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Seasonal partitioning of precipitation between streamflow and evapotranspiration, inferred from end-member splitting analysis

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The terrestrial water cycle partitions precipitation between its two ultimate fates: "green water" that is evaporated or transpired back to the atmosphere, and "blue water" that is discharged to stream channels. Measuring this partitioning is difficult, particularly on seasonal timescales. End-member mixing analysis has been widely used to quantify streamflow as a mixture of isotopically distinct sources, but knowing where streamwater comes from is not the same as knowing where precipitation goes, and this latter question is the one we seek to answer. Here we introduce "end-member splitting analysis", which uses isotopic tracers and water flux measurements to quantify how isotopically distinct inputs (such as summer vs. winter precipitation) are partitioned into different ultimate outputs (such as evapotranspiration and summer vs. winter streamflow). End-member splitting analysis has modest data requirements and can potentially be applied in many different catchment settings. We illustrate this data-driven, model-independent approach with publicly available biweekly isotope time series from Hubbard Brook Watershed 3. A marked seasonal shift in isotopic composition allows us to distinguish rainy-season (April-November) and snowy-season (December-March) precipitation, and to trace their respective fates. End-member splitting shows that about one-sixth (18±2%) of rainy-season precipitation is discharged during the snowy season, but this accounts for over half (60±9%) of snowy-season streamflow. By contrast, most (55±13%) snowy-season precipitation becomes streamflow during the rainy season, where it accounts for 38±9% of rainy-season streamflow. Our analysis thus shows that significant fractions of each season's streamflow originated as the other season's precipitation, implying significant inter-seasonal water storage within the catchment, as both groundwater and snowpack. End-member splitting can also quantify how much of each season's precipitation is eventually evapotranspired. At Watershed 3, we find that only about half (44±8%) of rainy-season precipitation evapotranspires, but almost all (85±15%) evapotranspiration originates as rainy-season precipitation, implying that there is relatively little inter-seasonal water storage supplying evapotranspiration. This proof-of-concept study demonstrates that end-member mixing and splitting yield different, but complementary, insights into catchment-scale partitioning of precipitation into blue water and green water. It could thus help in gauging the vulnerability of both water resources and terrestrial ecosystems to changes in seasonal precipitation.