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A Critical Zone Approach to Carbon Fluxes in the Arctic Tundra

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Motivation and context

Arctic tundra is undergoing significant changes induced by a temperature rise about twice as fast as in the rest of the world.

What will be the response of the system **permafrost - active layer - vegetation** is especially relevant, as positive climate feedbacks might be triggered through, for example, carbon flux changes. Quantitative **monitoring of the tundra dynamics** is thus needed.

In this work, we analyse soil-vegetation-atmosphere CO_2 flux data of a field campaign conducted in the high Arctic during summer 2019, measured by a portable accumulation chamber.

The Critical Zone Observatory @ Ny Ålesund (NO)

Several scientific installations exist at the Ny-Ålesund scientific base (Kongsfjorden, Svalbard, (NO), Fig.1), providing a large set of baseline data. In particular, CNR collects meteo-climatic data through the Climate Change Tower (CCT), investigates soil and permafrost properties, flow-rate and suspended solids in the Bayelva River, atmospheric chemistry and physics (Gruvebadet station), glacier melting dynamics, marine chemistry and biology. In June 2019, CNR-IGG installed a new permanent Eddy Covariance (EC) system at the CCT at 3 m height (Fig. 10).

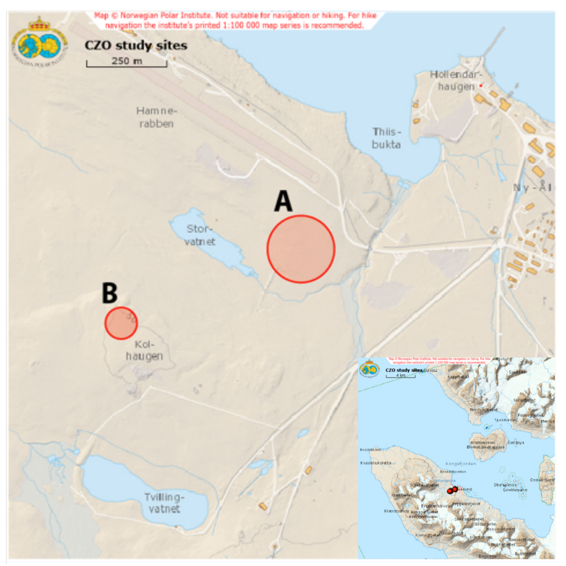

Fig. 1: Localization of the measurement plots

In the Bayelva proglacial area, downstream the retreating Austre and Vestre Brøggerbreen glaciers, a vast plain is covered with high-Arctic tundra. In this basin, we are establishing the northernmost Critical Zone[1] Observatory (CZO@Bayelva), to study some of the modifications taking place in the Arctic soil-vegetation-hydrologic system. We performed CO_2 flux measurements in the area showed in the close-up of Fig. 1, between July 25th and August 2nd 2019, during the peak of vegetative season.

