

Travels with an EM27, measurements of CO₂ and CH₄ below 45 degrees south.

David F. Pollard¹, Dan Smale¹, Hue Tran², Jamie McGaw², Frank Hase³, and Thomas Blumenstock³.

1. National Institute of Water and Atmospheric Research Ltd (NIWA), Lauder, New Zealand

2. Antarctica New Zealand, Christchurch, New Zealand

3. Karlsruhe Institute of Technology (KIT), Institute for Meteorology and Climate Research (IMK-ASF), Karlsruhe, Germany



Introduction

In 2004 NIWA's Lauder station became one of the first sites in the Total Carbon Column Observing Network (TCCON)(Wunch et al., 2011) and it currently maintains the longest TCCON data series in the Southern Hemisphere (Pollard et al., 2017).

The high precision TCCON retrievals of the column averaged, dry-air-mole fraction of several greenhouse gases, including CO₂, CH₄ and CO (denoted X_{gas}), have been essential for many satellite and model validation exercises as well as algorithm development. The demand for satellite validation data continues to grow as the number of satellites measuring atmospheric greenhouse gases increases.

The TCCON is, and will continue to be, the gold standard in ground based Near Infrared (NIR) Fourier Transform Spectrometry (FTS) remote sensing of greenhouse gases but does have some limitations. The instruments are large, expensive and require significant infrastructure. This means that the network is somewhat sparse, particularly in the Southern Hemisphere with no sites below 45 degrees South.

The low resolution, portable Bruker EM27/SUN spectrometer can measure X_{CO₂} and X_{CH₄} with a similar precision to TCCON (Gisi et al., 2012) and X_{CO} at nearly the same precision (Hase et al., 2016). A network like the TCCON is being developed based around the EM27/SUN, known as the Collaborative Carbon Column Observing Network (COCCON).

In this work we describe the deployment of an EM27/SUN to the Lauder TCCON site and then to the Arrival Heights atmospheric laboratory on Ross Island, Antarctica. An initial deployment for 2 weeks was carried out in February 2016 with a further deployment from November 2019 to March 2020 capturing an entire Austral summer season.

Data Processing

TCCON data are processed and retrieved using a standardised suite of software known as GGG, currently at the 2014 version (Wunch et al., 2015). Prior data are generated from NCEP reanalysis for meteorological fields with the chemistry generated using a set of empirical functions that are optimised to fit observations from several different in situ sources as a function of latitude, longitude and season, as well as taking account of long-term variability. Measured surface pressure is taken from the NIWA climate station at Lauder.

The 2016 EM27 spectra were processed using the PROFFIT retrieval code (Hase et al., 2004), while for the most recent deployment, a more efficient variant, specifically developed for these low resolution instruments, PROFFAST was used (<https://www.imk-asf.kit.edu/english/3225.php>). TCCON and NCEP prior data were generated for both Lauder and Arrival Heights and measured surface pressure from the Lauder and Scott Base climate stations were used for the Lauder and Arrival Heights retrievals respectively, with appropriate corrections for the difference in altitude.

Time series of daily average data from both EM27 deployments as well as the corresponding Lauder TCCON data are shown to the right.

Data Availability

TCCON data are available from the TCCON archive (<https://tccodata.org/>).

