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Vertical profile observations of greenhouse gases and their isotopic compositions using AirCore & LISA

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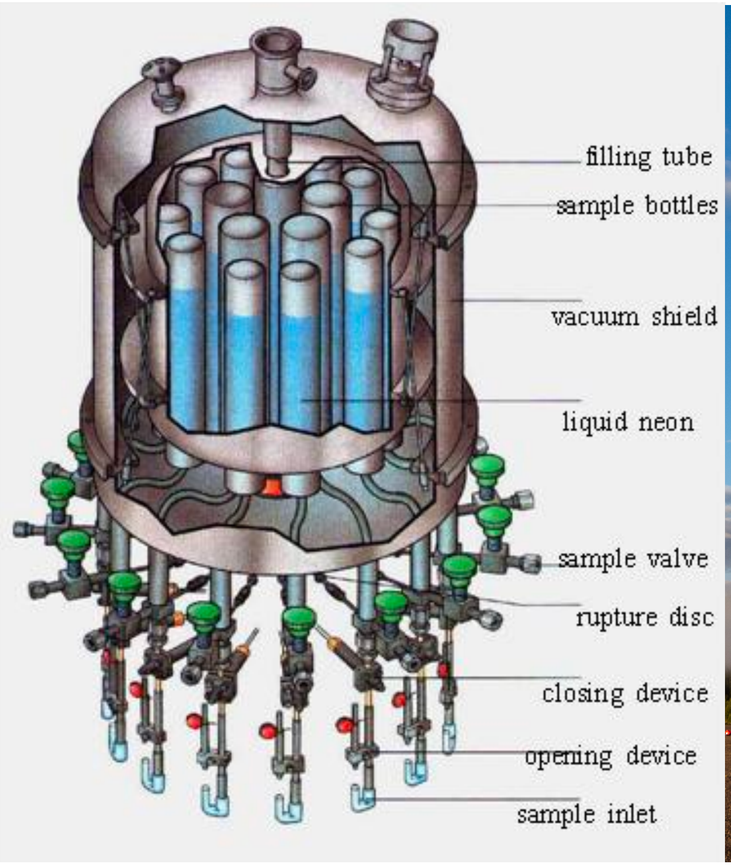
RINGO | Readiness of ICOS

NWO Netherlands Organisation for Scientific Research

[1]RUG, [2]FMI, [3]UBern, [4]LSCE, [5]GUF, [6]UEA, [7]NOAA, [8]LMD

Vertical profile measurements of greenhouse gases using AirCore

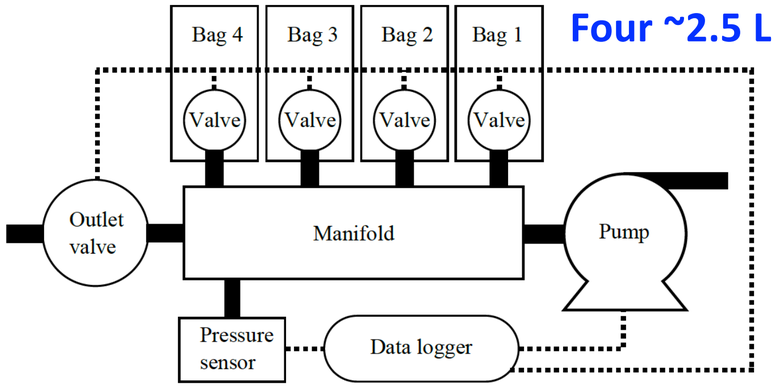


The cryogenic whole air sampler at the University of Frankfurt, Germany, flown with a large balloon (https://www.goethe-university-frankfurt.de/65563148/Cryogenic_Air_Sampler)

The 152 m–long AirCore, *[Karion et al. 2010], More recently, [Membrive et al. 2017], [Engel et al., 2017]*

