AGU 100 ADVANCING EARTH AND SPACE SCIENCE | **FALL MEETING**
San Francisco, CA | 9–13 December 2019

# ID: H53N-2004

# Physical, chemical and biological controls on surface-gas fluxes quantified with high-resolution monitoring of multiple tracers


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## I- BACKGROUND RESEARCH: Gas fluxes at the soil-atmosphere interface

### Aim of the research

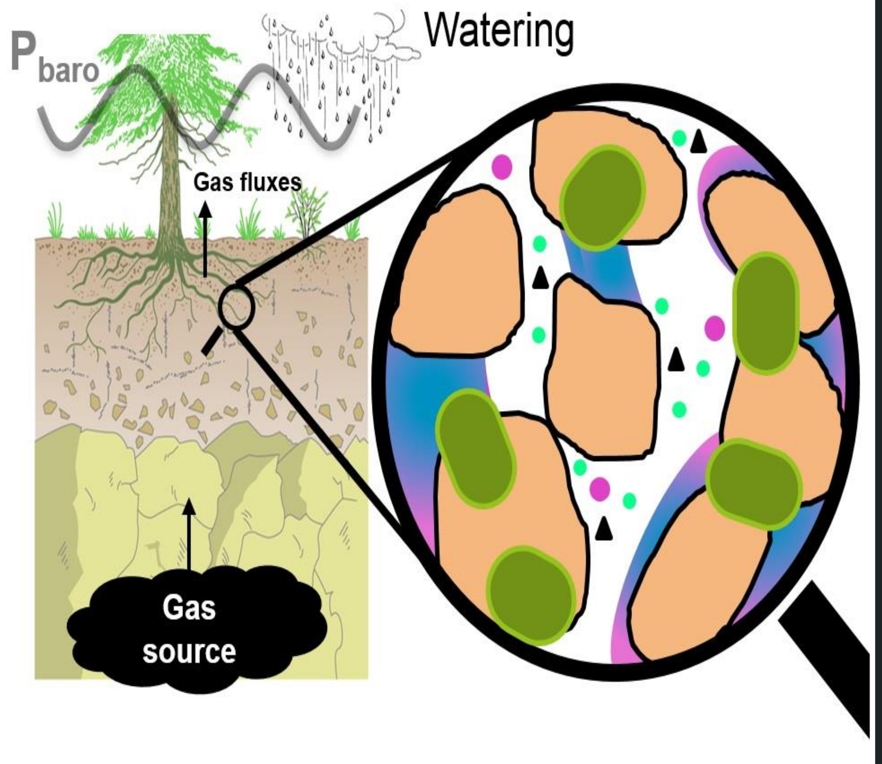
**Gas transport** in soils is **highly variable in space and time** leading to **modulations of gas fluxes** at the **soil-atmosphere interface** that must be understood

### Flux variability due to

- Nature and localization of gas source
- Soil permeability and porosity
- Barometric pressure fluctuations
- Water content and capillary pressures
- Respiration and biomass degradation

### Applications

Discrete **flux measurements are integrated in space and/or time to detect, identify or monitor subsurface gas sources** such as:
*$CO_2$ sequestration reservoir, volcanic emissions, carbon release from permafrost thaw, volatile contaminant plumes, shale gas production or underground nuclear explosions*




