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Experimental soil warming leads to sustained losses of old C from alpine treeline ecosystems

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The impact of climatic warming on the soil C balance is uncertain because rising temperature increases both C inputs into soils, but also respiratory C losses. 'Cold' ecosystems such as treeline ecotones will respond particularly sensitive to climatic changes because many processes are limited by temperature and soils store particular large amounts of labile soil organic matter. In our study, we investigate responses of carbon fluxes to 6 years of experimental soil warming by 4°C with heating cables on the soil surface. The warming study was conducted in a 9-year CO_2 enrichment experiment, in which the added CO_2 carried another [U+F064]13C signature than normal air, which allows the tracing of new carbon through the plant and soil system. This provides new insight into carbon cycling at the treeline and it shows which C flux respond most sensitive to climatic changes. Results showed that soil warming increased soil CO_2 effluxes instantaneously and persistent for six vegetation periods (+30-50%; +80 to 120 g C m y-1). Annual C uptake of new shoots was not significantly affected by elevated soil temperatures, with a 10 to 20% increase for larch, pine, and dwarf shrubs, respectively, resulting in an overall increase in net C uptake by plants of 20 to 40 g C m-2y-1. The temperature dependency of soil respiration did not change through six years of experimental soil warming, suggesting little impact of warming-induced lower soil moisture (-15% relative decrease) or a depletion in labile soil C. The fraction of recent plant-derived C in soil respired CO_2 from warmed soils was smaller than that from control soils (30 vs. 50% of total C respired), which implies that the warming-induced increase in soil CO_2 efflux resulted mainly from mineralization of older SOM rather than from stimulated root respiration. Analysis of phospholipid fatty acids indicated an unchanged microbial community on the group level, but significantly smaller fractions of new plant C in the warmed soils. In conjunction with the respiration data, this indicates that soil warming particularly increased the use of old SOM by the microbial community. Potential reasons for the different response of new and old SOM is either (i) a reduced root growth due to higher N mineralization requiring a smaller investment by plants into the belowground; and/or (ii) a drying of the surface soils with higher contents of new C in roots and litter smaller C inputs by roots. In summary, the 4°C soil warming led to C losses from the studied alpine treeline ecosystem by increasing SOM decomposition more than C gains through plant growth and inputs of new C into soils.