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Interactive Comment

Interactive comment on "Analysis of the PKT correction for direct CO_2 flux measurements over the ocean" *by* S. Landwehr et al.

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Response to Mingxi Yang's comment

General comments:

RC: This paper describes a recent set of air-sea CO2 eddy covariance flux measurements. Four effectively closed-path CO2 sensors were used, two dried to minimize the bias due to H2O cross-correlation, two undried (i.e. sampling moist air). Using flux from the dried sensors as reference, the authors convincingly demonstrated that the correction scheme based on similarity theory (i.e. PKT correction) does not remove the bias in the measured CO2 flux from the undried sensors under conditions of large latent heat flux.

The direct measurement of air-sea CO2 flux is obviously essential for the understanding of global carbon cycling and climate, with the open path sensors (e.g. Licor 7500) widely used. Since its publication (Prytherch et al. 2010a), the PKT method has been tried by several authors to correct eddy covariance CO2 flux. Thus it is important for the paper under consideration to be published.

The content of the paper is sound. Moreover, Referee #1 (who published the PKT method) already agreed with the authors of this paper. I only have a few anecdotal and editorial comments below:

AC : We wish to thank Mingxi Yang for his attention to our submission and the provided comments and suggestions that helped us to advance the publication.

RC: 1) The authors missed an opportunity to strongly recommend the drying of IRGA sensors, which appears to be the most reliable method thus far for making CO2 measurements.

AC : We appreciate the suggestion and added a sentence to the conclusion recommending the Miller et al (2010) method.

RC: 2) How does H2O cross-contaminate the CO2 flux? It's probably not related to sea salt, since the 7200 sensors are operated inline during this experiment. Knowing the cause for this cross-contamination might lead to improvement in open-path CO2 sensors. Any educated guesses?

AC : We are aware of the importance of this problem for the air-sea gas-exchange community and will continue searching for a solution. However at the current stage we have no educated guess.

RC: 3) This cross-contamination presumably cannot be clearly identified in the cospectrum. The authors can mention that spectral analysis by itself is inadequate as a quality control filter for CO2 fluxes.

AC : The following sentence was added to Sect. 2.1 "It has to be noted here, that the

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co-spectra of CO2 and H2O are similar. Therefore a cross-contamination of the CO2 signal with H2O can not be clearly identified by spectral analysis."

RC: 4) For the gas exchange community, it would be insightful for the authors to obtain the data from Prytherch et al. 2010b and see what the k values from HiWASE are like only for conditions of near-zero latent heat flux.

AC : The scope of this contribution is to show that the PKT correction is not as successful as initially considered, and that the "closed path with diffusion dryer" method is the only reliable one for making EC flux measurements of CO_2 over the ocean with Licor sensors. We would find it more appropriate for the authors of Prytherch et al. (2010b) to re-publish the HiWASE data and derived *k* values. However, it should be noted that for this study, the chosen latent heat flux limit of 7 Wm^{-2} did restrict the wind speed range to 11 ms^{-1}.

Specifics:

RC: Another recent paper that utilized the PKT correction (and suggested that it did not work) is Ikawa et al. (2013) (www.biogeosciences.net/10/4419/2013/).

AC : Thanks! We added a reference to Ikawa et al. (2013) and Huang et al. (2012) in the introduction and to table 1.

P 28282, line 18. Rather than "restricted to", it's more accurate to says "the EC method provides relatively robust CO2 flux measurements (uncertainty of $\sim$ %) in regions with air-sea gradient. . . "

AC : The text was changed following the suggestion.

RC: P 28283, line 9. The point of having a very high flow rate is to maintain a fully turbulent flow. Would be more insightful to present the critical Reynolds number here in addition to the number of SLPM.

AC : We added the critical Reynolds number of 2100 here and also give an estimate of

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the Reynolds number for the flow in the inlet tubing in Section 2

RC: 28285, line 9. What temperature was the inlet heated to, in order to preserve the latent heat flux? Water vapour is well known to be "sticky." Thus even in the absence of condensation, significant attenuation of water vapour flux at high frequencies is possible.

