

Triple isotopic composition of oxygen in the atmospheric dioxygen to reconstruct the dynamic of global biosphere productivity in the past from measurements in biological chambers



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The aim of the thesis (10/2020 - 10/2023)

- Improve the interpretation of the isotopic composition of the dioxygen trapped in the air bubbles in the ice cores (European Project : Beyond Epica)
- Reconstruct the past biospheric productivity
- $\delta^{18}\text{O}$ of O_2 / $\Delta^{17}\text{O}$ of O_2 measurements
 - $\Delta^{17}\text{O}$ of O_2 is the ^{17}O anomaly in the atmosphere : $\Delta^{17}\text{O} = \ln(1 + \delta^{17}\text{O}) - 0,516 \times \ln(1 + \delta^{18}\text{O})$
- Work on experiments in closed controlled biological chambers
- Study the fractionations during biological processes: respiration and photosynthesis
- Partnership : LSCE / ECOTRON Montpellier

1) Determination of O_2 fractionation coefficients in closed chamber (IRMS)

Biological chamber

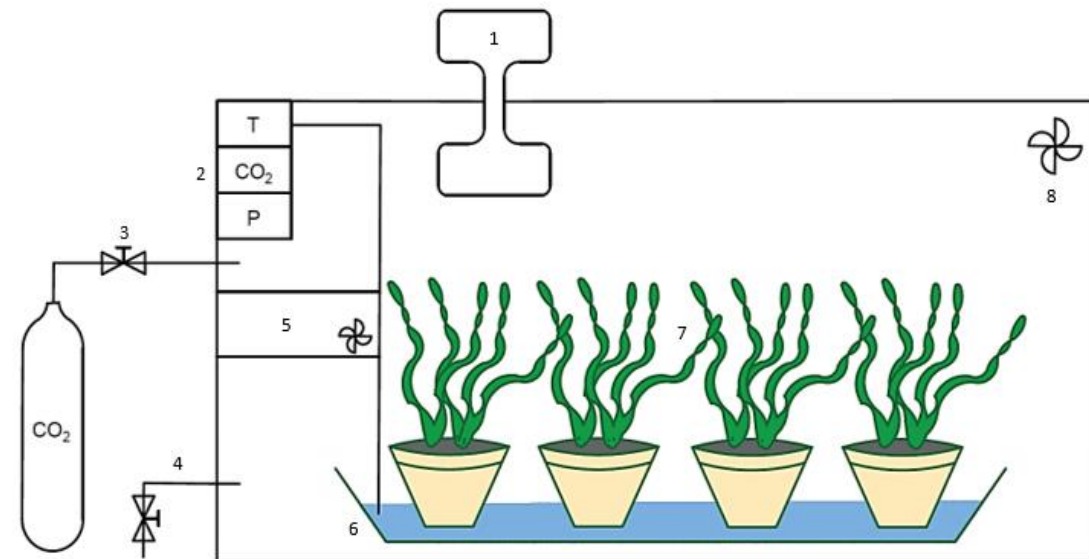
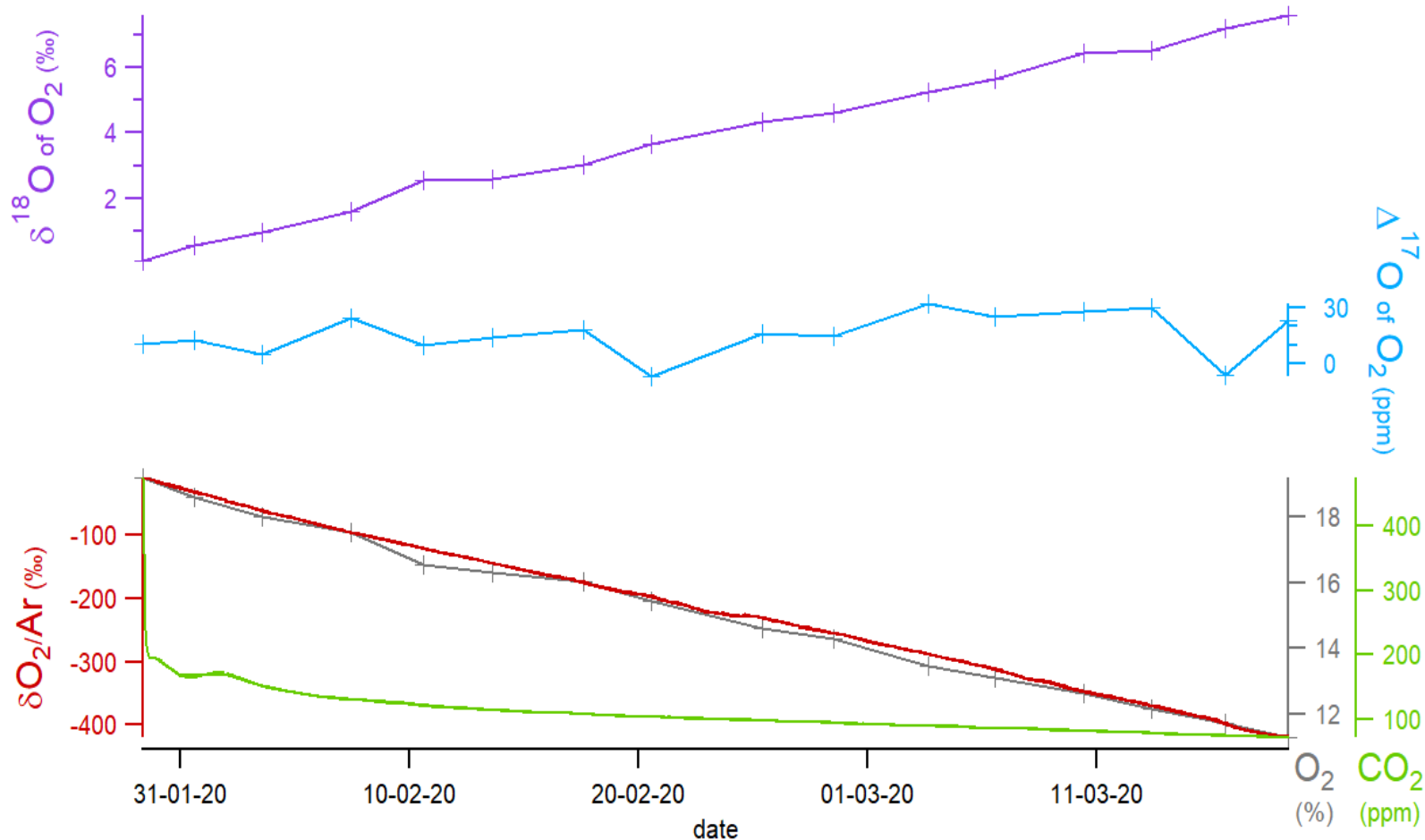


