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Mobile Spectrometer Comparison to TCCON Field Campaign Report

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ARM

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
CO	carbon monoxide
FTS	Fourier-transform spectroscope
GHG	greenhouse gas
ppb	parts per billion
ppm	parts per million
SGP	Southern Great Plains
SZA	solar zenith angle
TCCON	Total Column Carbon Observing Network

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1.0 Summary

During the summer of 2018, a field campaign took place to help characterize off-the-shelf portable solar-viewing Fourier-transform spectroscope (FTS) instruments (EM27/SUN). These instruments retrieve greenhouse gas (GHG) abundances from direct solar spectra (Wunch et al. 2011). The campaign included assistance and instrumentation from the University of Toronto, Environment and Climate Change Canada, and the California Institute of Technology and took place at the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) observatory from July 22 to July 28, 2018. The instruments were sited on the outside landing of the guest trailer (Figure 1) and were set up and taken down each morning and afternoon. During the campaign, we had minor inconveniences like overheating computers, but the experience involving the ARM site itself held nothing out of the ordinary for July in Oklahoma.

Figure 1. Instrument set-up at the SGP site.

A focus of this campaign was to test the performance of recent upgrades of these instruments to measure carbon monoxide (CO) with respect to different atmospheric conditions. Along with the ARM SGP site in Oklahoma, experiments were conducted in Pasadena, California; Park Falls, Wisconsin; East Trout Lake, Saskatchewan, Canada; and Armstrong Flight Research Center, Edwards Air Force Base, California. These locations are home to instruments in the Total Column Carbon Observing Network (TCCON). TCCON measurements were used as standards for the portable (EM27/SUN) measurements. Comparisons between the two types of instruments are crucial in the attempt to use the portable instruments to broaden the capabilities of GHG measurements for monitoring, reporting, and verification of carbon in the atmosphere.

This campaign was aimed at testing the response of the portable FTS to different atmospheric conditions both local and regional. Measurements made at ARM SGP provided data in an agricultural environment with a relatively clean atmosphere with respect to pollution. Due to the homogeneity of the region surrounding Lamont, Oklahoma, portable FTS measurements were less affected by large changes in column GHG abundances from air mass movement between regions. These conditions aided in characterizing potential artificial solar zenith angle (SZA) dependence of the retrievals. Data collected under atmospheric conditions at ARM SGP also provide for the analysis of cloud interference on solar spectra. ARM SGP is also more amenable to airborne measurements that TCCON relies on for calibration purposes. This fact, along with the new capabilities of the EM27/SUN, means this campaign will greatly

increase our knowledge of CO measurement biases. A similar comparison was performed in the summer of 2015 when the instruments were not able to measure CO and the TCCON in East Trout Lake was not operational (Hedelius et al. 2017). Growth in community knowledge and instrumentation prompted a return campaign; the data from the previous campaign is not be considered here.

2.0 Results

Data for this campaign was collected from five separate TCCON sites and compared with three or four EM27/SUN instruments to determine the biases between the TCCON and EM27/SUN retrievals, as well as bias between retrievals among the three or four EM27/SUN instruments. Of the four EM27/SUN instruments, two are owned by the University of Toronto (labeled ta and tb), one is from Environment and Climate Change Canada (tc), and one from the California Institute of Technology (dn). The high-resolution FTS instrument used by TCCON is tied to the World Meteorological Organization scale through extensive airborne measurements (Wunch et al. 2010). For these reasons, the TCCON measurements are used as a "truth" reference. This is helpful when attempting to characterize the new CO measurement capabilities of the portable FTS instruments and reevaluating biases in methane (CH_4) and carbon dioxide (CO_2). This is the first time that these portable instruments have been used to compare CO with multiple TCCON instruments, allowing for further scrutiny of CO measurements among TCCON instruments. Of the four portable instruments used here, one was previously compared to these TCCON stations and offers a possibility to assess changes in the instrumental offsets over longer periods.

