Tradeoffs between global warming and day length on the start of the carbon uptake period in seasonally cold ecosystems

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INTRODUCTION

In many mountain ecosystems, the net carbon dioxide (CO_2) uptake is limited by the presence of a seasonal snow cover. Projected global warming may thus be hypothesised to cause a shortening of the snow cover period and a larger net CO_2 uptake during the longer vegetation period (Fig. 1). Earlier melt and later establishment of the seasonal snow cover, however, will occur at shorter day lengths, reducing the time of the day during which the presence of sunlight allows plants to assimilate CO_2. The extent to which this effect negates the hypothesised warming-induced lengthening of the carbon uptake period (CUP) has received little attention to date.

We investigated the beginning of the CUP at three mountain grassland sites in the Austrian and Italian Alps along a gradient in elevation and thus temperature and the length of the snow cover period (Figs. 2 and 3). We hypothesised that the warming-induced lengthening of the vegetation period will be compensated most at the lowest elevation site, where snow melt occurs close to the spring equinox when day length changes fastest. In contrast, snow melt at the site with the highest elevation occurs closer to the summer solstice, when daily changes in day length are minimal, and we thus hypothesised that compensating effects due to day length will be smallest there.

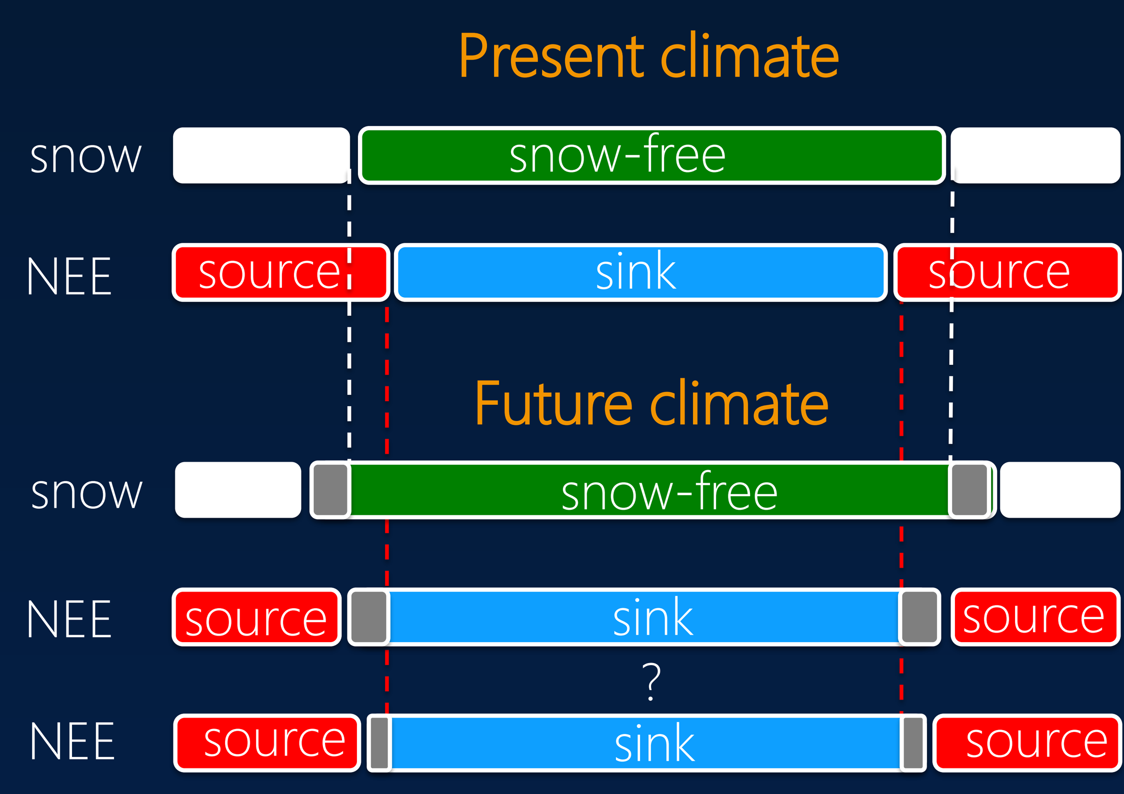

Figure 1 Schematic illustration of how temperature-driven reductions in snow cover duration may affect the net ecosystem CO_2 exchange (NEE).

Figure 2 Location of three mountain grassland study sites (with indication of elevation).