FIG.1 Scheme of the microcosm used for the terrestrial biosphere model (1: Tedlar bags 2 : CO₂, temperature and pressure sensors 3 : CO₂ injection valve 4 : sample collection valve 5 : Heat exchanger, connected to the temperature sensor 6 : water bath, heated by the heat exchanger 7 : *Festuca arundinacea* plants 8 : Fan

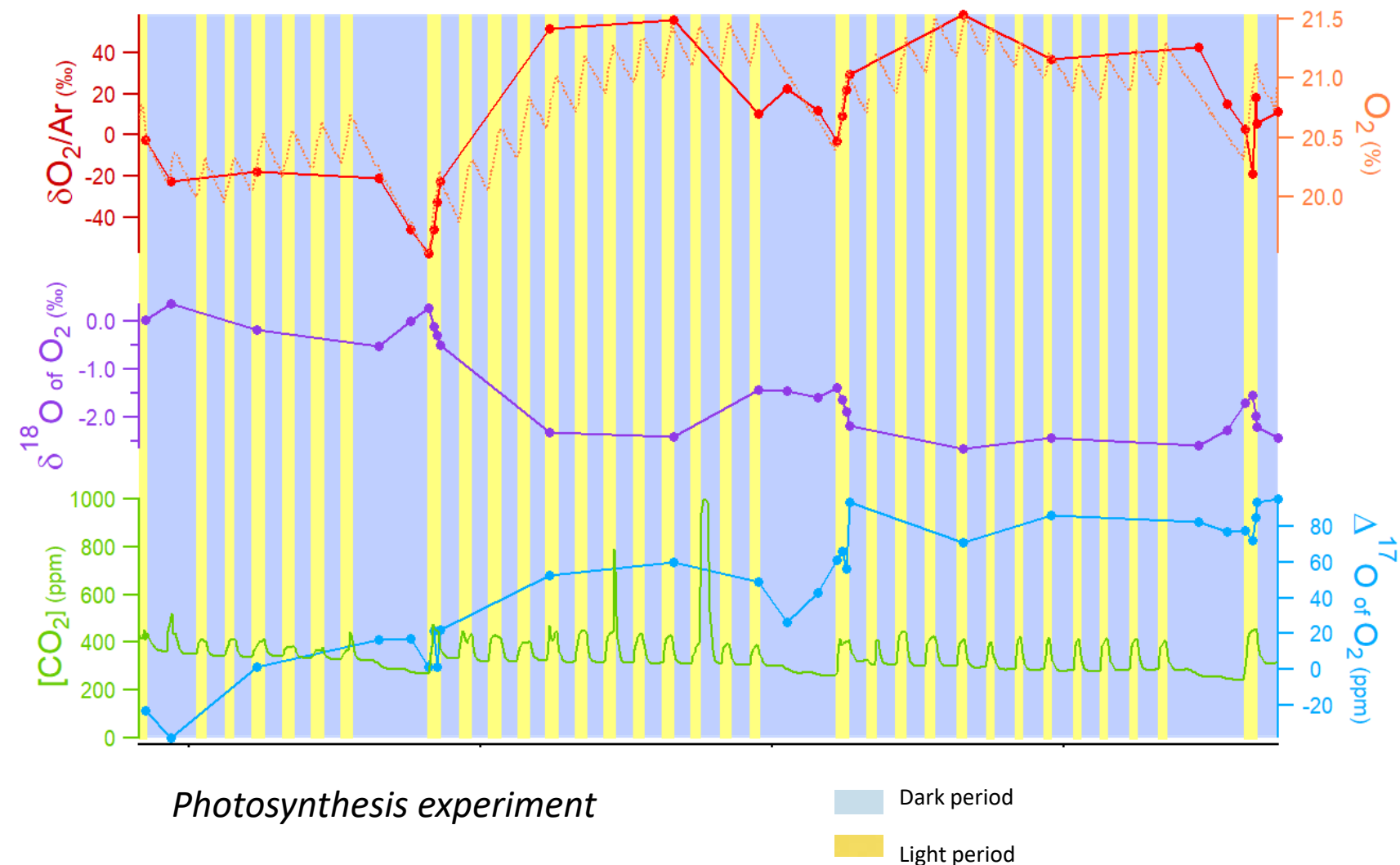
- Closed biological chamber
- Climatic parameters controlled : temperature, humidity, pCO₂, pressure, light intensity

Soil respiration experiments



- 4 replicates
- Each experiment : 1 month
- Interpretation :
 - Decrease of O_2/Ar : preferential assimilation of dioxygen by soil during soil respiration
 - Increase of $\delta^{18}\text{O}$ (7‰): preferential assimilation of light isotopes of oxygen by soil during respiration
 - $\Delta^{17}\text{O}$ of O_2 remains stable which is expected from pure respiration
 - the slope used to define it is the one characterizing relationship between ^{17}O and ^{18}O during respiration

Photosynthesis experiments



- 3 replicates
- Each experiment : 6 weeks
- Interpretation :
- Light periods :
 - Increase of O_2/Ar : liberation of dioxygen by plant in the atmosphere
 - Decrease of $\delta^{18}O$ (7‰): preferential liberation of light isotopes of oxygen during photosynthesis
 - Evolution of $\Delta^{17}O$ of O_2 of 100 ‰:
 - in the absence of stratospheric input with a negative $\Delta^{17}O$ of O_2 anomaly, the $\Delta^{17}O$ of O_2 increases toward the value characteristic of pure biosphere exchanges.
- Night periods :
 - Same as for soil respiration experiment

Coefficients fractionation of oxygen

- Determination of O₂ fractionation coefficients in closed chamber (**IRMS**)
 - Apply Rayleigh's distillation to calculate fractionation coefficients from the evolution of the isotopic composition of dioxygen in the chamber
 - Conservation of matter and isotopes for each time
 - Consider that respiration and photosynthesis fluxes are constant during the different night and day periods

