Drivers of carbon fluxes in high-altitude Alpine Critical Zone: a data-based model

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Scientific Aims

I) Provide empirical information on carbon controlling processes in high-altitude alpine tundra

II) Identify an empirical model which explains a large part of the CO_2 flux variability, thus improving the representation of observed fluxes

Site: CZO@Nivolet

In 2017, a Critical Zone Observatory (CZO) was established at the Nivolet Plain (CZO@Nivolet, about 2700m asl) in the Gran Paradiso National Park in the western Italian Alps.

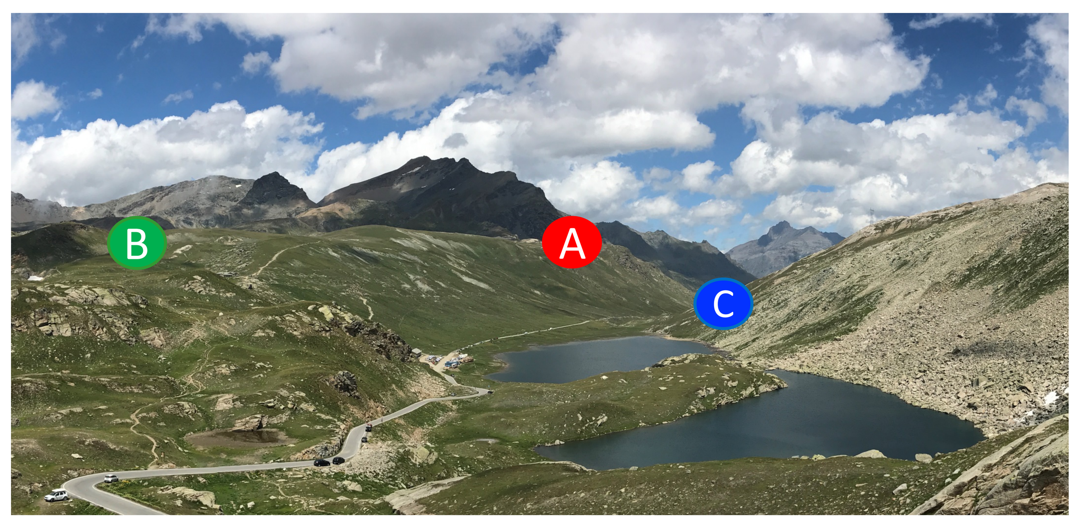

Figure 1. Location (above) and picture (side) of the Nivolet Plain. Measurement sites are marked by letters A (soil on carbonate rocks), B (soil on glacial deposits) and C (soil on gneiss rocks)

CO_2 fluxes at the soil-vegetation-atmosphere interface were measured from July to October in 2017, 2018 and 2019 using a portable accumulation chamber. **N**et **E**cosystem **E**xchange (NEE, i.e. net CO_2 fluxes) and **E**cosystem **R**espiration (ER, i.e. CO_2 emissions) were sampled in randomly chosen points within three selected plots. **G**ross **P**rimary **P**roduction (**GPP**, i.e. CO_2 uptake) was obtained as the difference of NEE and ER (GPP=NEE-ER). The plots (Fig 1) are characterized by soils developed over carbonate rocks (site A), glacial deposits (site B) and gneiss rocks (site C) embedded within the same watershed. Basic meteo-climatic variables, namely air moisture, air temperature, air pressure, solar irradiance, soil moisture and soil temperature were also measured during each campaign.

