Biogeosciences Discuss., 8, C5782–C5786, 2012
www.biogeosciences-discuss.net/8/C5782/2012/

Biogeosciences Discussions

Interactive comment on "Sea-to-air and diapycnal nitrous oxide fluxes in the eastern tropical North Atlantic Ocean" *by* A. Kock et al.

A. Kock et al.

akock@ifm-geomar.de

Received and published: 16 February 2012

We thank referee #2 for the very helpful comments on our manuscript. We thoroughly considered them during revision and believe we have thereby further improved the manuscript.

R2: "Sea-to-air fluxes are shown in Table 1. I think it would be more valuable if more information (i.e. wind speed, temperature and Δ N2O) was given. The significant figures of fluxes shown in Table 1 should be checked and keep consistent. Since the sea-to-air N2O fluxes estimated from the Tsai and Liu (2003) parameterization are much lower than those estimated by other more frequently used parameterizations, but still were thought as reasonable, more information about this parameterization should be given in the text. In particular more discussion on its reasonability and reliability should be

addressed. It is not reasonable to attribute the discrepancy to surfactant only because Tsai and Liu (2003) parameterization yield an appropriate flux to close the budget. How were the uncertainties to estimate diapycnal N2O fluxes and vertical advective fluxes in this manuscript? The choice of winds peed parameterization introduces considerable uncertainty into the estimate of N2O air-sea fluxes as shown in Table 1. Will all these uncertainties contribute much to the discrepancy between the sea-to-air and diapycnal fluxes of N2O?"

Author response: We disagree with the referee that significant information can be obtained from the inclusion of additional parameters in Table 1. The purpose of this table is the comparison of the different flux contributions to the mixed layer budget of N2O and contains the average fluxes during the period of the cruises, which, in total, covered more than six weeks in two different years. SST, wind speed and ΔN2O showed a large spatial and temporal variability throughout the area and the sampling period, and the inclusion of the average values of these parameters does not provide substantial information that improves the interpretation of the budget calculations.

The uncertainties of the sea-to-air fluxes, calculated with a Monte Carlo simulation, and diapycnal fluxes, calculated from error propagation, are given in the text as well as in Table 1. The uncertainty of the gas exchange coefficient was accounted for by the application of different gas exchange parameterizations to the calculation of the sea-to-air flux, as the common air-sea parameterizations do not provide statistically robust information on the uncertainty of the gas transfer velocity for an error estimate.

Additional information on the wind speed parameterizations is given by the addition of Figure 2 that shows the wind speed dependence of the gas exchange coefficient of N2O from the parameterizations used in our calculations. Furthermore, the plausibility of the application of this parameterization is discussed in the text:

"However, the gas exchange under the influence of surfactants is not well constrained so far, because a) the distribution of surfactants in natural waters is difficult to determine

and b) the influence of surfactants on gas fluxes is not well understood. Biological production has been identified as main source for surface slicks (Lin et al., 2002;Wurl et al., 2011), and SeaWiFs chlorophyll images (not shown) show that the investigated area was highly productive during the sampling periods. The occurrence of surfactants was furthermore associated with high intensities of solar radiation (Gasparovic et al., 1998) which can be found in the tropical upwelling areas. Therefore, the Mauritanian upwelling provides very favorable conditions for the occurrence of surfactants while their extent and individual distribution during the time of the sampling may show large variability, though.

The parameterization of Tsai and Liu (2003) is based on the experiments of Broecker et al. (1978), resulting in 70-80% reduced fluxes for CO2 . This is in the upper range of observed reduction rates (Salter et al., 2011;Upstill-Goddard, 2006;Schmidt and Schneider, 2011) and may therefore slightly overestimate the reducing effect of surfactants. However, recent publications point to a relatively large effect of surfactants on gas exchange (Schmidt and Schneider, 2011;Salter et al., 2011), and the applicability of the parameterization of Tsai and Liu (2003) for the budget calculation demonstrates that this effect may have a large impact on gas fluxes in upwelling areas."

R2: "The authors should compare their estimated sea-to-air fluxes and diapycnal N2O fluxes with published results from other upwelling regions."

Author response: We agree that the manuscript would improve by comparing our flux estimates to estimates from other upwelling regions. A comparison of our sea-to-air and diapycnal fluxes with other N2O fluxes from upwelling regions was included in the revised version of the manuscript that now states:

"Rees et al. (2011) calculated sea-to-air fluxes from upwelling filaments of the Mauritanian upwelling in a similar range to our results. Compared to other coastal upwelling systems, the average N2O fluxes from the Mauritanian upwelling are relatively low (Charpentier et al., 2010;Bange et al., 1996)."

Additionally, we added some lines to put the diapycnal fluxes in a broader perspective by adding:

"As shown by Schafstall et al. (2010), diapycnal mixing along the upper continental slope and the lower shelf region of the Mauritanian upwelling is strongly enhanced due to presents of non-linear internal tides that form due to critically sloping topography (e.g. Holloway, 1985). Diapycnal nutrient fluxes calculated for the upwelling region are amongst the highest reported to date (Schafstall et al., 2010). Nevertheless, diapycnal N2O fluxes from other coastal upwelling regions reported by Charpentier et al. (2010) are in the same order of magnitude as the diapycnal fluxes inferred here."

R2: "Wind speeds: This is important for the calculation of the air-sea fluxes because they heavily depend on the applied wind speeds. It was mentioned in the method section that wind speeds were obtained from the ship's underway observations (page 10232, lines 22-23). However, in section 3, the sea to air N2O fluxes were mentioned to be calculated from 3 day mean QuikScat wind speed (page 10235, lines 5-7). Does that mean different types of wind speeds were used for different parameterizations? The authors do not make this clear. Please give more details of the used wind speeds."

Author response: Indeed, the sea-to-air fluxes of N2O were calculated for the individual stations using in-situ wind speeds from the research vessels' underway data while for the regional estimate 3 day mean QuikScat wind speeds were used as in-situ measurements were not available for the whole region. All budget calculations were performed using the same wind speeds with the different gas exchange parameterizations, however. To clarify which wind speeds were used for the individual calculations, additional information is given in the methodological section of the revised manuscript:

"Wind speeds were obtained from the ships' underway observations for the calculation of the sea-to-air flux at the individual stations. For the calculation of regionally averaged sea-to air fluxes, we used three day mean QuikScat wind speeds (ftp://ftp.ssmi.com/qscat/bmaps_v03a/)."

Additionally, we altered the beginning of the Results and Discussion section to clarify our approach that is now stating:

To illustrate the N2O sea-to-air and diapycnal fluxes the estimates from the individual stations were projected onto the distribution of topography along 18°N (Fig. 3). For this comparison, wind speeds from the ship's underway measurements were used to evaluate sea-to air fluxes.

R2: "Figure 2: The symbol used in this figure is not clear enough, hence I suggest changing to other symbols."

Author response: We agree with the referee and changed the figure accordingly.

R2: "Figure 4: Box plot may be better to show the variations and average of N2O fluxes for different regions."

Author response: We agree with the referee that a box plot may show the average and the variations of the N2O fluxes more clearly. However, this information is already given in the text, and the purpose of Figure 4 is to show the dependency of the diapycnal fluxes from the water depths at the individual stations which, from our point of view, is well represented in our figure.

Interactive comment on Biogeosciences Discuss., 8, 10229, 2011.