AC : The inlet tubing temperature was not recorded continuously, but the LICOR temperature sensors recorded temperatures ranging from 23℃ to 36℃ at an outside air temperature ranging from 8℃ to 16℃. We cannot ensure that the water vapour flux was fully resolved by the un-dried sensors. However this does not affect the CO2 flux measurement, since the air-density flux correction is done with the humidity fluctuations in the measurement volume.

RC: 28287, line 3. The authors haven't showed that the IRGAdry measurements are completely unbiased. For example, was 97% of the H2O removed by the drier, as in Miller et al. (2010)? Also, is there any residual contribution of sensible heat flux to IRGAdry?

AC : We added Fig. 1 to the manuscript to show a time series of the air-density bias fluxes in comparison with the CO2 flux measured by the IRGA *dry*. The application of the diffusion dryer reduced F_q in average by 93%, from 36Wm^{-2} average latent heat flux magnitude to 2.4Wm^{-2}. All four IRGAs do also need a non-zero correction for sensible heat flux and the cross-correlation of pressure and vertical wind speed. We did however not find a correlation between the pressure or temperature bias fluxes and differences between the final CO2 flux estimates. As far as our observations go, the problem seams to be solely with H2O.

RC: P 28288, line 2. The Wanninkhof (1992) parameterization is now widely accepted to be too high due to a bias in the global radiocarbon estimate. This should be acknowledged if cited. If the authors believe k to be a quadratic function of wind speed, the Sweeney et al. (2007) parameterization would seem more appropriate.

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AC : We do not favour any parameterization but decided on picking one that is widely used in the gas-exchange community, to put our CO2 flux measurements in context. However, as you mention Sweeney et al. (2007) have shown that Wanninkhof (1992) needs to be corrected, we updated the parameterization used in Fig. 3.

RC: Line 8. Why did IRGAwetA give much larger scatter than wetB?

AC : This is not clear to us, but we assume that understanding why the two IRGA did behave different will help understanding the bias and mabye correcting for it.

RC: P 28290, line 4. "To investigate the unsatisfactory. . ." instead of "in the light of the unsatisfactory. . ."

AC : This sounds better, thanks.

RC: P 28290, line 15, parenthesize 0 in xc0 to be more consistent

AC : Did this; thanks

RC: p 28292, line 11. definition of F0TS? Line 21. "Overestimation of CO2 flux magnitude"

AC : The definition was added and the word "magnitude" added to the text.

RC: P 28294, line 3. As this is the summary section, rather than using nomenclatures, you can simply say that the PKT correction applied to undried IRGAs reduced the scatter but did not reduce the bias in flux compared to dried IRGAS. Line 11. ". . .to retrieve the true CO2 flux from. . ."

AC : We removed the nomenclature from the conclusion and the word "true" inserted. It reads easier now, thanks!

RC: Fig 3 Legend "flux calculated based on the parameterization of. . ."

AC : This was changed.

RC: Fig 4. Legend "Difference between. . ."

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AC : This makes more sense.

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References Cited

Huang, Y., Song, J.,Wang, J., and Fan, C.: Air-sea carbon-dioxide flux estimated by eddy covariance method from a buoy observation, Acta Oceanol. Sin., 31, 66–71, doi: 10.1007/s13131-012-0253-5, 2012.

Ikawa, H., Faloona, I.,Kochendorfer, J., Paw U, K., T., and Oechel, w., C.: Air–sea exchange of CO_2 at a Northern California coastal site along the California Current upwelling system, Biogeosciences, 10, 4419—4432, doi: www.biogeosciences.net/10/4419/2013/, 2013.

Miller, S. D., Marandino, C., and Saltzman, E. S.: Ship-based measurement of air–sea CO_2 exchange by eddy covariance, J. Geophys. Res., 115, D02304, doi: 10.1029/2009JD012193, 2010.

Prytherch, J., Yelland, M. J., Pascal, R. W., Moat, B. I., Skjelvan, I., and Neill, C. C.: Direct measurements of the CO_2 flux over the ocean: development of a novel method, Geophys. Res. Lett., 37, L03607, doi: 10.1029/2009GL041482, 2010a.

