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Everything, everywhere, all the time: quantifying the information gained from intensive hydrochemical sampling

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Catchment hydrochemical studies have suffered from a stark mismatch of measurement timescales: water fluxes are typically measured sub-hourly, but their chemical signatures are typically sampled only weekly or monthly. At the Plynlimon catchment in mid-Wales, however, precipitation and streamflow have now been sampled every seven hours for nearly two years, and analyzed for deuterium, oxygen-18, and more than 40 chemical species. This high-frequency sampling reveals temporal patterns that would be invisible in typical weekly monitoring samples.

Furthermore, recent technological developments are now leading to systems that can provide measurements of rainfall and streamflow chemistry at hourly or sub-hourly intervals, similar to the time scales at which hydrometric data have long been available – and to provide these measurements for long spans of time, not just for intensive field campaigns associated with individual storms. But at what point will higher-frequency measurements become pointless, as additional measurements simply "connect the dots" between lower-frequency data points?

Information Theory, dating back to the original work of Shannon and colleagues in the 1940's, provides mathematical tools for rigorously quantifying the information content of a time series. The key input data for such an analysis are the power spectrum of the measured data, and the power spectrum of the measurement noise. Here we apply these techniques to the high-frequency Plynlimon data set. The results show that, at least up to 7-hourly sampling frequency, the information content of the time series increases nearly linearly with the frequency of sampling. These results rigorously quantify what inspection of the time series visually suggests: far from simply "connecting the dots" between lower-frequency measurements, these high-frequency measurements instead contain a richly textured signature of dynamic behavior in catchment hydrochemistry.