# Control of N2O emissions by soil hydraulic functioning at the local scale

Catherine Hénault, Eva Rabot, Marine Lacoste, Isabelle I. Cousin

# Control of $N_2O$ emissions by soil hydraulic functioning at the local scale

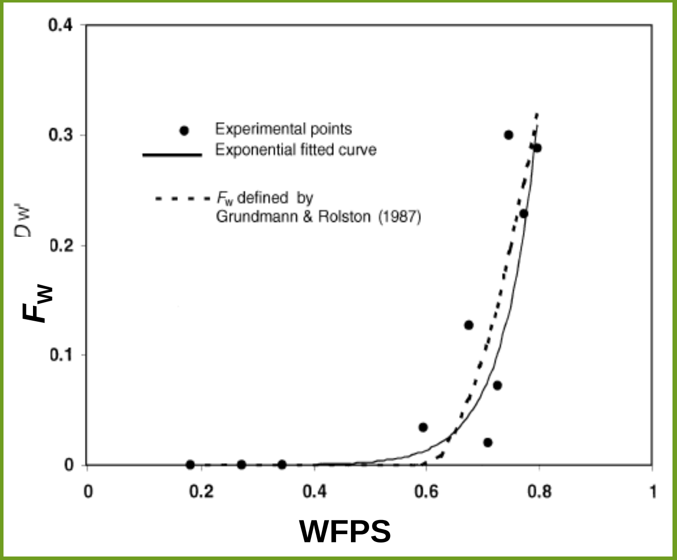
Hénault C., Rabot E., Lacoste M., Cousin I.

2015/09/08
Deutsche Bodenkundliche Gesellschaft

# INTRODUCTION

- $N_2O$ emissions are largely controled by soil WFPS

- WFPS, combines informations on soil water content and on soil porosity. It is a proxy of the aerobic status of soil




Example of th *Fw* function in $N_2O$ models (from Hénault and Germon, 2000)

- The relation between soil WFPS and $N_2O$ emissions (denitrification) is exponential, $N_2O$ emissions are very sensitive to little changes in soil WFPS

- This creates large uncertainties in $N_2O$ assessments by simulations

# INTRODUCTION

## AIMS

- To investigate the « soil – water » interactions at the local scale and their consequences on soil $N_2O$ emissions

## CONTENTS

- Dynamics of $N_2O$ emissions during wetting-drying cycles
- Soil porosity and $N_2O$ emissions during wetting-drying cycles
- Modeling of new knowledges …

# _01

# Dynamics of $N_2O$ emissions during wetting-drying cycles

# Materials and Methods

## Study site

- Cultivated with rape (*Brassica napus* L.)
- Classified as Glossic Retisol (WRB, 2014)
    - Silt loam texture

      clay = 13.7%, silt = 82.0%, sand = 4.3%
    - Soil organic carbon = 9.5 g $kg^{-1}$
- Bulk density = 1.43 g $cm^{-3}$

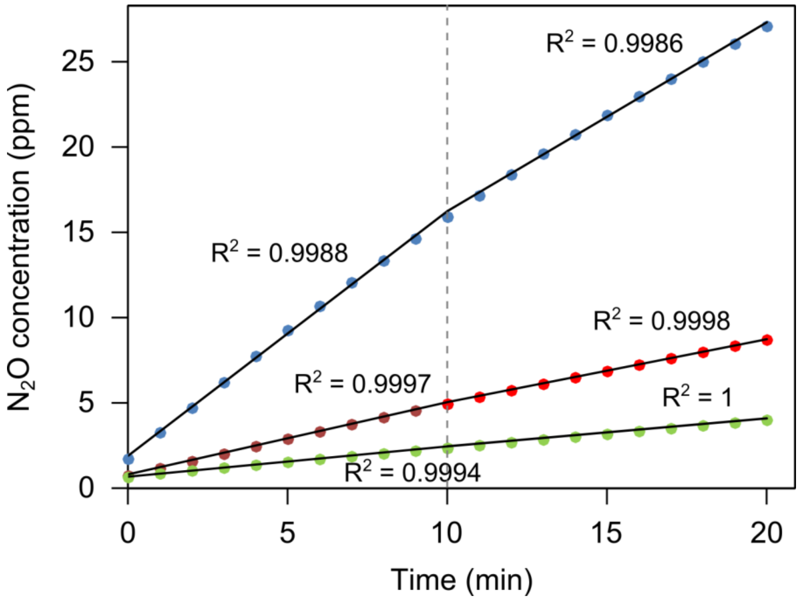
## Soil sampling

Undisturbed soil core collected in a PVC cylinder (13.2-cm diameter by 7-cm height) from the surface horizon

