



# TCCON and AirCore measurements of greenhouse gases over Sodankylä: comparisons with satellite borne observations

R. Kivi (1), P. Heikkinen (1), J. Tamminen (1), J. Hakkarainen (1), J. Hatakka (1), T. Laurila (1), L. Backman (1), H. Chen (2,3)

(1) Finnish Meteorological Institute, Finland, (2) Center for Isotope Research, University of Groningen, Groningen, Netherlands, (3) Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado, USA

## FTS measurements during 2009-2015

Bruker IFS 125 HR with A547N Solar Tracker

- Gold coated mirrors
- Optical path difference  $\leq 258$  cm
- Resolution  $\geq 0.0035$   $\text{cm}^{-1}$
- Detectors and wave number ranges
  - RT-Si: 25000\* – 9000  $\text{cm}^{-1}$
  - RT-InGaAs: 12800 – 4000  $\text{cm}^{-1}$
  - LN-InSb: 9600 – 1850  $\text{cm}^{-1}$



Retrieved gases include:

- Carbon dioxide,  $\text{CO}_2$
- Methane,  $\text{CH}_4$
- Nitrous oxide,  $\text{N}_2\text{O}$
- Hydrogen fluoride, HF
- Carbon Monoxide, CO
- $\text{H}_2\text{O}$  and HDO

Fourier transform infrared spectrometer (FTS) system was installed at Sodankylä (67.4°N, 26.6°E) in February 2009. The instrument, by recording direct solar spectra, is capable of greenhouse gas column retrievals, such as carbon dioxide and methane. Our instrument is participating in the TCCON network ([www.tcon.caltech.edu](http://www.tcon.caltech.edu)).