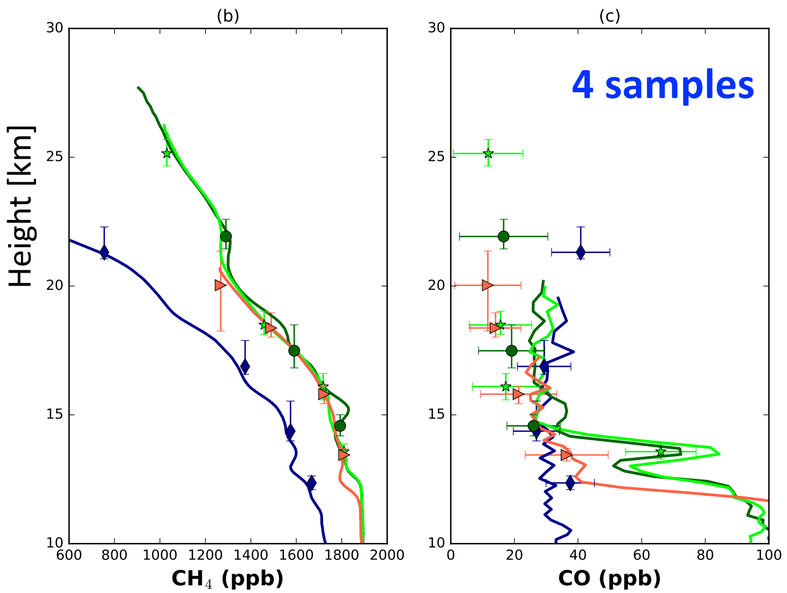
AirCore flown with a weather balloon

LISA: A LIghtweight Stratospheric Air sampler

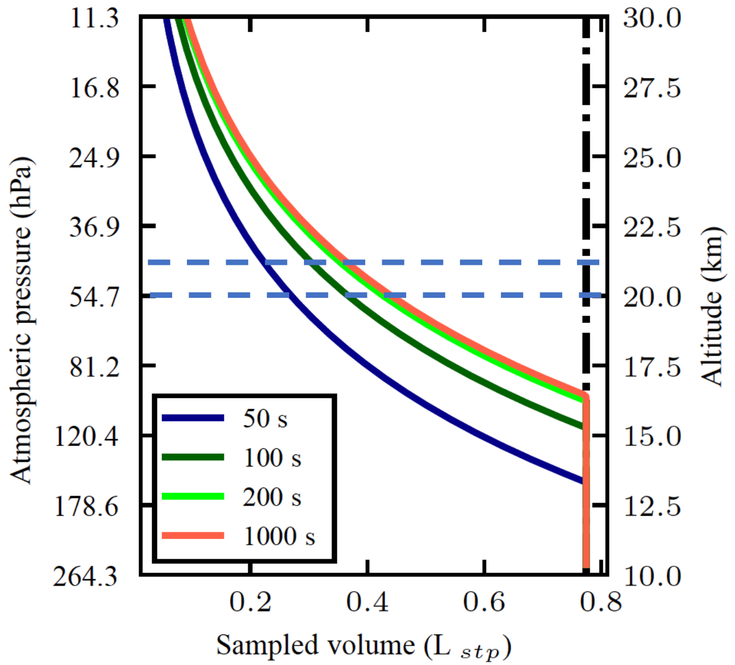


Four ~2.5 L bags

Schematic of the LISA sampler, 2 kg payload, suitable to be launched with a weather balloon



4 samples



At 20 - 21 km

- AirCore (1.4 L): ~ 10 mL air
- LISA: ~ 400 mL air

Expected volume of air samples with the current setup; a larger amount of air samples to be collected using bigger bags during the upcoming Hemera campaign.

Hooghiem et al., 2018

Applications:

- Validation of AirCore altitude registration
- Analysis of Isotopic compositions and other potential species

