Isotopic Signatures of Precipitation Quantify the Importance of Different Climate Patterns to the Hydrologic Budget: An Example from the Luquillo Mountains, Puerto Rico

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Abstract

Precipitation isotopic signatures can help determine the relative importance of different climate patterns to the hydrologic balance and water supply of a region. Puerto Rico's climate is dominated by easterly trade winds, and the U.S. Geological Survey Water, Energy, and Biogeochemical Budget (WEBB) program's study area in the Luquillo Mountains receives substantial orographic precipitation. Global climate change, deforestation, or defoliation may cause a rise in cloud base altitude (ceiling height) by as much as a few hundred meters, leading to a decline in trade-wind orographic precipitation amounts. To help determine the importance of different precipitation types in the forest water cycle, nine rain collectors and three cloud water collectors were installed on a windward-leeward transect over the Luquillo Mountains. The collectors were sampled monthly for 3 years and precipitation was analyzed for $\delta^{18}O$ and $\delta^{2}H$. A seasonal cycle in rainfall isotopic composition was apparent, despite the small seasonal variation in temperature in Puerto Rico. Cloud height was correlated with measured precipitation isotopic composition using NEXRAD radar echo tops to help establish distinct isotopic signatures for the different types of precipitation. Precipitation with average isotopic values of -1.5‰ $\delta^{18}O$ and +2.0‰ $\delta^{2}H$ was associated with the dry season weather pattern of orographic uplift and trade wind showers. Wet season precipitation, mostly convective rainfall associated with easterly waves, had average values of -3.6‰ $\delta^{18}O$ and -16‰ $\delta^{2}H$. Trade-wind orographic precipitation usually occurs as frequent, low-intensity, and low-volume rain events, whereas convective and low-pressure systems have higher volume and more intense rainfall. Isotopic composition of stream water at higher altitudes in the Icacos and Mameyes watersheds suggests that the orographic rain events are more important than convective events in maintaining stream base flow. High-intensity rain events run off quickly and may not effectively infiltrate the saturated, low-permeability tropical soils. Weather analysis showed that 29 percent of rain input to the Luquillo Mountains was trade-wind orographic rainfall, and 30 percent of rainfall could be attributed to easterly waves and low pressure systems. Isotopic signatures associated with these major climate patterns can be used to determine their relative importance to streamflow and groundwater recharge.

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