## II- EXPERIMENTAL SET-UP: Long-term and high-resolution monitoring

### Controlled experimental conditions

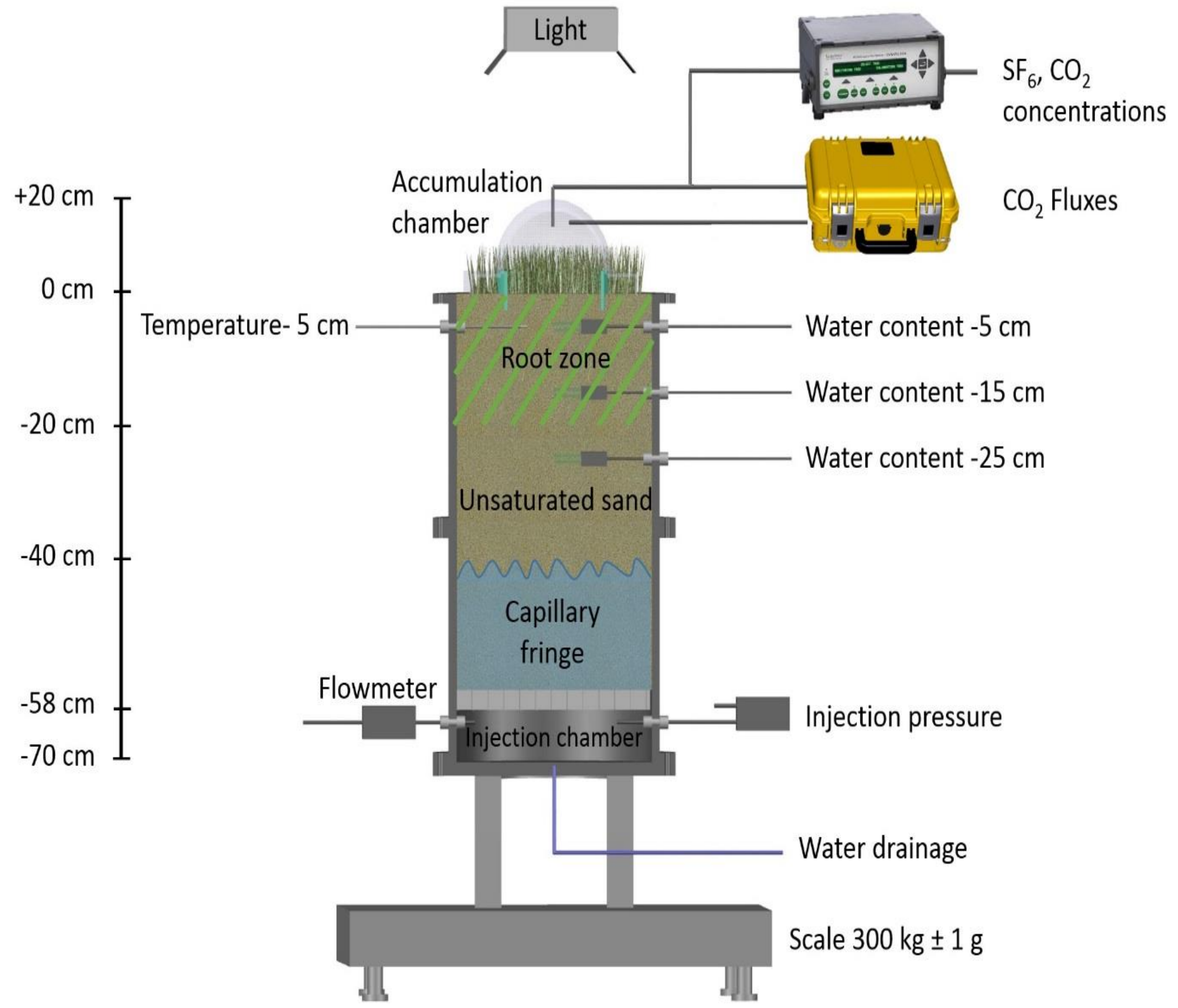
- In climatic chamber at the ECOTRON-IDF
- Constant temperature
- Barometric pressure
- Atmosphere renewal
- Diurnal light cycle and Periodic watering

