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Atmospheric Measurement Techniques Discussions
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Interactive comment on "Development of a balloon-borne instrument for CO_2 vertical profile observations in the troposphere" *by* M. Ouchi et al.

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General comments:

Ouchi et al. developed a balloon-borne in situ CO2 system for vertical profile observations in the troposphere. The system has been designed to be lightweight (2kg) and relatively cheap so that it can be flown on a regular basis. The weight limit was met mainly due to the use of lightweight calibration gas bags. As the calibration gas bags may be over pressurized or be exhausted at around 10 km, which determines the upper altitude limit of the measurements by the system. To this end, it is a nice system that has been developed for CO2 vertical profile measurements. The critical part is the (in)accuracy of the system. The observed average differences between the

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CO2 sonde and other aircraft measurements were on the order of 1 ppm up to 7 km, although the differences at individual altitudes could be significantly larger than that. It should be made clear that the differences between the measurements above 7 km were much larger than 1 ppm. That being said, the reviewer is skeptical about the usefulness of the system in the real world where the potential biases in the free troposphere simulated by carbon cycle models are often smaller than 1 ppm. The system may be limited to observe the difference of large signals in the boundary layer. There is certainly a need to further improve the accuracy of such a system before it can be useful for the carbon cycle research. However, given the significant development and the detailed documentation, it is worth considering publication after making the message clear. Perhaps it will be more suitable for a technical note.

(Reply)

Our CO2 sonde system is suitable for the measurements of the CO2 concentrations in boundary layer and lower troposphere (< 7 km altitude), where the CO2 concentrations are varied of the order of 10 ppm due to the anthropogenic and natural emissions, transportation and consumption. In the carbon cycle models these altitudes are critically important. However, no low-cost in-situ measurement system was available before. The CO2 concentrations in the upper troposphere (7-10 km) are relatively stable and the absolute CO2 concentration in the 7-10 km altitude range is about 20% of that in the 0-7 km range. Since number of the experiments is small, it is difficult to explain the differences between the sonde and CONTRAIL observations at altitude above 7 km. In this article we are focusing on the altitude range of 0-7 km and have already written as follows: (L.456-458) The estimated error value up to an altitude of 7 km was 0.6±1.2 ppm for the CO2 sonde observation with a 240 m altitude resolution and 3 m s-1 ascending speed. (L. 518-522) The CO2 sonde and CONTRAIL data were consistent. The CO2 sonde data on January 31st, 2011 was in good agreement with the chartered aircraft data on the same day, but the CO2 sonde data observed on February 3rd, 2011 was larger by approximately 1.4 ppm, as compared with the chartered aircraft data obtained on the same day from the ground to an altitude of 7 km. The measurement errors of the CO2 sonde system up to an altitude of 7 km were estimated to be 1.4 ppm for a single point of 80 s period measurements with a vertical height resolution of 240–400 m.ãĂĂ

Detailed comments:

L28: It is certainly not "accurately".

(Reply)

We will delete “accurately”.

L34-35: In my opinion, the usefulness of the instrument is not justified.

(Reply)

Our CO2 sonde system is suitable for the measurements of the CO2 concentrations in boundary layer and lower troposphere (< 7 km altitude), where the CO2 concentrations are varied of the order of 10 ppm due to the anthropogenic and natural emissions, transportation and consumption. In the carbon cycle models these altitudes are critically important. However, no low-cost in-situ measurement system was available before. Actually Inai et al. already obtained scientific results using our CO2 sonde systems: Inai Y., Aoki, S., Honda, H., Furutani, H., Matsumi, Y., Ouchi, M., Sugawara, S., Hasebe, F., Uematsu, M., Fujiwara, M.: Balloon-borne tropospheric CO2 observations over the equatorial eastern and western Pacific, Atmos. Env., 184, 24-36. doi: 10.1016/j.atmosenv.2018.04.016, 2018.

L141: What’s the source of 2 kg based on the legal restriction by the US FAA? The weight limit may be higher.

(Reply)

This is the 6 lb (2.721kg) rule for unmanned fee balloons. Basically, if you fly a payload that is under six lbs, you are exempt from most FAR 101 rules of FAA. http://www.chem.hawaii.edu/uham/part101.html http://www.rfgeeks.com/HAB/FAR101/ https://stratostar.net/how-much-weight-can-a-high-altitude-weather-balloon-carry/

L139: Design of the CO2 sonde: Why was the dehumidifier not placed in front of the pump to avoid a wet pump that may be a contamination source of CO2? Does the pump create significant pressure variations in the cell of the CO2 sensor? It may be useful to monitor the cell pressure.

(Reply)

The constant-volume piston pump with a flow rate of 300 cm3 min-1 (Meisei Electric co., Ltd.), which is originally used for ozone sonde instruments, directed the gas flows from the inlets through the solenoid valves into a dehumidifier, a flow meter, and a CO2 sensor. The flow from the piston pump had pulsation and the dehumidifier vessel also worked as a buffer to reduce the pulsation.

L288 Data processing procedures: the use of cubic spline fitting curves for the observation points needs to be justified, e.g. by comparing with a linear interpolation approach to see whether the measurements will be more stable in the laboratory or will compare better with aircraft measurements in the field.

