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Update on AirCore flights at Sodankylä

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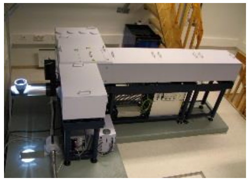
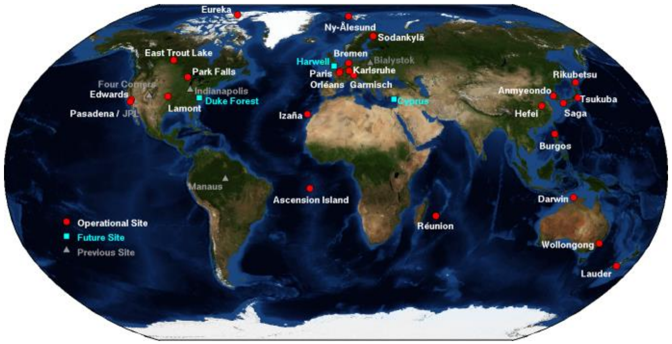
Sodankylä site is operated by the Finnish Meteorological Institute. Location of the site is 67.4 °N, 26.6 °E, 179 m altitude. Networks: GRUAN, TCCON, NDACC, ICOS, AERONET, GAW, EUBREWNET, SAOZ, CFH, O3sondes, etc.

Sodankylä FTS

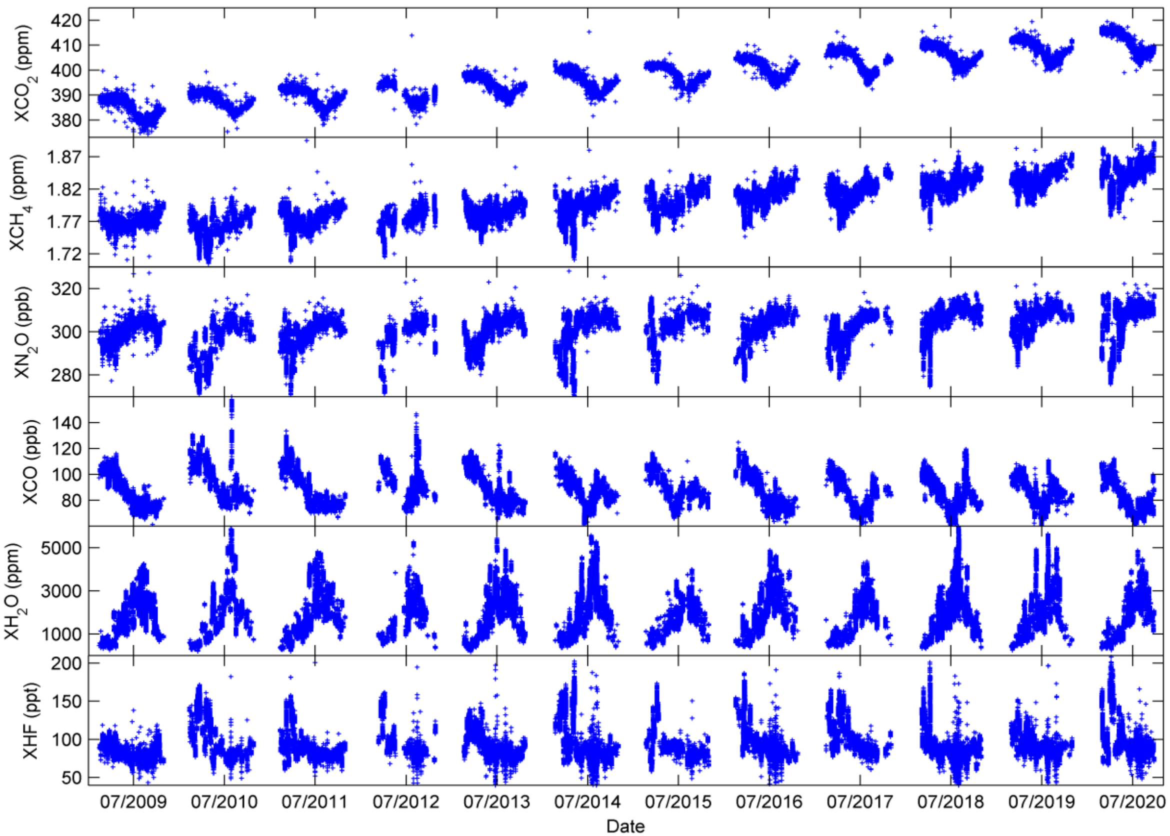


Bruker *IFS 125HR* with *A547N* solar tracker.
Detectors:
RT-InGaAs: *12800 - 4000 cm^{-1}*
RT-Si: *25000 - 9000 cm^{-1}*
LN-InSb: *10000 - 1850 cm^{-1}*

