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

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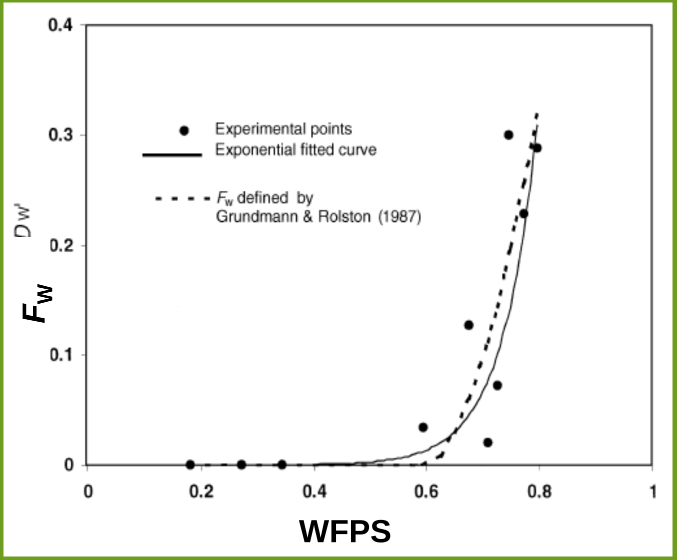
INTRODUCTION

- 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 …

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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}

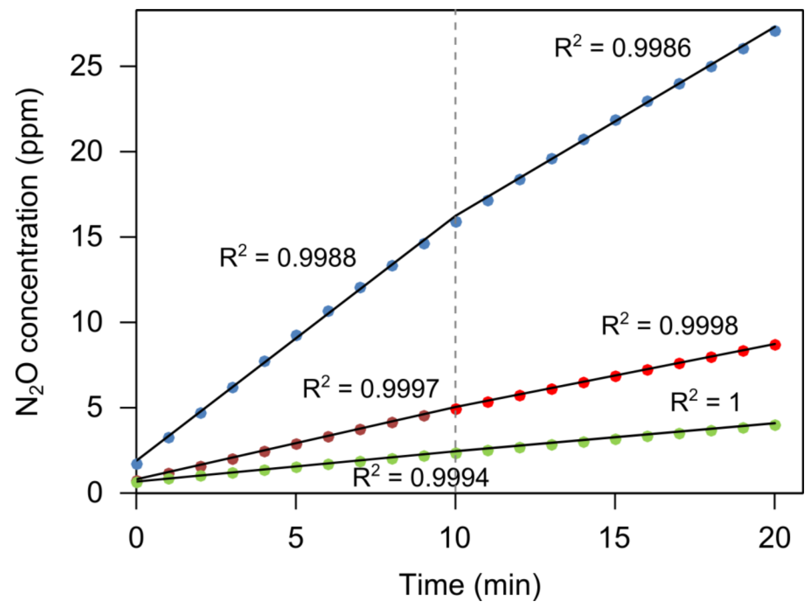
Soil sampling

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

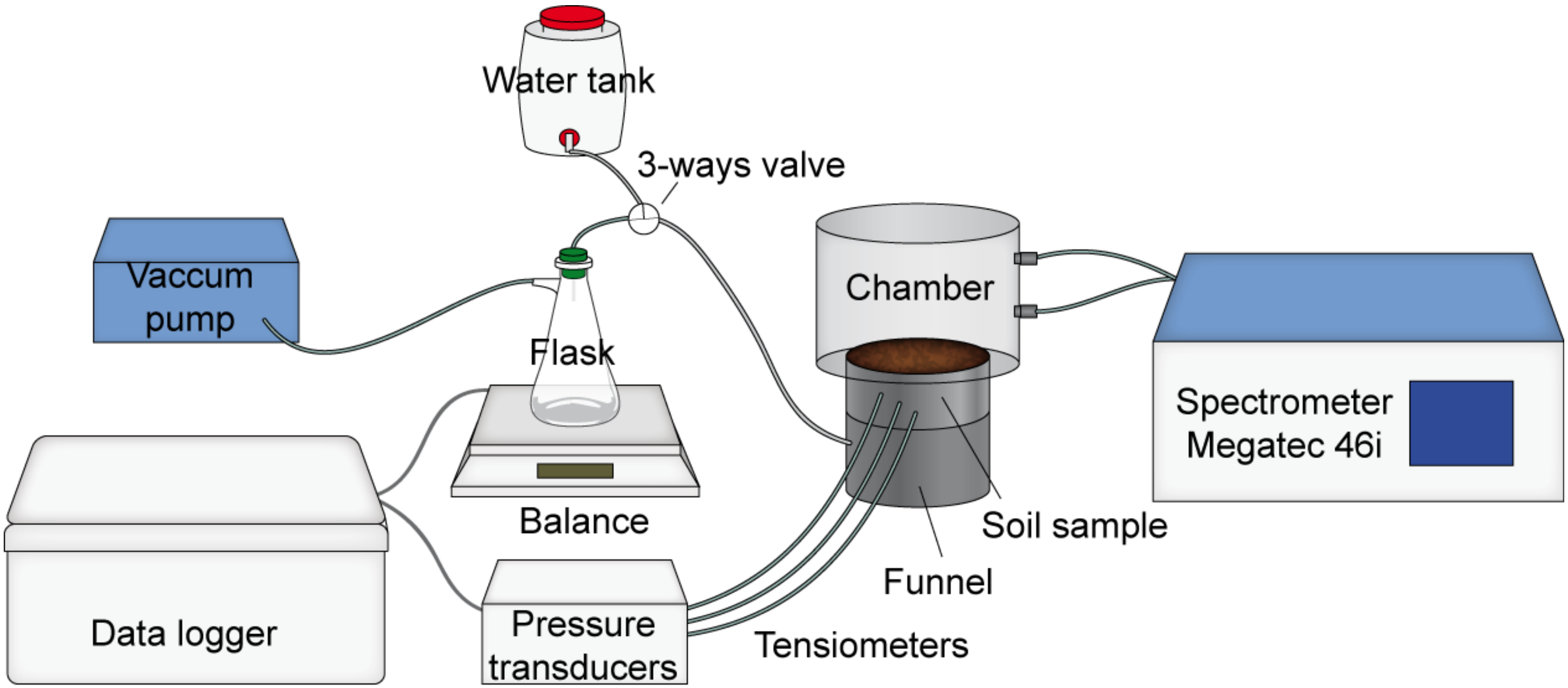
- **Closed-chamber method**
- **N_2O monitoring: infrared correlation spectroscopy (N_2O Analyzer model 46i, Thermo Scientific), detection limit 0.02 ppm, concentration value recorded every minute**
- **Flux calculated linearly from the observed change in N_2O concentration during the first 10 min after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



