Biogeosciences Discuss., 9, C2318–C2328, 2012
www.biogeosciences-discuss.net/9/C2318/2012/

Biogeosciences Discussions

Interactive comment on "Variations of net primary productivity and phytoplankton community composition in the Southern Ocean as estimated from ocean-color remote sensing data" *by* S. Takao et al.

S. Takao et al.

takao@ees.hokudai.ac.jp

Received and published: 7 July 2012

We appreciate your kind and constructive comments. Following the helpful suggestions from you and another reviewer, we believe our manuscript has been modified significantly. Below are our replies to your comments. RC = Referee's Comments; AR = Authors' Response

Major changes

RC 1: Since only an analysis of the Indian Sector of the Southern Ocean is shown, the

title and the abstract should state that properly.

AR 1: According to your suggestions, the words 'in the Indian sector of the Southern Ocean' have been added in the title and abstract in the revised manuscript.

RC 2: Page 4364, line 25 ff.: Because in the Southern Ocean ocean color data are scarce, it is dangerous to base the analysis on monthly means of satellite data. These can be represented by very few observations especially in wintertime. I therefore recommend to first use the daily level-3 data and calculate from that monthly mean values in case a threshold for a reasonable amount of observation exists.

AR 2: We checked sampling frequencies of daily level-3 data per month in our study area. As a result, we found that most monthly data were composed of only 1-4 daily data even during austral summer. Some of the results have shown in Figure S1. Use of monthly level-3 data is common in studies of the Southern Ocean (e.g., Smith et al., 2001, 2008; Moore and Doney, 2006; Johnston and Gabric, 2011). Thus, we also made an attempt to use monthly means of satellite data for our study.

RC 3: Validation of PHYSAT: In chapter 2.2 it is stated that pigment data from 5 austral summer cruises within the Indian Sector of the Southern Ocean were used for validation. Later on in Fig. 4 and Table 6 only the collocation and validation results of 10 matches of Jan-Feb 2006 are shown. Why is that? In addition, this figure and this table deviate from the text in the results section where on page 4372 line 18 it states "the PHYSAT outputs matched at 32 out of 39 data in CHEMTAX". It is necessary to at least present the whole results of the PHYSAT validation also regarding the three other dominating phytoplankton groups and other seasons besides the summer.

AR 3: Thank you for pointing them out. Our explanations about the validation of PHYSAT might be equivocal for you. As you mentioned above, pigment data from 5 austral summer cruises within the study area were used for validation. In terms of the predominance of diatoms, the PHYSAT outputs derived from daily ocean color data matched at 10 out of 314 in situ pigment data. At 7 out of the 10 stations, PHYSAT out-

BGD

9, C2318–C2328, 2012

puts derived from daily ocean color data were in good agreement with our CHEMTAX results, as demonstrated in Fig. 4 and Table 6. On the other hand, in P. 4372 L. 18 in the previous manuscript, we had checked for disparities between the PHYSAT outputs, which estimated from HPLC pigment data and the criteria of Alvain et al. (2005), and those of CHEMTAX using the 60 HPLC pigment data. Thus, the figure and table did not deviate from the text in the results. In order to avoid misreading, we have modified some sentences in sections 3.3 and 4.1 as follows:

Section 3.3: In terms of the predominance of diatoms, the PHYSAT outputs derived from daily ocean color data were matched with 10 out of 314 in situ pigment data. The estimates of PHYSAT were in good agreement with the results of CHEMTAX, that is, these matched at 7 out of 10 stations. The mismatches between PHYSAT and CHEMTAX were caused by chlorophytes and cryptophytes as estimated from CHEMTAX (Table 6). However, in terms of the predominance of the three other dominating phytoplankton groups (i.e., haptophytes, Prochlorococcus, and Synechococcus), sufficient data was not available to validate the results of the PHYSAT performance.

