Validation of Satellite Measurements with Portable Fourier Transform Spectrometers

Nasrin Mostafavi Pak[1] *, Jacob Hedelius[1], Jonathan E. Franklin[3], Sajjan Heerah [1], Taylor Jones [3], Harrison Parker[2], Elaine Gottlieb [3], Debra Wunch[1], Steve Wofsy[3], Paul Wennberg[2]

[1]*Department of Physics, University of Toronto,* [2]*Atmospheric Chemistry and Environmental Science and Engineering, California Institute of Technology,* [3]*School of Engineering and Applied Sciences, Harvard University*

* *nasrin.mostafavipak@mail.utoronto.ca*

Introduction

Satellite observations of atmospheric greenhouse gases (GHGs) seek to increase our understanding of the global carbon cycle. The Orbiting Carbon Observatory-2 (OCO-2), launched in 2014, and Greenhouse gases Observing SATellite (GOSAT) launched in 2009 have been measuring column abundance of Carbon Dioxide (CO_2) and Methane (CH_4, GOSAT only). Although the primary goal of the satellite observations are to understand regional sources and sinks of GHGs, measurements performed on a high spatial resolution have been used to analyze emissions on local scales.

The Total Carbon Column Observing Network (TCCON), a network of ground based Fourier Transform Spectrometers (FTS), is used for validation of GHG retrievals from satellites. In this study, we examine using low-resolution portable spectrometers (EM27/SUN) for satellite validation in regions not covered by TCCON. In addition, we combine satellite retrievals and ground based FTSs deployed at different locations around urban regions to constrain emissions in two campaigns performed in Pasadena, California and Boston, Massachusetts.

EM27/SUNs

In this study, FTS instruments (Bruker EM27/SUN) were used to validate satellite retrievals of greenhouse gases.

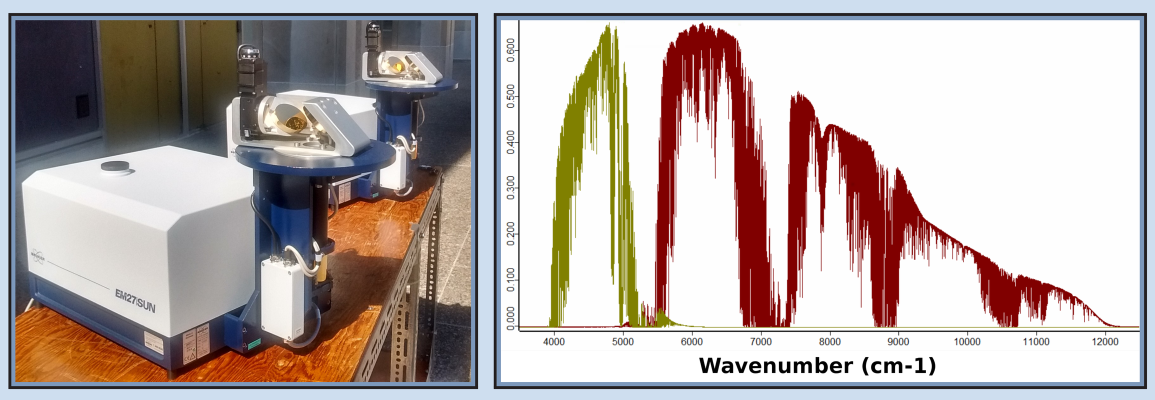

Figure 1. Left: EM27/SUN instruments at the University of Toronto. Right: An example spectrum.

Comparison with TCCON (Pasadena)

Since TCCON is the main source of OCO-2 validation, it is essential to compare EM27/SUN retrievals with TCCON during side by side measurements. During the campaign, the three EM27/SUNs were deployed by Caltech's TCCON station for 4 days. Figure 2. shows XCO_2 values from EM27/SUNs have a consistent bias of about -0.9 ppm relative to TCCON. This bias was added to the retrieved values from July 11th where the OCO-2 overpass occurred. An offset of 6 ppb was added to EM27/SUN values of XCH_4 to better agree with TCCON.

