Atmos. Meas. Tech. Discuss., 3, C110–C114, 2010
www.atmos-meas-tech-discuss.net/3/C110/2010/


Atmospheric Measurement Techniques Discussions



# *Interactive comment on* "Total column $CO_2$ measurements at Darwin, Australia – site description and calibration against in situ aircraft profiles" *by* N. M. Deutscher et al.

**Anonymous Referee #1**

Received and published: 1 April 2010

GENERAL COMMENTS

The present manuscript describes deployment, calibration and performance of a ground-based Fourier Transform Spectrometer (FTS) at Darwin, Australia, for the purpose of $CO_2$ total column measurements within the Total Carbon Column Observing Network (TCCON). The authors emphasize that accuracy and precision are the key challenges for remote-sensing ground-based instrumentation and related data reduction techniques. The manuscript in particular suggests a thorough approach how to validate and calibrate the remote sensing FTS measurements by means of airborne in-situ observations.

The demonstrated research is innovative and well suited for publication in AMT since it combines state-of-the-art methods to estimate $CO_2$ total column concentrations with high accuracy at a tropical location making the measurements appealing for use in satellite validation and inverse modelling of sources and sinks. In general, I consider the manuscript reasonably written and the employed methods well suited to address the key challenges for ground-based total column $CO_2$ measurements.

SPECIFIC COMMENTS

In my opinion, the paper lacks in-depth discussion on some specific issues that could be of interest to the general reader. These are

- long-term precision of the FTS measurements. Unfortunately, the paper is very sparse in showing actual data although the FTS instrument has been operative since 2005 (p.994, l.2). I would be interested in a time series of $CO_2$ total column measurements that covers several months or years. This could be useful to illustrate the long-term precision and to highlight instrument problems (and their resolution) such as mirror degradation (p.995, l.19). A comparison with the colocated in-situ data time series (p.996, l.11) could help to emphasize the different (and complementary) nature of ground-based in-situ sampling and total column measurements.

- the airmass dependent correction. Appendix A describes an airmass dependent correction that is applied to the retrieved total column $CO_2$ data. The manuscript refers to this correction only very shortly (p.999, l.5) although accuracy is one of the key points of the paper. The correction is estimated to 1% (p.999, l.5) which is 10 times larger than the estimated precision 0.1% (p.999, l.24). Therefore, I recommend to add a discussion on the origin of the observed airmass dependent bias beyond a mere mentioning of "spectroscopic deficiencies". What about instrument related



AMTD
3, C110–C114, 2010





uncertainties such as uncertain knowledge of the ILS? What about a lightpath effect due to a wavelength-dependent shift of the apparent brightness center of the sun from the bright center towards the darker limb at high airmass? I am sure that the authors are aware of these and a lot of other potential causes. I would consider it very insightful to discuss these.

- the application of the FTS averaging kernel to the in-situ validation profile (p.1003, l.12). The total column $CO_2$ data are inferred from the FTS observations by scaling a first guess $CO_2$ vertical profile. It is not obvious to me how one calculates and applies the averaging kernel for such a scaling retrieval. To my knowledge, this case is not covered by the standard references Rodgers, C., World Sci., 2000, and Rodgers, C. and Connor, B., J. Geophys. Res., 2003. A more explicit discussion on this, eg. by including the exact formulae how the averaging kernel is applied, could be enlightening to me and others.

Further, I find the description of the airmass dependent correction in appendix A (p.1006) confusing and sometimes hard to follow due to the use of confusing notation ("$y_i$" vs "$X_{CO_2}$", "$\theta$" vs "$\theta_i$"). In particular, I wonder how equations (A1) and (A2) fit together. I might be missing the point here, but following from equation (A1), $X_{CO_2}^{corrected}$ should be given by

$$X_{CO_2}^{corrected} = X_{CO_2} - \beta \times S(\theta_i),$$

which is not identical to equation (A2). Please clarify the manuscript. Is it possible to motivate from physics considerations the functional form of $S(\theta)$?

MINOR COMMENTS

p.991, l.24: Vertical transport modeling errors and their impact on inverse esti-



AMTD
3, C110–C114, 2010





mates of $CO_2$ have been discussed in eg. Gerbig et al., ACP, 2008, which might be a reference to add. Besides referring to the advantage of total column measurements being little sensitive to vertical transport, the authors should mention the disadvantage that total column measurements are less sensitive to sources and sinks at the surface than in-situ sampling.

p.992, l.11: The manuscript should distinguish between precision and biases. To my knowledge, the 2.5 ppm requirement refers to precision, systematic biases must be less than "a few tenths of a part per million" (eg. Chevallier, F. et al., J. Geophys. Res., 2006)

p.992, l.28: "The TCCON can provide these data." Given that there is only one tropical TCCON station operational, this statment seems questionable. How many future tropical stations are foreseen?

p.993, l.17: I would consider carbon stocks in the tropical rainforest, deforestation, and tropical wetlands more prominent reasons to investigate the tropical $CO_2$ flux budgets than "savannahs" and "biomass burning".

p.998, l.7: What is an "absorber weighted" gravitational acceleration?

p.999, section 6: It seems awkward to me that "precision" can improve when ratioing two quantities given that "precision" contains only random errors. One could replace "precision" by "standard deviation" except for the last occurrence in l.23 which indeed should refer to a purely random error contribution (given all biases cancel in the ratio).

p.999, l.14: Please, clarify what you mean by "pressure transducer variability".



AMTD
3, C110–C114, 2010

TECHNICAL COMMENTS

p.991, l.10: $X_{CO_2}$ is undefined at this point.

p.992. l.19: this site ->? the site considered here

p.993, l.27: . . . and Sect. . . . -> (split in 2 sentences)

p.995, l.1 and throughout the manuscript: mb ->? hPa or mb ->? mbar

p.995, l.10: $X_{CO_2}$ is undefined at this point.

p.996. l.18: measured ->? model assimilated

p.998, l.14 and throughout the manuscript: $X_i^{dry}$ -> $X_i$

p.1003, l.11: are allocated errors -> ? have/exhibit allocated errors

p.1004, l.21: dominate the derived column. -> ? dominate the derived column error.

---

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 989, 2010.