

***Interactive comment on* “Uncertainties in wind speed dependent CO₂ transfer velocities due to airflow distortion at anemometer sites on ships” by F. Griessbaum et al.**

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Received and published: 19 April 2010

Reply to Anonymous Referee 1

RC1: It would have been nice to have included a discussion of the turbulent spectra and potential implications for eddy covariance studies, but I appreciate that that was outside of the scope of the intended paper.

Answer1: The effect of flow distortion on ship born eddy covariance measurements is addressed in another paper, currently in preparation.

RC2: One point to consider is that the same sorts of wind speed errors are inherent in

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both the observations used to derive k (from dual tracer studies etc.) and those used to estimate fluxes (from research vessels or VOS's). Doesn't this mean that these biases should cancel (at least to some extent)? ie, the parameterizations were derived with overestimated winds, but the flux calculations are also made using overestimated winds. Perhaps the authors should address this point in the manuscript.

Answer2: The biases would only cancel if the derivation of k , and the flux calculations are obtained using data from the very same ship/platform and anemometer location. However, a small change nearby the anemometer location, e.g. new instrumental boxes or instruments, or e.g. a temporary container fixed on the deck, can change the wind speed bias significantly. In addition, since the mean bias depends on the wind speed and the relative wind direction, these would have to be the same for the biases to cancel. Where different platforms are used, the biases could even add together, if one platform tended to bias the wind speed measurements low and the other high. In general, "similar" shaped ships/platforms should also cause similar biases in wind speed measurement. However, the location of the anemometer is highly variable among the platforms, causing different biases. Furthermore, if k is derived from a research ship/platform, and then applied on wind speed measurements obtained from a different type of platform or from e.g. satellite, the pattern and scale of biases is completely different. Due to the fact, that the bias on wind speed has a big impact on wind speed depended gas exchange, we strongly recommend to use only flow distortion corrected wind speed data. We will include this issue in the manuscript.

RC3: I also wondered to what extent uncertainty in wind measurements was incorporated into the published uncertainties associated with various parameterizations. It would be worth noting whether this was included in various studies, or not. I seem to remember that wind speed errors were discussed in detail in some of the early dual tracer papers. Overall, I think this is a useful contribution to the field and to ACP.

Answer3: Problems in wind speed were discussed in various studies concerning transfer velocity experiments and application of the derived wind speed parameterisations.

Discussed problems are wind speed distribution effects on CO₂ flux calculation (e.g. Wanninkhof, 1992), the standard correction of wind speed to 10 m measurement height asl (e.g. Nightingale et al., 2000, Ho et al. 2006), wind sector control to exclude heavily disturbed wind directions (e.g. Wanninkhof and McGillis, 1999, McGillis et al., 2001a, Jacobs et al., 2002, Weiss et al., 2007), and the correction of flow distortion by a simple numerical model of nearby instruments (e.g. Jacobs et al., 2002). Other studies do solely mention the effect of flow distortion (e.g. Ho et al. 2006) or refer to an earlier flow distortion intercomparison of a bulky and a non-bulky platform to estimate the flow distortion effect on flux measurements (Edson et al., 1998, McGillis et al., 2001a). Some studies also intercompare ship based measurements – not corrected for flow distortion - with satellite based measurements to try to improve data quality (e.g. Wanninkhof 2004, Ho et al. 2006).

In summary, the community is aware of wind speed biases measured from bulky platforms. There are attempts to minimize the flow distortion effect by different means as e.g. wind sector control, or anemometer locations far away from the platform (e.g. foremast top or boom). However, as shown in this study, even well selected locations and wind directions are still subject to significant wind speed biases.

Reply to Anonymous Referee 2

RC1: A significant omission of the paper is the lack of reference to satellite scatterometer wind data. Reading the paper one would think that all gas exchange parameterizations are based on ship- or platform-based wind measurements. In fact many studies, including ones cited in the paper, are based on satellite scatterometer winds which are not subject to the flow distortion errors. However the point can still be made that in order to compare ship-based wind speed parameterizations with satellite-based ones, it is necessary to address the airflow distortion effect.

Answer1: Scatterometer products usually employ in-situ wind measurements from buoys as ground truth. It might be hoped that this would lead to scatterometer winds

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being un-biased but in practice there are many unresolved problems when winds from different remote-sensing platforms are compared to each other, with significant global mean biases (order 1 m/s, e.g. Schlaw et al., 2001) observed and larger or smaller biases seen depending on time and location. A discussion of scatterometer winds is outside the scope of the paper, but a note will be made in the paper that mean wind speed biases should be taken into account, whatever the cause of the bias. We will include also the point “in order to compare ship-based wind speed parameterizations with satellite-based ones it is necessary to address the airflow distortion effect.” in the manuscript.