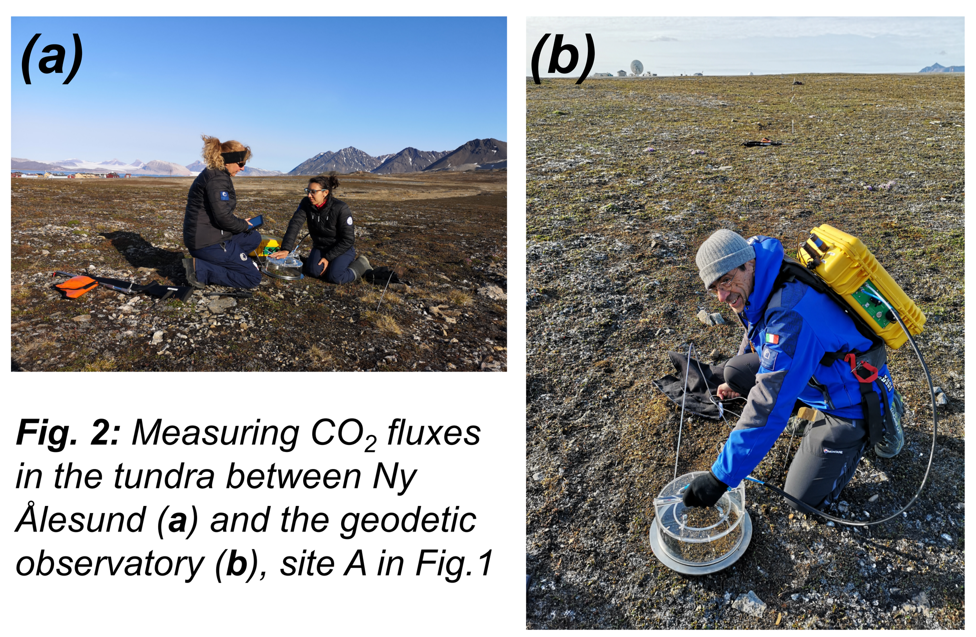

*Fig. 2: Measuring CO_2 fluxes in the tundra between Ny Ålesund (**a**) and the geodetic observatory (**b**), site A in Fig.1*

In this area, the vegetation consists of a mix of vascular plants of different species of grass and sedges and several species of mosses and lichens (Fig 3 -1). Some of the dominant vascular are *Salix polaris*, *Saxifraga oppositifolia (2)*, *Dryas octopetala (3)*, several *Carex species (4, glacialis, fuliginosa, rupestris)*, and *Silene acaulis (5)*.

Fig. 3: Tundra vegetation (see text)

CO_2 Fluxes Results

We measured **N**et **E**cosystem **E**xchange (**NEE**) and **E**cosystem **R**espiration (**ER**), and derived **G**ross **P**rimary **P**roduction **(GPP)**, in more than 320 sample points in the areas A and B showed in Figure 1. In the area A measurements have been taken in 5 plots distributed along a slope gradient. For each sample point, vegetation cover has been classified according to the dominant species (see Fig 4 caption). We averaged the sample point results for soil moisture (SM%) and fluxes (NEE, ER, GPP) for each plot and each vegetation class. Here, we show NEE and ER, which are the variables directly measured in the field.

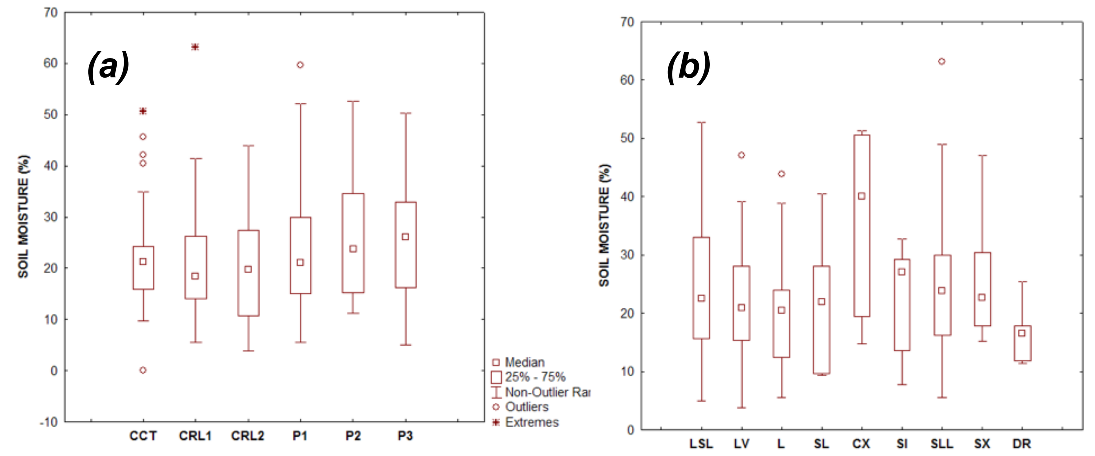

***Fig. 4:** SM% per site (**a**) and per different vegetation type (**b**). P1, P2, P3, CRL1 and CRL2 are located in A, CCT in B (Fig 1). CX = Carex; DR = Dryas; L = Lichens; LV: lichens and mix vascular plants; LSL= mix lichens-silene, lichens dominant; SLL= mix salix-lichens, salix dominant; SI = Silene; SX = Saxifraga; SL: Salix*

Median values of soil moisture differ slightly between sites and more strongly between vegetation species (Fig 4 a, b).

