A new portable infrared laser spectrometer for field measurements of N_2O & CH_4 emissions.

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The « SPIRIT » instrument

Spectromètre IR *in situ* troposphérique

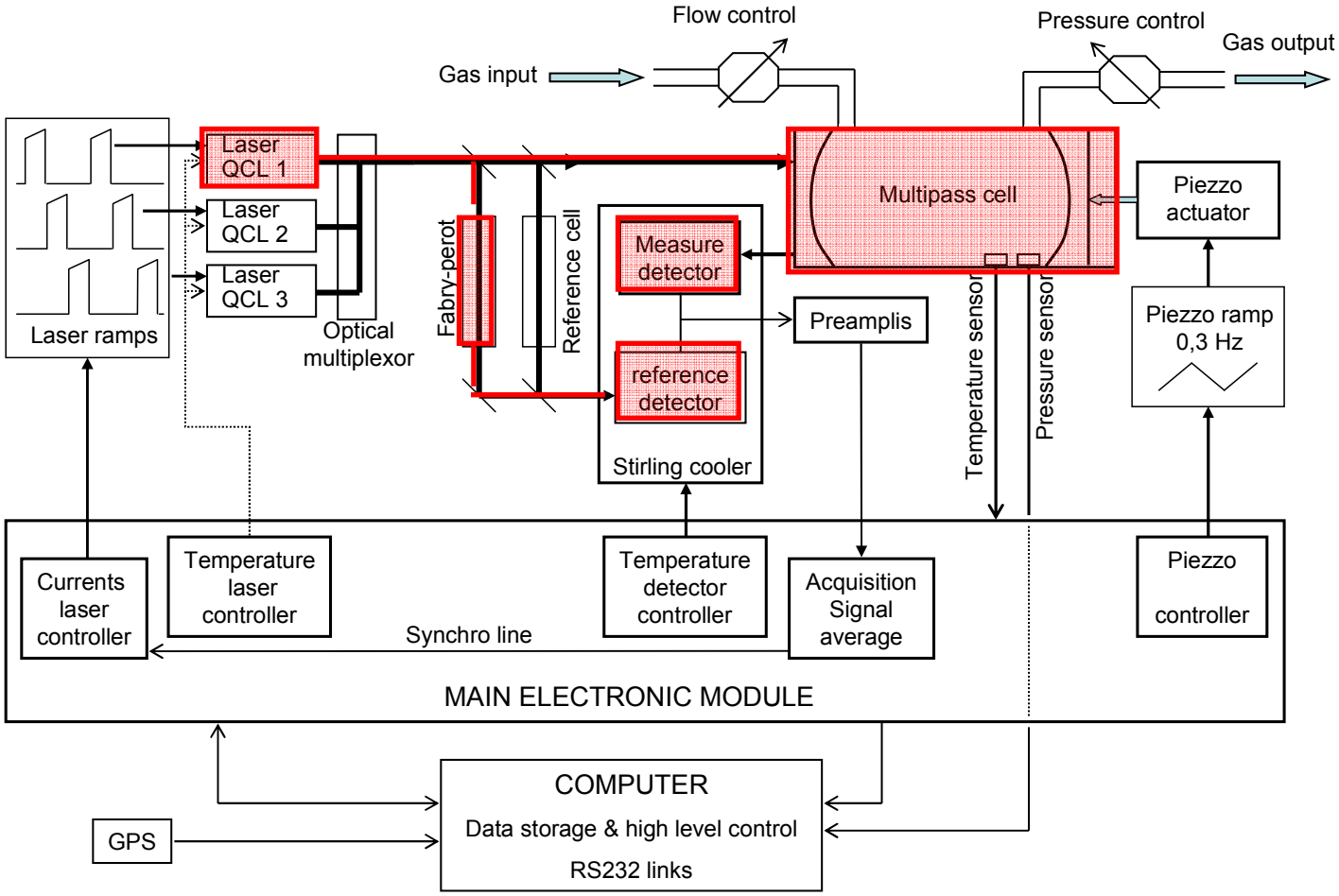
- QCL spectrometer

Laboratory-built : LPC2E (laboratory of physics and chemistry for the atmosphere and space).

