FRM4GHG
Fiducial Reference Measurements for Greenhouse Gases

Deliverable D22 for CCN2
Campaign report

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1 DOCUMENT CHANGE RECORD

Issue	Date	Item	Comment
V0.0	2019-11-09	-	Initial version
V0.1	2019-11-11	-	Added updates from all project partners

2 ACCESS LIST

This document is the deliverable "D22: Campaign report" created for the project FRM4GHG CCN2 for submission to ESA. The document can be downloaded from the project webpage http://frm4ghg.aeronomie.be.

3 PURPOSE

This document provides an overview of the campaign activities in year 2019.

4 DOCUMENT STRUCTURE

Section 5. Campaign report
Section 6. Reference documents

5 CAMPAIGN REPORT

All instruments were operational during CCN2, covering the measurement period March – October 2019.

The TCCON instrument:

The TCCON instrument (Kivi and Heikkinen, 2016) alignment was performed prior to the start of the 3rd year of the project. FTS settings were similar to the 2018 operation to minimize InGaAs detector non-linearity effect, which was observed for 2017 and later the 2017 data were postprocessed. Regular cell measurements were performed to monitor the instrumental behavior, no data quality deviations were detected by the measurements. The instrument has been stable through 3 years of measurements.

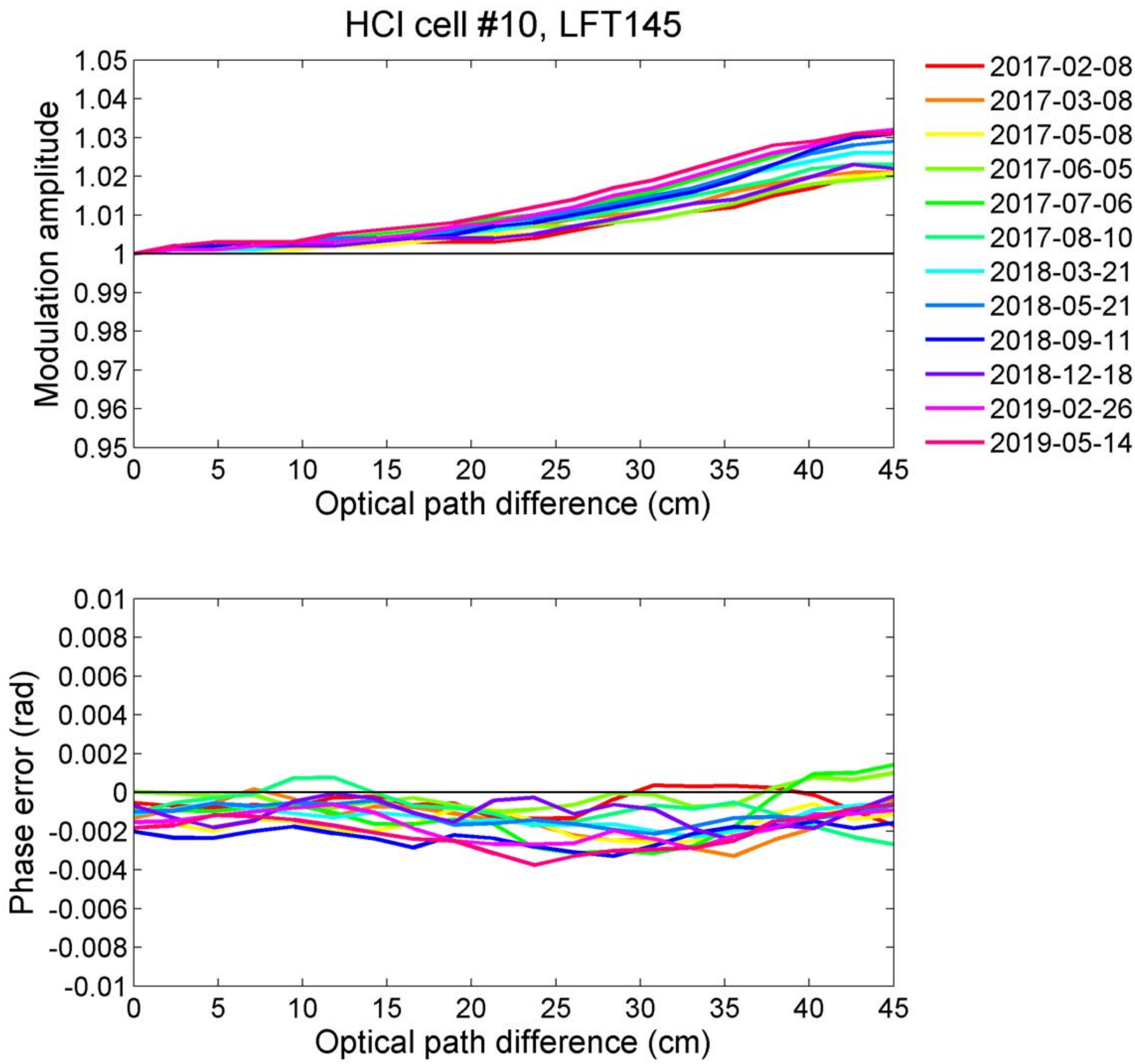

Figure 1: Time series of measurements of modulation efficiency: amplitude (upper panel) and phase errors (lower panel) are shown as a function of optical path difference.

Vertex 70:

The operation of the Vertex 70 instrument was continued. The cold filter has been removed in Bremen from the InSb detector in August, the detector without the cold filter has been reinstalled in Sodankyla on Sep 9th, 2018. It is now possible to measure in a wider wave-number region to retrieve additionally other trace gases like HCHO. To improve the signal to noise ratio in specified regions, two filters have been installed to the internal filter wheel before the start of the measurement season 2019. The automatic measurement procedure has been modified on March 6th

2019 to run alternating InGaAs measurements and InSb measurements using the two filters.

Table 1: Different measurement setups for the Vertex 70

Measurement No.	Detector	Filter No.	Wave-number start	Wave-number end	Scans coadded
0	InGaAs	open	3800	11000	6
1	InSb	1	3950	5100	12
2	InSb	open	2000	11000	12
4	InSb	4	2400	3300	12

