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No snow for Christmas: the impact of the 2015 extreme winter on CO_2 fluxes in European mountain grasslands

Edoardo Cremonese (1), Marta Galvagno (1), Albin Hammerle (2), Gianluca Filippa (1), and Georg Wohlfahrt (2)
(1) Environmental Protection Agency of Aosta Valley, ARPA Valle d'Aosta, Climate Change Unit, Italy, (2) University of Innsbruck, Institute of Ecology, Innsbruck, Austria

The increasing frequency in extreme climate events is very likely to impact the Alps since this region is characterized by very sensitive ecosystems. Typical alpine ecosystems such as mountain grasslands, show a strong seasonality in carbon uptake and release mostly driven by the onset and the end of the snow season. Extreme climate events, such as long warm and/or dry periods, could change typical snow cover temporal pattern, thereby altering the duration of the period of CO_2 uptake and release. In recent years many studies have analyzed the impact of delayed or anticipated snowmelt on alpine plant phenology, growth and carbon cycling. However, little is known on the effects of a delayed onset of the snow season. During 2015 the whole planet witnessed several record-breaking warm spells which exceptionally warmed the Alps where the temperature anomaly reached +4°C during both the autumn and winter periods. In particular, the onset of the 2015 winter in the Alps was marked by one of the most prolonged lack of snow in years.
In this study, we investigate and discuss the impact of the altered temperature and precipitation pattern during the autumn/winter 2015 on the net ecosystem CO_2 exchange of mountain grasslands at high and low altitudes measured by means of the eddy covariance method. In particular we test the following hypotheses: (i) The presence of a snowpack impedes plant photosynthesis, while without a snowpack, plant net CO_2 uptake may be possible even during wintertime provided temperatures are warm enough. (ii) Below a snowpack, soil temperatures are around zero degrees Celsius, allowing for microbial activity resulting in intermediate soil respiration; without a snow cover soil temperatures may be either lower or higher than zero degrees Celsius, decreasing or increasing soil respiration. The magnitude and direction of the net ecosystem CO_2 exchange of mountain grassland ecosystems is governed by the complex interplay of the factors addressed in hypothesis (i) and (ii).