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Measuring δ^{17}O and Δ'^{17}O in precipitation across various spatial and temporal scales: spanning from global to local and from multi-year to sub-hourly resolutions

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During the past decade, the rare O isotope ^{17}O and the ^{17}O-excess became attractive for potential new applications in hydrology, climatology, and broader oxygen isotope research. Although laser-based analysers are technologically capable of the needed Δ'^{17}O assays, progress was hindered by the metrological challenges and the absence of fundamental spatiotemporal data on precipitation inputs. Uncertainties surrounding the input function of the water cycle complicate advancements of ^{17}O as a tracer. This “emerging tracer dilemma” is a potential obstacle for further triple-O isotope research.

In this work, >3500 archived water samples from the Global Network of Precipitation (GNIP) sample archives (2015-2021) were re-analysed for for δ^{17}O and Δ'^{17}O. For >60 GNIP stations, four or more years' of samples were analysed, assessing the seasonality of Δ'^{17}O, and constructing δ^{17}O/ δ^{18}O Local Meteoric Water Lines (LMWL). This global dataset allowed for a first-ever comprehensive assessment of the spatial patterns of δ^{17}O/ δ^{18}O LMWLs, and to devise a first-ever precipitation-weighted Global Meteoric Water Line (GMWL): δ'^{17}O = 0.5280 ± 0.0002 δ'^{18}O + 0.0153 ± 0.0013. This GMWL definition is similar to previous efforts albeit with a lower ordinate intercept.

We further analysed the Δ'^{17}O of a 6-year daily/fortnightly precipitation sampling in Vienna as an example of seasonal isotopic variations at synoptic weather patterns' resolution. Air moisture sources were determined by backwards trajectory analysis and corroborated with synoptic weather data from Austria's meteorological service. The Δ'^{17}O values correlated with δ^{18}O seasonality. A comparison with the deuterium excess patterns (stemming from the Atlantic and Mediterranean domains) demonstrated that the “two excesses” carried different signals. While elevated d-excesses
mainly came from the central/eastern Mediterranean Sea or easterly continental sources during all seasons, we found elevated Δ'^{17}O precipitation originated only from northerly or north-easterly sources, and predominantly during the winter season.

Finally, we present pilot Vienna precipitation events sampled at sub-hourly (to 5-minute) resolution, which included both cyclonic and convective rainfall events, which demonstrate the interplay of moisture sources using triple oxygen isotopes and deuterium excess. This work will help to shape our understanding of $\delta^{17}O$ and $\Delta'^{17}O$ in Earth's precipitation, despite the ongoing metrological challenges faced, and promote discussion regarding the scientific value of routine measurements for triple-oxygen isotopes in precipitation.