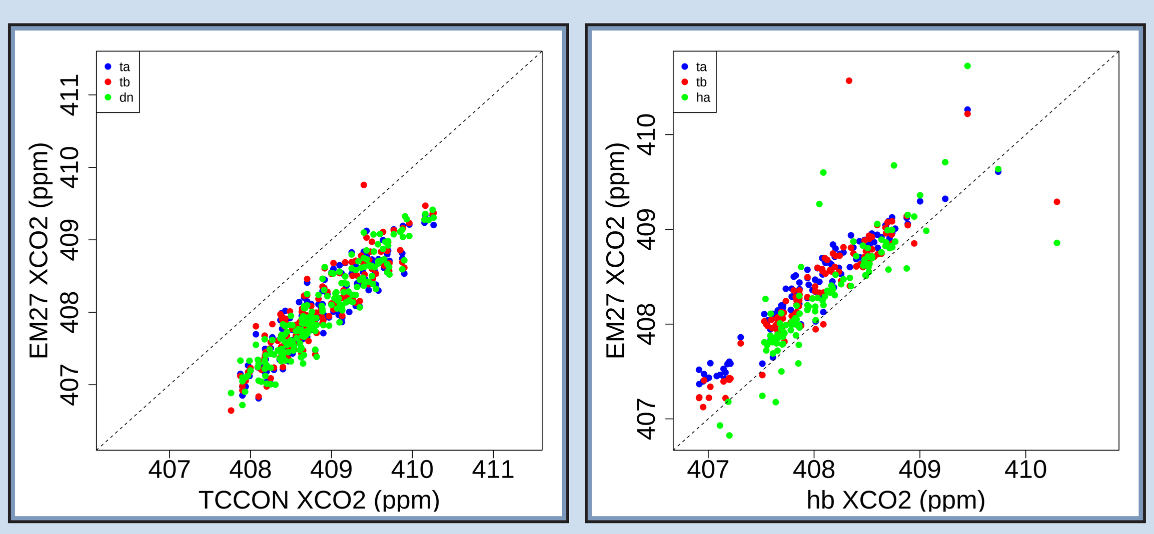

Figure 2. Left: XCO_2 retrievals from the three EM27/SUNs against TCCON during July 12th-18th, 2017 when side by side measurements took place at Caltech. Right: XCO_2 retrievals from the three EM27/SUNs against the one EM27/SUN selected as a reference, during January 18-27th, 2018 when side by side measurements took place at Harvard.

Intercomparison between EM27/SUNs (Boston)

Since there are no TCCON stations available near Boston, in order to address instrumental biases, the XCO_2 from the three instruments were compared to one of the EM27/SUNs chosen as a reference. As shown in Figure 2, biases of 0.1 to 0.4 ppm were observed. Similar analysis for CH_4 suggested offsets smaller than 1 ppb which is below the single-scan instrument precision.

Pasadena

On July 11th 2017, OCO-2 nadir ground track passed through South Coast Air Basin (SoCAB) in Southern California. On that day, we deployed three EM27/SUNs (ta, tb: Toronto instruments, nn:Caltech instrument) across the north end of the SoCAB, near I-210 highway, and measured XCO_2 and XCH_4. The three instruments were distributed evenly between the Pasadena TCCON station to the West, and the OCO-2 measurement track about 50 km to its East.

