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Biogeosciences Discussions

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Interactive Comment

Interactive comment on "An algorithm for detecting <i>Trichodesmium</i> surface blooms in the South Western Tropical Pacific" *by* C. Dupouy et al.

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Author response on comment to bg-2011-C2493-C2500. Reply to Ajit Subramaniam (AS) C. DUPOUY and co-authors October 2011

I would like to thank Dr Ajit Subramaniam for his constructive comments which will greatly improve the quality of this manuscript. In my comments herein, I shall address each reviewer's comments and suggestions. Each comment from the reviewer is reproduced in blue italics and enclosed in quotation marks, after which our response is presented. We hope that incorporating these corrections will make the publication more clear and convince you of the utility of the algorithm in the South Western Tropical

Pacific Zone to detect surface blooms of Trichodesmium.

Following the referee' comments and suggestions, the manuscript has been revised as indicated below.

A.S., C2494 1st paragraph, "…But to convince me that they have a functioning algorithm, they need to show that 1) the technique works where they know Trichodesmium was reported in the in-situ data; 2) that they do not pick up Trichodesmium where none was reported; 3) that they only pick up Trichodesmium and nothing else with the technique. While I accept that no algorithm is going to be perfect, we do need to know the error statistics for this technique – for both the type I and type II errors."

In the SP area, we have demonstrated that: 1) TRICHOSAT picks up Trichodesmium blooms in summer coincident with in situ data. We have shown that over the 1998-2010 period, TRICHOSAT screened pixels with a peak in February as do our observations. In our new Figure 3a, colors allow the reader to follow the screened pixels day by day during the 10-22 February 2003 specific summer period. TRICHOSAT finds pixels close to slick observations of the 17 and 22 February 2003 by the French Navy (Table 1). Moreover, the 1997-2010 composite blob in new Figure 7 which covers the whole Western Pacific shows that TRICHOSAT finds a majority of Tricho blooms in the SP during summer. 2) TRICHOSAT does not pick up much Tricho in winter where none was reported and this is well shown for a small winter period during 9-12 June 2003 (our new Figure 3b). For the 1997-2010 composite, the winter blob in New Figure 7 (the whole Western Pacific) shows there is only a few screened pixels in the SP. 3) TRICHOSAT only picks up Trichodesmium, as their Nb increases regularly each year from October to March with a peak in February which is in favor of phytoplankton surface blooms rather than of an accumulation of other material. Moreover, it does not select shallow water pixels near New Caledonia while other algorithms do.

We agree with A.S. that TRICHOSAT was not tested in other regions where Trichodesmium surface blooms are known to occur. Our publication aims at showing the performance of TRICHOSAT in the SP. We will respond point by point to the A.S. comments below.

A.S., C2494 2nd paragraph "At this point I am not suggesting that there is anything wrong with their technique – there is not enough information presented for me to judge that, just that they have not really presented the evidence that it really works. I believe that they should be able to do this relatively easily given that they seem to have an extraordinarily rich in situ dataset. In summary, I am completely sympathetic to the author's objectives and think that their approach might actually work and hope they will take my comments as constructive, but as detailed below, I am not at all persuaded, by the evidence as presented (see comments below for Fig. 3), that Dupouy et al have a functioning algorithm to uniquely detect and quantify Trichodesmium."

New figure 7 (old Fig.3) allows to seeing the response of Trichosat year by year (Figure 7 replaces Fig.3). From 2000 to 2011, few Tricho pixels were retrieved during boreal winter in the Northern Pacific area by TRICHOSAT (except on a short period in 98 and 99, see also comments below on new Figure 7). Generally, the frequency of Trichodesmium bloom pixels detected by TRICHOSAT in the northern hemisphere was low in boreal summer comparatively to that observed in the SP during austral summer. The medium frequency in May or October (interseason) is also in accordance with in situ observations. See our comments for Fig.3 on the additional Figure 7 below, which replaces Figure 3, page 14).

C2494 Specific comments and suggestions AS "To begin with, I would suggest that they focus on a smaller region for proving the technique works"

We have re-organized the text to first show our results in the smaller region (SP: 8S-24S and 160E to 180°W) i.e. our new- Figure 3. See also our comments on the results of TRICHOSAT on the small region and for short periods in summer (February 2003) and in winter (June 2003). See also our comments with a try to extend the results to a larger region (WP: our new-Figure 7).