$^{18}\alpha_{\text{respi_soil}}$	0.986	0.985	0.990	0.988
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The average of fractionation coefficients during soil respiration experiment

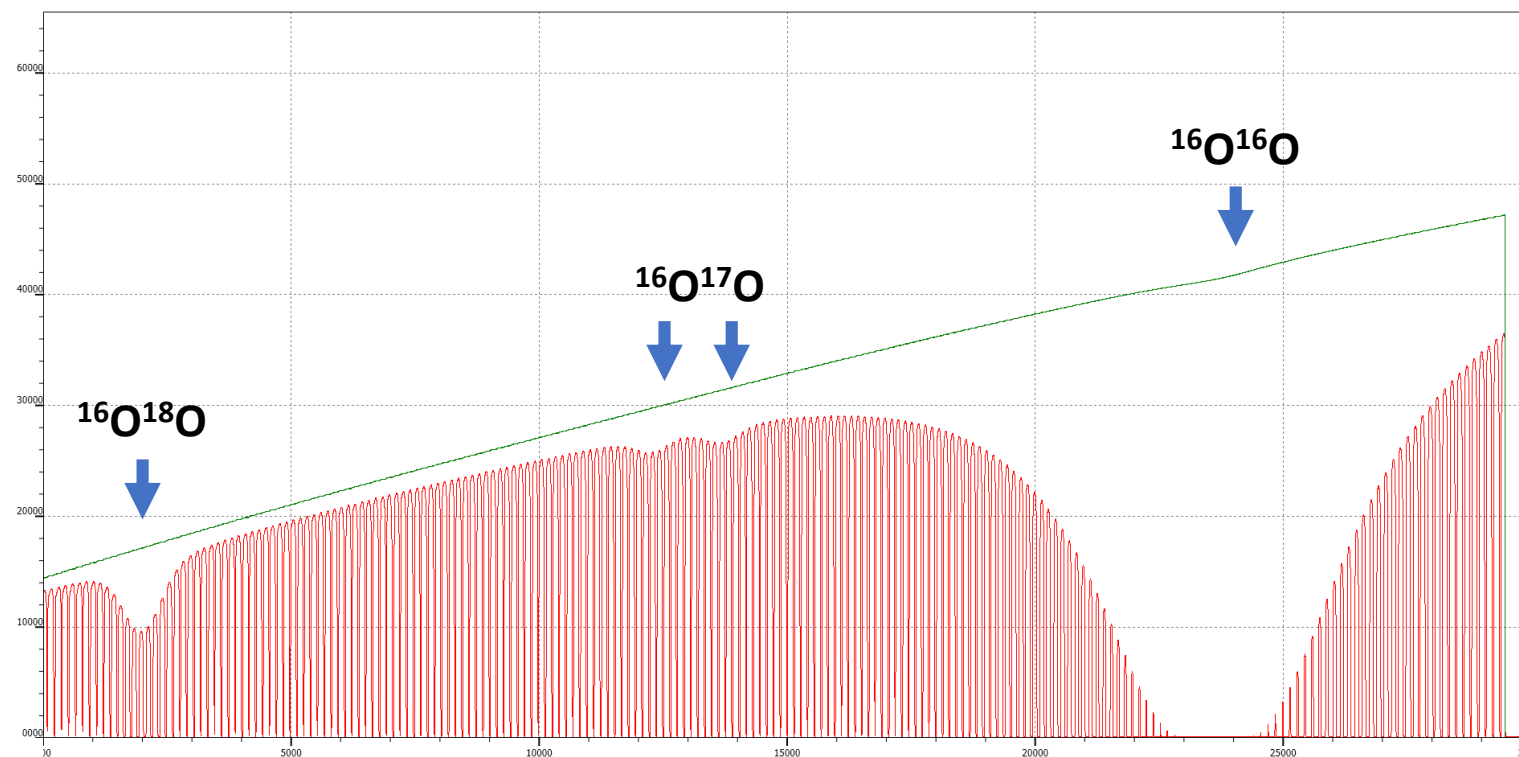
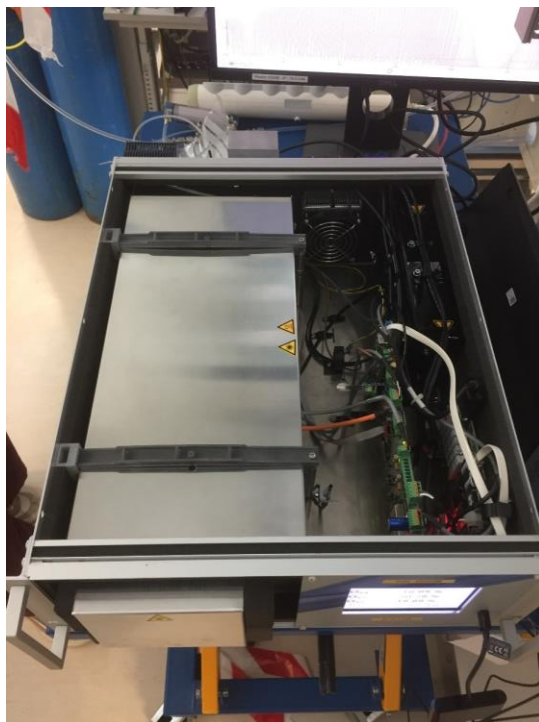
$^{18}\alpha_{\text{photo}}$	1.004	1.003	1.004
$^{18}\alpha_{\text{respi_dark}}$	0.984	0.979	0.983

