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High temporal resolution and high precision measurements of water isotopologue ratios by laser absorption spectrometry using Kalman filter

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Stable isotopes of water (in the vapor or liquid phase) are powerful tracers for study of the hydrological cycle, climate change, ecological process and paleoclimatic archives. Laser absorption spectroscopy offers an excellent opportunity to *in situ* real-time continuous measurements without requiring chemical conversion. However, high sensitivity, high precision and high temporal resolution measurement required by many applications represents a real challenge.

In this paper we report on the first implementation of the Kalman adaptive filtering approach to simultaneous measurements of water isotopic ratios using laser absorption spectroscopy at 2.73 μm. Measurements of the oxygen and hydrogen isotopologue ratios δ^{18}O, δ^{17}O, and δ^{2}H in water showed a 1-σ precision of 0.72‰ for δ^{18}O, 0.48‰ for δ^{17}O, and 0.84‰ for δ^{2}H, while sampling the output of the tuned Kalman filter at 1-s time intervals. Using a standard running average technique, averaging over $\sim$30-s is required to obtain the same level of precision.

The Kalman filter shows the advantage of a faster response to step-like changes in the input than the 30-s averaged output and is significantly less susceptible to outlier values ('spikes'). This is an important advantage for applications in which small but fast changes in the isotopic composition need to be resolved with high measurement precision.