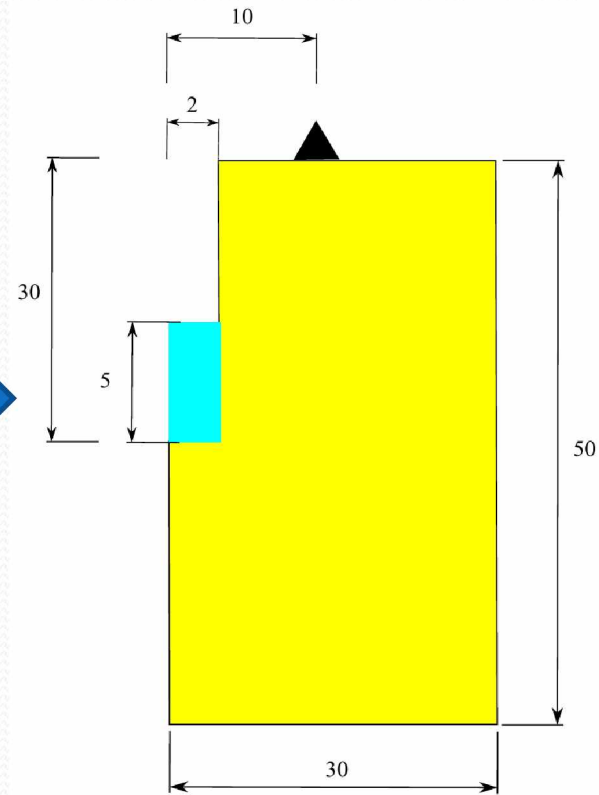
- Which hydrodynamic parameters to consider?
  - Soil water retention curves and hydraulic conductivity depending on the head  $h$
  - Described by Mualem-van Genuchten equations :
    - $$K(S_e) = K_0 S_e^L \left\{ 1 - \left[ 1 - S_e^{n/(n-1)} \right]^{1-1/n} \right\}^2$$
    - With : 
$$S_e = \frac{\theta(h) - \theta_r}{\theta_s - \theta_r} = [1 + (\alpha h)^n]^{1/n-1}$$
    - 5 parameters :  $K_s, \theta_r, \theta_s, \alpha, n$



# Experimental method



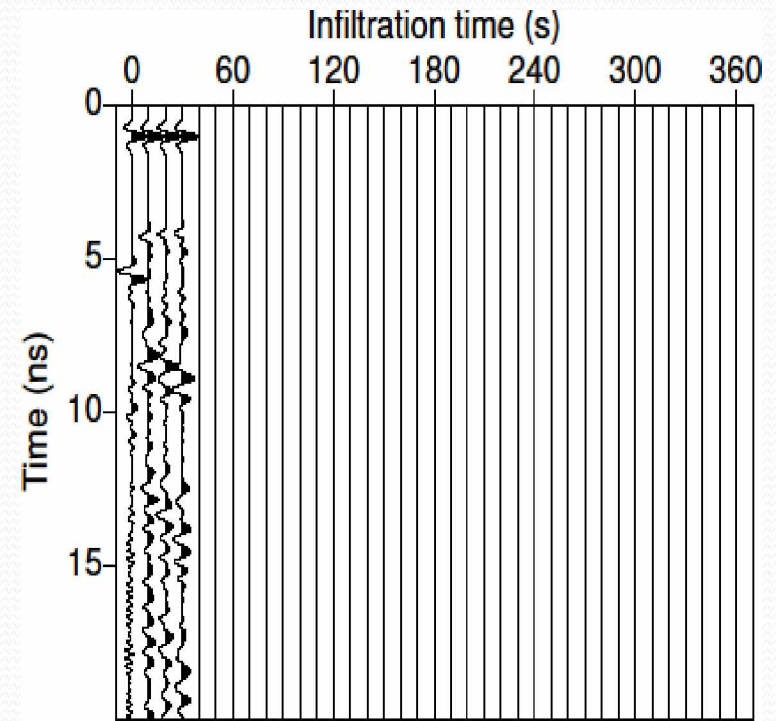
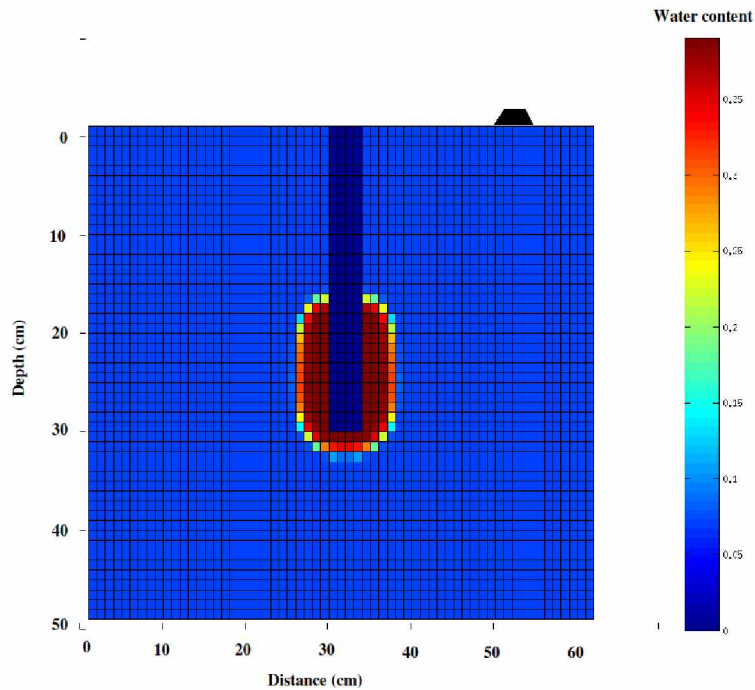
Field