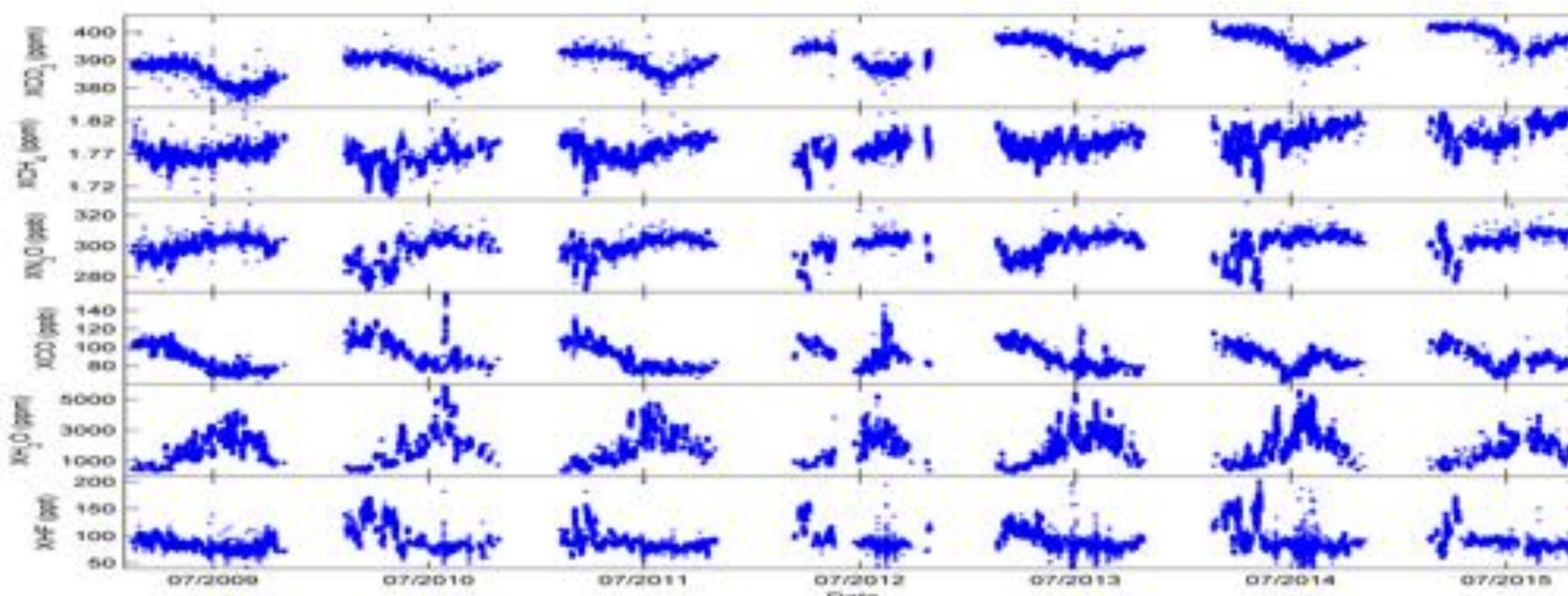


Figure 1: Column-averaged mixing ratios measured by the FTS at Sodankylä, reprocessed data using GGG2014.

