Replay to anonymous Referee #3

This paper investigates the metabolic balance in the Sargasso Sea during an eddy event through the use of in situ dissolved oxygen measurements combined with a 1D model and through in vitro bottle incubation studies. The aim of the paper was to see if there was a discrepancy between the two methods when they are conducted in an eddy and thus whether a frequent explanation of in situ vs in vitro differences due to mesoscale variability is reasonable. The authors found that the two methods disagree in the eddy. This paper was interesting and well-written and I recommend publishing it after minor revisions.

My largest disagreement with the paper is that because the two methods disagree in this particular eddy the authors state that mesoscale features are not responsible for causing the difference between the in vitro and in situ techniques. However, the authors also state that this eddy is in a state of decline. Thus perhaps it is not surprising that the in vitro technique, which has a shorter time scale and a more local spatial scale, shows net heterotrophy reflective of just the decline phase of the eddy while the in situ technique which averages over longer temporal and spatial scale may be reflecting production during both the grown and decline of the eddy. Thus while this work is certainly valuable, I do not think the authors can necessarily conclude that in general eddy features cannot explain the difference between the techniques. Thus statements like the one on page 3251, lines 15 to 17 are too strongly worded.

The in vitro measurements were made on 22 June and 5 August, while the in situ estimates are based on oxygen profiles from 21 June to 4 August. Thus the in situ estimates do not reflect a period earlier than 21 June, but span the same time frame as the in vitro measurements.

However, we agree with the Referee that just because in situ and in vitro NCP did not agree in eddy C1, that does not prove that in vitro and in situ NCP does not agree in other eddies. We have modified our statements to say that our findings in this eddy suggests (but does not prove) that the differences between in vitro and in situ NCP are likely methodological or submesoscale rather than due to undersampling of mesoscale fluxes.

I appreciated the details given about how the model was constructed and the various formulations used. Such detail is necessary in order for a reader to evaluate the work. Have the authors considered the possibility that their optimization technique may be finding a local minimum rather than truly the biological oxygen flux?

The "cost function" that the optimization scheme is minimizing is the difference between the observed and model oxygen profiles. As the observed oxygen profiles are fitted almost exactly (Fig. 2b), the oxygen model does not reach a spurious local minimum in the cost function. Regarding the optimization of κ and w, both Cases 1 and 3 (effectively) optimize only one parameter each, and it was easily to see that there were no other local minima. In Case 2 we never found an instance with more than one minimum, though optimizing two parameters simultaneously did require a combination of descent and "scatter" methods to make sure we found the global minimum accurately.

In Table 2, the fluxes for advection at 100 m and horizontal advection are both very large – much larger than the NCP. How are errors in the two fluxes coupled? How much uncertainty is added to NCP estimates because of the uncertainties associated with these fluxes?

While the uncertainty of any one of the vertical diffusion, vertical advection and horizontal advection terms is quite large, these estimates are not independent. Conservation of volume

constrains that high horizontal advection can only exist with high vertical advection, and the observed temperature evolution constrains that vertical advection can only be high if vertical diffusion is low. These relationships cause their impacts on the oxygen budget to largely cancel. Consequently the variance in the net advection + diffusion term is much smaller than the variance in any individual term. To accumulate the errors in the three terms as if they were independent estimates would be a mistake. This is now discussed in Section 3.4 (see next comment).

Overall, a more extensive discussion of the uncertainties would be good. It seems like the uncertainty in the in situ NCP is given as the standard deviation between the three cases but what about systematic uncertainties associated with using a 1D model? Or with the gas exchange paramterizations? With uncertainties in the oxygen measurements?

In Section 3.4 we now discuss many additional uncertainties associated with the modelling of the gas transfer velocity, mixed-layer depth, uncertainty in the initial and final profiles and the O_2 calibration. In particular, we recently became aware of the gas transfer velocity formula of Ho et al. (2006, Geophysical Research Letters 33, L16611), and now use this instead of Wanninkhof (1992). We now include these uncertainties in the error estimates in Table 2 (see below):

