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Method Article

Maximizing the information obtained from chamber-based greenhouse gas exchange measurements in remote areas

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A B S T R A C T

Measurements of greenhouse gas (GHG) fluxes, particularly methane (CH_4) and nitrous oxide (N_2O) in mountain ecosystems are scarce due to the complexity and unpredictable behavior of these gases, in addition to the remoteness of these ecosystems. In this context, we measured CO_2, CH_4, and N_2O fluxes in four semi-natural pastures in the Pyrenees to investigate their magnitude and range of variability. Our interest was to study GHG phenomena at the patch-level, therefore we chose to measure the gas-exchange using a combination of a gas analyzer and manual chambers. The analyzer used is a photoacoustic field gas-monitor that allows multi-gas instantaneous measurements. After implementing quality control and corrections, data was of variable quality. We tackled this by categorizing data as to providing quantitative or only qualitative information:

- 50% and 59% of all CH_4 and N_2O data, respectively, provided quantitative information above the detection limit.
- We chose not to discard data providing only qualitative information, because they identify highest- and lowest-flux peak periods and indicate the variability of the fluxes, along different altitudes and under different climatic conditions.
- We chose not to give fluxes below detection limit a quantitative value but to acknowledge them as values identifying periods with low fluxes.

A R T I C L E I N F O

Method name: Soil-atmosphere multi-gas exchange in remote areas
Keywords: CO_2, CH_4, N_2O, Detection limit, Quantitative and qualitative data
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Specifications Table	
Subject area	• *Agricultural and Biological Sciences*
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Method name	*Soil-atmosphere multi-gas exchange in remote areas*

Method details

To investigate the patterns of greenhouse gases (GHG) in extensively managed semi-natural grasslands in the Eastern Pyrenees, we measured vegetation and soil fluxes of CO_2, CH_4, and N_2O from four grassland locations along an altitudinal gradient in the Eastern Pyrenees (Fig. S1 in Supplementary material). The locations are in remote mountain areas, with neither practical possibility of connection to the electrical network, nor capability for storage. The fluxes were measured intermittently during 2012 and 2013 with a portable gas-exchange system. Two of the four locations (BERT1276 and CAST1850) were equipped with eddy-covariance towers which provide continuous recordings of the photosynthetically active radiation (PAR), air temperature (T_a), and soil water content (SWC) and thus describe the seasonal patterns and give a temporal context for the GHG flux campaigns, which covered the growing season. The altitudinal gradient is clearly reflected in the air temperature, with sites going from warmer to cooler with altitude. In the sites with SWC data, the low-altitude site presents the driest soil. Note that in 2012 there was a rather intense drought period that affected also the highest-altitude sites.

System setup

We used a self–assembled portable gas-exchange system to perform *in-situ* field surveys. The use of PAS seemed to be a good alternative to do multi-gas concentration measurements due to its relatively high portability, ease of use, and low energy consumption [1]. The potential of this technology has been contemplated in a number of reviews of GHG chamber-based measurements [2,3]. The system consisted of a cylindrical chamber (20 l nominal volume), connected to a multi-gas analyzer through Teflon tubing. The chamber was made of uncoated transparent methacrylate that was darkened when needed with a reflective cover manually placed on its top (see details of the set up in Fig. 1).

We measured all gases simultaneously with a photoacoustic spectroscopy (PAS) analyzer (INNOVA 1412, LumaSense Technologies, Denmark). PAS has a measurement cycle that implies intermittent air flow from the chamber. The cycle starts by drawing air from the sampling point in order to flush the old air in the system and thereafter obtain a sample of fresh air. When the required volume of the sample is reached, the flow stops. From this, the concentration of the desired gases is consecutively determined inside the cell of the analyzer. The sample is irradiated in a modulated way to produce intermittent expansions, which can be detected photoacoustically. Each gas of interest is determined separately, as the irradiation is delivered through optical filters with selected wavelengths, and the filters are applied in sequence. The response time depends on the sampling integration and the flushing time defined; which in this study was approximately 60 s including the three gases and water vapor. This implies that the concentration output rate was of approximately one value per minute. The air removed from the headspace including flushing and sampling represents about 1% of the total chamber headspace. The removal happens during less than 10 s, leaving the system more than 50 s to replace the air -which will be homogenized by the small ventilator- before the next sampling volume is removed.

The nominal detection limits of the various gases are: 5, 0.03, and 0.24 ppm for CO_2, N_2O, and CH_4, respectively. Prior to the field campaigns, the PAS was fully calibrated by the vendor [4] and taken into use in a plug-and-play basis with no need for recalibration during use, according to the recommendations of the vendor and as applied in other studies [e.g. 5,6]. Conforming to the