Section 4.1: In this study, we did not follow the validation process of Alvain et al. (2008; 2012), because in our HPLC pigment data, only 19% of the whole data (60 out of 314 samples) matched the criteria for pigment data by Alvain et al. (2005) (see Table 4 of Alvain et al. (2005) for details). Therefore, CHEMTAX was used to validate the PHYSAT performance. For diatoms, the estimates of PHYSAT derived from daily ocean color data were in good agreement with the results of CHEMTAX in the Indian sector of the Southern Ocean (i.e., 7 out of 10 stations; Table 6). In order to check for disparities between the estimates of PHYSAT and those of CHEMTAX, both procedures were conducted using the 60 HPLC pigment data (see above). The predominance of diatoms among the phytoplankton assemblages was also observed by analyzing the 60 pigment data with CHEMTAX. In terms of the dominance of diatoms, the PHYSAT outputs, which estimated from HPLC pigment data and the criteria of Alvain et al. (2005), matched at 32 out of 39 data in CHEMTAX (i.e., 82%). Thus, the results represent

BGD

9, C2318–C2328, 2012

that the validation of PHYSAT with respect to the DR for diatoms estimated from ocean color data succeeded in the Indian sector of the Southern Ocean.

RC 4: It is difficult to compare the results of Fig. 4a and 4b, probably with including more data in the validation a new presentation will be necessary.

AR 4: Following the helpful suggestions from you and another reviewer, we also have added stars in Fig. 4b as well. As mentioned above (see AR 3), in terms of the predominance of diatoms, there were only 10 stations where comparisons between the PHYSAT outputs derived from daily ocean color data and in situ pigment data were feasible. The results of Fig. 4a and 4b also represent that even during austral summer, it is difficult to match in situ measurements (i.e., CHEMTAX results) with ocean color products (i.e., PHYSAT) in our study area.

RC: 5 The new NPP derived satellite product uses the method of Hirawake et al. (2011) – it would be good to have some information on the accuracy and precision of this product (page 4365, 2nd paragraph) –The authors should check for this part of the Southern Ocean also other pigment and primary production data sets in order to include these with their own measurements in the validation of NPP and PHYSAT satellite derived data products (e.g. data presented in: Uitz, J., H. Claustre, N. Garcia, F.B. Griffiths, J. Ras and V. Sandroni (2009). A phytoplankton class-specific primary production model applied to the Kerguelen Islands region (Southern Ocean). Deep-Sea Res I, doi:10.1016/j.dsr.2008.11.006.)

AR 5: Following your kind suggestion, we have added some information on the accuracy and precision of the method of Hirawake et al. (2011) into section 2.1 in the revised manuscript. For your information, we have shown a result of validation of satellite NPP estimated by the method of Hirawake et al. (2011) using additional in situ NPP data (i.e., 10 data presented in Uitz et al., 2009) below. NPP derived from daily ocean color data matched with 4 out of 10 in situ data within $\pm$ 1 pixel and $\pm$ 1 day. If we use 13 in situ NPP data (9 from Hirawake et al. (2011) and 4 from Uitz et al. (2009)),

BGD

9, C2318–C2328, 2012

satellite NPP were in good agreement with in situ NPP (r2 = 0.68, slope = 0.87, RMS = 0.16, p < 0.001) in the Indian sector of the Southern Ocean (Figure S2). RMS means root mean square of the log-difference error. Unfortunately, additional pigment dataset and other NPP data are unavailable.

RC 6: Chapters 2.3, 3.1.2 and 3.2: the inter-annual variations and trends in the different regions have been calculated for NPP, SST and the dominant ratio of PFTs. They are only described in detail for NPP. It would be good if the results of PHYSAT and SST are presented in a table in the appendix, because the discussion on the relation of the parameters actually misses concrete values for those two. E.g. in chapter 4.2 and specifically at Page 4375 last sentence: how much is the NPP actually increasing with decreasing SST and what temperature differences actually will considerably reduce microzooplankton grazing?

