Geophysical Research Abstracts
Vol. 12, EGU2010-2918, 2010
EGU General Assembly 2010

Winter soil respiration originates mainly from old soil organic matter – a 13CO2-tracer study at the alpine treeline

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In high latitude and altitude ecosystems, soil respiration during winter contributes substantially to annual CO2 effluxes. Despite low air temperatures, soil microbes remain still active under thick insulating snow packs. However, there are no appropriate methods to quantify soil CO2 effluxes under thick snow packs, and the sources of soil-respired CO2 in winter are highly uncertain.

The aim of this study was to assess winter soil respiration and its components at the Swiss alpine treeline near Davos. We quantified soil CO2 effluxes by measuring the CO2 gradients in the snow pack, estimating the diffusion coefficients in the snow, and validating the method by controlled CO2 effluxes from an artificial sandbox. To identify the sources for soil-respired CO2 we made use of a nine-year CO2 enrichment experiment where the added CO2 was depleted in 13C. This provided a unique 13C label for recent plant-derived C in the plant and soil system. Results indicate that the commonly used gradient method underestimated soil CO2 effluxes. At this treeline site, about 25% of the annual CO2 efflux from soils occurred during the seven month long winter. The 13C-tracing reveals substantial changes in the sources of soil-respired CO2 during the year. While approximately 50 to 60% of the respired CO2 originated from recent plant-derived C (root and litter) during the growing season, this fraction accounted only for 20 to 30% of the respiration losses in winter. One reasons for the small losses of recent plant-derived C during winter are negligible plant activities under the more than 1 m thick snow pack. Another reason could be the temperature profile in soils with frozen litter layer and ‘warm’ subsoils, and thus, relative higher respiratory activity in deeper soils with older soil organic C. We tested the latter

In summary, our results show that soil respiration in winter contributes significantly to annual CO2 effluxes and that it is dominated by old C. Therefore, it plays an important in the balance of soil organic matter.