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Streamwater time series coupled to groundwater age tracers informs the hydrologic partitioning of rainfall, the transient age distributions and their associated reactivity

Jean Marçais, Jean-Raynald de Dreuzy, Louis A. Derry, Luca Guillaumot, Aurélie Guillou, Camille Vautier, Luc Aquilina, and Gilles Pinay
Inrae, UR Riverly, Villeurbanne, France (jean.marcais@inrae.fr)

Intricated variabilities of stream water quality and of stream discharge can provide key insights of integrated processes occurring at the watershed scale. Yet it is difficult to disentangle the effects of hydrologic vs biogeochemical processes occurring in the different compartments of the critical zone, as well as the mixing associated to it. Here we developed a *quasi*-2D hillslope scale model able to represent the partitioning of precipitation into real evapotranspiration, shallow subsurface lateral flow and deeper groundwater flow circulation. Enhanced with an advective-dispersive particle tracking algorithm, the model delineates the age distributions of the associated flow lines and the resulting transient streamwater transit time distributions (TTDs). To relate geochemical datasets to TTDs, we connected the biogeochemical reactivity, spatially, to the compartment (regolith vs bedrock) and, in time, to the residence time of the different flowpaths.

We hypothesized that streamwater time series datasets (discharge and dissolved silica) and *in-situ* groundwater age tracers (CFCs) would build minimal but orthogonal information upon these partitioning and tracing processes. Applied to 4 different catchments in Brittany, we were able to represent the seasonal dynamics of evapotranspiration, discharge and dissolved silica (DSi) in rivers as well as CFC concentrations in aquifers once key characteristics of the watershed have been informed (evapotranspiration ratio, amount of water stored in the regolith and in the aquifer, bedrock transmissivity, weathering capacity). We found evapotranspiration ratio (ET/P) in average equal to 54% in agreement with independent, large-scale estimates (derived from the French climate Surfex model). The model also provides estimates for typical bedrock transmissivities around 5.10^{-4} m^2/s, mean transit times around 10 years with an important spatial and temporal variability, amount of stored water in average equal to 160 mm (resp. 3.10 m) in the regolith (resp. bedrock) and DSi weathering capacity of 0.3 mg/L/yr, which is in accordance with previous studies carried in crystalline contexts like Brittany [Leray et al. 2012, Kolbe et al. 2016, Marçais et al. 2018]. Simplifying the transient behavior of the catchment model with some analytical considerations enabled to directly inform these key characteristics with some properties of the measured datasets (e.g. average low flow rate, mean and standard deviation of the DSi time series, average CFC apparent ages).

This shows that these datasets can be used as standalone tracers and provide powerful indicators

of critical zone characteristics described above. This also opens new avenues to spatialize the reactivity in the deep critical zone, and to integrate the information provided by different datasets (e.g. climatic forcing, discharge, solute concentrations, groundwater age tracers) measured in streams and in groundwater. Such modeling exercice paves the way toward an interdisciplinary understanding of the critical zone.