AR 6: In section 4.2, we mainly discussed relationships between NPP, dominant phytoplankton groups, and SST in the PFZ and SACCZ during summer as demonstrated in Fig. 3. Because the results of SST and the dominant ratio of PFTs are shown in Fig. 3, we consider that further explanations were unnecessary for the results of PHYSAT and SST. Unfortunately, we cannot indicate the reduction rate of microzooplankton grazing with decrease in temperature in this study. One could expect a general relationship approximating Q10 = 2. A study by Burkill et al. (1995) found a strong relationship with temperature, but this was compromised by much lower prey concentrations observed at the coldest sites (10% of warm site).

RC 7: Appendix A: what kind of cluster analysis was used. Can you provide more details on that?

AR 7: The sentence 'For the CHEMTAX calculations, a hierarchical cluster analysis by Ward method was used to classify the 314 pigment data into groups.' has been added in the revised manuscript.

Minor changes

BGD

9, C2318–C2328, 2012

RC 8: Fig. 3 – no intermediate ticks are necessary (they are rather confusing), since only 1 value per summer is shown.

AR 8: The intermediate ticks in Fig. 3 have been removed.

RC 9: Page 4364, line 3: change “filed” to “field”

AR 9: Corrected.

RC 10: Page 4364, line 12: change to ...estimated on global scale....”

AR 10: Corrected.

RC 11: Page 4365, line 4: change to “Satellite data were analyzed for five frontal zones ...”

AR 11: Corrected.

RC 12: Page 4366, line 13: unclear! - change to “..., Pi is the number of pixels where PFT_i dominates, P_PFTs is the number of all pixels.”?

AR 12: As you mentioned above, Pi is the number of pixels where PFT_i dominates. However, P_PFTs is not the number of all pixels, but the sum of the number of pixels where PFTs dominated.

RC 13: Page 4367, line 1: give number of HPLC samples used for validation and clustering

AR 13: Following your suggestion, we have given the number of HPLC samples used.

RC 14: Page 4370, line 9: add more information here as well, e.g. “and the difference between highest and lowest value are below xxxTg C in the entire STZ”

AR 14: We made a wrong description in the sentence. We have corrected them and added more information as follows: ‘In winter, although inter-annual variations of the spatial averaged NPP were highest in the PFZ, the difference between the highest and lowest values was only 15 mg C m-2 d-1 and was below 8 Tg C in the entire PFZ’.

BGD

9, C2318–C2328, 2012

RC 15: Page 4371, line 1: change to "...NPP correlated not only with the DR for diatoms positively (. . .) but also with the DR for haptophytes ..."

AR 15: Corrected.

RC 16: Page 4372, line 4: change to "...carried out except for coastal . . ."

AR 16: Corrected.

RC 17: Page 4373, line 13: can you give an explanation here why it was not possible to separate hetero- and autotrophic dinoflagellates.

AR 17: In our microscope observations, many dinoflagellates cells could be identified at the genus or the order level. Although autotrophic dinoflagellates (e.g., Ceratium, Prorocentrum, and Oxytoxum) could be distinguished from heterotrophic and/or mixotrophic cells (e.g., Dinophysis and Gymnodinium) on the basis of literature (Tomas, 1997), we did not confirm the presence or absence of chloroplasts nor chlorophyll cellular fluorescence in the samples.

RC 18: Page 4374, line 18 end: change sentence to "South of 60S, Smith and Comiso ...was strongly influenced by sea ice melting."

AR 18: Corrected.

RC 19: Page 4376, line 15: change to "in several frontal zones..."

AR 19: Corrected.

RC 20: Page 4376, line 20: change to "...northwest of South Georgia"

AR 20: Corrected.

RC 21: Page 4377, line 5-6: change to "...we found over the decade within the PFZ a statistically significant reduction of NPP."

AR 21: Corrected.