Selective detection of CH_4 and N_2O (~8 μm), strong greenhouse gases

Applications to the detection of N_2O emissions from croplands

Schematics


Flow control
Gas input
Pressure control
Gas output
Laser QCL 1
Laser QCL 2
Laser QCL 3
Laser ramps
Optical multiplexor
Fabry-perot
Reference cell
Measure detector
reference detector
Stirling cooler
Multipass cell
Preamplis
Temperature sensor
Pressure sensor
Piezzo actuator
Piezzo ramp 0,3 Hz
Currents laser controller
Temperature laser controller
Temperature detector controller
Acquisition Signal average
Piezzo controller
Synchro line
MAIN ELECTRONIC MODULE
COMPUTER
Data storage & high level control
RS232 links
GPS

Instrumental set-up

1. IR laser source : QCL

High spectral resolution (laser line < 5MHz)

High power : multiple reflexions in the cell

2. Multi-pass cell

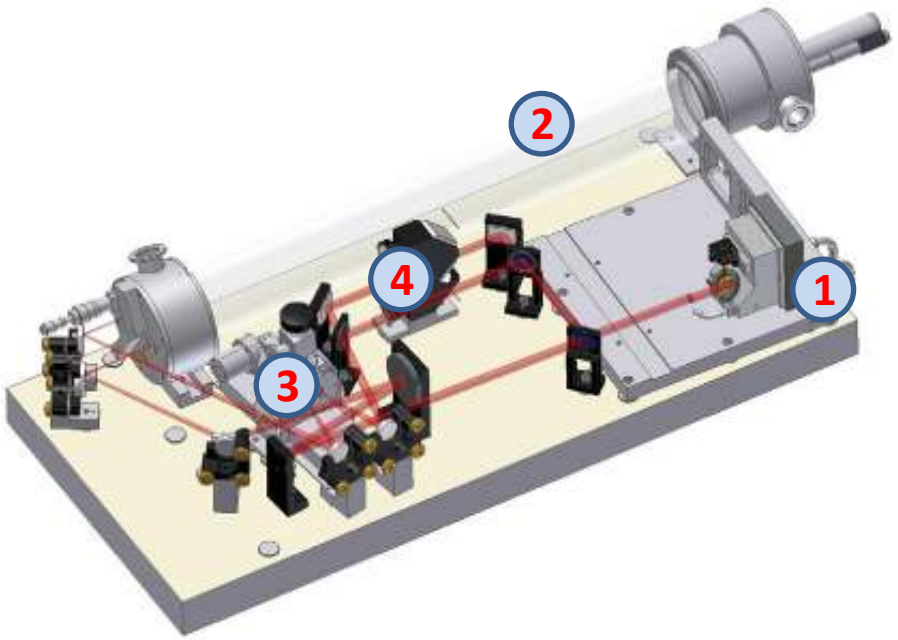
144 m optical path

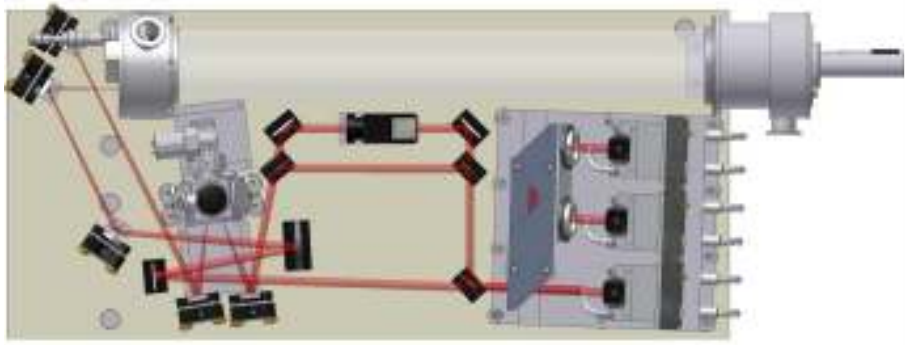
3. IR detectors

Stirling cycle cooled detectors (130K)