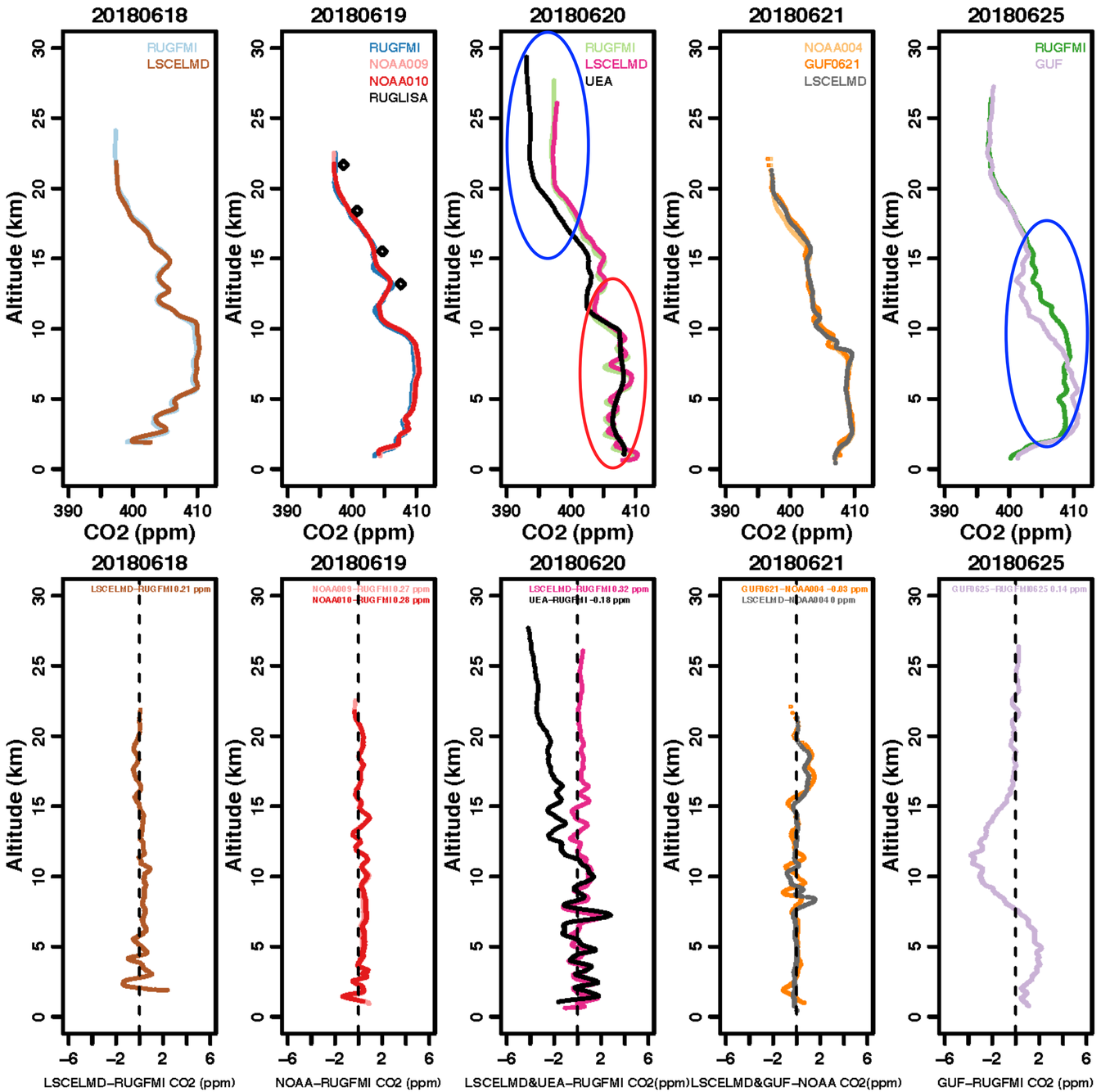
RINGO AirCore Comparison Campaigns

RINGO aims to develop the readiness of in situ vertical profile measurements using **AirCore** at ICOS stations & vertical **TCCON** profile measurements of CH_4.

- 1st campaign Sodankylä 2018
- 2nd campaign Trainou 2019

	Day 1 (Jun 18)		Day 2 (Jun 19)		Day 3 (Jun 20)		Day 4 (Jun 21)		Day 5 (Jun 25)		Day 6 (Jun 26)		Day 7 (Jun 29)
1	RUG/FMI	2	RUG/FMI	3	RUG /FMI	4	LSCE/LMD	6	RUG/FMI	9	GUF	10	LISA
	Bern		LISA		LSCE/LMD		NOAA		GUF				Bern
	LSCE/LMD		NOAA		UEA		Bern		Bern				Bern-light
						5	GUF	7	LISA				
									UEA				
									Bern				
								8	Bern				