Model

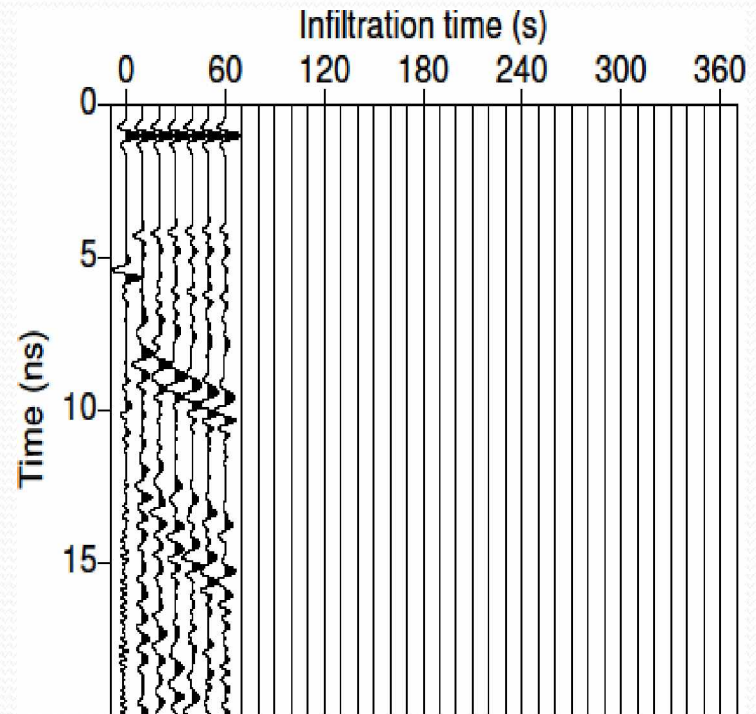
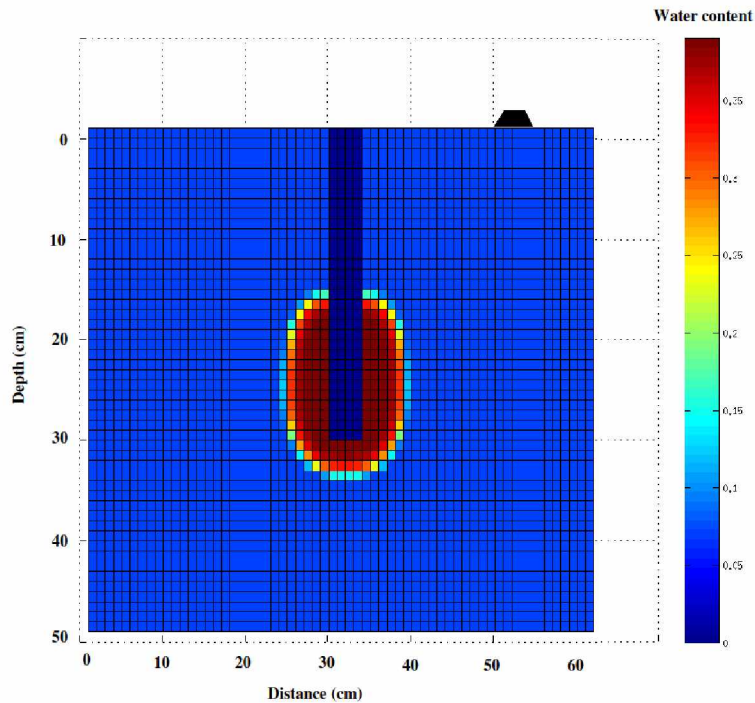


# Construction of radargram : 30 s



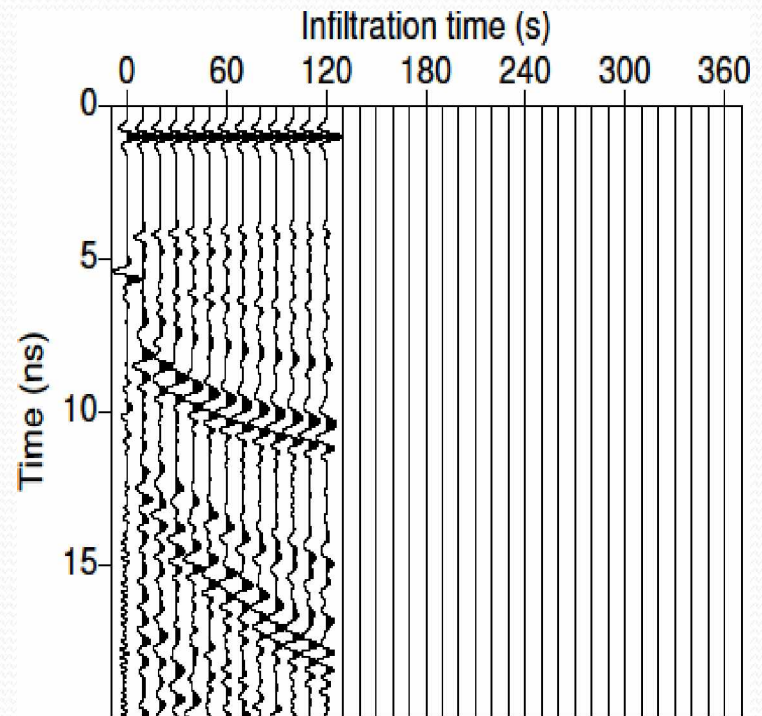
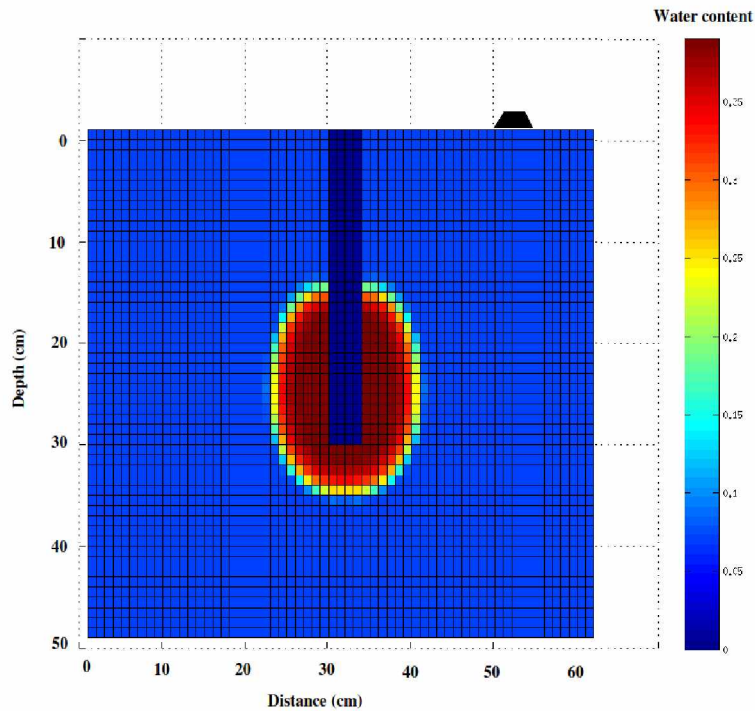