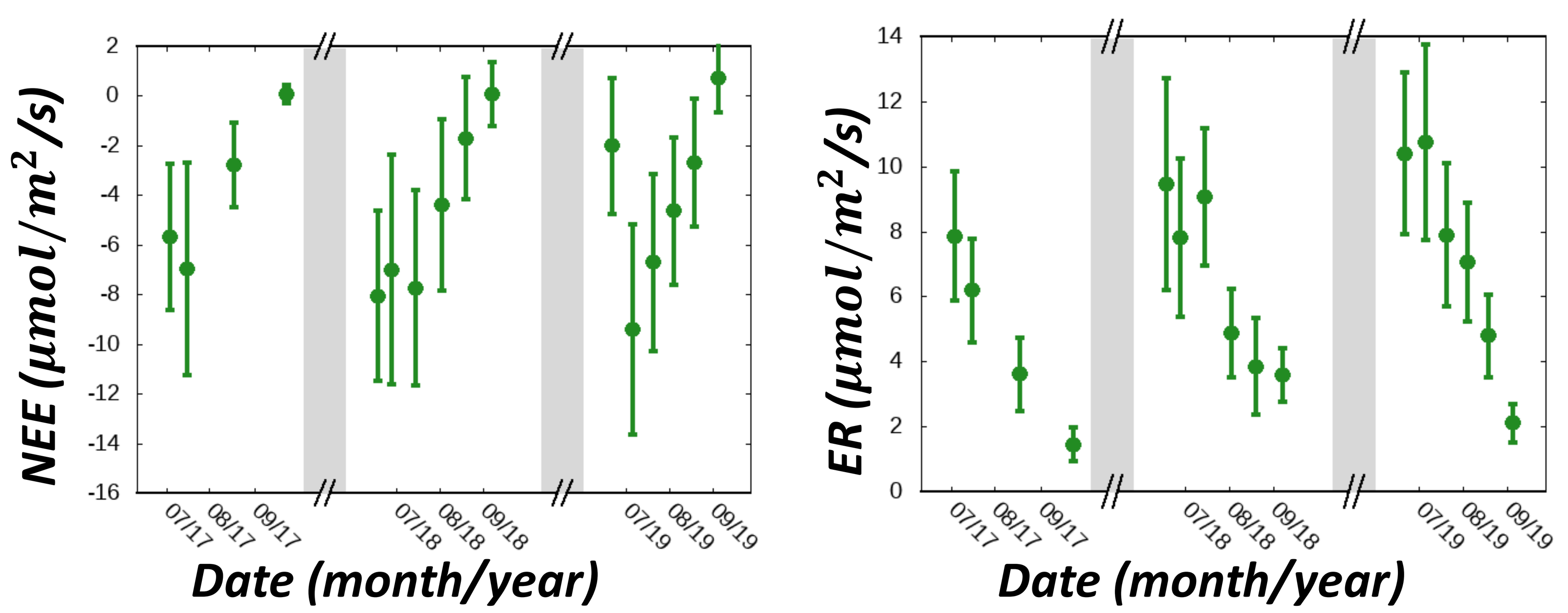

Figure 2. Temporal evolution of the average Net Ecosystem Exchange (NEE, left) and Ecosystem Respiration (ER, right) for site B (soil developed over glacial deposits). Error bars correspond to one standard deviation.

Standard drivers

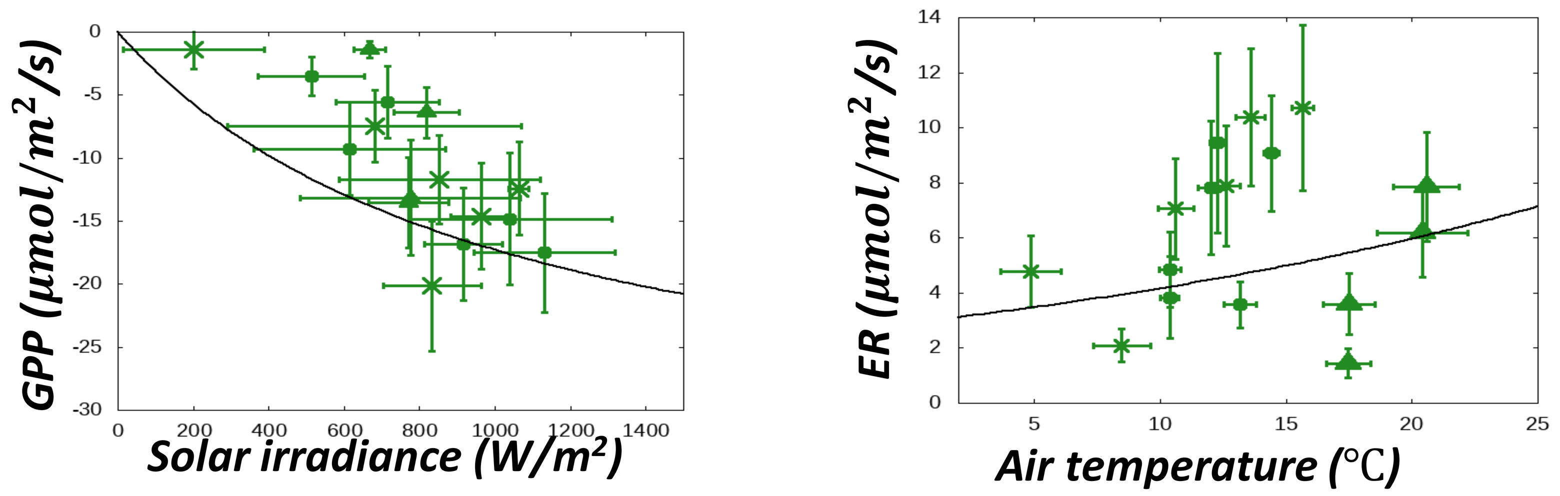

Figure 3. Gross Primary Production versus solar irradiance (left) and Ecosystem Respiration versus air temperature (right) for site A (soil developed over glacial deposits). Black curves are regressions obtained with equations (1) and (2), respectively. The three years of sampling are marked with triangles (2017), circles (2018) and stars (2019)

The standard drivers[a,b] commonly used for ER and GPP are air or soil temperature and light, respectively. However, a large scatter was clearly visible between the data of different sampling years. Lower ER were observed in 2017, the warmest and driest year in the series.