4. FP etalon

Wavelength etalon for the spectra fit





The optical cell

- Absorption can be enhanced by long optical path

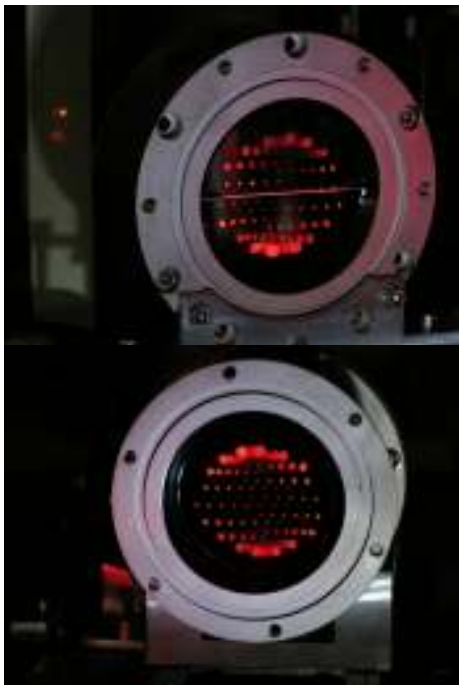
=> Use of multi-path cells

- Most common cells : White, Herriott, astigmatic Herriott

- **SPIRIT : special design, generalization of previous cells.**

Patents :
France (05/08396) and International (WO 2007/017570 A1)
3 spherical mirrors
Advantages :

Compactness, high path
Simple to adjust *in situ* (rotation of a single mirror)
Excellent opto-mechanical stability.



