

GGG retrieval of EM27/SUN and intercomparisons against TCCON

TCCON Meeting
Spa, Belgium

Nasrin Mostafavi Pak

13 June 2023

EM27/SUNs for GHG Measurements in Toronto

Seven EM27/SUNs currently measuring in the GTA.

*Three have visited TCCON sites in North America.

University of Toronto

ta* (since June 2017)

tb* (since June 2017)

Environment Canada

tc* (since Jun 2018)

td (since Jun 2019)

te (since Dec 2019)

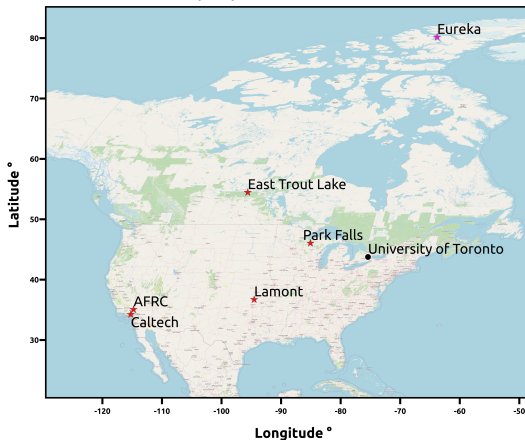
tf (since Sep 2021)

tg (since Jun 2022)



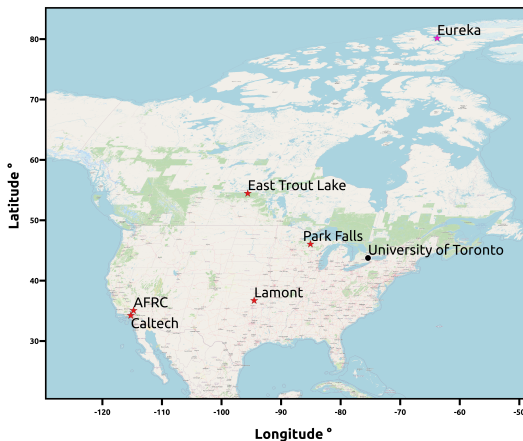
TCCON Road Trip

- ▶ Summer 2018 road trip campaign :
 - ▶ TCCON sites: Caltech (ci), AFRC (df), Lamont (oc), Park Falls (pa) and East Trout lake (et)
 - ▶ EM27/SUNs: Toronto (ta, tb, tc) and one EM27/SUN from Caltech (dn)
- ▶ Spring-Fall 2020: Eureka (eu), only of the instruments (tb)



TCCON Road Trip

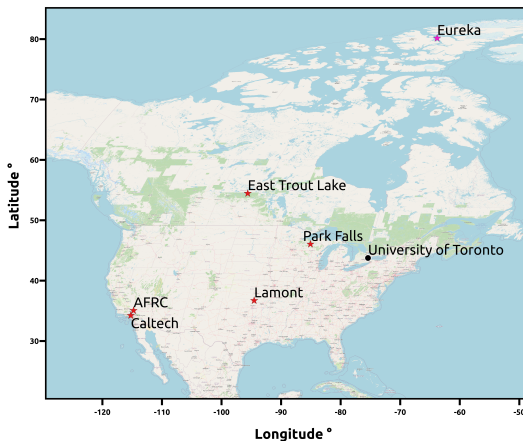
- ▶ Test the durability of EM27/SUNs when they are moving frequently
- ▶ Investigate the biases between the EM27/SUNs
- ▶ Investigate the biases between the EM27/SUNs and TCCON sites
- ▶ Indirectly Compare TCCON Stations to each other



TCCON Road Trip

In addition we planned for:

