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Tradeoffs between global warming and day length on the vegetation carbon uptake period

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There has been much discussion about whether earlier vegetation greenup associated with global warming will allow for an earlier starts of the net carbon dioxide (CO_2) uptake period (CUP) by vegetation and thus possibly increase the terrestrial carbon sink. One aspect of this discussion that has received little attention so far is that earlier vegetation greenup will occur at shorter day lengths which reduces the time of the day during which the presence of sunlight allows for photosynthesis and thus carbon uptake.

We hypothesise that shorter day lengths associated with earlier vegetation greenup will partly compensate for any temperature-mediated earlier starts of the vegetation period. To test this hypothesis we use eddy covariance CO_2 flux data from three mountain grasslands in the Alps: Neustift (970m), Monte Bondone (1500m), Torgnon (2160m). The three grassland sites are at the same latitude, but differ in elevation and thus temperature and thus the length of the snow cover period. We hypothesise that the warming-induced lengthening of the vegetation period will be compensated most by day length 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 hypothesise that compensating effects due to day length will be smallest there.

The hypothesis was tested using a phenomenological model of the net CO_2 exchange of mountain grassland ecosystems that has been trained with measured eddy covariance CO_2 fluxes. On average, the model was well able to simulate both daytime and nighttime NEE and thus predicted the start of the CUP reasonably well. The model was then used to simulate the start of the carbon uptake period using climatological time series of air temperature by uniformly increasing air temperature between 0 and 3 K. A 10 day earlier start of the CUP went along with a 32, 27 and 20 min reduction in day length at Neustift, Monte Bondone and Torgnon, respectively. Simulated warming (up to +3K) caused both snow melt and the start of the CUP to occur earlier. The earlier start of the CUP, however, did not match the earlier snow melt due to concurrent reductions in day length and so the time period in between increased with warming. As hypothesised this increase scaled with elevation and the timing of snow melt. A 10 day earlier snow melt caused the time period until the start of the CUP to increase by 1.8, 1.3 and 0.6 days at Neustift, Monte Bondone and Torgnon, respectively.

As hypothesised, warming-induced earlier snow melts did not translate one-to-one to earlier starts of the CUP due to concurrent reductions in day length. 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 thus most responsive to warming.