AS: Page 5654 L14: “what is the time scale for the total surface estimate. Is this a single bloom, per month, per year ?”

The screening by TRICHOSAT is done on every single Level-2 SeaWiFS GAC daily scene. So the number of pixels is obtained per single day. Then, we simply summed the number of screened pixels by months, to get monthly statistics. I shall better describe the procedure in the Method chapter. The total surface area at Line 14 of our summary, comes from the pixels Nb detected within a particular month multiplied by the surface of one SeaWIFS pixel (4 km x 4 km). So this is a measurement of a total Tricho bloom surface summed per month. For answering the question of the lasting of a single bloom, we redraw the figure 3 as a composite showing the percentage of pixels screened within each single day indicated by different colors (see New Figure 3).

AS: “Considering all the analysis is presented in a %pixel basis, it is impossible to figure out how big or long lasting any single bloom feature – whether contiguous or not – may be”. We have changed the figure 8 to show the evolution of the % pixel day by day. Also, to better answer the questions of 1) the size of a particular bloom and 2) its lasting over successive days 3) whether contiguous or not they are, we have modified figures 3 and 7 (different colors allow the reader to followx the evolution of the Tricho blooms detected by TRICHOSAT. The answer to these questions is limited by cloudiness and coarse 4 km x 4 km resolution of GAC level2 images. TRICHOSAT was set to detect a specific case of Trichodesmium bloom. This configuration is when Trichodesmium is concentrated on 1 mm or maybe more, and visible by eye. Densities are then between 17000 trichomes.L-1 to 39 106 trichomes.L-1 (Devassy et al., 1978). We have calculated that within a strong accumulation (about 3 mg.L-1), if this concentration is on 1 mm, we obtain an integrated concentration of 3 mg.m-2. If the surface bloom is 100 m2 large and if we compare with the size of the pixel (4 x 4 km) or 16000000 m2, we obtain an average value for the pixel of 0.018 mg.m-3 of chlorophyll linked to Tricho. Supposing that the rest of the phytoplankton represents on average 0.1 mg.m-3, we need about 500 m2 of concentrated accumulation within the pixel to double the chloro-

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phyll concentration. An accumulation of 1 mm of concentrated Trichodesmium with 3 mg/L would be equivalent to 10 m of Trichodesmium with 0.3 μg/L. AS: Page 5655, "Is this a web page ?"

This is the way to properly cite the data source as indicated on the OBPG site itself.

AS: "C2495. Page 5656-5657. "In situ observations... Also I think it is essential that they present information on how big features is – we have no way of telling whether a slick reported was 1m wide, 1 km, 10km or how long."

We have added a supplementary figure where some pictures of the blooms as seen from ships, aircraft, and finally long line airplanes for February 2004. For shipboard observations, slick visual obs are usually of 2 to 5 nautical miles long, and a few meters large. They spread over a larger area. When observers see one, they see many of them at the horizon aligned in parallel. For aerial observations. Depending of the height of the aircraft, they generally are 10 meters wide and many nautical milles long. They can form more denser spots. Observations are from 1 km2 to more. Observers remark that aligned slick lines are often parallel but not always. Then as in Figure 1, they can be joined together so that a 4 kilometer pixel may be impacted. Longline aircrafts: At the end of the summer season, slicks are so numerous that they can cover a very wide area which means 500 km x 500 km of potential orange slicks (Photograph 1) or only kilometers long (from ships). This was observed 3 times in the series: November 1998 in November 1999, and February 2004 (additional document). The exceptional bloom in summer 2004 bloom is well described in the paper. We can follow its space and time extension as described in our text.

AS:C2495 "Is is unclear from the way this is written how many of the slicks reported from the aerial photos were actually ground truthed" I shall correct the text to add more quantitative informations on surface and lasting of the slicks. Also, our Figure 1b allows to see that aerial and microscopic observations very often coincide.

At the end, 38 dates were fully ground-truthed i.e. for them we received together

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formaline samples full with Trichodesmium, aerial or shipboard photographs of Trichodesmium slicks. These dates are indicated by asterisks in the Table 1. Other dates correspond to photographs at sea or from airplanes or to formaline samples obtained independently.