(Reply)

We will modify Table 2, and add the following sentences in the section 3b. “The results with both cubic spline and linear interpolation methods were also listed in Table 2 for the balloon-borne experiments on January 31, 2011 in the comparisons with the JAXA-NIES aircraft measurements. This clearly indicates that the cubic spline interpolation method is better than the linear one."

L388 Comparison with aircraft data: the large difference between CONTRAIL and the CO2 sonde measurements at certain altitudes, especially above 7000 m in Figure 7&8 could be partially explained by the observed large variations at low pressures seen in Figure 5, but the large part of the difference will remain unexplained.

(Reply)

It is difficult to explain the difference between the sonde and flight observations at altitudes above 7 km, since number of the experiments is small. We are focusing the altitude range of 0-7 km as written in L.456-458 and L. 518-522.

[END]

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2018-376, 2019.

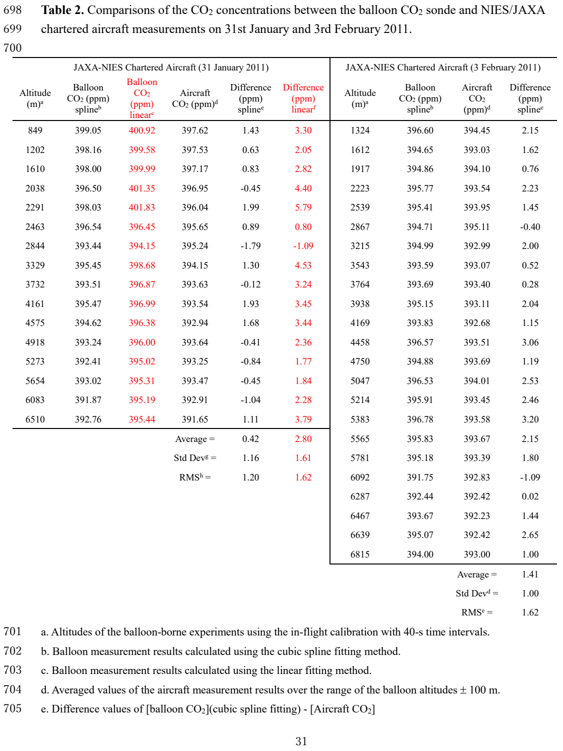

Table 2. Comparisons of the CO_2 concentrations between the balloon CO_2 sonde and NIES/JAXA chartered aircraft measurements on 31st January and 3rd February 2011.

JAXA-NIES Chartered Aircraft (31 January 2011)						JAXA-NIES Chartered Aircraft (3 February 2011)			
Altitude (m)[a]	Balloon CO_2 (ppm) spline[b]	Balloon CO_2 (ppm) linear[c]	Aircraft CO_2 (ppm)[d]	Difference (ppm) spline[e]	Difference (ppm) linear[f]	Altitude (m)[a]	Balloon CO_2 (ppm) spline[b]	Aircraft CO_2 (ppm)[d]	Difference (ppm) spline[e]
849	399.05	400.92	397.62	1.43	3.30	1324	396.60	394.45	2.15
1202	398.16	399.58	397.53	0.63	2.05	1612	394.65	393.03	1.62
1610	398.00	399.99	397.17	0.83	2.82	1917	394.86	394.10	0.76
2038	396.50	401.35	396.95	-0.45	4.40	2223	395.77	393.54	2.23
2291	398.03	401.83	396.04	1.99	5.79	2539	395.41	393.95	1.45
2463	396.54	396.45	395.65	0.89	0.80	2867	394.71	395.11	-0.40
2844	393.44	394.15	395.24	-1.79	-1.09	3215	394.99	392.99	2.00
3329	395.45	398.68	394.15	1.30	4.53	3543	393.59	393.07	0.52
3732	393.51	396.87	393.63	-0.12	3.24	3764	393.69	393.40	0.28
4161	395.47	396.99	393.54	1.93	3.45	3938	395.15	393.11	2.04
4575	394.62	396.38	392.94	1.68	3.44	4169	393.83	392.68	1.15
4918	393.24	396.00	393.64	-0.41	2.36	4458	396.57	393.51	3.06
5273	392.41	395.02	393.25	-0.84	1.77	4750	394.88	393.69	1.19
5654	393.02	395.31	393.47	-0.45	1.84	5047	396.53	394.01	2.53
6083	391.87	395.19	392.91	-1.04	2.28	5214	395.91	393.45	2.46
6510	392.76	395.44	391.65	1.11	3.79	5383	396.78	393.58	3.20
			Average =	0.42	2.80	5565	395.83	393.67	2.15
			Std Dev[g] =	1.16	1.61	5781	395.18	393.39	1.80
			RMS[h] =	1.20	1.62	6092	391.75	392.83	-1.09
						6287	392.44	392.42	0.02
						6467	393.67	392.23	1.44
						6639	395.07	392.42	2.65
						6815	394.00	393.00	1.00
								Average =	1.41
								Std Dev[d] =	1.00
								RMS[e] =	1.62

a. Altitudes of the balloon-borne experiments using the in-flight calibration with 40-s time intervals.

b. Balloon measurement results calculated using the cubic spline fitting method.

c. Balloon measurement results calculated using the linear fitting method.

d. Averaged values of the aircraft measurement results over the range of the balloon altitudes ± 100 m.

e. Difference values of [balloon CO_2](cubic spline fitting) - [Aircraft CO_2]

Fig. 1. Table 2 Revised

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