Institutions	AirCore Tubing	Flights
1. RUG/FMI	40 m 1/4” O.D. + 60 m 1/8” O.D.	4
2. LSCE/LMD	23 m 8 mm O.D. + 46 m 4 mm O.D.	3 (no drying)
3. GUF	20 m 8 mm O.D. + 40 m 4mm O.D. + 40 m 2 mm O.D.	3
4. UBERN	105m 3.4 mm O.D.	7
5. NOAA	100 m 1/8” O.D. x 2	4
6. UEA	8.5 m 1/2” O.D. + 63 or 85 m 1/8” O.D.	2
7. RUG	LISA (4 bags)	3
Sum	All analyzed on Picarro, primarily G2401	23 AC + 3 LISA



CO_2

Larger differences

- **UEA stratospheric part on June 20: Tubing no coating**
- **GUF on June 25, possibly smearing during analysis**

Due to different spatial resolution

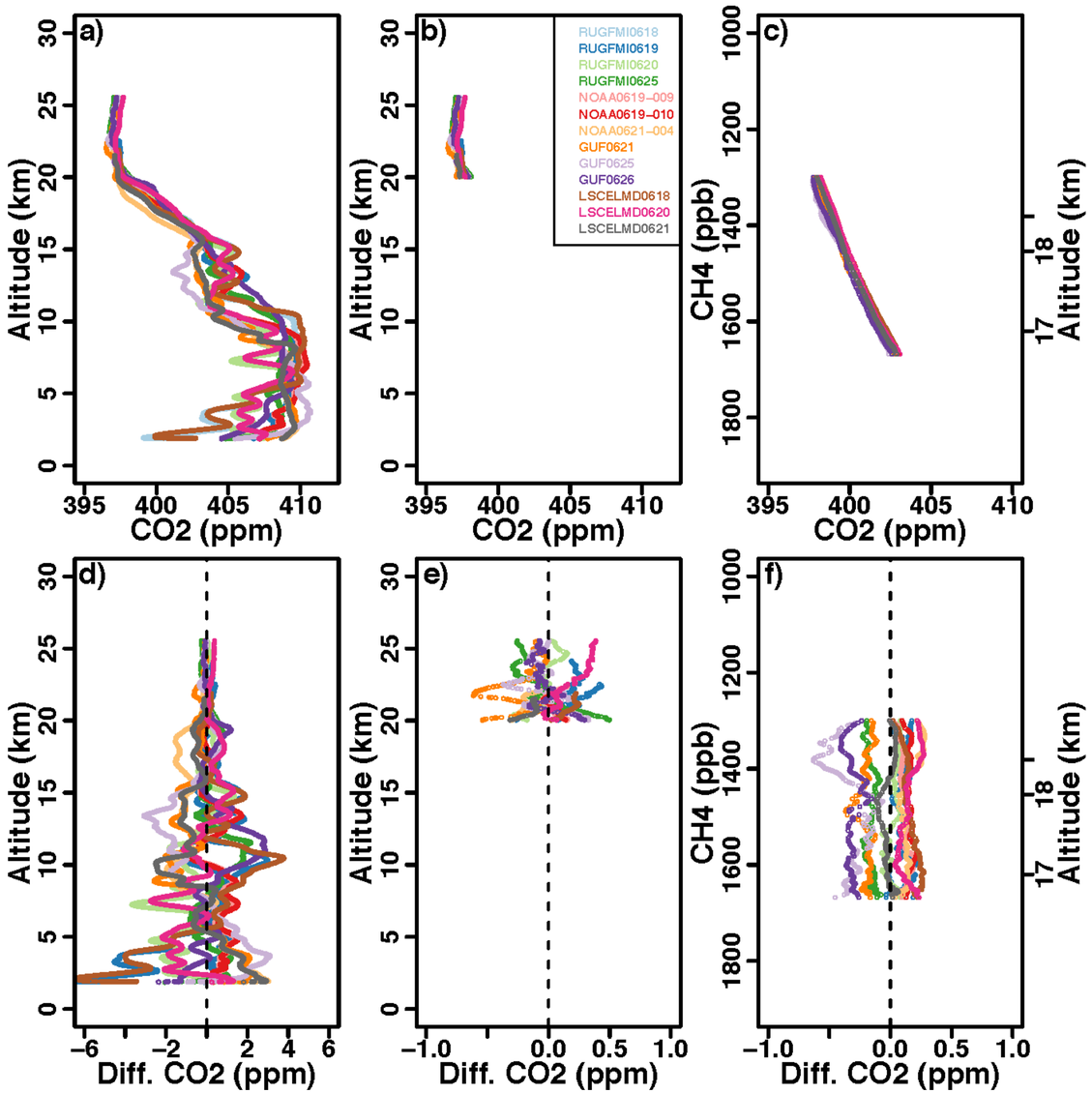
- **UEA tropospheric part on June 20 ½ in. diameter, coated**