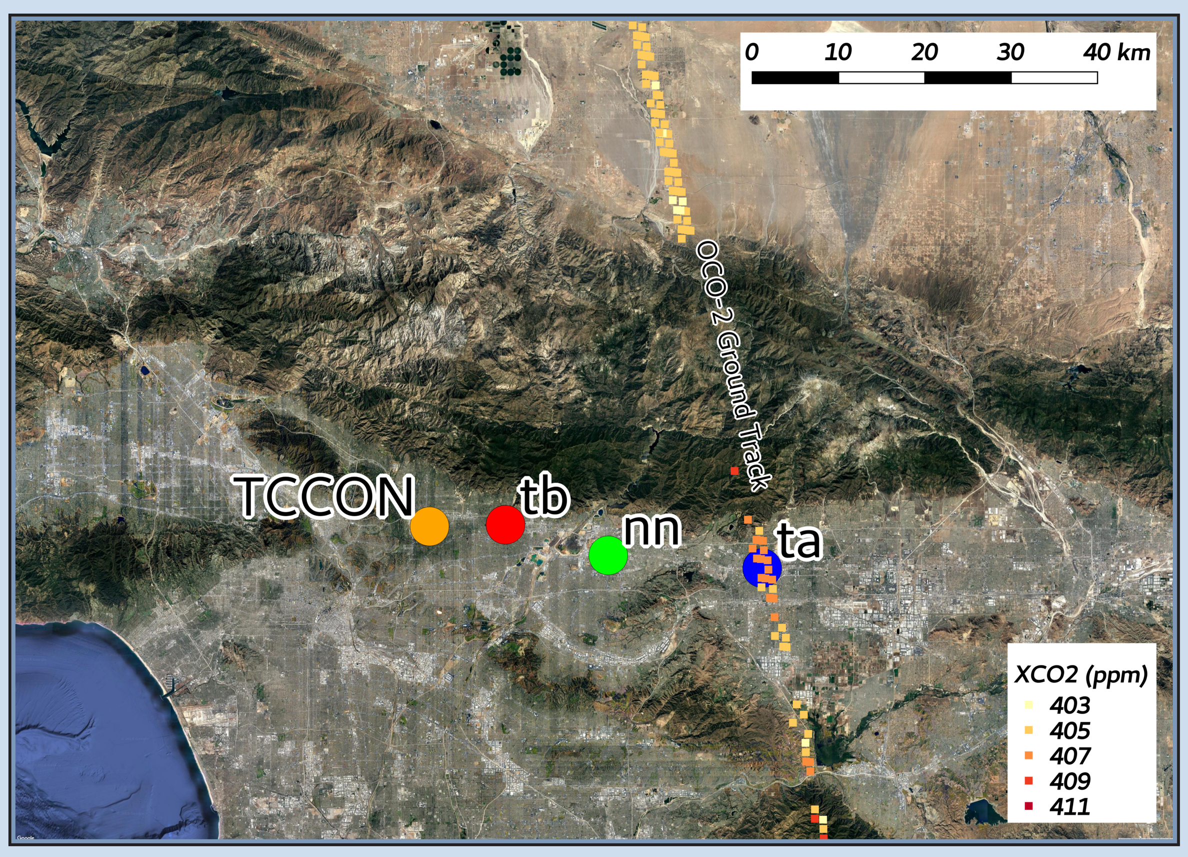

Figure 3. Deployment locations of the 3 EM27/SUN instruments and OCO-2 retrieved XCO_2 values on 11th July 2017.

As seen in Figure 4, the development of the urban plume and its transport from west to the east is apparent both in XCO_2 and XCH_4. Enhancements of more than 3 ppm in XCO2 and 15 ppb in XCH_4 were observed in the afternoon at the urban site (tb) compared to the rural site on the east end (ta). The OCO-2 XCO_2 retrieval shows good agreement with the EM27/SUN XCO_2 (ta) deployed under the satellite track.