AS: "How do we know what the slicks are made of" ?

Observed slicks in formaline samples were at 99% made of Trichodesmium. Coral spawning in New Caledonia occurs once a year at the full moon in October-November in the lagoon, and lasts only a few days. Observations of coral spawns are extremely littoral as eggs are pushed to the beaches and give a typical purple color to the water. Coral slicks are extremely fugitive, and could not be advected for long as material is highly labile and probably grazed immediately. At the opposite, Trichodesmium surface blooms regularly occur during the whole summer period. I cite recent papers published about pummices in this region. When pumice images were available, they do not show the streaks shape. Though it is a phenomenon which can occur after submarine eruptions (pumices are sometimes found on beaches of Loyalty Islands and even in the New Caledonia lagoon), it is an erratic phenomenon. It would not been observed as regularly as Trichodesmium. I agree with A.S. that I should discuss this more deeply. I did not think this was the place in the manuscript or can be as an attached document (refer to my report Dupouy et al., 2004). We obtained once a sample containing pumices mixed to Trichodesmium colonies (Dec 2002). In the case of deep convergence of currents, I suppose that Trichodesmium slicks aggregate all sorts of material during its surface bloom as high colloidal material sticks every kind of particles. A.S. suggests that TRICHOSAT does not detect only Trichodesmium. I agree with A.S. that it could detect a mix of all sorts of particules of all sizes. These particles would have to aggregate to the Trichodesmium bloom later without changing the specific RAS of Trichodesmium.

AS: "5659-5660: Also, how do, if at all, tables 1 and 2 relate ? i.e. are there any slicks that were well studied and reported at Table 2 correspond to aerial photos reported in

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Table 1?"

A few number of slicks were observed during cruise or transects. Those reported at Table 2 were reported in Table 1 (Diapalis 1, Diapalis 7, Motevas). These slicks were ground-truthed (via microscopy) on board the Alis ship. Transect 4 was eliminated from Table 1 as no slick was observed though a high biomass of Trichodesmium phycoerythrin measured. Diapalis 01: we observed slicks, and did microscopic photographs. Bloom obs : Yes Diapalis 07: February 2003: Bloom obs: Yes. This was corrected and reported Table 1. Transect 4: There were no slicks observed but a high density of colonies at the extremities of the transects near the coast of New Caledonia and Vanuatu. I then deleted the line in Table 1 as no real slick was observed. Motevas : 28-29 February 2004: slicks observed with colonies at 0m and 5 m, Hydroscat-6 measured a thick layer of Trichodesmium (then reported at Table 1).

AS: "Page 5661 Line 23-25: I am confused by this – neither figure 5 nor my own quick analysis of the region show any values of chlorophyll with values greater than 0.2 mg.m-3. It is for the authors to present how many pixels they found that were greater than 0.2 (none according to their figure 5) and how many of these were found to be identified as Tricho."

Our processing routine extracts chlorophyll from single 4km x 4 km level2-GAC data and finds many occurrences of chlorophyll > 0.2 mg.m-3. This is shown in blobs 1 composites of the different rows of Figure 3B. In Figure 5, I used the Giovanni extraction on a monthly basis to make a good correspondence between numbers. Therefore, this panel C of figure 5 (Giovanni) does not correspond to real chlorophyll values extracted from pixels of each daily Level2 GAC SeaWiFS file. Indeed, all values > 0.2 mg.m-3 disappeared in the spatial and temporal averaging process (from 4 to 9 km resolution, and from day to month averaging). The Giovanni monthly chlorophyll extracted at 9km simply helps the reader to see what is the regular seasonal chlorophyll cycle in the South Pacific region by SeaWiFS. It shows the strong winter maximum and the summer maximum which is lower in intensity and less regular. To avoid confusion, we could have omitted this curve and also Blobs1 Figure 3 as the chlorophyll concentration is not a criteria for TRICHOSAT. TRICHOSAT only analyzes RAS with objective mathematical parameters S and Yt, bumps and troughs and does not test chlorophyll concentration.

AS: " Table 2 shows chl values of 0.22 in Aug 2002 with almost no tricho in the water (76 trichomes L-1)".