Schlaw MG, Chelton DB, Freilich MH, 2001: Sampling errors in wind fields constructed from single and tandem scatterometer datasets. Journal Of Atmospheric And Oceanic Technology. 18 (6), 1014-1036

RC2: The opening sentence of the Abstract should be expanded to include platforms (as well as research vessels and merchant ships), since 3 of the 4 parameterizations in Table 1 and Figure 5 are based on platform rather than vessel measurements.

Answer2: This will be adapted in the manuscript.

RC3: p 18841 line 3: The description of the gas flux equation is somewhat loose. $p\text{CO}_{2,sw}$ is described as the concentration of CO_2 , but technically it is the partial pressure of CO_2 . The convention is to use C for concentration, ie $k = F/(C_w - C_a)$.

Answer3: This will be adapted in the manuscript.

RC4: p 18842/3 There are several paragraphs of discussion concerning voluntary observing ships (VOS). While the airflow distortion aspects are well referenced, there is a lack of reference to their use for measurement of CO_2 fluxes, which is the novel theme of this paper. How widespread is the use of VOS for CO_2 fluxes, or what is the likely use in the future? e.g. Padin et al. (2007) J. Mar. Sys.

Answer4: Estimates of the global air-sea exchange of CO_2 are based on climatologies

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of the delta $p\text{CO}_2$. These are in turn derived on in-situ measurements made from research ships, moorings and VOS (e.g. Padin et al. 2007) or other ships of opportunity. A number of countries are involved in equipping ships with underway CO_2 systems, and given the lack of in-situ data it is hoped that these efforts will be continued, and expanded upon (refer for instance to the Carbon Dioxide information Analysis Center CDIAC: <http://cdiac.ornl.gov/oceans/home.html>). This issue will be included in the introduction.

X.A. Padin, M. Vázquez-Rodríguez, A.F. Ríos, F.F. Pérez, 2007. Surface CO_2 measurements in the English Channel and Southern Bight of North Sea using voluntary observing ships/ Journal of Marine Systems, Volume 66, Issues 1-4, June 2007, Pages 297-308

RC5: In the Methods section it is stated that the initial conditions of the simulation include a turbulent regime downstream. If this was the case, then could the authors elaborate on the turbulence parameters used to initialize the simulation? Commonly, simulations are started with laminar flow, and allowed to evolve into a turbulent regime.

Answer5: Yes, the sentence in the manuscript is a bit ambiguous. Actually, the turbulent regime is developing with time, and not initially defined in the simulation. We will describe this more clearly in the manuscript.

RC6: The Summary and conclusion section provides valuable advice for minimizing the impact of flow distortion effects around the hull. I would like to see some guidance on avoiding flow effects from pedestal effects which the authors have shown to be important, based on the modelling.

Answer6: At best case, we would provide a parameterization or a rule of thumb, how far an obstacle has to be away from the wind measurement. However, the obstacles, as e.g. pedestals are not uniformly shaped. In addition, the “global” flow distortion effect of the platform (e.g. ship) is interfering with a local flow distortion effect as it is caused by a pedestal.

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Hence, we will include a rather “qualitative” guidance into the manuscript:

- The pedestal should be small in size, and the floor plate should be not a closed type (e.g. metal plate, better: grate type floor), which is causing vertical wind blockage.
- The wind sensor should be mounted as high above and most possible ahead of the pedestals (into the main wind direction; on ships is that to the bow, in terms of minimum hull induced flow distortion)

Previous studies on effects of a cylindrical mast to wind measurements recommend that the anemometer should be located not less than three mast diameters from the mast (Gill et al. 1967) to achieve wind measurements within 5 % accuracy. Another study (Perrin et al. 2007) found, that an error of less than 1 % is expected for an anemometer mounted at the wind ward side of the tower and five times the diameter (of the mast) above the mast. However, these are rules for cylindrical masts, and can not be applied to evaluate the effects of pedestal platforms to the wind measurement.

Gill, G. C., L. E. Olsson, J. S. Sela, and M. Suda, 1967: Accuracy of wind measurements on towers and stacks. Bull. Amer. Meteor. Soc., 48, 665–674.

RC7: p18852 | 23: The wording says that k will be biased by a factor of 2 or 3 (i.e. 200

Answer7: This will be corrected in the manuscript

RC8: p18853 line 13 cubical -> cubic. Table 1 caption: ist -> is

Answer8: This will be corrected in the manuscript

We thank all the reviewers for their time and effort.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 18839, 2009.

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