- ▶ AirCore launches at 3 sites: Dryden, Lamont and Park Falls

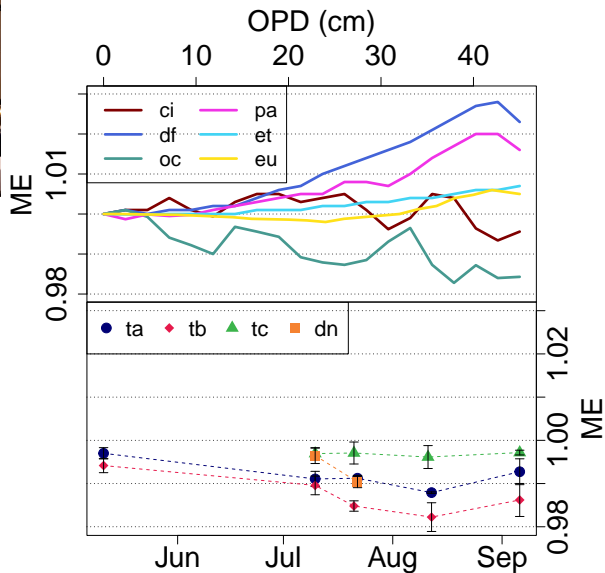
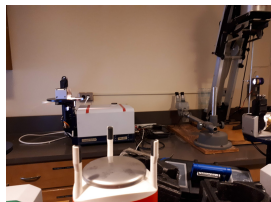


Overview of the trip

Site	Dates	# days	EM27/SUNs	# EM27/SUN ifgs	# TCCON ifgs	AirCore
Caltech	2018-07-06 – 2018-07-12	7	ta,tb,tc,dn	21356	1541	-
Dryden	2018-07-13 – 2018-07-19	7	ta,tb,tc,dn	16522	3775	6
Lamont	2018-07-21 – 2018-07-19	5	ta,tb,tc,dn	12942	872	9
Park Falls	2018-07-31 – 2018-08-07	4	(ta),tb,tc	3324	406	4
East Trout Lake	2018-08-09 – 2018-08-18	6	ta,tb,tc	10665	861	-
Eureka	2020-03-04 – 2020-09-25	61	tb	132279	5166	-

Retrieval Procedure

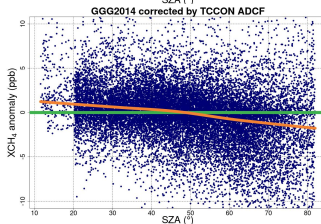
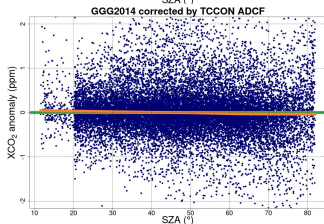
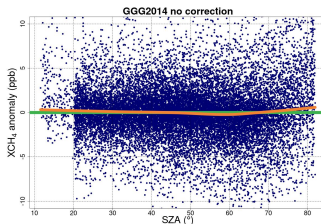
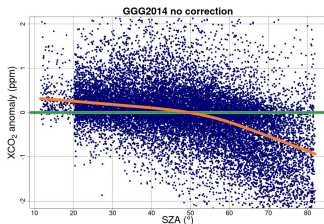
- ▶ Software: EGI/GGG2014 and EGI/GGG2020
- ▶ Data were processed with identical pressure data taken from TCCON and a priori profiles
- ▶ Revised Post-Processing steps for the EM27/SUNs:
 - ▶ Calculated Airmass Dependant Correction Factors (ADCFs) →will go to EGI
 - ▶ Calculated an additive instrument-to-instrument bias →using ghost correction feature in GGG (will need to change the name at some point)
 - ▶ Calculated Airmass Independant Correction Factors (AICFs) using coincident AirCore measurements →will go to EGI
- ▶ Added truncated low resolution 125HR spectra to match EM27/SUN resolution