Within the current phase, the Vertex was operating without problematic issues or out-times. The retrieval showed stable results compared to the other instruments. For other trace gases in the InSb region, retrievals are tested and compared. This work is ongoing and the results will be included in the final report of the deliverable D23 and D24 to be submitted to ESA by April 30, 2019.

EM27/SUN:

The KIT EM27/SUN instrument was remotely controlled after the shelter was put into service on September 25, 2018. The operation was continued as performed before. The instrument was moved from the ground to the roof of the FRM4GHG project container (2.8 meters higher). The ILS experiment was performed on March 4, 2019 and no obvious change of the ILS parameters were found. The measurements started on March 5, 2019 and stopped on November 4, 2019. In total, there were 71 observation days in 2019. The EM27/SUN spectrometer showed highly reliable performance and no instrument modifications were done.

(photo from Pauli Heikkinen)

LHR:

The LHR was reactivated on the 26/02/2019 after consultation and coordination with the BIRA team, as the LHR shares the solar tracker with the Vertex instrument. Except for a chiller that appeared not to have survived the winter, the switch on was successful. The level of laser signals were found to be similar to that of November 2018, before instrument hibernation.
However, the level of heterodyne signal suffered a significant decrease compared to its November 2018 level. It was diagnosed to originate from a field of view (FoV) alteration and misalignments, currently unexplained. A remote alignment was performed with the local support from FMI. Issues with FoV instabilities with a period of 400s (period of detector change within the Vertex) were subsequently observed. These FoV instabilities that appeared when the two detector arrangement was implemented within the Vertex seriously affected the whole 2019 campaign, despite mitigation measures.
As a remedy, a LHR upgrade visit was organized between 27 May 2019 and 07 June 2019. The following activities were conducted:

- Replacement of solar optical arm with improved alignment control
- Installation of a new detector and mounting
- Optimization of amplification chain
- Global instrument re-alignment

Upon departure from Sodankyla, the instrument SNR were improved up to 180 for the CO_2/H_2O channel, and 250 for the CH_4 channel. The difference in raw spectra is shown in Figure below.

