Geophysical Research Abstracts
Vol. 13, EGU2011-12552, 2011
EGU General Assembly 2011
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The Value of Natural Tracers for Parameter Estimation in a Creek-Wetland Complex

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Residence time and environmental signatures of natural tracers can provide information about flowpaths and provenance, insight valuable to modeling groundwater flow and tracer transport through the hydrologic cycle. Different natural tracers provide distinct information about processes. In this work, we focus on δ18O and temperature in a wetland-stream complex at the Trout Lake Water, Energy and Biogeochemical Budgets/North Temperate Lakes Long Term Ecological Research site in northern Wisconsin, USA. Modeling δ18O provides information on provenance of water flowing through the wetland into the stream due to fractionation signatures that differentiate recharge through a nearby lake, wetland or terrestrial sediments. Modeling temperature profiles near the wetland surface and temperature anomalies measured in the stream characterizes the distribution of water exchange occurring between preferential flowpath conduits in soil pipes and slower flowpaths traveling through the peat matrix. A coupled model of groundwater flow (using MODFLOW-2005) and δ18O and heat transport (using MT3DMS) is constructed with 24 layers in a highly-parameterized context using pilot points to represent spatially variable hydrogeologic and thermal properties. The highly-parameterized approach allows for flexibility facilitating identification of potential heterogeneity and reduction of the structural component of epistemic uncertainty. The coupled model was calibrated to conditions in 2005 and 2006 using PEST. Through the parameter estimation process, the identifiability of specific parameters was examined using singular value decomposition and associated statistics. The leverage and influence of the three data types (hydraulic data, heat and δ18O), before and after calibration, are quantified and examined to indicate the relative value of the distinct tracer types for the processes being simulated by the model. The outcome of this work is a systematic approach to evaluating the impact of natural tracers on accurately modeling groundwater and surface water interaction in a wetland-stream environment. Important considerations of linking the flow and transport models are discussed. While δ18O provides integrative flowpath delineation on the large scale, temperature informs the local interactions near the surface and their combination in a holistic approach results in a model capable of addressing the response of the wetland-stream environment to multiple scales of changing conditions.