## FTS and satellite comparisons

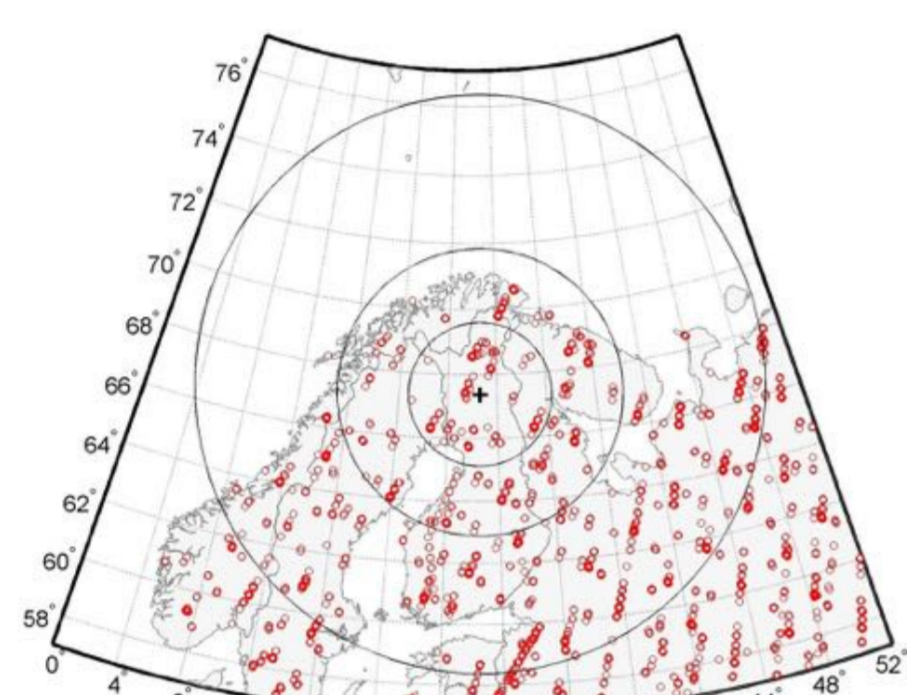
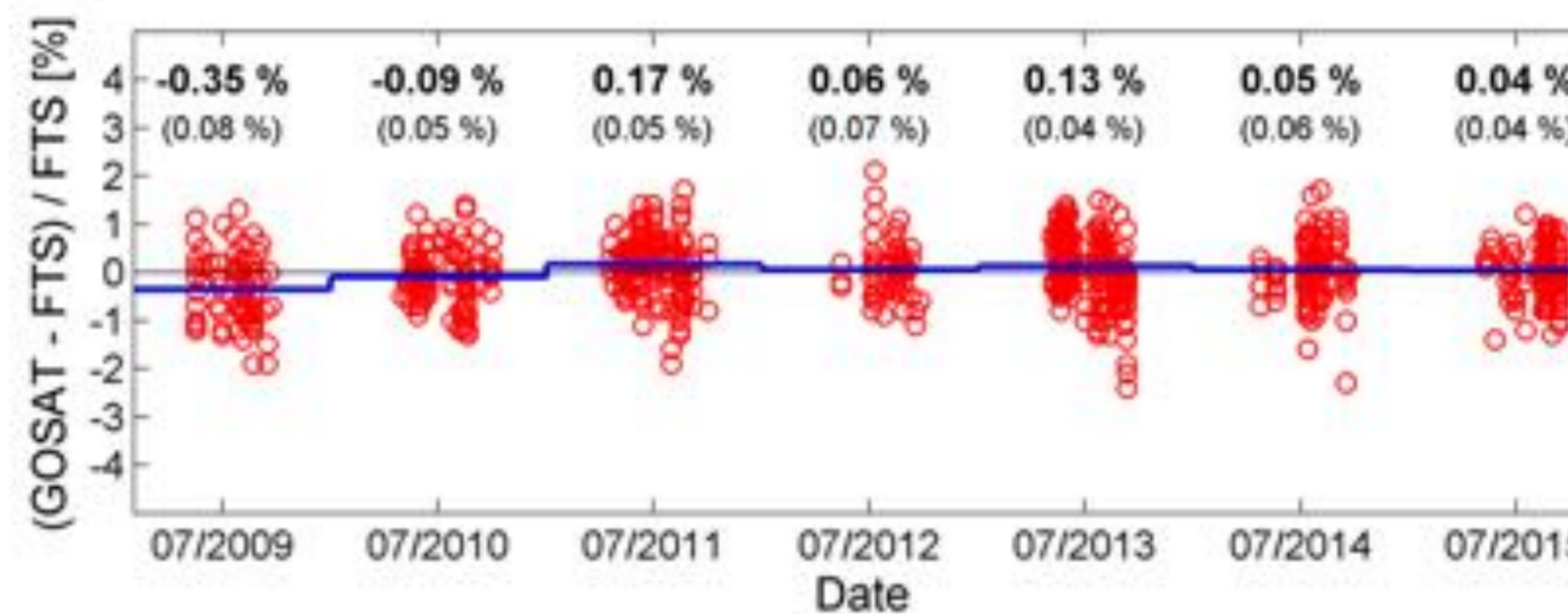


