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Stable isotope techniques to investigate cloud water in forested mountain watersheds in the trade wind latitudes – Hawaii and Puerto Rico

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Fog and cloud water can contribute to stream flow, soil moisture, groundwater recharge and plant uptake in mountain watersheds in the trade wind latitudes. Results from three island sites, two in Hawaii and one in Puerto Rico, are discussed to evaluate the utility of isotopic methods in studies of fog and cloud water in watersheds. In forests that are immersed in orographic clouds, the precipitation consists of a range of droplet sizes from fog to rain. Stable isotopes distinguish precipitation source to a greater extent than precipitation size, and isotopic composition of fog-sized droplets may be similar to the smallest raindrops in a cloud. Therefore, results from isotopic methods can differ from estimates using fog collectors, canopy water balances, eddy covariance, and other methods. Examples from study sites in Hawaii and Puerto Rico illustrate these differences. East Maui in Hawaii rises 3054 m above the ocean, and clouds intercept the mountain slopes between 600 and 2200 m on both windward and leeward sides of the island. The eastern mountains of the island of Puerto Rico receive cloud water input at their highest altitudes, between 900-1100 m. In both study areas, stable isotopes of fog/cloud water and rain were measured monthly using passive fog and rain collectors. The sites on Maui were instrumented with weather stations and throughfall gages to estimate cloud water input with canopy water balance methods. Estimates of cloud water as a fraction of total precipitation input from isotopic mixing models and the canopy water balance calculations were 29% and 15%, respectively, on leeward Maui and 27% and 32% on windward Maui, using the most conservative mixing model end member for fog. Cloud water input at Pico del Este in Puerto Rico was estimated to be 45-56% of total precipitation from isotope mixing model results, compared with 10-16% from previous studies using various methods. Sources of uncertainty in using isotope mixing model analyses to distinguish fog from rain inputs include sampling precipitation on a monthly time scale, the fact that isotopes may measure a different droplet size fraction than other methods, and the use of single end-member values when isotopic composition of cloud water may be variable. The uncertainty in mixing model results may be reduced if sampling is done on a shorter (weekly to event) time scale, however, monthly isotope measurements very effectively quantified input from the orographic precipitation pattern that included fog. Isotopic composition of stream water in Maui and Puerto Rico indicated that cloud water was an important component of high-elevation streamflow year-round (62% in PR, 37% in Maui). In Puerto Rico, determining the isotopic composition and amount of rain from different weather patterns showed that streams contained a higher proportion of orographic precipitation than the bulk rainfall, suggesting that the low-intensity cloud water precipitation events were important in maintaining stream baseflow. On Maui, ohia lehua (Metrosideros polymorpha) xylem water isotopic composition indicated different water use strategies by the trees at the windward and leeward sites, which had very different precipitation regimes. Isotope analyses work very well for tracing the pathways of cloud water within watersheds, and results can lead to a better understanding of the role of cloud water in forested mountain watersheds.