In operation since FEB-2009, participates in TCCON and NDACC

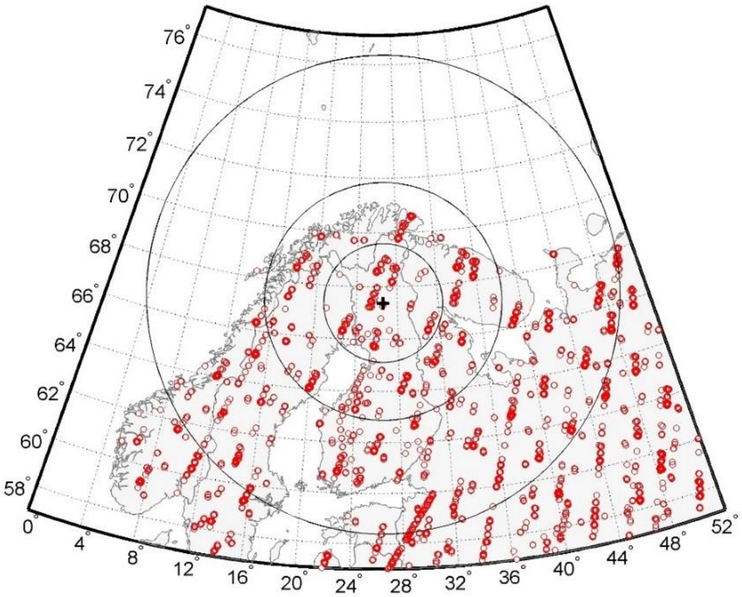


Map of the TCCON sites



Column-averaged dry air mole fractions at Sodankylä since 2009. Carbon dioxide has increased by 2.3 +/- 0.2 ppm per year and methane by 7.0 +/- 0.5 ppb per year. Updated September 24, 2020 from Kivi and Heikkinen (2016).

GOSAT/FTS



GOSAT data points near Sodankylä. Three different co-location radii have been indicated; 250 km, 500 km and 1000 km.

CO_2

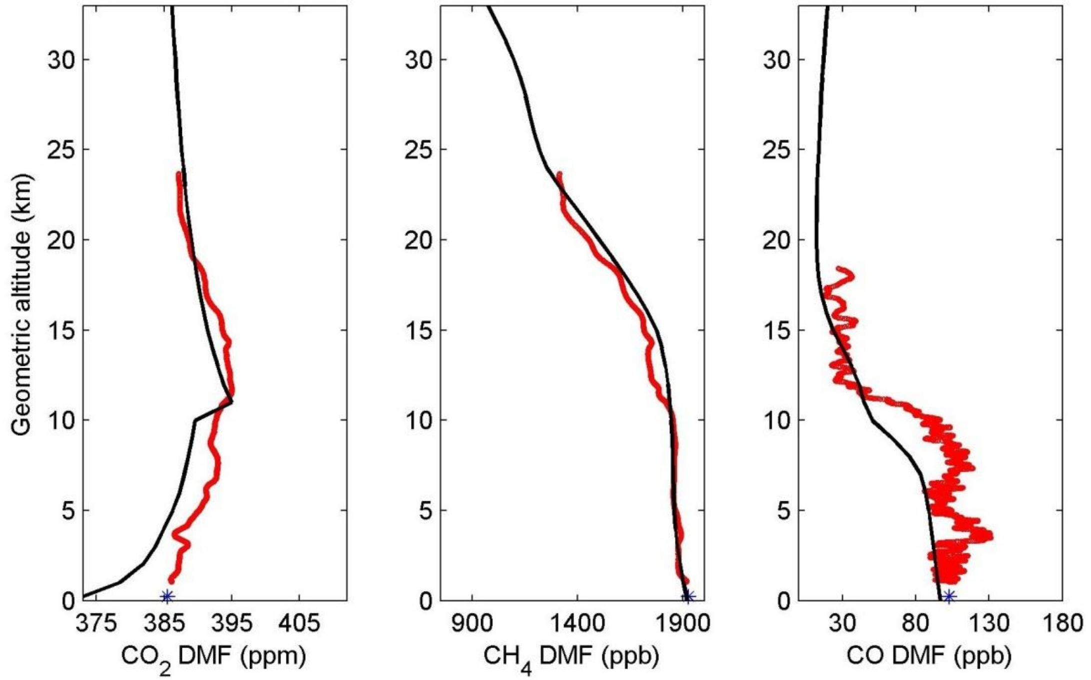
Spatial coverage	1000 km radius	500 km radius	250 km radius
Time window	± 3 h	± 2 h	± 1 h
Number of coincident measurements	3697	1584	513
Absolute difference, GOSAT – Sodankylä FTS [ppm]:			
Mean	0.3	0.4	0.6
StdDev	2.66	2.5	2.2
StdErr	0.04	0.1	0.1
Relative difference, (GOSAT – Sodankylä FTS) / Sodankylä FTS [%]:			
Mean	0.08	0.09	0.16
StdDev	0.67	0.63	0.56
StdErr	0.01	0.02	0.02

