Automatic semi-continuous accumulation chamber for diffuse gas emissions monitoring in volcanic and non-volcanic areas

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1. Introduction

Since 70[th], the accumulation chamber method was used in agronomy sciences to measure CO_2 fluxes diffused from soil, which are referred to as soil respiration (Witkamp, 1969; Kucera and Kirkham, 1971; Kanemasu et al., 1974; Parkinson, 1981). However, since last three decades up to now, this method is intensively used in monitoring activities of diffuse degassing in volcanic and non volcanic areas. Although some improvements have been performed in terms of sensitivity and reproducibility of the detectors, the equipment used for long-term monitoring of gas emissions usually requires expensive and bulky equipment. This work describes the low cost unit designed and realized for quasi-continuous measurements of CO_2 diffused from soil, using the accumulation chamber method, and gives some details about its first field test.

2. CO_2-S-Pot device

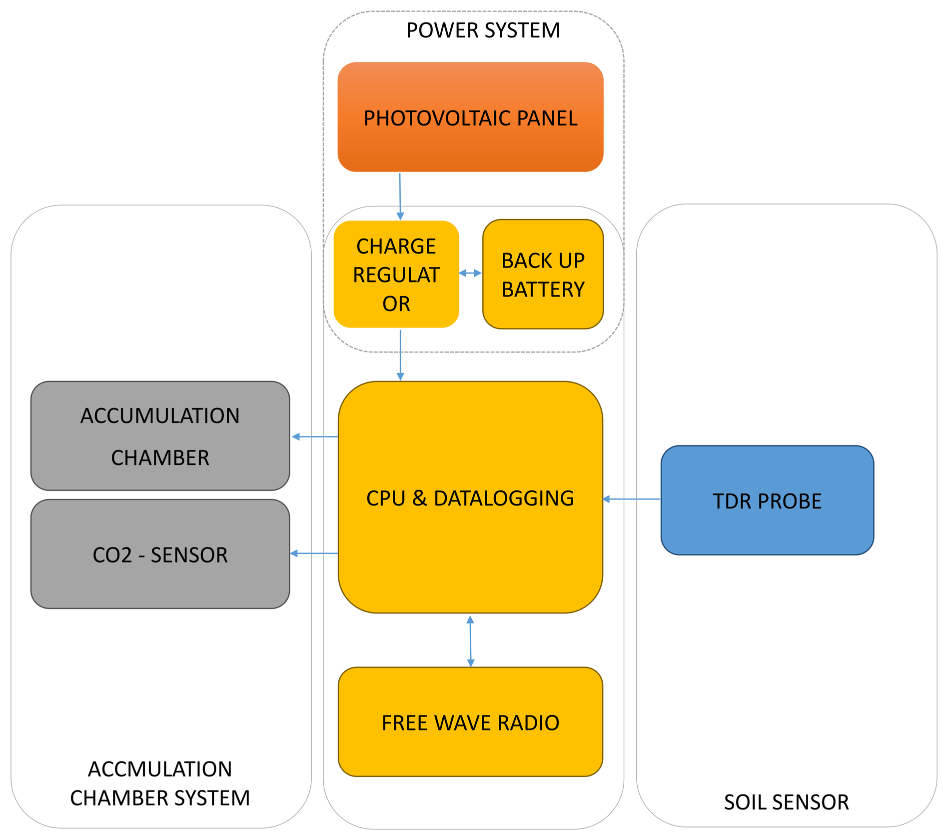

Figure 1 – Block diagram of the unit

CO2-S-Pot is able to measure CO_2 (and also H_2S if requested), Barometric pressure, Soil temperature , Soil water content and other detectors connected to rs-485 port (i.e. anemometer…). CO2-S-Pot is a completely automatic unit, power supplied by a solar cell and backup battery, which performs the measurement cycles with a configurable frequency (by default every hour).