C. Robert, Applied Optics, 2007

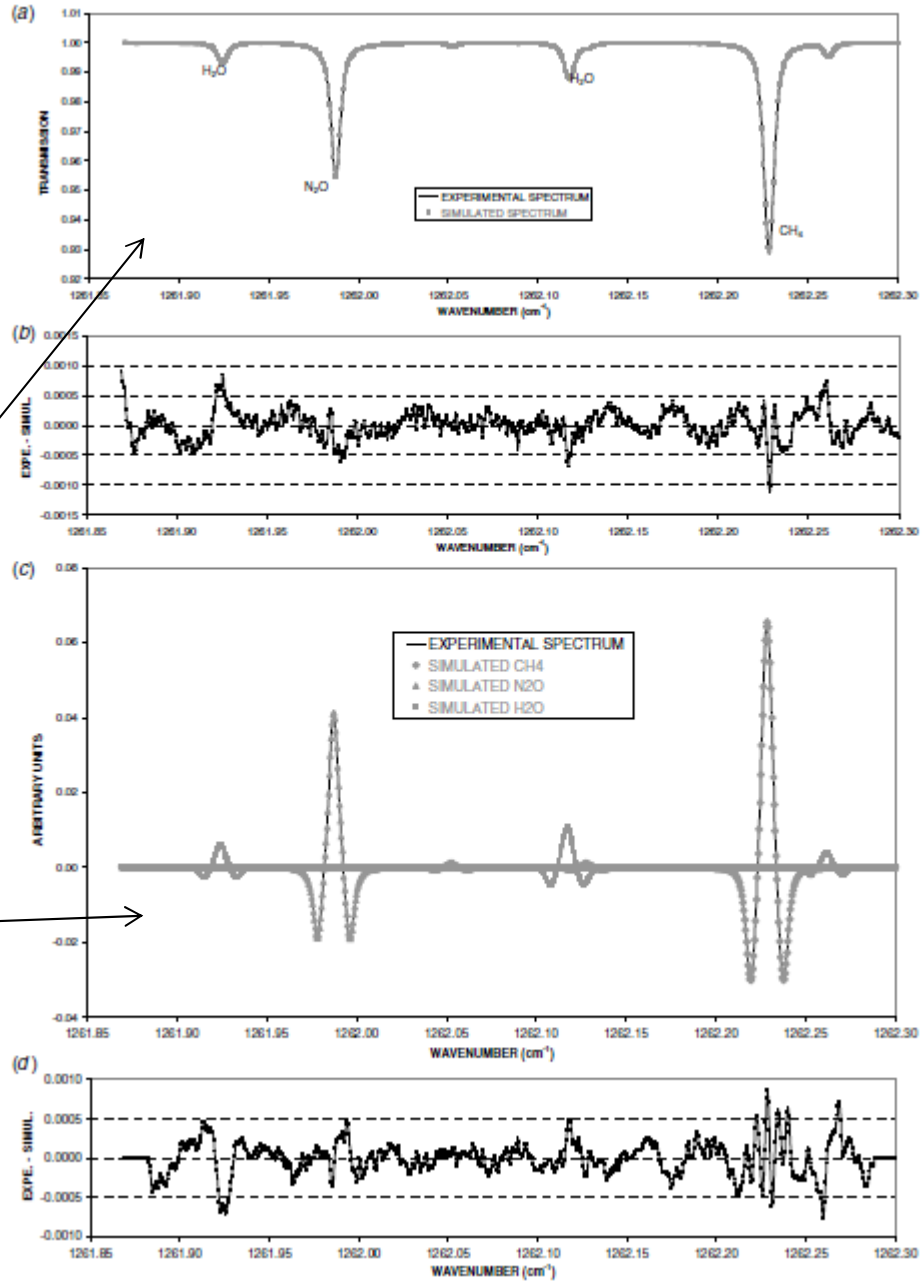
Spectra

- QCL ~ 7.8 μm <-> 1260 cm^{-1}

Simultaneous N_2O and CH_4 measurements

Direct spectrum

Second derivative

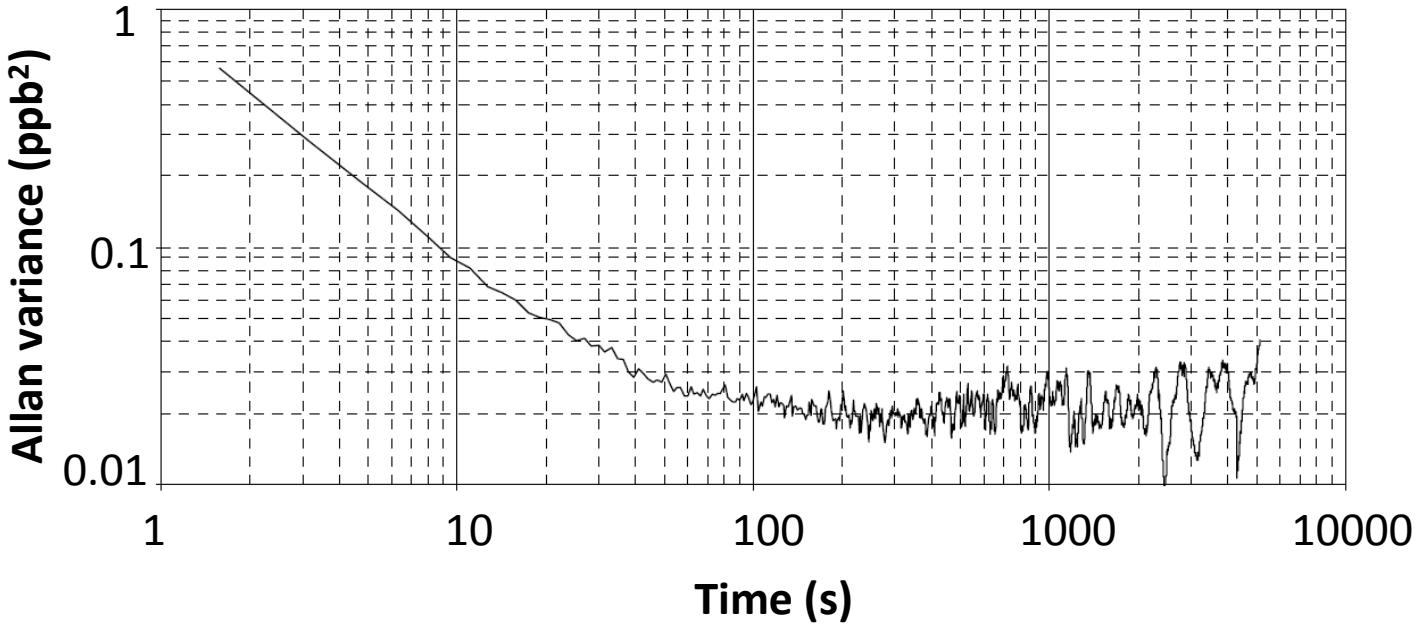


Instrumental achievement

- At 0.7 Hz, theoretical absorption resolution 1.5 .10^{-5}, 10^{-4} achieved.

