Testing and deployment of an EM27 FTS with new fibre optic solar tracking system in Toronto (IWGGMS-20, 29 - 31 May 2024)

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Background and motivation

The EM27/SUN FTS has offered an amazing opportunity to collect total column measurements of CO_2, CH_4, and CO from sites where a TCCON station has not been feasible or practical, or in regions where multiple instruments are needed to constrain local emissions. While this instrument has expanded our ability to validate satellite-based measurements and monitor urban emissions, fully automated observations and better weatherproofing could expand these capabilities even further. An EM27 with an alternative solar-tracking arrangement consisting of an optical fibre, telescope, and external solar tracking instrument (Eko Suntracker) has already been used with some success at Wollongong [1]. This setup eliminates the risk of exposing sensitive optics during operations and the need for daily alignment of the solar tracker. If correctly implemented, this would allow data collection to be fully automated, thus increasing the rate of data acquisition while decreasing the demand for on-site or remote maintenance.

Instrument setup

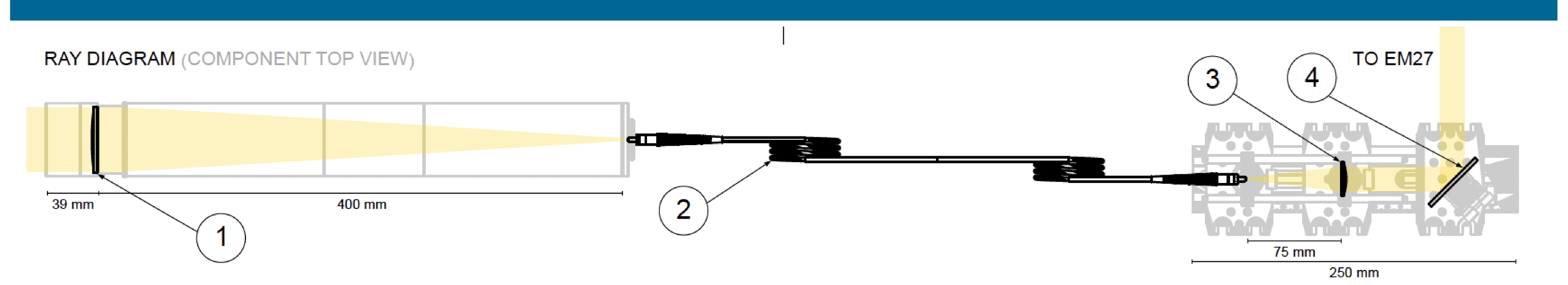

Fig. 1: Ray diagram for the first version of the FO tracking set up with glass lenses.

1. Telescope mounted to Eko suntracker. We have tested a glass telescope lens with 400 mm focal length and two CaF_2 lenses with 500 mm and 150 mm focal lengths. With a shorter focal length more light should enter the optical fibre and with the CaF_2 lenses there should be more transmittance at longer wavelengths (may be important for the CO channel).
2. Optical fibre, currently using a 2 m long 0.22 NA, low OH silica core fibre with 550μm internal diameter. We have tested some longer fibres that had too much attenuation in CO channel.
3. Second collimating lens with 75 mm focal length. We have tested glass and CaF_2 (matching the telescope lens).
4. Flat mirror with manual positional adjustments.

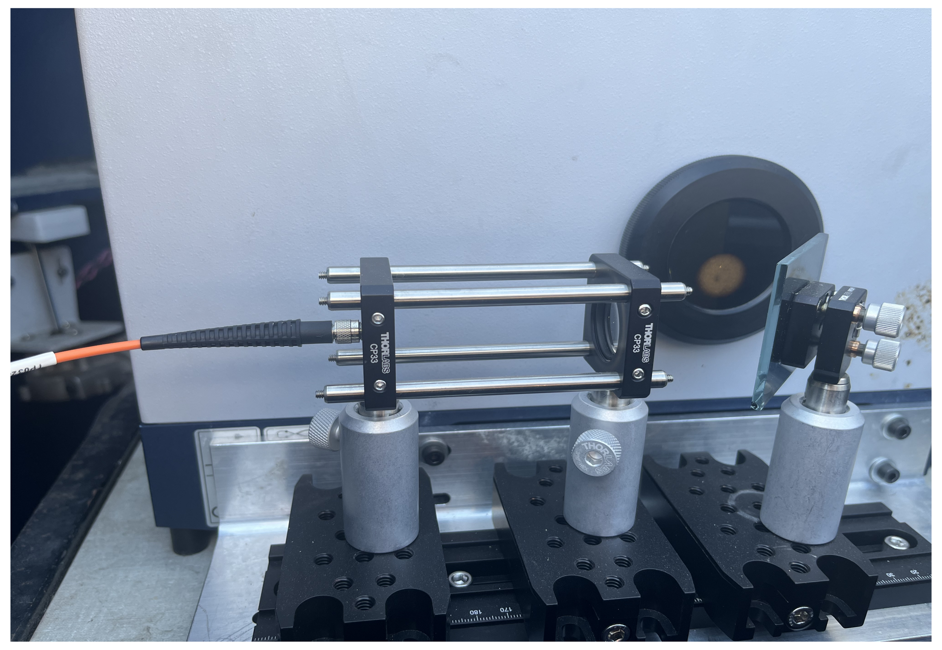

Fig. 2: Fibre mount, collimating lens, and flat mirror used to direct the sunlight from the optical fibre into the spectrometer.

