Author's response to comments by Reviewer 3 (Biogeosciences Discuss., 12, C3507–C3508, 2015).

By

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We thank the Reviewer for the positive and constructive comments. Below, all comments from the Reviewer are written with '*italic*' font. Our responses are written with 'normal' font.

The manuscript by Berg et al. presents a new method for correction of benthic flux measurements using a fast oxygen sensor with an AUV. The correction makes use of periodic vertical advection of the oxygen gradient to find the effective time offset between the velocity and oxygen data. The paper represents a novel and valuable contribution. My recommendation is for publication with response/attention to further comments listed below.

I'm a bit uneasy about the magnitude of the time offsets that are calculated. Lags of nearly 2 seconds are observed, comparable to the wave period and much larger than the response time of the instrument. It's apparent that the authors are similarly uncomfortable based on the discussion on pg 8410, where this is attributed to 'phyto-detritus'. Presumably this would result in a slower sensor response. It's unclear whether this slow response would affect the flux calculation. Berg et al. 2015 suggests that a lag of 0.51 would have minimal effects on the flux, although a 2 sec. lag suggests a much slower sensor response.

The second data example (Fig. 6) had the largest time lag with an average of 1.1 s and a wave period of 2.3 s. And yes, we find that the most likely explanation for this relatively large time lag is that the microelectrode, with an initial response time ($t_{90\%}$) < 0.3 s, was damaged or coated by phytodetritus during the deployment.

The effect of this slow electrode response is that it is not likely to capture the full amplitude of the wave signal in oxygen concentration, which, in itself, will add time lag to the recorded periodic wave signal (Berg et al. In press). While this definitely can add substantial time lag bias to calculated fluxes in the presence of waves (Fig. 2), it may not have a large effect on its ability to capture the flux signal associated with current-driven turbulent mixing. Co-spectral analyses of the oxygen concentration and vertical velocity typically show that only a small fraction of the flux contribution is associated with frequencies higher than 0.5 Hz. So, even if a larger portion of the flux signal is lost at high frequencies, it may not affect the total flux significantly.

We acknowledge that a specific explanation of this pattern or dependency was missing, and suggest adding this information to the text.

The focus here is on temporal misalignment due to oxygen sensor response and also due to sensor spatial separation, although sensor misalignment relative to the vertical can also play a role. It appears that the flux calculation is made without any correction for sensor misalignment (i.e. Shaw and Trowbridge) (the references listed in describing the flux calculation (Line 19, p8403) all deal with cases without waves). In that case, the flux calculation may be contaminated by a wave-induced component resulting from the apparent phase shift between w and c. Of course this shift would also affect the calculation for z˜ in equation (1), which would result in a time offset. This offset could then contribute to the calculated offset, and would thus be addressed by the proposed method. If I'm interpreting this correctly, this may account for some part of the observed lags.

Fluxes shown in Fig. 5 were calculated without the traditional rotation (nullification of the transverse and vertical mean velocities for each 15 min based flux calculation). The current velocities were too small to produce robust rotation estimates for most of the deployment. However, for the first part of the deployment, which had current velocities > 2 cm s^{-1}, fluxes calculated without and with rotation equaled -70.3 ± 12.0 and 72.1 ± 11.0 mmol m^{-2} d^{-1} (n = 3, SE), respectively. The rotation angle with the vertical was 7°. We see the small difference in the flux of 2% as an indication that the effects of so-called wave bias due to sensor tilt was marginal. The deployment shown in Fig. 6 had larger current velocities, and the fluxes calculated included the rotation described above.

We believe that the reviewer is correct, the time lag correction that we propose will compensate, at least partly, for the bias arising from sensor tilt. While effects of a phase shift between *w* and *C* should be removed, projections of horizontal velocity variations, due to waves or turbulence, are not. The latter would require a rotation to correct any sensor tilt.

We can add this information, or part of it, to the text.

It would be useful if the authors provide wave velocities along with significant wave heights where they are describing conditions (sect. 3.1) – this is the relevant value to assess the wave strength at the measurement site. The reader can calculate this using the dispersion relation, of course, but it would be nice to have it given.

We agree, and suggest adding this information to the text.

The authors discard stirring sensitivity effects based on the characteristics of oxygen variations on pg. 8411. I agree that the data in Fig. 6a appear qualitatively to be symmetric, but this could be assessed more quantitatively. The presence of a harmonic in the signal is also not readily apparent, although I expect that would be damped significantly by the slow sensor response. A spectral analysis of the concentration signal might be useful to identify higher harmonics and show the sensor response cutoff. I'm unclear on what effects this would have on the calculations though.

Please see our detailed response to Reviewer 2 who posed a similar question on stirring sensitivity. The effects of this unwarranted sensitivity are evaluated in our detailed response.

Also, the effects of the slow sensor response with respect to capturing the full amplitude of the wave signal in concentration, the added time lag it causes, and how it may affect the size of the calculated fluxes, are addressed above.

References:

Berg, P., D. Koopmans, M. Huettel, H. Li, K. Mori, and A. Wüest. In press. A new robust dual oxygen-temperature sensor for aquatic eddy covariance measurements. Limnol. Oceanogr.: Methods.