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# AirCore flights at Sodankylä

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# Location

Sodankylä site is operated by the Finnish Meteorological Institute Arctic Research Centre (FMI-ARC). Location of the site is 67.4 °N, 26.6 °E, 179 m above mean sea level; station's WMO number is 02836. Participates in GRUAN, TCCON, ICOS, GAW, NDACC, AERONET, EUBREWNET, etc.

GCOS Reference Upper-Air Network





## Observations at the meteorological observatory

- First thermo-/barometer based records in 1856
- Met station during the 1st IGY 1882/83
- Continuous weather records since 1908
- Radiosondes since 1949
- Solar radiation observations since 1957/58 (1st IPY)
- Radioactivity monitoring since 1963
- Air quality observations since 1970s
- Ozone sondes and Brewer 1988
- SAOZ since 1990
- First Lidar campaign in 1991/1992
- Stratospheric Aerosol sondes since 1994
- Frost Point Hygrometers since 1996
- RS92 since 2004, RS41 will start in April 2017
- Automated sonde launches since 2005, parallel manual launches
- TCCON FTS started in 2009
- AirCore since 2013
- FRM4GHG campaign 2017-2018
- CoMet campaign April-June 2018







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# Sodankylä FTS

Bruker *IFS 125HR* with *A547N*  
solar tracker.

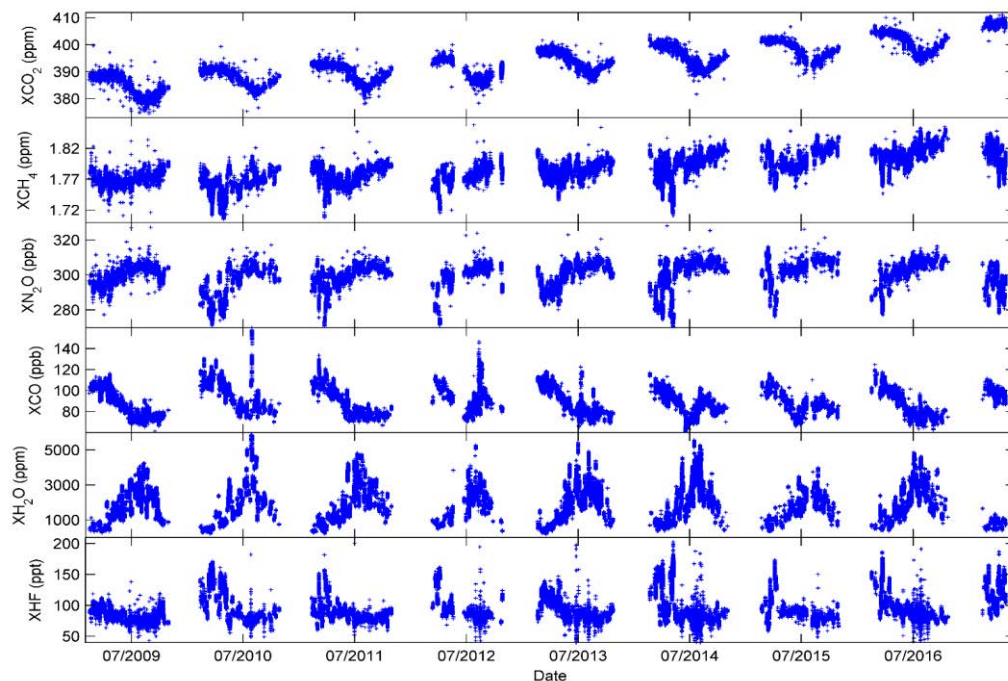
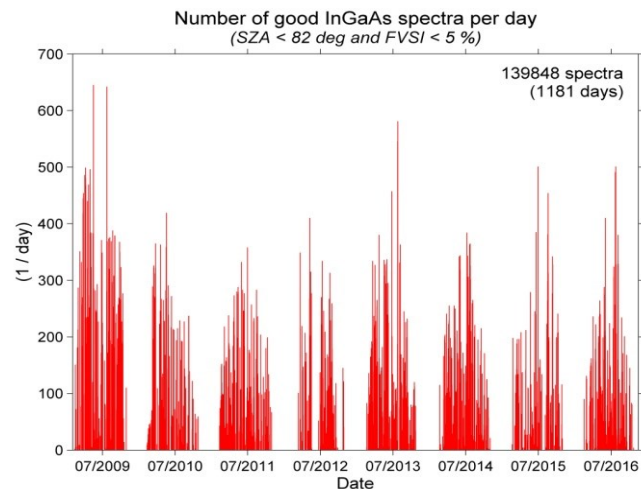
Detectors:

