Tracking the deuterium in raindrops, one molecule at a time

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New research led by the University of Massachusetts Amherst refines our understanding of the chemical traces that act as the rain's fingerprint. The work, which appeared recently in *Global Biogeochemical Cycles*, is crucial for understanding Earth's water cycle, especially as it undergoes rapid change due to global warming, deforestation and other environmental catastrophes.

You no doubt know that water (H_2O) is composed of two molecules of hydrogen and one of oxygen. What you may not know is that there are a few different varieties of both hydrogen and oxygen. The "normal" hydrogen, for example, has a nucleus with only one proton, but there's another version: "heavy hydrogen," or deuterium, which has both a proton and a neutron in its nucleus. This deuterium is comparatively rarer, and it can be used both to track rainfall amounts over time as well as to understand evaporation and seasonal changes in climate. The same is true for oxygen, which has both a common light version and a rare heavy version.

"Deuterium excess," or when the ratio of heavy hydrogen to heavy oxygen increases, is a fingerprint that is widely used in climate and hydrological modeling and for reconstructing past climates to understand the history of a raindrop. But the processes that lead to the excess of deuterium aren't entirely understood.

"Our paper is the first to look at seasonal variations of deuterium excess in rainfall across the globe to better understand what affects these chemical tracers at regional scales," says Matthew Winnick, professor of geosciences at UMass Amherst, and the paper's senior author.

Winnick and his team, led by Zhengyu Xia, who completed this study as part of his postdoctoral research at UMass Amherst and is now a faculty member in the School of Geographical Sciences at Northeast Normal University, China, have shed new light on how and where different processes combine to impact deuterium excess. For instance, in the tropics, deuterium excess most clearly reflects seasonal changes in humidity and the evaporation of raindrops as they fall through the air. In the mid-latitudes, deuterium excess is primarily tied to climate conditions over the oceans where clouds first form, though these ocean signals are modified as clouds move inland over continents.

"There are multiple processes that can affect the deuterium excess of rain and these have been well recognized, but perhaps, have also puzzled the research community," says Xia. "Our study combined data analysis and simple modeling to tease apart these complex controls at global scales, filling an important knowledge gap."

"My hope," says Winnick, "is that our findings will be used to better track the entire history of a raindrop, from when it first evaporates from the ocean to when it falls on land, trickles into a river and then flows back to the ocean."

More information: Zhengyu Xia et al, The Seasonality of Deuterium Excess in Non-Polar Precipitation, *Global Biogeochemical Cycles* (2022). DOI: 10.1029/2021GB007245

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