"3.4. Oxygen model sensitivity tests
The oxygen model infers the NCP from the temporal change in oxygen concentration, the air-sea flux and the net advective-diffusive input. Here we examine the uncertainty in each of these estimates. In addition to providing our error estimates, this shows where improvement is most needed for making NCP estimates with this model.
The impact of the uncertainty in the initial and final mean temperature and oxygen profiles was estimated by trying different station combinations to compute the mean profiles (e.g. station 18 versus station 20 as the initial profile on 21 June), re-running both the temperature and oxygen models with the new profiles for Case 2, and computing the standard deviation of the resulting NCP estimates. The estimated 0-100 m NCP uncertainties are ± 4.4, 3.3 and 3.2 mmol O_2 m^{-2} d^{-1} for periods 1, 2 and 3, respectively. Thus sensitivity to our ability to accurately estimate the initial and final conditions (based on the variability of the observed profiles) is significant. The sensitivity of the air-sea flux and the advection+diffusion estimates to the mean profiles was smaller, averaging ± 1 mmol O_2 m^{-2} d^{-1}.
The air-sea flux estimate relies on several factors, the first being the O_2 data calibration. The air-sea diffusive flux is driven by the supersaturation, and as this is only a few percent, a small calibration error can have a large impact. According to the BATS Methods handbook (Knap et al. 1993), field precision of bottle samples using the Winkler method versus CTD profiles can vary from 0.005 to 0.03 ml L^{-1}. We will consider here a possible systematic calibration error of 1 mmol O_2 m^{-3} added to (or subtracted from) all profiles. This causes a mean uncertainty in the air-sea flux of ± 3.2 mmol O_2 m^{-2} d^{-1}, which propagates directly into the NCP estimates, though the impact on the advection+diffusion term is negligible.
Another source of uncertainty in the air-sea flux is the equation used for the gas transfer velocity. To test sensitivity, the gas transfer velocity of Ho et al. (2006) was increased and decreased by 30% in Case 2, spanning the formulas of Wanninkhof (1992) and Nightingale et al. (2000). The Wanninkhof and McGillis (1999) formula is not considered as it includes the bubble flux within it, though for a case unlike here in which the bubble flux and diffusive flux were in the same direction. The 30% uncertainty changes the average air-sea flux by ± 3.5 mmol O_2 m^{-2} d^{-1}, which again propagates directly into the NCP uncertainty, with negligible impact on the advection+diffusion term.
Sensitivity to the bubble flux formula was examined for all Cases in all 3 periods. The Stanley et al. formula yielded a 43-day mean downward bubble flux of 9.1 mmol O_2 m^{-2} d^{-1} while the Woolf and Thorpe formula yielded 7.1 mmol O_2 m^{-2} d^{-1}. These are both close to the summer estimate at HOT

of approximately 8 mmol O_2 m^{-2} d^{-1} (Hamme & Emerson 2006), and counterbalance more than half of the upward air-sea diffusive flux. This 2.0 mmol O_2 m^{-2} d^{-1} decrease in the bubble flux causes only a 1.1 mmol O_2 m^{-2} d^{-1} increase in the net air-sea flux and the NCP, because the model requires oxygen concentrations to match the observed values.

Sensitivity to our linear MLD time series was estimated as follows. As a perturbation run, the MLD was fixed for the first 24 hours to the initial observed MLD, and then it was changed abruptly to the final observed MLD for the remainder of the period. For the opposing perturbation, the MLD was fixed to the initial MLD until switching to the final MLD in the final 24 hours. While this perturbation method is crude, it likely encompasses one standard deviation of the variability. Note that the original profiles did not show great diurnal variability (Figure 1). This yielded NCP error estimates of ± 0.3, 3.5 and 1.1 mmol O_2 m^{-2} d^{-1} for periods 1, 2 and 3 respectively, greatest for Period 2 because of its long duration and the large difference between the initial and final observed MLD. The uncertainty in the advection+diffusion term was on average ± 0.4 mmol O_2 m^{-2} d^{-1}.

Sensitivity to the uncertainty in the diffusivity and vertical velocities is illustrated in Table 2. While the uncertainty of any one of the vertical diffusion, vertical advection and horizontal advection terms is quite large, these estimates are not independent. Conservation of volume constrains that high horizontal advection can only exist with high vertical advection, and the observed temperature evolution constrains that vertical advection can only be high if vertical diffusion is low. These relationships cause their impacts on the oxygen budget to largely cancel. Consequently the variance in the net advection + diffusion term is much smaller than the variance in any individual term. The uncertainty in κ versus w causes an uncertainty in the net advection + diffusion term of ± 2.3, 0.7 and 4.0 mmol O_2 m^{-2} d^{-1} for periods 1, 2 and 3 respectively, with similar impact on NCP estimates, though only an average uncertainty of ± 0.3 mmol O_2 m^{-2} d^{-1} on the air-sea fluxes.