Fig. 3: A close up of the Eko Suntracker with the 15 cm telescope.

Testing at University of Toronto

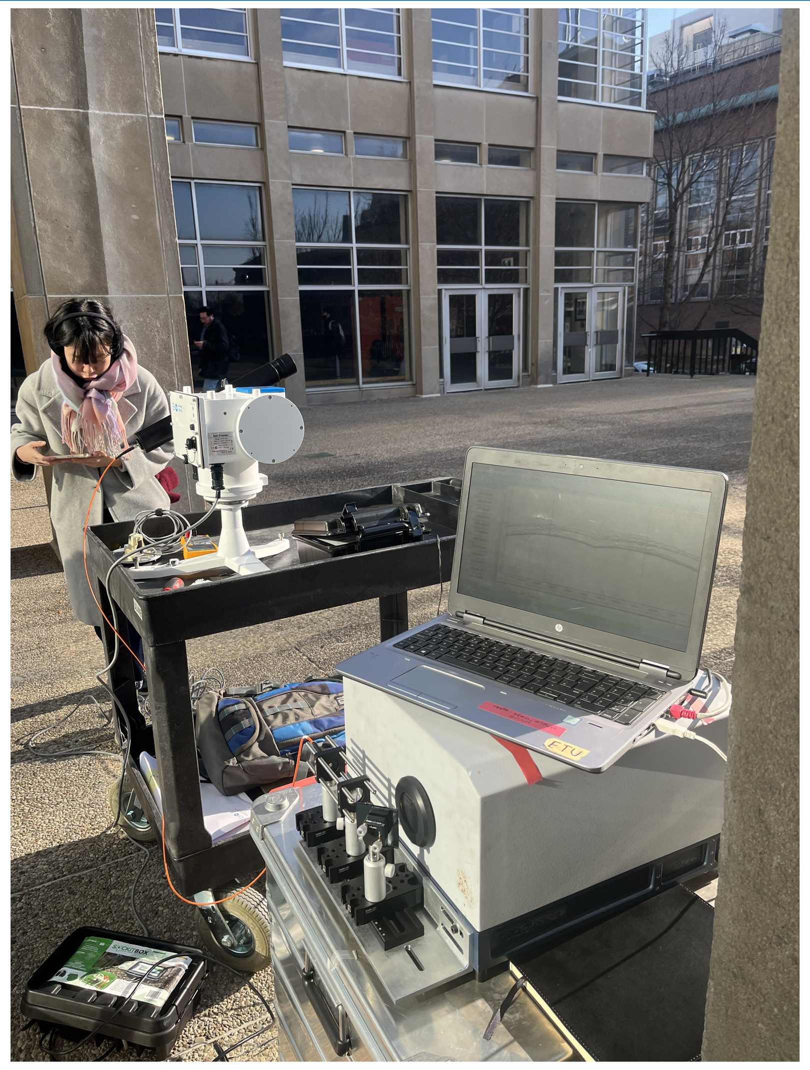

Fig. 4: An undergraduate engineering student (Maggie Wang) at one of our first outdoor tests, 2023-11-30. At this time, we were using a 10 m optical fibre.

