UNIVERSITÉ D'AVIGNON

UNIVERSITÉ D'AVIGNON ET DES PAYS DE VAUCLUSE

CIRE CHIRURGIE - IMAGERIE - RECHERCHE - ENSEIGNEMENT

EGU

INRA SCIENCE & IMPACT

EmmaH UMR 1114 INRA UAPV Environnement Méditerranéen et Modélisation des Agro-Hydrosystèmes

EGU Meeting

Session Soil water Infiltration. Measurements, assessment and modeling (co-organized - SSS7.6/HS8.3.11)

Comparing dynamics recording of infiltration by X-Ray tomography to the results of a dual porosity model for structured soils

Anne-Sophie LISSY

supervised by: Stéphane Sammartino – Stéphane Ruy – Liliana Di Pietro

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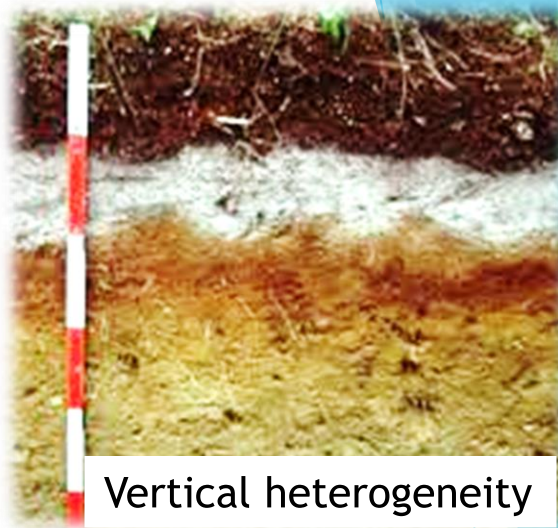
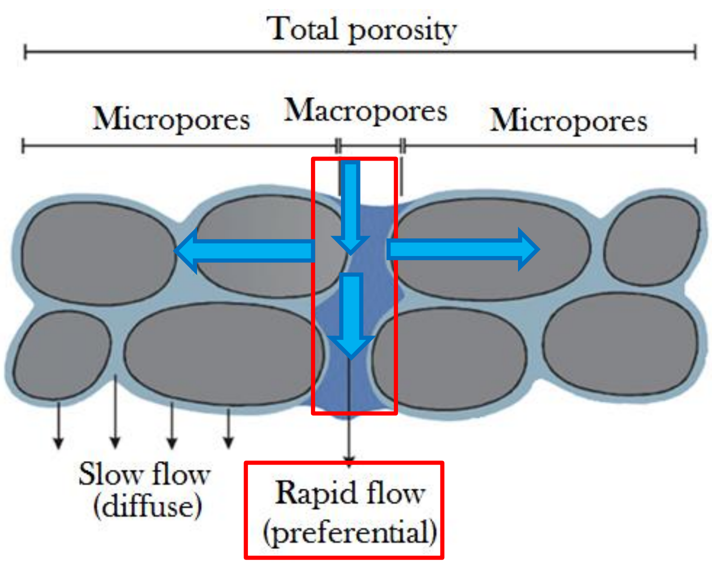
Introduction

Soil: major resource for agronomy
➔ water quality ; water balance ; cultural support

BUT temporal and spatial variation



Climate change impact
→ Rain intensity and frequency in Mediterranean zone
→ Preferential flows can be more frequent (i.e. rapid flow in macropores and micropores “short circuit”)



➔ Impact on time arrival to water table, and transport pollutants/colloids (ref. 5)
➔ **Environmental risks**

Introduction

How to study preferential flow phenomenon ?

