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Conference Abstract

CO_2 Fluxes: Measurements and Modelling in the Changing Arctic Critical Zone

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Abstract

In terrestrial ecosystems, biotic and abiotic components are interconnected and respond to environmental and climate pressures. The tundra is the life support system of Arctic ecosystems, but it is exposed to climate change. Its frozen soil, a major carbon stock, is affected by temperature rise. It is therefore important to understand its functioning and dynamics, in particular regarding the carbon cycle. For this purpose, we established the first High Arctic “Critical Zone” observatory in the Bayelva basin in Svalbard (NO).

The term Critical Zone (CZ) means the “heterogeneous, near surface environment in which complex interactions involving rock, soil, water, air, and living organisms regulate the habitat and determine the availability of life-sustaining resources” (Giardino and Houser 2015). In its approach, biotic and abiotic interactions are seen as a continuum, which demand scientists to overcome the partition between disciplines. Hence, chemistry, biology, physics, and geology must be used together to interpret a complex system where living and non-living components are interconnected.

In the Bayelva Critical Zone Observatory, we investigate the CO_2 fluxes between soil, vegetation and atmosphere. Since the Holocene, the High Arctic soil has been slowly but consantly acting as a carbon sink, despite the little primary productivity (GPP), as the low temperatures and the scarce presence of grazers and decomposers have limited

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decomposition and ecosystem respiration (ER). With the temperatures rise, however, such processes are rapidly changing, but the direction of change is still uncertain. In fact, the multiple factors of change are acting on both GPP and ER: due to the thawing permafrost, more organic matter is available in the active layer for bacterial decomposition, whose metabolism is enhanced by temperature rise. At the same time, the widening of the snow-free season and vegetation composition shifts may cause an increase of carbon uptake. On top of this, climatic and environmental factors as soil moisture, topography, vegetation cover, can influence GPP and ER at the local scale, modulating the spatial variability.

To understand the trends in future balance between GPP and ER, it is necessary to identify their primary drivers and model their contribution to CO_2 fluxes. As the tundra is heterogenous, the spatial scale and representativeness are important factors to take into account.

To this aim, we measure and model CO_2 fluxes at the soil-vegetation-atmosphere interface at several scales, using flux chambers, Eddy Covariance and remote sensing data.

In the High Arctic, the flux chamber method is particularly suitable to assess ecosystem variability at fine scale Figs 1, 2. Moreover, it allows to directly measure ecosystem respiration by shading the chamber, and the low air temperatures and irradiance reduce the chamber disturbance during the measurement. Its use allowed us to investigate CO_2 fluxes as a function of soil moisture and temperature and vegetation cover, as well as investigating CO_2 fluxes at both plot scale and at single species level.

Figure 1. doi

Measuring CO_2 fluxes in the Arctic tundra with portable flux chambers. To be noted: the prostrate sparse vegetation mixed with lichens.

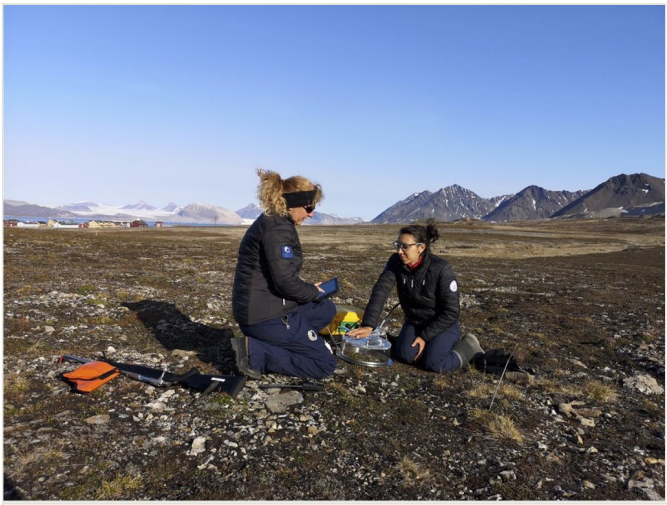

Figure 2. doi

Measuring CO2 fluxes: note the flux chamber, the soil sensors, IRGA fluxmeter (within the yellow box). The IRGA and the sensors are connected via radio to a palmtop computer handled by the operator (no blue tooth is allowed in Ny Alesund). Operators in the field must carry a gun for protection against polar bears.

We conducted five field campaigns since 2019, over three areas differing for aspect, vegetation density, species composition, and age of deglaciation. Surveys were conducted during the vegetative peak season (mid July, with shifts modulated by the date of snowmelt). At each site, at least 20 single point measurement per day of NEE and of ER were taken, together with the recording of solar irradiance, air temperature and moisture (Fig. 3), soil temperature and volumetric water content, and taking RGB pictures of the vegetation cover to extract the green fractional cover (Fig. 4) (around 2,000 single point measurements). We then built empirical models describing CO_2 fluxes as a function of the most relevant drivers. A non-linear model was built by taking Solar Irradiance and Soil Temperatures as main drivers of respectively GPP and ER (Lloyd and Taylor 1994, Ruimy et al. 1995), and the other drivers as local perturbations of the classic equations. Linear models were also calculated, with the only constrain to include Solar Irradiance and Temperature. We thus explored the ecosystem response in terms of interannual, spatial, and species-specific variability, speculating on the possibility to extent the models use in space and time.