# Construction of radargram : 60 s



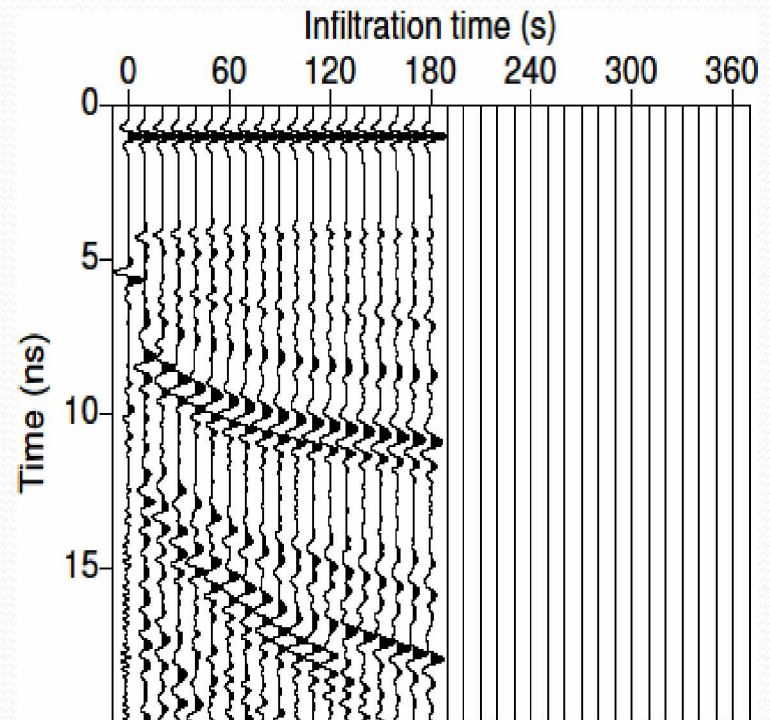
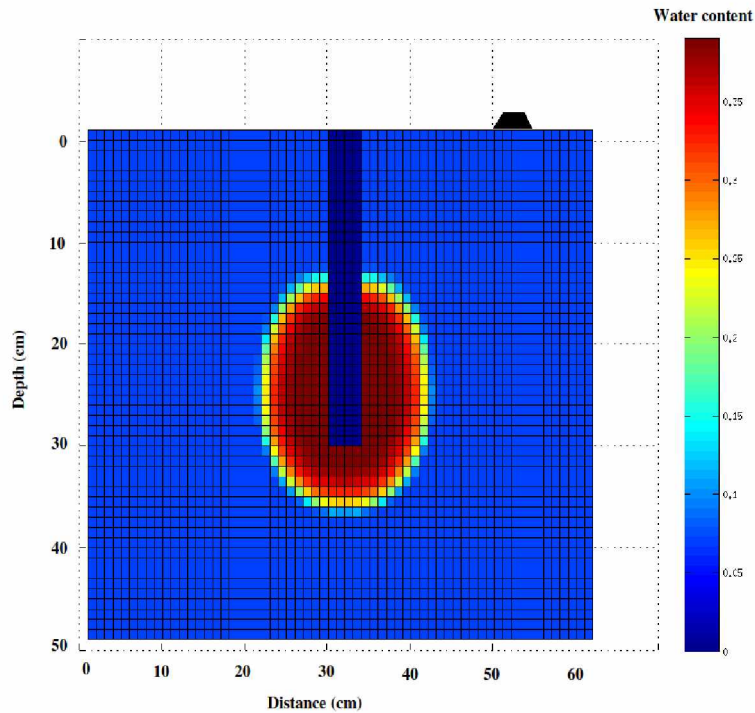


# Construction of radargram : 120 s



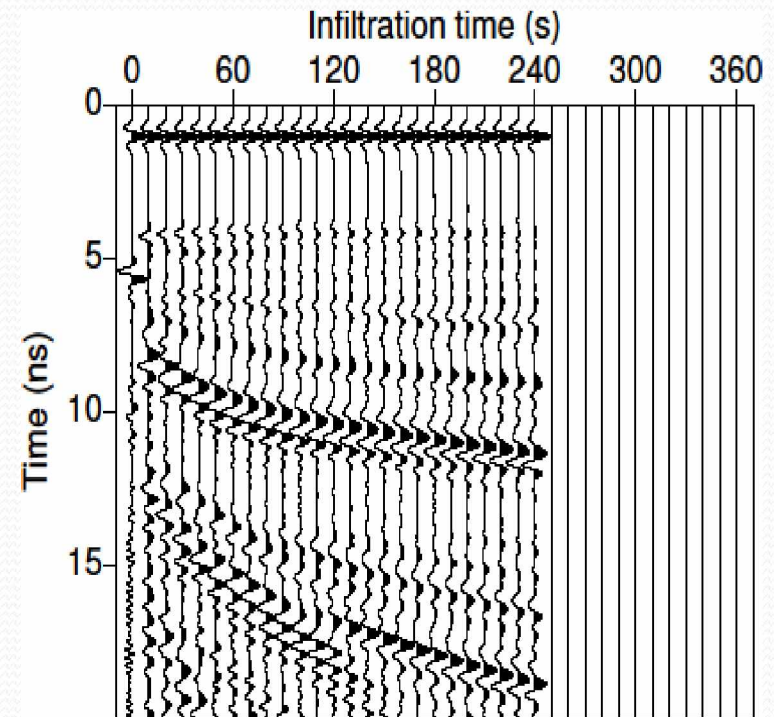
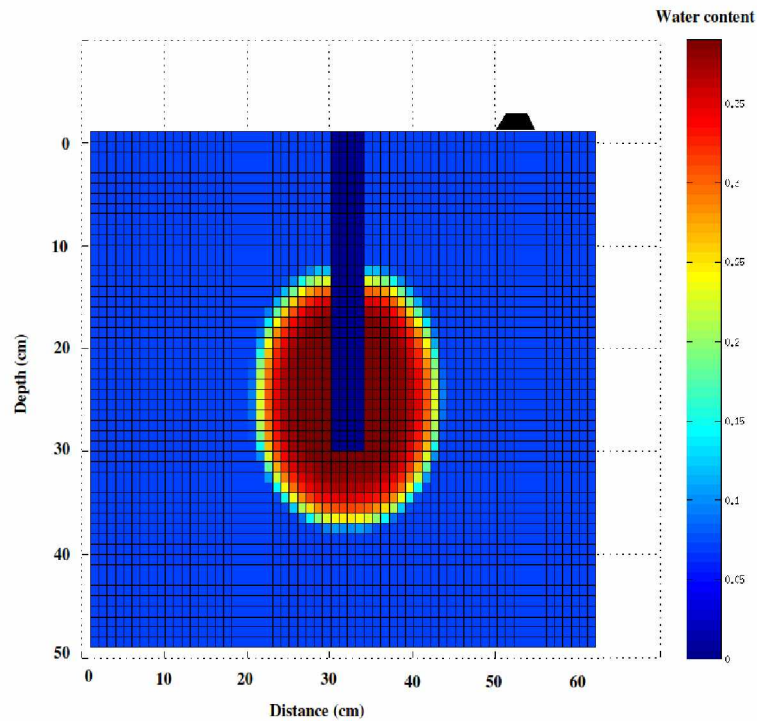


