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Evaluation of short-term tracer fluctuations in groundwater and soil air in a two year study

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The application of gas tracers like noble gases (NGs), SF_6 or CFCs in groundwater studies such as paleo temperature determination requires a detailed understanding of the dynamics of reactive and inert gases in the soil air with which the infiltrating water equilibrates. Due to microbial gas consumption and production, NG partial pressures in soil air can deviate from atmospheric air, an effect that could bias noble gas temperatures estimates if not taken into account. So far, such an impact on NG contents in groundwater has not been directly demonstrated. We provide the first long-term study of the above mentioned gas tracers and physical parameters in both the saturated and unsaturated soil zone, sampled continuously for more than two years near Mannheim (Germany). NG partial pressures in soil air correlate with soil moisture and the sum value of O_2+CO_2, with a maximal significant enhancement of 3-6% with respect to atmospheric air during summer time. Observed seasonal fluctuations result in a mass dependent fractionation of NGs in soil air. Concentrations of SF_6 and CFCs in soil air are determined by corresponding fluctuations in local atmospheric air, caused by industrial emissions. Arising concentration peaks are damped with increasing soil depth. Shallow groundwater shows short-term NG fluctuations which are smoothed within a few meters below the water table. A correlation between NG contents of soil air and of groundwater is observable during strong recharge events. However, there is no evidence for a permanent influence of seasonal variations of soil air composition on shallow groundwater. Fluctuating NG contents in shallow groundwater are rather determined by variations of soil temperature and water table level. Our data gives evidence for a further temperature driven equilibration of groundwater with entrapped air bubbles within the topmost saturated zone, which permanently occurs even some years after recharge. Local subsurface temperature fluctuations may thus lead to subsequent variations of NG contents in groundwater, independent of the former recharge temperature. This effect is of major importance for gas tracer applications in recent and shallow groundwater.