Overall, our results may have relevant implications on modelling carbon fluxes in the tundra at larger scale. At present, vegetation models used in global climate models operate only at a large scale (10 – 100 km), while small scale variability is not taken into account. In addition, they are affected by large uncertainties that need to be reduced to properly predict the changes in CO_2 budget. Deriving new, small-scale models based on measured data can help bridging the gap between the large-scale climate-vegetation models and the reality of carbon exchanges.

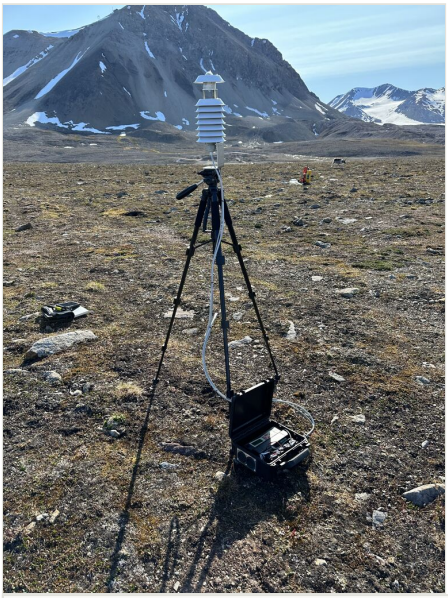

Figure 3. doi

The portable meteo station used for recording solar irradiance and air temperature and relative humidity, with its datalogger. Note a reindeer grazing on the background.

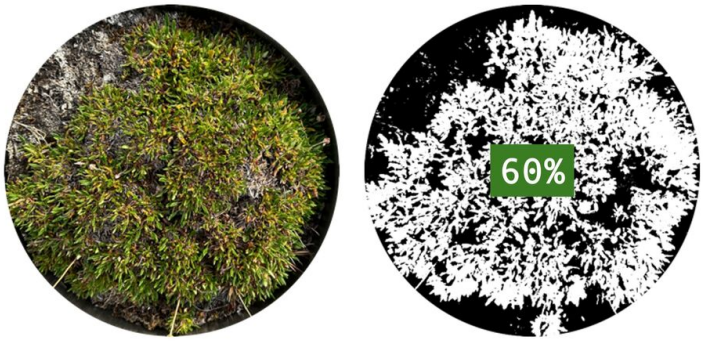

Figure 4. doi

Extraction of the Green Fractional Cover from RGB images.

Another source of uncertainty in the Arctic carbon budget comes from winter fluxes. Recent studies revealed that biological activity is present under the snow cover, as soil respiration occurs at temperatures below zero. Eddy covariance (EC) also revealed low positive fluxes during the snow-covered season. Howewer, accurate quantification of the

fluxes from snowpack by means of EC is hampered by the buffering effect of the snow pores, and by the sudden release of the CO_2 trapped in the snow during wind guts, when horizontal advection is dominant. To overcome such difficulties, we are measuring CO_2 emissions from the snowpack using a different approach, based on an array of CO_2 sensors embedded in the snowpack (Fig. 5), where the flux is calculated using the Fick's law of diffusion in a porous medium. In our presentation, we will give an overview of the results obtained so far.

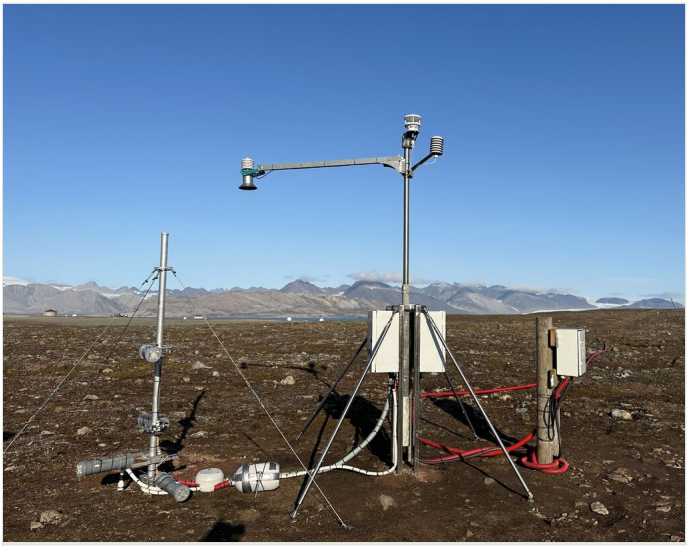

Figure 5. doi

Installation of sensors and meteo-nivological station for measuring CO2 fluxes from the snowpack. Sensors are meant to be covered with snow during winter.

Keywords

CO_2 fluxes; flux chambers; Primary Productivity; Ecosystem Respiration; Arctic; tundra; modelling; Critical Zone.

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Conflicts of interest

The authors have declared that no competing interests exist.

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