# Materials and Methods

## $N_2O$ measurements

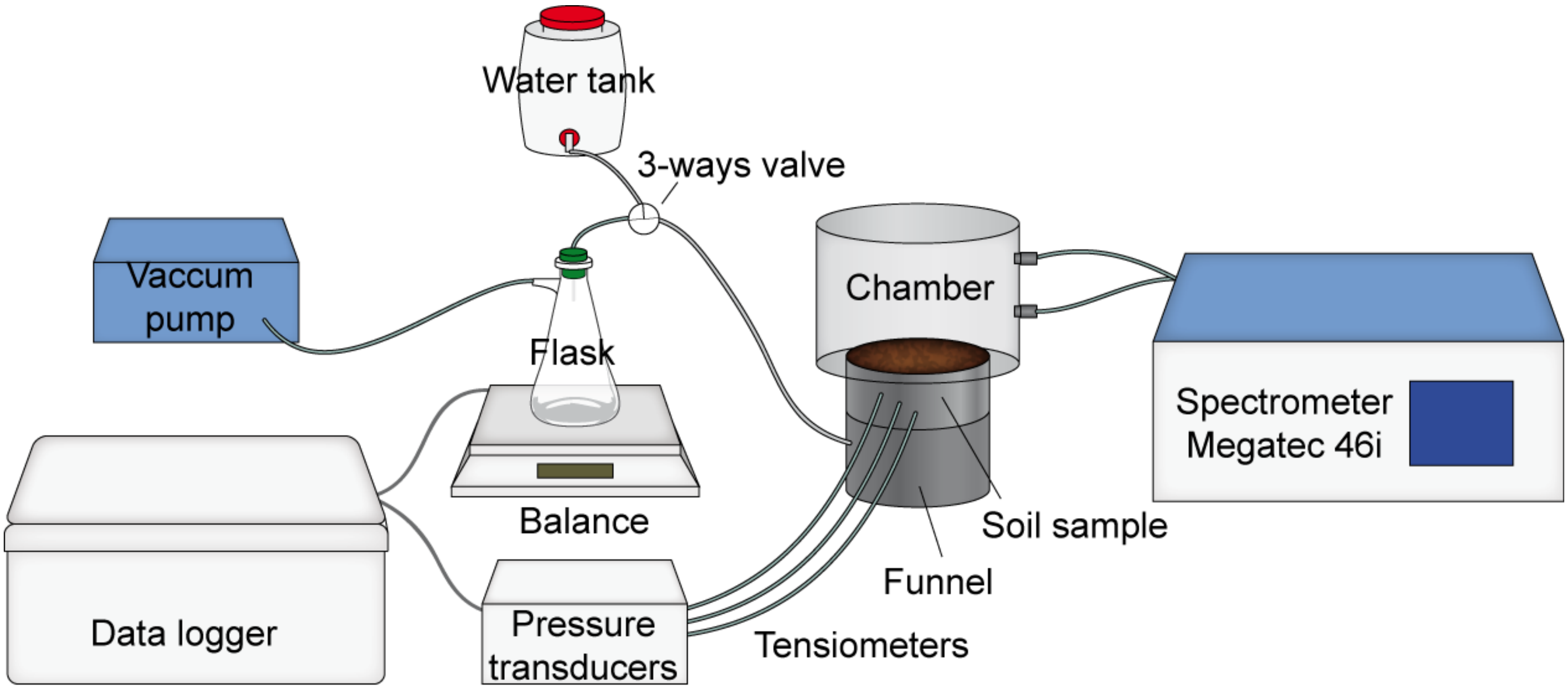
- **Closed-chamber method**
- **$N_2O$ monitoring: infrared correlation spectroscopy ($N_2O$ Analyzer model 46i, Thermo Scientific), detection limit 0.02 ppm, concentration value recorded every minute**
- **Flux calculated linearly from the observed change in $N_2O$ concentration during the first 10 min after the chamber was closed**