Power supply: 12V 7 A/h lead battery, which is charged during the day by a solar cell.; **Accumulation chamber:** Automatic aluminum accumulation chamber without mixing device. Chamber surface: 700 cm^2; **CO_2 flux measurement:** The CO_2 is measured by a NDIR (Non-Dispersive Infrared) detector, placed inside the chamber, protected by a large P3 filter to avoid dust contamination of the detector. The system is equipped with 2 interchangeable CO_2 detectors: (0 – 5.000 ppm), (0 – 5%). **Soil parameters:** The system is equipped with a soil probe able to measure temperature (-40 to 80°C acc. ± 1°C), volumetric water content (0 to 100% acc.± 3%) and electrical conductivity (0 to 23 mS/cm ±5% from 0 to 5 mS/cm±10% from 5 to 23 mS/cm). The unit stores the data internally into a SD card. In case of telemetry fault, the data can be imported by manually removing the card.

Telemetry

The unit can be equipped with either an 869 MHz, 2.4 GHz (or 900 MHz) license-free radio with a range in line of sight of 20 miles or GPS/GPRS modem; The telemetry allows remote configuration and to download the data. The type of telemetry must be specified at purchase order time.

Figure 2 – Picture showing some details about electronic components

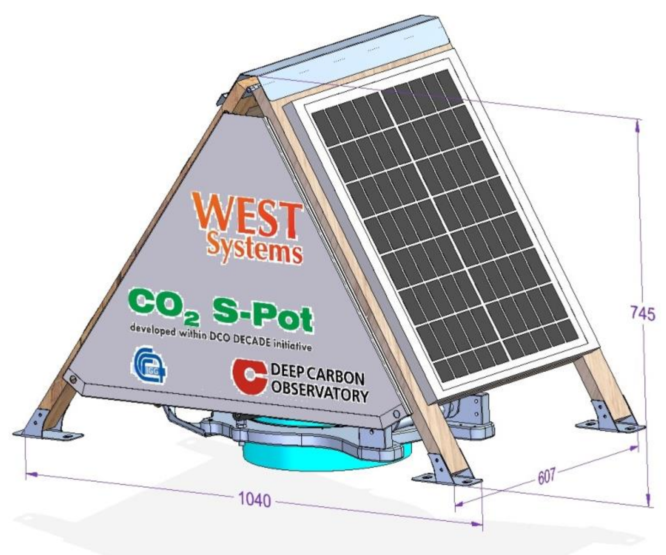

Figure 3 – Station configured for field work

3. Instrument set-up

3.1 - Laboratory tests

As described in figure1, the CO_2-S-Pot is composed by various «parts», connected to each others. Therefore, laboratory test and calibration of the system is mandatory in order to verify the correct functioning of the instruments and its performance. Several tests were performed in order to: **1)** check the reproducibility; **2)** calculate the *Accumulation Chamber Constant* $\left(\text{A.C.K.}=\frac{86400 \cdot P \cdot V}{10^6 \cdot R \cdot T \cdot A}\right)$, where R is gas constant, A is bottom surface of the chamber (0.07 m^2) and V is the chamber volume (6.9*10^{-3} m^3); **3)** evaluate the detection limit.

Figure 4 shows the device used as flux simulator: a constant gas flux is set by means of mass flow controller, goes through a plain desk (simulating the soil surface) and then enters in the instrument.