### Unsaturated soil column experiment

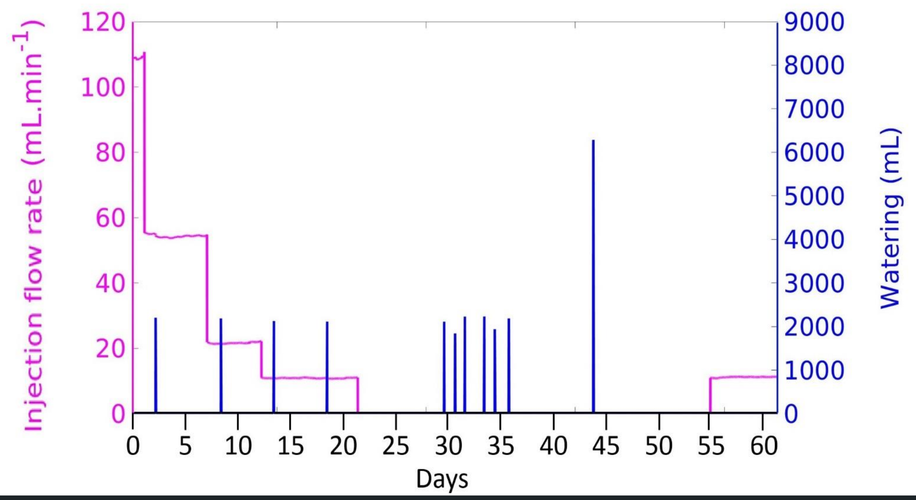
- Pure Fontainebleau sand
- 2 Columns: 1 with bare soil, 1 with plants
- Unsaturated porous media with water
- Water content profile monitoring

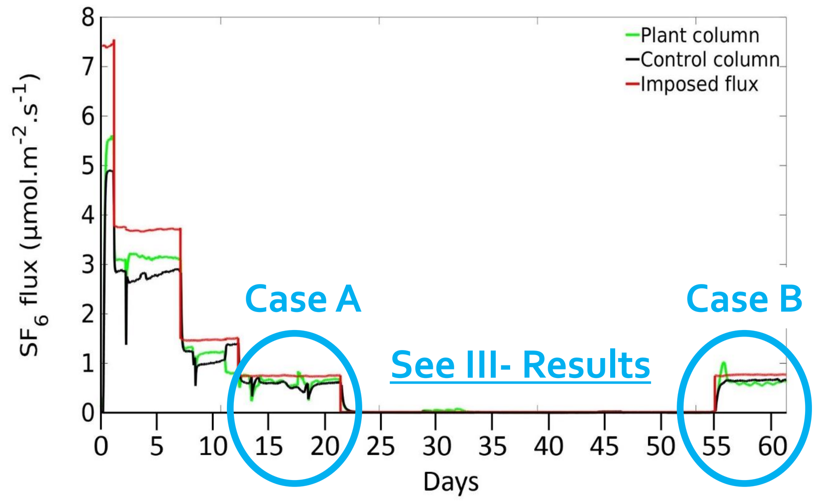
### Gas percolation and flux measurements

- Constant injection flow-rate of 10,000ppm $SF_6$ in $N_2,O_2$
- Pressure gradient monitoring between injection chamber and atmosphere
- Flux measurements of $SF_6$ and $CO_2$ by accumulation chamber