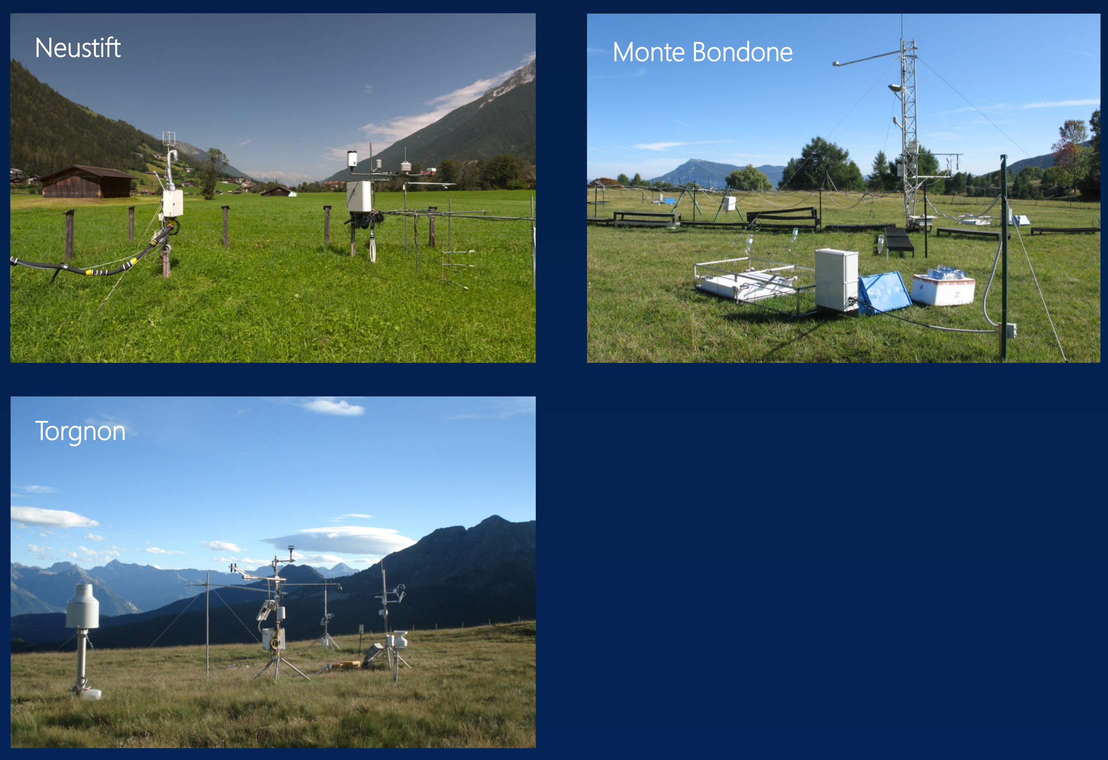

Figure 3 Pictures of the three study sites.