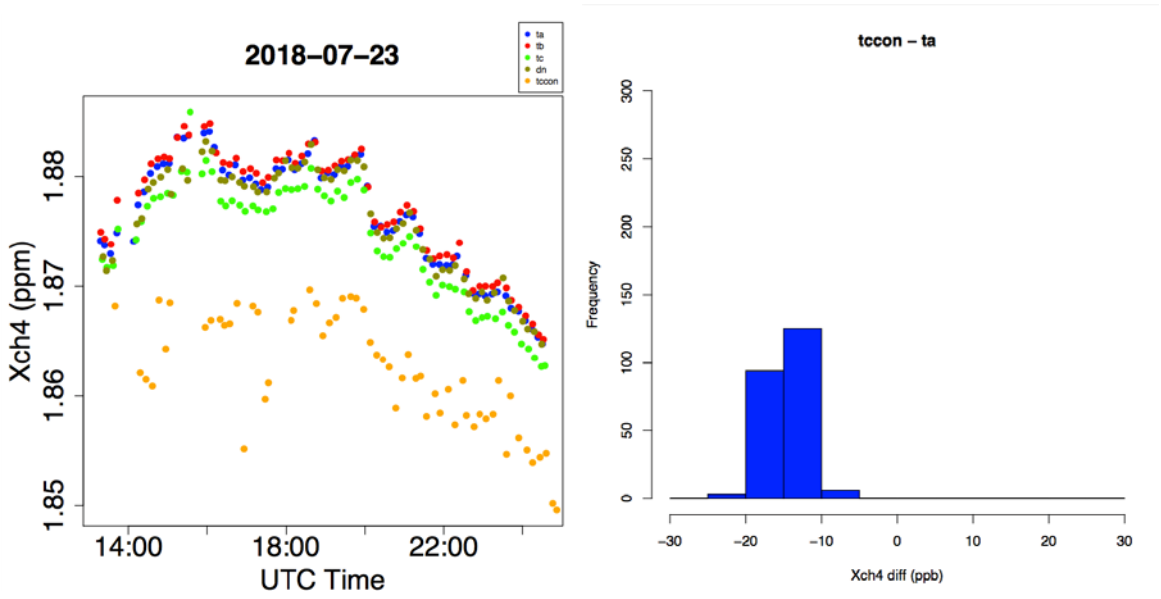

Figure 2. (Left) Time series of TCCON and multiple EM27/SUN total column CH_4 measurements for July 23, 2018. (Right) Histogram of differences in ppb from EM27/SUN labeled ta and the TCCON spectrometer for July 22 through July 28.

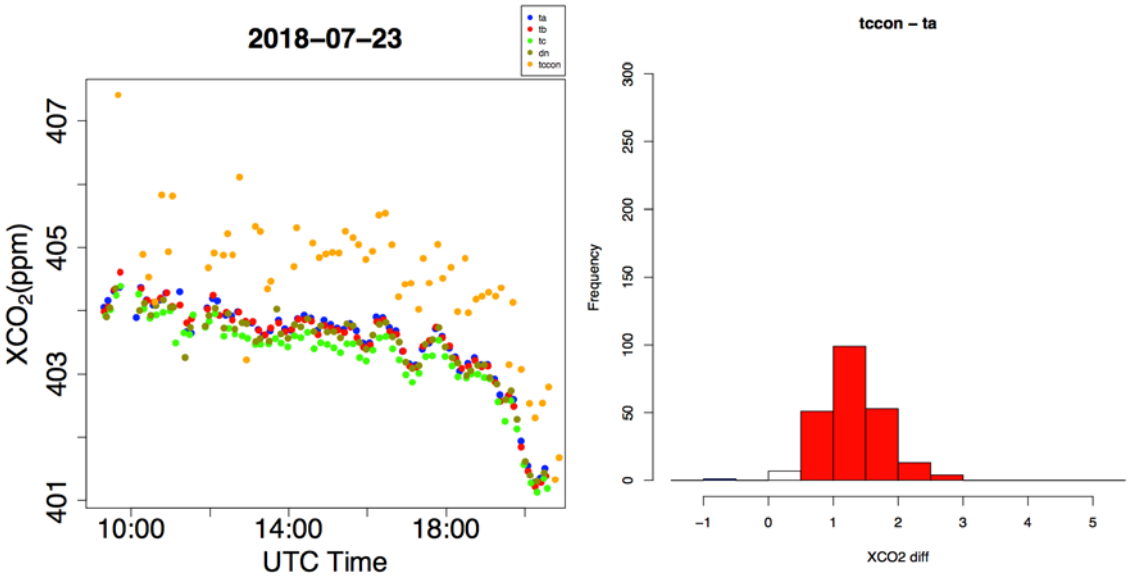

Figure 3. (Left) Time series of TCCON and multiple EM27/SUN total column CO_2 measurements for July 23, 2018. (Right) Histogram of differences in ppm from EM27/SUN labeled ta and the TCCON spectrometer for July 22 through July 28.