*RT-InGaAs*: 12800 - 4000  $\text{cm}^{-1}$

*RT-Si*: 25000 - 9000  $\text{cm}^{-1}$

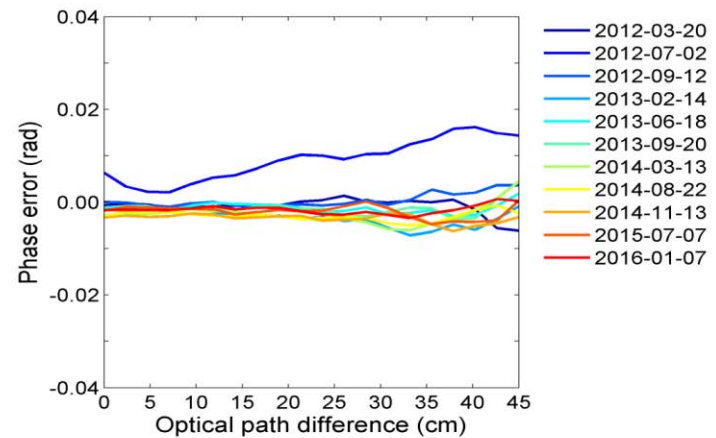
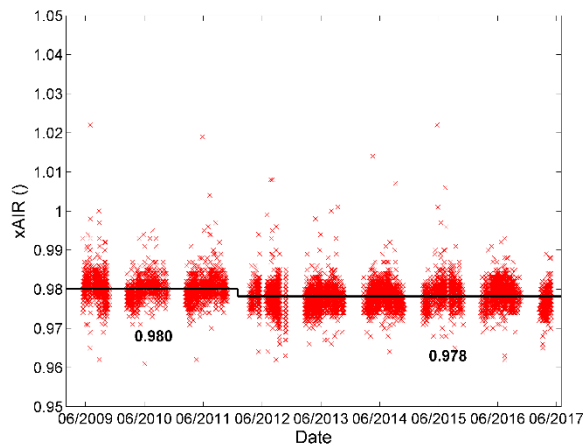
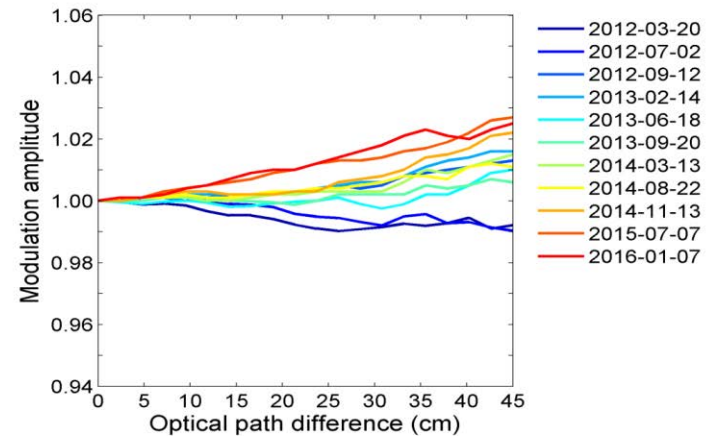
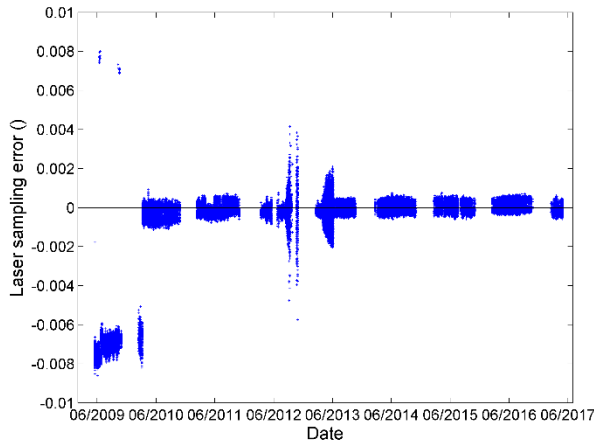
*LN-InSb*: 10000 - 1850  $\text{cm}^{-1}$