Experiments on undisturbed soil cores samples ($\phi\ 12\ cm\ ;height = 15cm$)

- Rain simulation in laboratory
- Rain simulation in X-Ray medical tomograph
- Water flow models:

→ Matrix flow (slow flow) : well described by *Darcy* – *Richards* equation
→ Preferential flow (rapid flow) : calculated with Kinematic Dispersive Waves (KDW)

➔ Coupling Darcy – Richards and KDW → "natural water flow" (ref. 3)

→ Image analysis
→ Experimental data
→ Modelling of rain

I - Comparison and parametrization with images

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II - Comprehension of KDW parameters

(by sensitivity analysis and parameters estimation)

Materials and methods - Image

Samples	Rain
3 samples	30 mm each
2 different textures (clay-loam; loamy-sand)	2 intensity (20 & 6 mm/h)
2 different structure (tilled or not)	Gravimetric monitoring

X-Ray tomography	Model
1 rain at 20 mm/h for 30mm	Using ***VirtualSoil*** platform (http://www6.inra.fr/sol_virtuel)
Gravimetric monitoring	Richards – KDW coupled equation
Image acquisition regularly in 10 s with ~350µm of resolution	

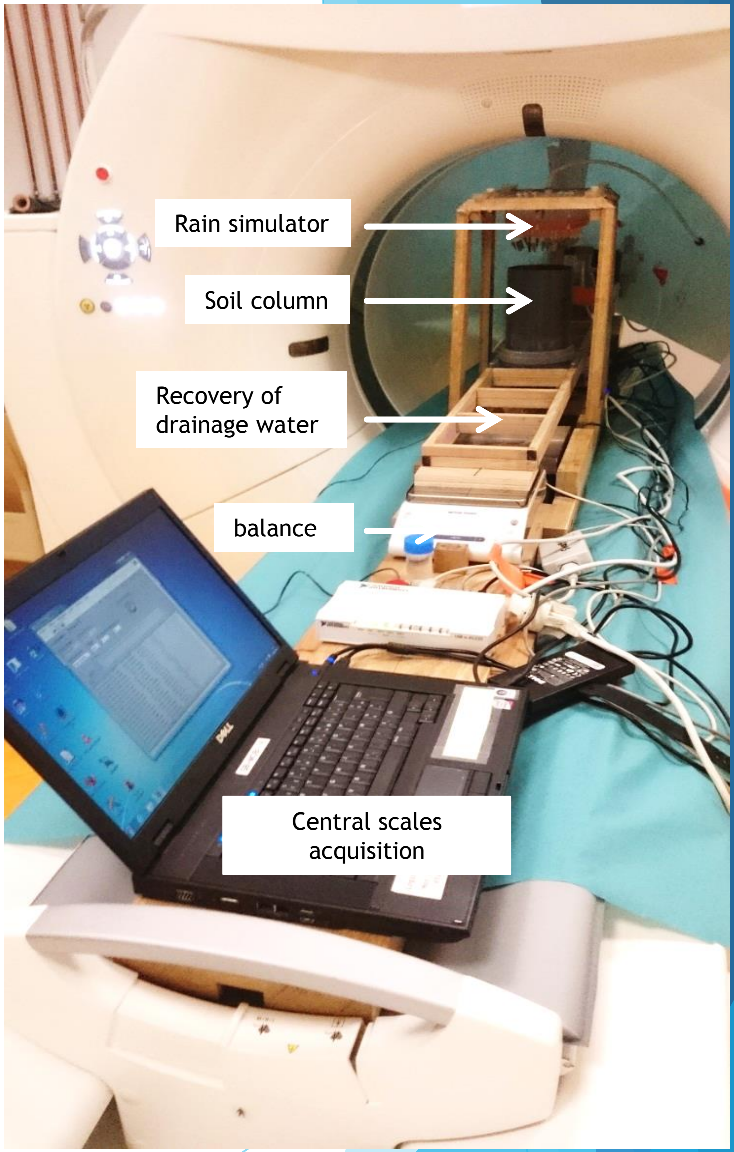
Image Analysis

(1) Determination of functional macroporosity (ref. 1)

(2) Determination of water flow dynamics in largest macropores (ref. 2)