Prytherch, J., Yelland, M. J., Pascal, R. W., Moat, B. I., Skjelvan, I., and Srokosz, M. A.: Open ocean gas transfer velocity derived from long-term direct measurements of the CO_2 flux, Geophys. Res. Lett., 37, L23607, doi: 10.1029/2010GL045597, 2010b.

Webb, E. K., Pearman, G. I., and Leuning, R.: Correction of flux measurements for density effects due to heat and water vapour transfer, Q. J. Roy. Meteor. Soc., 106, 85–100, 1980.

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Fig. 1. (Fig. 4 in the revised manuscript) Time series of the bias fluxes in Eq. 3, caused by air density fluctuations (Webb et al., 1980). Top: Bias flux caused by humidity fluctuations F_q upstream of the dryer *wet* and down stream *dry* and the CO2 flux F_c as measured by the IRGA *dry* (there are only small differences between *A* and *B*). Bottom: Bias flux caused by temperature fluctuations F_T as measured by the bow mast sonic and as measured by the CP-IRGAs, and the bias flux caused by pressure fluctuations F_P.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 28279, 2013.

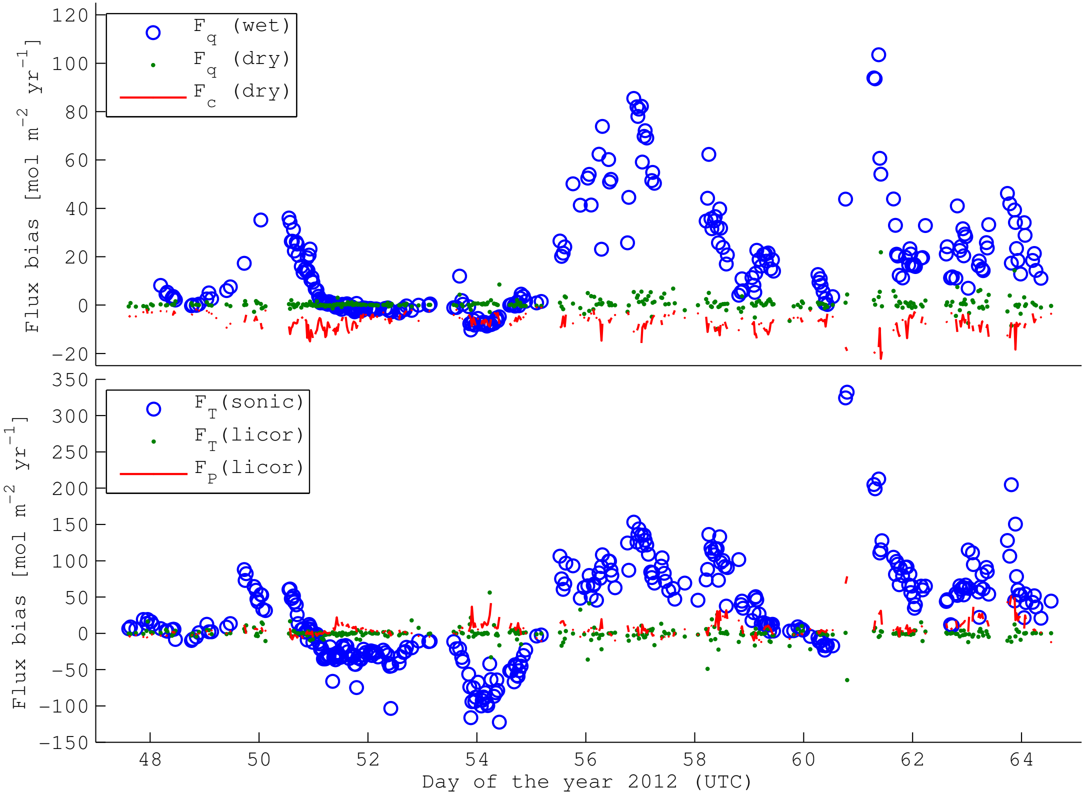

Fig. 2.

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