Mean column differences

- **0 – 0.32 ppm**

Comparison of CO_2 profiles

13 CO_2 and CO profiles from RUGFMI, NOAA, GUF, LSCELMD



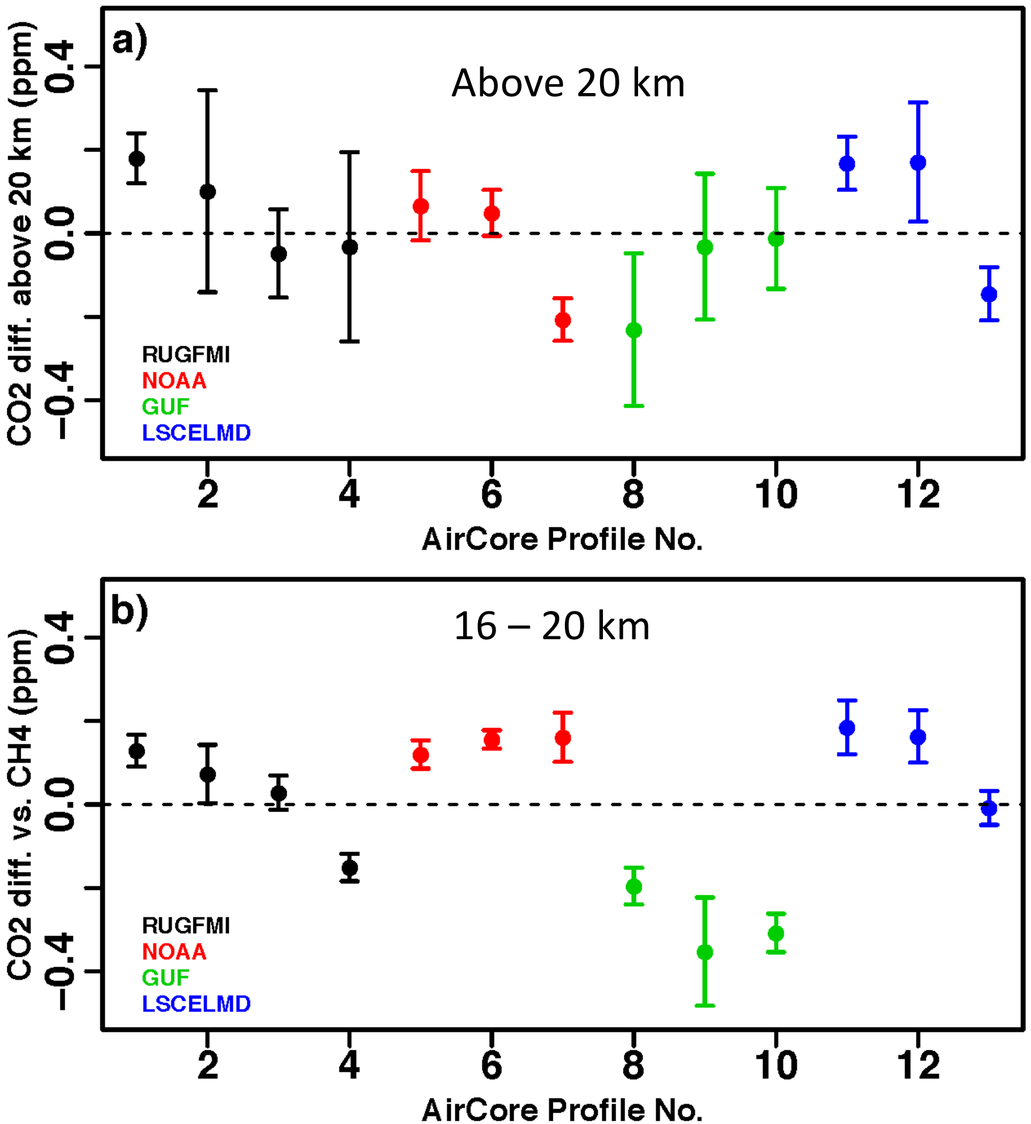
Large variations in the troposphere

- **Surface emissions**
- **Transport**

Small variations in the stratosphere

- **CO_2 above 20 km**
- **In the CH_4 domain 1300 – 1700 ppb (16 – 20 km)**

Uncertainty of CO_2 mole fraction observations



Above 20 km