Chla values of 0.22 in Aug 2002 are winter chlorophyll (July peak) not due to Trichodesmium as indicated by the very low measured percentage of chla > 10 μm in our observations (minimum in Table 2 is 9%). The percentage of chla > 0.2 at Table 2 indicates that winter and summer chlorophyll enrichments are of different origin. Our goal was to build an algorithm to reproduce the seasonality of Trichodesmium accumulation with no (or exceptional) observation in winter

AS: "The authors have to figure out a better way to present this information"

Figure 1a could be omitted (it aimed to show what objective mathematical parameters of the RAS spectra were retained for the definition of the RAS spectrum of Trichodesmium). Figure 2b has been ameliorated by highlighting the envelope of Trichodesmium RAS (see New Figure 2 in the new version, as Figure 1 and 2 have been inverted in the last version).

AS: "Page 5662 Line 20-25. "I do not see actually this – the blob in southwest pacific in figure 3a top panel seems very similar to the blob in figure 3d top panel (Nov-Mar, corresponding when the Tricho is expected to be maximum)"

Figure 3 (see figure 7 in the new version)

We simplified Figure 3 with only two rows: the upper row shows the selection by the algorithm and the lower row shows the results of TRICHOSAT for the three different seasons. See also comments on this figure (becomes Figure 7 in the new version).

Over 12 years, the composite blob in figure 3a may resemble the composite blob figure 3d. However, there are no Trichodesmium pixels in the huge equatorial upwelling maximum, nor on the north of the Pacific Ocean after the screening by TRICHOSAT. It might be better to omit the blobs1 as the TRICHOSAT performance is independent of the chl-a concentration of the pixel, There is no relation between TRICHOSAT detection and chla concentration. I found difficult to show the results of TRICHOSAT in the WP without showing where high chlorophyll can be found but there is no relation between these two parameters. See also below our discussion of these blobs on the new figure 7. AS: "Page 5663. "I really do not like this approach. While looking at 7.2 million km2, will give a lot of pixels for statistical computation, it is not at all clear using this method how big any particular bloom was: how long it lasts etc..." To double the chlorophyll concentration of a pixel, we need 500 m2 of accumulation. This surface represents 1/32000e of the pixel surface, which is very small. Indeed, the probability of finding contiguous Tricho pixels is low as the probability to observe a 500 m2 patch within a pixel, is also weak. We have found a way to present a better representation of how big is a bloom and how long it lasts. Our new Figure 3AB shows how Tricho pixels are found around New Caledonia and Vanuatu by TRICHOSAT for small (10 days) summer and winter periods (10 days). Colors allow the reader to follow the screened pixels day by day.

AS: "And it means even less when extended over the entire Western Pacific. Figure 6 is not very intelligible." "C2497. Figure 5b is poorly scaled ..." We have changed this Figure 6 which is now a seasonal cycle of Tricho blooms (see New-Figure 6 in pdf). We have rescaled our Figure 5B by drawing 1 separate panel for each parameter. As suggested, we highlighted the bbp variability. Only the panel 1 compares the SP (5-25°S 160-190°E) and the WP (30N-25°S 160°E-160°W). Other panels relate to the SP. AS: "Table 2 says that there were 1000 trichomes/L in May 2002 (not quite low densities)." During inter-season, Trichodesmium may be abundant as in May 2002, but rarely shows surface slicks. Table 2 related to the 0-30 m obs though Tricho counts are available from 0-60 meters and pigment profiles from 0-150 meters (as found in Tenorio, PHD, 2006, DIAPAZON data PROOF data-basis, Masotti et al. 2007). AS: C2497 "I suspect the authors mean Dec 2001- Jan 2002"

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Yes, we shall correct, it should be December 2001-January 2002. I wanted to compare in Table 2: December 2002 and February 2003, as two representative months of Summer 2002 and Summer 2003 respectively. Also we will correct the text.

TABLE 1: C2498 from A.S TABLE 1: Last column: Do the authors mean Observation Platform? As pointed out earlier, I think this table can be considerably cleaned up with the extraneous information that do not contribute to validating the technique. But at the same time the table should be expanded to include information on the size of the slicks.

