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Process-based modeling for mountain pasture dynamics in unusual warm and long snow-free wintertime

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Alpine plant ecosystems are known as a carbon source mainly in colder periods when soil respiration is exceeding gross primary productivity. However, there is still little information about the specific impact of snow cover and thus the response of these ecosystems to climate warming and accompanying snow cover shortening is unclear. Here, we coupled a multi-layer atmosphere-SOiL-VEGetation model (SOLVEG) with a detail snow scheme, a grass growth scheme, and a soil microbiology scheme to investigate managed grassland-snowcover dynamics. The employed grass growth module can simulate key processes under cold environment such as leaf formation, elongation and death, tillering, carbon allocation, and acclimation on temperature on photosynthetic activity and frost damages. We applied the modified SOLVEG to pre-alpine grassland sites in TERestrial ENvironmental Observatories (TERENO) networks in Germany for a year with an exceptional small amount of snowfall (2013-2014). The modified model reproduced temporal changes in observations of surface energy and CO_2 fluxes, soil temperature and moisture, and aboveground biomass. Our simulations and measurements demonstrate that grasses at lower elevation continuously assimilate atmospheric CO_2 even in the middle of winter season. On the other hand, dead leaf biomass increases due to frosts over cold snow-free days. As a result, snow-free wintertime carbon uptake was not as large as expected (13% of the annual carbon uptake), and it almost balanced with wintertime soil respiration. However, under temperature rise conditions, grass ecosystems act as a strong sink of CO_2 from winter to early spring (25% of the annual carbon uptake) due to a decrease of frost damages of foliage. Future climate developments may enhance the importance of wintertime carbon uptake of typical mountain grass species in the world.

Keywords: managed grassland dynamics, snow-free period, land surface model, photosynthesis, frost damage, European Alps