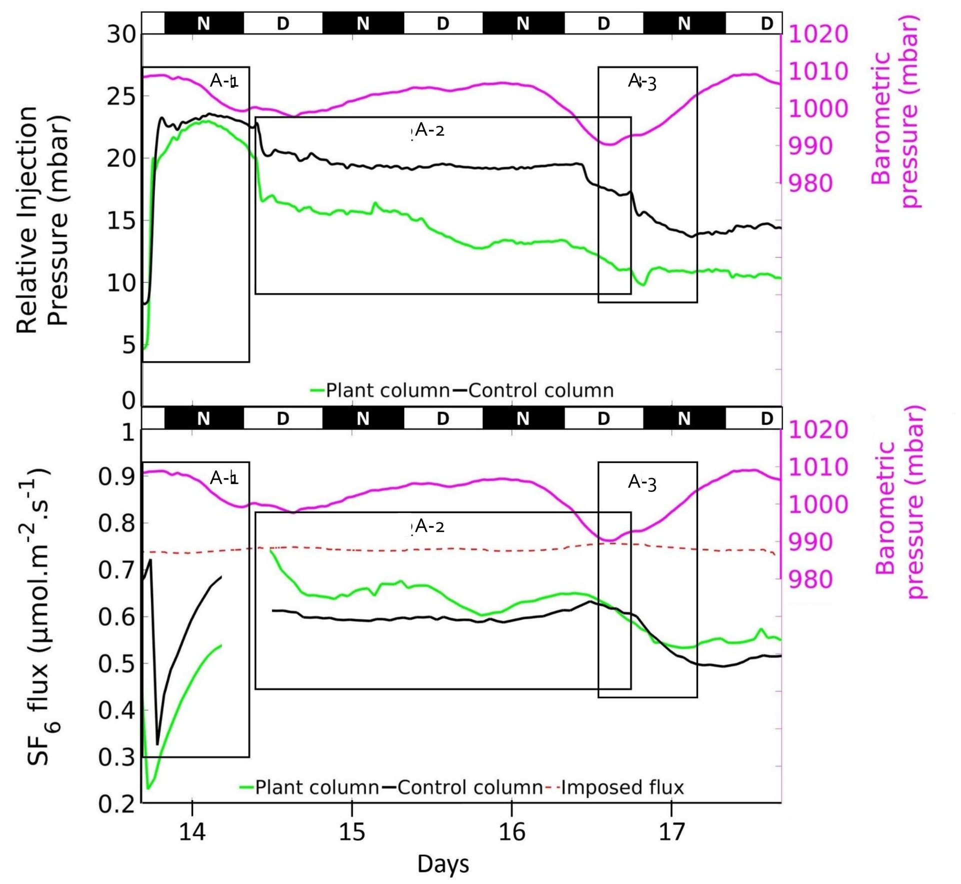

### More than 60 days of experimentation, Flux measurements at 1 hour time-step, Experimental conditions monitoring at 5 minutes time-step

