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Use of Environmental Tracer Data for Groundwater Modelling

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Environmental tracers released into the atmosphere since the early ‘50s by human activities provide an innovating tool to investigate the subsurface dynamics of water. Groundwater age and other types of information can be estimated by comparison of the measured atmospheric input function and the concentration in groundwater samples. In this work we focus on the investigation of water movement in the subsurface by means of the environmental tracers ^{3}H, ^{3}He and ^{85}Kr as well as their implementation in groundwater modelling. A combination of information coming from different tracers is expected to make their application more reliable. The reference test site for this study is the Baltenswil aquifer (Switzerland).

As shown by Cook and Solomon (1995), thick unsaturated zones ($>$10m) act as buffer zones that result in a non negligible time-delay effect that must be considered in the calculation of the groundwater age. We assume that different transport processes (advective for water-bound in ^{3}H and purely diffusive for gas-tracers ^{3}He and ^{85}Kr) in the unsaturated zone cause the differences in ^{3}H/^{3}He and ^{85}Kr ages as observed in groundwater samples from the Baltenswil aquifer. Therefore, a numerical solution of the vertical advection-diffusion equation in the unsaturated zone was calculated. Lower and smoothed temporal concentration distributions, compared to the atmospheric input function, were found at depth. Sensitivity analysis showed that the most important parameters to the final concentration time series at the groundwater table are

the effective diffusion coefficients, the unsaturated zone thickness, the water content and porosity.

The flow model for the saturated zone was assessed using a Stochastic Inverse Modelling Technique. A set of 500 multiple equally likely 2d realizations of the log-transmissivity field was generated with GCOSIM3D (Gomez-Hernandez and Journel, 1993) conditional on 17 transmissivity (T) measurements. In addition, these *logT* fields were also conditioned to 55 transient hydraulic head measurements by the Sequential Self-Calibrated Method (Gomez-Hernandez et al., 1997), implemented in the code INVERTO (Hendricks-Franssen, 2001).

Selected calibrated stochastic T-realizations were then used as input into a transport model for the years 1950-2005. Breakthrough curves at observation locations showed that a fair agreement between simulated and observed concentration values can only be achieved if the tracer transport in the unsaturated zone is considered. Simulated groundwater ages were found to be dependent on the selected T-realization, which directly influence the flow pathlines and thus the water residence time in each of the two zones. Information based on the tracer transport simulations was proven to be very valuable for the calibration of parameters such as effective diffusion coefficient, water content and porosity. As a next step, tracer-derived ages can be used to further restrict the ensemble of acceptable T-realizations, thus contributing to a better characterization of the flow field.