CH_4

Spatial coverage	1000 km radius	500 km radius	250 km radius
Time window	± 3 h	± 2 h	± 1 h
Number of coincident measurements	3706	1593	519
Absolute difference, GOSAT – Sodankylä FTS [ppm]:			
Mean	0.0033	0.0011	0.0033
StdDev	0.0165	0.0149	0.0128
StdErr	0.0003	0.0004	0.0006
Relative difference, (GOSAT – Sodankylä FTS) / Sodankylä FTS [%]:			
Mean	0.19	0.06	0.18
StdDev	0.92	0.83	0.71
StdErr	0.02	0.02	0.03

Sodankylä FTS comparisons with GOSAT observations for CO_2 (upper panel) and CH_4 (lower panel).

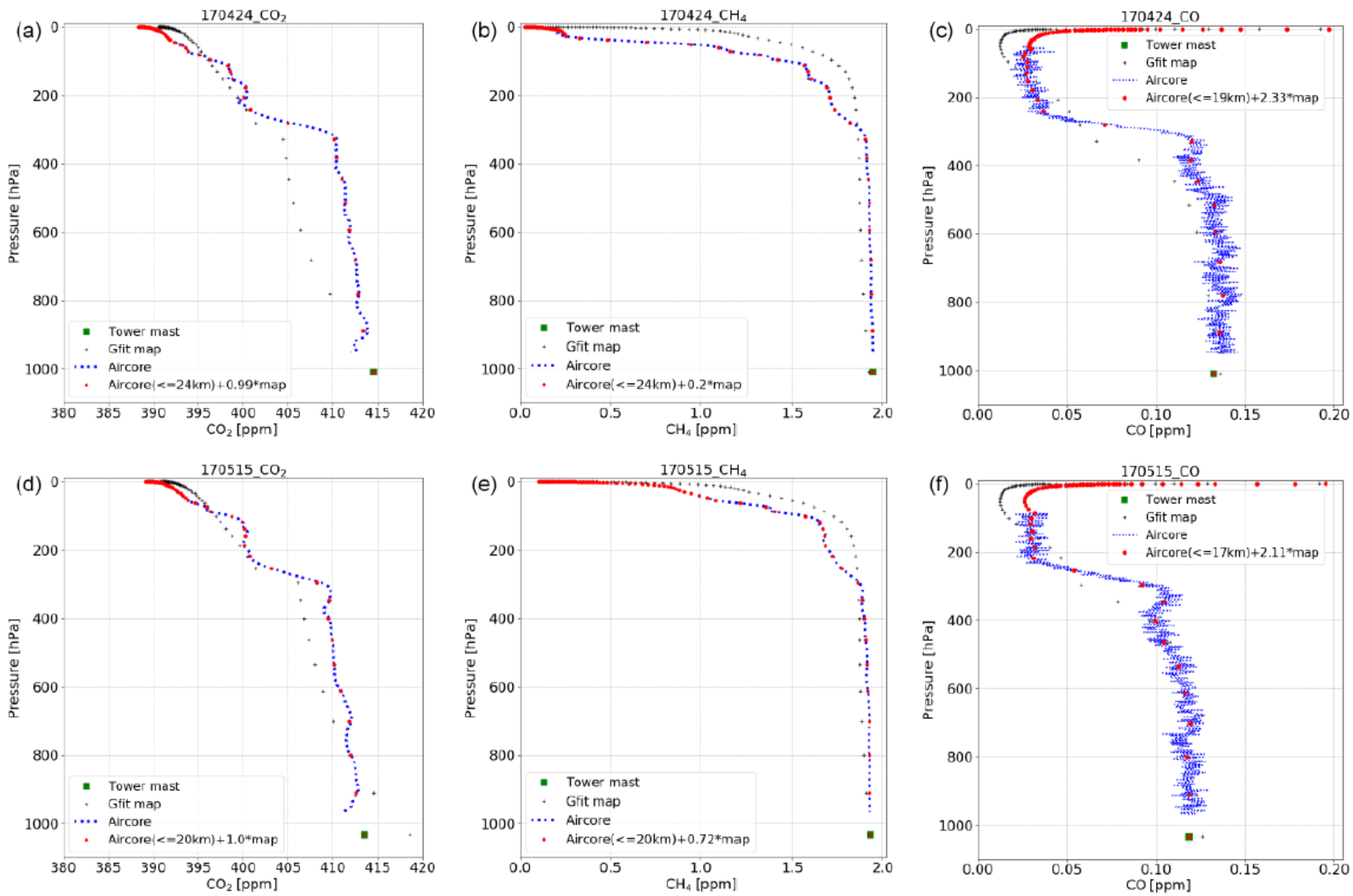
AirCore



Balloon and drone borne AirCore instruments.

- At Sodankylä we have performed AirCore observations during all seasons. An example of AirCore profiles of CO_2, CH_4 and CO is shown above. AirCore profiles are in red and the TCCON a priori profiles in black. Blue star corresponds to tower measurements at Sodankylä. Recent measurements were made within RINGO and FRM4GHG projects.
- The AirCore system at Sodankylä is built as a stainless steel tubing of about 100 m long, consisting of ~40 m of ¼” and ~60 m of 1/8” tube. This configuration makes it possible to measure profiles with vertical resolution of 5 mb in the stratosphere and 15 mb in the troposphere.
- The system also involves a data acquisition unit to store pressure and temperature during an AirCore flight, a RS92 radiosonde and a positioning device.
- AirCore is lifted to the stratosphere using a meteorological balloon. Shortly after landing we have analysed the sample using a Picarro G2401 gas analyser. Recently we have flown also a drone borne AirCore instrument.

AirCore



An example of AirCore profiles measured during the FRM4GHG campaign in Sodankylä, From Sha et al., Atmos. Meas. Tech., 13, 4791–4839, 2020.