# Construction of radargram : 180 s



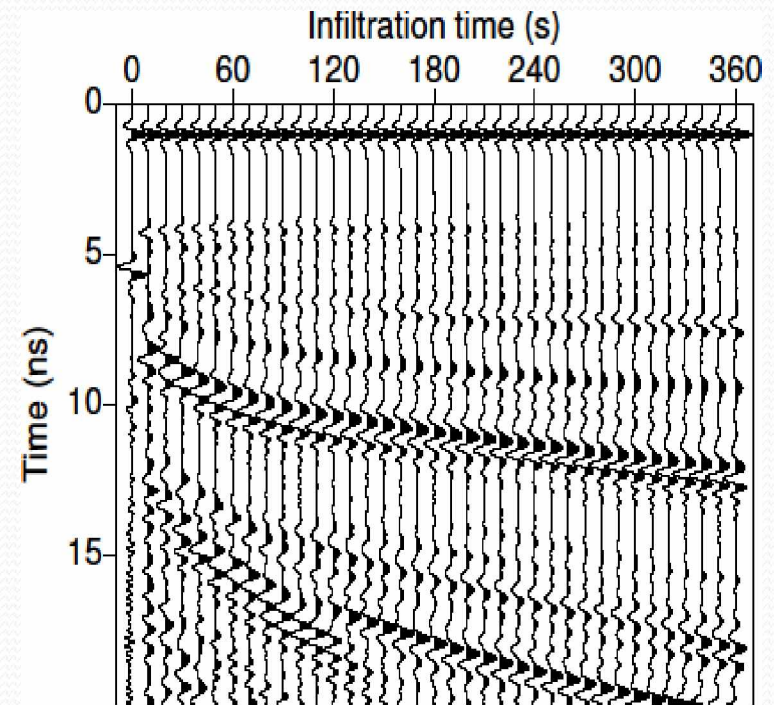
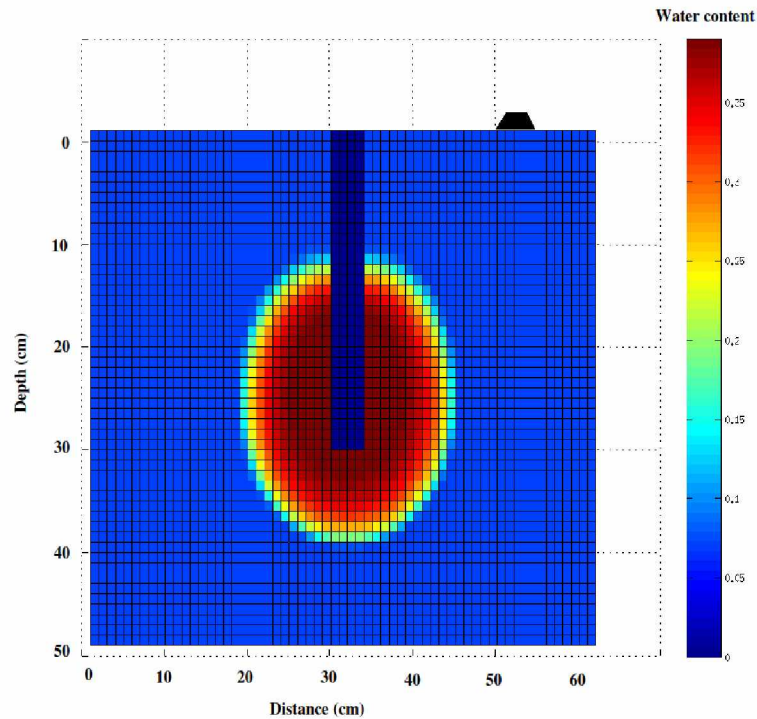