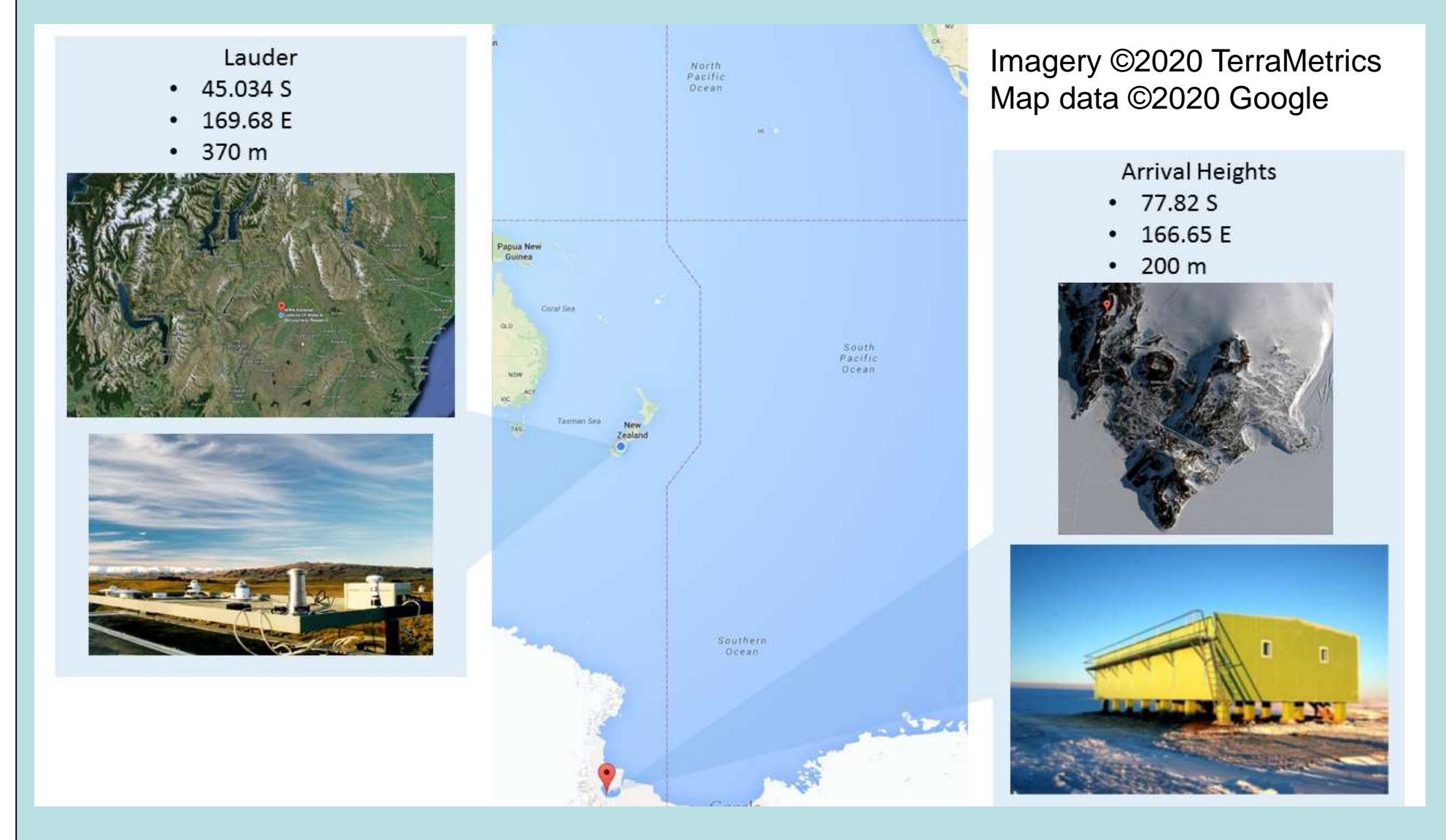
The EM27/COCCON data are available from the authors and will be made available on the COCCON centralised data server which is currently in development.

Map showing the locations of TCCON sites, Lauder is the southernmost site no stations at Southern latitudes greater than 45 ° (compared to 10 operational stations north of 45 °N)



Location of the NIWA's Lauder atmospheric observatory and TCCON site and the Arrival Heights laboratory, Ross Island, Antarctica.

The Arrival Heights laboratory is within an Antarctic Specially Protected Area (ASPA) which limits electromagnetic emissions and development above the skyline.



Instrument deployments

On two occasions the Karlsruhe Institute of Technology have loaned an EM27/SUN to NIWA in order to make comparisons alongside the Lauder TCCON site and at New Zealand's Arrival Heights laboratory on Ross Island, Antarctica.

In 2016, an instrument was taken to Arrival Heights for two weeks during February. During this period the instruments built in camera guided solar tracker was used and the instrument placed on the laboratory roof with a makeshift insulated enclosure on a day-to-day basis. The EM27 performed flawlessly in temperatures down to -10 °C and with windchill down to -30 °C.

For the 2019 deployment, the instrument was installed inside the laboratory with a small fraction of the solar beam from an existing solar tracker directed via the built-in camera tracker. This meant that the instrument could be left in place for an extended period and measurements were made from November 2019 to March 2020, over the full summer season. The instrument used for this deployment also had the additional detector installed as described by Hase et al., 2016, allowing retrievals of X_{CO} to be made.