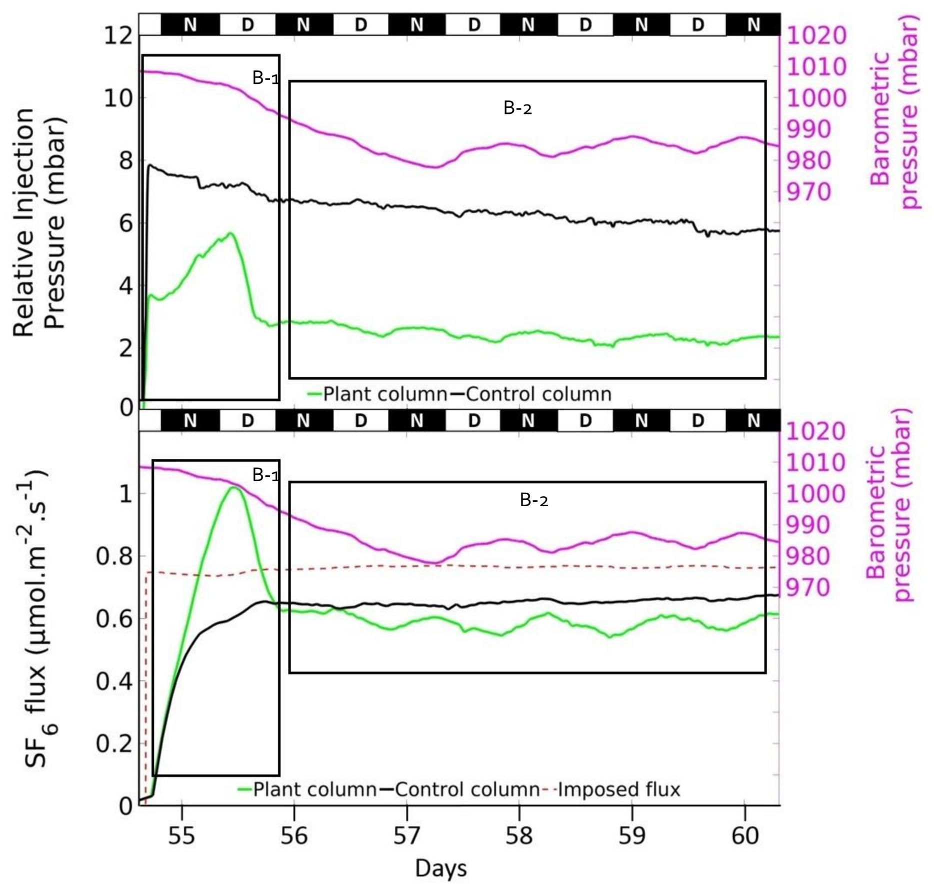



## III- RESULTS

### First order variations mainly physical and chemical



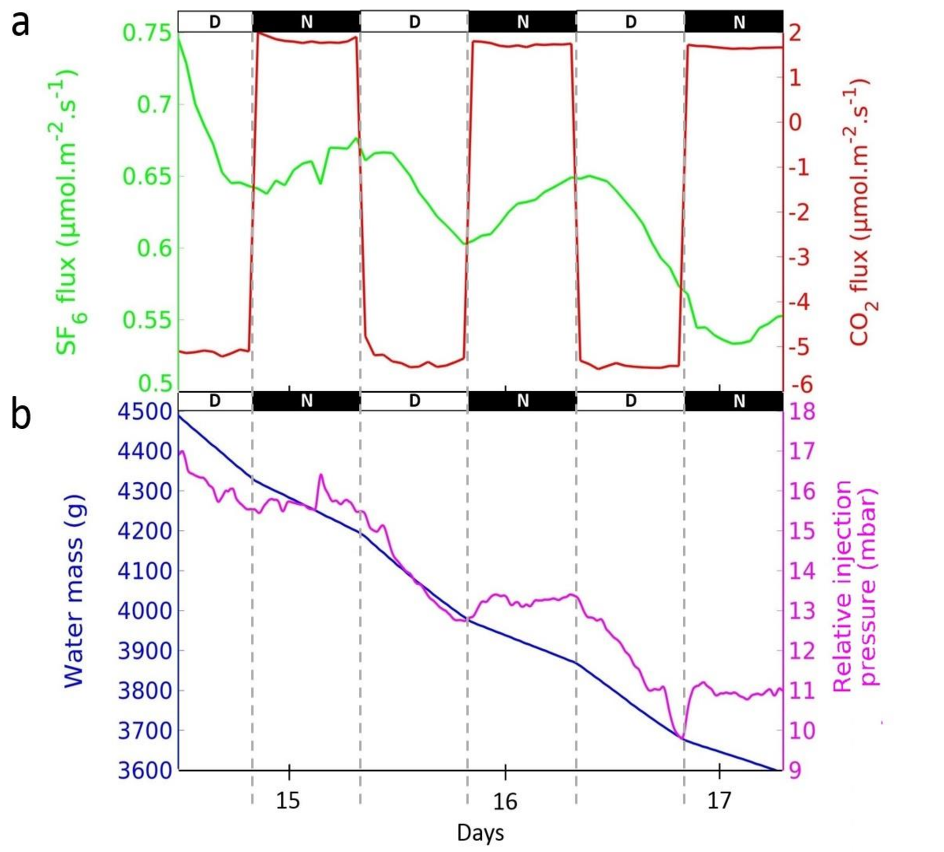



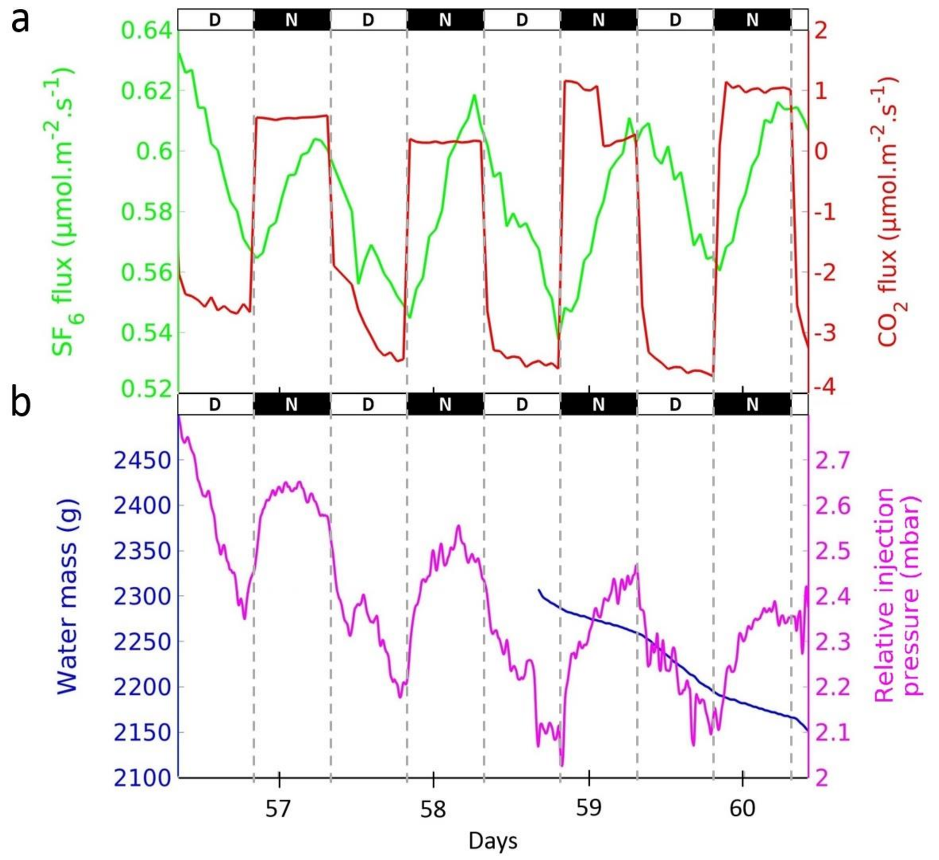

- A-1: Watering + overflow
- A-2: Evapotranspiration or evaporation
- A-3: Increase of barometric pressure

- B-1: Sudden overflow due to switching injection from diffusion to advection regime
- B-2: Steady state regime reached

Main processes : **1) Water budget, 2) Barometric pressure, 3) Injection pressure, 4) Solubility ?**
What are those **modulations** appearing on fluxes for the **plant column** ?

### Second order variations due to diurnal biological activities: evapotranspiration and respiration




**DAYTIME: Water loss by evapotranspiration -> Decrease of pressure gradient -> Decrease of $SF_6$ fluxes**
*increase in gas porosity and relative air permeability. This leads to more dispersion and storage of gases in the porous medium*