# Materials and Methods

## Hydric control

Multistep outflow system

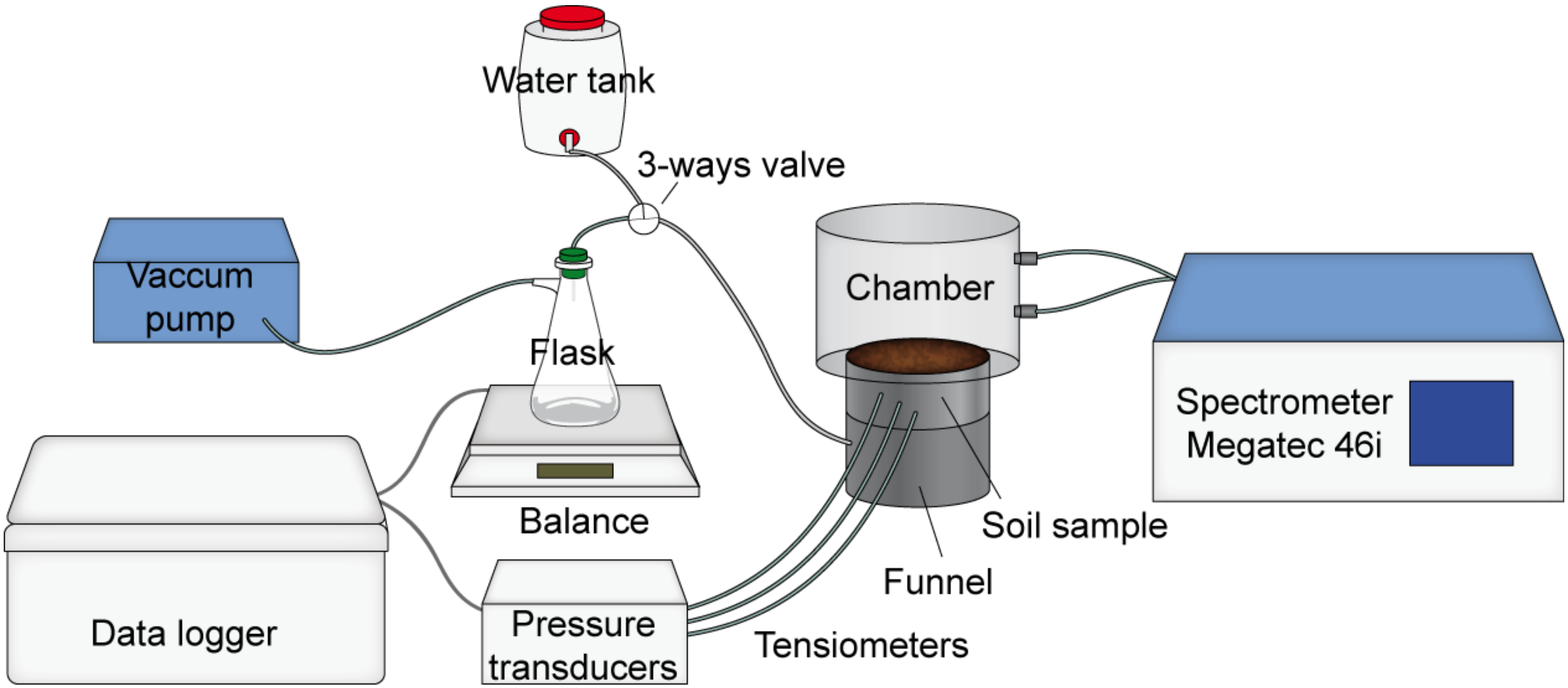


# Materials and Methods

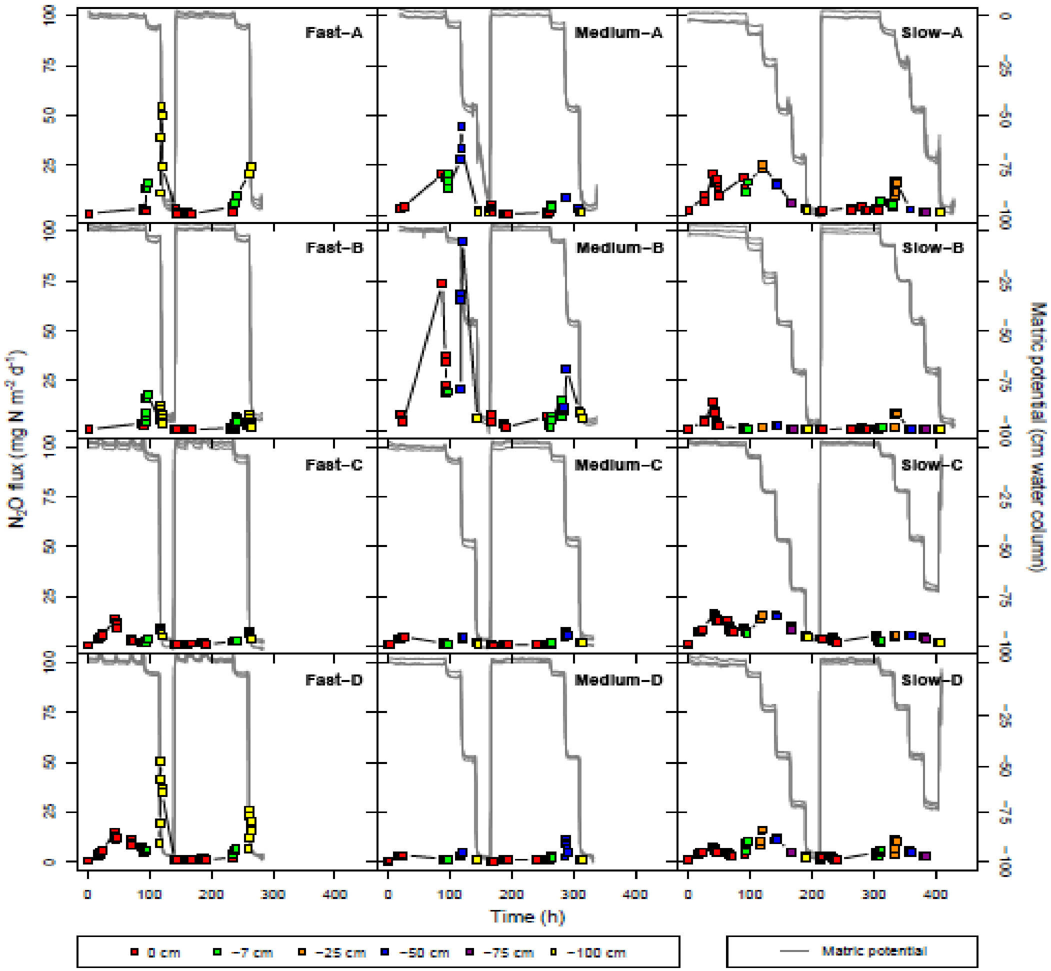
## Hydric control

- **Creation of two wetting-drying cycles with different rates of drying**

Multistep outflow system



# Results and Discussion




***Rabot et al. 2014 - SSSAJ***

- Main peaks of $N_2O$ emissions are observed
  - → not during the wetting phase
  - → but during the drying one
- The shapes of the peaks depend of the rate of the drying phase
- Peaks are attributed to
  - → $N_2O$ dissolution during the wetting phase
  - → $N_2O$ transport when soil pores are reconnected

⇨ To continue to investigate the effect of soil structure (porosity)