# Construction of radargram : 240 s



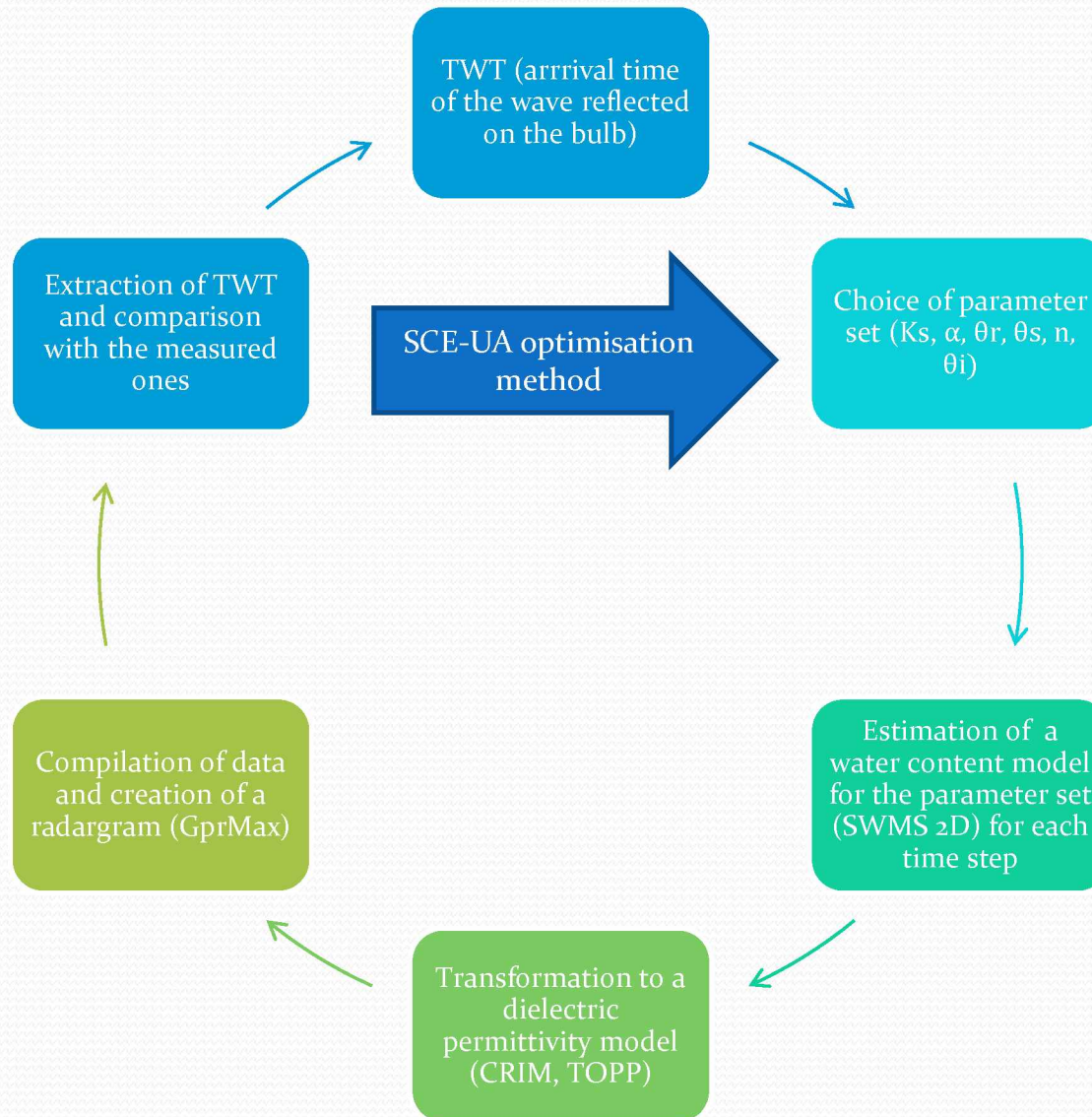


# Construction of radargram : 360 s





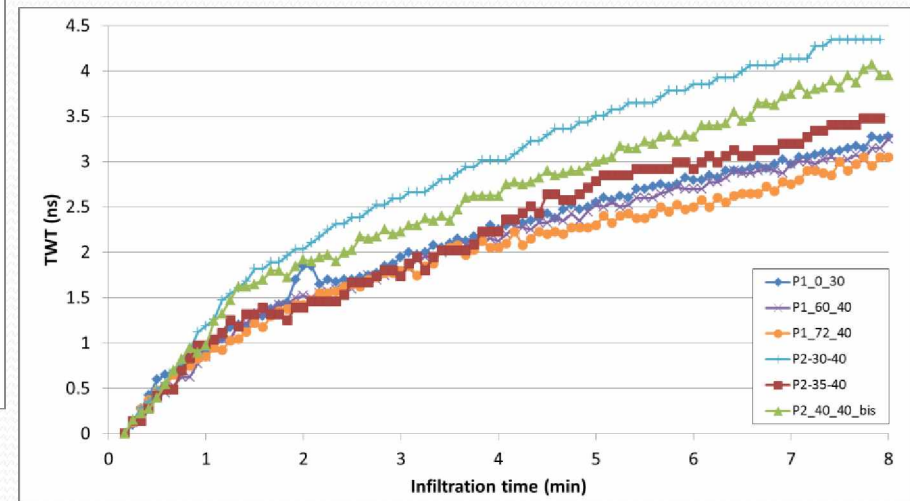
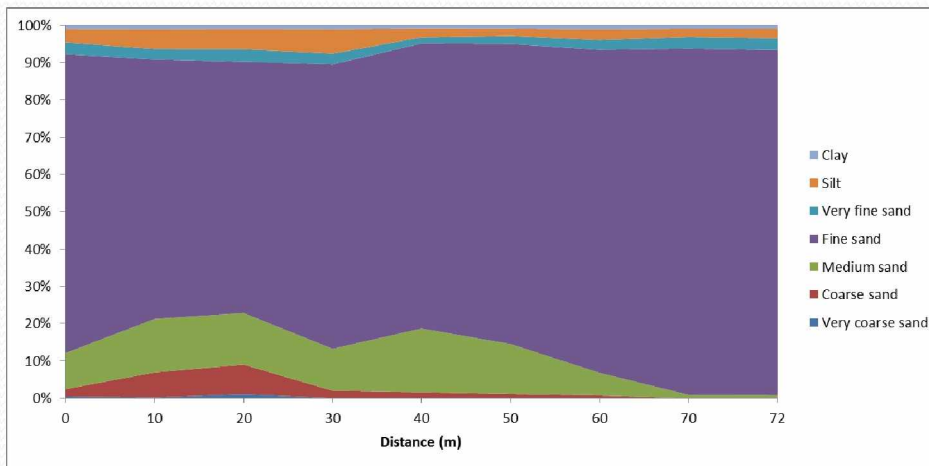
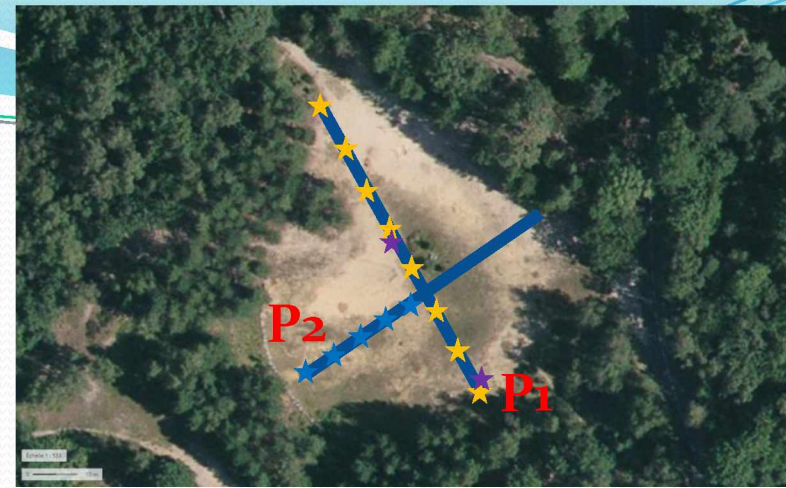
# Construction of the code





# Results

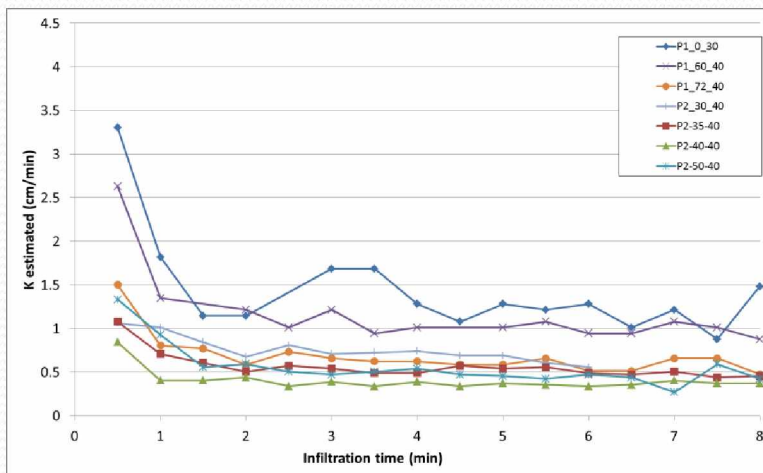
- SandPit : Auffargis (France)



ROSETTA (Schaap et al., 2001) variations

	$K_s$ (cm/min)	$\theta_r$	$\theta_s$	$\alpha$ (1/cm)	$n$
Min	0.37	0.048	0.37	0.033	3.2
Max	0.82	0.053	0.42	0.036	3.8

- After 6 min :  $2.5 < TWT$  (ns)  $< 3.8$
- Infiltrated volume :  $0.5 < K_s$  (cm/min)  $< 1.25$