Materials and Methods

Hydric control

Multistep outflow system

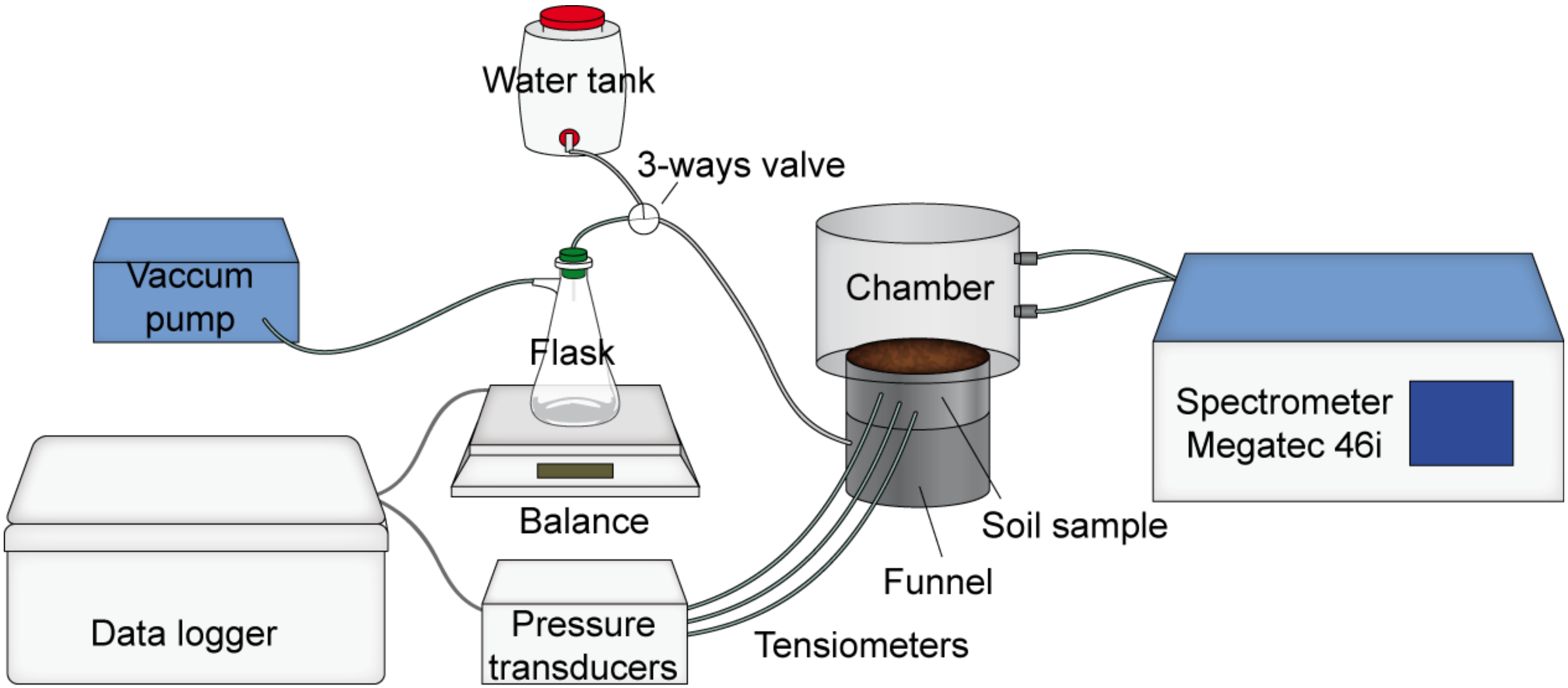


Materials and Methods

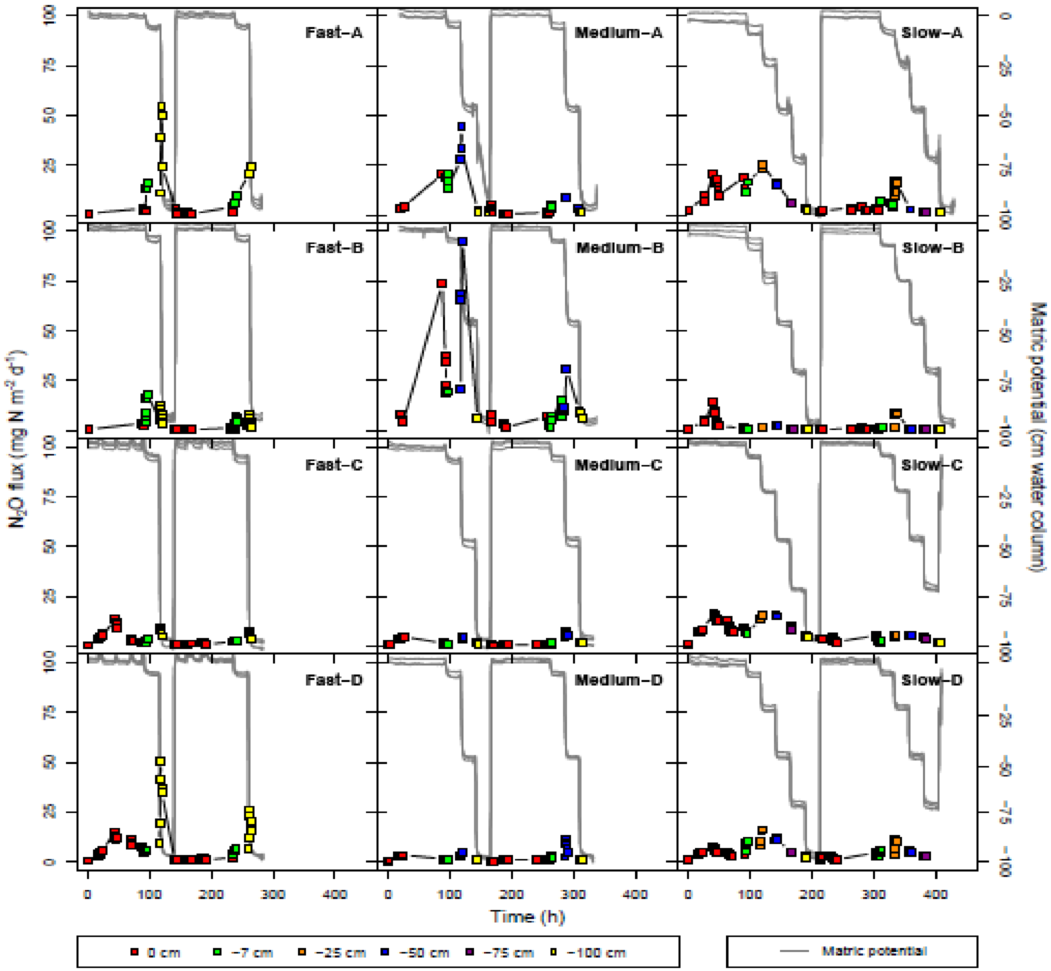
Hydric control

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

Multistep outflow system



Results and Discussion



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- 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

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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

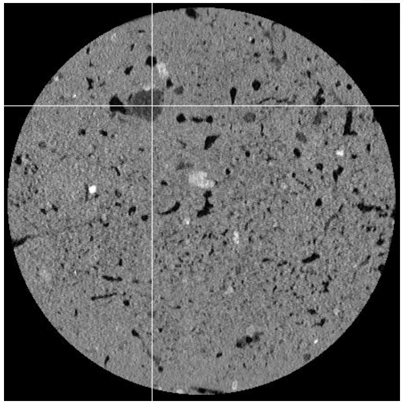
- **1 scan at the end of the wetting phase**
- **7 to 9 scans during the drying phase**