I indicated the size of shipboard observations when available (slick visual obs) (nautical miles slicks). In some occasions, I added indications from crews and pilots on the size of the slicks. In three occasions, long line aircrafts, I gave an estimated total covered surface.

TABLE 2. “See comments above. Again, listing of cruises that don’t add information about Tricho seems extraneous (transects2-6: how do these correspond to Tricho in any way?).”

Transects as inter-island crossings were organized to allow sampling with buckets on the Navy ship or on the Alis ship In order to check whether Trichodesmium blooms occur during winter (as no aerial or Navy ship observations were available). The winter transect (Transect 6 in July 2003) was interesting as no Trichodesmium accumulations was observed. Winter cruises also confirmed us that no Trichodesmium accumulation was ever visible in winter (Diapalis 06 in August 2002, Diapalis 08 in June 2003). The only bloom that was observed in winter (July) was the one in Fiji (Table 1), and seems rather anecdotal (1 obs against 85).

AS C2498. Figure 2B. “The symbols, notations are way too small to see anything.”

Notations have been omitted in the figure. Color Symbols have been highlighted. See New Figure 1abc in pdf)

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At first, May or October (inter-season) surface Trichodesmium blooms have sometimes been observed without being as frequent as the December-March ones and are probably indicative of exceptional favourable conditions for surface blooms (see also Moutin et al., 2005). At second, when looking at the temporal evolution at Figure 5 where the curve of Trichodesmium percentage is drawn for the Whole Pacific compared to the one of the SP, we can see that the seasonal cycle is not modified so that their influence is small. Last, for the extension of TRICHOSAT to the whole Western Pacific (WP) area, results for different years for the 1997 to 2010 period are shown by different colors. It allows to seeing the response of TRICHOSAT year by year (Figure 7 additional in the supplementary pdf file).

The relatively high response by TRICHOSAT in the northern hemisphere around 160°W was found between 1998 and 1999 during boreal winter (November-December 1998 (in yellow); January-March 1999 (in black)) contrary to was expected from visual observation made in this hemisphere (Dore et al., 2008). From 2000 to 2010, no Tricho pixels were retrieved during boreal winter in the Northern Pacific area by TRICHOSAT. We have no explanation for what happened during the 98-99 boreal winter period near Hawaii. We conclude that there is some signal there in the northern hemisphere picked up by the TRICHOSAT algorithm. Blooms of unknown origin were already reported using CZCS observation in December (Dore et al, 2008). This has to be caused by floating living material similar in reflectance to Trichodesmium and therefore having the same SeaWiFS RAS. A new research on this zone should be done to determine the nature of this signal in the Northern Hemisphere. A high number of Tricho pixels were found during our inter season period (Fig 7B) in the Northern Hemisphere. This corresponds to observations by Wilson et al. (2007). TRICHOSAT pixels are particularly abundant for the 2005 inter season (in cyan).

During the austral winter (boreal summer), TRICHOSAT pixels are less numerous in the SP and are more numerous each year in the northern hemisphere.

AS C2498. Fig. 5 “comments above, needs better scaling to make the various features

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easier to see. The choice of brown color is poor because it is barely distinguishable from the red line. Which region does the Chl a concentrations correspond to?" The figure 5 has been redrawn in 4 panels. All curves now correspond to the SP zone (5°S-25°S-160°S-170°WE). Only, in Figure 1a, I superimposed the pixel percentage for the whole Pacific Ocean (30°N-25°S 160°E-200°E) in blue. The three Giovanni curves are for the SP (5°S-25°S-160°S-170°WE). See Figure 5 in a pdf file.

AS C2498. Fig 6. This figure has been replaced by the mean seasonal cycle of Tricho pixel number (see figure 6 in pdf).

AS C2498. Fig. 8. "This is an extremely striking and wholly irrelevant figure/data presentation. The two parameters are not on the same spatial scale.

Figure 8 has been extended from 1998 to 2010 to show the daily evolution of Tricho bloom pixel numbers for the whole series of observations (1997-2010) (see figure 8 pdf file). In the new version of the figure, each red vertical bar represents the percentage of Tricho pixels within a single SeaWIFS GAC image. This figure allows the reader to follow the progression of this percentage day after day during each summer period. For the French Navy observations, we kept the monthly sum (black circles) as in the first version.

