Reanalysis, Stable Isotopes and the Age of Water: Improving Constraints for Model Identification at a Critical Zone Observatory

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This paper presents a hydrologic model for an upland catchment constrained by climate observations and stable isotopes of oxygen and hydrogen at the Susquehanna/Shale Hills Critical Zone Observatory (SSH_CZO).

Model forcing uses NLDAS-2 reanalysis time series for daily weather forcing and IsoRSM regional atmospheric model (isotope-incorporated regional spectrum model) for simulating stable isotopes in precipitation and water vapor at 10 km x 10 km spatial resolution. The regional model is developed through a dynamical downscaling technique that applies the results of the global simulation and a spectral nudging technique to produce the higher resolution data (Kei Yoshimura & Kanamitsu, 2008). The regional model results were compared to 4 years of daily sampled stable isotope data in precipitation at the SSH/CZO and good agreement is found, extending the precipitation isotope data to the full reanalysis period (1979-2014).

The paper next develops the theoretical basis for simulation of flow, isotope ratios and “age” as water moves through the canopy, to the unsaturated and saturated zones and finally to an intermittent stream. The model formulation demonstrates that the residence time and age of environmental tracers can be directly simulated without knowledge of the form of the underlying residence time distribution function and without the addition of any new physical parameters.

The model is then used to explore the rapid attenuation of event and seasonal isotopic ratios in precipitation over the depth of the soil, and the impact on streamflow and stream isotope ratios. The results suggest the importance of mobile macropore flow on recharge to groundwater during the non-growing cold-wet season. The soil matrix is also recharged during this season with a cold-season isotope signature on recharge and baseflow. During the growing (dry) season, root uptake and evaporation from the soil matrix along with a declining water table determines the growing season isotope signature.

The paper concludes by illustrating how system memory, age and residence time estimation can be used to constrain the model through sensitivity analysis of parameters as a function of mean isotopic age.

Keywords: catchment hydrology, stable isotopes , dynamical model, isotopic age of water

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