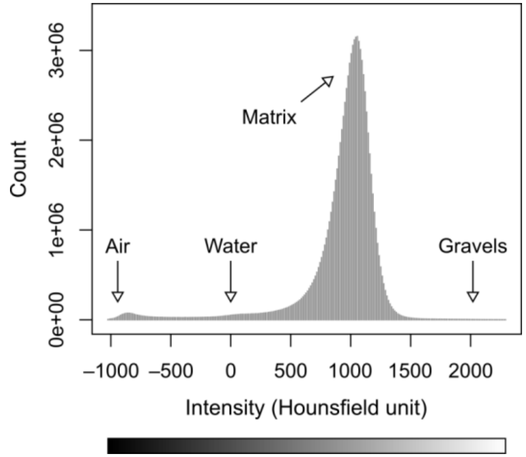
Alternating with N_2O measurements

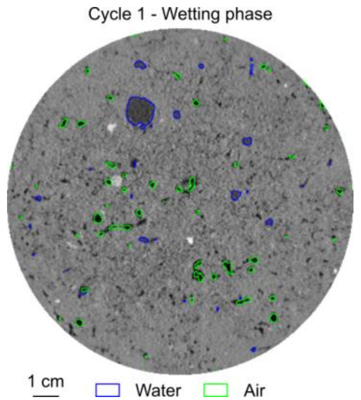
Materials and Methods

Image analysis

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

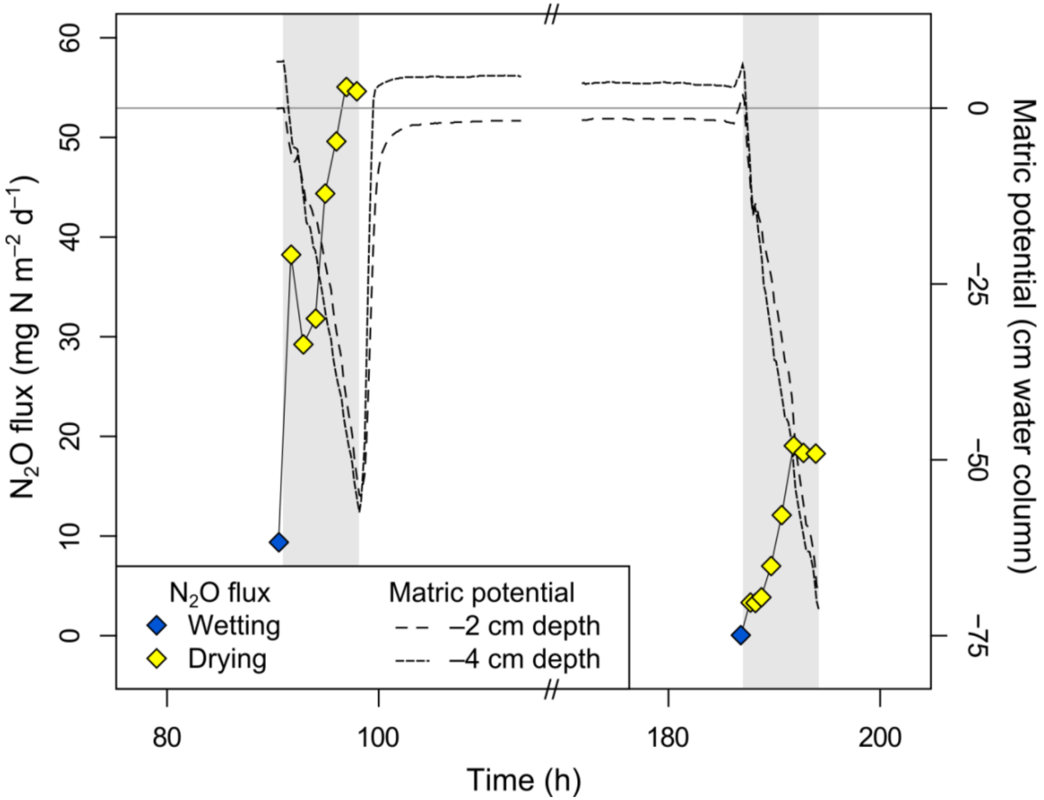






- Description of the pore network geometry : Image J software, C/C++ Quantlm library (Vogel, 2008)
  - Volume of air-filled and water-filled macropores
  - Euler number : connectivity of the air-filled pore space (vogel et al., 2010)
- Functionning description
  - Relative gas diffusion coefficient (DS/D0)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