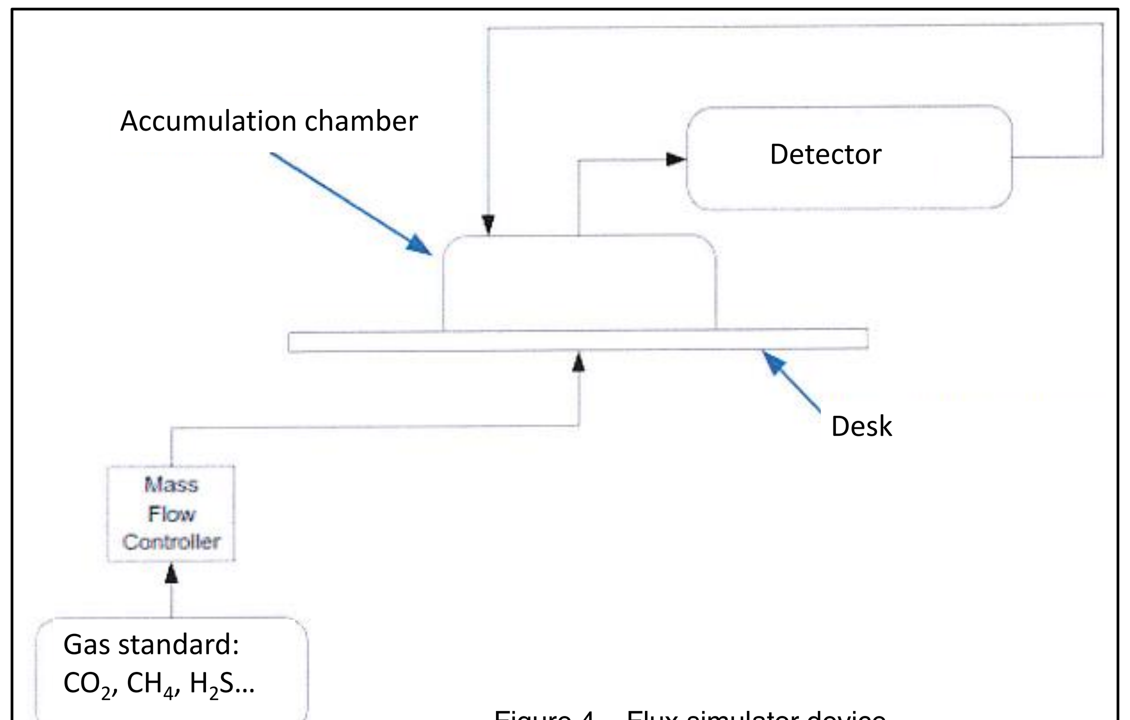

Figure 4 – Flux simulator device

The performed lab tests show that the device reaches better results, in terms of reproducibility, for data acquisition time of about 180 sec or more. Theoretical A.C.K. is 0.35, but this value differ significantly from that evaluated experimentally in each lab test. In addition, taking into account that A.C.K. depends on the total volume of the chamber, in each installation site particular attention should be given to the positioning of the chamber when it is in closed position (measurement). The Low Detection Limit (L.D.L.) is 0.1 mol/m^2 day.

Figure 5 shows an example of calibration curve performed with the simulator device (Fig.4). Flux data in cc/min are compared with the instrument outputs in ppm/sec. Using the slope of the calibration curve is possible to convert directly the measurement expressed in ppm/sec to cc/min and then to mol/m^2*day.