⇨ To introduce a transport module and a dissolution module into $N_2O$ models

_02

# Study of the soil porosity and $N_2O$ emissions during wetting-drying cycles

# Materials and Methods

## X-ray computed tomography


**Medical X-ray scanner: Siemens Somatom Definition AS**

**Acquisition time: 70 s**

**Voxel size: 316 × 316 × 100 µm**

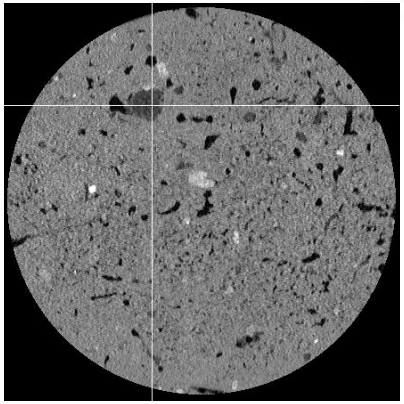
- 1 scan at the end of the wetting phase
- 7 to 9 scans during the drying phase

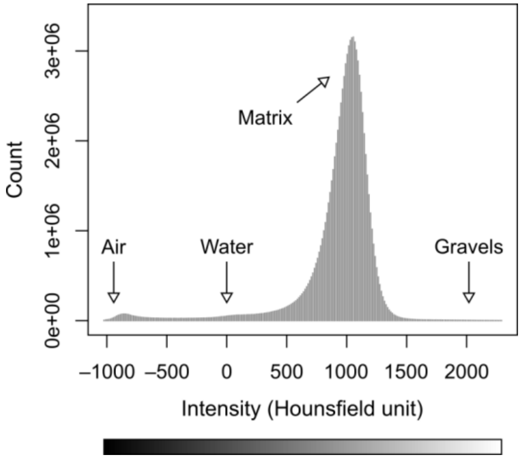
Alternating with $N_2O$ measurements

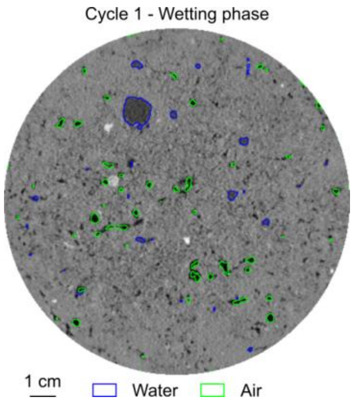