Results and discussion



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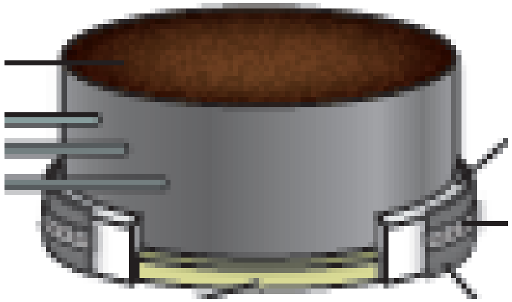
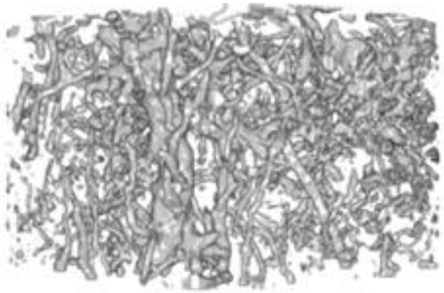
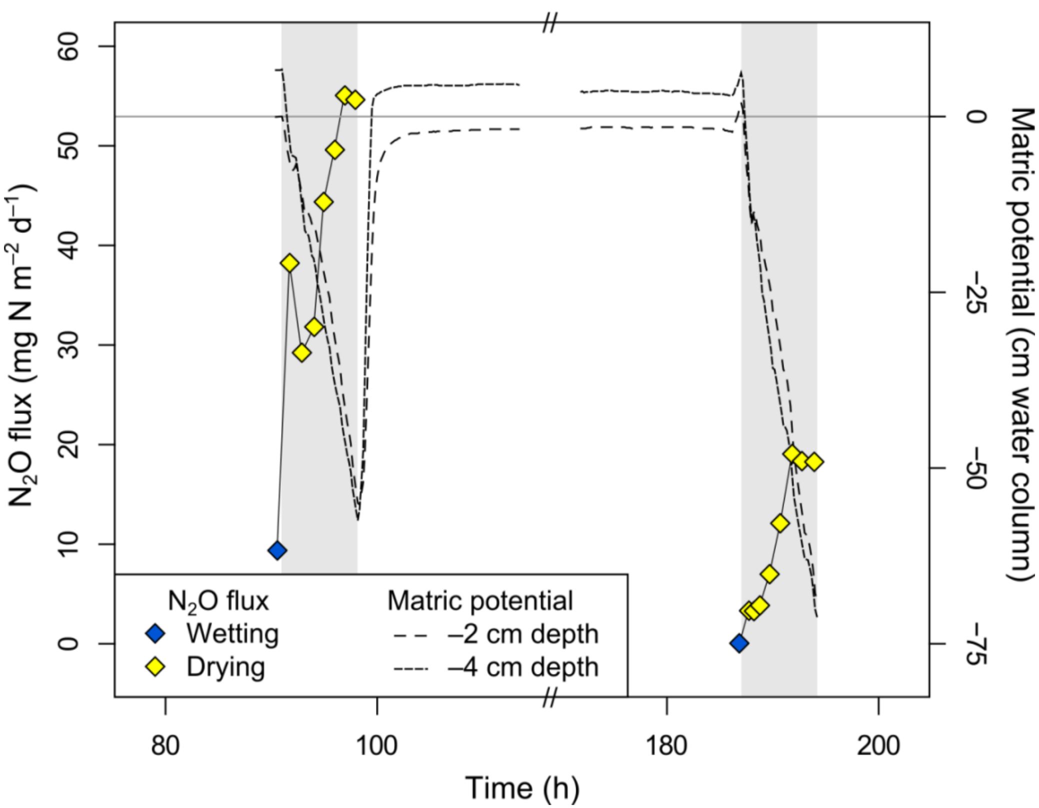
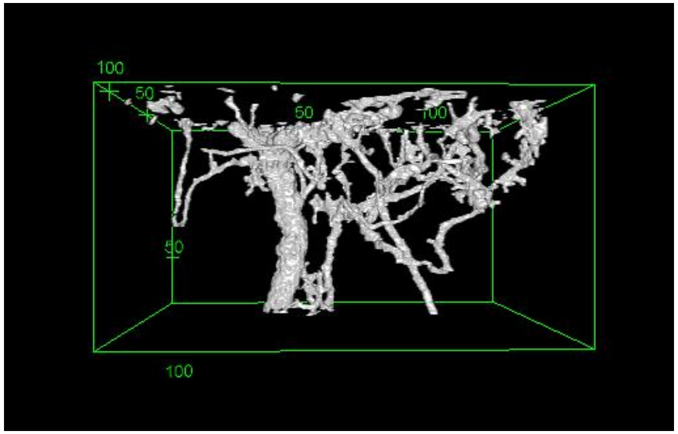
Results and discussion