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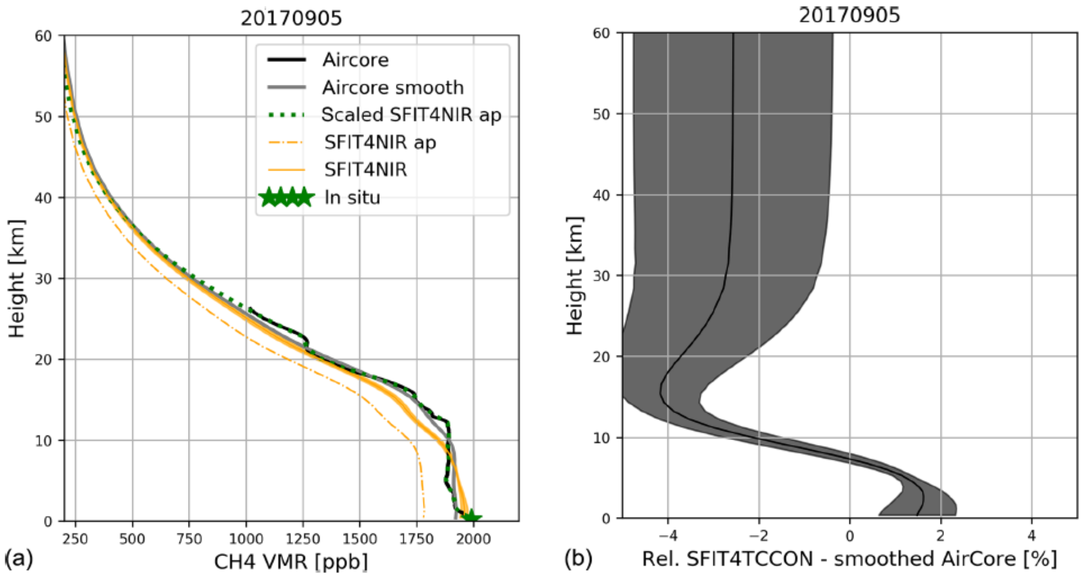