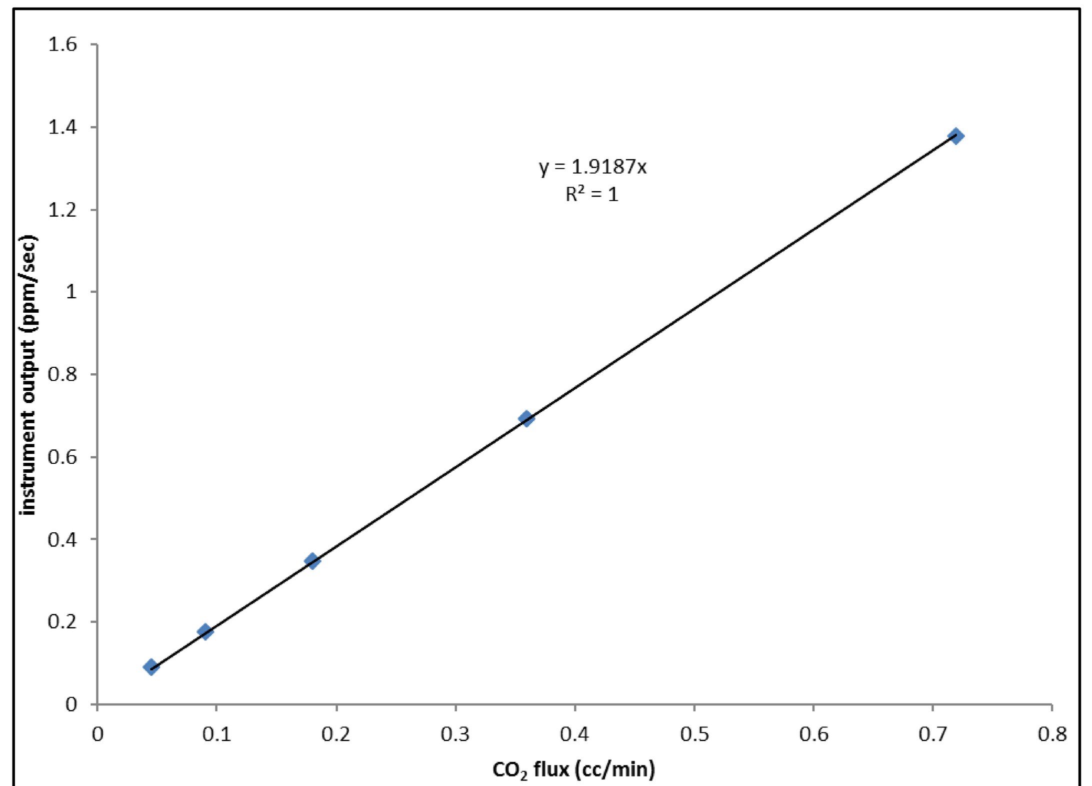

Figure 5 – Example of flux calibration curve

3.2 - Field test and data processing

The semi-automatic station was installed and tested in the filed at Lipari island (Sicily). In 2014, from 11[th] June to 10[th] September, more than 2100 CO_2 flux data, together with air pressure and temperature, soil temperature, soil electrical conductivity and rainfall were collected.

Figure 6 – Location of Lipari island (Sicily, Italy)

Figure 7 – Installation site at Lipari island (old kaolin quarry)

Figure 8 – Detailed picture of the accumulation chamber used

Figure 9 shows the comparison between CO_2 flux (raw data) with air pressure, soil temperature, soil humidity and rainfall. Strong control operated by meteorological parameters is evident, in particular by rainfall and air pressure. All measurements have R^2 coefficient >0.98 and the reproducibility ≅10%.

Data elaboration has been performed using time series spectral Fourier analysis-TSFA (daily variations for CO_2 flux, P_{air}, T_{air} and W_{soil}), moving average at 24 h (smoothing CO_2 flux data) and Principal Component Analysis (PCA).

From factors extracted (only 2) by the PCA, a Multiple Linear Regression Analysis (MLRA) was used in order to predict CO_2 flux data, trying to identify anomalies not explained by the data measured. Figure 10 shows the comparison between CO_2 flux data recorded in the field and predicted by the model. Red points represent CO_2 flux anomalies not correlated with external variables (such as meteorological parameters).

The station has been tested in the field also in others areas (i.e. Azores, Las Furnas; Parco del Reno, Bologna), obtaining good data sets.

