

## Dual Frequency Comb Measurements of Greenhouse Gases over Boulder

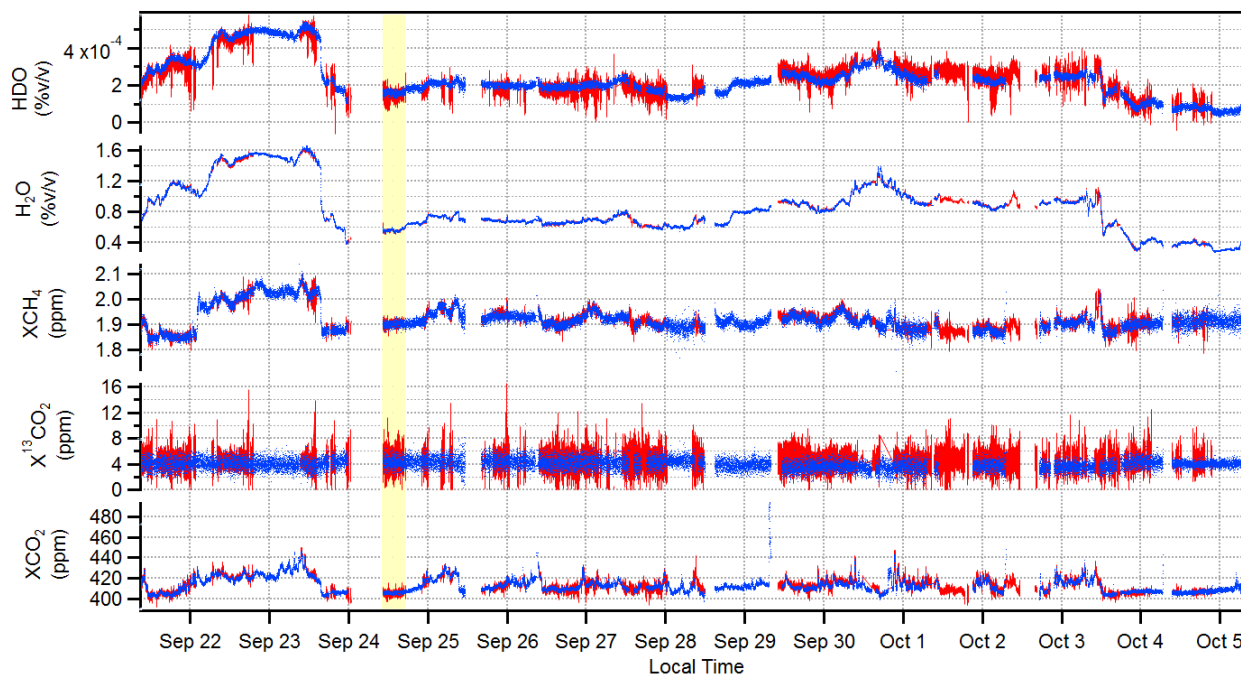
E. Waxman<sup>1</sup>, K. Cossel<sup>1</sup>, G.W. Truong<sup>1,2</sup>, F. Giorgetta<sup>1</sup>, W. Swann<sup>1</sup>, S. Coburn<sup>3</sup>, R. Wright<sup>3</sup>, G.B. Rieker<sup>3</sup>, I. Coddington<sup>1</sup> and N. Newbury<sup>1</sup>

<sup>1</sup>National Institute of Standards and Technology (NIST), Boulder, CO 80305; 303-497-4483, E-mail: eleanor.waxman@nist.gov

<sup>2</sup>Crystalline Mirror Solutions, Santa Barbara, CA 93101

<sup>3</sup>University of Colorado, Department of Mechanical Engineering, Boulder, CO 80309

Dual frequency comb spectroscopy (DCS) is a new technique that combines the precision of laser-based measurements with the broad spectral bandwidth of traditional incoherent spectroscopic techniques, resulting in a portable instrument with broad spectral bandwidth, high spectral resolution ( $0.0067\text{ cm}^{-1}$ ), absolute frequency accuracy, and rapid data acquisition. We have compared two dual frequency comb instruments over a 2-km round-trip open-air path behind NIST. We find that the two instruments agree to better than 0.6 ppm carbon dioxide ( $\text{CO}_2$ ), 7 ppb methane ( $\text{CH}_4$ ), and 36 ppm water vapor ( $\text{H}_2\text{O}$ ) over a two-week period of near-continuous measurements. We also compared the frequency comb measurements against a nearly co-located Picarro and find that they agree to better than 3.4 ppm  $\text{CO}_2$  and 17 ppb  $\text{CH}_4$ . We attribute these discrepancies primarily to differences between the HITRAN database and the WMO scale. We also present preliminary frequency comb data measured over the city of Boulder showing strong enhancements in  $\text{CO}_2$  relative to background measurements allowing us to estimate traffic emissions from the city.



**Figure 1.** Comparison of two dual comb spectroscopy instruments over a 2-km round-trip path behind NIST showing excellent agreement between the two instruments. Blue: DCS A. Red: DCS B. There is more noise on DCS B data because the instrument had lower power reaching the detector.