# Materials and Methods

## Image analysis

- **Pre-processing:** ImageJ *(Rasband, 1997-2014)* and Avizo software

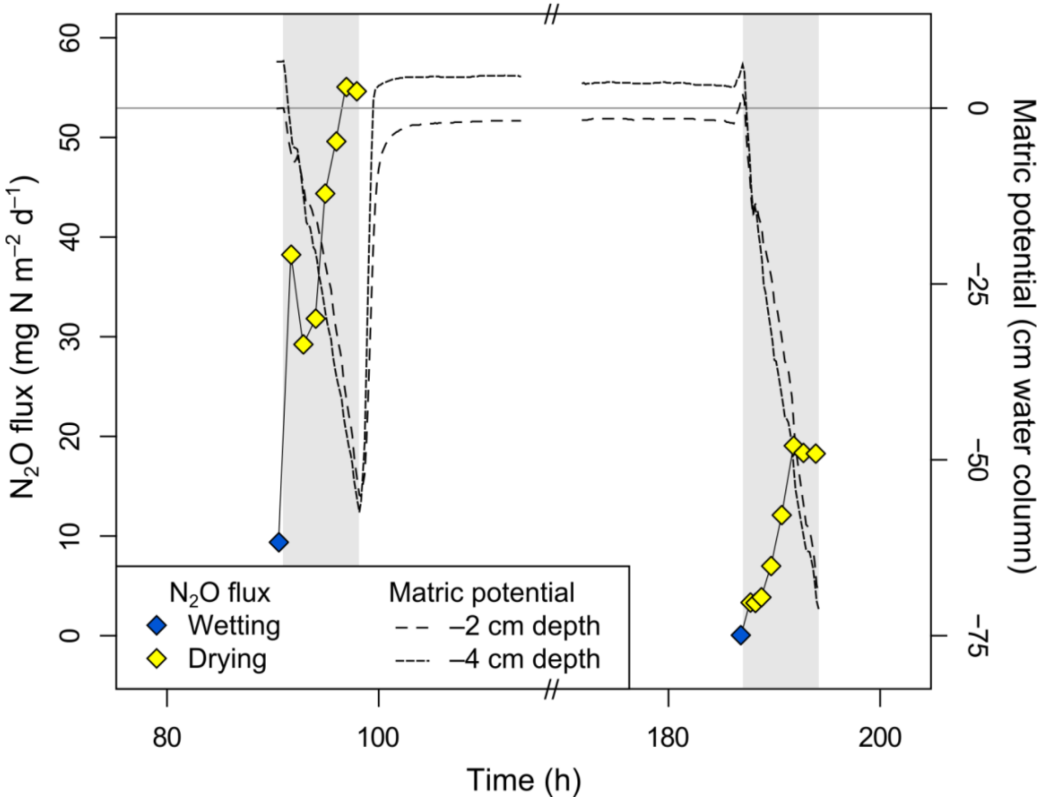




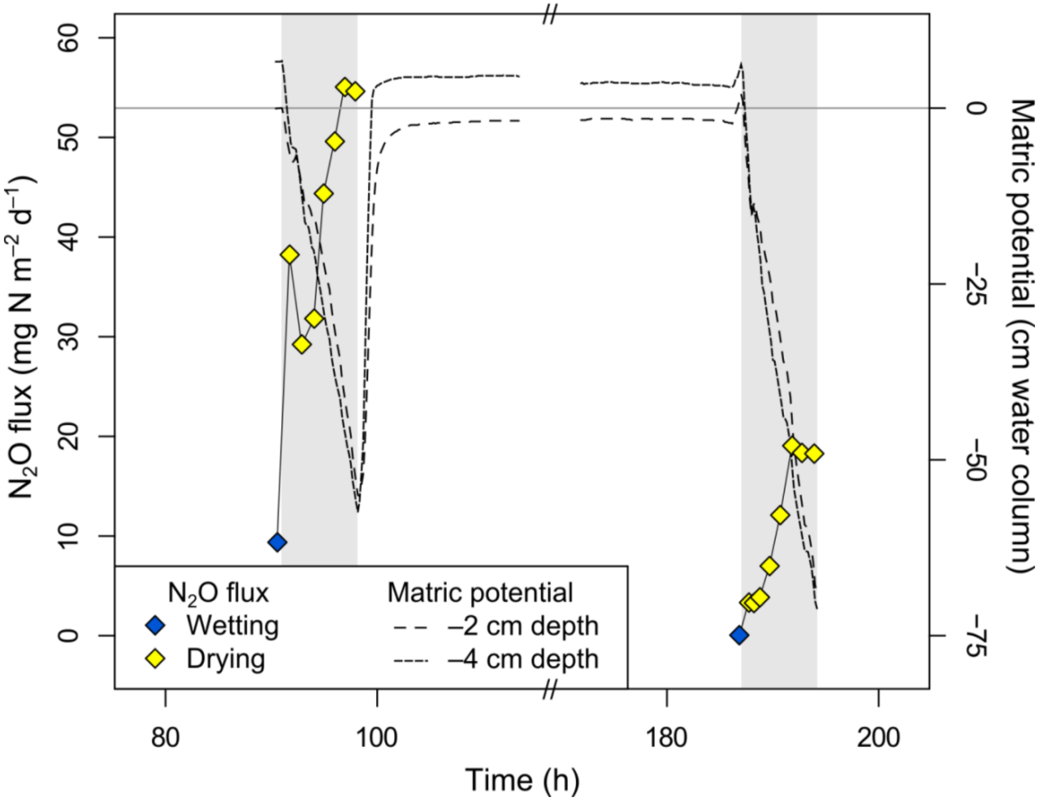

- Description of the pore network geometry : Image J software, C/C++ Quantlm library (Vogel, 2008)
    - Volume of air-filled and water-filled macropores
    - Euler number : connectivity of the air-filled pore space (vogel et al., 2010)
- Functionning description
    - Relative gas diffusion coefficient (DS/D0) from the segmented air-filled pore space