ADCF calculation

GGG2014

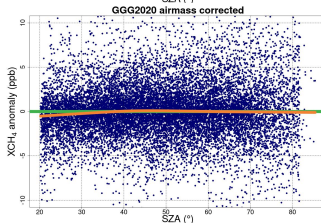
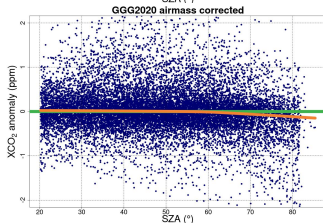
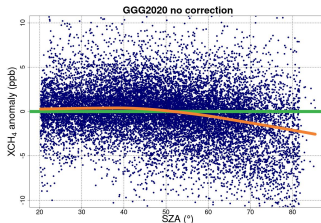
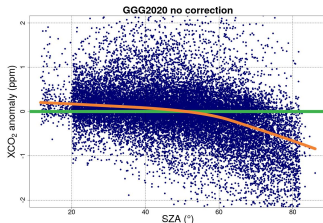
	TCCON GGG2014 ADCF	EM27/SUN GGG2014 ADCF
XCO ₂	-0.0068	-0.0068
XCH ₄	0.0053	0
XCO	-0.0483	0



ADCF calculation

GGG2020

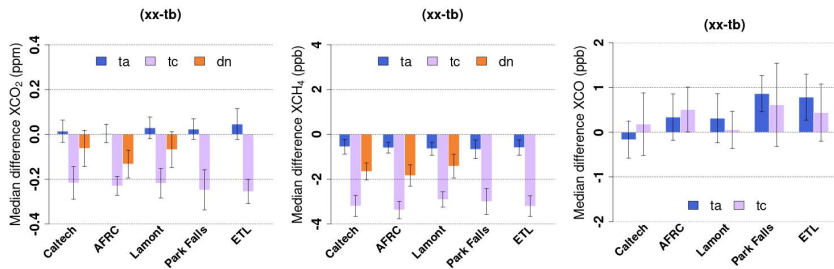
	TCCON GGG2020 ADCF	EM27/SUN GGG2020 ADCF
Xluft	0.00053	0.0027
XCO ₂	-	-0.0049
XCH ₄	-	-0.0045
XCO	0	0



Comparison of EM27/SUNs

GGG2014

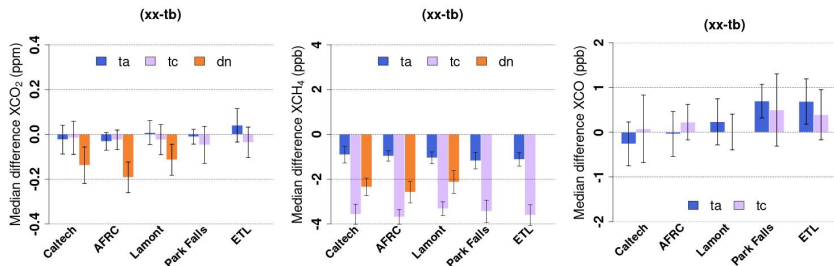
Consistent bias between the EM27/SUNs throughout the road trip.



Comparison of EM27/SUNs

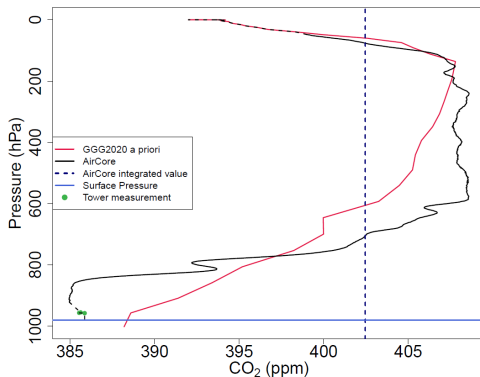
GGG2020

Consistent bias between the EM27/SUNs throughout the road trip.