In operation since FEB-2009,  
participates in the TCCON network





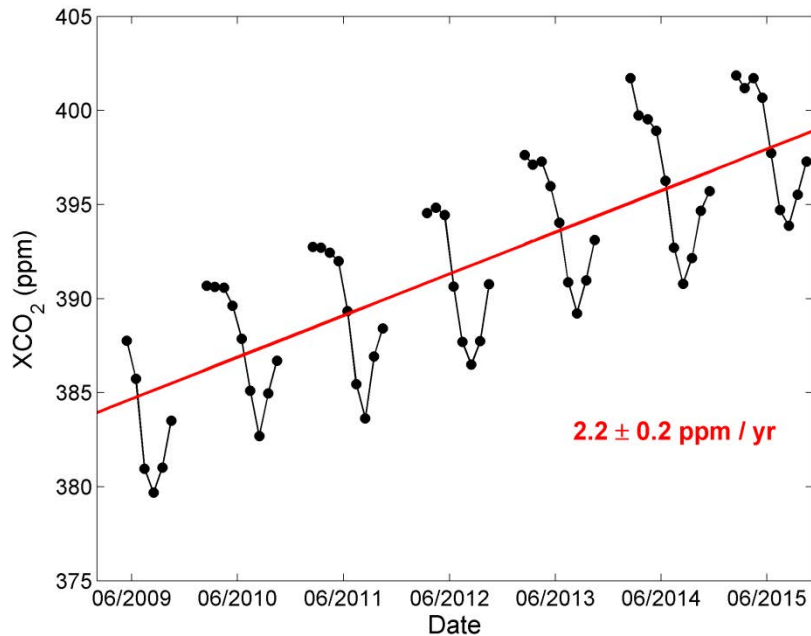
# Long term stability of the FTS



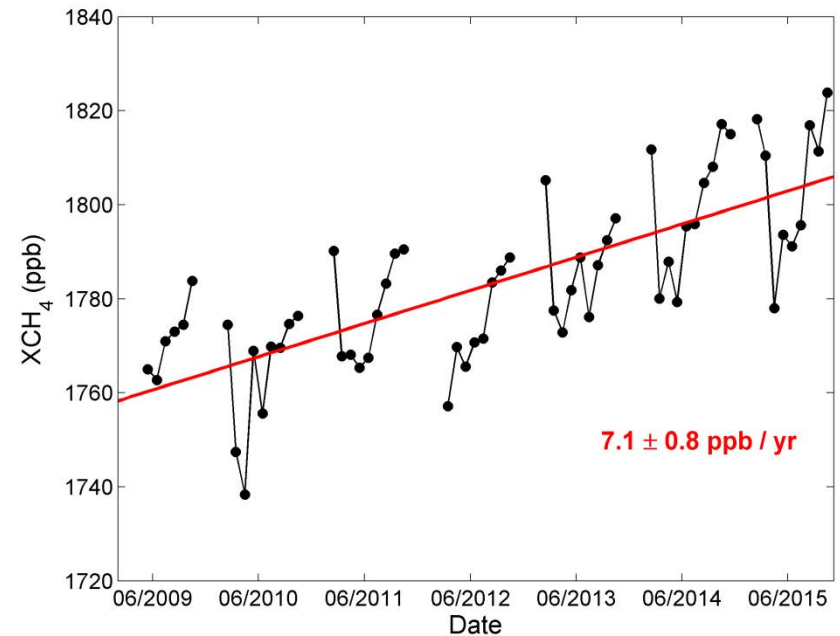
From left to right LSE, xAIR, ILS time series



xCO<sub>2</sub>



xCH<sub>4</sub>

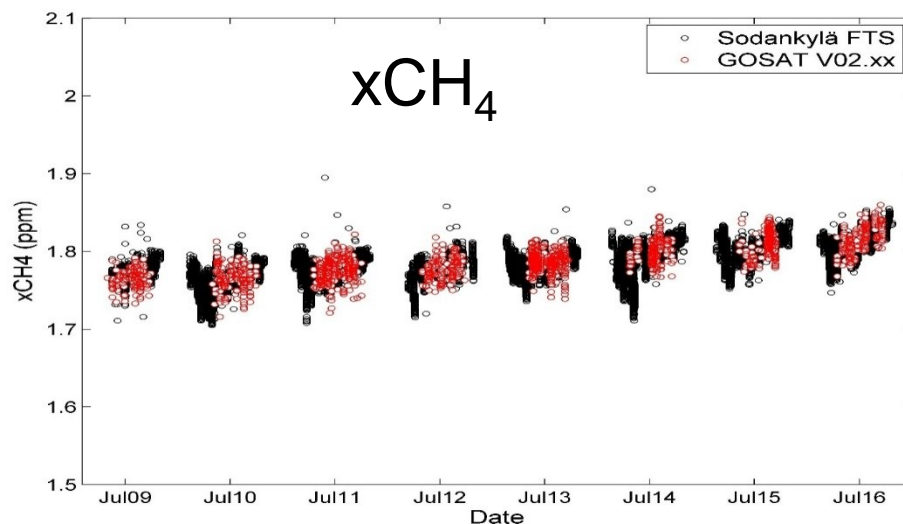
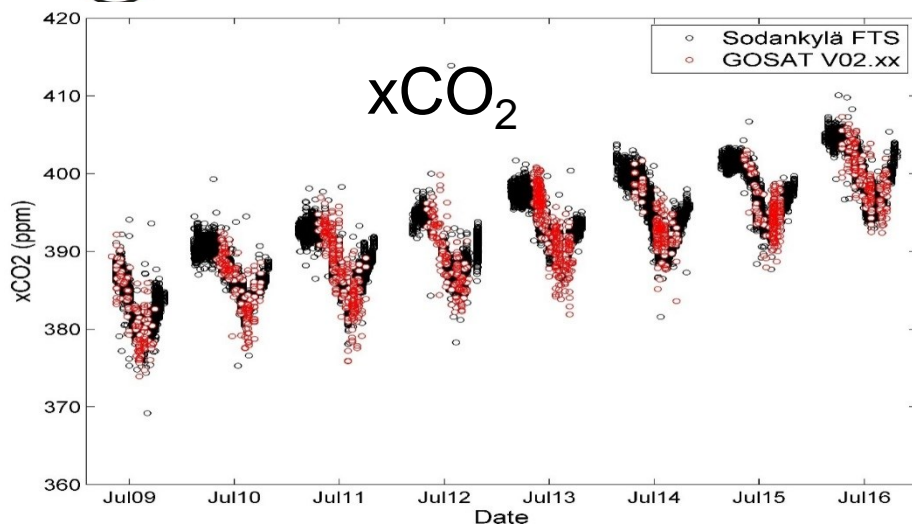


