Short description of ICOS atmospheric measurements at the SMEAR II site

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This document gives a short overview of the continuous greenhouse gas sampling system at SMEAR II site which is related to ICOS atmospheric measurements. SMEAR II is projected to be a level 1 ICOS atmospheric site and, in addition to other measurements, at such site carbon dioxide (CO2), methane (CH4) and carbon monoxide (CO) concentrations should be measured continuously at a tower which is over 100 m tall. This document briefly describes those measurements.

1. Measurement setup

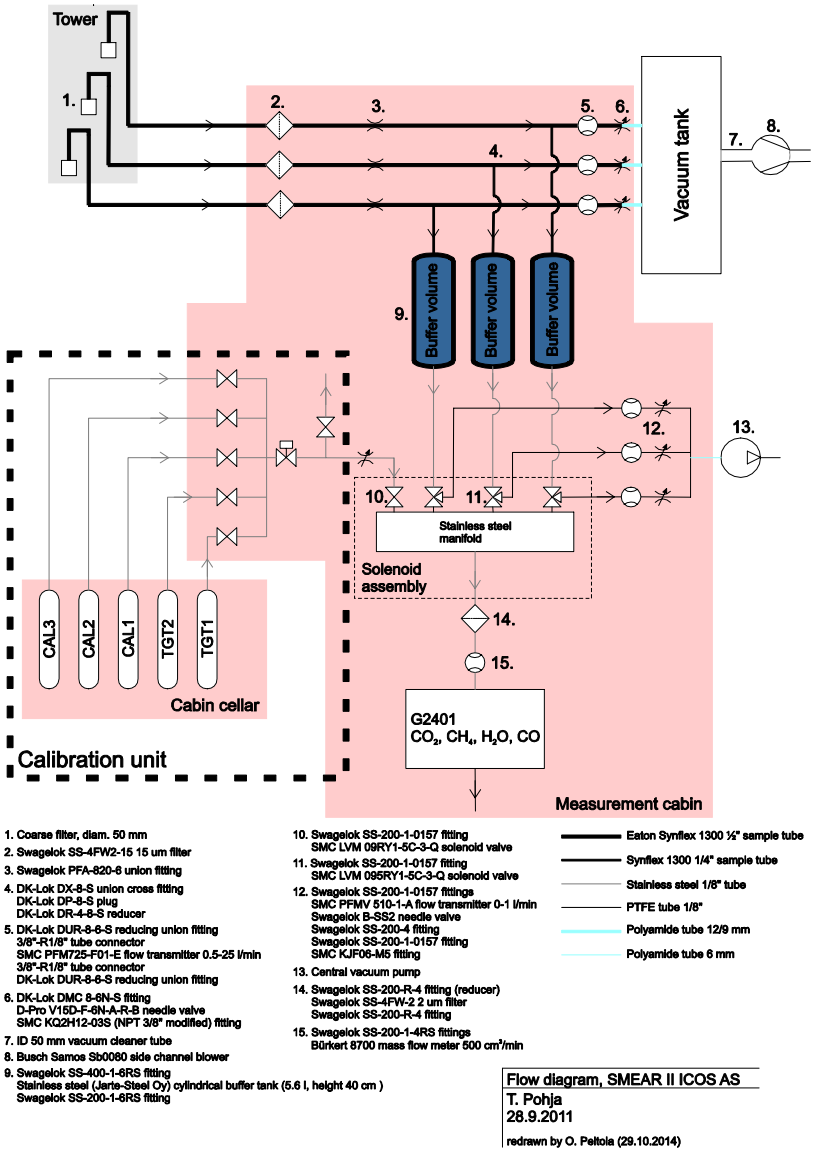

Figure 1: Flow diagram of the ICOS AS measurements at the SMEAR II.

Air is sampled from three levels: 16.8 m, 67.2 m and 125 m. Main sampling lines coming down from the mast are Eaton Synflex 1300 sampling tubes (diam. ½"). See the flow diagram in Fig. 1. The sampling line length differs between levels (157 m (125 m level), 99 m (67 m level) and 49 m (16 m level)), whereas the flow rate is kept similar (approx. 12 LPM). This results in a pressure drops of approximately 35 hPa, 23 hPa and 16 hPa and a residence times of 60 s, 40 s and 20 s for 125 m, 67 m and 16 m sampling levels, respectively. The main sampling lines are constantly flushed and the flow rates monitored.

Air is subsampled from the main lines and the subsampled air is directed through cylindrical stainless steel buffer volumes (volume 5.6 l, height 40 cm). The buffer volumes are used to remove high frequency variation in the signal and furthermore they allow simultaneous measurement of three sampling levels with just one instrument. The sampled air enters the buffer from the bottom and exits from the top of the volume. Flow rate through the buffers is kept close to 350 ml min^{-1}. If the buffers mix the air like a first order system, this flow rate leads to an averaging time of 16 min (63 % of a step change is observed after this time). The buffers are continuously flushed and the flow is created with the central vacuum pump.