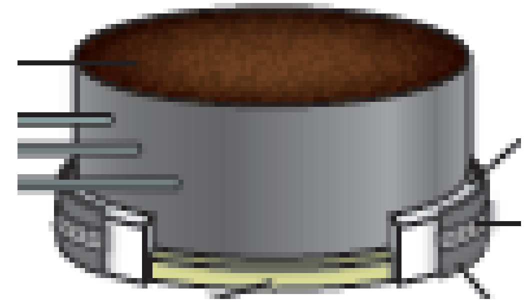
# Results and discussion

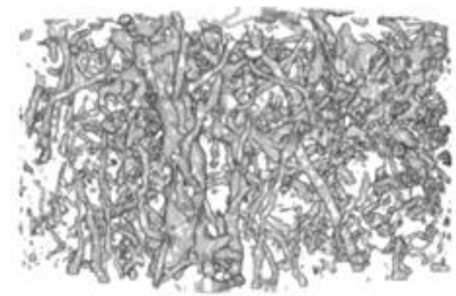


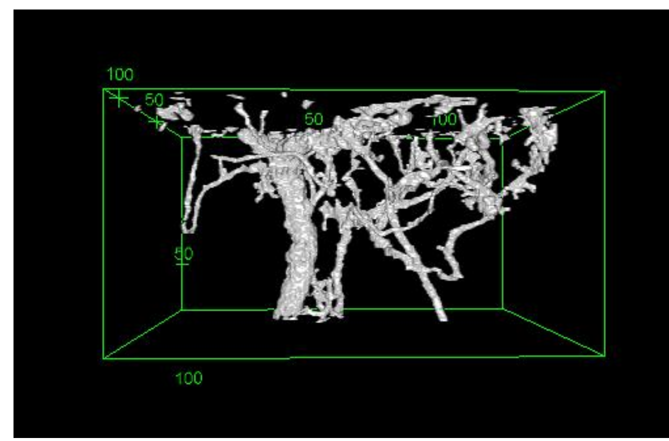

*Rabot et al. In Press – Vadoze Zone Journal*

# Results and discussion



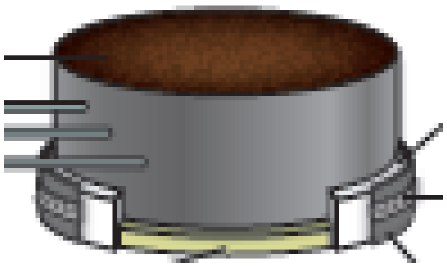



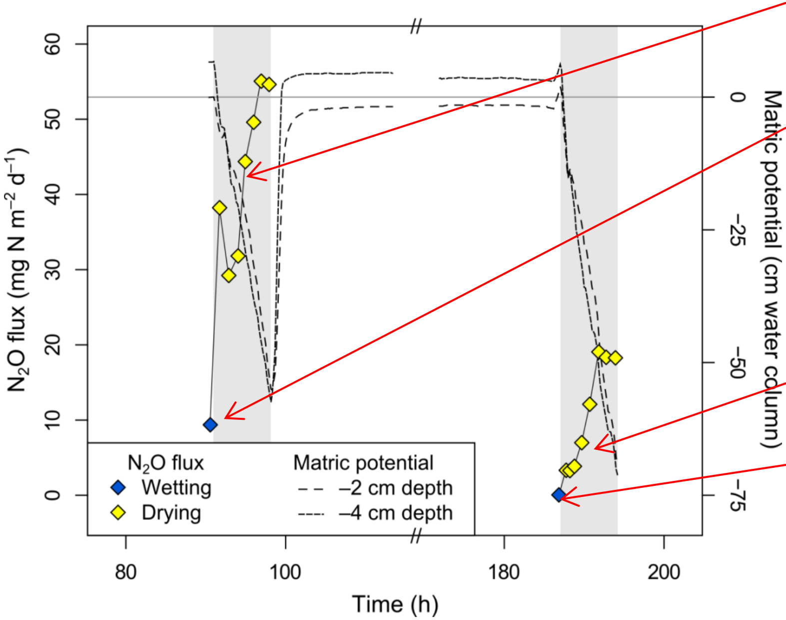


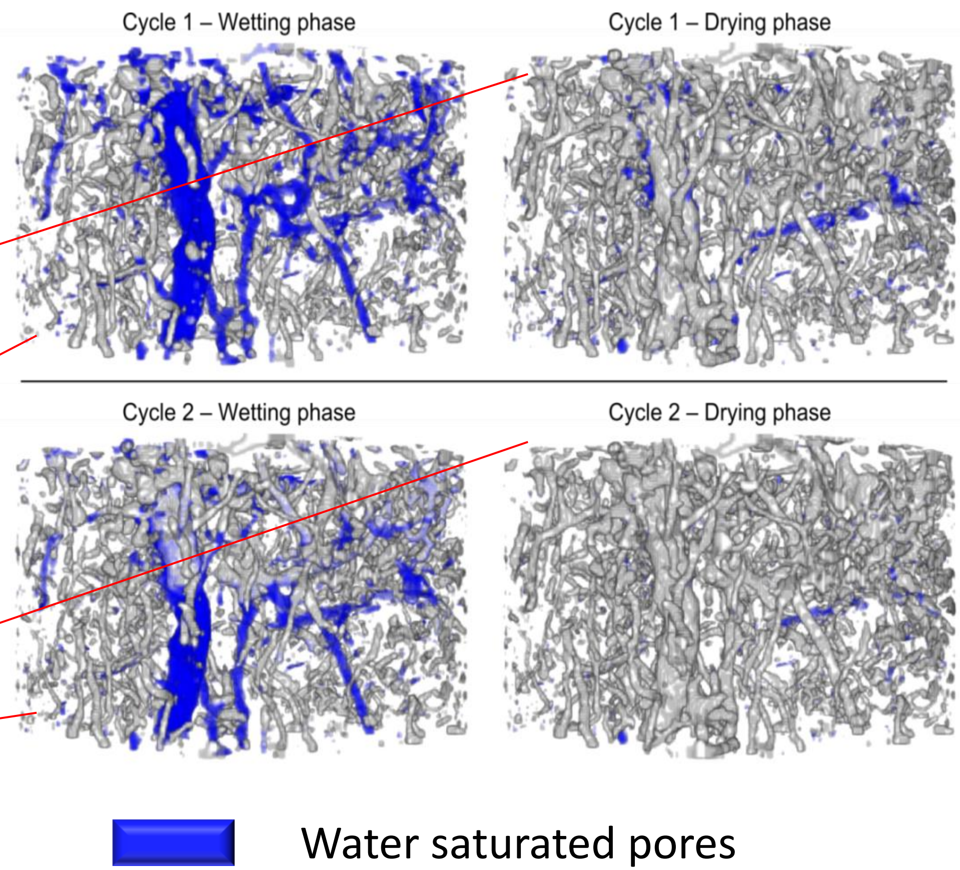



*Rabot et al. In Press – Vadoze Zone Journal*

# Results and discussion

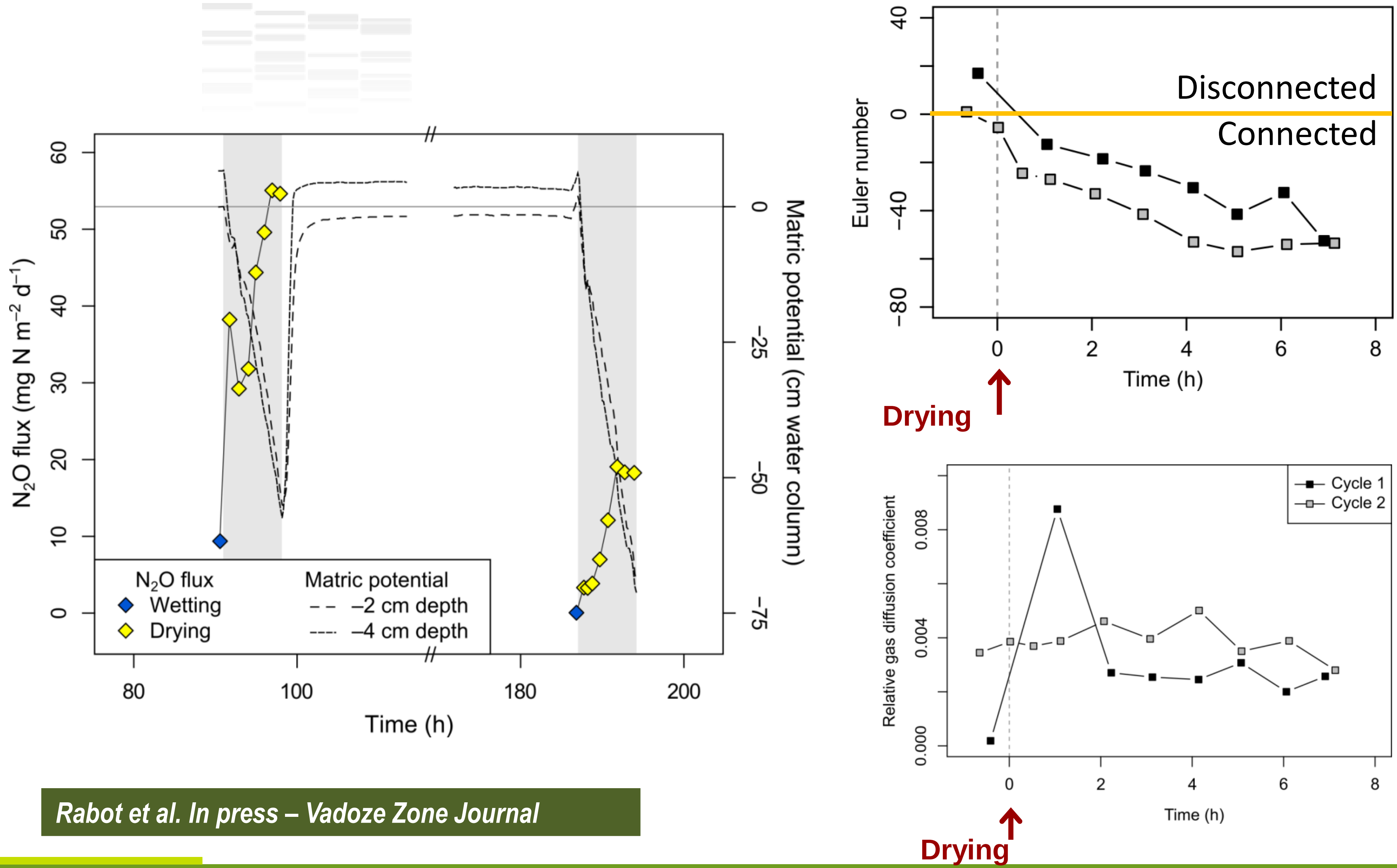





***Rabot et al. In Press – Vadoze Zone Journal***

# Results and discussion




***Rabot et al. In press – Vadoze Zone Journal***

## _03

# Modeling of