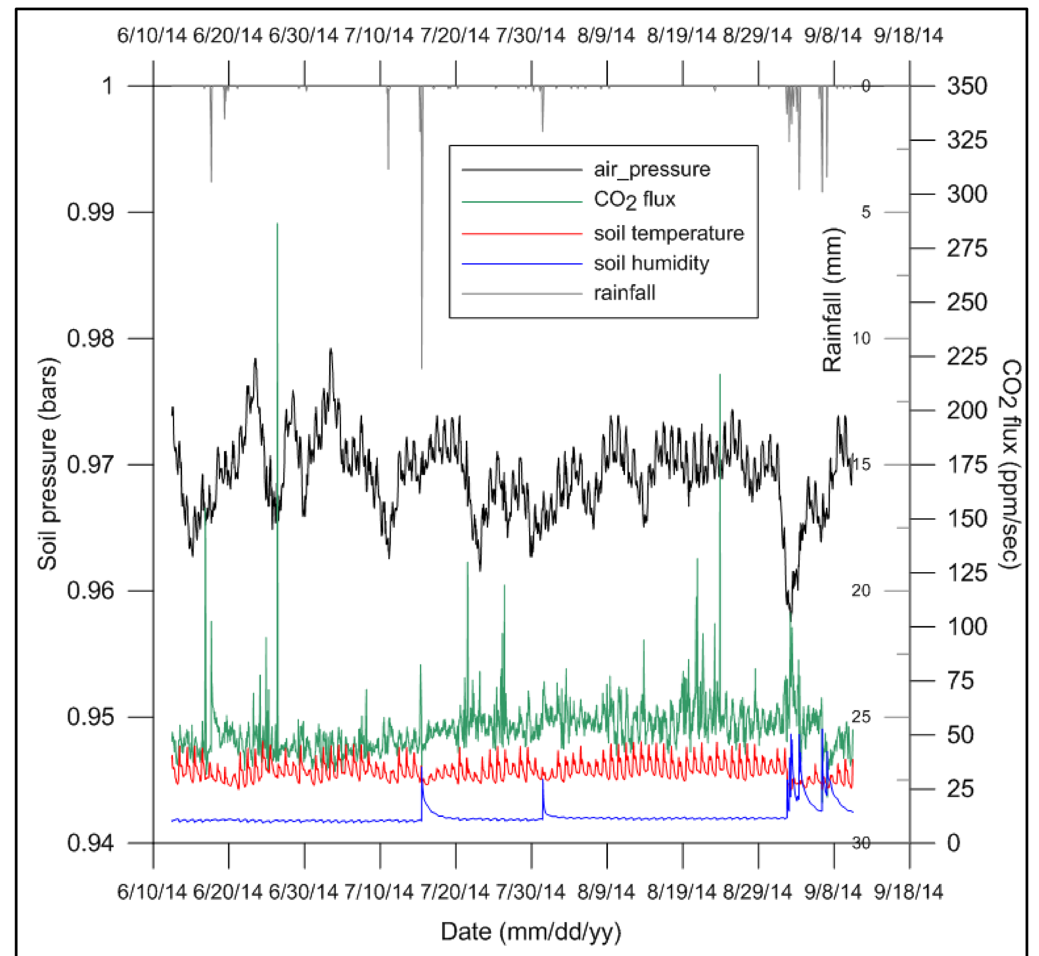

Figure 9 – Comparison between CO_2 flux data and with air pressure, soil temperature, soil humidity and rainfall