Solenoid valves (points 10. and 11. in the flow diagram) are used to control which height is measured. After opening a valve the sampled air enters special made stainless steel manifold, goes through a filter and a flow meter and finally enters the gas analyser (see the flow diagram). Flow through the analyser is created with gas analyser's internal pump and it is usually around 200-300 ml min^{-1}.

Figure 2: Picture of the buffer volumes

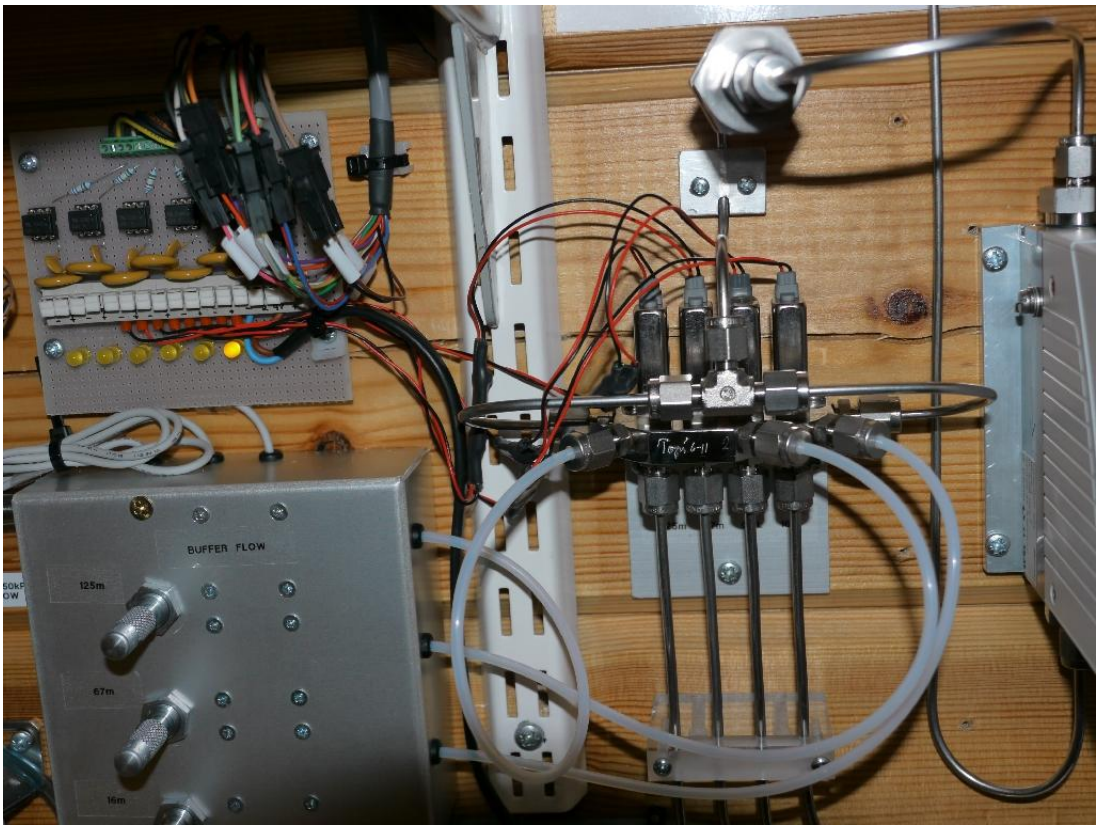

Figure 3: Picture of the stainless steel manifold

2. Ambient air sampling

Each level is measured for 2 min and with three measurement levels this leads to a cycle of 6 min. Thus with buffers which average over 16 min, the “same” volume of air is measured twice with two measurement cycles. After changing the measurement level (switching a valve) only the stainless steel manifold, filter, flow meter and approx. 1 m of stainless steel tubing (diam. 1/8”) needs to be flushed (see again the flow diagram). When designing the manifold the internal volume was minimised in order to reduce the flushing time after switching the valve. Fig. 4 shows a typical 2 min sampling period: during the first 10-20 seconds the manifold, filter, flow meter and the 1 m of tubing is flushed and thus the concentration is not constant. After the flushing, constant value is attained and it describes the concentration in the buffer volume at that particular moment. However, during calm summer nights when the CO2 concentrations change rapidly a constant value after the flushing is not attained, since the concentration in the buffer volume is not constant during the 2 min sampling (see Fig. 5).

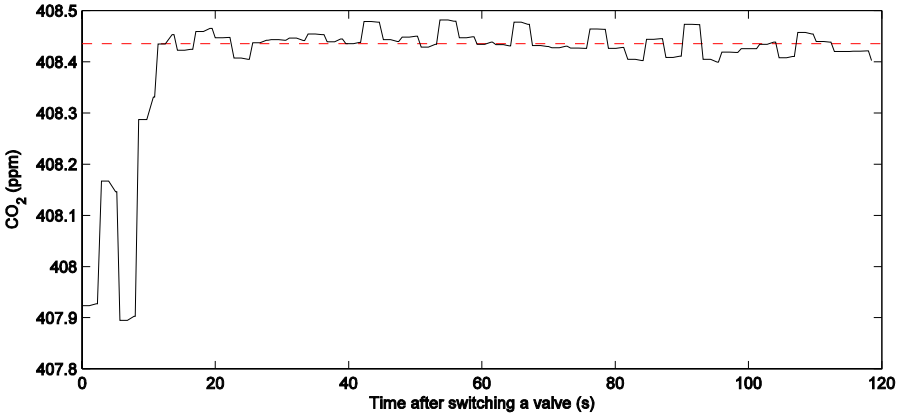

Figure 4: Typical 2 min sampling period. Data measured from 16.8 m sampling height at 29.10.2014 between 00:37-00:39 is shown.