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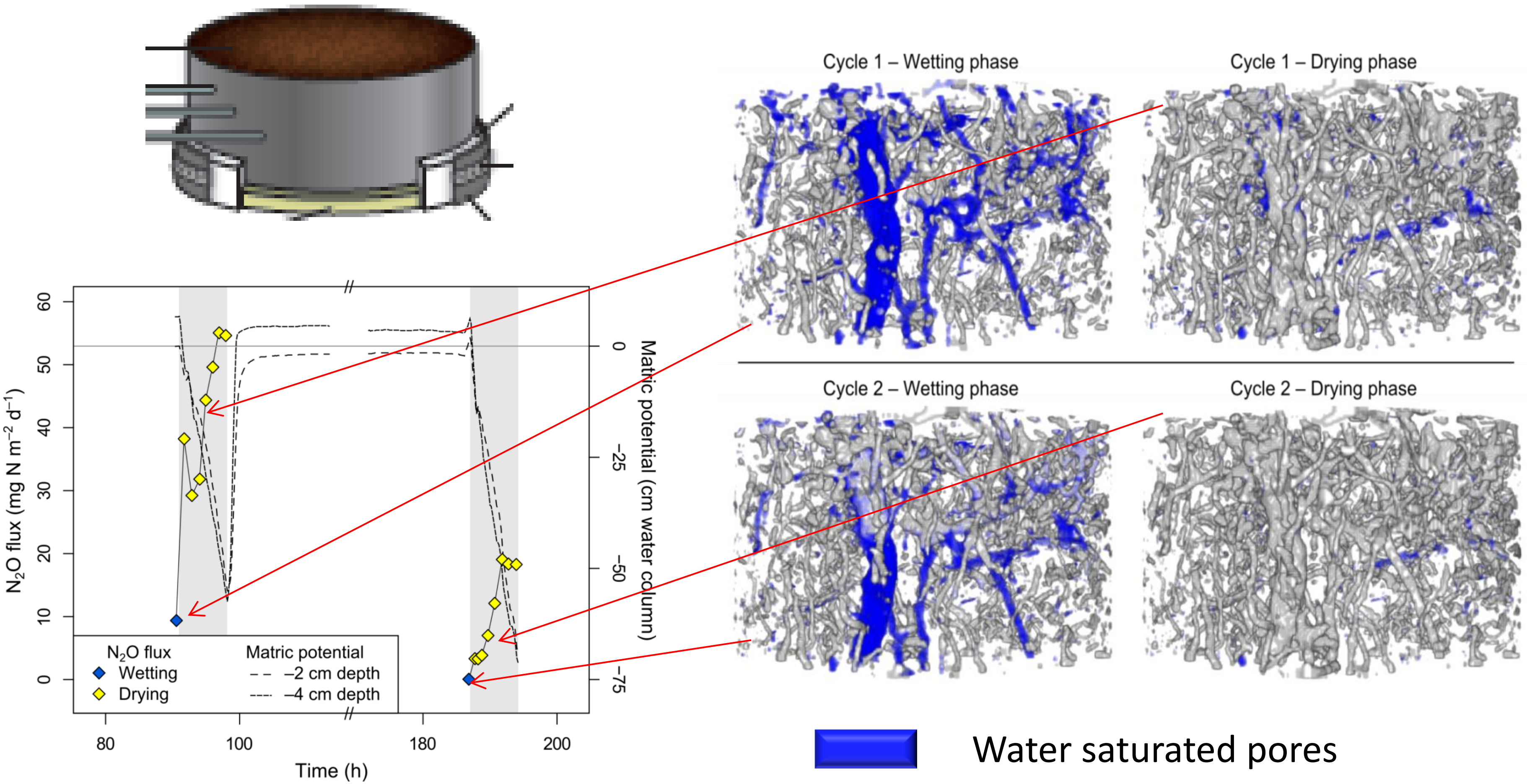

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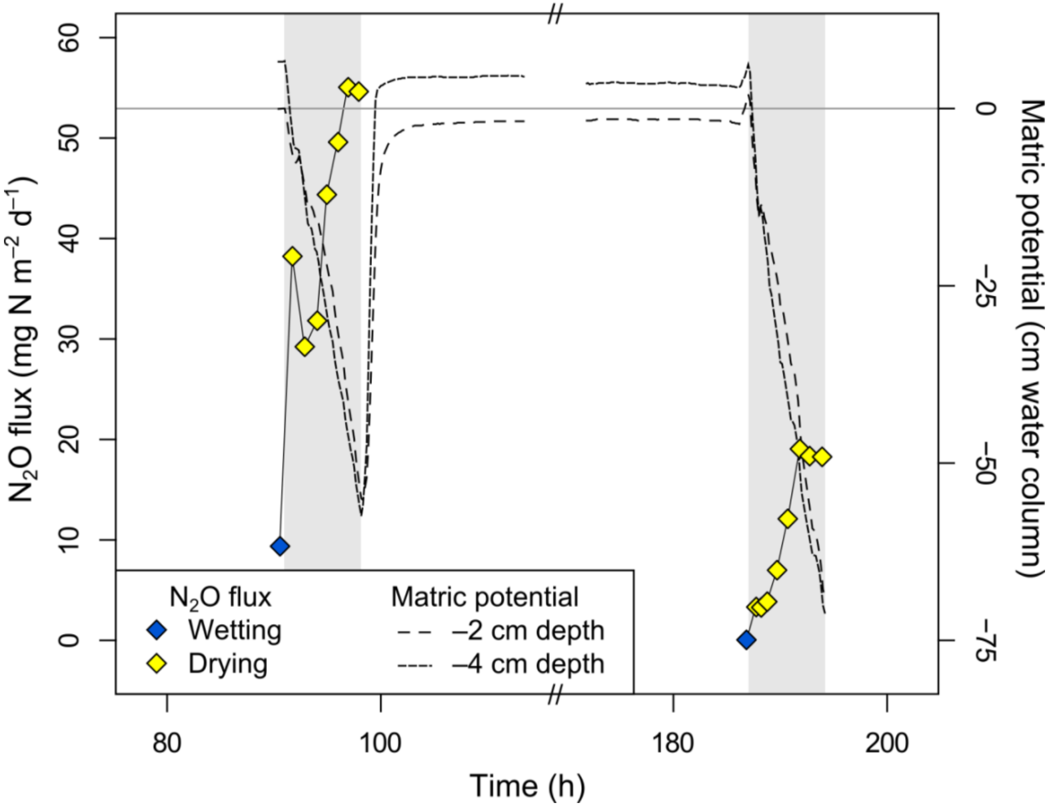