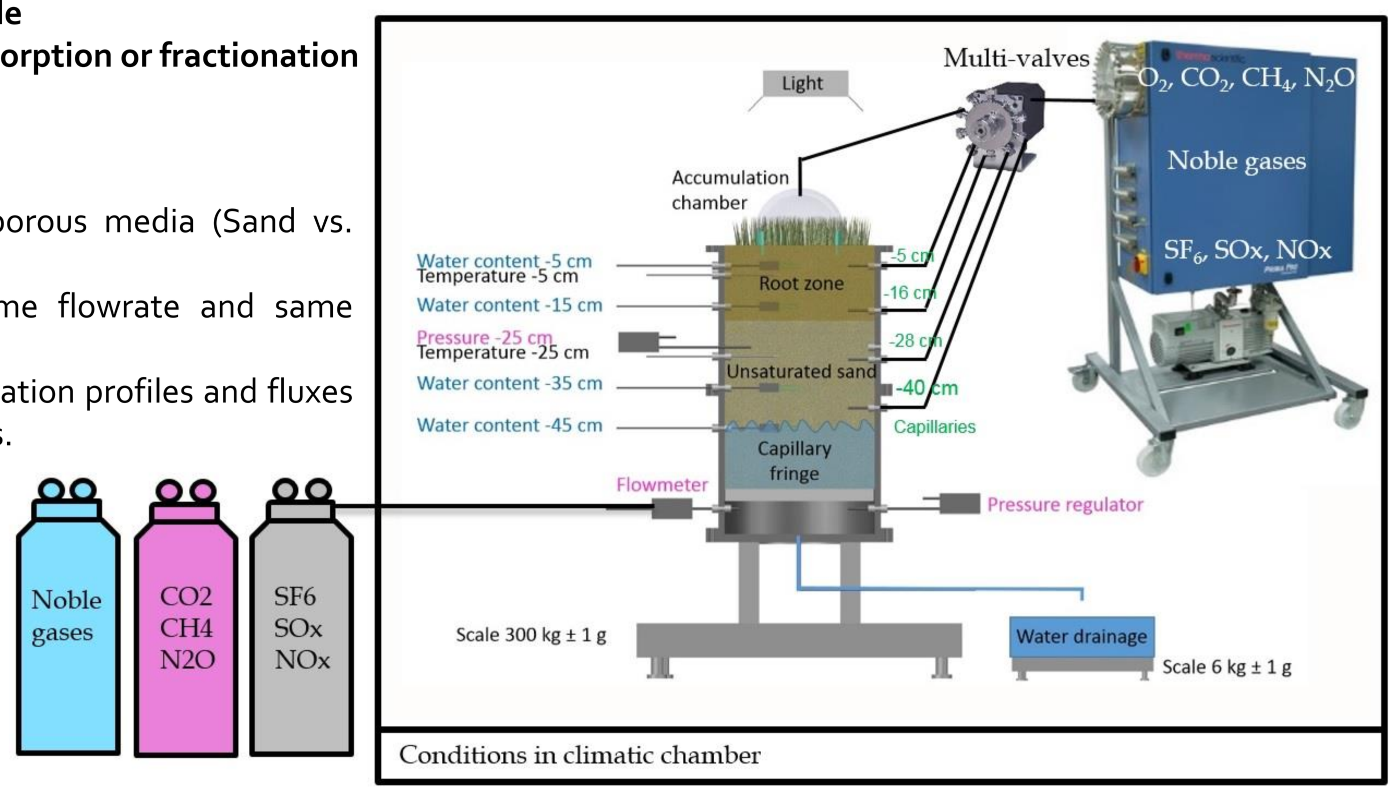
**NIGHTTIME: Respiration -> Consumption $O_2$ and production of $CO_2$ -> Increase of $SF_6$ fluxes**
*i) Dissolution of $CO_2$ higher -> local decrease of partial pressure -> increase of pressure gradient between injection and root-zone*
*ii) Possibility of scavenging due to $CO_2$ fluxes.*

## IV- ON GOING EFFORT

### New experimental design to determine new processes:

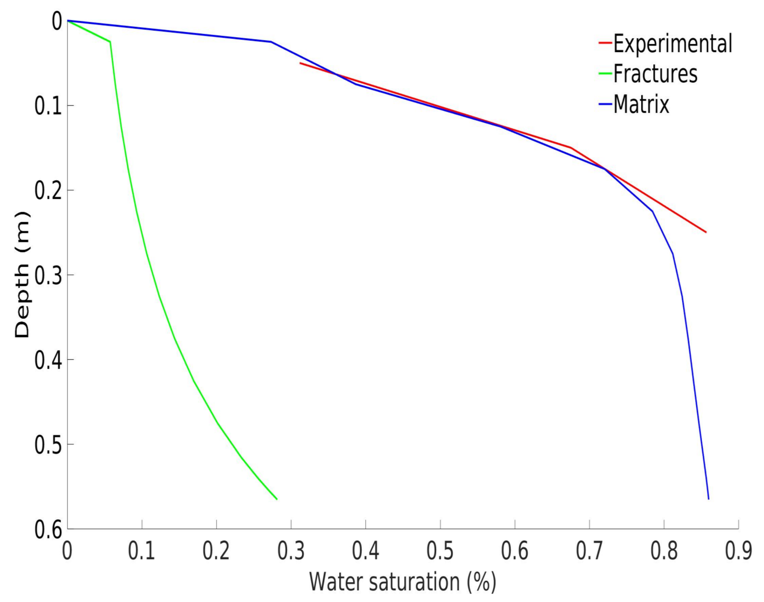
**Allows concentration profiles and multi-tracer gas experiments**
**Freeze and thaw cycle possible**
**Observation of solubility, adsorption or fractionation effects**

