Ocean Sci. Discuss., 6, C858–C864, 2009
www.ocean-sci-discuss.net/6/C858/2009/

Ocean Science
Discussions

Interactive comment on "Subsurface primary production in the western subtropical North Pacific as evidence of large diapycnal diffusivity associated with the Subtropical Mode Water" *by* C. Sukigara et al.

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Received and published: 4 December 2009

To Referee #1,

Thank you for your comment concerning the manuscript entitled "Subsurface primary production in the western subtropical North Pacific as evidence of large diapycnal diffusivity associated with the Subtropical Mode Water" which we submitted for publication in Ocean Science.

We have considered your comment thoroughly. Regarding your major criticism 1(A),

you are right and we should have estimated the net nitrogen production below the mixed layer and above the top of the mode water. But, fortunately, chlorophyll concentration in the mixed layer and below the top of the mode water was generally very small during the study period. Consequently, an error in our estimation is probably small. We are not going into the details of error estimation, because we decided not to take this approach to the estimation of net nitrogen production as described below.

Regarding your major criticism 1(B), we have to fully accept it. We agree that the argument depending on the HOT dataset is not strong enough. We thus decided to take a completely different approach to the arguments; we estimated diffusion coefficient and NCP using time-series dissolved oxygen (DO) data of our profiling float and ship observation as follows.

We cannot estimate the NCP above the STMW directly from the increment of DO, because DO in the top 500 m or the potential density range lower than 25.5 kg m-3 tended to decrease with time (reply-figure 1). Temporal decrease of DO at about 24.9-25.0 kg m-3 (100-150m) was much smaller than that at 25.1-25.2 kg m-3 in the Subtropical Mode Water (STMW). The decrease of DO in the former layer was 5 umolO2 kg-1 at a maximum (reply-figure 2). On the other hand, DO decrease in the STMW from May to July was 11 – 21 umolO2 kg-1 or on average 16 umolO2 kg-1 (reply-figure3). In the former layer (100-150 m), which is near the top of STMW and under the euphotic zone, photosynthesis (oxygen emission) hardly occurs and oxygen consumption exclusively occurs. Oxygen consumption in this layer should be, at least, as large as that in the latter layer (STMW) because the former layer immediately below the euphotic zone should be richer in organic matter. We presumed that the oxygen consumption in the former layer was offset by downward diffusive oxygen flux from the subsurface oxygen maximum (SOM) layer and estimated this downward oxygen flux. Based upon this assumption, we estimated vertical diffusivity near the top of STMW as described below.

If we assume that the oxygen consumption rate in the former layer is the same as that in the STMW layer (16 umolO2 kg-1 decrease over the 50 day period from mid-may to mid-July) at a moderate estimate, the DO concentration in the layer between 100 m and 150 m offset by the downward flux of DO over the 50 day period is as follows:

[DO decrease in the STMW (16 umolO2 kg-1)] –[DO decrease in the layer between 100m and 150 m (5 umolO2 kg-1)] = 11 umolO2 kg-1 $\sim$ 11 mmol O2 m-3.

DO supply to the layer of 100-150 m from the SOM layer over the 50 day period is estimated as,

11 mmolO2 m-3 x 50 m = 550 mmolO2 m-2.

Downward DO flux averaged over the 50 day period is thus calculated as,

550 mmolO2 m-2 / 50 days = 11 mmolO2 m-2 day-1.

Vertical diffusivity needed to maintain this downward flux is then calculated as,

[DO flux (11 mmolO2 m-2 day-1)] / [average of DO concentration gradients under SOM layer from May to July (0.49 mmolO2 m-3 m-1)] = 22.4 m2 day-1 / 86400 s d-1 = 2.6 x10-4 m2 s-1.

This estimate of diffusivity is consistent with the result of previous study (Qiu et al., 2006). Since our assumption of the DO decrease in the layer of 100-150 m over the 50 day period is modest, this vertical diffusivity can also be modest estimate. On the other hand, the nitrate upward flux could be calculated by the results of the ship observation. The depth of nitracline coincides with that of maximum DO gradient under SOM layer in each station. The averaged maximum gradient of nitrate concentrations is 0.055$\pm$0.011 mmolN m-3 m-1. The nitrate flux can be estimated by this nitrate gradient and the diffusivity estimated above as follows.

[Nitrate upward flux] = [Nitrate gradient (0.055 mmolN m-3 m-1)] x [diffusivity (2.6 x10-4 m2 s-1)] = 0.143 x 10-4 mmolN m-2 s-1 x 86400 s day-1 = 1.2 mmolN m-2 day-1.

The ratio of the upward flux of nitrate to the downward flux of oxygen are 9.2, which is

well close to Redfield ratio (N / O2 = 16 / 150 = 9.4).

If all of transported nitrate are utilized for photosynthesis, and all of transported oxygen originated in SOM layer, the Net Community Production (NCP) can be estimated as follows.

NCP = [Nitrate flux (1.2 mmolN m-2 day-1)] * [Redfield ratio (C / N = 106 / 16)] = 8.0 mmolC m-2 day-1.

We believe that the dataset of our float and cruise observations with the new approach described above support the existence of large diffusivity on the STMW proposed by Qiu et al.(2006). We will delete the most of discussion of NCP estimate based on the HOT dataset from the revised version to be submitted to Ocean Science. Alternatively, discussion of DO and nitrate fluxes and new estimation of NCP will be added to the revised version. We hope that this revision responds adequately to your major criticisms.

Concerning to the minor comment, we agree and will rectify the units of the concentrations and fluxes. NPP will be rewritten NCP. We found your comments most helpful. We hope revise manuscript will acceptable for publication.

Yours sincerely, Chiho Sukigara Physical Oceanography Laboratory, Department of Geophysics, Graduate School of Science, Tohoku University 6-3, Aramaki-Aza-Aoba, Aoba-ku, Sendai, 980-8578, Japan. Tel: +81-22-795-6529, Fax: +81-22-795-6530 e-mail: suki@pol.gp.tohoku.ac.jp

Interactive comment on Ocean Sci. Discuss., 6, 1717, 2009.

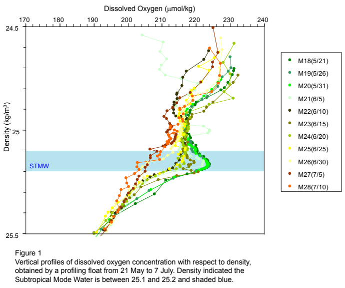

Fig. 1. reply-figure 1

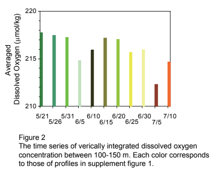

Fig. 2. reply-figure 2

Figure 3 (Table)
Decrements of dissolved oxygen concentration in the Subtropical Mode Water.

	σ_θ = 25.10		σ_θ = 25.15		σ_θ = 25.20		
	depth (m)	DO (μmoll/kg)	depth (m)	DO (μmoll/kg)	depth (m)	DO (μmoll/kg)	average
26-May	197.6	220.23	248	223.40	397.9	220.25	
10-Jul	217.8	209.51	257.3	202.75	277.6	203.26	
differece		10.72		20.65		16.99	16.12

Fig. 3. reply-figure 3