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Atmospheric Measurement Techniques Discussions

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:

The paper thoroughly describes a useful approach for measuring CO2 profiles up to an altitude of CO2 with moderate precision using balloons. The paper is well-organized and clear but has many minor grammatical errors that should be addressed before publication.

(Reply)

Thank you for your comments.

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Magnesium perchlorate is a hazardous material (oxidizer). Are there regulations that describe the maximum quantity that is allowable for this application? Perhaps a nafion membrane could be used instead if not too expensive. If calibration gases and atmospheric samples were both routed through a nafion tube then artifacts would be minimal. Several studies have shown that configurations are possible where humid ambient samples and dry standard gases emerge from a sufficiently long nafion tube with nearly identical humidity so that water-related errors become negligible. The fact that the payload is not recovered and instead "thrown away in the ocean" is unfortunate due to toxic/hazardous batteries and magnesium perchlorate, and styrofoam packaging and other components that are not biodegradable.

(Reply)

Thank you for your suggestion about the nafion membrane instead of the chemical dehumidifier. Recently, it is essential to use environmentally friendly materials. In this study, we developed the prototype of a CO2 sonde system to test the usefulness of the sonde system for the time being, in which some of the materials were not favorable for environment. Now we are replacing them. The following sentence will be added in the manuscript in the end of the section 2b: "We are trying to use more environmentally friendly materials instead of the chemical dehumidifier and styrofoam packing etc." -

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What is the approximate cost per flight (including time to manufacture and test the sensor package)? How does the cost compare to a typical charter aircraft flight such as the NIES/JAXA flights described here?

(Reply)

The costs of the NIES/JAXA observation flights were not open to public. The cost of an airplane observation depends on flight plans, types of the airplane, the degrees of modification and inspection of the airframe. Usually flight measurements cost in several ten thousand to several hundred thousand US dollars. The cost of the CO2

sonde described here is about four thousand dollars only for the equipment.

More than 20 flights have been performed. Are these data publicly available?

(Reply)

We are now preparing the papers about the results of the balloon-borne flights for the validation of thee GOSAT satellite data. The data will be open to the public in future.

Figure 3: It would be nice to include a measure of the uncertainty of the time interpolation (i.e. uncertainty bands on each of the spline curves for the high and low standard.)

(Reply)

Since the balloon-borne instrument is only equipped with one NDIR absorption cell and the balloon ascends continuously, it is not possible to measure the ambient air sample and the two standard gases at the same time and at the same altitude. Therefore, the ambient air and the two standard gases were measured time sequentially and the time interpolations were essential for the analysis. We estimated the overall uncertainties and it was difficult to identify those for the time interpolation.

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page 15, line 359 & Figure 5: The vertical error bars are said to represent "the square root of the sum of squares for the standard deviations of the sample and standard gas at each step". Is the the standard deviations of the 30s intervals that are retained for each measurement? Is the ambient air / calibration gas sequence the same as shown for the flight in Figure 3? Is there interpolation of the standards over time? It is not clear whether there is drift in the sensor response over the course of the experiment that should also be taken into account. It would be useful to try to separately estimate random uncertainty and bias.

(Reply)

In the chamber experiments, like actual balloon experiments, the ambient air and the two standard gases were measured time sequentially and the time interpolations were essential for the analysis. The chamber pressure was reduced gradually from 1010 hPa to 250 hPa in an hour, as written in L. 349-352. The signal behaviors of the NDIR cell were similar to those in Fig.3. Therefore, it is difficult to separate the random uncertainty and bias.

The black dashed line in Figure 5 seems to be quite close to the stated value of the sample gas (377.3 ppm). Was the cylinder measured separately? Or was the value inferred based on this experiment? That is, does this experiment provide information about bias? The errors given on line 361 evidently correspond to the 30-sec measurement periods, and Fig 5 seems to show that some of this variability is random. It would be interesting to see how averaging groups of points (e.g. n=3, n=5) reduces the scatter (information similar to what can be learned form an Allan variance plot).

(Reply)

The chamber pressure was reduced gradually from 1010 hPa to 250 hPa in an hour, as written in L. 349-352. The horizontal axis of Fig. 5 was pressure values. It is not adequate to calculate the Allan variance of time series data, because the experimental conditions were changing with time. The grouping of the points in Fig. 5 is not necessarily meaningful, because each data was obtained under different pressure condition. The grouping procedure corresponds to the reduction of the altitude resolution.