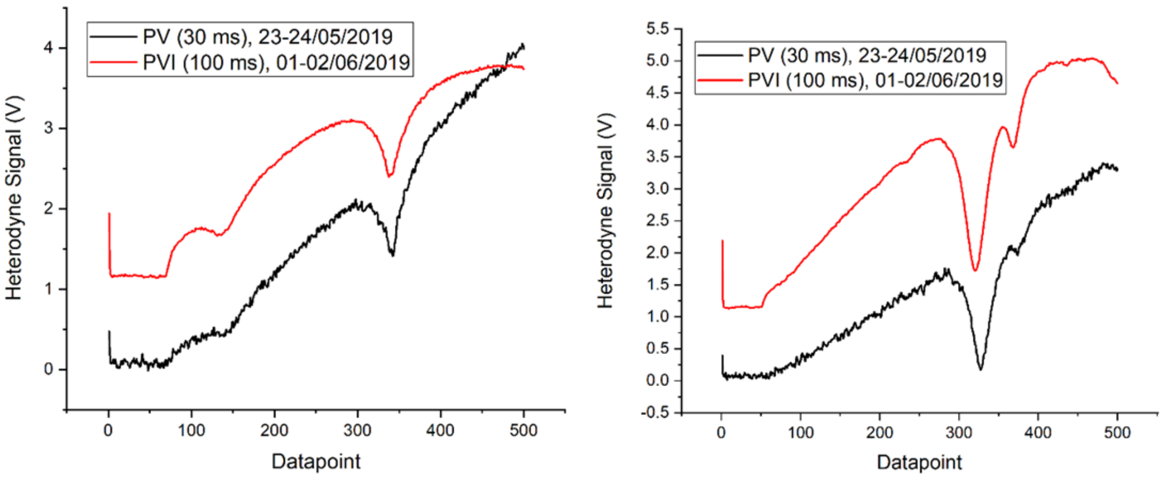

Figure 2: Raw spectra showing the effect of the improvement implemented in June 2019. Left, CO_2 and H_2O channel, right CH_4 channel. The red line indicates the improved measurements.

The instrument was then operated remotely with the novel configuration. However, the FoV instabilities were still affecting the signal and ~70% of our spectra shows traces of FoV alteration due to solar tracker motion.
A second visit to Sodankyla was made the week of September the 2nd. During this visit a quarter waveplate was added to the CO_2 channel to suppress optical standing waves (fringing) observed on the signal.
Measurements continued whenever possible until the first week of November 2019. The FoV instabilities and the installation of a new detector were found to require a significant update of the L0 to L1 processor. The processor update is planned to allow for release of a first data batch on 15

of January 2020. Depending on resource availability, incremental improvements are planned up to June 2020.

IR Cube:

Wollongong Campaign: 17 January to 23 August 2019

The IRCube was transported at the end of the 2018 campaign from Finland to Wollongong/Australia. Since the shipment arrived at the height of the Australian summer holiday season, the installation of the instrument at Wollongong was delayed for a few weeks. The spectrometer was setup in the Wollongong high resolution spectroscopy lab next to the TCCON HR125 spectrometer in mid-January. The solar tracker with fibre-optic coupling was mounted on the roof of the building housing the lab (approximately 5 metres above the IRCube). Once the IRCube optical bench was established, ILS measurements were taken using a lamp as per the usual practise during the FRM4GHG campaign. From mid-January to early February a number of sensitivity test were run (optical bench iris aperture, spectrometer field stop and FO rotation). Normal collection of spectra commenced after this, with the IRCube running in "measurement mode" from February 18th. The system ran well from February through to packup for the Darwin campaign (23 August). There were a total of 165 measurement days, and 56,000 spectra recorded.

Darwin Campaign, 12th September to 31th December 2019

The IRCube was shipped to Darwin and installed there on September 12th 2019. After ILS lamp measurements were taken, the system began data collection. Since the start of the Darwin campaign the IRCube has run without issues and attests to the reliability of the hardware and software. Data has been collected on 52 measurement days so far, but the number of good spectra is not yet known until post processing of the spectra has been completed. Figure 1 below shows the IRCube tracker installed on the roof of the Darwin shipping container that houses the IRCube and HR125 spectrometers.

The EM27/SUN had been part of another campaign in New Zealand and was shipped directly to Darwin at the same time as the IRCube. However the EM27/SUN had a failure on the CAMTracker system (the camera itself stopped working). This requires a new camera so the spectrometer has been shipped back to Wollongong for repair. Planned AirCore launches for the 2019 period have been delayed (due to operational issues with air traffic control in Australia) until 2020. While this is a setback for this particular part of the Darwin campaign, the main purpose of this exercise is to test the bias in the IRCube against the TCCON instrument which can still be achieved.

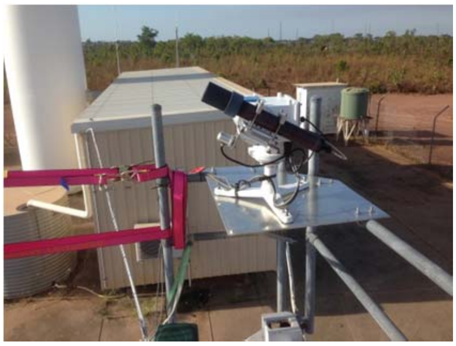

Figure 3: The IRcube solar tracker installed on the roof of the Darwin shipping container.