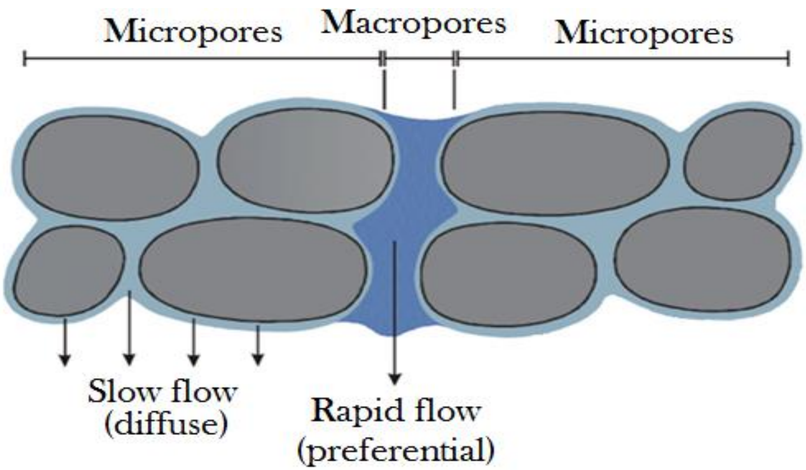
Modelling

Develop after ....



Materials and methods - Model

Dual porosity model



Matrix / microporosity (Mi)

$$q_{mi} = -K_{mi}(h)\frac{\partial(h-z)}{\partial z}\ (Darcy)$$

$$+continuity\ equation \rightarrow Richards$$

$$\frac{\partial\theta_{mi}(h)}{\partial t} + \frac{\partial}{\partial z}\left(-K_{mi}(h)\frac{\partial(h-z)}{\partial z}\right) = 0$$

$$\frac{\partial\theta_{mi}(h)}{\partial t} + \frac{\partial}{\partial z}\left(-K_{mi}(h)\frac{\partial(h-z)}{\partial z}\right) = S$$

Parameters : $K_{mi}(h)$, $h(\theta_{mi})$

Macropores (Ma)

$$q_{ma} = b\ \theta_{ma}{}^{a} - \nu\frac{\partial\theta_{ma}}{\partial t}$$

$$+\ continuity\ equation\ \rightarrow KDW$$

$$\frac{\partial q_{ma}}{\partial t} + c(\theta_{ma})\frac{\partial q_{ma}}{\partial z} = 0$$

$$\frac{\partial q_{ma}}{\partial t} + c(\theta_{ma})\frac{\partial q_{ma}}{\partial z} = -S\ c(\theta_{ma})$$

Parameters : a, b, ν

Coupling

$$S = f(Ma, Mi) = \frac{K_{mi}(h)}{d} \cdot -\frac{h_{mi}}{d} \cdot \frac{\theta_{ma}}{\theta_{ma}^{max}}$$

(ref.3-4)

Materials and methods - Model

Sensitivity Analysis & Parameters estimation

Sensitivity analysis

- Mathematical method: FAST 99 (ref. 6)
- Goal: which parameters are the most important ?
- Interest of method: detect principal and interaction effects
- Limitation: time calculation

Parameters estimation

- Mathematical method: Levenberg-Marquardt (LM) & DREAM test (ref. 7-8)
- Goal: estimation some parameters which are not measurable or uncertain
- Interest of method: fitting experimental curves
- Limitation:
  LM: may not detect global minimum.
  DREAM: global but long time for calculation.

KDW : $q_{ma} = \boldsymbol{b}\ \theta_{ma}{}^{\boldsymbol{a}} - \nu \frac{\partial\ \boldsymbol{\theta_{ma}}}{\boldsymbol{\partial t}}$

Sink source term : $S = \frac{K_{mi}(h)}{\boldsymbol{d}} \cdot - \frac{h_{mi}}{\boldsymbol{d}} \cdot \frac{\boldsymbol{\theta_{ma}}}{\boldsymbol{\theta_{ma}^{max}}}$