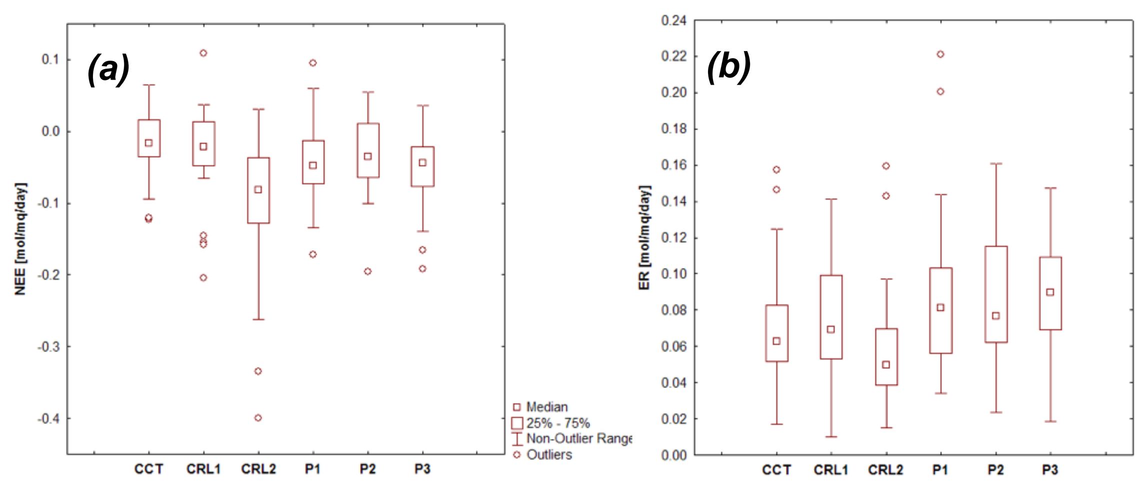

Fig. 5: Median NEE (a) and ER (b) in each plot.

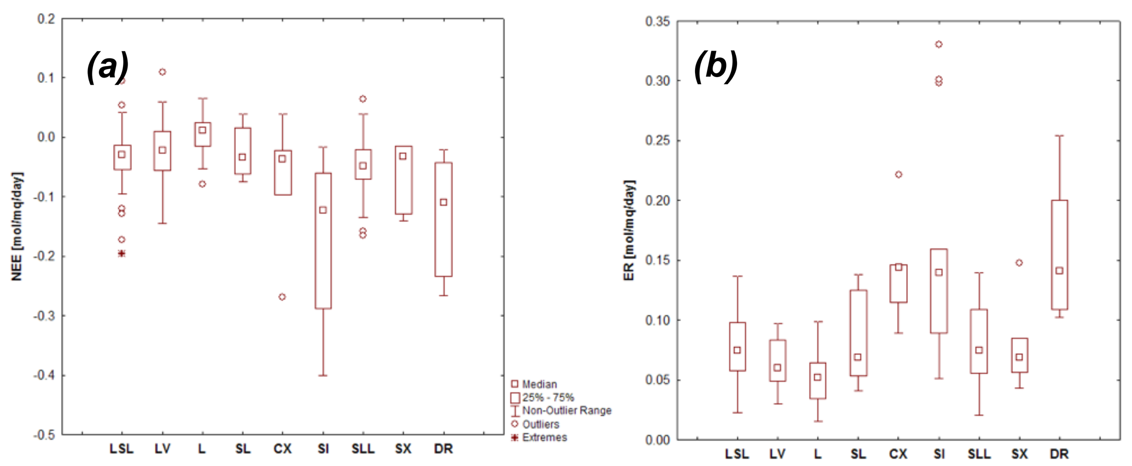

Fig. 6: Median NEE (a) and ER (b) as a function of vegetation type. Labels: see Fig. 4.

We do not observe large differences in the median flux values between sites (Fig 5) if pooling together all vegetation types.

Different types of vegetation cover show different median and interquartile values for both NEE and ER (Fig. 6), but the same vegetation type shows slight differences also according to the plot where it is located (Fig. 7). The dependence of fluxes on soil moisture and temperature will be further investigated by empirical models [2,3] and related to soil characteristics.