Figure 2: GOSAT data points near Sodankylä. Three different co-location radii have been indicated; 250 km, 500 km and 1000 km.

Spatial coverage	1000 km radius	500 km radius	250 km radius
Time window	$\pm 3$ h	$\pm 2$ h	$\pm 1$ h
Number of coincident measurements	2211	900	305
Absolute difference, GOSAT – Sodankylä FTS [ppm]:			
Mean	0.0	0.2	0.4
StdDev	2.5	2.4	2.2
StdErr	0.1	0.1	0.1
Relative difference, (GOSAT – Sodankylä FTS) / Sodankylä FTS [%]:			
Mean	0.01	0.04	0.10
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	$\pm 3$ h	$\pm 2$ h	$\pm 1$ h
Number of coincident measurements	2211	900	305
Absolute difference, GOSAT – Sodankylä FTS [ppm]:			
Mean	0.0009	-0.0016	-0.0002
StdDev	0.0155	0.0139	0.0116
StdErr	0.0003	0.0005	0.0007
Relative difference, (GOSAT – Sodankylä FTS) / Sodankylä FTS [%]:			
Mean	0.05	-0.09	-0.01
StdDev	0.87	0.78	0.65
StdErr	0.02	0.03	0.04

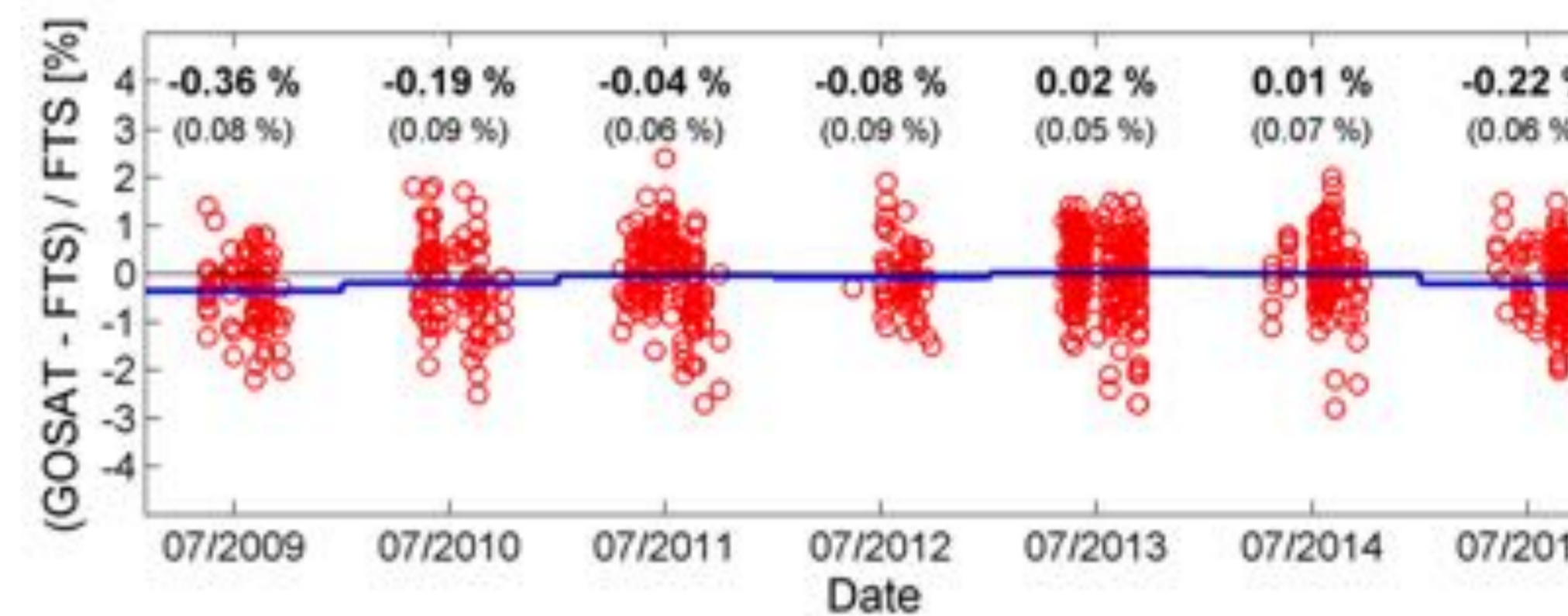


Figure 4: Sodankylä FTS comparisons with GOSAT observations for  $\text{CO}_2$  (upper panel) and  $\text{CH}_4$  (lower panel).

