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Isotopic evolution of a seasonal snowcover and its melt by isotopic exchange between liquid water and ice

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Understanding an isotopic evolution of a snowpack is important for both climate and hydrological studies, because the snowmelt is a significant component of groundwater and surface runoff in temperate areas. In this work, we studied oxygen and hydrogen isotopic evolution from new snow to snow profile and to meltwater through two winter seasons (1998 and 2001) at the Central Sierra Snow Laboratory, California, USA. The slopes of the D vs. 18O regression for the new snow are similar to that of the global meteoric water line (GMWL) of 8. However, this slope decreases in the snow profile and decreases further in the meltwater. We attribute this systematic slope changes to the isotopic exchange between ice and liquid water that is generated at the snow surface by melting and flows through the snowpack by percolation. A physically based one-dimensional model, including melting of snow at the surface and isotopic exchange between percolating water and ice, were used to simulate isotopic variation of snowmelt in 2001. A successful simulation was obtained for the D-18O slope of snowmelt (6.5), which is significantly lower than the slope of the meteoric water line (8.2) defined by the new snow. This result indicates that the liquid water evaporation should not be considered as the only process that yields slopes of the D vs. 18O relationship in surface water and groundwater. The d-excess of the snowmelt is changed from the original snow because of the D-18O relationship controlled by ice-liquid exchange. With a D-18O slope less than 8, the d-excess would be anti-correlated with D or 18O. The model is also used to examine how isotopic heterogeneity of a snowpack affects the isotopic redistribution in the pore water, ice and meltwater of the snowpack. The results show that isotopic heterogeneity of the snowpack may significantly affect the temporal changes in the D-18O slopes, and a measured slope at a given time is a combined result of meteorological conditions, which affect both isotopic composition of the original snow and the process of snow metamorphism, and the melting history of the snowpack.