Coincident AirCore Measurements

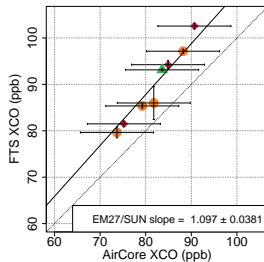
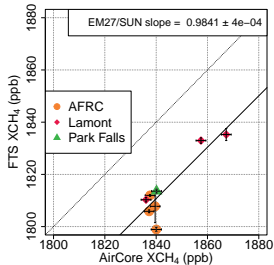
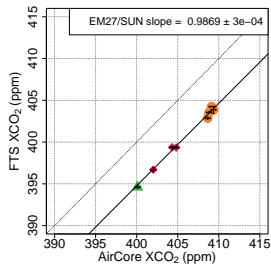
Site	Date	Launch time (UTC)	Number of launches	Collocated EM27/SUN(s)
AFRC remote site	2018-07-16	21:30	2	ta
	2018-07-17	14:00	1	ta
	2018-07-17	21:30	1	ta
	2018-07-18	18:00	2	ta
Lamont	2018-07-23	17:00	2	ta,tb,tc,dn
	2018-07-25	17:00	4	ta,tb,tc,dn
	2018-07-27	17:00	3	ta,tb,tc,dn
Park Falls	2018-07-31	17:00	2	tb,tc
	2018-08-03	17:00	2	-



AICF Calculation

GGG2014

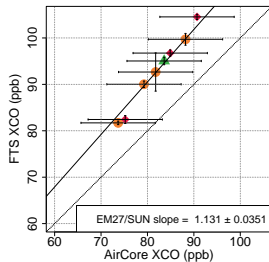
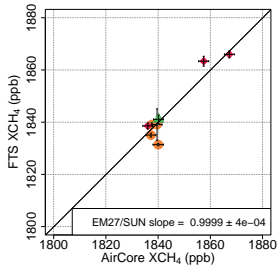
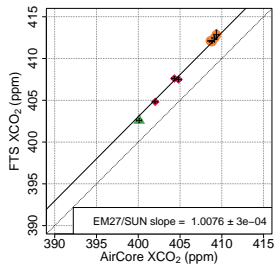
	TCCON GGG2014 AICF	EM27/SUN GGG2014 AICF
XCO ₂	0.9898	0.9869
XCH ₄	0.9765	0.9840
XCO	1.0672	1.0965



AICF Calculation

GGG2020

	TCCON GGG2020 AICF	EM27/SUN GGG2020 AICF
XCO ₂	1.0101	1.0076
XCH ₄	1.0031	0.9999
XCO	1.0	1.0



Comparison of EM27/SUNs with TCCON

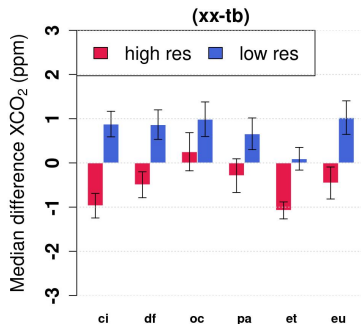
XCO₂

GGG2014

Maximum difference:

High resolution= 1.33 ppm

Low resolution= 0.89 ppm

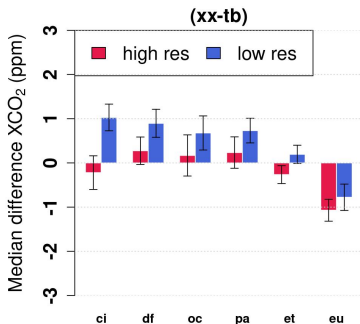


GGG2020

Maximum difference:

High resolution= 0.53 ppm

Low resolution= 0.83 ppm



Comparison of EM27/SUNs with TCCON

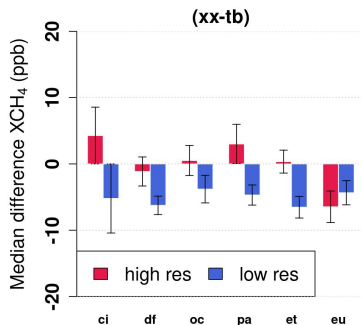
XCH₄

GGG2014

Maximum difference:

High resolution= 5.4 ppb

Low resolution= 2.7 ppb

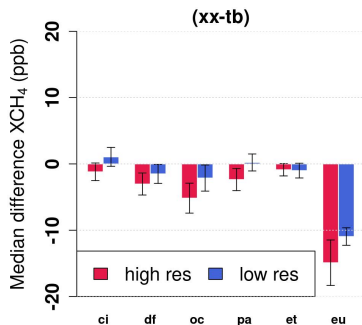


GGG2020

Maximum difference:

High resolution= 4.3 ppb

Low resolution= 3.2 ppb



Comparison of EM27/SUNs with TCCON

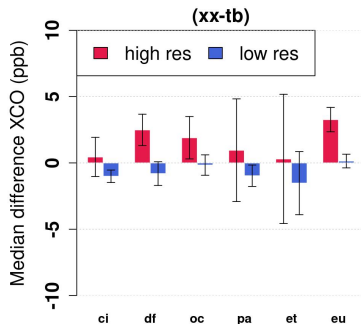
XCO

GGG2014

Maximum difference:

High resolution= 2.2 ppb

Low resolution= 1.4 ppb

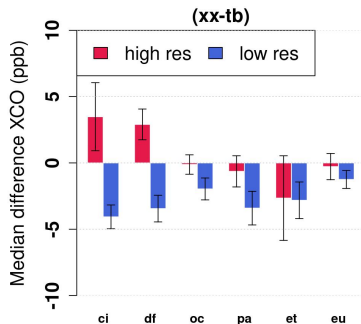


GGG2020

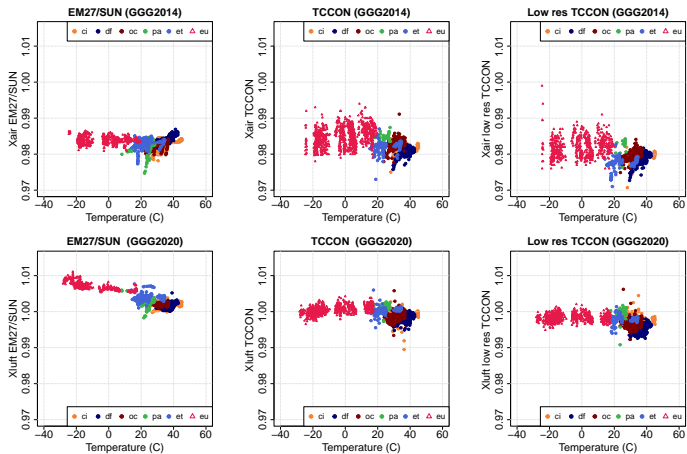
Maximum difference:

High resolution= 6.1 ppb

Low resolution= 2.1 ppb



GGG2020 Temperature correction issue



Details and datasets available on AMT



Article

Articles / Volume 16, Issue 5 / AMT, 16, 1239–1261, 2023

Search



<https://doi.org/10.5194/amt-16-1239-2023>

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Peer review

Metrics

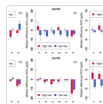
Related articles

09 Mar 2023

Research article |

Using portable low-resolution spectrometers to evaluate Total Carbon Column Observing Network (TCCON) biases in North America

Nasrin Mostafavi Pak , Jacob K. Hedellus, Sébastien Roche, Liz Cunningham, Bianca Baier, Colm Sweeney, Coleen Roehl, Joshua Laughner, Geoffrey Toon, Paul Wennberg, Harrison Parker, Colin Arrowsmith, Joseph Mendonca, Pierre Fogal, Tyler Wizenberg, Beatriz Herrera, Kimberly Strong, Kaley A. Walker, Felix Vogel, and Debra Wunch



Download

- ▶ Article (10426 KB)
- ▶ Full-text XML
- ▶ BibTeX
- ▶ EndNote

Short summary

Ground-based remote sensing instruments in the Total Carbon Column Observing Network (TCCON)...
▶ Read more