this new knowledges

# Materials and Methods

## The NOE ALGORITHM

*(Hénault et al., 2005 – Global Change Biology)*

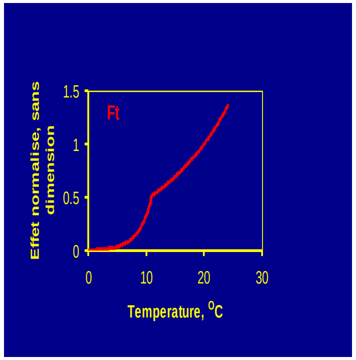
$$N_2O = (N_2O)_{denit} + (N_2O)_{nit}$$

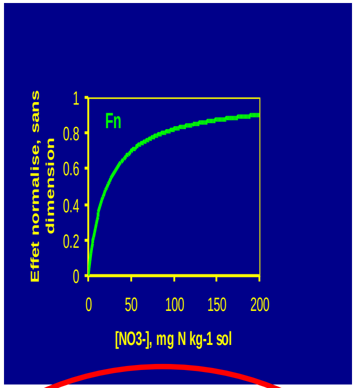
- $denit = K \cdot F_T \cdot F_{NO3-} \cdot F_{WFPS}$
  *(Hénault and Germon, 2000)*

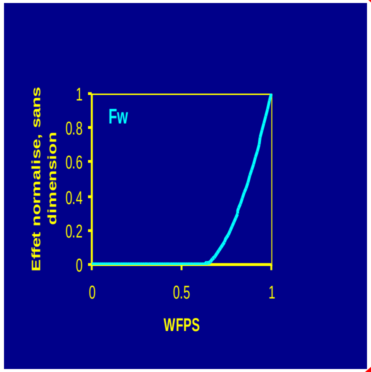
- $nit = f \cdot ( H_m \cdot [NH_4^+] \cdot T )$

Biological parameters

Environmental functions and parameters



# Conceptual proposition ($NOE_{GTE}$)

**A transport module**

- 1D diffusion equation of Fick
- Use of the Millington and Quirk model (1961)