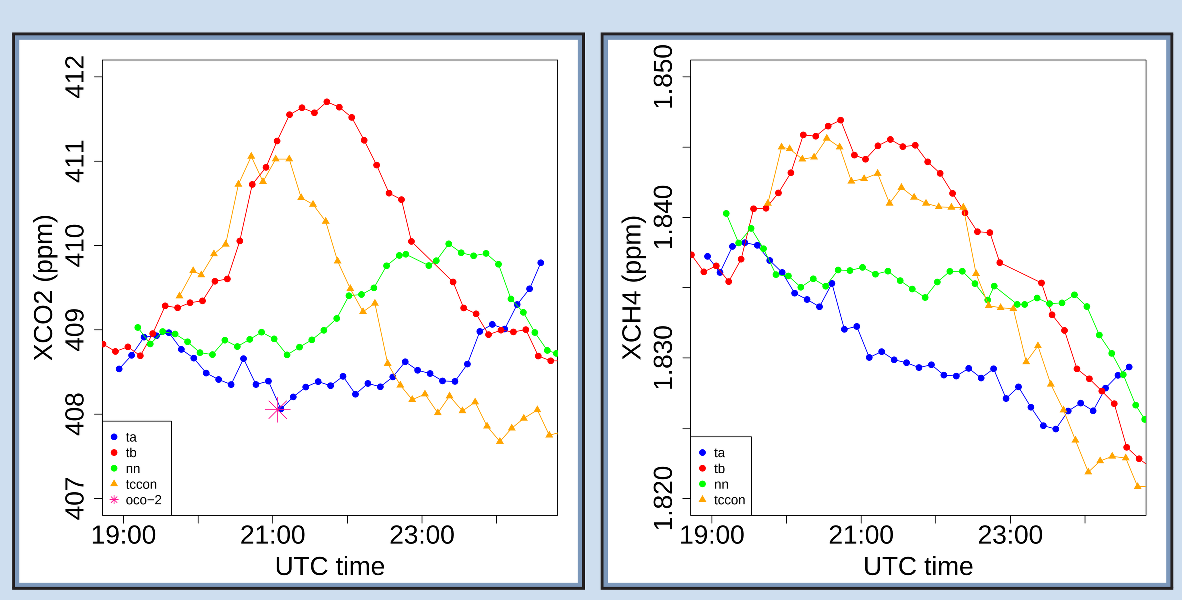

Figure 4. XCO_2 (left) and XCH_4 (right) values measured on July 11th 2017 at Pasadena TCCON station and 3 locations along highway I-210 on the east.

Boston

On January 26th 2018, both OCO-2 and GOSAT made observations in Boston, when we deployed four EM27/SUN instruments (ta and tb: Toronto instruments, ha and hb: Harvard instruments) in the area. One instrument was deployed in Harvard Forest approximately 20 km east of the OCO-2 measurement track, and the other three instruments were deployed downwind of the Harvard Forest on the east end of Boston.

