Spatial and Seasonal Variability of δ13C of Soil CO2 and Flux in Complex Terrain

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Topography can modify the distribution and availability of biophysical resources in complex terrain, resulting in spatial and temporal patterns of carbon transformation at the landscape level. Although the biogeochemical processes driving the spatial variability in soil CO2 and its production have been well studied, little is known about the variability in the spatial distribution of the stable carbon isotopes that make up that soil CO2, particularly in complex terrain. Spatial differences in stable isotopes of soil CO2 could be indicative of fundamental differences in isotopic fractionation at the landscape level, and may be useful to inform process modeling of carbon cycling over large areas. In this study, we examine the spatial and seasonal variability of the δ13C of soil CO2 (δS) and the δ13C of soil respiratory source (δP) in a subalpine forest ecosystem located in the northern Rocky Mountains of Montana. We found consistently more isotopically depleted values of δS and δP in low and wet areas of the landscape (i.e., riparian areas) relative to steep and dry areas (i.e., upland forests). Our results suggest that the spatial patterns of both δS and δP are strongly mediated by soil moisture and the rate of soil respiration at the landscape scale. More interestingly, our analysis revealed a seasonal pattern of δP across the landscape, which might be the result of differential dynamics in the seasonality of soil moisture and its effects on soil CO2 production and flux. Our results suggest concomitant yet independent effects of soil water on physical (i.e., soil gas diffusivity) and biological (i.e., photosynthetic discrimination) processes that mediate the dynamics of δS and δP, and are important when evaluating the composition of CO2 exchanged between the land surface and the atmosphere in complex terrain.