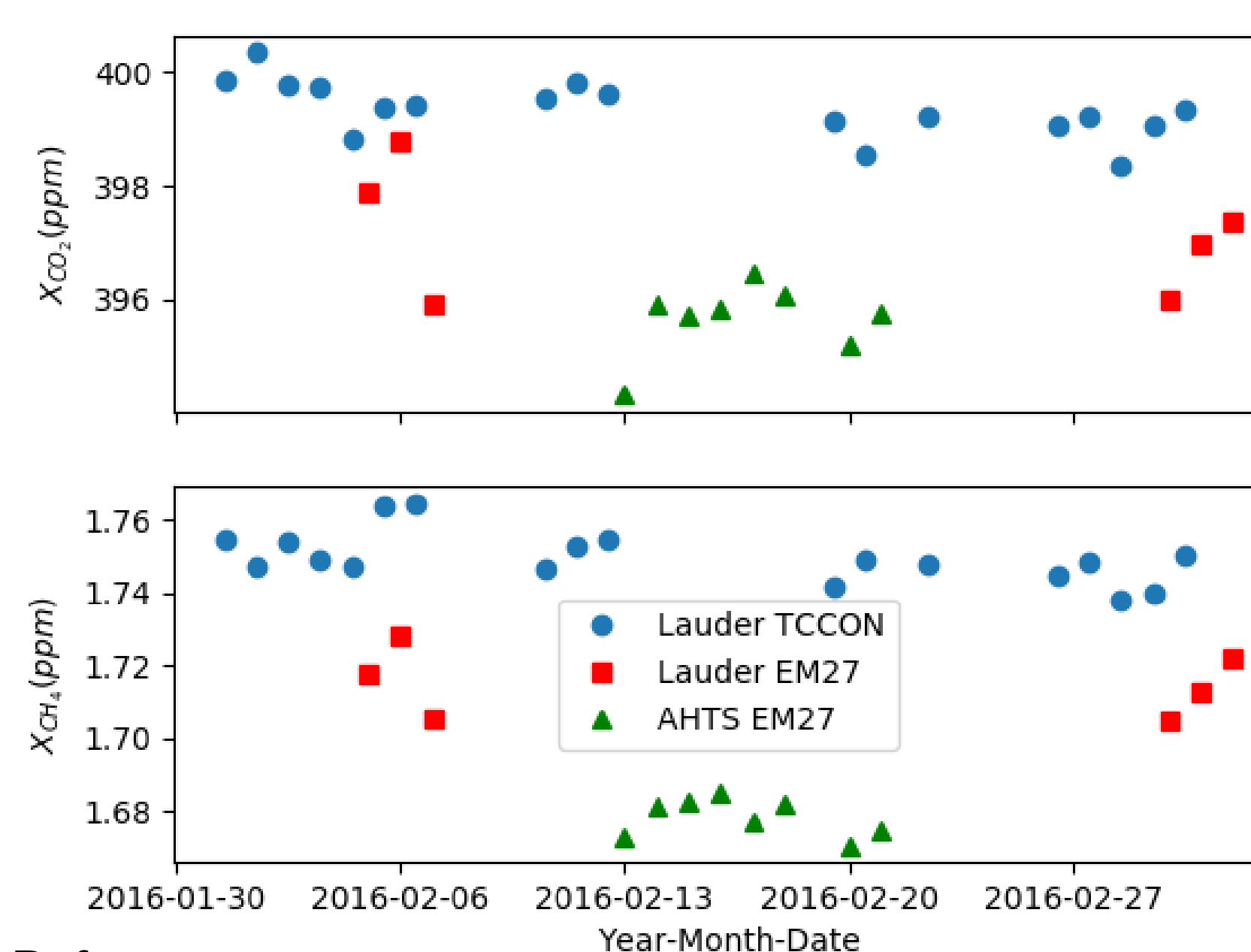
It is anticipated that deployment of this type will become a regular summer season activity at Arrival Heights.