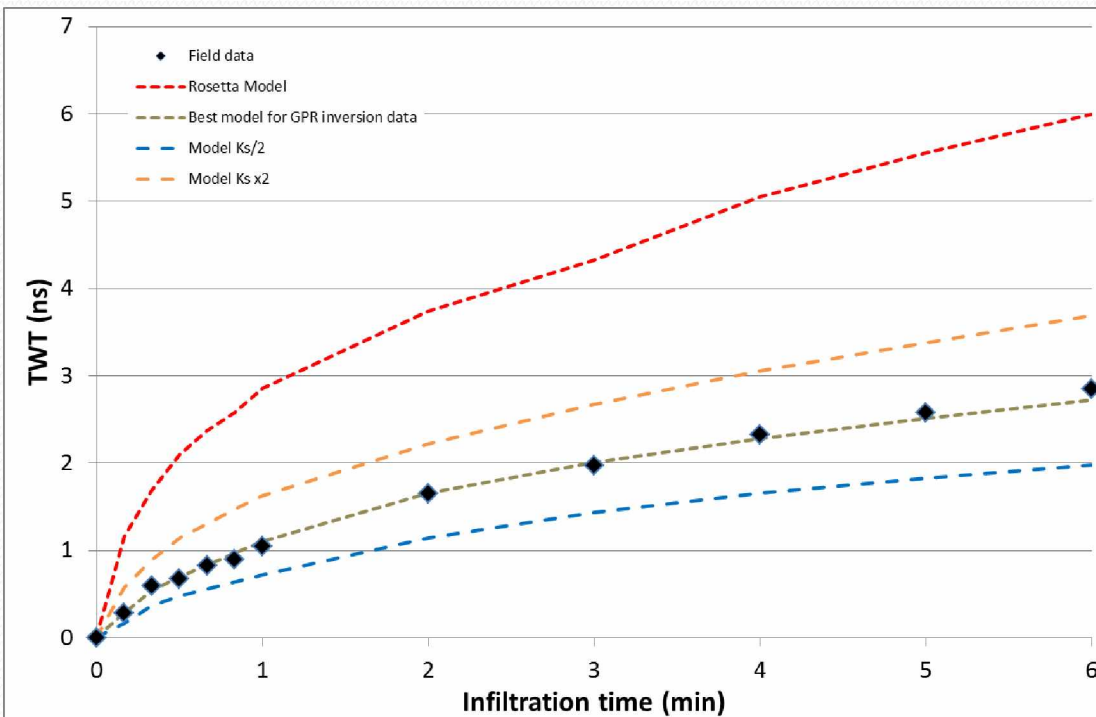
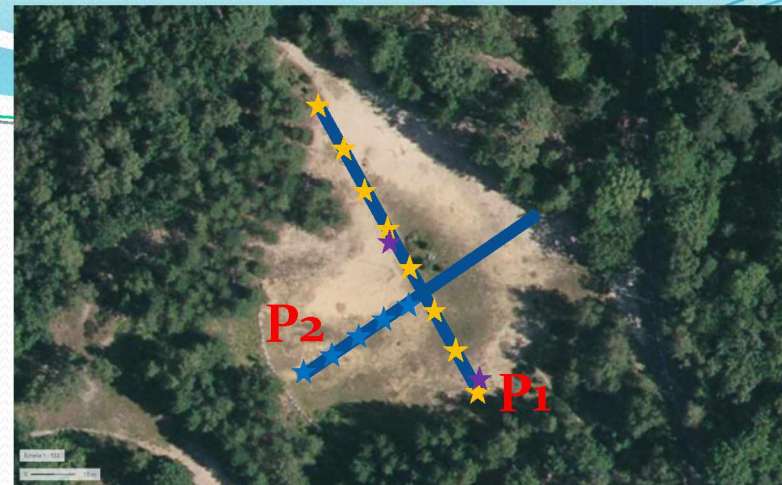




# Results

- SandPit : Auffargis (France)

Example of data inversion



- Comparison between ROSETTA estimation and GPR data inversion :

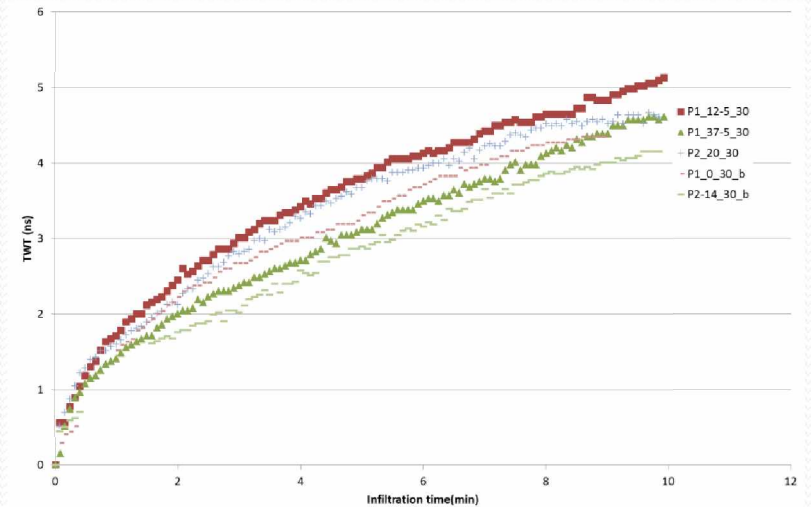
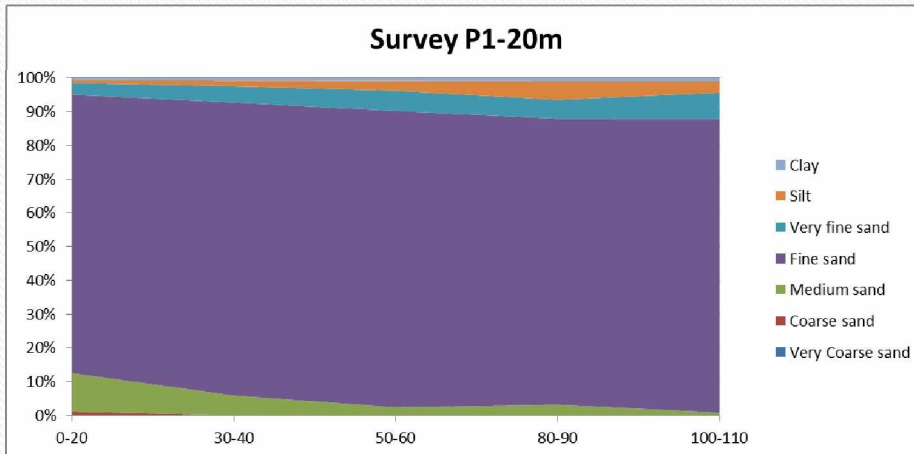
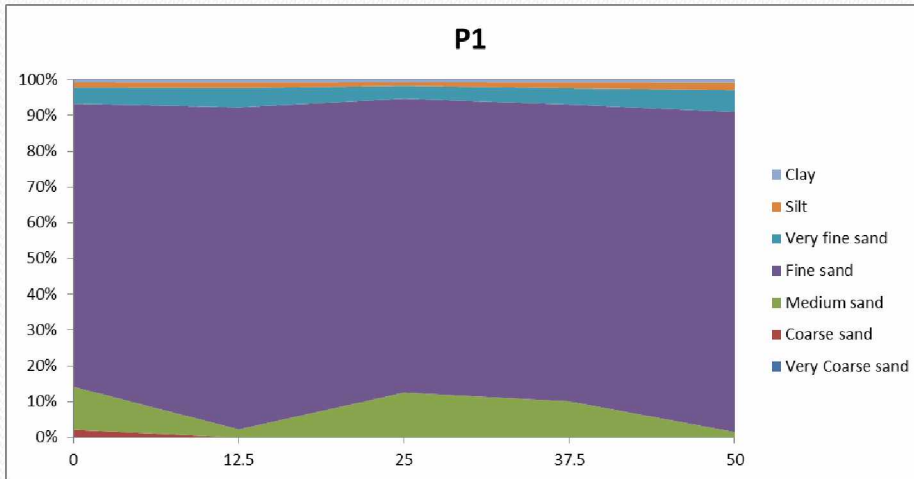
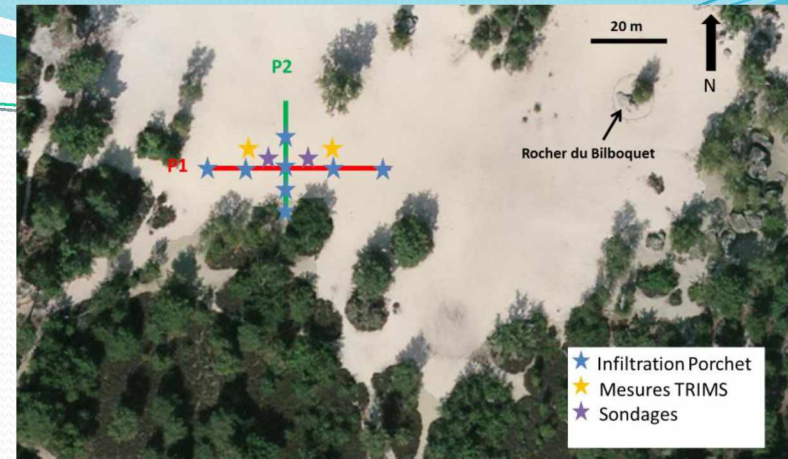
	$K_s$ (cm/min)	$\theta_r$	$\theta_s$	$\alpha$ (1/cm)	$n$
Rosetta	0.56	0.05	0.37	0.033	3.7
Data inversion	0.32	0.03	0.25	0.1	1.43

