DMS gas transfer coefficients from algal blooms in the Southern Ocean

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Summary

This paper presents the results of a study of air-sea exchange of DMS undertaken off New Zealand, with a significant fraction of the measurements being undertaken within or around algal blooms – strong sources of DMS.

The DMS gas transfer velocity results are in good general agreement with previous studies, but show a high degree of scatter. A notable and welcome feature of the paper is the extensive analysis of the nature of this scatter and the identification of a mismatch between the flux footprint upwind of the ship and the location of the mean water-side DMS concentration measurement (at the ship) used to determine the air-sea concentration gradient and hence transfer velocity. This spatial offset is identified through a lag analysis of mean concentrations and wind-speed normalised flux to be about 2.5km. Compensating for this reduces the scatter in the measurements. This is the first time this analysis has been undertaken and is a significant result.

The paper is clear and well written, and for the most part a pleasure to read – a few minor points are noted below, along with mostly minor issues and suggestions relating to the analysis.

Publication is recommended after these issues are addressed.

Detailed Comments

P28456, line 2 – it would be useful to list the compounds for which gas transfer estimates have been made via eddy covariance here.

P28460, line 5 – the reader is referred to Bell et al. (2013) for details of the eddy covariance flux calculations. Following that reference it appears (from section 2.4, paragraph 5) that flow distortion over the ship is considered only as a source of uncertainty in the eddy covariance measurements (which is true), but no consideration is made for the effect of flow distortion on the mean wind. The mean flow over the ship is lifted and (depending on location) accelerated or decelerated relative to the free-stream flow at the same level. This means that the measured mean wind is (usually) biased, and hence U_{10} is biased. This can have a significant impact on the parameterization as a function of U_{10} and hence on the differences between estimates made from different ships. See for example Griessbaum et al, (2010).

A series of computation fluid dynamics modelling studies of the distortion over various research ships has been made by Margaret Yelland and Ben Moat at NOC (publications and internal reports on all these are available at: http://noc.ac.uk/project/wages/cfd-modelling-research-ships). Notably the RV Tangaroa is among the ships modelled and with corrections for the flow distortion available (report: http://eprints.soton.ac.uk/38483/). Inclusion of this correction to the mean wind would be highly beneficial (a quick look at the figure for the Tangaroa on the web page suggests it is, however, not a large distortion).

P28461, eqn 5 – the waterside only transfer velocity k_w, and subsequently k_{600} are derived using the measured total transfer velocity, K_{DMS} and the air-side transfer velocity, k_a, obtained from the NOAA COARE bulk flux algorithm. The results thus depend on the validity of the NOAA COARE algorithm; any bias in its K_a value will impact the value of k_w. Although K_w dominates the total transfer velocity, some discussion of the uncertainty associated with the reliance on NOAA COARE should be included. This is potentially relevant to the occasional non-random divergence of the COARE gas transfer velocity from the measured estimates noted at the bottom of p28463.

P28464, line 3 – the line of best fit to the observed transfer velocities as a function of wind speed is discussed, but not shown on the relevant figure (fig 3a) where on the NOAA COARE function is shown. It would be useful to the reader to have the best fit show too.

P28465, line 7 – the authors state that for both this (SOAP) cruise and a previous cruise on the Knorr, the use of a geometric mean rather than arithmetic mean results in a 'shallower slope' of k_{600} with wind speed. I think this gives a slightly misleading impression. For the SOAP cruise one might make this interpretation, but for the Knorr cruise data all you can really say is that the geometric means are lower than the arithmetic means.

P28465, line 10-20. The reduced transfer velocity at high winds is convincing for the Knorr cruise, but rather less so for SOAP since it applies only to a single wind speed bin. In the absence of the Knorr data I would discount this point as an outlier – small data volume, and potentially suffering from the limitations inherent in evaluating data at the limit of the independent variable (over bulk of range a wind bin may include include values from both increasing and decreasing winds, at the upper limit it can include values from increasing or constant wind only, by definition). Taking the Knorr data into account also, lends some support to this suppression being a real effect. The substantial difference in wind speed at which the suppression begins is then notable and worthy of discussion (or at least speculation).

Line 19 – the authors suggest the suppression of transfer velocity might arise from a suppression of near-surface turbulence, but fail to specify whether that is in the water, air, or both.

P28467 – the discussion of the spatial mismatch between flux footprint and estimate of air-sea concentration difference is a really nice piece of work, and highlights the significant challenges of making such measurements. The comparison with the flux footprint model raises some questions because it fails to reproduce a spatial offset as large as that implied by the measurements. I suggest this might arise because of the slightly different physical properties being evaluated by each approach. The flux footprint model evaluates the fraction contribution to the total flux as a function of distance upstream – crucially is assumes spatially homogeneous conditions. The observational approach maximises the correlation between water-side DMS concentration and the U_{10}-normalised DMS flux* – crucially the surface source is NOT spatially homogeneous. The location of the peak contribution to the flux is thus not (necessarily) the same as the peak in the footprint model. Where the DMS gradient increases with distance upwind, the maximum flux contribution would be expected to be further upstream than implied by the model. This is predominantly the case here, where the perturbations in DMS concentration and normalised flux used to evaluate the lag here are dominated by increase in DMS concentration upstream. It is difficult to assess confidently by eye, but my impression from Figure 7, is that the increase in flux precedes an increase in DMS concentration by more than the subsequent decrease in flux precedes the decrease in concentration. It would be interesting to partition the time series into portions that show an increase or decrease in DMS, and see if different lag intervals are produced when these are analysed separately.

*as an aside, surely you ought to maximise the correlation between the DMS gradient (water-air) not just water concentration, since this is what drives the flux...granted this is dominated by the water side concentration.

Minor issues

There are a few statements in the text to the effect that 'figure N describes/plots' etc... One could argue the ability of a bit of ink on paper (or pixels on screen) to actively do anything. Better to describe the data not the figure: 'The gas transfer velocities are shown in figure 7' rather than 'Figure 7 also plots gas transfer velocities...'. Also, it would be useful to label each panel (a), (b) etc to allow easy reference to 'figure 7e' rather than having to describe where in the plot the panel is.

There is a movement afoot to improve figure quality and readability, and stop using rainbow colour maps (matlab's default 'jet' map, as used in several figures here). It's not readable by anyone with red/green colour blindness, and suffers from over-emphasis of a couple of colour transitions that give a misleading idea of gradients. See:

http://www.climate-lab-book.ac.uk/2014/end-of-the-rainbow/

http://www.climate-lab-book.ac.uk/2014/which-colour-scale/

and consider switching to an alternative colour map.

References

Griessbaum, F., Moat, B.I., Narita, Y., Yelland, M.J., Klemm, O., Uematsu, M. 2010 Uncertainties in wind speed dependent CO2 transfer velocities due to airflow distortion at anemometer sites on ships. *Atmospheric Chemistry and Physics*, 10, 5123-5133. doi:10.5194/acp-10-5123-2010