→ parameters for statistical analysis

→ $a = macropores\ flow\ distribution\ index\ [-]$

→ $b = conductance\ term\ [m.s^{-1}]$

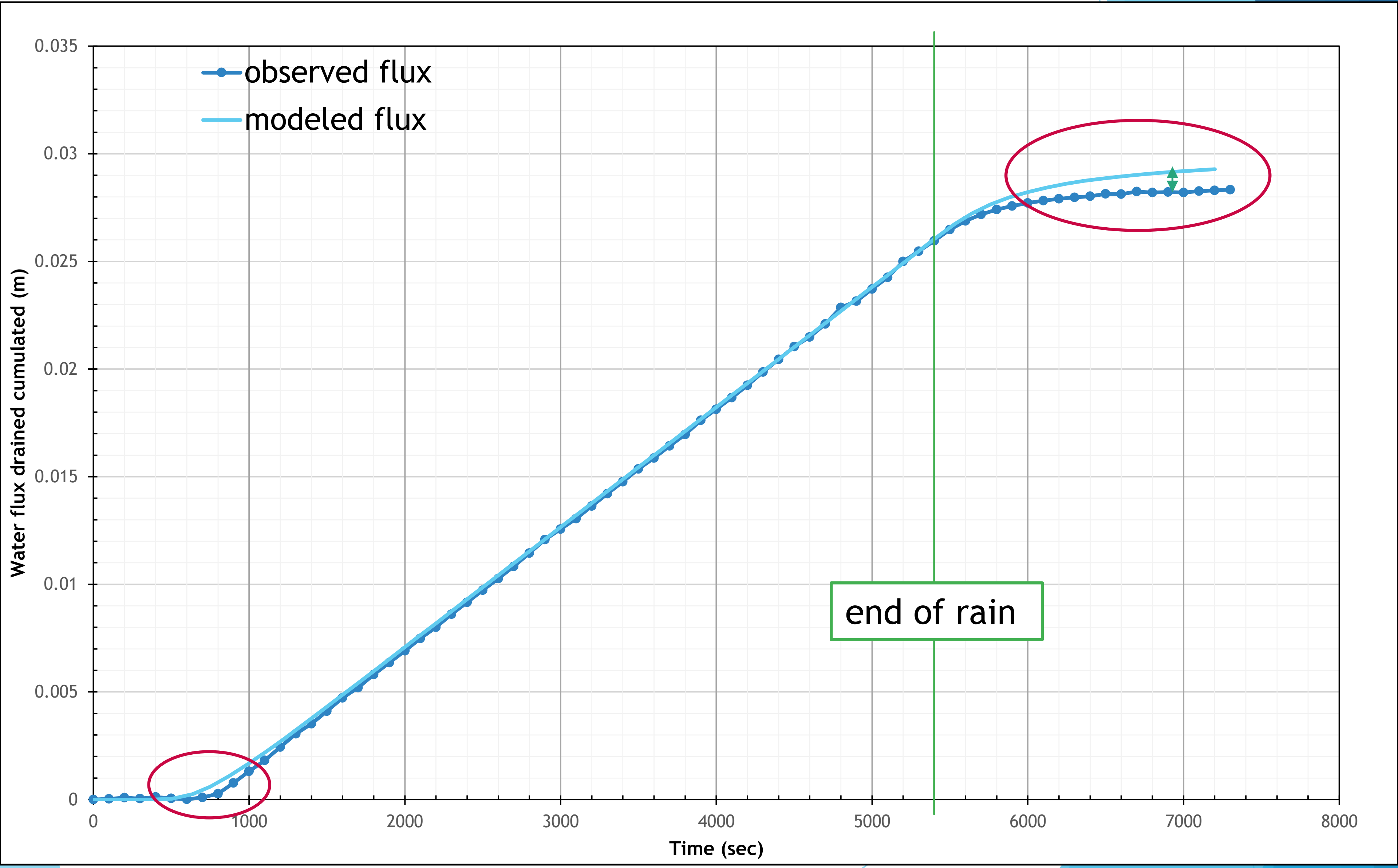
→ $\nu = dispersion\ coefficient\ [m]$

→ $d = estimated\ effective\ diffusion\ distance\ \ [m]$

→ $\theta_{ma}^{max} = water\ content\ in\ saturated\ macropores\ [m^3.m^{-3}]$

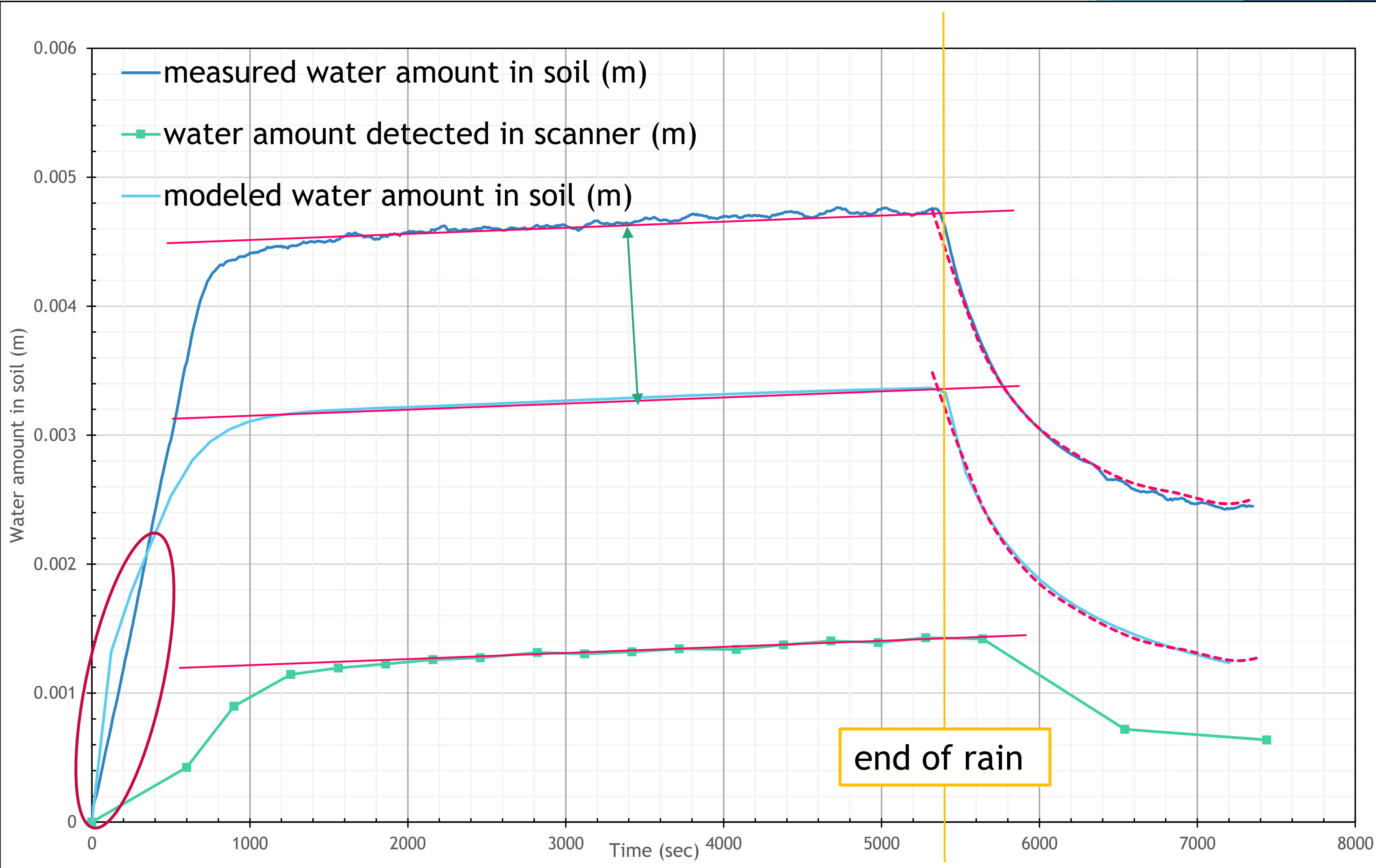
Results – Model VS experiment

Observed VS modeled drained flux – Soil clay loam no tilled