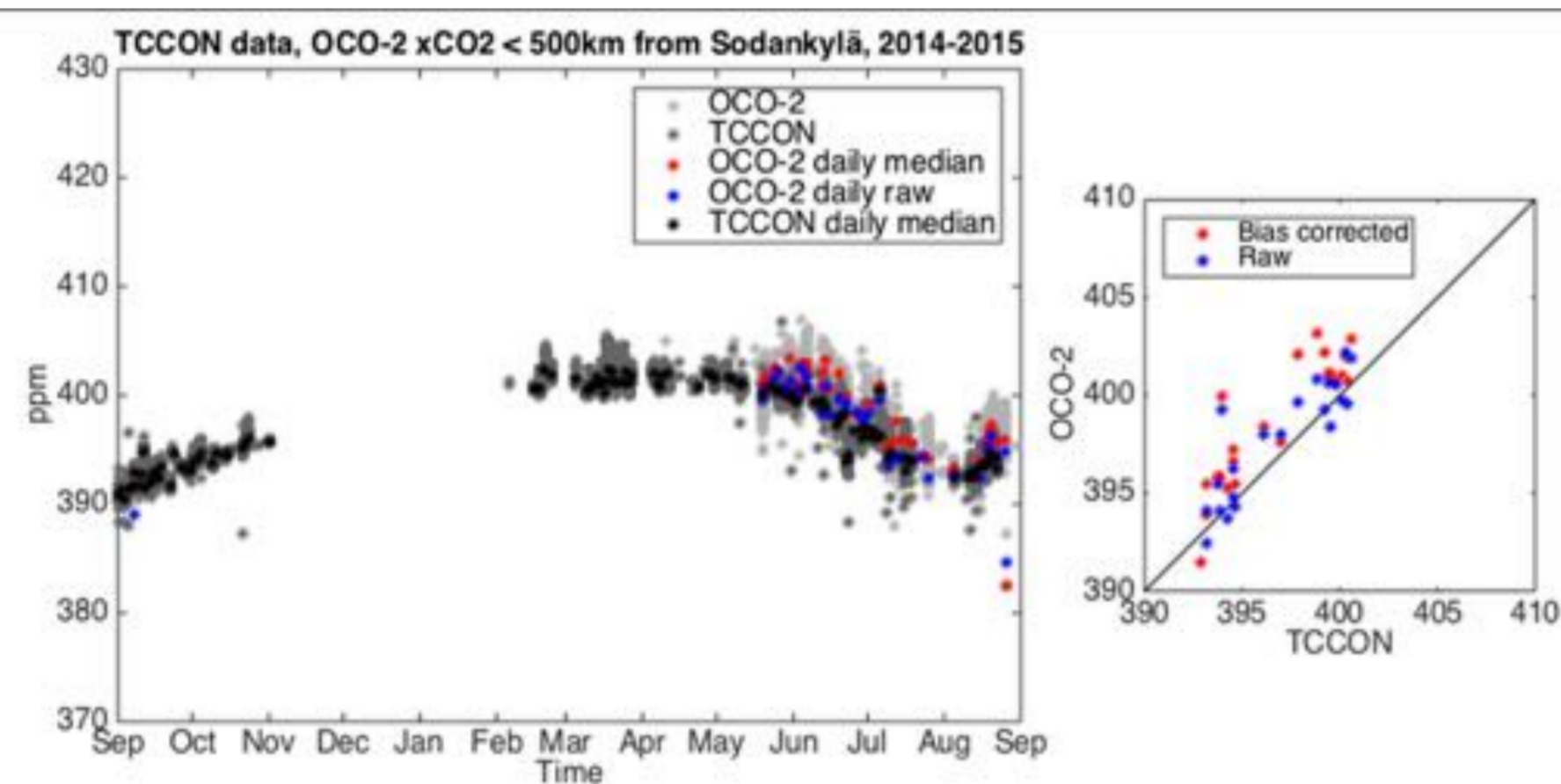


Figure 3: FTS and OCO-2 data over Sodankylä.

