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

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In high mountains, the Critical Zone (CZ) is a thin layer sustaining the whole local ecosystem. Here, however, the effects of climate change are manifesting most rapidly than in the surrounding lowlands. This is especially critical for the high-altitude carbon cycle, for which our knowledge is still patchy and new feedbacks could possibly be triggered. In particular, models of the processes that control carbon fluxes in mountain grasslands and Alpine tundra need to be improved. To contribute to fill this knowledge gap, in 2017 a new Critical Zone Observatory was established at the valley of the Nivolet Plain (CZO@Nivolet) in the Gran Paradiso National Park (GPNP), in the western Italian Alps, at about 2700 m asl. Three measurement sites were identified along the flanks of the valley. The sites are characterized by soils developed over carbonate rocks, gneiss rocks and glacial deposits. Since 2017, every year, from July to October, fluxes of carbon dioxide (CO_2) were measured using a portable accumulation chamber, together with basic meteo-climatic and environmental variables, such as soil and air temperature and moisture, air pressure and solar radiation. This work is focused on a novel empirical model that uses unbiased and rigorous statistical analysis of these data to identify the environmental variables that control CO_2 fluxes in Alpine tundra. The modelling approach is applied to the full dataset of simultaneous in situ measurements of the net exchange, ecosystem respiration and environmental variables for the three sites and the three measurement years. Since a large year-to-year variability in the dependencies on solar irradiance and environmental temperature is observed, a multi-regressive model has been implemented, where additional variables are introduced as perturbations of the standard functions. The multi-regressive model identifies the main drivers, highlighting the crucial role of soil moisture, and largely explains the temporal variability of the fluxes, with explained variance up to 90%. This model provides a basis for estimating future scenarios of carbon fluxes in high-altitude Alpine ecosystems.