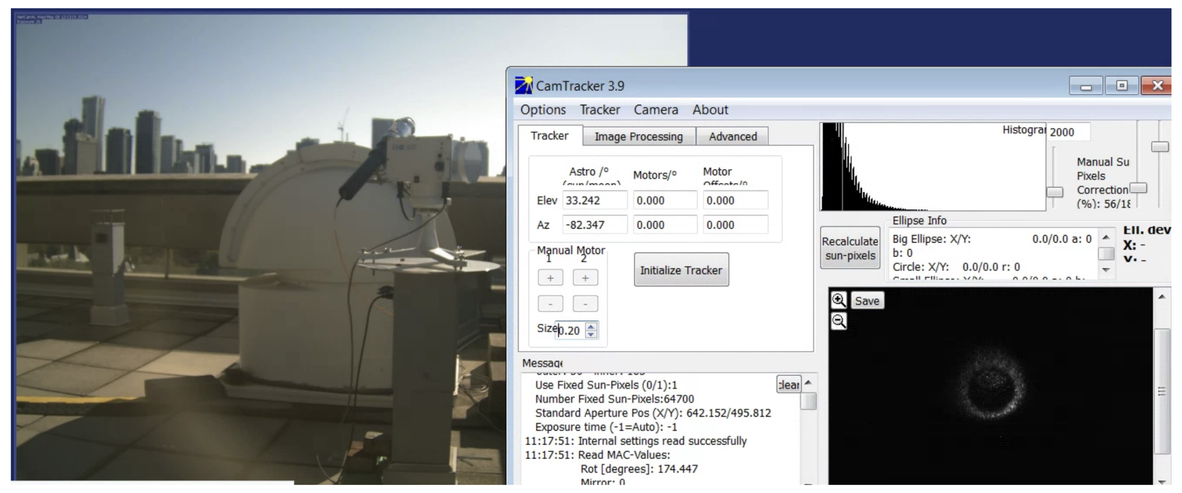

Fig. 5: Setup at the University of Toronto and camera image of the detector with CaF_2 lenses and a 50 cm telescope, on 2024-05-08.

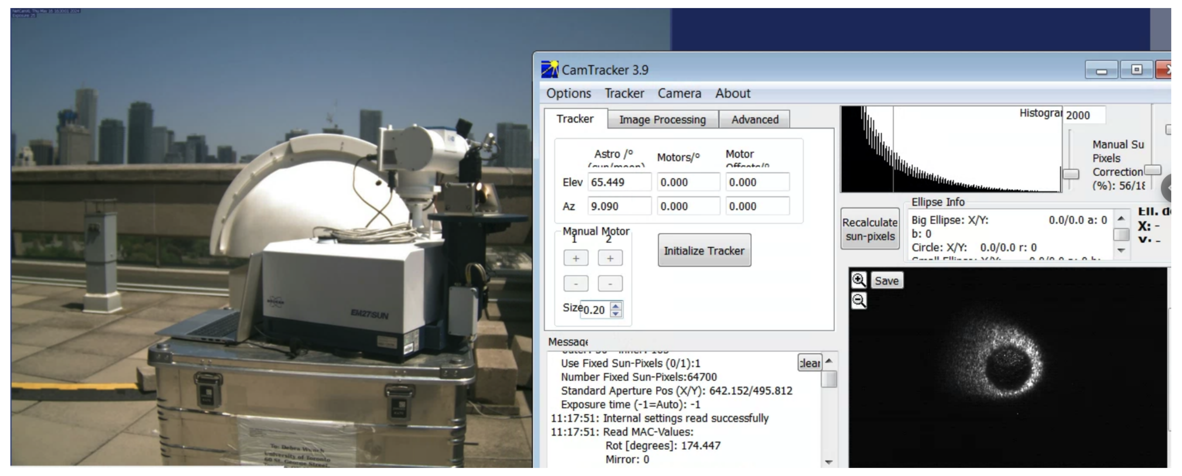

Fig. 6: Setup at the University of Toronto and camera image of the detector with CaF_2 lenses and 15 cm telescope, on 2024-05-16. A collocated EM27/SUN with standard tracker is also measuring.