Observed trends of CO<sub>2</sub> and CH<sub>4</sub> (from Kivi, R. and Heikkinen, P.: Fourier transform spectrometer measurements of column CO<sub>2</sub> at Sodankylä, Finland, Geosci. Instrum. Method. Data Syst., 5, 271-279, doi:10.5194/gi-5-271-2016, 2016).



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# GOSAT vs. TCCON



Spatial coverage	1000 km radius	500 km radius	250 km radius
Time window	± 3 h	± 2 h	± 1 h
Number of coincident measurements	2492	1040	338
Absolute difference, GOSAT – Sodankylä FTS [ppm]:			
Mean	0.1	0.1	0.4
StdDev	2.5	2.4	2.2
StdErr	0.1	0.1	0.1
Relative difference, (GOSAT – Sodankylä FTS) / Sodankylä FTS [%]:			
Mean	0.02	0.04	0.09
StdDev	0.64	0.61	0.56
StdErr	0.01	0.02	0.03

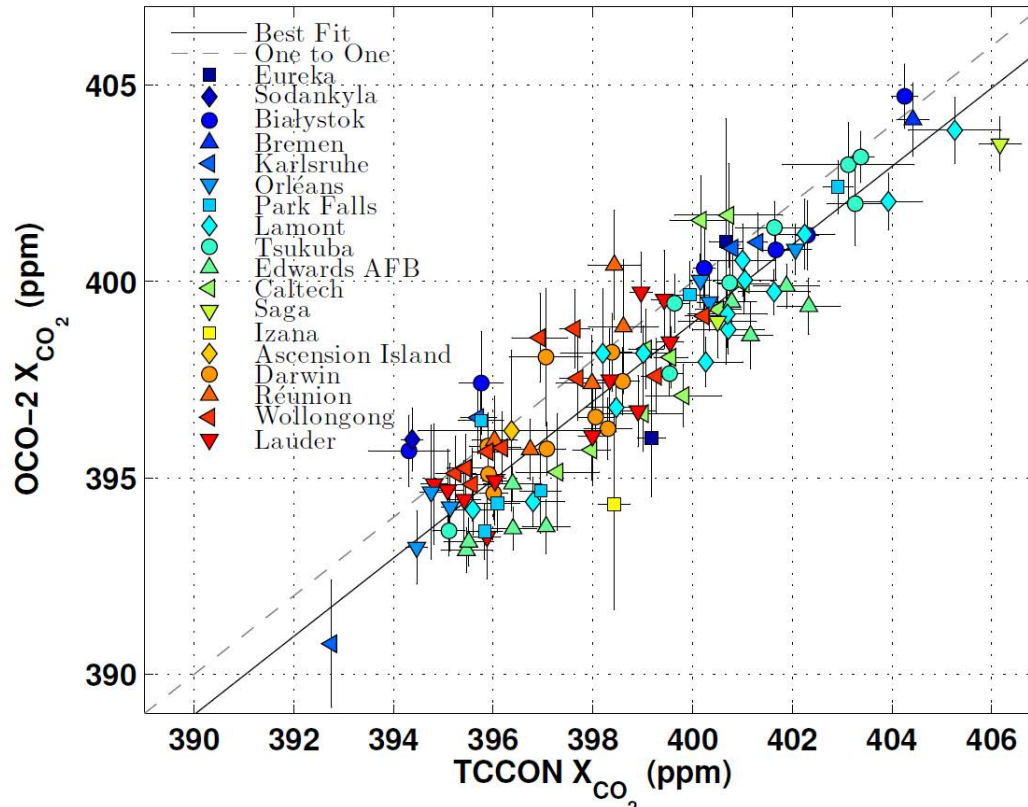
Spatial coverage	1000 km radius	500 km radius	250 km radius
Time window	± 3 h	± 2 h	± 1 h
Number of coincident measurements	2492	1040	338
Absolute difference, GOSAT – Sodankylä FTS [ppm]:			
Mean	0.0012	-0.0012	0.0002
StdDev	0.0155	0.0138	0.0116
StdErr	0.0003	0.0004	0.0006
Relative difference, (GOSAT – Sodankylä FTS) / Sodankylä FTS [%]:			
Mean	0.07	-0.07	0.01
StdDev	0.87	0.77	0.65
StdErr	0.02	0.02	0.04