1-Sigma: 0.15 ppm

In the CH_4 domain
1-Sigma: 0.19 ppm

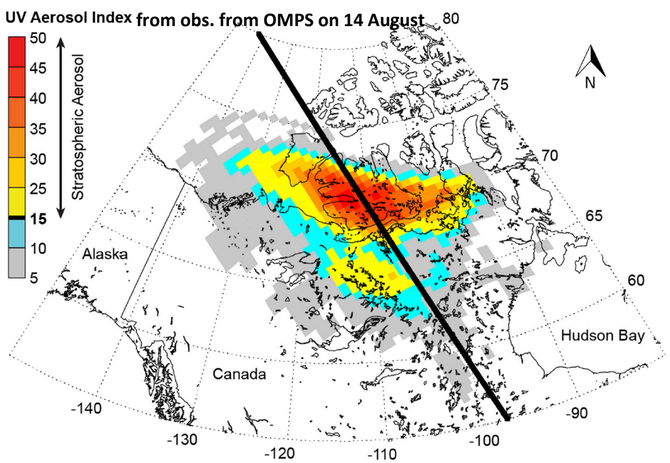
VS.

Round-Robin cylinder comparison
1-Sigma: 0.10 ppm

With vs. without drying the air sample above 16 km

- **0.08 ± 0.18 ppm above 20 km**
- **0.15 ± 0.11 ppm between 16 and 20 km**

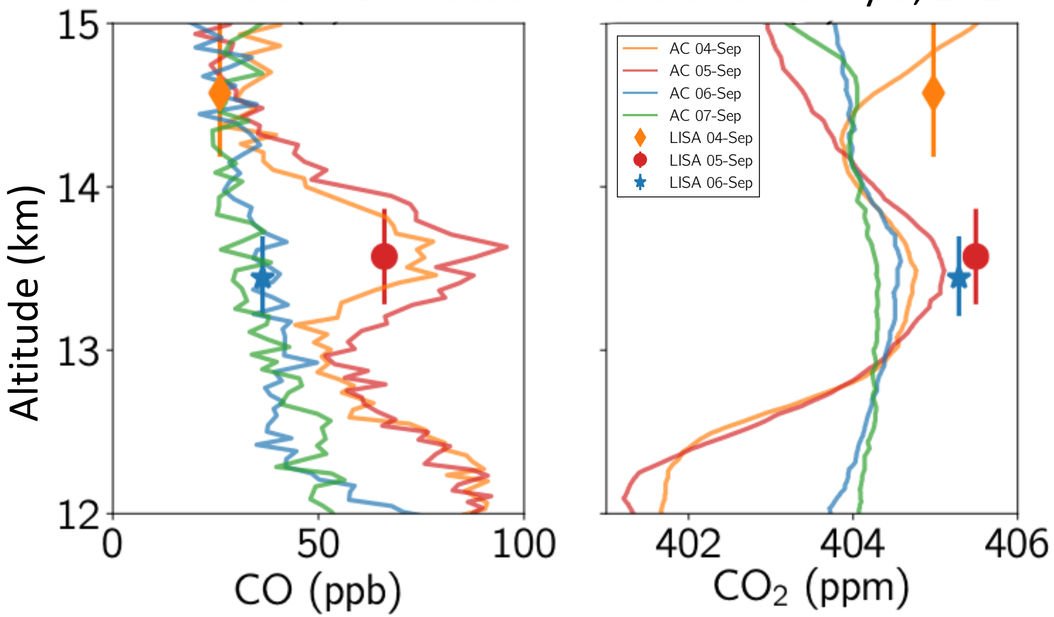
Wildfire smoke in the lower stratosphere identified by AirCore & LISA Observations September 2017



