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Real-time Stable Isotope Analysis of Atmospheric Water Vapor

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Routine analysis of the stable isotopes of oxygen and hydrogen in liquid water has become a standard method for tracing the flow in precipitation, and ground and surface water catchments and flows. The relative abundances of oxygen 18 and oxygen 16, and deuterium and hydrogen, act as tracers that provide information about the sources of water and transport through the hydrosphere. These powerful methods, properly applied, give unique insight into the liquid water cycle.

By contrast, understanding of the transport of water in vapor form in the atmosphere is relatively poor. Given the ubiquity and utility of stable isotope analysis in liquid hydrology, it is natural to attempt to extend these methods to the analysis of atmospheric water vapor. Until recently, these attempts have been foiled primarily by the technical limitations of the existing analysis methods. These methods rely on cryogenic capture of atmospheric water vapor followed by transport of the sample to the central laboratory for subsequent IRMS (isotope ratio mass spectrometry) analysis. These technical limitations have restricted researchers to small data sets that are far too limited to provide the detailed information needed to track atmospheric water vapor.

We present the development of a novel portable water vapor instrument capable of measuring the stable isotopes in real time of water vapor in the field without human intervention. The instrument is based on cavity ringdown spectroscopy, a powerful new technology for stable isotope analysis. Stable isotope ratios of oxygen 18 and deuterium in water vapor are possible with a single device at the sub-permil levels and lower, with measurement rates of up to 5 Hz, and at dew points ranging from above 20 C to below -30 C (< 400 ppm). Field data are presented that illustrate the power of the technique for investigating in detail the transport of water vapor in the atmosphere. Calibration methods and instrumentation suitable for field deployment are discussed.