Capturing small-scale variations of water isotopes in ambient air and natural waters of California: Results of field measurements using Wavelength Scanned Cavity Ring-Down Spectroscopy

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Abstract

Stable isotope analysis is a valuable tool for establishing links between ecology and hydrology. Measurements of stable isotopes in water vapor and liquid water are traditionally made with IMS systems in core labs that preclude real-time field use. Recent advances in wavelength scanned cavity ring-down spectroscopy (WS-CRDS) have led to field-deployable instrumentation capable of making real-time high-throughput stable isotope measurements of water. Furthermore, the high precision of such instrumentation (typically <0.2‰ for 8D and <0.07‰ for 818O) allows for high-resolution measurements that enhance our understanding of the processes that govern natural variability in water isotopes.

This presentation demonstrates the results from two different applications of the Picarro isotopic water analyzer. First, the analyzer was used to measure vertical gradients in ambient water vapor isotopes at Blue Oak Ranch Reserve, CA. The Picarro analyzer was deployed with a novel, field-durable and automated calibration system that introduces liquid water standards, as vapor, without fractionation effects. The results show clear gradients in water vapor isotopes during convective nighttime periods, which subsequently break-up during daytime warming. The second set of results show measurements of liquid water isotopes collected from three different watersheds at Mammoth Lakes, CA. The data are comprised of samples collected from thirty different locations including snow melt lakes, creeks and rain water. The isotopic measurements shed some light on the dominating hydrological phenomena which affect the isotopic content of the water. However, and more importantly, the data demonstrate a complex relationship between the hydrological cycle, volcanic activity and hot springs contributions, and illuminates the fact that a simple explanation involving fractionation along water courses is not sufficient.

Schematic of Picarro WS-CRDS Isotopic Water Analyzer

[Diagram of the Picarro WS-CRDS analyzer showing optical cavity and sample gas flow]

Water Vapor Data Interpersed with Liquid Water Calibrations

- Picarro analyzer demonstrates the necessary precision for measuring small gradients in water-vapor isotopes over ambient air.
- The use of auto-calibration system allowed for calibrating in with multiple standards at multiple concentrations resulting in higher credible data.
- The Picarro analyzer is robust and field-deployable, able to withstand large ambient temperature fluctuations, and can operate for weeks without human intervention.

Measurements of Vertical Gradients of Water Vapor Isotopes at Blue Oak Ranch Reserve

- The isotopically heavier vapor near the ground suggests an evaporation source, while the isotopically lighter vapor aloft is likely influenced by plant water.
- Strong positive shifts in the ground data (e.g. from approx. 1500 to 5000 on Sept. 22 to approx. 1500 to 300 on Sept. 23-24) suggest a ‘condensation’ fingerprint, where the water is sourced from condensed mineral aerosol uplift surfaces.
- Future measurements will be aimed at studying the different small-scale variations (elevation, transpiration) and larger scale [marine vs. urban vs. rural source-air mass signatures].

Conclusion and Future Work

- We aim to provide a better understanding and predictive ability of the effects of snow depth/melt manipulations on the water chemistry.
- Conclusively, these results suggest significant evaporation from June, Mono and Gull Lakes. The Mono Lake signature may also be affected by lakes going through the unique chemical (high levels of chlorides, sulfates, heavy metals and radionuclides), and isotopic exchange feedbacks in water chemistry.

Picarro Isotopic Water Analyzer used to determine how surface flow fractions meteorological water sources

- In water-limited terrestrial ecosystems of the western U.S., changes in precipitation patterns may be important for plant mortality, recruitment, biogeochemistry, and the emergent functions and distributions of ecosystems.
- Snow provides up to 80% of the annual hydrologic input of western ecosystems, and is a key timing event for the onset of physiological processes for many species.
- How altered snowfall patterns will affect the biogeochemistry of terrestrial ecosystems, and how vegetation responses will feedback on processes over multiple spatial and temporal scales is an important scientific question to be further explored.
- We aim to provide a better understanding and predictive ability of the effects of snow depth/melt manipulations on the water chemistry.

Mammoth Creek Watershed, bulk isotopic measurements suggest significant evaporation (temperature vs. D for evaporation source) (shown in the figure below). The isotopic composition of precipitation (e.g. from Mono Lake) is affected by lakes going through the unique chemical (high levels of chlorides, sulfates, heavy metals and radionuclides), and isotopic exchange feedbacks in water chemistry.