CO<sub>2</sub> and CH<sub>4</sub> comparisons during 2009– 2016 using TCCON FTS and TANSO-FTS L2 CO<sub>2</sub>/CH<sub>4</sub>



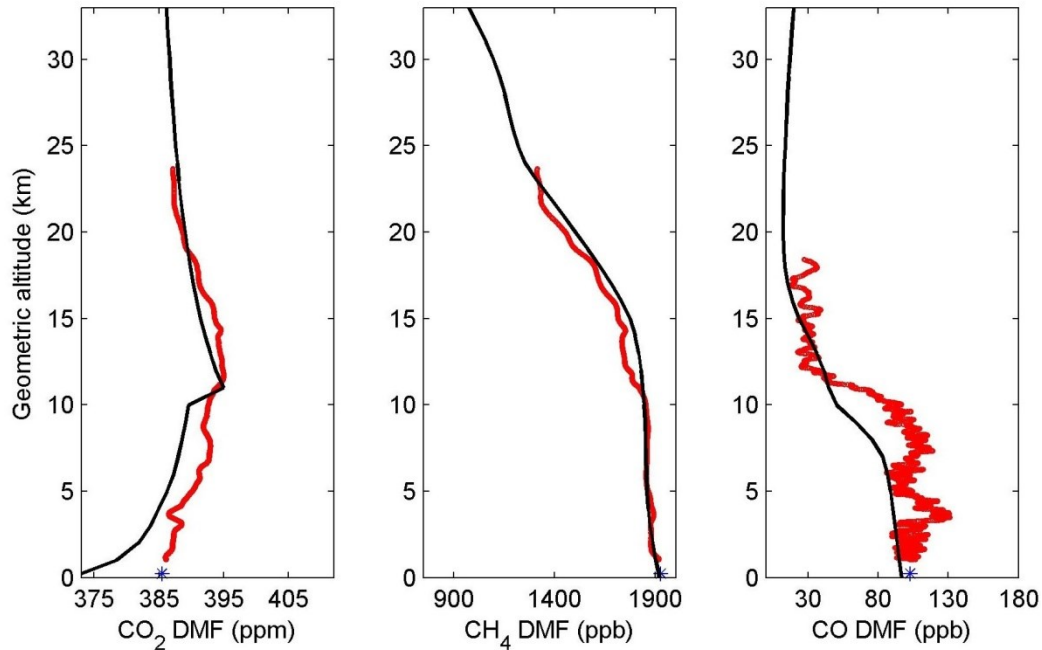


## OCO-2 vs TCCON $x\text{CO}_2$

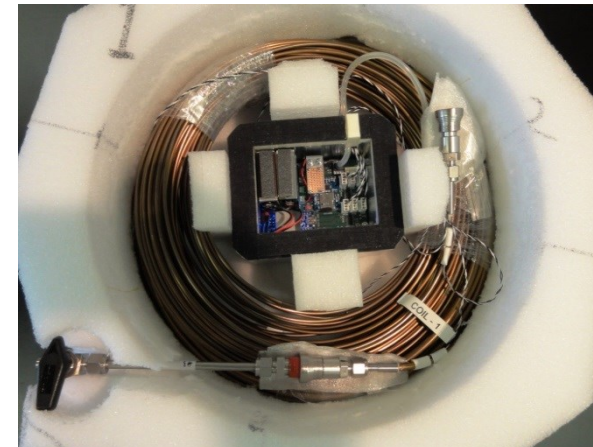


FTS vs. OCO-2 observations. From Wunch et al., Comparisons of the Orbiting Carbon Observatory-2 (OCO-2)  $x\text{CO}_2$  measurements with TCCON, Atmos. Meas. Tech., doi:10.5194/amt-2016-227, 2017.