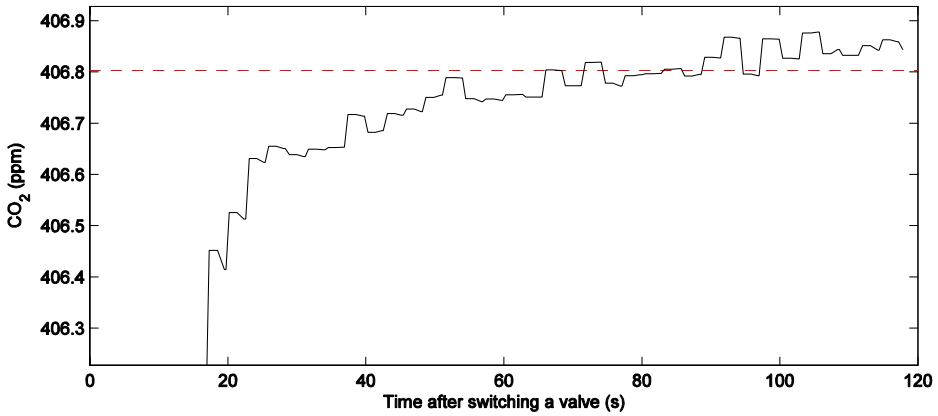

Figure 5: Typical sampling period during a calm summer night when ambient CO2 concentrations change rapidly. Data measured from 16.8 m sampling height at 19.9.2014 between 03:20-03:22 is shown.

3. Calibration and target-gas cylinders and sampling

Calibration and target gas cylinders are located in the measurement cabin cellar. Three calibration gases (L, M, H) and two target cylinders (T1, T2) are used. The currently used cylinders are described in Table 1 and the gas concentrations in the cylinders are given in Table 2. Approximately 10 m long stainless steel (diam. 1/8") sampling lines go from the cylinders to the measurement cabin where the flow is controlled with solenoid valves, mass flow controller and needle valve (see the left side of the flow diagram). Excess flow is directed out. The T1 is used as performance target gas (measured daily at 10:30-10:45) and T2 is archive target gas (measured approximately once per month). The performance target is used for quality control and uncertainty estimation. An archive target gas is used also for quality control purposes but over the station lifelong. Calibration and target gas concentrations are given in Table 1. They were estimated against WMO scales WMO CO2 X2007, WMO CH4 X2004 and WMO CO X2004.

Table 1: Calibration and target gas cylinders currently in use.

Cylinder	Material	Size	Cylinder manufacturer	Cylinder filling date	Cylinder valve	Pressure regulator
D609163 (L)	aluminium	40 l	Luxfer Gas Cylinders Ltd., UK	9.1.2014	Air Liquide UK Ltd	Scott 20051 14B D14 2-ST
D609171 (M)	aluminium	40 l	Luxfer Gas Cylinders Ltd., UK	9.1.2014	Air Liquide UK Ltd	Scott 20051 14B D14 2-ST
D489489 (H)	aluminium	40 l	Luxfer Gas Cylinders Ltd., UK	9.1.2014	Air Liquide UK Ltd	Scott 20051 14B D14 2-ST
D489546 (T1)	aluminium	40 l	Luxfer Gas Cylinders Ltd., UK	9.1.2014	Air Liquide UK Ltd	Scott 20051 14B D14 2-ST
87026 (T2)	aluminium	27 l	Luxfer Gas Cylinders Ltd., UK	1.3.2014	Air Liquide UK Ltd	AGA RedLine

Table 2: CO2, CH4 and CO concentrations in the calibration and target gas cylinders (st dev in the parentheses). The concentrations were estimated by Hermanni Aaltonen (29.1. and 12.2.2014), except for T2 by Juha Hatakka (30.1.2013).

Cylinder	CO2 (ppm)	CH4 (ppb)	CO (ppb)
D609163 (L)	378.880 (0.010)	1788.94 (0.17)	63.5 (0.5)
D609171 (M)	395.575 (0.004)	1860.48 (0.02)	97.1 (1.2)
D489489 (H)	427.775 (0.008)	1982.51 (0.00)	260.1 (0.2)
D489546 (T1)	406.231 (0.009)	1916.01 (0.01)	136.8 (0.2)
87026 (T2)	396.74 (0.02)	1878.88 (0.13)	167.6

Calibration is done once per month, usually at the beginning of the month by sampling each calibration gas for 15 min. Thus one calibration period lasts 45 min.

Figure 6. Calibration and target gas cylinders located in the main cabin basement.