The average of fractionation coefficients during photosynthesis experiment :

→ Photosynthesis fractionation during light period ($^{18}\alpha_{\text{photo}}$) and dark respiration fractionation of plant and soil during night period ($^{18}\alpha_{\text{respi_dark}}$).

2) New development : Optical Feedback – Cavity Enhanced Absorption Spectroscopy (OF-CEAS)

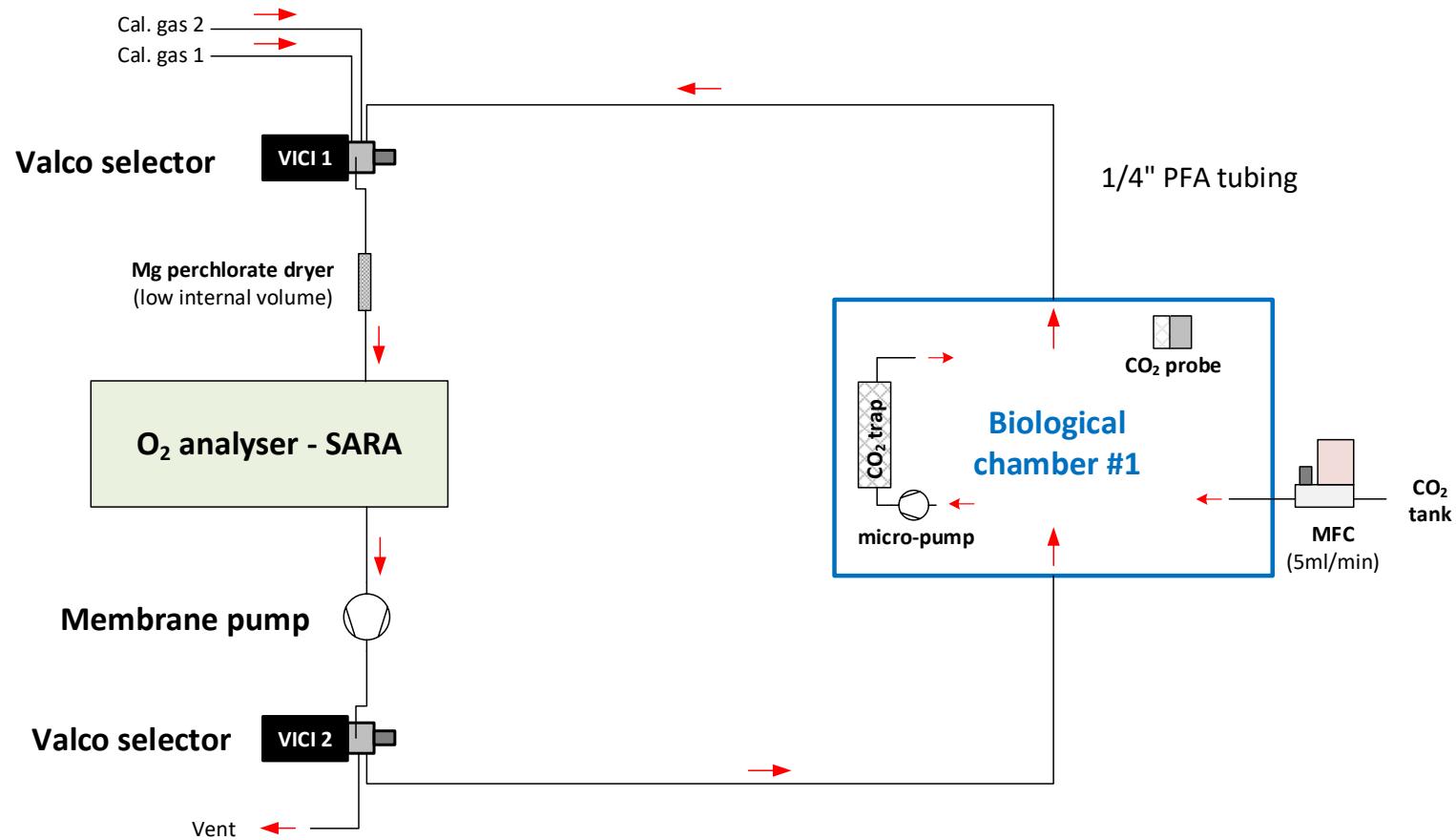