Fig 7 & 8. It would be useful to show the corresponding CO2 profiles from a CO2 data assimilation system or inverse model (e.g NOAA's CarbonTracker or the ECMWF/CAMS system for which simulated mole fractions are readily available or other

 similar product). Since the profiles are not co-located, some differences are to be expected, and it would be interesting to see how the modeled gradients compare to the observations. This is especially true for the case in Feb 2011, where the Contrail flight is on the previous day. Although these models are imperfect, they do a reasonable job of capturing gradients associated with weather systems.

(Reply)

We also think that the comparisons of the sonde observation results with model calculations are very interesting and reasonable, as the reviewer suggested. Since it takes time to do it, we do not present the comparisons in this article. Next time, we will perform such kind of comparisons.

Figure 9 & 10, it would be nice to also show the H2O mole fraction in panel c.

(Reply)

We will add the H2O mole fraction in panel c of Figures 9 and 10.

If length is a concern, then the information provided in the Tables could be moved to a supplement.

(Reply)

We leave the tables in the main body of article, since we think they are important to show the performances of the CO2 sonde system.

[END]

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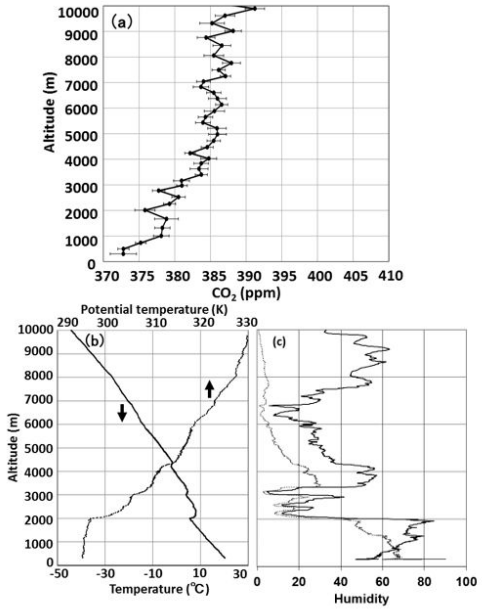

Figure 9. Profiles of (a) CO_2 mole fraction, (b) temperature (solid line) and potential temperature (dotted line), and (c) relative humidity (Solid line, %)) and water mol fraction (dotted line, x1/5000 mol/mol) observed over a forest area, Moshiri in Hokkaido, Japan by the balloon launched on August 26, 2009 at 13:30 (LST). The black circles with error bars in panel (a) represent the data obtained by the CO_2 sonde.

Fig. 1. Revised figure 9

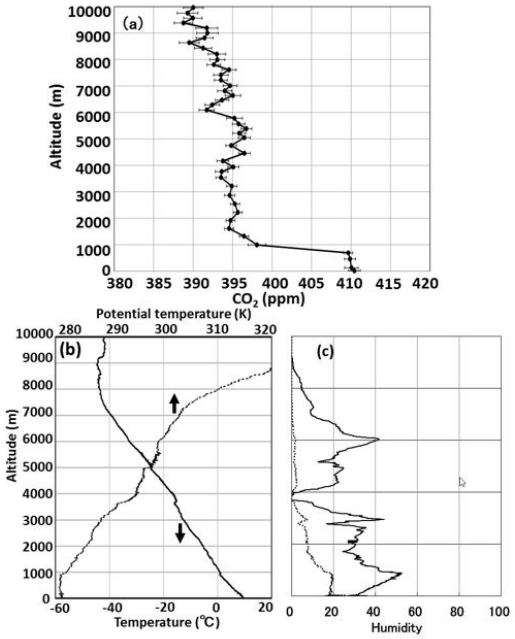

Figure 10. Profiles of (a) CO_2 mole fraction, (b) temperature (solid line) and potential temperature (dotted line), and (c) relative humidity (Solid line, %)) and water mol fraction (dotted line, x1/5000 mol/mol) observed over an urban area, Moriya near Tokyo on February 3rd, 2011 at 13:10 (LST).

Fig. 2. Revised figure 10