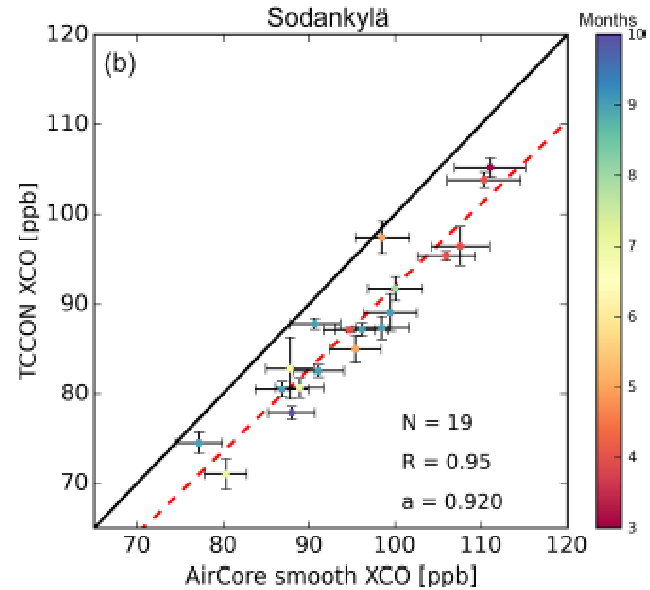
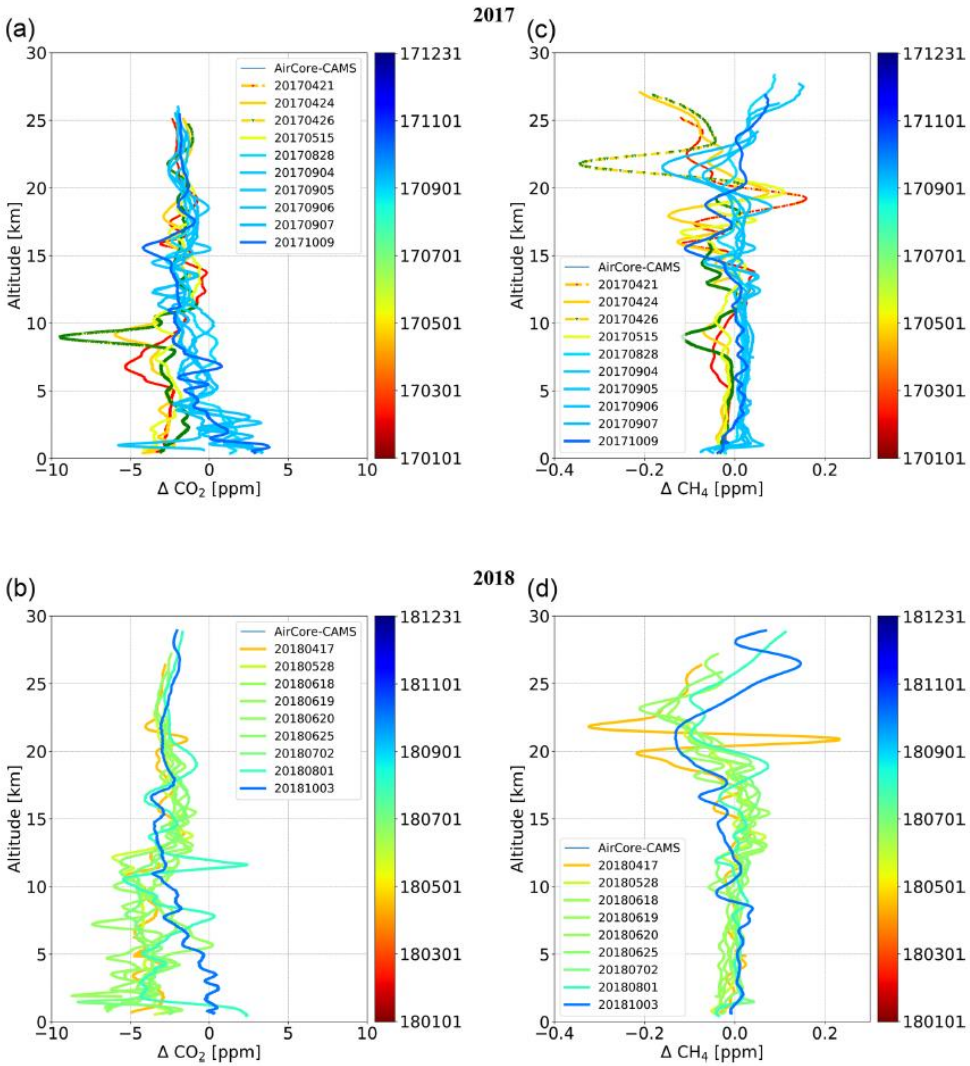
AirCore