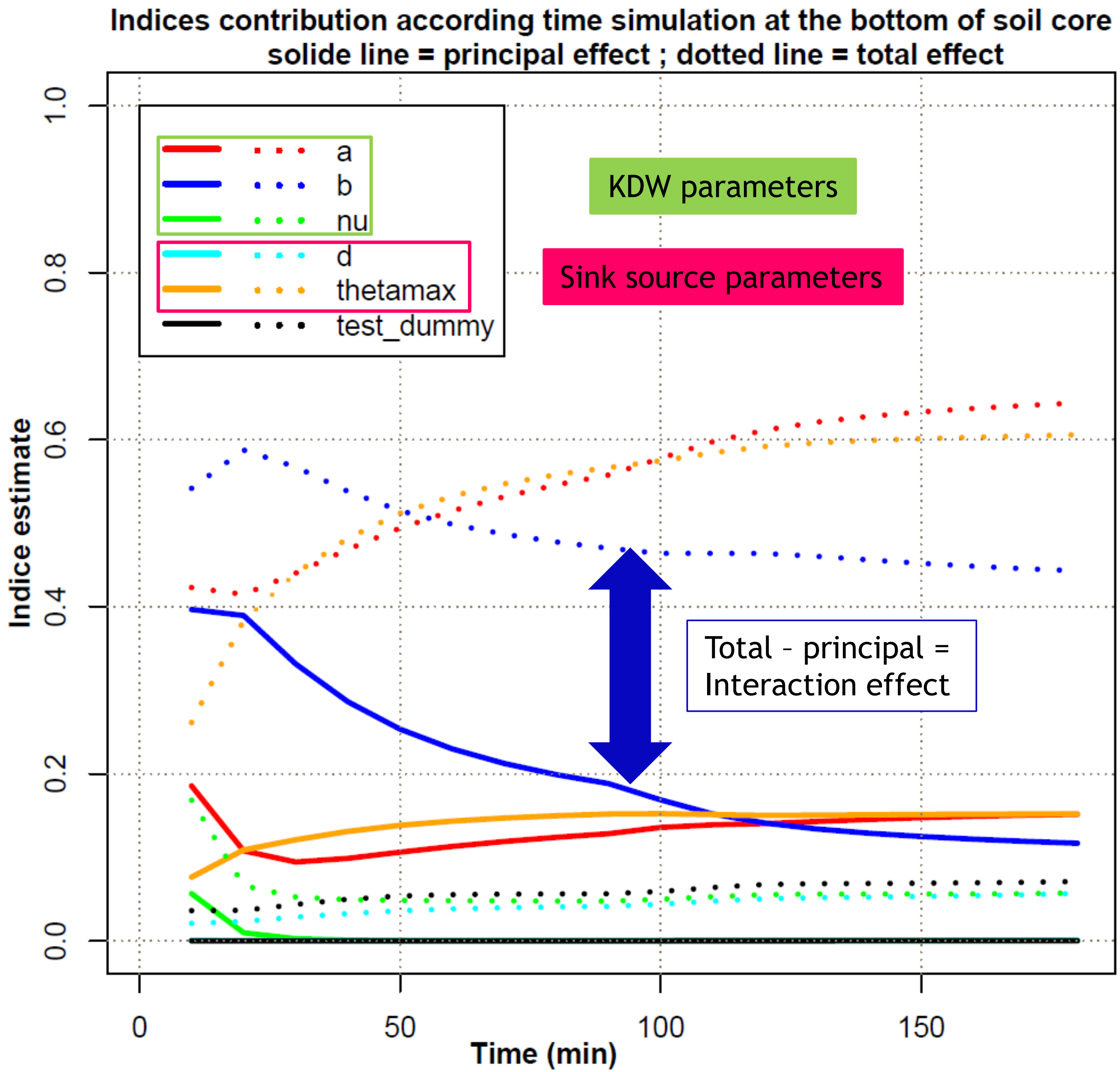


Results – Model VS Image

Observed VS modeled water amount in soil – Soil clay loam no tilled



Results – Sensitivity analysis of KDW & Sink source term



Conclusion

- *On rain experiments*

→ Good approach to see water flow dynamic in general
→ Improvement for a better detection of breakthrough time in “real time”

- *On X-ray tomography: image analysis*

→ Good representation of water flow dynamic with an internal vision for larger object
→ Improvement of image analysis with development of new structure and water flow index for integration in KDW model **(IN PROGRESS)**

- *On water flow modelling*

→ Good modelling in general of water flux at the bottom and water stored in column
→ Improvement of KDW model ➔ new formulation ! **(IN PROGRESS)**

- *On sensitivity analysis (model)*

→ Promising firsts results. KDW parameters show great interactions who need to be understand
→ Need more time to continue analysis…