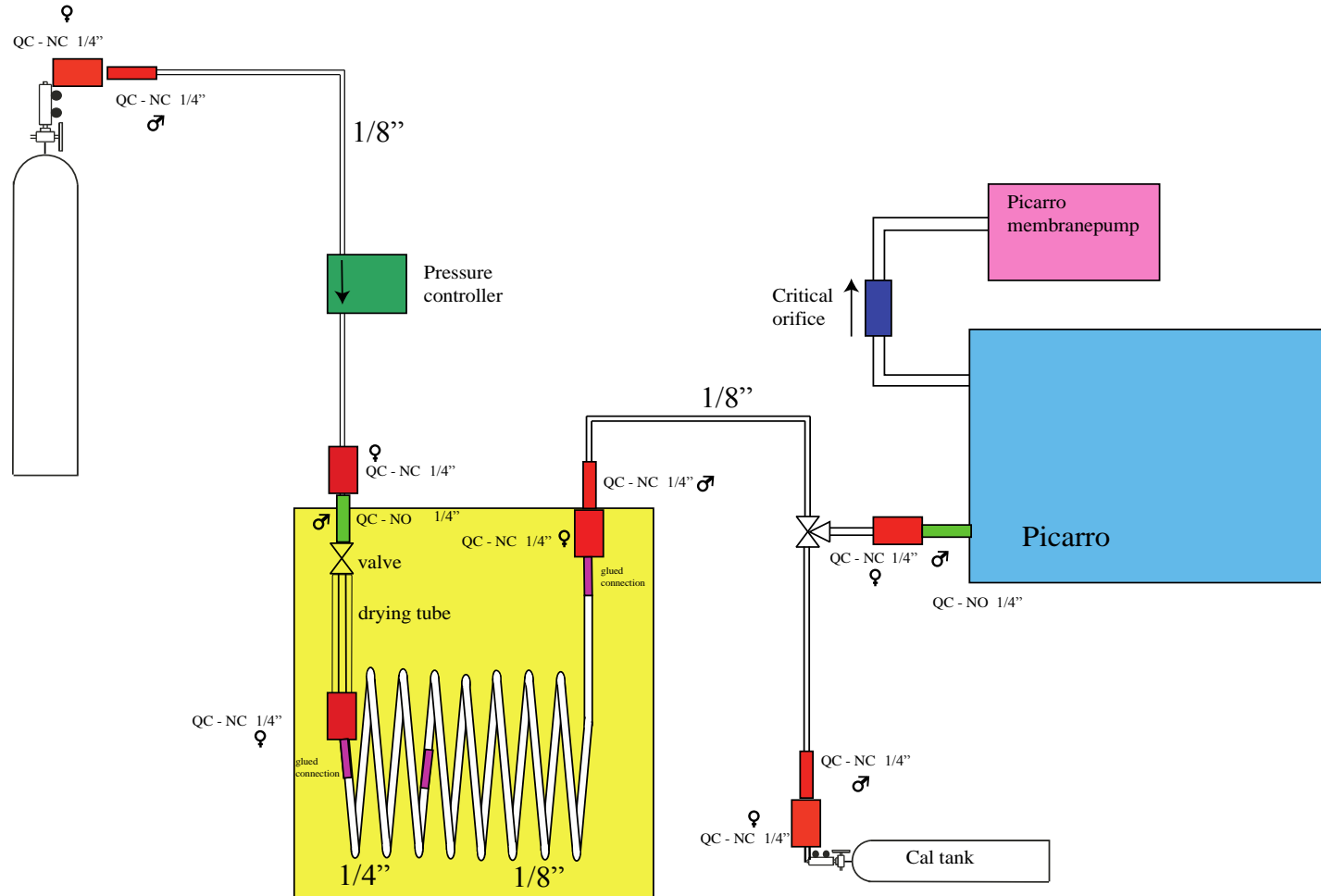
- At Sodankylä we have performed AirCore observations since September 2013. The measurements cover all seasons. An example of AirCore profiles of CO<sub>2</sub>, CH<sub>4</sub> and CO is shown above (from September 3, 2013). AirCore profiles are in red and the TCCON a priori profiles in black. Blue star corresponds to tower measurements at Sodankylä.
- 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. After the landing we have analysed the sample using the Picarro G2401 gas analyser.