## FTS and AirCore measurements

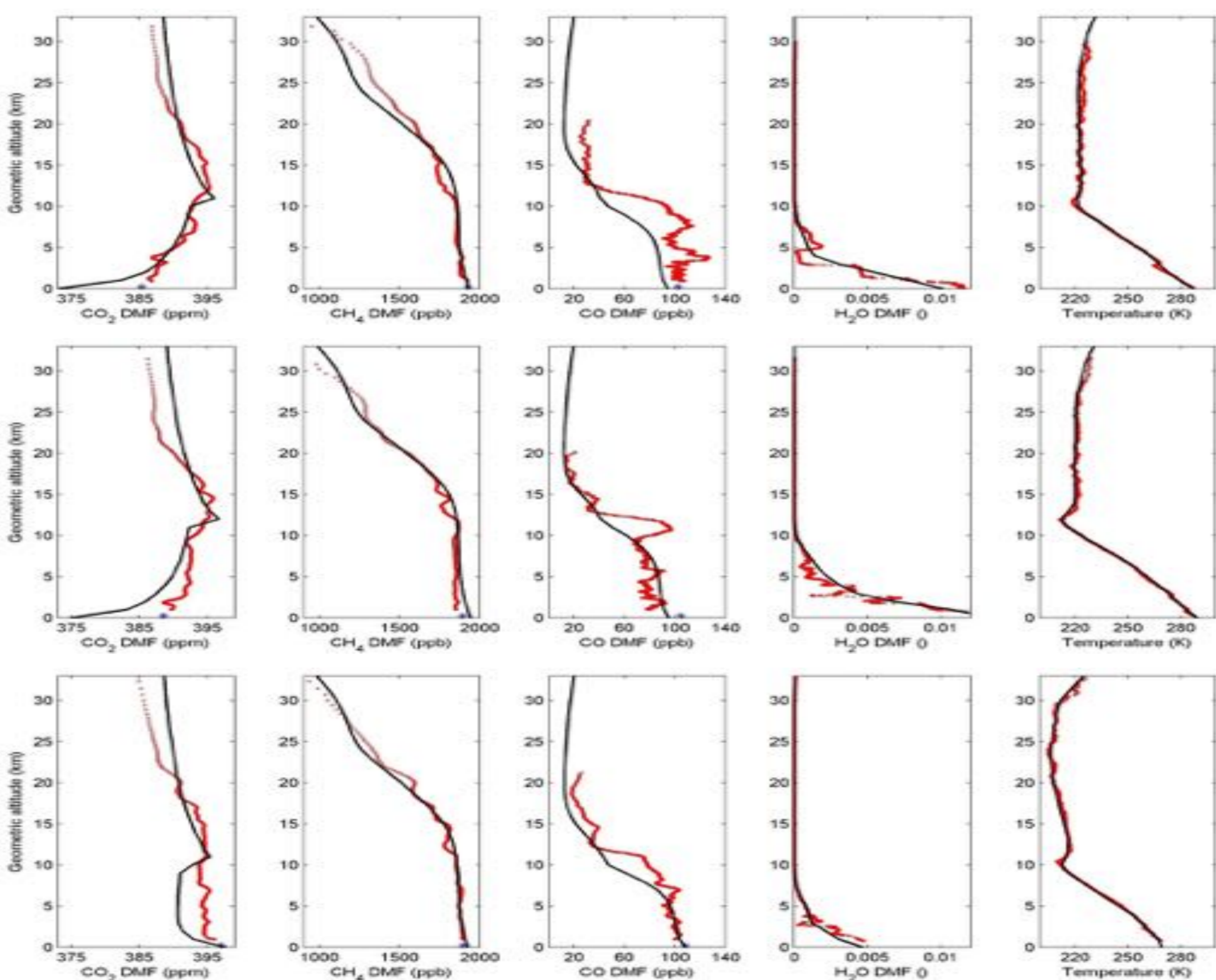


Figure 5: AirCore profiles (red) versus TCCON a priori profiles (black curve). Blue star corresponds to tower measurements in the vicinity of the AirCore landing site.

**AirCore** is an atmospheric sampling system to measure vertical profiles of greenhouse gases in the troposphere and stratosphere (Karion et al., 2010). AirCore profile measurements of  $\text{CO}_2$ ,  $\text{CH}_4$  and CO have been made since autumn 2013 in Sodankylä. AirCore measurements can be used for comparisons with the FTS data.



Regular AirCore soundings can provide a useful tool to monitor on regular basis the data quality of a TCCON instrument. The TCCON calibration lines derived from 8 AirCore flights covering all seasons are presented in Figure 6. In this plot AirCore profiles were used as a priori in the GFIT retrievals. Similar results are seen if the standard TCCON a priori is used instead.