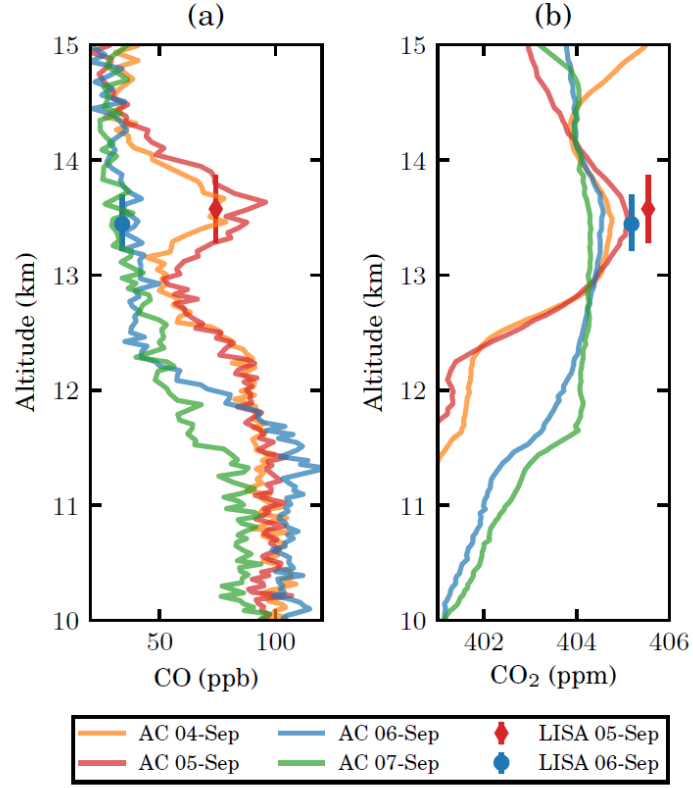


(a) The CH4 profile from the AirCore measurement (solid black line) on 5 September 2017, together with the SFIT4NIR a priori (dash-dotted orange line) and retrieved (solid orange line) profiles. The AirCore measurement is extrapolated with the surface in situ measurements (green star) and the scaled SFIT4NIR a priori profile (dotted green line). The grey line is the smoothed AirCore profile. (b) The mean (solid black line) and the stand deviation (shading) of the relative difference between the co-located SFIT4NIR-retrieved profiles and the smoothed AirCore measurements ((SFIT4NIR–AirCore)/AirCore100 %). From Zhou et al., Atmos. Meas. Tech., 12, 6125–6141, 2019
Right panel: The scatter plots between the TCCON XCO retrievals and the smoothed AirCore XCO measurements at Sodankylä The black line is the one-to-one line, and the red dashed line is the linear fitting (forced to cross the zero). The data are colored their measurement times in each month. The error bar of the TCCON XCO retrieval is the daily SD, representing the random uncertainty of the TCCON data, while the error bar of the AirCore data is the total uncertainty for each measurement. N is the number of co-located measurements, R is the correlation coefficient and a is the slope of the fitting line. Zhou et al., Atmos. Meas. Tech., 12, 5979–5995, 2019.