Past year of observations in Downtown Toronto

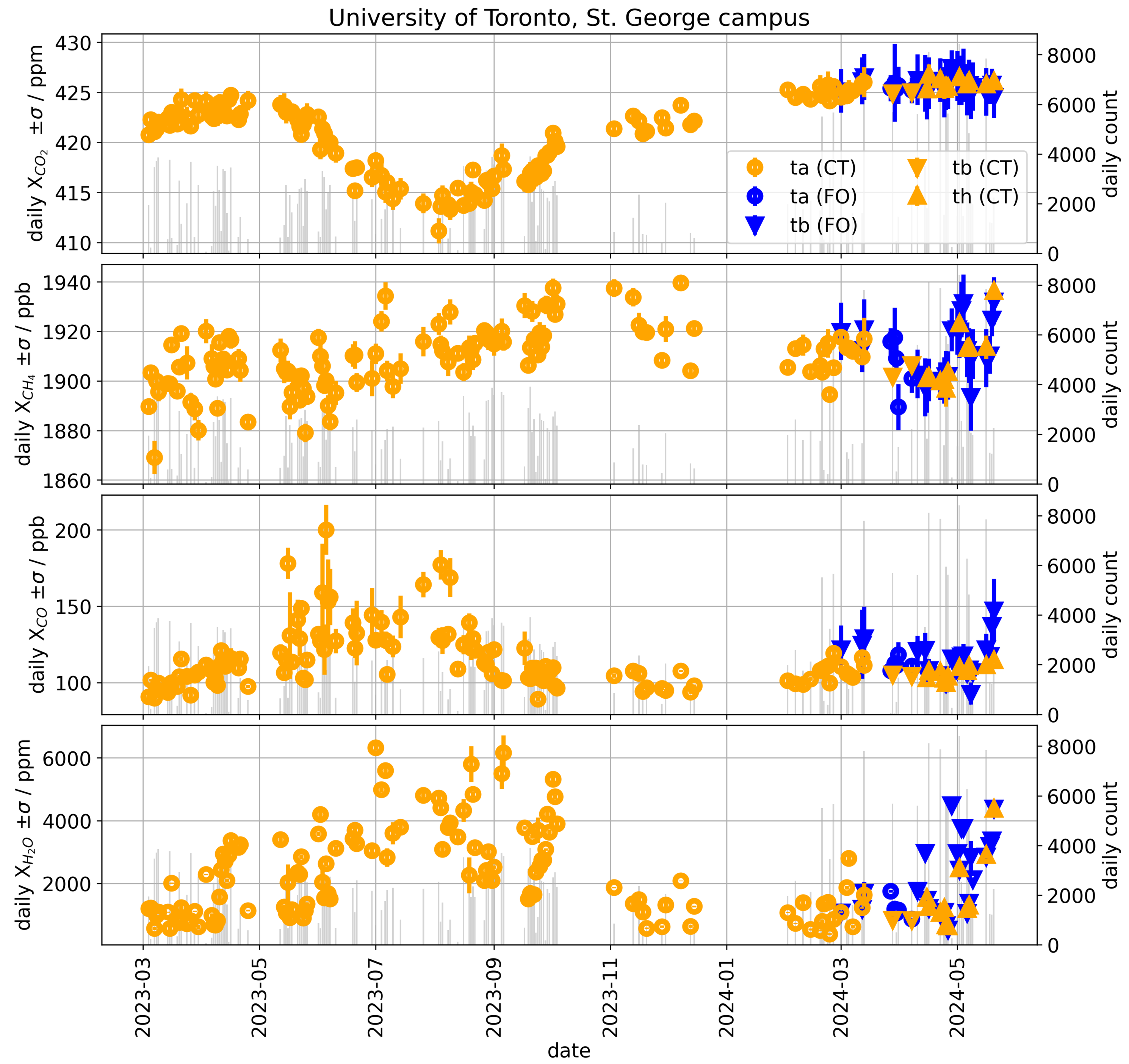

Fig. 7: Daily average ± standard deviation of GGG2020 retrievals from the site at the University in downtown Toronto, for 2023-03-01 through 2024-05-20.

- Daily averages for collocated measurements are generally in good agreement.
- The daily standard deviation in X_{CO_2}, X_{CH_4}, and X_{CO} are notably larger for the FO (fibre optic) measurements. We are still investigating the cause, but suspect this is due to issues with alignment.
- There are some days that we were able to observe with the FO tracking that we would not have wanted to risk with the CT due to rain or not having anyone on site (our enclosures are malfunctioning).
- The number of measurements on a given day are larger on most days with the FO tracking because we can start earlier, end later, and measure between clouds without risking the CamTracker wandering far in the wrong direction.

Discussion

- The fibre optic (FO) tracking method offers great potential for increasing the amount of data collected, while reducing or eliminating the need for regular maintenance.
- Our FO tracking setup still does not seem to perform as well as the CamTracker (CT) and we still need to find out why the quality of our results in Toronto do not match those of the observations in Wollongong. Hardware modifications have been shown to significantly impact the variance in the retrievals, so we remain hopeful that a solution exists that would allow FO tracking to provide full automation while yielding comparable data to CT.
- We have considered a number of hardware modifications in addition to the ones presented in these slides, including the following:
  - One can see in Fig. 5 and 6 that shortening the focal length of the telescope provides a substantial increase in the number of photons that reach the detector.
  - Changing the optical fibre. The current fibre is a 2 m long silica core fibre with a 550μm diameter. It significantly attenuates wavelengths in the 2nd channel (i.e., the CO channel), so the 5 m and 10 m fibres of this type did not provide enough spectral information to retrieve CO. A fluoride fibre would have less attenuation in the 2nd channel and have a flatter attenuation curve, but would also have more attenuation in the first channel than the current fibre.
  - Continuing to fine-tune the alignment and seeking fixed mounts or integrated optics with less freedom of movement for directing the light from the fibre into the spectrometer.
  - Possibly trying a different solar tracker, if it became apparent that the tracking remains an issue after other sources of instrument error are eliminated.

Acknowledgments

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References

[1] D. Griffith, N. Jones, N. Deutscher, C. Murphy, D. Pollard, and D. Noone. *Solar FTS measurements with a fibre optic coupled suntracker and EM27 FTS: Side by side comparisons with TCCON, EM27SUN, IRcube and Aircore.* presented at the TCCON annual meeting in Spa, Belgium. Available from David Griffith, griffith@uow.edu.au, on request., June 2023.