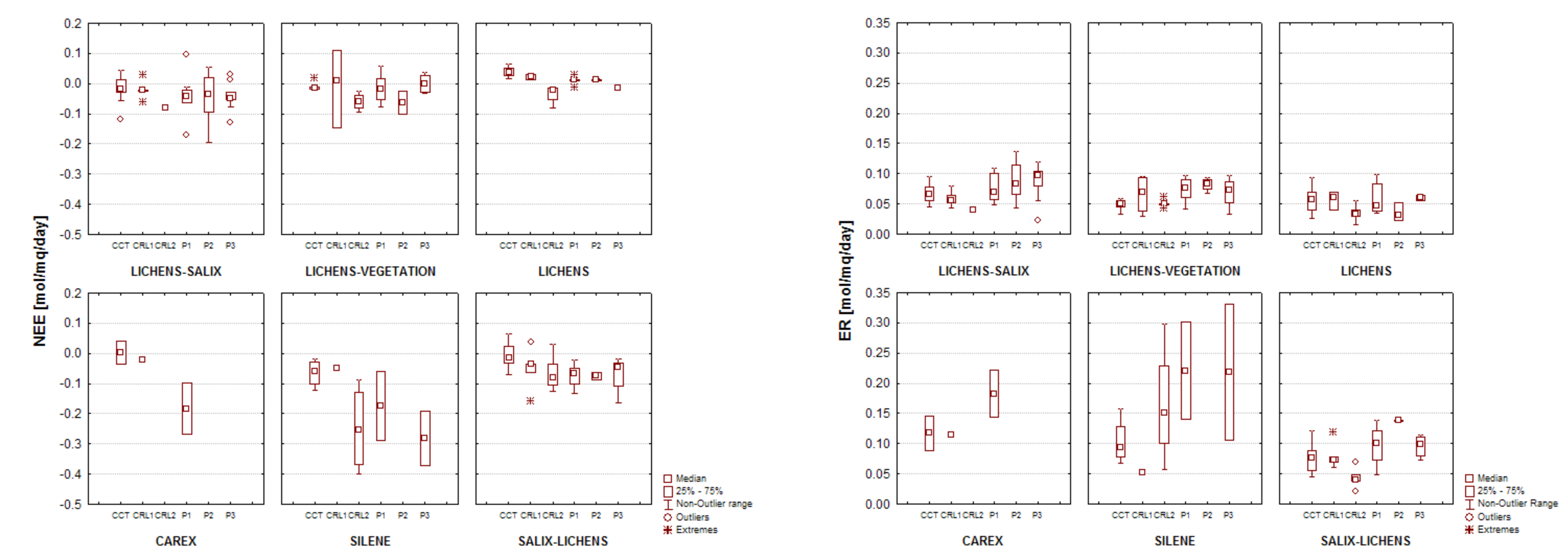

Fig. 7: Median NEE and ER as a function of vegetation cover in the six different plots. Labels: see previous figures.

Measuring CO_2 fluxes: materials and methods

CO_2 fluxes at the soil-atmosphere interface were measured using a portable, transparent accumulation chamber (AC), equipped with an IR spectrophotometer in more than 320 points (Fig. 8). We measured **NEE** using a transparent chamber and **ER** using an opaque chamber. Radiance, air temperature, soil moisture and temperature were also measured. For each point, vegetation cover has been classified and recorded (Fig. 9)

***Fig. 8:** The flux chamber in polymethyl-metachrylate, designed to have a high transmission coefficient of light in the visible spectrum, and how to insert it over the steel collar posed on the ground. The dark cover, soil temperature and moisture sensors are visible.*

***Fig. 9:** Examples of measurement points: (a): Carex spp.; (b): Dryas octopetala; (c): Lichens (d): Silene acaulis.*

Outlines and future perspectives

NEE, GPP and ER show a non-linear dependence on solar irradiance and temperature, but are also influenced by soil moisture[2]. We aim to test existing models[2,3] and investigate how soil physical and geochemical properties influence CO_2 fluxes both at plot level and in relation to single species distribution, also including the active layer depth. Comparison with Eddy Covariance measured fluxes will enable to extend the spatial and temporal estimate of the results obtained by accumulation chambers. We plan to run a long-term experiment, improving both empirical and process-based climate-vegetation models.

***Fig. 10:** Eddy covariance system in Ny Ålesund*

References

[1] Giardino, J., Houser, C., 2015. ISBN: 978-0-444-63369-9, 674 pp.; [2] Magnani et al., 2020, STOTEN, in press. Preprint available at: http://arxiv.org/abs/2004.14262;
[3] Ekici et al., The Cryosphere, 9, 1343–1361, 2015.