Published January 17, 2023 | Version 2020.0

Software

EM27/SUN GGG Interferogram processing suite

Hedellus, Jacob Wennberg, Paul

Contact person: Hedellus, Jacob

Project leader: Wennberg, Paul

Citation

Style APA

Hedellus, J., & Wennberg, P. (2023). EM27/SUN GGG Interferogram processing suite (2020.0). CaltechDATA. <https://doi.org/10.22002/25tve-4h822>

Description

The EM27/SUN GGG Interferogram processing suite (EGI) is a collection of software tools to simplify processing data collected using EM27/SUN instruments through GGG. Complete processing is simplified down to a one-line command or can even be setup with a cronjob to run automatically e.g., overnight. EGI completes steps of matching meteorological, and location data, and obtaining a priori files automatically. EGI2020 also includes tools to create basic plots for quick QC purposes. EM27/SUN instruments are commercial, portable, solar-viewing FT-IR spectrometers (manufactured by Bruker). GGG is open-source software used to FFT the interferograms to spectra, and then fit the spectra to obtain column averaged abundances of CO₂, CH₄, H₂O, CO, and N₂O. GGG is used for the TCCON (<https://tccon.wiki.caltech.edu/>).

Versions

Version 2020.0	Jan 17, 2023
10.22002/25tve-4h822	
Version 2014.5	Jan 17, 2023
10.22002/5nwk-rg704	
Version 2014.4	Jan 17, 2023
10.22002/j68e-ek124	
Version 2014.3	2017
10.22002/D1.306	

[View all 4 versions](#)

Keywords and subjects

EM27/SUN Remote Sensing Climate change
TCCON

Details

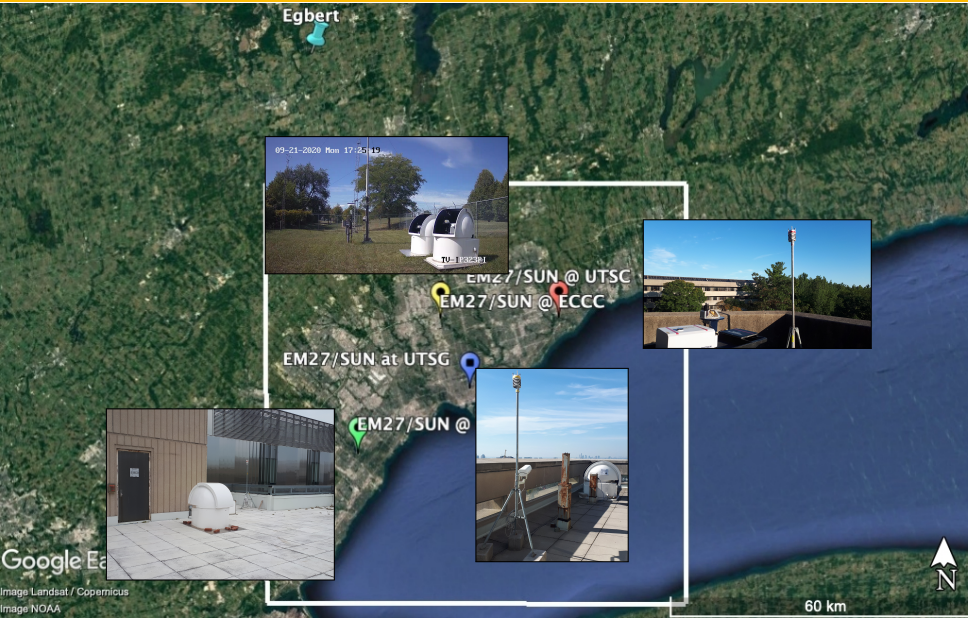
DOI

DOI [10.22002/25tve-4h822](https://doi.org/10.22002/25tve-4h822)