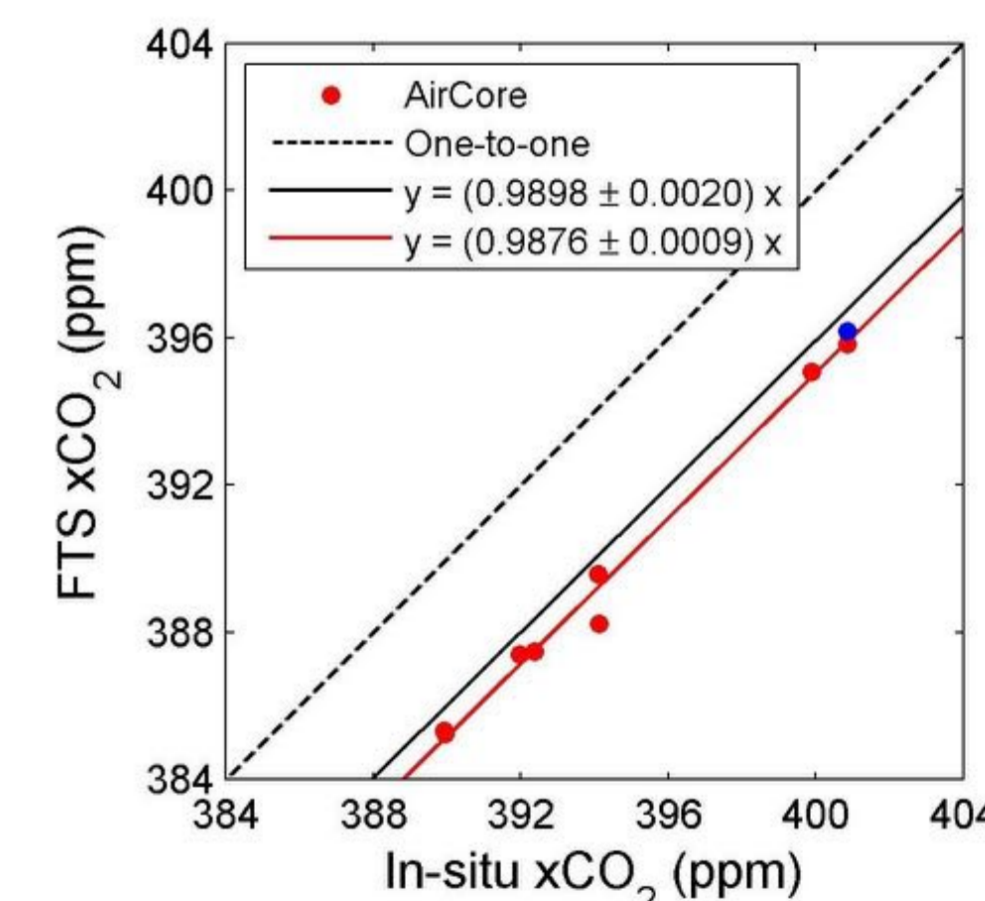


Figure 6: Comparison of the FTS retrievals of  $\text{CO}_2$  with the AirCore measurements. Black curve corresponds to the default calibration and red curve represents a fit based on the AirCore comparisons.

### AirCore system at Sodankylä

The system is built as a stainless steel tubing of about 100 m long, consisting of ~40 m of 1/4" 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. Meteorological balloons lift the AirCore to the stratosphere typically to about 32 km of altitude. Gas analyzer by Picarro, model G2401, has been used at the site of measurements.

### Conclusions

FTS measurements have been performed at Sodankylä since early 2009. We found good agreement between the GOSAT  $\text{xCO}_2$  and  $\text{xCH}_4$  values and the measurements by our FTS instrument. With the 500 km /  $\pm 2$  h coincidence criterion the mean difference in the seven-year period was found to be  $-0.04\% \pm 0.02\%$  for  $\text{xCO}_2$  and  $-0.09\% \pm 0.03\%$  for  $\text{xCH}_4$ .

In September 2013 we have started AirCore measurements at Sodankylä. First results with the AirCore system have been obtained. The data will be used for TCCON, satellite and model validation purposes. In addition, stratospheric studies will be performed, using air samples collected by the AirCore system.