BGD

9, C2318–C2328, 2012

RC 22: Page 4377, line 8: change to "...NPP correlated not only with the DR for diatoms positively, but also with the DR for ..."

AR 22: Corrected.

Reference:

Alvain, S., Moulin, C., Dandonneau, Y., and Breon, F. M.: Remote sensing of phytoplankton groups in case 1 waters from global SeaWiFS imagery, Deep-Sea Res. Pt. I, 52, 1989–2004, 2005.

Alvain, S., Moulin, C., Dandonneau, Y., and Loisel, H.: Seasonal distribution and succession of dominant phytoplankton groups in the global ocean: A satellite view, Global Biogeochem. Cy., 22, GB3001, doi:10.1029/2007GB003154, 2008.

Alvain, S., Loisel, H., and Dessailly, D.: Theoretical analysis of ocean color radiances anomalies and implications for phytoplankton groups detection in case 1 waters, Opt. Express, 20, 1070–1083, 2012.

Burkill, P. H., Edwards, E. S., and Sleigh, M. A.: Microzooplankton and their role in controlling phytoplankton growth in the marginal ice zone of the Bellingshausen Sea, Deep-Sea Res. Pt. II, 42, 1277–1290, 1995.

Hirawake, T., Takao, S., Horimoto, N., Ishimaru, T., Yamaguchi, Y., and Fukuchi, M.: A phytoplankton absorption-based primary productivity model for remote sensing in the Southern Ocean, Polar Biol., 34, 291–302, 2011. Johnston, B. M. and Gabric, A. J.: Interannual variability in estimated biological productivity in the Australian sector of the Southern Ocean in 1997–2007, Tellus, 63B, 266–286, 2011.

Moore, J. K. and Doney, S. C.: Remote sensing observations of ocean physical and biological properties in the region of the Southern Ocean Iron Experiment (SOFeX), J. Geophys. Res., 111, C06026, doi:10.1029/2005JC003289, 2006.

Smith, R. C., Baker, K. S., Dierssen, H. M., Stammerjohn, S. E., and Vernet, M.: Vari-

BGD

9, C2318–C2328, 2012

ability of primary production in an Antarctic marine ecosystem as estimated using a multi-scale sampling strategy, Am. Zool., 41, 40–56, 2001.

Smith, R. C., Martinson, D. G., Stammerjohn, S. E., Iannuzzi, R. A., and Ireson, K.: Bellingshausen and western Antarctic Peninsula region: Pigment biomass and sea-ice spatial/temporal distributions and interannual variability, Deep-Sea Res. Pt. II, 55, 1949–1963, 2008.

Tomas, C. R.: Identifying Marine Phytoplankton, Academic Press, 858pp., 1997.

Uitz J., Claustre, H., Griffiths, F. B., Ras, J., Garcia, N., and Sandroni, V.: A phytoplankton class-specific primary production model applied to the Kerguelen Islands region (Southern Ocean), Deep-sea Res. Pt. I, 56, 541–560, 2009.

Interactive comment on Biogeosciences Discuss., 9, 4361, 2012.