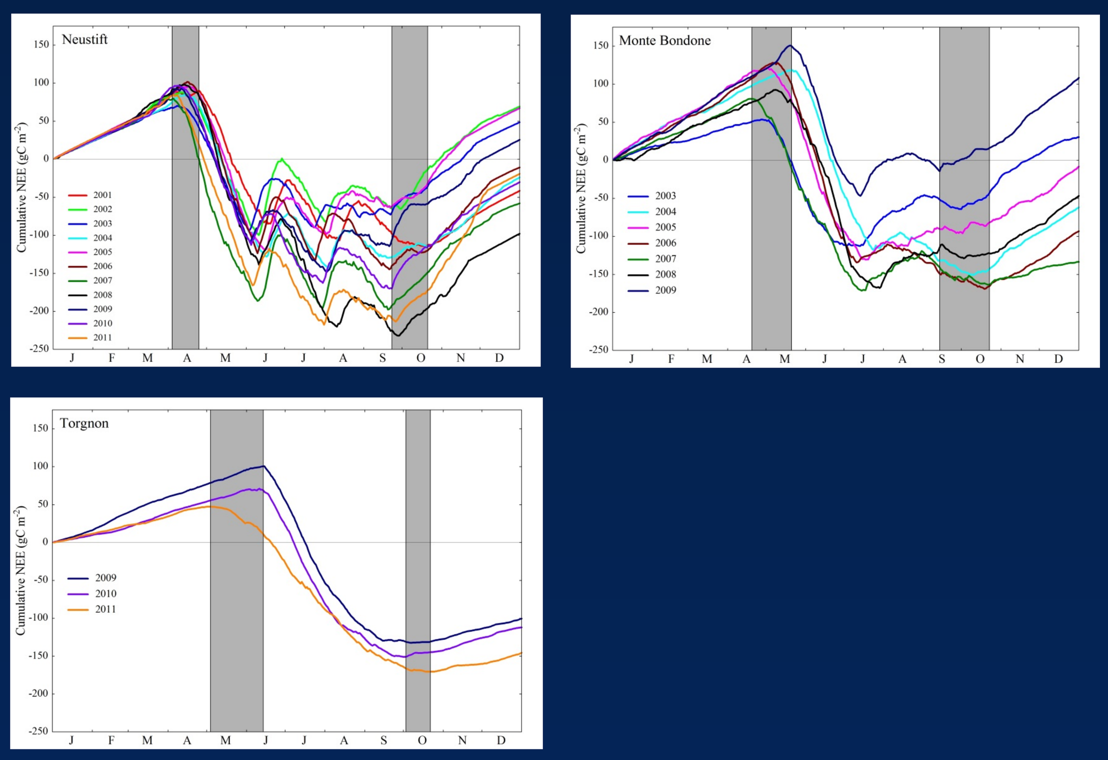

Figure 4 Net ecosystem CO_2 exchange (NEE) measured at the three study sites.

METHODIK

Three study sites (Figs. 2 and 3) in the Austrian and Italian Alps along a gradient in elevation were chosen: Neustift (970 m), Monte Bondone (1550 m) and Torgnon (2160 m). At all three sites the net ecosystem CO_2 exchange (NEE) was measured by means of the eddy covariance method (Fig. 4), along with measurements of environmental drivers such as air temperature, solar radiation and snow presence. A simple empirical model of NEE was calibrated and successfully validated on the basis of the empirical data (Fig. 5).

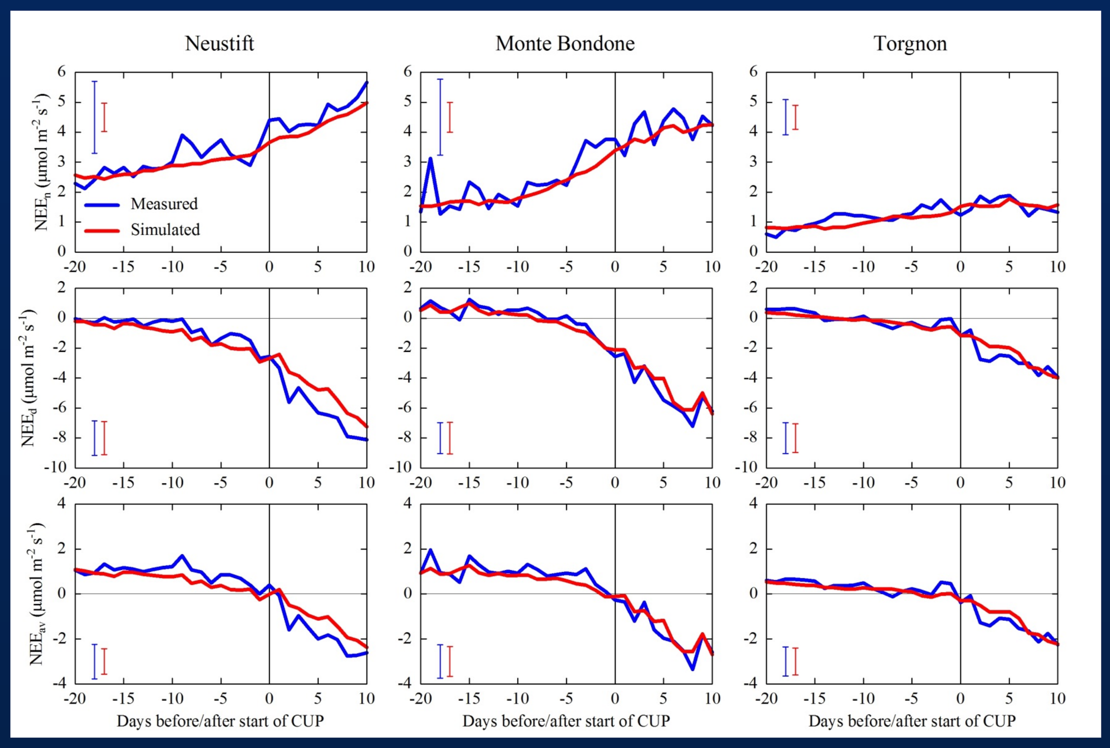

Figure 5 Comparison between measured (blue lines) and simulated (red lines) nighttime (upper panels), daytime (middle panels) and daily average (lower panels) net ecosystem CO_2 exchange (NEE).