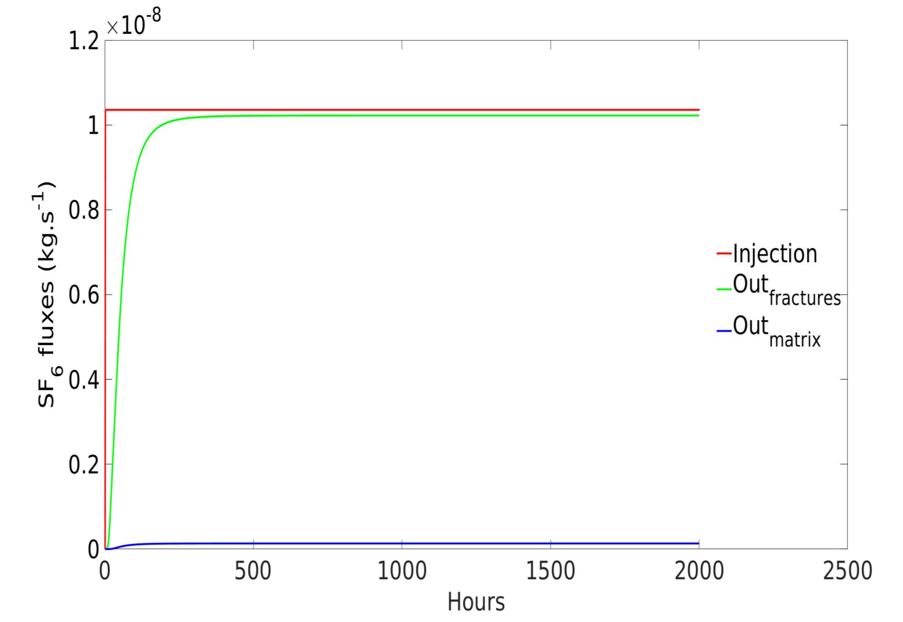
**In-coming experiment:**
2 columns with 2 different porous media (Sand vs. zeolite).
Injection of $SF_6$ and Xe: same flowrate and same concentration.
Observe evolution of concentration profiles and fluxes by comparing the two columns.




### Modelisation with NUFT code:

**Quantify processes brought to light with experiments (water budget variations, barometric pressure variations, solubility).**
**Double-permeability approach to mimic gas preferential path**
**First results obtained for a steady-state regim and unsaturated sand column at equilibrium**




## V- CONCLUSION

- New experimental set-up for long-term and high-resolution monitoring of gas percolations under controlled conditions in unsaturated columns, including plant growth.
- Large dynamical response of gas fluxes at the soil-atmosphere due to combined physical, chemical and biological controls acting mainly on pressure gradient.
- Nighttime-daytime gas flux modulations due to the combined effects of plant root respiration and photosynthesis-related evapotranspiration.

## REFERENCE AND ACKNOWLEDGEMENTS


Alibert C., Pili E., Barre P., Massol F., Chollet S. (2019) Biologically-controlled gas fluxes revealed by high-resolution monitoring of unsaturated soil columns. *Vadose Zone Journal*. (Submitted and under review)



This study was carried out in the framework of the LRC Yves-Rocard joint laboratory between CEA and ENS. This work also benefited from technical and human resources provided by the CNRS IR ECOTRONS and CEREEP-Ecotron IleDeFrance (CNRS/ENS UMS 3194). At Lawrence Livermore National Laboratory, this work was supported by the U.S. Department of Energy under contract DE-AC52-07NA27344. C.R. Carrigan also thanks the Lawrence Livermore Professional Research and Teaching Program and the Office of Proliferation Detection (NA-221), U.S. Department of Energy for supporting his contributions to this study.