Measurement locations since July 2019



Measurement locations since July 2019

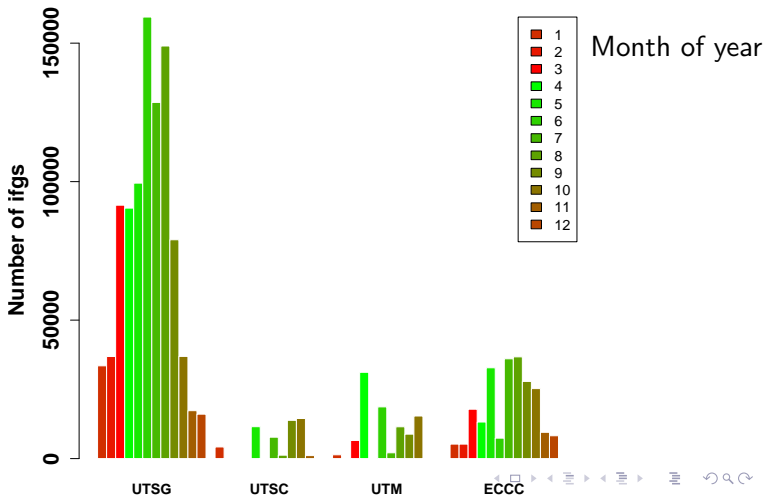


Data availability

More data is available from the Downtown (UTSG) and Downsview (ECCC) that were automated before COVID-19 lockdown.

Mississauga (UTM) and Scarborough (UTSC) are now automated.

EM27/SUN data summary



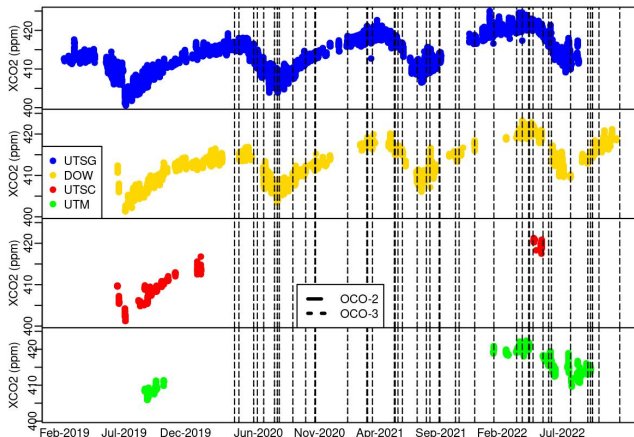
Data Availability

XCO₂

10 minute average precision = 0.5 ppm

Maximum site to site relative enhancement ≈ 6 ppm

75th percentile site to site relative enhancement ≈ 0.7 ppm



Debra Wunch Dataverse

(University of Toronto)

Borealis > University of Toronto Dataverse > Debra Wunch Dataverse >

Submitted for Review – The draft version of this dataset is currently under review prior to publication.

Total Column Mixing Ratios of Carbon Dioxide, Methane and Carbon Monoxide from Toronto (ta)

[Draft](#) [In Review](#)



Mostafavi Pak, Nasrin; Wunch, Debra; Lawson, 2019, "Total Column Mixing Ratios of Carbon Dioxide, Methane and Carbon Monoxide from Toronto (ta)", <https://doi.org/10.56683/SP2/RNCAWQ>, Borealis, DRAFT VERSION

[Cite Dataset](#) - [Learn about Data Citation Standards.](#)

Access Dataset ▾

Submitted for Review

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Description

Column-averaged dry-air mole fractions (DMF) of trace gases CO₂, CH₄ and CO were collected using a Bruker Optics EM27/SUN Fourier Transform Spectrometer (FTS) at the University of Toronto, St George Campus. The data were processed using GGG2020. (2023-05-03)

Dataset Metrics

62 Downloads

Subject

Physics; Earth and Environmental Sciences

Keyword

Greenhouse Gases, Carbon Dioxide, Methane, Carbon Monoxide, Fourier Transform Spectrometry

Related Publication

N Mostafavi Pak, Quantifying Methane Emissions from the Greater Toronto Area, PhD Thesis, University of Toronto, 2022

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ta20170616_20171206_experimental_public.nc