Horizontal advection of T and O_2 gradients (e.g. $u\partial O_2/\partial x$) was neglected in the models, which is justifiable as follows. Eight of the nine runs in Table 2 have no horizontal divergence below the mixed-layer (i.e. $w_{grad} = 0$). The remaining one has very weak divergence viz. if the downwelling occurs over a 20 km radius, the outward horizontal velocity below the mixed layer at radius r = 20 km is $-w_{grad}\pi r^2/2\pi r = 4\text{x}10^{-6}$ m s^{-1}. More significant is the horizontal convergence that occurs in the mixed layer that feeds the downwelling. In the most extreme case (Period 1 Case 3) the inward horizontal velocity at 20 km radius is $w_{max}\pi r^2/2\pi r z_{mld} = 9.5\text{x}10^{-3}$ m s^{-1}. For the temperature model, any heat gain from $u\partial T/\partial x$ in the mixed layer is already included in the non-solar surface heat flux, which is computed as the difference between the observed heat gain and the other fluxes. For oxygen, from CTD data and underway surface measurements $\partial O_2/\partial x$ in the mixed layer is estimated as $5\text{x}10^{-5}$ mmol O_2 m^{-4} (i.e. a concentration difference of 1 mmol O_2 m^{-3} over 20 km), such that $u\partial O_2/\partial x$ vertically integrated over the mixed layer depth ($0.5 w_{max} r\ \partial O_2/\partial x$) is 0.28 mmol O_2 m^{-2} d^{-1} This is negligible compared to the estimates and uncertainties in Table 2.

Another simplification in the temperature model was the use of a constant solar heat flux. Variations in the solar flux indicated by the shipboard and NCEP data were estimated, but were found to be a negligible source of error relative to the other sources.

The error estimates given in Table 2 are the square root of the sum of the squares of the uncertainties related to the initial and final profiles, O_2 calibration, gas transfer velocity, bubble flux, mixed layer depth and the role of advection versus diffusion. The other error sources mentioned above were estimated as negligible in comparison. Although the error estimates are considerable, the model-derived in situ NCP estimates are statistically significantly greater than the in vitro NCP estimates."

A little more detail on why those particular stations were selected would be useful.

This is now discussed in a little more detail in the first sentences of Section 2.2:

“The location of eddy center as a function of time was estimated from a combination of Sea level Anomaly (SLA), expendable bathythermograph (XBT) and Acoustic Doppler Current Profiler (ADCP) data (McGillicuddy et al. 2007). Of the CTD stations within 20 km of this estimated location, stations were chosen as representing eddy center based on their temperature and salinity (T-S) properties and the vertical displacement of their main and seasonal thermoclines (Table 1, Figure 1).”

Sometimes K is given in units of m2 s-1 and sometimes in cm2 s-1. It would be better for the authors to be consistent.

K units have been converted to $m^2\ s^{-1}$ through the manuscript.

Table 2. Model results. κ_{deep} is the vertical diffusion coefficient, w_{max} and w_{grad} are vertical velocity parameters, NCP is net community production of oxygen, STD is standard deviation. $d[O_2]/dt$, NCP and all subsequent oxygen fluxes are in mmol O_2 m^{-2} d^{-1}. The air-sea O_2 flux is defined negative upward while the diffusive and advective O_2 fluxes at 100 m are defined negative downward, i.e. negative indicates a loss to the 0-100 m O_2 integral. STD is computed as the square root of the sum of the error variances from various sources (see Section 3.4).

Variable (units)	21 June – 1 July				1 July – 27 July				27 July – 3 August			
	Case 1	Case 2	Case 3	Mean (±STD)	Case 1	Case 2	Case 3	Mean (± STD)	Case 1	Case 2	Case 3	Mean (± STD)
κ_{deep} (m^2 s^{-1})	3.1 x 10^{-4}	4.0 x 10^{-5}	1.0 x 10^{-5}		2.7 x 10^{-4}	4.8 x 10^{-5}	1.0 x 10^{-5}		3.2 x 10^{-4}	1.21 x 10^{-4}	1.0 x 10^{-5}	
w_{max} (m day^{-1})	0	-0.53	-0.57		0	-0.46	-0.51		0	-0.38	-0.54	
w_{grad} (day^{-1})	0	0	0		0	-3.5 x 10^{-5}	0		0	0	0	
$d[O_2]/dt$, 0 - 100 m	0.6	0.6	0.6		-17.1	-17.1	-17.1		-14.9	-14.9	-14.9	
NCP, 0 – 100 m	19.3	16.0	15.6	17 (± 6)	-3.1	-3.3	-4.9	-4 (± 7)	13.9	8.4	3.6	9 (± 8)
Air – sea O_2 flux	-7.6	-8.7	-9.1	-8 (± 4)	-3.4	-4.3	-3.1	-4 (± 7)	-9.5	-9.2	-9.0	-9 (± 6)
Diffusive flux at 100 m	-11.1	-1.4	-0.4		-10.6	-1.9	-0.4		-19.4	-7.7	-0.7	
Advective flux at 100 m	0	-118.5	-127.4		0	-101.5	-113.4		0	-84.9	-120.3	
Horizontal advection	0	113.1	121.7		0	94.0	104.8		0	78.4	111.4	
Advection + diffusion	-11.1	-6.8	-6.0	-8 (± 2)	-10.6	-9.5	-9.0	-10 (± 2)	-19.4	-14.1	-9.6	-14 (± 5)