AirCore instrument with an open cover



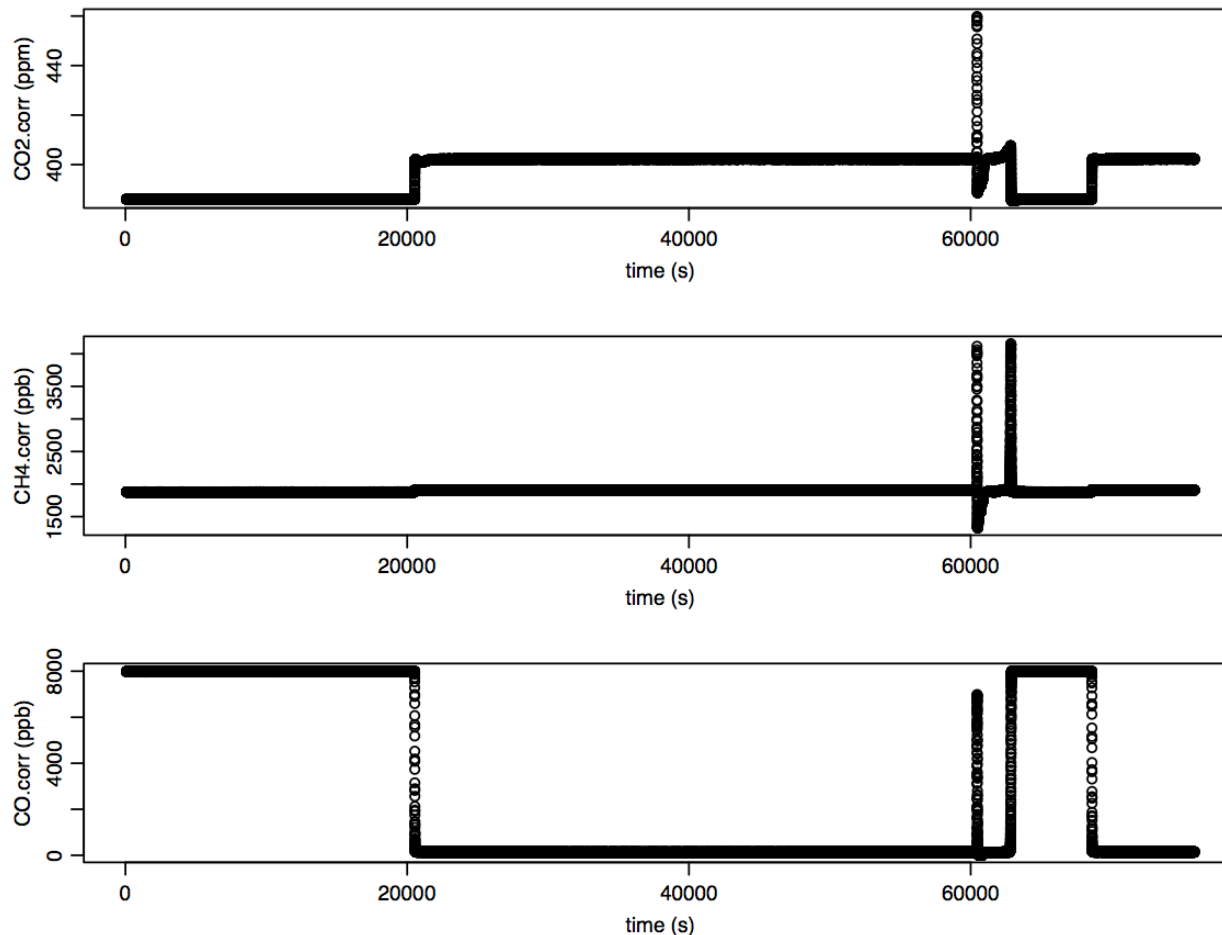
## AirCore analysis system





## AirCore analysis on Picarro

fill air → cal air → AirCore air → fill air → cal air

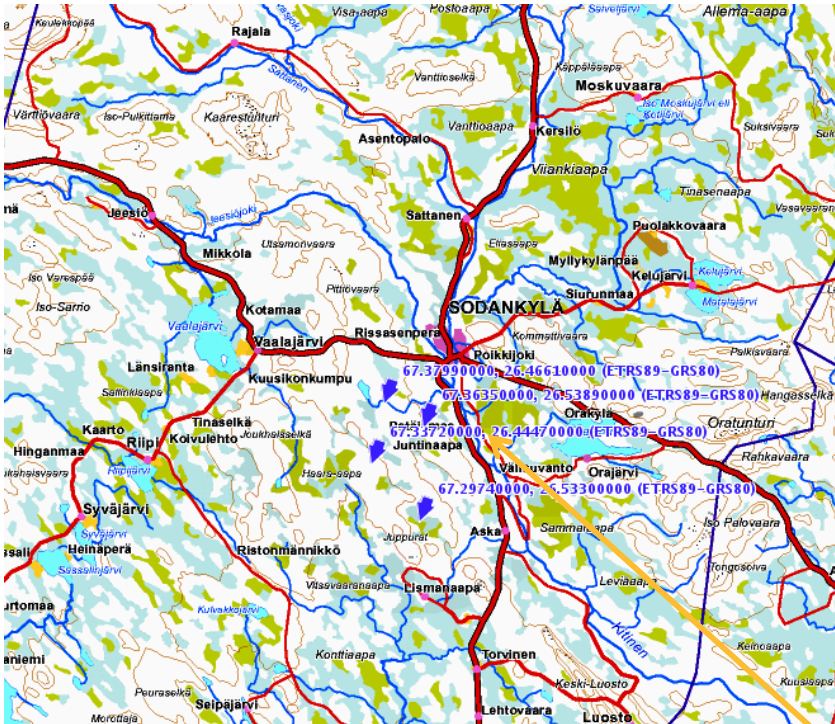




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# AirCore

## AirCore recovery



TCCON  
site





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## AirCore campaign in Sodankylä



Helicopter flights and multiple AirCore launches were performed in July 2014. Participants from FMI Sodankylä and Helsinki; University of Groningen, BIRA-IASB, Brussels; NOAA, Boulder; Le Laboratoire de Météorologie Dynamique, Paris.



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## Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG), 2017-2018



Instrument	Spectral range	Resolution	Main GHGs
Bruker 125HR	1800-15000	0.004 cm <sup>-1</sup>	XCH <sub>4</sub> , XCO, XCO <sub>2</sub>
Bruker Vertex70	2500-15000	0.16 cm <sup>-1</sup>	XCH <sub>4</sub> , XCO, XCO <sub>2</sub>
EM27/SUN	4000-9000	0.5 cm <sup>-1</sup>	XCH <sub>4</sub> , XCO, XCO <sub>2</sub>
IR Cube	4500-15000	0.5 cm <sup>-1</sup>	XCH <sub>4</sub> , XCO <sub>2</sub>
Heterodyne	950/1280	0.002 and 0.02 cm <sup>-1</sup>	CH <sub>4</sub> , CO <sub>2</sub>
AirCore balloon		13.4 mbar (AmbP>232 mbar)- 3.9 mbar (AmbP<232 mbar)	CH <sub>4</sub> , CO, CO <sub>2</sub> vertical profiles

Campaign in Sodankylä 2017-2018. FRM4GHG Project is led by the University Bremen and BIRA. Participants in FRM4GHG Project are FMI, University Bremen, BIRA, KIT, Uni Wollongong, RAL, Uni Groningen. Campaign web site <http://frm4ghg.aeronomie.be/>. AirCore measurements are also made within the FRM4GHG Project



