National Aeronautics and Space Administration

Innovative Boundary Layer Measurements of Atmospheric Isotopologues of Water Vapor, Carbon Dioxide and Methane from a Simulated Geostationary Platform

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OBJECTIVE

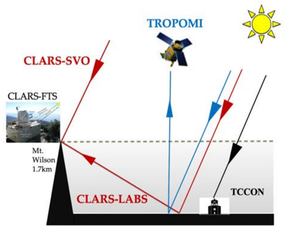
The objective of this research is to investigate the isotopic fraction of atmospheric minor gases to understand the chemical and physical processing in the atmosphere. To accomplish this, we have used IR spectra of reflected sunlight from discrete points in the LA basin using a Fourier transform spectrometer (FTS) located on Mt. Wilson, California. The specific tasks include:

1. Identify spectral windows for accurately retrieving HDO, $^{13}CO_2$, and $^{13}CH_4$ from FTS observations;
2. Perform the first-ever retrievals of the three isotopologues using long-duration (2011-2020) archived observations from Mt. Wilson with high spatial and temporal resolution in the urban boundary layer.
3. Quantify the uncertainties in the retrievals of the atmospheric isotopologues. The primary risk is that the isotopologues may not be retrievable with sufficient precision to quantify fractionation.

BACKGROUND

Atmospheric isotopologues of water vapor (e.g., HDO), carbon dioxide (e.g., $^{13}CO_2$) and methane (e.g., $^{13}CH_4$) are important tracers for understanding earth's hydrological and carbon cycles. Water vapor fractionation occurs in the environment because heavier isotopologues preferentially condense. Fractionation allows measurements of HDO to serve as a proxy for water vapor movement through the global hydrological cycle.

(a)



(b)

Figure 1. (a) Schematic figure showing the observations of CLARS-FTS, TROPOMI, and TCCON in the Los Angeles Basin; (b) The spatial distribution of CLARS-FTS surface reflection targets

APPROACH AND RESULTS

- We retrieved HDO and H2O columns from observations by the California Laboratory for Atmospheric Remote Sensing Fourier Transform Spectrometer (CLARS-FTS), a mountaintop observatory on Mt. Wilson.
- Retrievals were conducted using spectral windows between 6000-7000 cm-1 from CLARS-FTS observations (2011-2019) (Figure 2). The isotopological abundance δD, which represents the relative difference of the HDO/H2O ratio to a standard abundance ratio, is also calculated. The averaged δD retrievals are (−156.1±60.0)‰ with an uncertainty of (6.1±10.2)‰ for LA Basin Survey mode and (−344.7±95.0)‰ with an uncertainty of (42.4±31.6)‰ for Spectralon Viewing Observation mode.
- In LA, the δD shows a seasonal cycle that is primarily driven by the change of atmospheric humidity.
- We conclude that the HDO and δD measurements from CLARS-FTS provide high spatial and temporal resolution datasets for further study of hydrological processes, such as the partitioning of the water flux into soil evaporation and transpiration, standing water evaporation, or transport and mixing from the oceans, in the LA megacity.

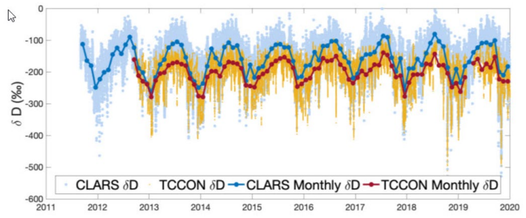


Figure 2. Comparisons of time series of δD measurements between CLARS-FTS and TCCON

SIGNIFICANCE OF RESULTS/BENEFITS TO JPL

This work provides the first long-duration (9-year) data record for the seasonal variability of deuterium enrichment in water vapor in an urban area. The SWIR retrievals of HDO proved to be very robust despite the small mixing ratio of HDO in the atmosphere. The results are important for future studies of the hydrological cycle in an urban atmosphere which is driven by evapotranspiration from fertilized and irrigated plants, water vapor transported by synoptic weather systems, and other anthropogenic emissions including swimming pools, sewage treatment plants and reservoirs. Decoupling these sources using other tracers is a potential step forward. The measurements from CLARS are significant because they simulate the data that would be acquired by a satellite instrument in a geostationary or highly elliptical orbit.

PUBLICATIONS

Cheng, Z-C, Addington, O., Pongetti, T., Herman, R. L., Sung, K., Newman, S., Schneider, A., Borsdorff, T., Yung, Y. L. and Sander, S. P., "Remote sensing of atmospheric HDO/H2O in southern California from CLARS-FTS, submitted to J. Quant. Spectrosc. Rad. Transfer

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