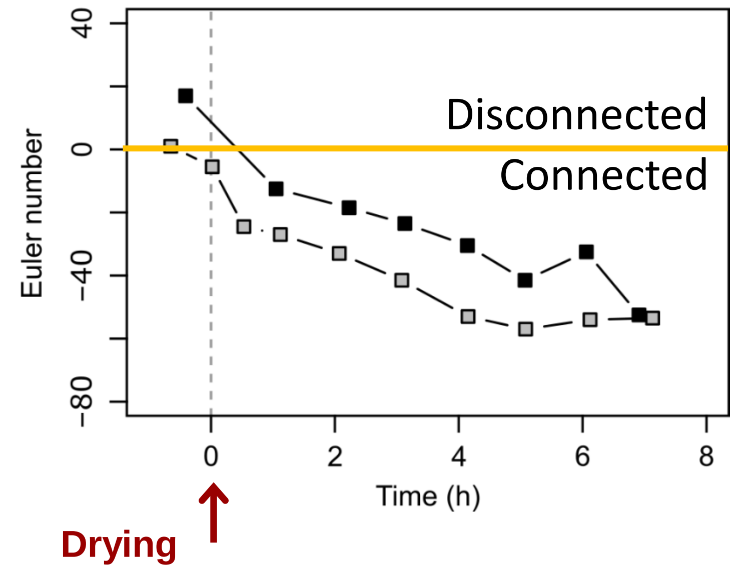

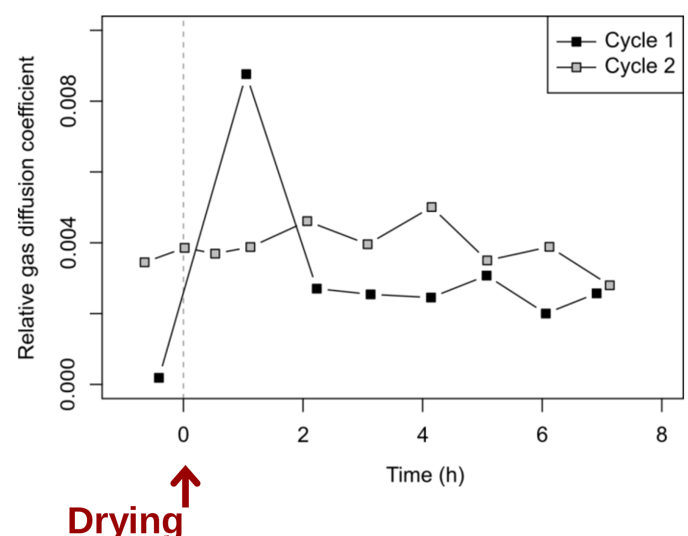

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Modeling of this new knowledges

Materials and Methods

The NOE ALGORITHM

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

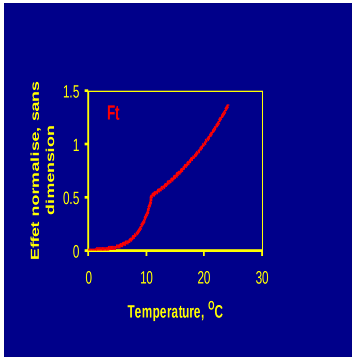
$$N_2O = (N_2O)_{denit} + (N_2O)_{nit}$$

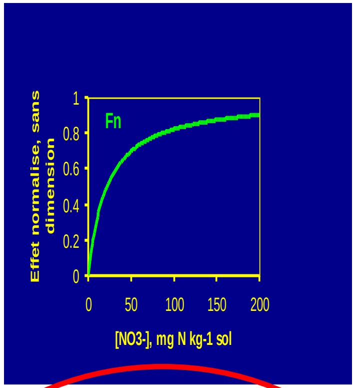
- denit = K . F_T . F_{NO3-} . F_{WFPS}
  (Hénault and Germon, 2000)