Network Common Data Form - 21.5 MB

Deposited May 3, 2023

MD5: 91a...580

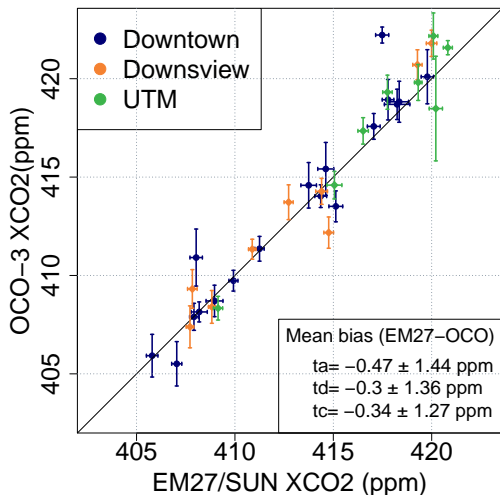
Retrievals of EM27/SUN SN.75, at University of Toronto St George Campus, McLennan Physical Laboratories



Average OCO-3 (within site grid box) vs EM27/SUN

EM27/SUN values: Averaged over \pm half an hour from target time

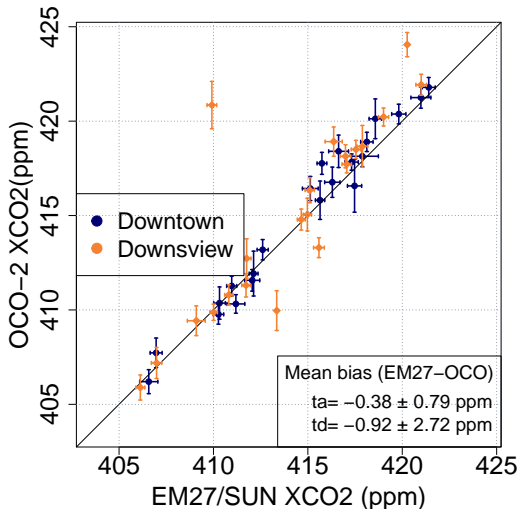
OCO-3 values: Average inside site specific grid box



Average OCO-2 vs EM27/SUN

EM27/SUN values: Averaged over \pm half an hour from target time

OCO-2 values: Average inside site specific grid box



Summary

- ▶ We have developed post processing steps specific to EM27/SUNs to be followed by all GGG users - Implemented into EGI2020
- ▶ We have shown that EM27/SUNs are stable enough when moving frequently
- ▶ GGG2014: Comparisons between EM27/SUN and TCCON retrievals show some variations from site to site which improves using the low resolution spectra
- ▶ GGG2020: There are some improvements in site-to-site biases except for XCO
- ▶ We see some temperature dependence in Xluft which could cause additional biases in Eureka
- ▶ More investigation needs to be performed on GGG2020 low resolution TCCON retrievals
- ▶ Long term measurements in Toronto and satellite validation, more measurement stations have been set up in last year, all GGG2020 public files will be available on Borealis

Collaborators

- ▶ Jacob Hedelius
- ▶ Harrison Parker
- ▶ Liz Cunningham
- ▶ Colin Arrowsmith
- ▶ Joseph Mendonca
- ▶ Tyler Wizenberg
- ▶ Coleen Rohel
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- ▶ Sonia Wolter
- ▶ Bianca Baier
- ▶ Colm Sweeney
- ▶ Laura Iraci
- ▶ Jim Podolske
- ▶ Joshua Laughner
- ▶ Sebastien Roche
- ▶ Banyan Lehman
- ▶ Sebastien Ars
- ▶ Tazeen Ajmari
- ▶ Pierre Fogal
- ▶ Beatriz Herrera
- ▶ Geoffrey Toon
- ▶ Paul Wennberg
- ▶ Kimberly Strong
- ▶ Kaley A Walker
- ▶ Felix Vogel
- ▶ Debra Wunch