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Young water dominance in the humid tropics in Costa Rica

Alicia Correa[1], Christian Birkel[1,4], Jason Gutierrez[1], Joni Dehaspe[1,2], Ana María Duran-Quesada[3], Chris Soulsby[4], and Ricardo Sánchez-Murillo[5]

[1]Department of Geography and Water and Global Change Observatory, University of Costa Rica, San José, Costa Rica (alicia.correa@ucr.ac.cr)

[2]Umweltforschungszentrum Leipzig, Germany

[3]Atmospheric, Oceanic and Planetary Physics Department; Climate System Observation Laboratory School of Physics and Geophysical Research Center (CIGEFI), University of Costa Rica, San José, Costa Rica,

[4]Northern Rivers Institute, University of Aberdeen, Aberdeen, Scotland

[5]Stable Isotopes Research Group and Water Resources Management Laboratory, Universidad Nacional, Heredia, Costa Rica

The headwater catchments in the humid tropical forests are of major hydrological importance for regional and global climate systems and provide essential ecosystem services such as water supply for other ecosystems and industrial use in the lowlands. Anthropogenic pressure together with global environmental changes critically alter the hydrological functioning of these catchments. However, limited knowledge jeopardizes a proper water resources management of such water towers.

To contribute to filling this gap, we conducted a field monitoring of hydro-climatic and isotopic data (01.2013 – 07.2018) in a pristine tropical rainforest catchment (3.2 km^2) in Costa Rica and used this data to test hypotheses about water age dynamics. The Spatially-Distributed Tracer-Aided Rainfall-Runoff model for the tropics (STARRtropics) was applied in high temporal (hourly) and spatial (10m) resolution. The best-obtained model simulations reflected a highly variable range and distribution of water ages. Nevertheless, superficial flow paths with young water contributions (40 months at most) dominate the streamflow generation entirely. The maximum water age was independently evaluated calculating the tritium-derived baseflow mean transit time. The highest simulated ages of transpiration flux varied between 12 days and 5.5 months depending on the soil depths where the water was uptake. Soil water age peaked at 5.4 months and groundwater at 40 months. The oldest stream water age, integrating all catchment processes, reached 24 months. Overall, the water age increased during dry conditions. The frequency of water ages reflected high occurrences of young water for transpiration flux and streamflow in their respective ranges. Maximum occurrences were reported for transpiration with 10 hours and streamflow with 2.8 months. The soil water age presented a bimodal distribution with peaks of 2.8 and 4.4 months and groundwater age occurrences peaked at 32 and 37 months. Spatially, high age dynamics of transpiration flux were associated with a higher leaf area index on the northern hillside in relation to the southern hillside. The oldest soil water was related to more developed soils and the groundwater age increased towards the bottom of the catchment. In the context of the tropics, our study is one of the first that quantitatively evaluated water age dynamics and

distributions, and globally using such a high spatial and temporal resolution with a non-stationary perspective. These findings will support decision-makers to manage the water resources and ecosystem in the humid tropics and reduce the research gap regarding hydrological processes of tropical headwater towers under environmental changes.