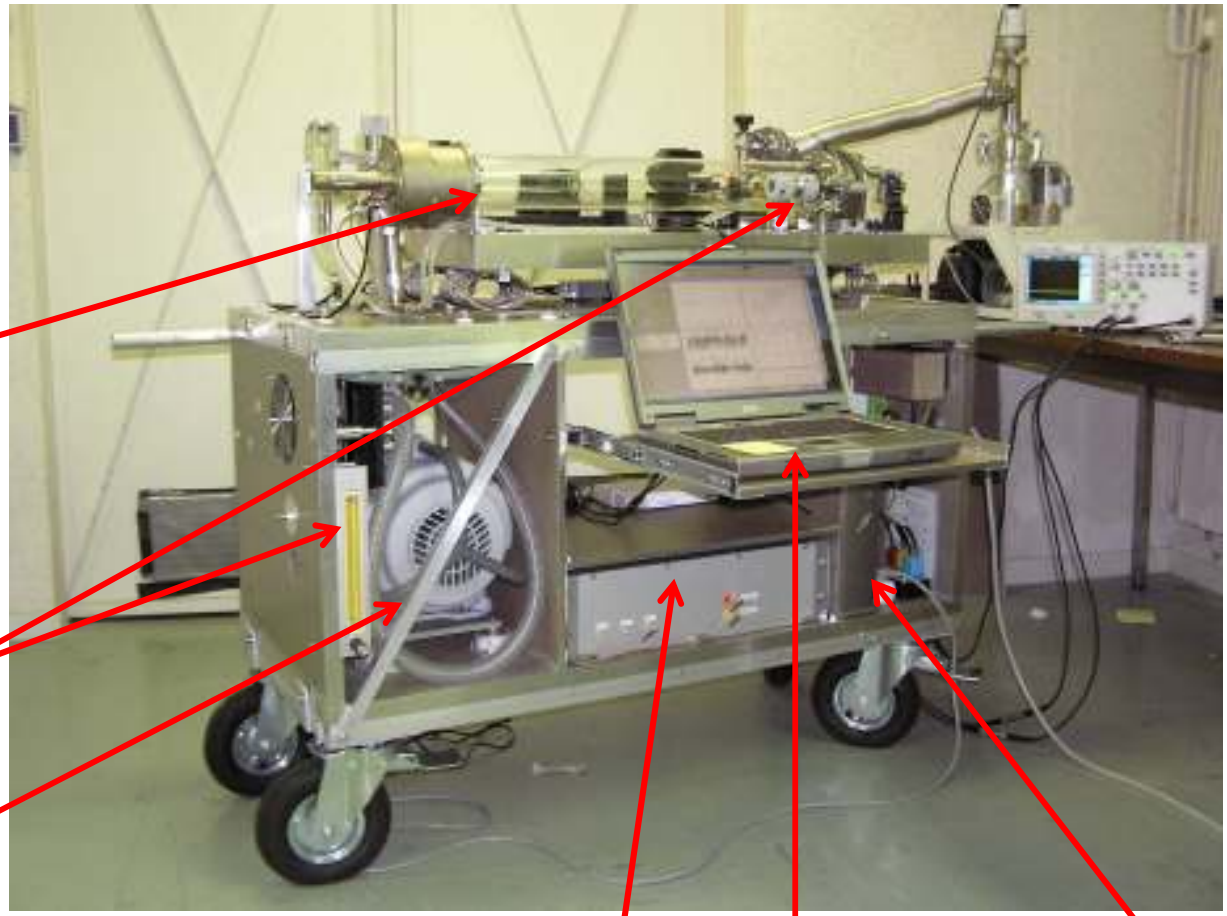
$\Rightarrow$0.6 ppb of N_2O and 4 ppb of CH_4 (1σ)

Allan variance : 0.13 ppb of N_2O and 0.62 ppb of CH_4 in 250 s.