AirCore:

A total of 6 AirCore flights were successfully performed in 2019. Table 2 provides a summary of the AirCore flights during CCN2. Figure 4-6 present measured vertical profiles of CO_2, CH_4 and CO mole fractions. The mole fraction measurements are traceable to the WMO scales of 2007 for CO_2, 2004A for CH_4 and 2004A for CO, respectively.

Two potential issues are associated with the CO measurements:

First, the CO mole fractions in the calibration cylinders tend to drift over time, which has been assessed within ICOS to be ~+1ppb/year. The potential drift due to possible cylinder drift has not been corrected.

Second, a bias of 5-10 ppb for the stratospheric parts (13 – 17 km) of this AirCore has been found when compared to other AirCores during the RINGO 2018 campaign; however, no significant bias of CO for the tropospheric profiles was found. A plan is currently to compare the AirCore flown during CCN2 with a second AirCore from the University of Groningen to assess the possibility of a 5-10 ppb bias of CO in the stratosphere.

Table 2: AirCore flight dates during CCN2.

Flight #	Date
1	20190410
2	20190628
3	20190724
4	20190801
5	20190828
6	20190909

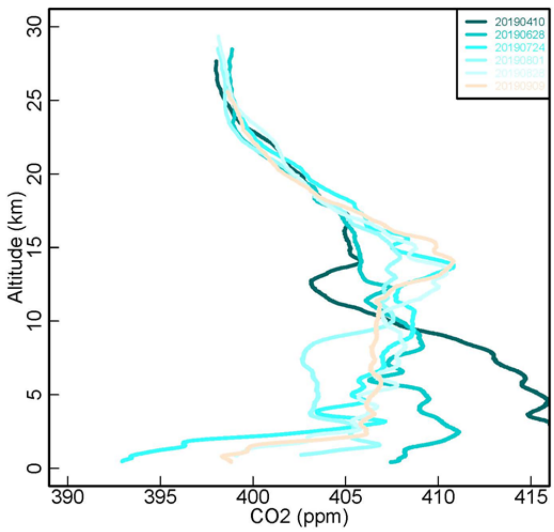

Figure 4: CO_2 profiles measured by AirCore.

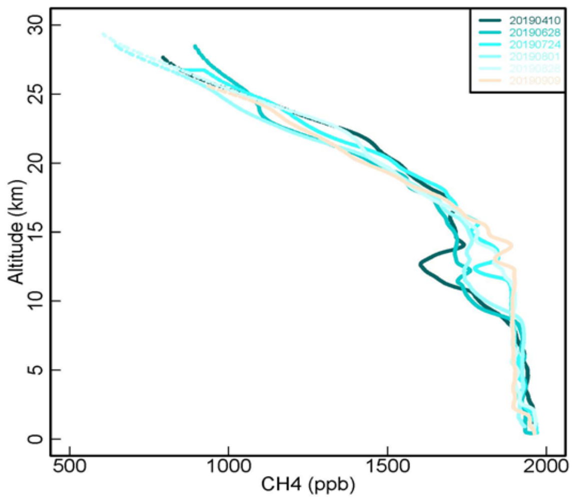

Figure 5: CH_4 profiles measured by AirCore.

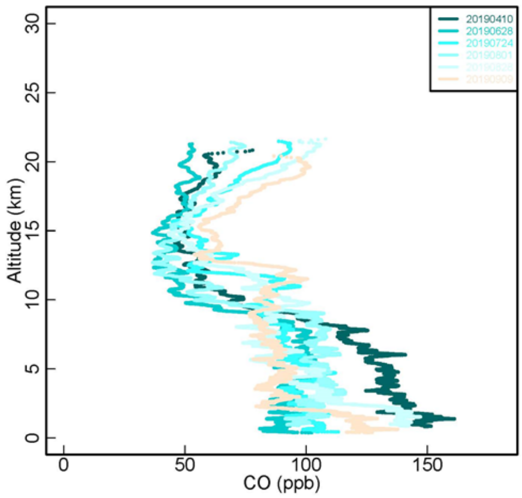

Figure 6: CO profiles measured by AirCore.

6 REFERENCES

Kivi, R. and Heikkinen, P.: Fourier transform spectrometer measurements of column CO_2 at Sodankylä, Finland, Geosci. Instrum. Method. Data Syst., 5, 271-279, https://doi.org/10.5194/gi-5-271-2016, 2016.