"The mega pyro-cumulonimbus (pyroCb)" event in British Columbia on Aug. 12 2017

Peterson et al. 2018

AirCore and LISA observations at Sodankylä, 2017

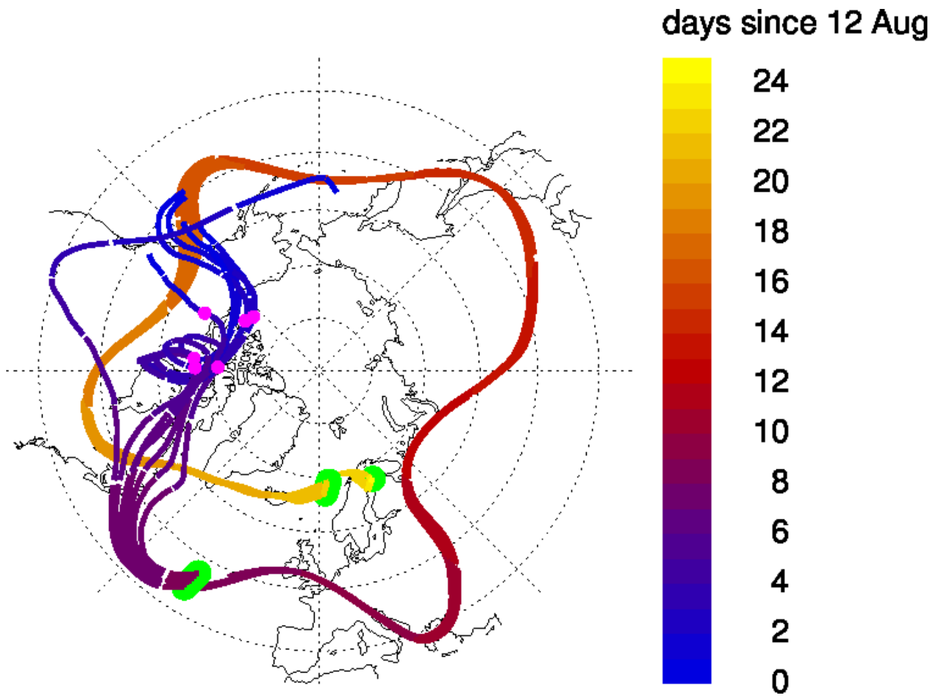


Air samples (~350 mL) analyzed for $\delta^{13}C$ and $\delta^{18}O$ in CO using CF-IRMS at IMAU, Utrecht University (*Pathirana et al., 2015*)

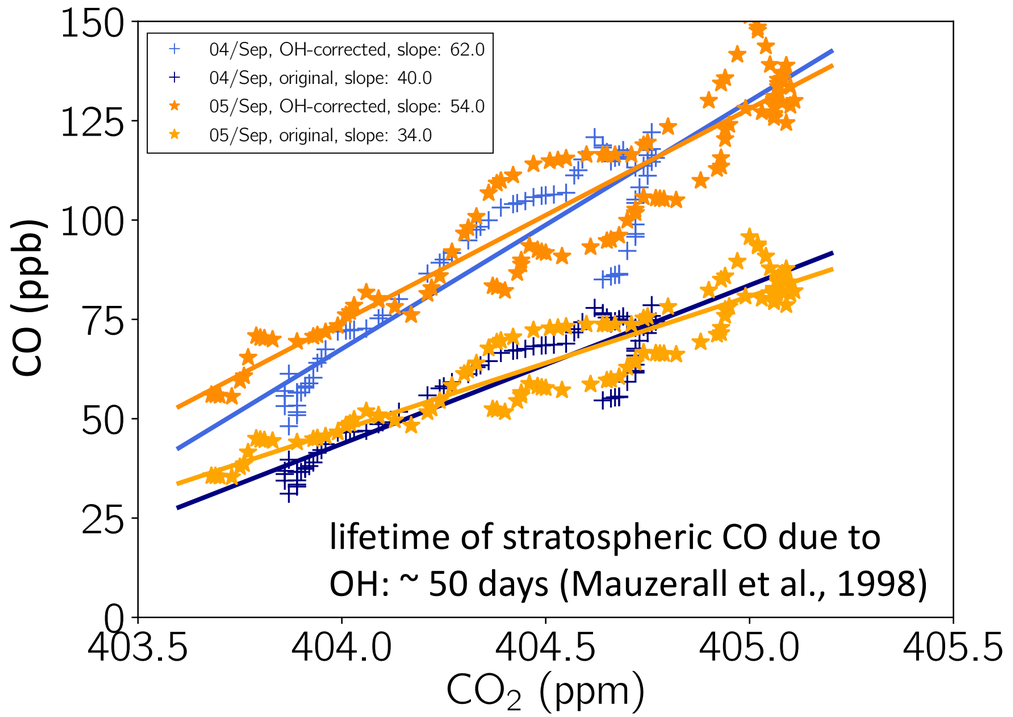
	Altitude (km)	θ (K)	CO (ppb)	CO_2 (ppm)	$\delta^{13}C(CO)$ ‰	$\delta^{18}O(CO)$ ‰
P (05 Sep)	13.6	370.3	74	405.5	-28.8	4.3
B (06 Sep)	13.4	368.9	34	405.2	-29.6	-1.0