Guimbaud et al, Measurement Science and Technology, 2011

The whole set-up

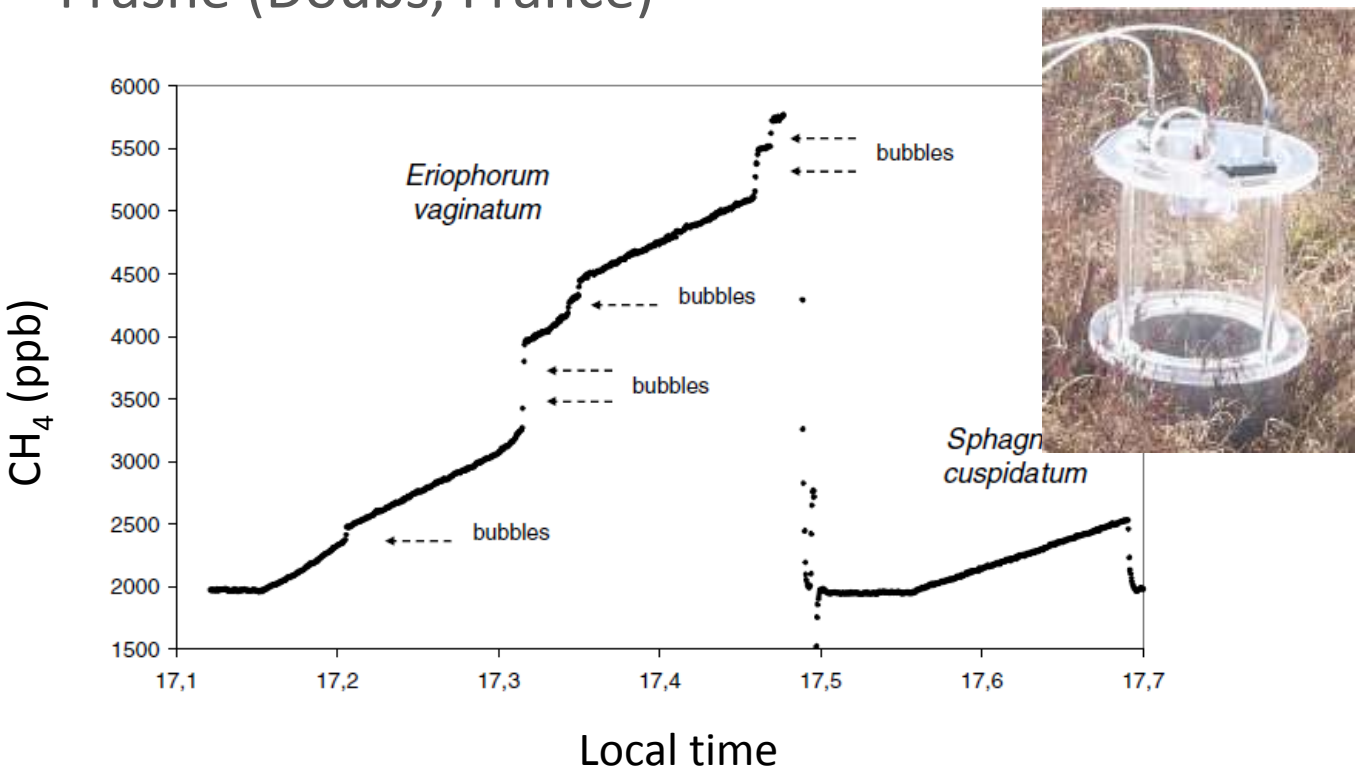


Some applications…

1. CH_4 emissions from peatlands (LPC2E)

Objective : study of climate change and anthropic perturbation on the carbon sink function of peatland

Experimental sites : La Guette (Centre France) : Frasne (Doubs, France)



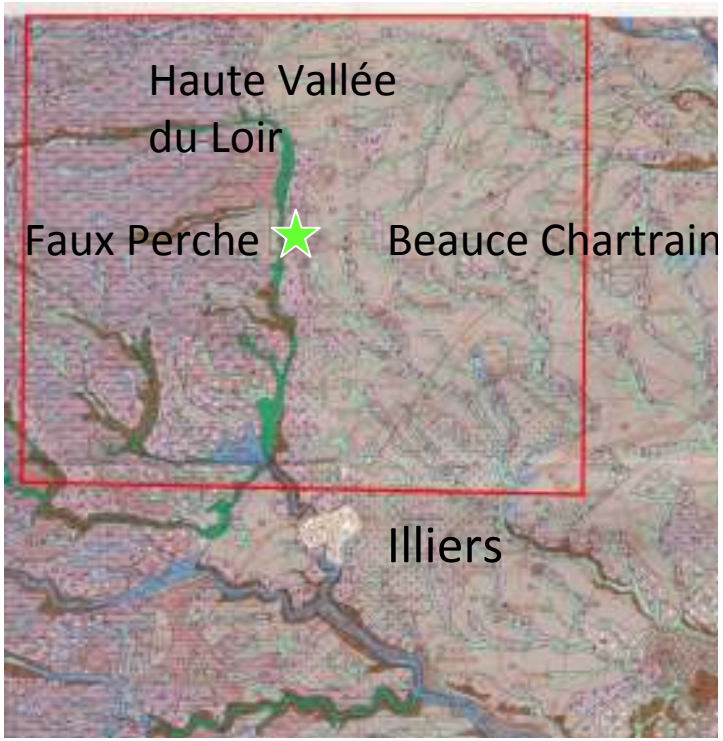
Agricultural studies

2. **N_2O emissions from agricultural soils** (INRA, Soil Science Lab).