SARA-O₂ instrument



Absorption spectrum

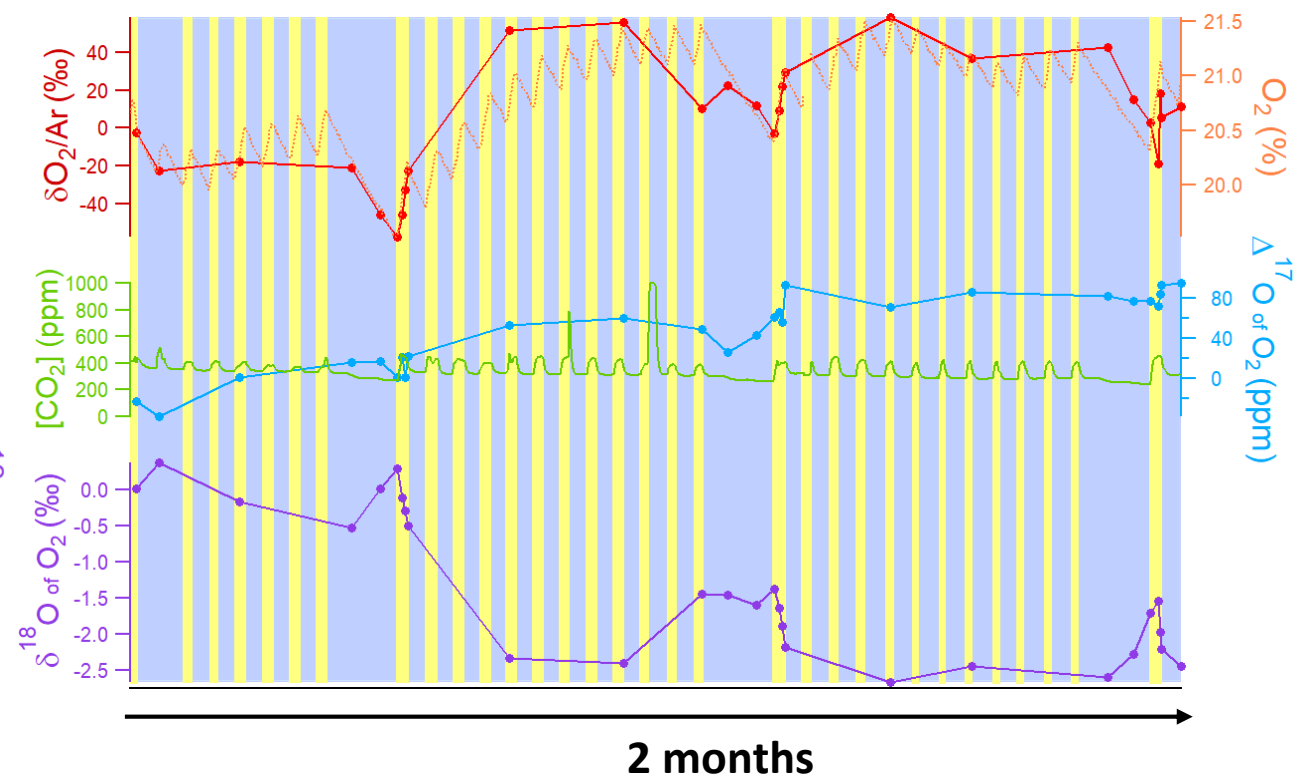
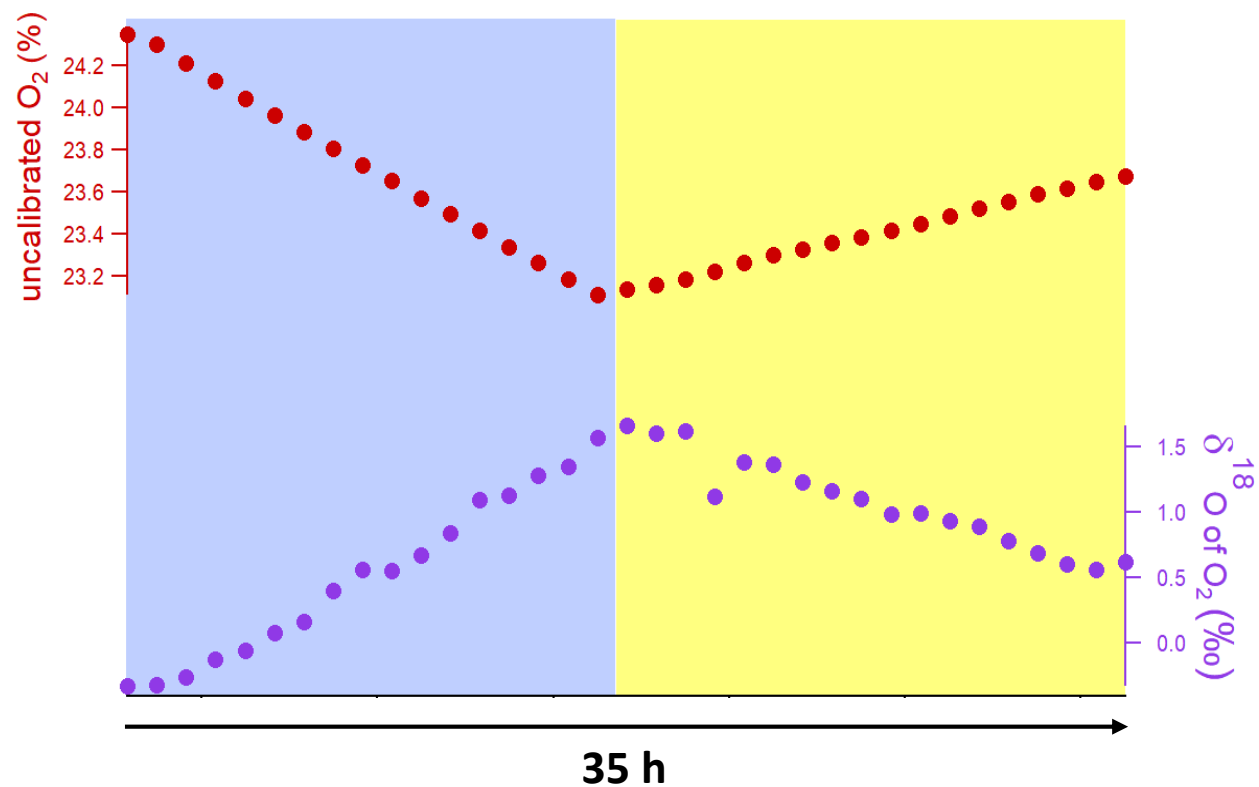
- **Continuous data** – 1 Hz
- **Performance :**
 - $\sigma(\delta^{18}\text{O}) = 0.045 \text{ ‰}$ during 18 min
 - $\sigma(\text{O}_2) = 18 \text{ ppm}$ during 12 min
- **Calibration** : 1 per hour

Experimental set-up



6 biological chambers with environmental control

SARA-O₂ test : continuous data



SARA-O₂ test : respiration/photosynthesis

Dark period
Light period

Photosynthesis experiment : without continuous data

→ CONTINUOUS DATA with SARA-O₂

Future

- 6 biological chambers in parallel
- Study respiratory and photosynthetic fractionations for several types of soils and plants (C3 and C4) and possibly macrofauna