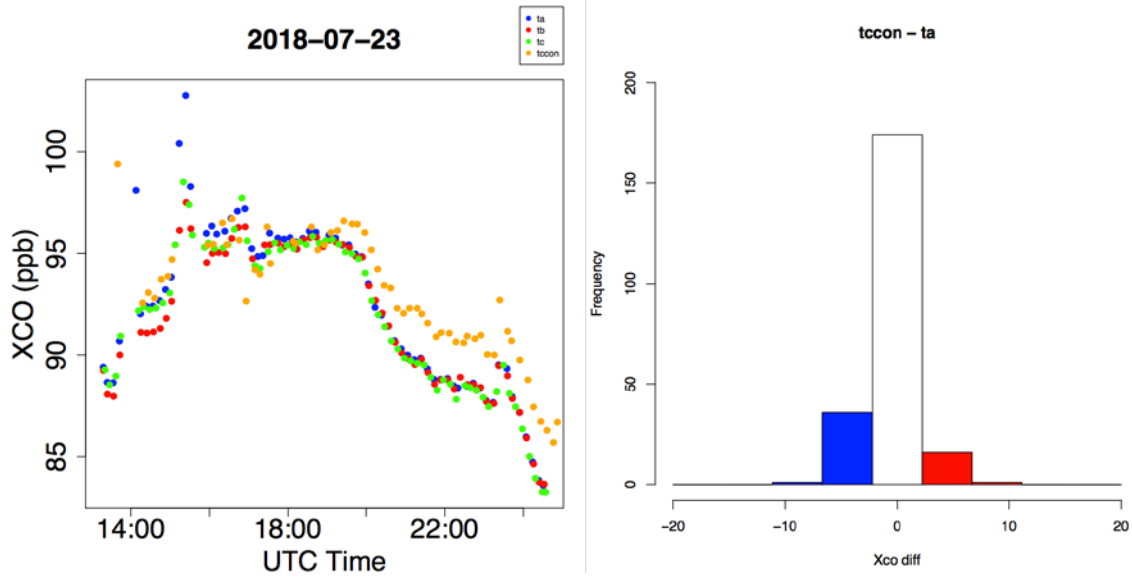

Figure 4. (Left) Time series of TCCON and multiple EM27/SUN total column CO measurements for July 23, 2018. (Right) Histogram of differences in ppb from EM27/SUN labeled ta and the TCCON spectrometer for July 22 through July 28.

The differences between the TCCON instrument and the portable instruments for each of the three molecules of interest are shown in Figures 2-4 with example time series data and difference histogram plots. The differences represented by the histograms are mostly consistent among the four portable instruments and, as the focus is on the TCCON instrument comparison, only one instrument histogram is shown here. There is a positive bias in the measurement of CH_4 between the two types of spectrometers of around 12 parts per billion (ppb) that is consistent among portable instruments and with previous data (Hedelius et al. 2017). A negative bias near 1.5 parts per million (ppm) was observed for total column

CO_2. This is the largest bias during the five-site campaign and is still being investigated. The comparison of CO is novel and shows that overall there is minimal (0 ppb average) offset between the two types of instruments. The time series data shows biases that change over the day, particularly at higher SZAs. This means that there may be different corrections needed for the two types of instrument with respect to CO specifically.

Spectra gathered by all three instruments are processed using GGG2014, which includes the GFIT retrieval algorithm (Wunch et al. 2017). GGG2014 uses an empirical correction for measurements of larger air masses (higher SZAs). The correction is applied based on the TCCON data, but this correction may not extend to the data from the EM27/SUN. Since the EM27/SUN has a lower resolution, it is expected to behave differently when dealing with larger air masses.

The data collected from the portable and TCCON spectrometers was complemented by an in situ air core measurement. While this data has not yet been fully analyzed, it will provide further understanding of biases in a priori profiles of measured molecules used in the total column abundance retrievals.

3.0 Publications and References

3.1 Presentations

N Pak, Comparison of EM27/SUNs with TCCON, no date.

3.2 References

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