- Models considering the same parameters but with  $K_s / 2$  and  $K_s \times 2$  surround all the field data



# Results

- SandPit : Cul-du-chien (France)



ROSETTA variations :

	$K_s$ (cm/min)	$\theta_r$	$\theta_s$	$\alpha$ (1/cm)	$n$
Min	0.36	0.049	0.361	0.032	2.66
Max	0.88	0.049	0.368	0.035	3.92

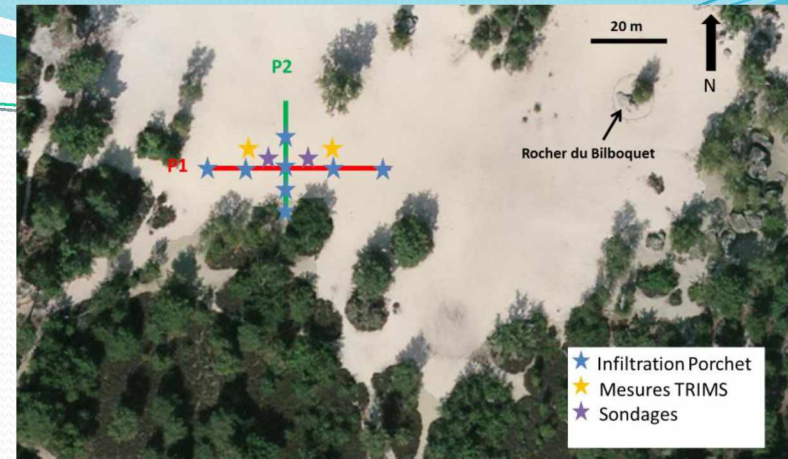
Infiltrated volume :  $0.5 < K_s$  (cm/min)  $< 1$

GPR data :  $4 < TWT$  (ns)  $< 5$



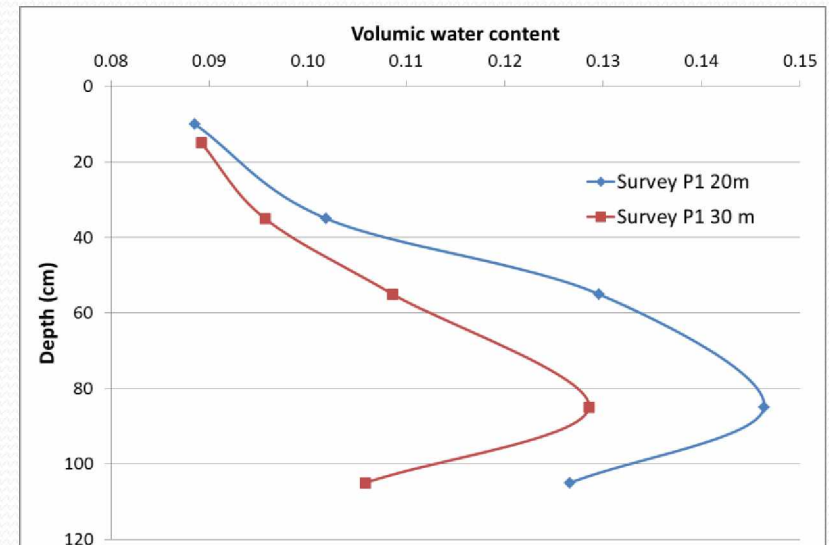
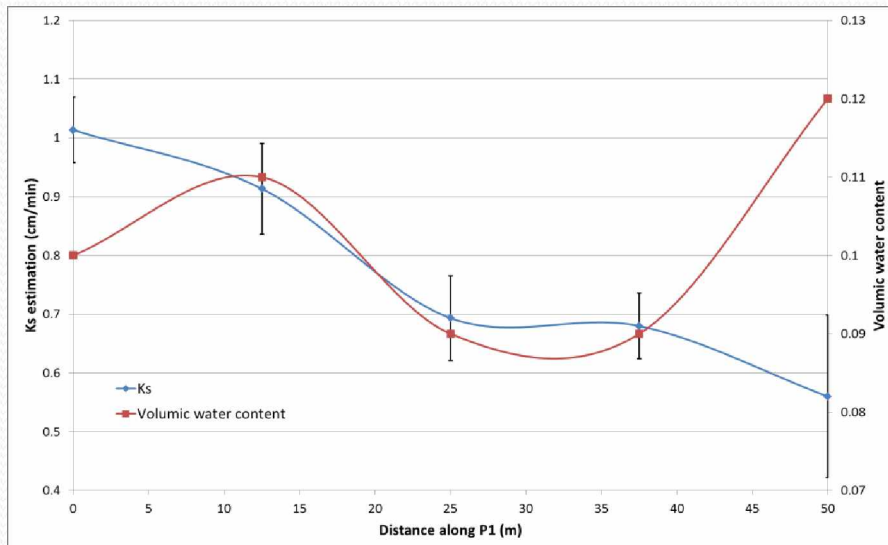
# Results

- SandPit : Cul-du-chien (France)