$$\text{Gross Primary Production} = \frac{F_{max}\ \alpha_0\ \text{Solar Irradiance}}{F_{max} + \alpha_0\ \text{Solar Irradiance}} \quad (1)$$

$$\text{Ecosystem Respiration} = a\ e^{b_0\ \text{Air temperature}} \quad (2)$$

Multi regression models

Multi regression models were built for ER and GPP aiming to improve the model representativeness. The explored drivers were the meteo-climatic measurements , the day of the year (1-365 d) and the sampling hours (0-24 h) of the measurement campaigns. A systematic statistical analysis allowed to select the most efficient model among three choices, corresponding to different hypotheses on the effect of the drivers. In all the three sites the best models were parametric ones, with the following formulation:

$$\text{Gross Primary Production} = (A_0 + A_1\ \text{Soil Moisture} + A_2\ \text{Day Of the Year})\ \frac{F_0\ \alpha_0\ \text{Solar Irradiance}}{F_0 + \alpha_0\ \text{Solar Irradiance}} \quad (3)$$

$$\text{Ecosystem Respiration} = (a_0 + a_1\ \text{Soil Moisture} + a_2\ \text{Air Pressure} + a_3\ \text{Day Of the Year})\ e^{b_0\ \text{Air temperature}} \quad (4)$$

Results

1. The parametric model that we built, Equations (3) and (4), explained large inter- and intra-annual variabilities of the CO_2 fluxes (Table 1)
2. The models were calibrated separately for the three sites and significant ($P<0.05$) differences were observed between the parameters of soil moisture, suggesting a possible effect of the parental material on the soil properties and, in turn, on the carbon fluxes.
3. Qualitative projections of fluxes under the expected warmer and drier climate suggest an attenuation of both CO_2 emissions and uptake owing to the effect of decreased soil moisture. However, further studies are needed to obtain quantitative assessments of the combined effect of higher temperatures and lower soil humidity.

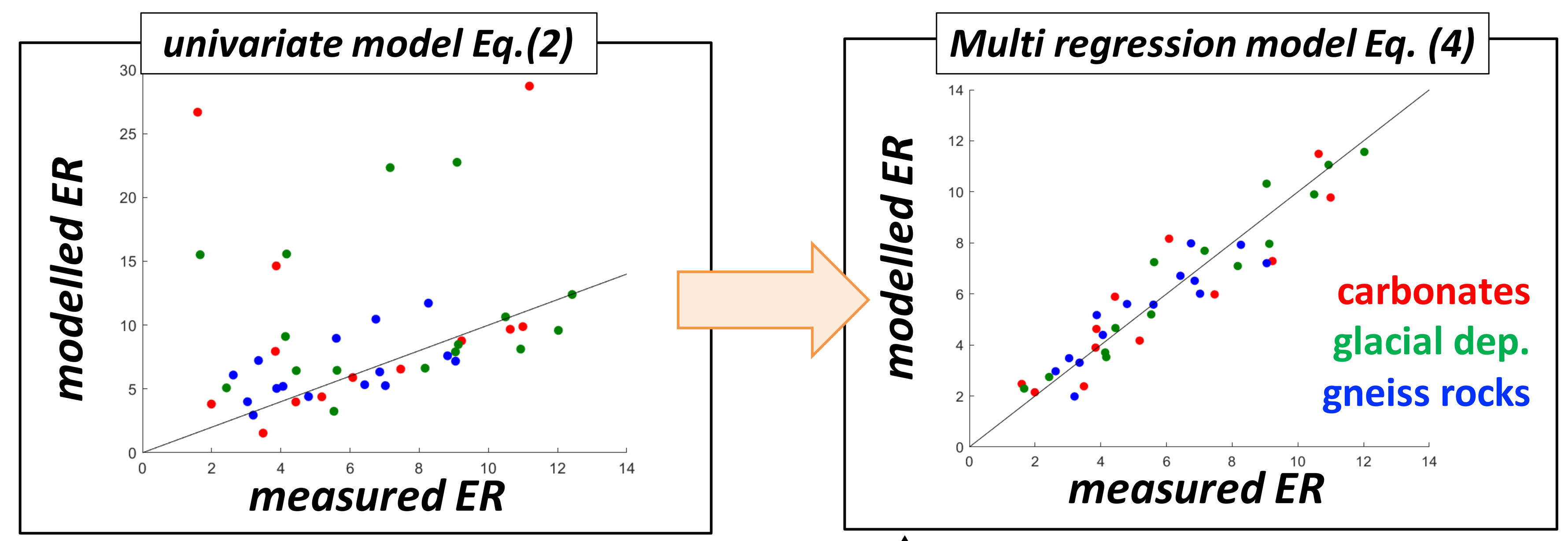

Figure 4. Measured versus modelled data of carbon dioxide emissions (ER) using standard univariate regression (left) and multi regression model (right). Red (site A), green (site B) and blue (site C)

	carbonates	glacial dep.	gneiss
GPP	0.84	0.88	0.89
ER	0.85	0.94	0.83

Table 1. Explained variance of the models (3) of GPP and (4) of ER for the three sites

From Magnani, M, Baneschi, I, Giamberini, M, Mosca, P, Raco, B, Provenzale, A. Drivers of carbon fluxes in Alpine tundra: a comparison of three empirical model approaches, Science of Total Environment, *in press*. Preprint available at: http://arxiv.org/abs/2004.14262

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