## Summary:

- The first AirCore flight in September 2013. Since then we have launched 30 AirCores.
- Sodankylä has a high resolution FTS installed in the observatory to measure column amounts of CO<sub>2</sub>, CH<sub>4</sub>, CO and other gases in the atmosphere. At Sodankylä we can use AirCore to evaluate the FTS retrieval, as the AirCore sampling is directly traceable to the WMO standard gases.
- The AirCore activity is ongoing and we are currently building two new instruments.
- The ongoing FRM4GHG campaign involves regular AirCore launches.



## References:

Kivi, R. and Heikkinen, P.: Fourier transform spectrometer measurements of column CO<sub>2</sub> at Sodankylä, Finland, *Geosci. Instrum. Method. Data Syst.*, 5, 271-279, doi:10.5194/gi-5-271-2016, 2016.

Mrozek, D. J., van der Veen, C., Hofmann, M. E. G., Chen, H., Kivi, R., Heikkinen, P., and Röckmann, T.: Stratospheric Air Sub-sampler (SAS) and its application to analysis of  $\Delta^{17}\text{O}(\text{CO}_2)$  from small air samples collected with an AirCore, *Atmos. Meas. Tech.*, 9, 5607-5620, doi:10.5194/amt-9-5607-2016, 2016.

Paul, D., Chen, H., Been, H. A., Kivi, R., and Meijer, H. A. J.: Radiocarbon analysis of stratospheric CO<sub>2</sub> retrieved from AirCore sampling, *Atmos. Meas. Tech.*, 9, 4997-5006, doi:10.5194/amt-9-4997-2016, 2016.

Tukiainen, S., J. Railo, M. Laine, J. Hakkarainen, R. Kivi, P. Heikkinen, H. Chen, and J. Tamminen (2016), Retrieval of atmospheric CH<sub>4</sub> profiles from Fourier transform infrared data using dimension reduction and MCMC, *J. Geophys. Res. Atmos.*, 121, 10,312–10,327, doi:10.1002/2015JD024657.

Wunch et al., Comparisons of the Orbiting Carbon Observatory-2 (OCO-2) X<sub>CO2</sub> measurements with TCCON, *Atmos. Meas. Tech.*, doi:10.5194/amt-2016-227, 2017.