2016

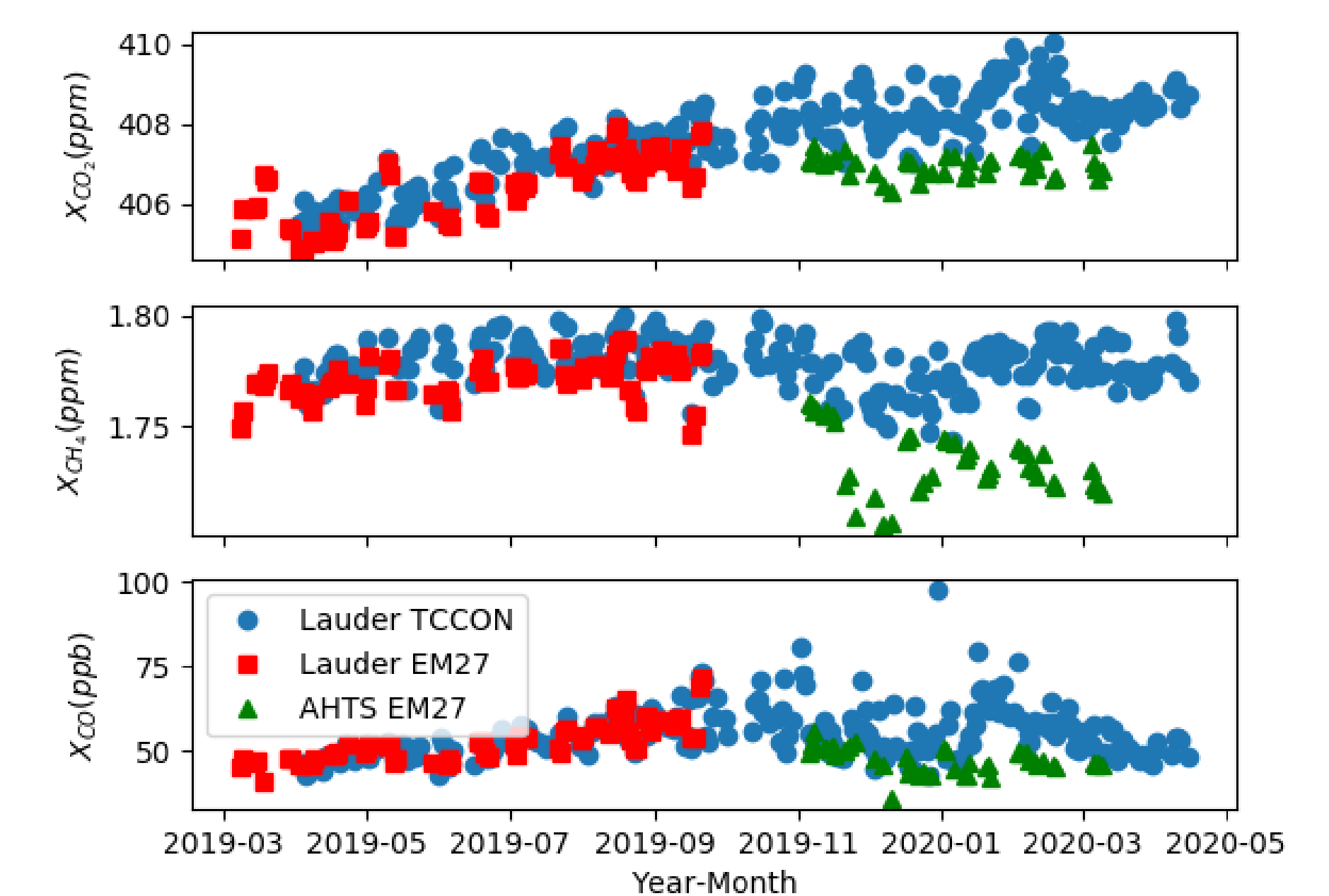
2019 - 2020



Daily mean X_{gas} retrievals



Daily mean X_{gas} retrievals



References

- Gisi, M., Hase, F., Dohe, S., Blumenstock, T., Simon, A., and Keens, A.: XCO₂-measurements with a tabletop FTS using solar absorption spectroscopy, Atmos. Meas. Tech., 5, 2969-2980, 2012.
- Hase, F., Frey, M., Kiel, M., Blumenstock, T., Harig, R., Keens, A., and Orphal, J.: Addition of a channel for XCO observations to a portable FTIR spectrometer for greenhouse gas measurements, Atmos. Meas. Tech., 9, 2303-2313, 2016.
- Hase, F., Hannigan, J. W., Coffey, M. T., Goldman, A., Höpfner, M., Jones, N. B., Rinsland, C. P., and Wood, S. W.: Intercomparison of retrieval codes used for the analysis of high-resolution, ground-based FTIR measurements, Journal of Quantitative Spectroscopy and Radiative Transfer, 87, 25-52, 2004.
- Pollard, D. F., Sherlock, V., Robinson, J., Deutscher, N. M., Connor, B., and Shiona, H.: The Total Carbon Column Observing Network site description for Lauder, New Zealand, Earth Syst. Sci. Data, 9, 977-992, 2017.
- Wunch, D., Toon, G., Sherlock, V., Deutscher, N. M., Liu, C., Feist, D. G., and Wennberg, P. O.: The Total Carbon Column Observing Network's GGG2014 Data Version, doi:10.14291/tcccon.ggg2014.documentation.R0/1221662, 2015. 2015.
- Wunch, D., Toon, G. C., Blavier, J. F. L., Washenfelder, R. A., Notholt, J., Connor, B. J., Griffith, D. W. T., Sherlock, V., and Wennberg, P. O.: The Total Carbon Column Observing Network, Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences, 369, 2087-2112, 2011.