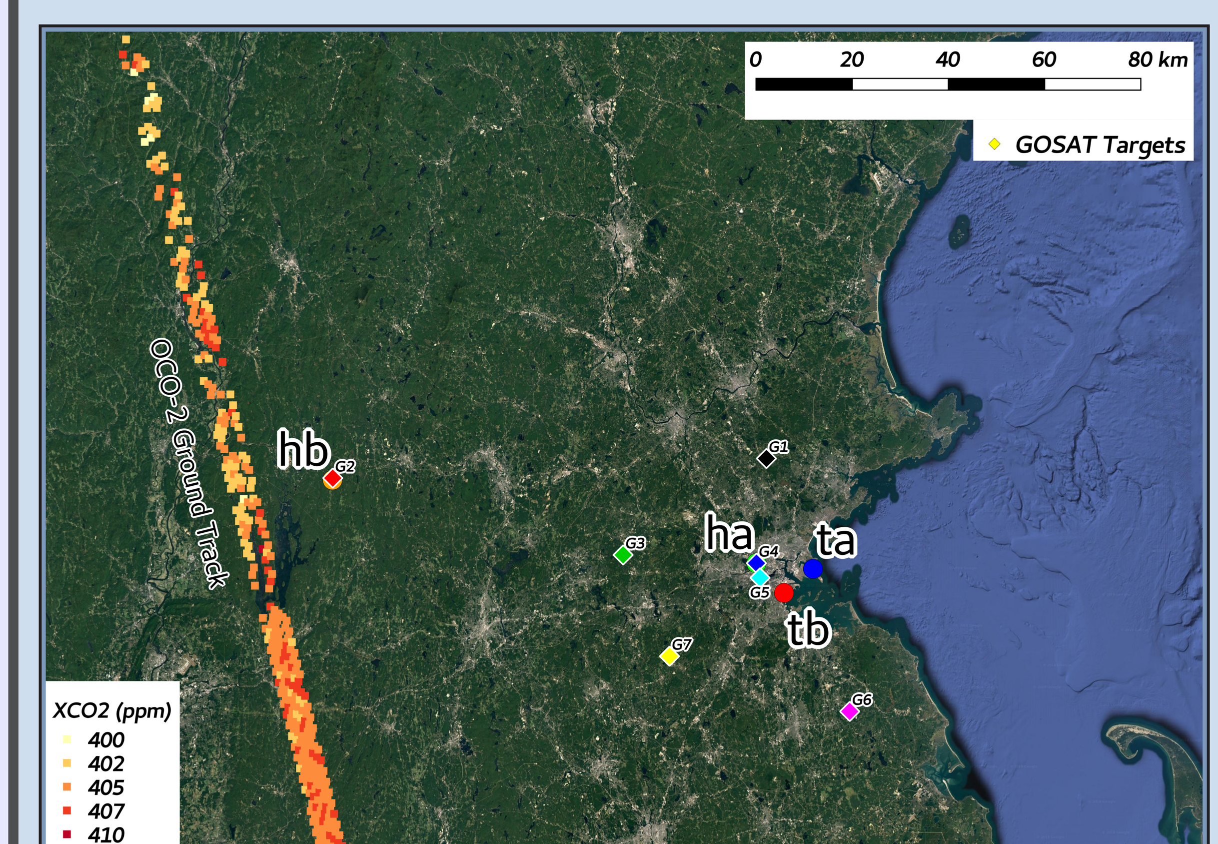

Figure 5. Deployment locations of the 4 EM27/SUN instruments, OCO-2 retrieved XCO_2 values, and GOSAT targets (G1-G7) on 26th January 2018.

The observations suggest enhancements of less than 2 ppm in XCO_2 in the urban area compared to Harvard forest. XCH_4 enhancements of up to 8 ppb are significant enough to be used to constrain the flux from the city. GOSAT retrievals suggest high variability both in XCO_2 and XCH_4. Coincident measurements of GOSAT and EM27/SUNs have discrepancies as large as 4 ppm for XCO_2 and 18 ppb for XCH_4 that are comparable to GOSAT's single-retrieval precision precision of $\sim 1\%$.

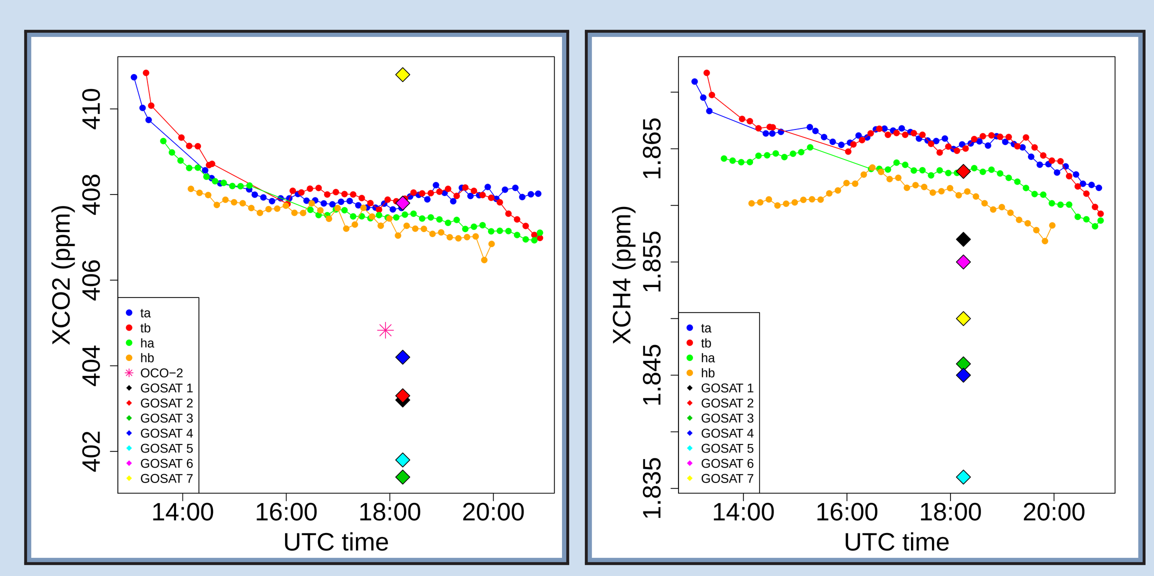

Figure 6. Left. XCO_2 and Right CH_4 values measured on January 26th 2018 by the 4 EM27/SUN instruments deployed at different locations in downtown Boston and Harvard forest.

Conclusion

EM27/SUNs are promising for validating satellite measurements specifically where TCCON stations do not exist. In addition, satellite measurements along with ground based measurements with EM27/SUNs deployed at upwind and downwind locations in urban areas could be used to constrain urban emissions.

References

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