The use of environmental tracer concentration data within the context of coupled flow and reactive transport modeling

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Groundwater flow models are routinely used to gain a better quantitative understanding of groundwater flow systems and often provide the basis for important water resources management decisions. Traditionally such models are mostly constrained by hydraulic head observations. However, even perfectly calibrated models remain subject to significant non-uniqueness and considerable predictive uncertainties as they can only provide reliable estimates of the ratio of hydraulic conductivity to recharge and/or aquifer transmissivity to storage. Those uncertainties can potentially be reduced by including the transport of environmental tracers (e.g., ^{14}C, tritium, CFC's or SF6) into the simulation framework and by using observed environmental tracer concentrations as additional calibration constraints. This generally benefits the conceptualisation of the flow system and the quantification of groundwater fluxes. In addition, if integrated into a reactive transport modeling framework they can also play an important role in unravelling the interplay between flow and geochemical processes in complex groundwater systems. By simultaneously assessing flow, environmental tracer concentrations and water quality evolution, conceptual models can be developed and numerically tested to discern if hydraulic processes govern the geochemistry, or whether concentration patterns are predominantly controlled by geochemical processes.

The utility of the approach is demonstrated for several applications that span over different time- and length-scales and address a variety of groundwater quality problems.