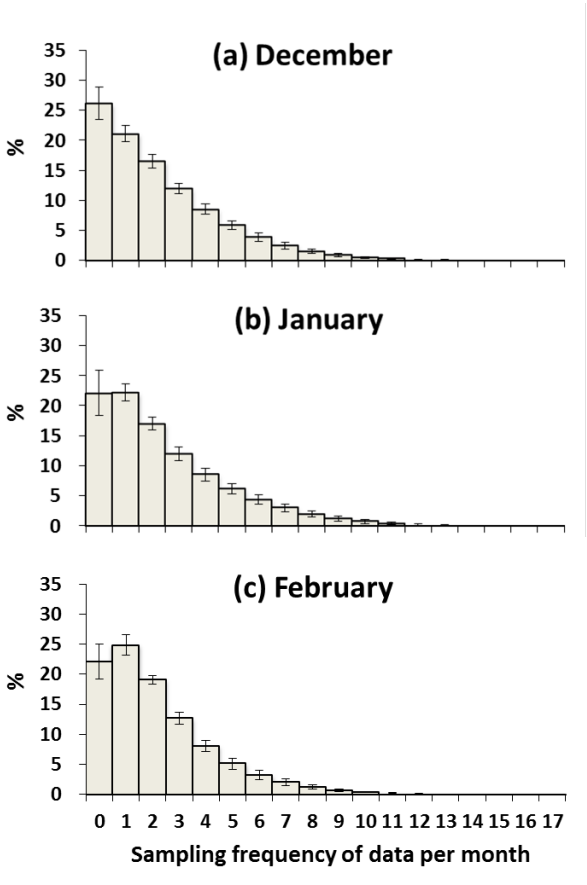

Fig. 1. S1: Mean sampling frequencies of daily data per month in the Indian sector of the Southern Ocean over 1997-2007: (a) December, (b) January, (c) February. Error bars indicate the standard deviation.

BGD
9, C2318–C2328, 2012

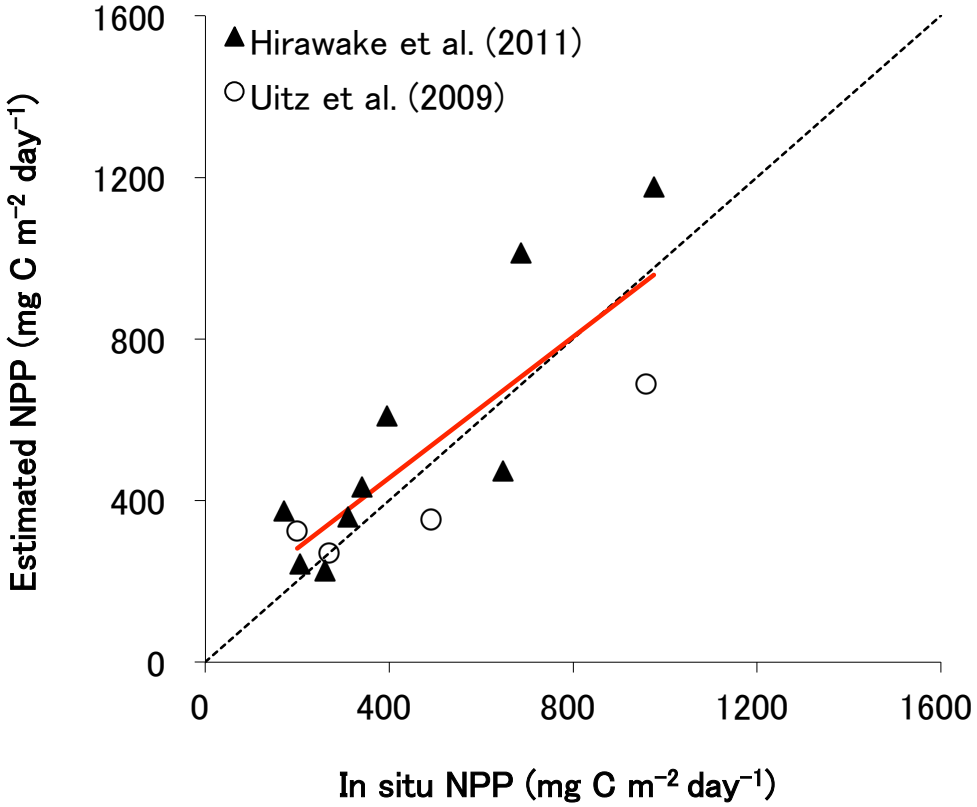

Fig. 2. S2: Comparison between in situ NPP and satellite NPP estimated by the method of Hirawake et al. (2011). Solid red line indicates regression line and dashed line indicates 1:1 line.

BGD
9, C2318–C2328, 2012