Profiles of the Water Vapor Isotope Composition for Determining Regional Water Sources and Trace Gas Exchange in the Boundary Layer

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The exchange of water and carbon between the atmosphere and the land surface remains poorly understood, particularly in regions of complex terrain and in the case of stable nighttime boundary layers. While limitations in knowledge of transport of carbon dioxide in the boundary layer is the leading source of error in estimate of CO_2 fluxes from global models, understanding the transport of water is critical to resolving regional water recycling and the surface energy balance. The stable isotope chemistry of water is invaluable for evaluating hydrological exchanges and has proven to be a clear tracer of air mass transport. In this regard the isotopic composition can be used for identifying surface water sources and tracking the fate of that water as it moves though the boundary layer. High resolution profile measurement of water, the isotopic composition of water and CO_2 concentration were made at the NOAA Boulder Atmospheric Observatory (BAO) tall tower facility in Erie, CO in February of 2010. Measurements were made by placing instruments on the elevator, and manually controlling the ascent and decent every 15 minutes, leading to a total of 311 profiles. The 4-day observation period followed a storm that left about 1 inch of snow. The recently fallen snow sublimated over the 4 days and our analysis (Figure 1) shows the isotopic composition unambiguously tracks the sublimated water from the surface though the surface layer during the daytime and that there is a significant advective sink. Snow began falling on the final day, and seemed to be associated with an isotopically distinct (enriched) air mass. Nighttime conditions were very stable leading to strong surface trapping of water vapor and that also restricted transport of near surface (respired or anthropogenic) CO_2. The experimental results are of particular interest because of the extremely weak transport during times of the very stable nighttime boundary layer, which is poorly modeled. Our analysis shows that this is associated with a board failure of simple turbulence theory which is of the type typically found in global and regional scale models. To this end, they are improving the representation of the evolution of our observed water isotope and CO_2 profiles provides a clear way to improved models. The results thereby reinforce the call for detailed water, energy and trace gas exchange studies at tower sites in complex terrain to better constrain surface exchange and allow baseline trace gas measurements to better constrain surface flux estimates with atmospheric inverse calculations.

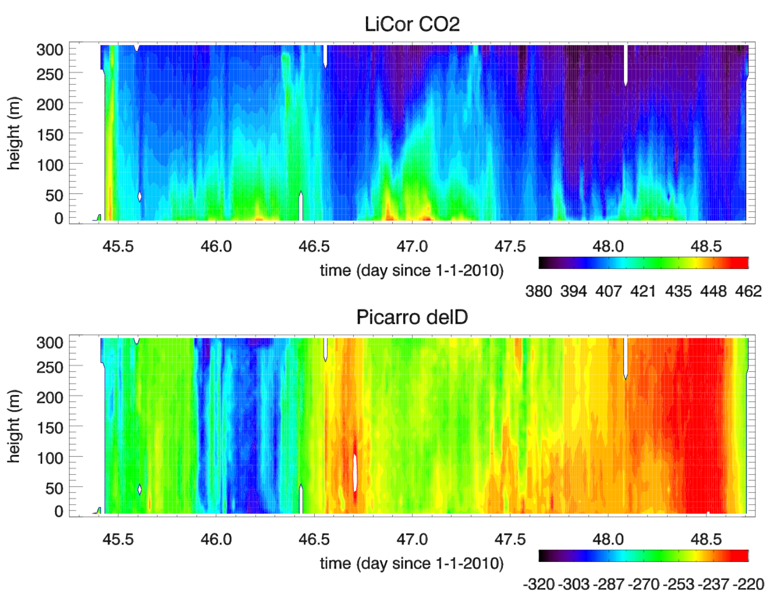

Figure 1. Profile measurements of a) HDO/H_2O water isotopologue ratio (as dD) and b) CO_2 during a 4-day period February 15-18, 2010 at the NOAA/BAO. Daytime sublimation is seen in the dD of water and the restriction of trace gas transport is seen at nighttime in the CO_2.