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Partitioning fast flow from stratified groundwater flow modulates seasonal variations of old streamwater transit times

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We develop a parsimonious model-data fusion to capture the groundwater contribution to stream discharge and its effect on variable transit times. The modeling strategy relies on partitioning infiltration between 1) Boussinesq groundwater flows in shallow aquifers and 2) fast flows close to the surface. Partitioning is controlled by the relative aquifer saturation inducing groundwater return flows and fast flows on saturated soils. Flowpaths are computed with a new 2D particle tracking algorithm to obtain transient transit time distributions. Hydraulic conductivity, total and drainable porosities are constrained through a sequential calibration strategy based on discharge time series and point-based CFC tracer data. Application on a 43 km2 catchment in Brittany (France) highlights the important contribution of old groundwater flow dynamics to streamflow's transit time distributions in all seasons under temperate climate conditions. The calibrated model succeeds in reproducing CFC-based groundwater ages as well as discharge dynamics at the outlet of the catchment. Slow groundwater circulation (baseflow and return flow) represents ca. 75% of the streamflow with strong seasonal variations (between 40 and 95%). Mean transit times are ca. 13 years, varying between 5 and 20 years, inversely proportional to the groundwater contribution. These seasonal variations are dominantly due to the flow partitioning between the aquifer and soil compartments with a second-order contribution of the groundwater transit times stratification.