Objective : study of the spatial variability of N_2O emissions

Experimental site : OS² (Observatoire spatialisé Orléanais des Sols) = croplands, Centre France

Loamy soils



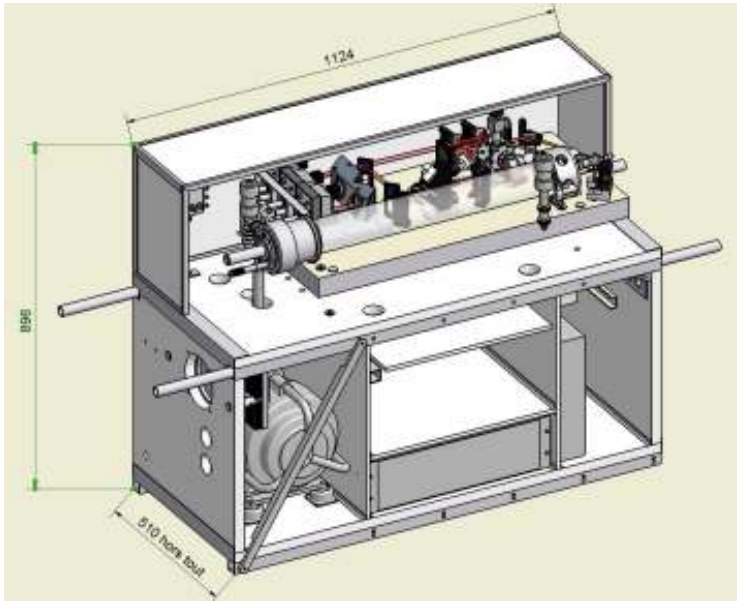
The INRA SPIRIT
the second instrument

- More compact: 51*112*90 cm

Optical cell length : 64.5 cm (usual optical path 117 m)

Cell width : 8 cm⇔3.2L

- powered in the field with a generator



generator

Flux measurements techniques

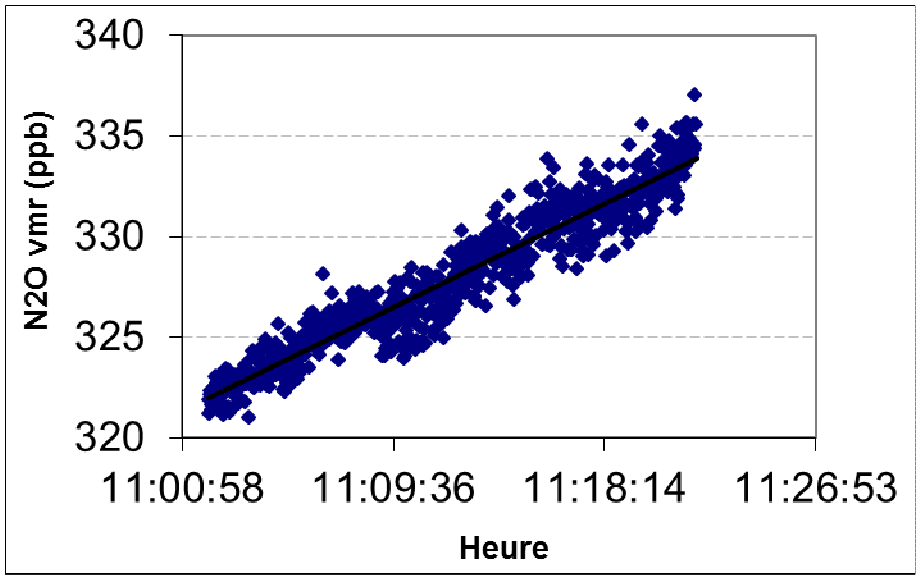
- **Chambers**

Minimum measurable flux estimated with 1.2ppb (2σ) error on N_2O, **6 minutes** accumulation and a **15 cm chamber height** : **0.5 g.N.N_2O.ha^{-1}.d^{-1} or 0.57 g.N.N_2O.m^{-2}.s^{-1}**

Air inlet and outlet

- **Fast box**

Minimum flux ~ **2 g.N.N_2O.ha^{-1}.d^{-1}**



Thank you for your attention

And also thanks :

To the whole LPC2E team who built up the instrument

And to the technical team of UR Sol (INRA)

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