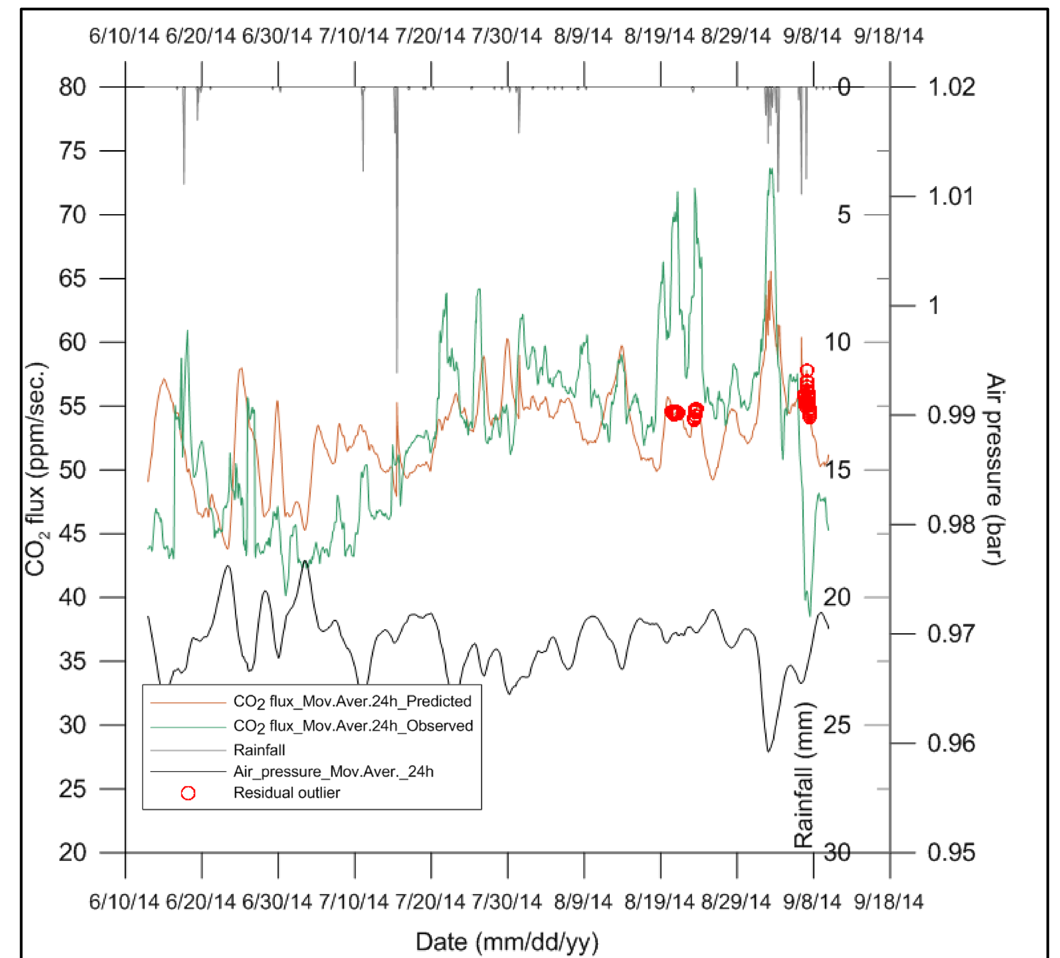

Figure 10 – Results obtained from Multiple Linear Regression Analysis. Air pressure and rainfall are also reported.

4. Improvement of the prototype version

The GPRS signal strength was very low in the installation site and for this reason sometimes problems to transmit data were occurred. Since a good signal is available in a near location of the installation site, less than 1 km, a good solution would be installing there a radio telemetry bridge. The bridge is powered by a battery and a solar panel, and it contains the GPRS modem and an 869 MHz radio. A second 869 MHz radio, configured point-to-point with the bridge, is installed inside the flux station.

Acknowledgement

This work was partially supported by the Deep Carbon Observatory (DCO), in the framework of the DECADE Project.

5. Summary and conclusions

The semi-automatic station designed, developed and tested in this work is easy to install and use (installation phases took place in less than 2 hours). Lab test were performed to evaluate the correct functioning of the device and to calculate some fundamental parameters (L.D.L., reproducibility, A.C.K., ecc.). Calibration curve method is more accurate than A.C.K. in the data conversion between ppm/sec to cc/min and then to mol/m2*day.

Various parameters have been measured, without data lost. It should be noted that during the field tests, no ordinary or extraordinary maintenance was necessary. The improvement regarding radio telemetry bridge and radio module inside the station will allow to overcome signal loss problems in areas characterized by low level signal.

The possibility to measure in semi-continuous mode, and at the same time, the gas fluxes from soil and many external parameters, helps the time series analysis aimed to the identification of gas flux anomalies due to variations in deep system (e.g. onset of volcanic crises) from those triggered by external conditions. The results of this work could have a significant implication on the monitoring activities of volcanic areas.

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