Hooghiem et al., ACPD

Wildfire smoke in the lower stratosphere identified by AirCore & LISA Observations September 2017



CLaMS backtrajectories starting from the observed CO plume at 13 – 14 km Sodankylä on Sep. 5 2017, the starting points were reset at locations marked in green based on the matches with CALIOP data, and the magenta dots are the matches with the plume shown in Peterson et al., 2018 on Aug. 14 2017 (figure provided by Dr. Jens-Uwe Grooss).



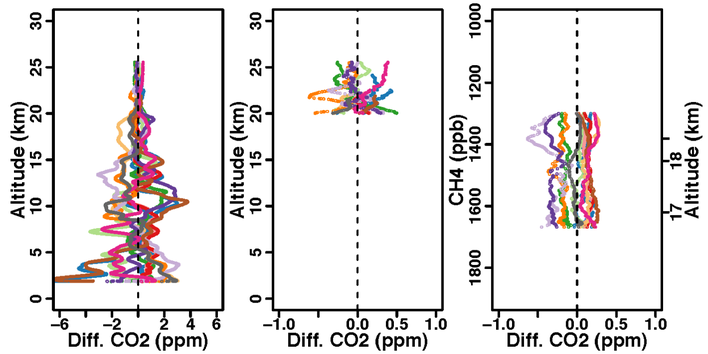
The ratio of $\Delta CO/\Delta CO_2$ of the observed plume, original and after OH-corrections

- 50 ppb ppm^{-1} by Jost et al., 2004 (10 – 14 days old)
- 48 - 73 ppb ppm^{-1} by Andreae et al., 2001 (9-10 days old)

Hooghiem et al., ACPD

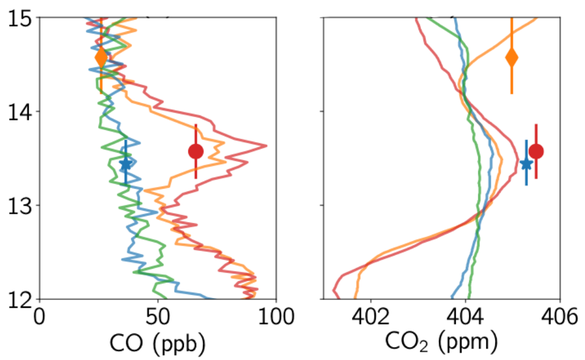
Conclusions & Future work

- AirCore & LISA cost-effective tools for stratospheric greenhouse gas and related tracer measurements



- AirCore mole fraction uncertainties
  - Mole faction CO_2 0.15-0.20 ppm (vs. 0.10 ppm due to calibrations)
  - No tubing surface coating can cause large differences (up to ~ 5 ppm) for CO_2
  - Dry vs. no dry insignificant differences for stratospheric CO_2 above 16 km

- AirCore&LISA observations useful to characterize biomass burning plumes in the stratosphere



- Hemera campaign with a large balloon in Kiruna (68°N,21°E) summer 2021 (Whole air sampler, regular AirCores, mega-AirCore, mega-LISA)