**A dissolution module**

- A gas-liquid equilibrium according to Henry's law

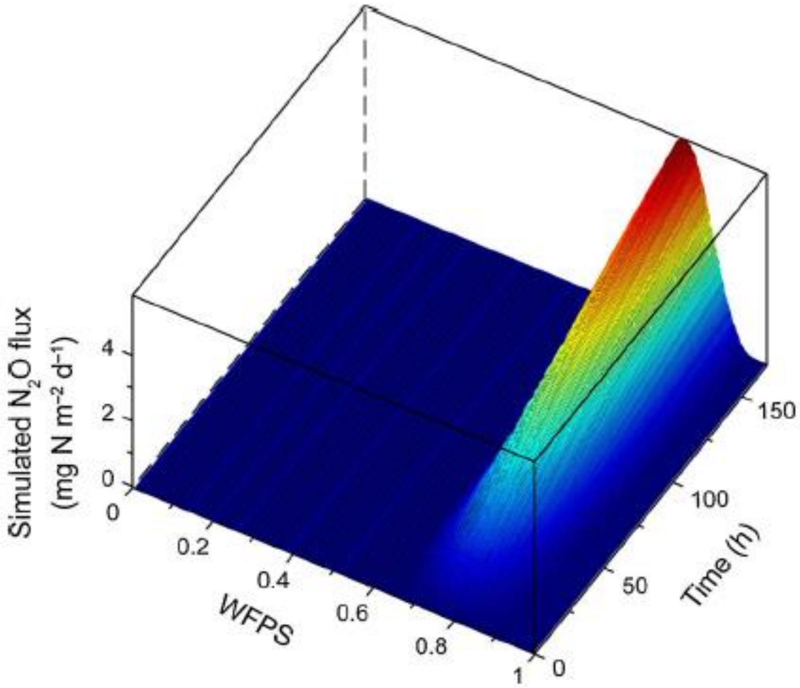



**Fig. 1** Simulated nitrous oxide flux with time for water-filled pore space in the range [0, 1]. At time = 0 h, initial conditions were applied. For the next time increments, the nitrous oxide production module, and the gas transport and equilibrium modules were activated

*Rabot et al. 2015 – Biogeochemistry*

# Experimental evaluation

➢ Measurements and simulation of $N_2O$ emissions in laboratory on undisturbed soil cores submitted to wetting/drying cycles with different rates

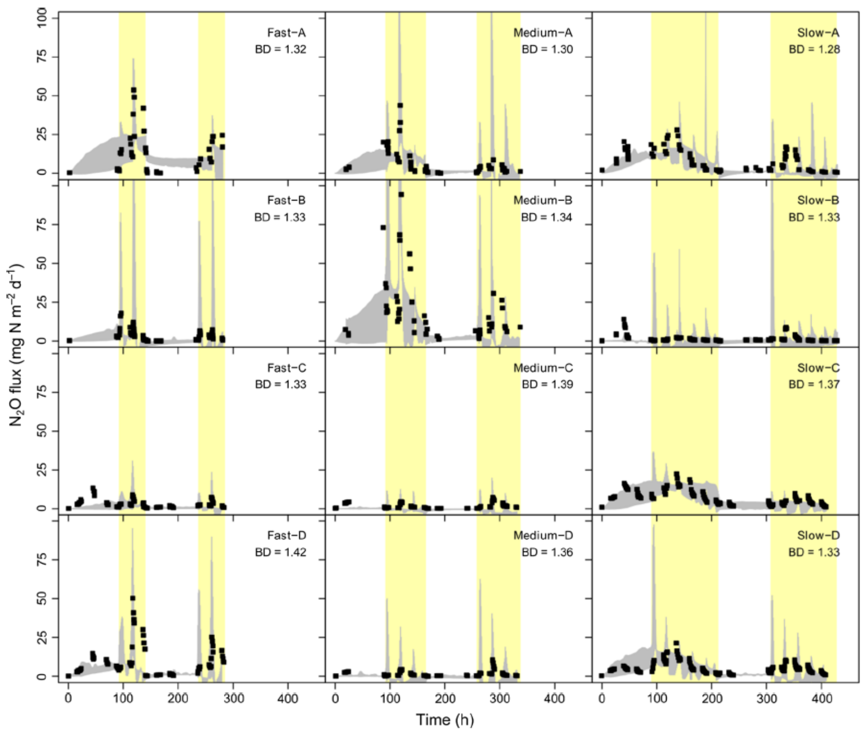



**Fig. 5** Measured (*black squares*) and 95 % confidence interval of simulated $N_2O$ fluxes (*grey areas*). Sample names refer to the number of decreasing pressure heads applied during one wetting–drying cycle (Fast: 3 values, Medium: 4 values, Slow: 6 values, *BD* bulk density in g cm$^{-3}$). *Yellow areas* represent the drying phases, and *white areas* the wetting phases. (Color figure online)

***Rabot et al. 2015 – Biogeochemistry***

# CONCLUSIONS

- Great interest of dynamic studies : they have revealed peaks of $N_2O$ emissions during the drying phase of wetting-drying cycles

- To continue to characterise soil structure, pore soil network. This is probably a key for understanding soil emissions dynamics (our study could be improved by higher resolution tomography) and intensity.

- To continue to define some physical indicators of soil structure and to introduce them in modeling