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Isotopic measurements of atmospheric water vapor help infer moisture origins during large-scale weather events

Los Gatos Research (LGR)

Researchers at San Diego State University have demonstrated that ground-based isotopic water vapor measurements at a single site can complement those from satellites in general climate modeling (GCM) investigations

Measurement made easy

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Introduction

The researchers studied how synoptic (large scale) weather events influence the isotope composition of atmospheric moisture in Southern California. In particular, they measured water vapor isotopes (HDO and $H_2{}^{18}O$) over 30 days during locally extreme weather conditions.

These conditions included Santa Ana winds and winter rainstorms. Rapid and drastic changes in air humidity and temperature often occur under the influence of Santa Ana winds. For example, under these conditions, an easterly wind of high velocity and low humidity prevails that can lead to wildfires.

The ground-based isotopic measurements of water vapor, in combination with GSM simulation, permitted researchers to infer the location of the moisture origins.

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ABB Instrumentation

The researchers employed a Water Vapor Isotope Analyzer made by Los Gatos Research, a member of the ABB Group. This analyzer can accurately and rapidly measure $\delta^{17}O$, $\delta^{18}O$ and $\delta^{2}H$ in ambient water vapor with high precision. It does not require any sample preparation or user intervention. In this case the analyzer hourly measured the near-surface atmospheric moisture content and its isotope composition (HDO and $H_2{}^{18}O$) from January 30 to February 24, 2011.

The analyzer uses LGR's patented laser absorption technology called Off-Axis Integrated Cavity Output Spectroscopy (OA-ICOS). This fourth-generation cavity enhanced absorption technique greatly extends the laser's optical path, providing exceptional sensitivity and accuracy. Off-axis ICOS is insensitive to alignment, has a shorter measurement time and does not require expensive and power consuming auxiliary components.

Researchers installed a sample inlet 1.5 meters above a non-permeable surface. A diaphragm pump drew ambient air through PTFE tubing at a flow rate of 800 milliliters per minute. This flow rate minimized the instrument response time, since the total length of the sampling tube was only three meters from the tip of the inlet to the analyzer for hourly averaging. Data acquisition took place at 2 Hz.

Results

Figure 1 shows the hourly averages of near-surface water vapor concentration (expressed as Volume Mixing Ratio, VMR), $\delta^{18}O$, δD and deuterium excess d observed during February, 2011. Observed isotope ratios ranged from –23.2 ‰ to –11.1 ‰ for $\delta^{18}O$, –170.6 ‰ to –84.1 ‰ for δD and –7.2 ‰ to 33.7 ‰ for deuterium excess d. Synoptic weather events depicting large day-to-day variability with rapid transitions in the VMR and the isotope ratios usually correspond to the timing of these air masses moving in and out of San Diego. Two distinct periods of Santa Ana winds (episodes A and B in the figure) were characterized by low near-surface VMR (~2000 ppmV) along with a transition to much lower $\delta^{18}O$ and δD values under the strong influence of the synoptic event. As the Santa Ana wind subsided, $\delta^{18}O$ and δD rapidly recovered to higher and more typical values.

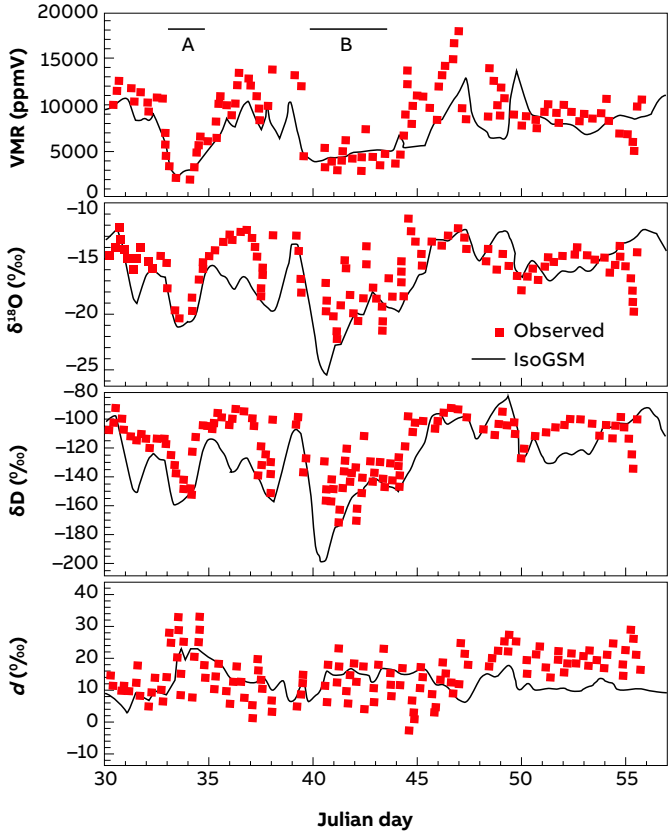

Figure. 1 Hourly averages of near-surface water vapor concentration

Researchers observed a rapid increase to the highest d values under the influence of the Santa Ana episode A period. This synoptic weather event occurred two days after a small rainfall of 3.1 mm for the area. These high d values can most likely be attributed to highly evaporative conditions (exceptionally low humidity but relatively wet surface) that removed a great deal of surface moisture at this time.

By contrast, researchers did not observe elevated d values during the second Santa Ana period (episode B). This second Santa Ana event occurred a week later and was not preceded by major rainfall. As a consequence, little surface evaporation took place despite low humidity.

Following the two intensive rainstorms that occurred on day 47 and again between day 49 and 51, d values increased by roughly 9 % for an extended period. These elevated d values in the vapor can be explained by the enhanced evaporative condition (wet surface). These results suggest that d values in near-surface water vapor are sensitive to surface wetness. Careful evaluations of the continuous d measurements may be useful for revealing landscape scale surface wetness and evaporative conditions.

References

Information based on “Influence of synoptic weather events on the isotopic composition of atmospheric moisture in a coastal city of the western United States” Water Resources Research, VOL. 49, 1-12, doi:10.1002/wrcr.20305, 2013.

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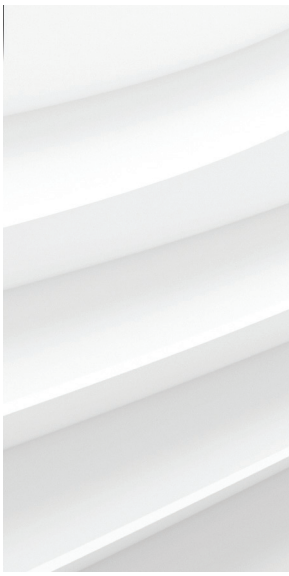

AT/ANALYTICAL/031-EN Rev. A 01.2019