Perspectives

➔ Find a better way to best integration of generic macrostructure parameters in water flow model

→ *Image Analysis: development of structure parameters (connection, shorter water path connected top - bottom…)*

→ *Model: sink source term improvement (re-formulation), add contribution of imaging*

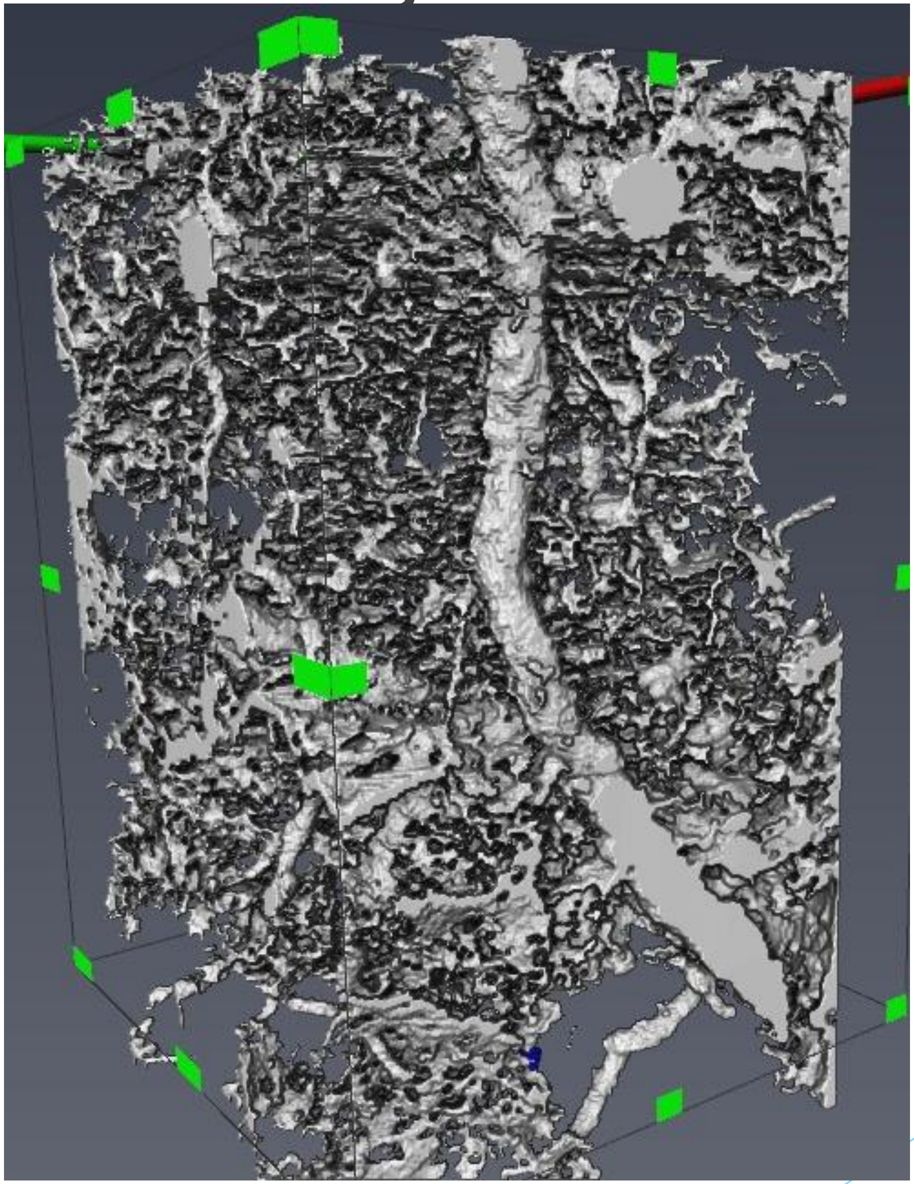
<u>In the future:</u>

➔ Visualization of micro – macropores exchange

→ *Using dye tracer (water non-reactive)*

→ *Increase of X-ray tomograph resolution by using smaller sample.*

Thanks for your attention !



Contact: anne-sophie.lissy@inra.fr

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