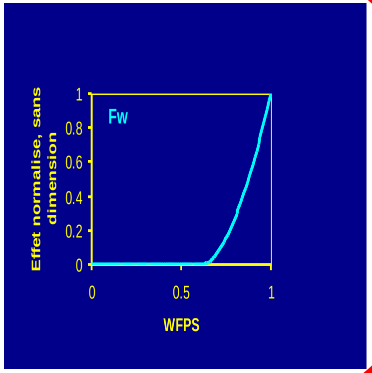
- nit = f . (H_m . $[NH_4^+]$. T)

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

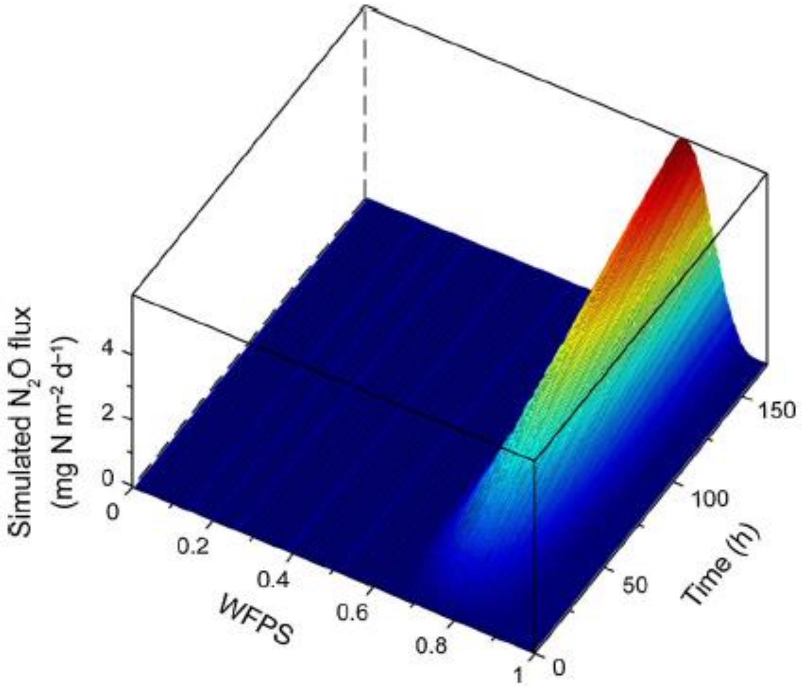


Fig. 1 Simulated nitrous oxide flux with time for water-filled pore space in the range [0, 1]. At time = 0 h, initial conditions were applied. For the next time increments, the nitrous oxide production module, and the gas transport and equilibrium modules were activated

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Experimental evaluation

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

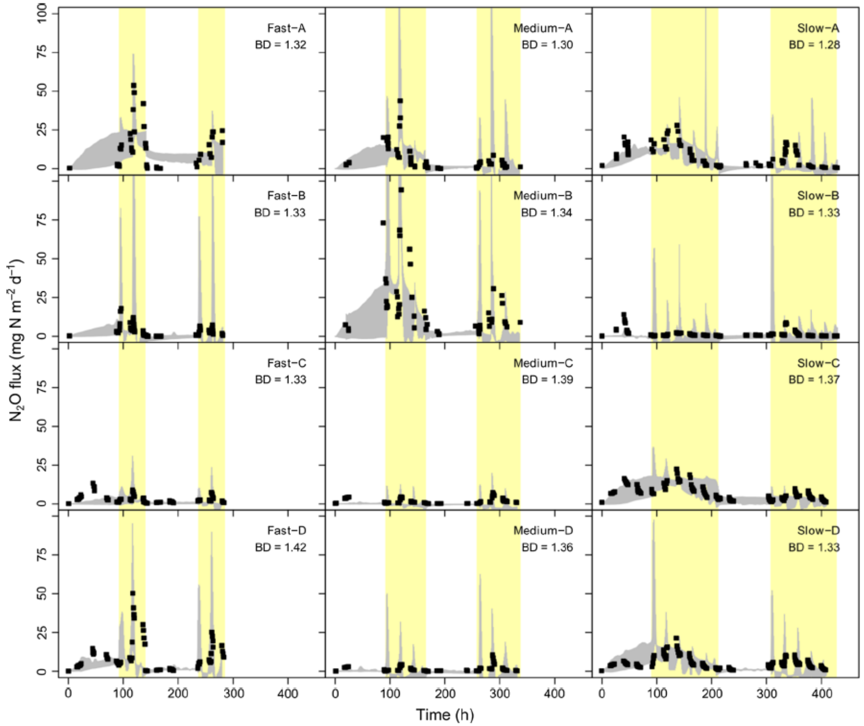

Fig. 5 Measured (*black squares*) and 95 % confidence interval of simulated N_2O fluxes (*grey areas*). Sample names refer to the number of decreasing pressure heads applied during one wetting–drying cycle (Fast: 3 values, Medium: 4 values, Slow: 6 values, *BD* bulk density in g cm^{-3}). *Yellow areas*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

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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