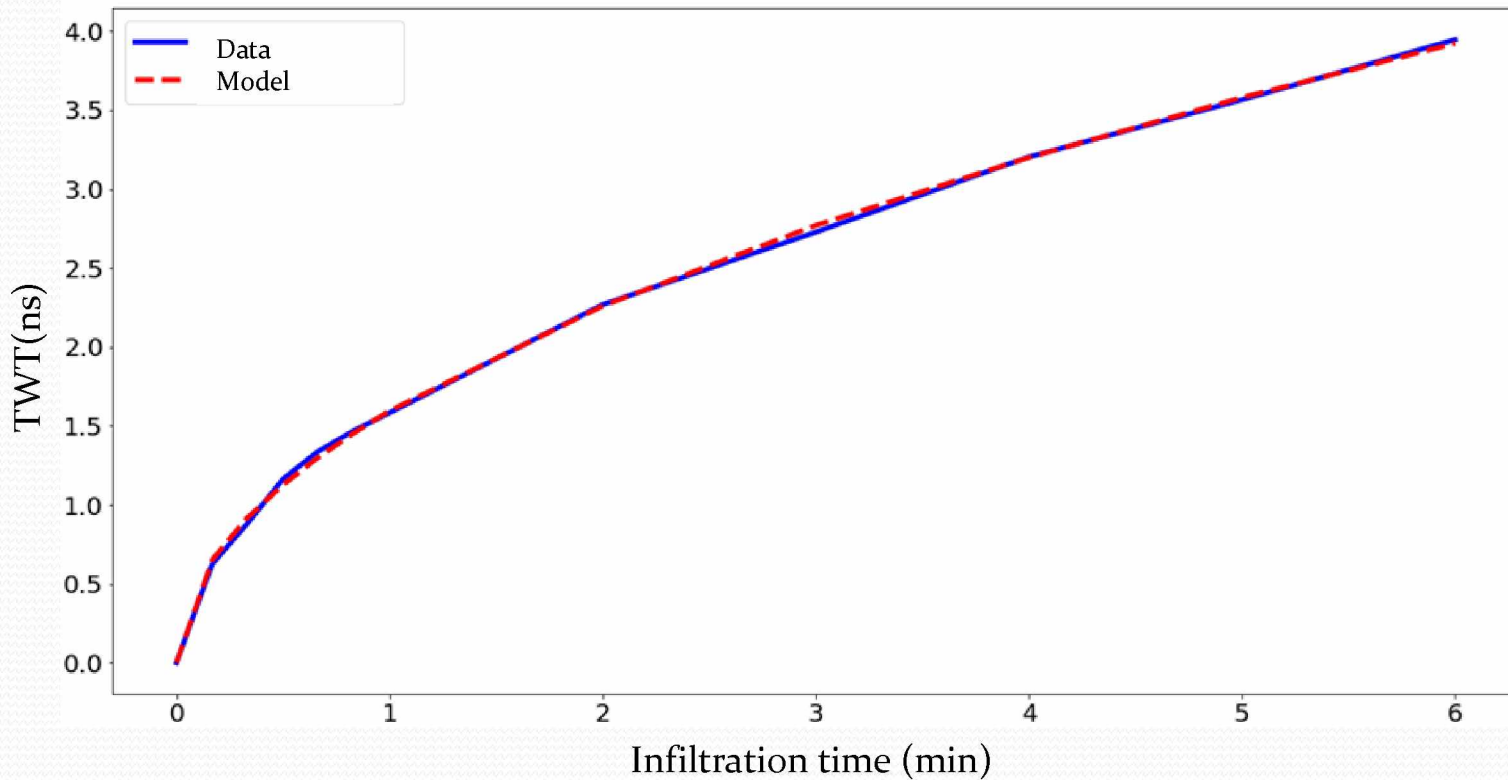
Comparison between **ROSETTA PTF** data and **suspended columns/infiltration results**

	$K_s$ (cm/min)	$\alpha$ (1/cm)	$n$	$\theta_r$	$\theta_s$
P1 12.5	0.786 / 0.9	0.034 / 0.017	3.73 / 6.93	0.049 / 0.05	0.362 / 0.39
P1 37.5	0.784 / 0.67	0.034 / 0.017	3.72 / 9.0	0.049 / 0.04	0.362 / 0.345





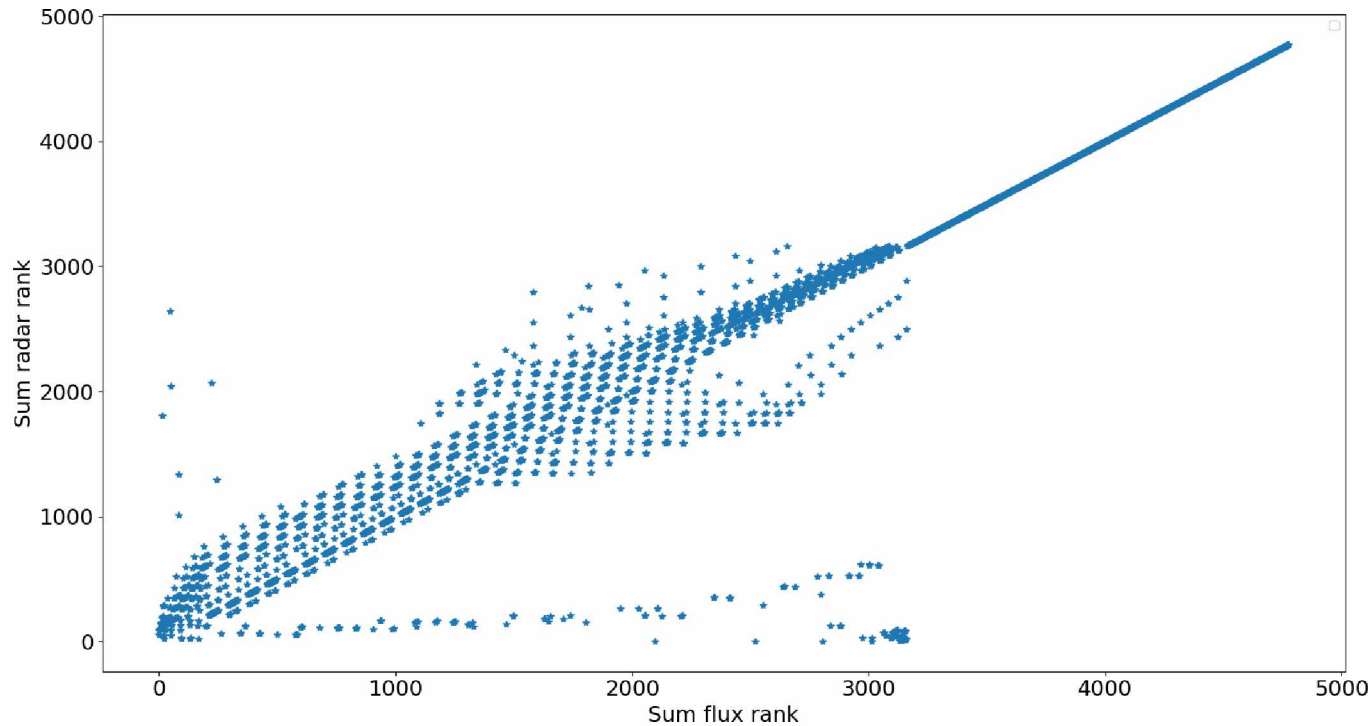
# Data fitting



Data fitting for TWT is possible using a power law function :  $at^b$   
→ Relation with the hydrodynamic parameters ?



# Relation between TWT and the infiltrated volume?



Clear relation between the total infiltrated volume and the sum of arrival time of reflected wave

# Conclusion

- Development of in-situ experiments with various tools (TRIMS, direct sampling, GPR, Porchet infiltration)
- Estimation of the hydrodynamic parameters with textural data (ROSETTA), infiltrated volume (Porchet) and inversion of GPR data
- Values of the parameters strongly depends on the employed technique (effect of  $n$ ,  $\alpha$  and  $K_s$  on GPR data)
- For ROSETTA/Porchet :Variations in  $K_s$  estimations ( $K_s/2 < K_s < 2K_s$ ) are similar to the litterature (McBratney and Mulla, 2002)
- GPR data are not fitted by ROSETTA's parameters
  - Anisotropy effect?
  - Hysteresis?
  - Link between  $K_s$  and  $n$  values?
- Relations between TWT and infiltrated volume is investigated





Thank you!