AirCore

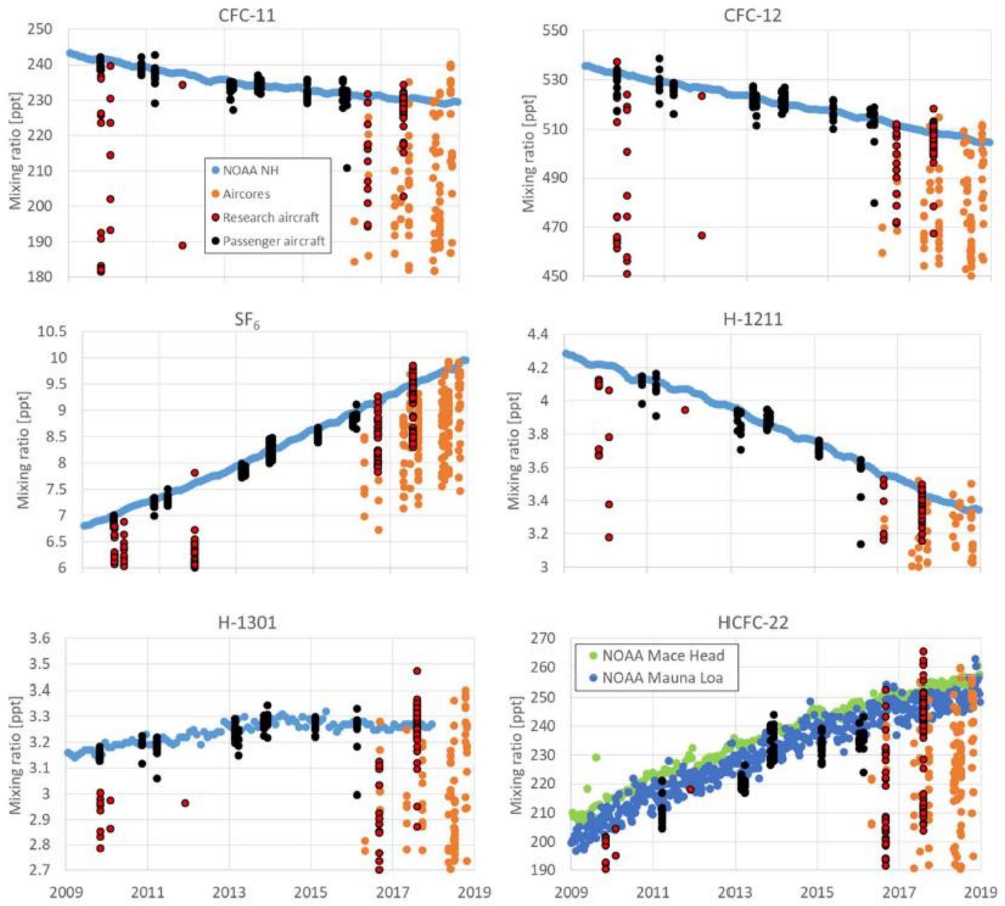


Differences between AirCore and CAMS (Copernicus Atmosphere Monitoring Service) for CO2 (a, b) and CH4 (c, d) profiles in 2017 and 2018. From Tu et al., Atmos. Meas. Tech., 13, 4751–4771, 2020.



The CO, (a), and CO2, (b), profiles from AirCore (lines, abbreviated as AC in the legend) and the LISA sampler (markers). The profiles are shown between 12 and 15 km altitude and are coloured by date. The LISA sampler vertical error bars represent the total vertical coverage of the sample, with the mean altitude as shown. From Hooghiem et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-65, 2020.

AirCore



Aircraft- and AirCore-based mixing ratios of six halogenated trace gases in the upper troposphere and stratosphere as compared to the NOAA/GMD ground-based northern hemispheric GGGRN time series (https://www.esrl.noaa.gov/gmd/, last access: 11 January 2020). Lower mixing ratios generally represent higher altitudes. For all gases except SF6, some higher-altitude data are not shown to better demonstrate the good comparability of near-tropopause data to the NOAA time series. From Laube et al., Atmos. Chem. Phys., 20, 9771–9782, 2020.

EM27/SUN

New EM27/SUN at Sodankylä: operational since early 2020

Summary

AirCore observations have been performed at the Sodankylä FTS site on regular basis. The AirCore in situ observations have been used to study accuracy of the remote sensing retrievals and to measure stratospheric trace gases. A new drone based AirCore instrument is under development. The goal is to combine balloon and drone-based measurements.

FTS measurements have been performed over a 12-year time period at Sodankylä. We observe a statistically significant increase of column amounts of carbon dioxide by 2.3 +/- 0.2 ppm per year and methane increase by 7.0 +/- 0.5 ppb per year.

GOSAT versus TCCON differences were calculated for 2009-2018. In case of CO_2 the relative difference between the two data sets has been 0.09 +/- 0.02 % (0.4 ppm) and in case of CH_4 the relative difference has been 0.06 +/- 0.02 % (0.001 ppm).

EM27/SUN, Vertex 70, IR Cube, LHR in 2017-2019 or 2017- early 2020 (EM27/SUN). New EM27/SUN operational since early 2020.

Future work:
SIF, involve drone borne measurements.

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