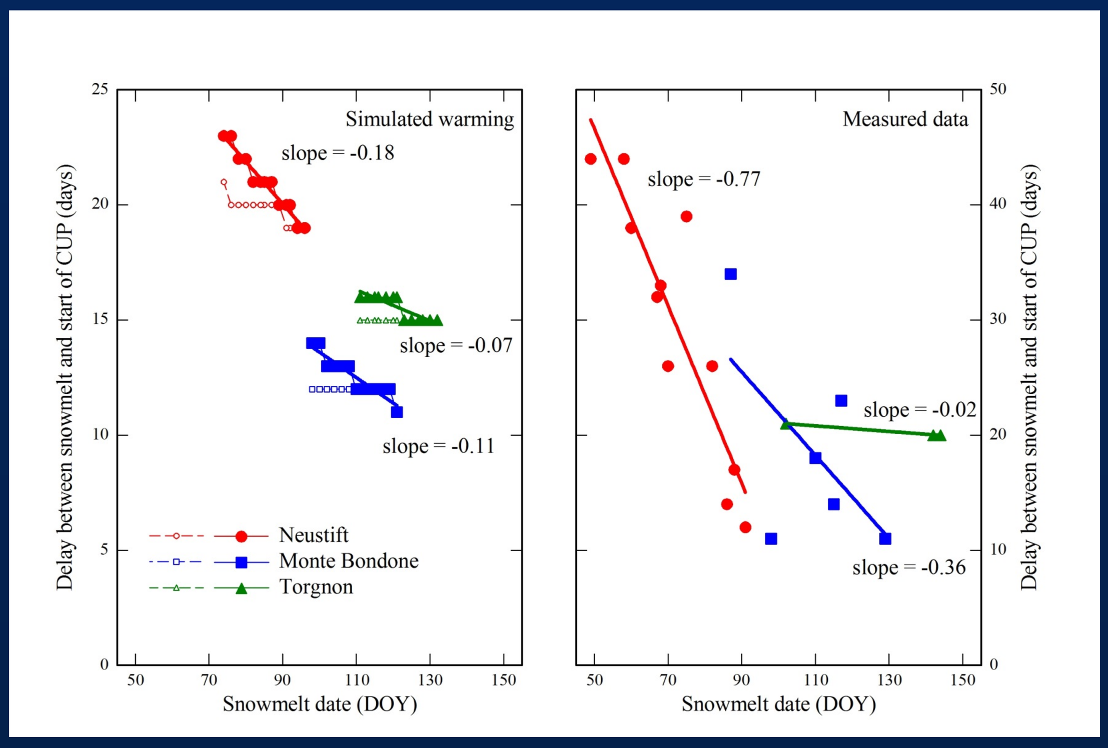

Figure 6 Effects of changes in simulated (left panel) and actual (right panel) snowmelt date on the time delay between snowmelt date and the start of the carbon uptake period (CUP).

ERGEBNISSE

We show that reductions in the quantity and duration of daylight associated with earlier snowmelts were responsible for diminishing returns, in terms of carbon gain, from longer growing seasons caused by reductions in daytime photosynthetic uptake and increases in nighttime losses of CO_2. The earlier snowmelt (simulated or actual) occurred, the longer it took the grassland ecosystems to turn into sinks for CO_2 (Fig. 6).

This effect was less pronounced at high, compared to low, elevations, as evident from the smaller slopes of the responses shown in Figure 6.

CONCLUSIONS

As hypothesised, warming-induced earlier snow melts did not translate one-to-one into earlier starts of the CUP due to concurrent reductions in the quantity and duration of daylight. The magnitude of this effect depended on the time of year when snow melt occurs. For the investigated grasslands along the elevational gradient, snow melt occurred the latest at highest elevation (Torgnon) and the start of the CUP at this site was most responsive to warming. Our results thus suggest that higher as opposed to lower elevation mountain grasslands will be better able to take advantage (in terms of carbon gain) of likely future longer growing seasons.

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