Figure 8 was simply an illustration of what can be obtained if both observations and SeaWifs data are abundant and was limited to 2004 simply because observations from the French Navy were scarce before 2002. The 2004 striking coincidence results from the conjunction of favourable conditions - the French Navy was very active in the region - there was an exceptionally long bloom with numerous and thick surface blooms – good weather favored both visual observations (as these ones disappear or are no more visible if rain or wind disrupt them) and satellite coverage.

The Nb numbers are observations taken from Table 1. Slick observations from this table 1 were summed to get a monthly Number Nb. These Nb were superimposed onto the curve of Tricho pixel from SeaWIFS, calculated from daily GAC, and also summed on a monthly basis. We also agree that is rather difficult to compare such scarce in situ observations with gridded satellite products obtained over the whole study region. The graph relates to the western tropical South Pacific area (SP, 5S-25S, 160E-170W) area, not the whole Pacific Ocean (5-25N, 160E-170W). We selected the SP area (5°S-25°S-160°E-170°W) because observations from the French Navy were obtained in this domain.

AS: We have no information on the size of the blooms observed or the spatial extent of the features mapped using the satellite algorithm – is it 0.2% of pixels that are contiguous within the 7.2 million square km region or random pixels scattered everywhere? How persistent were these pixels? How much did they coincide in space" Information on the size, spatial extent of persistence is difficult to obtain. Our redrawn Figure 3 identifies screened pixels day by day. As one square is 16 "real" SeaWifs Pixels of 4 x 4 km2, it is not sure that we can detect contiguous or persistent pixels. Nevertheless, pixels are assembled in patches visible at 16°S between 162°E and 166°E and from 20 to 21°S at 162°S. Bloom persistence can be seen from yeardays 42-43 (February 2003, 11-12) and 47-52 (February 2003, 17-22) in some places, as at the northern east of New Caledonia.

We would like to sincerely thank again Dr Ajit Subramaniam for advices and constructive comments. We hope that incorporating these corrections will make the publication more clear and convince you of the utility of the algorithm in the South Western Tropical Pacific Zone to detect surface blooms of Trichodesmium.

Sincerely, Cécile DUPOUY and co-authors October 2011.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/8/C3802/2011/bgd-8-C3802-2011-supplement.pdf

Interactive comment on Biogeosciences Discuss., 8, 5653, 2011.

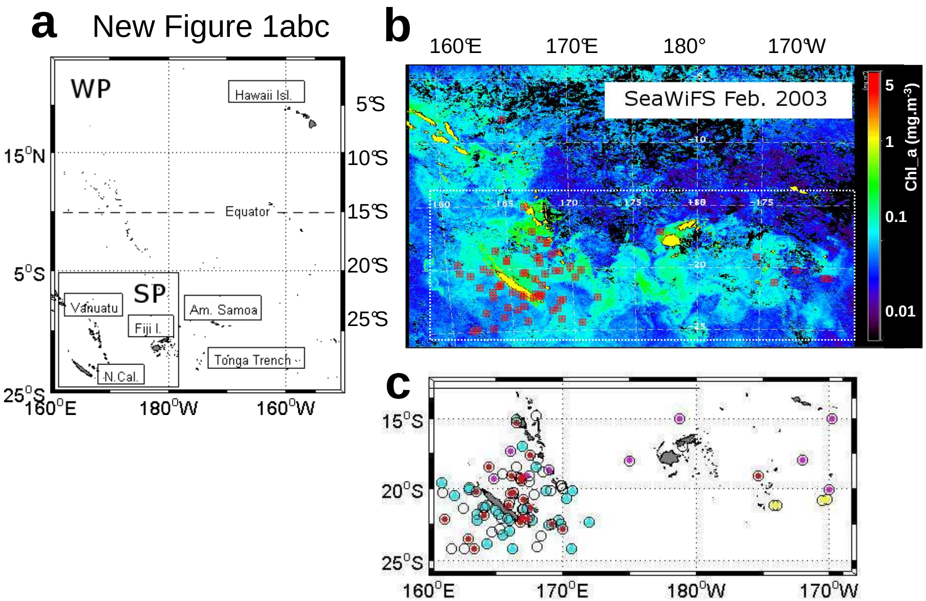

Fig. 1.

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Figure 2

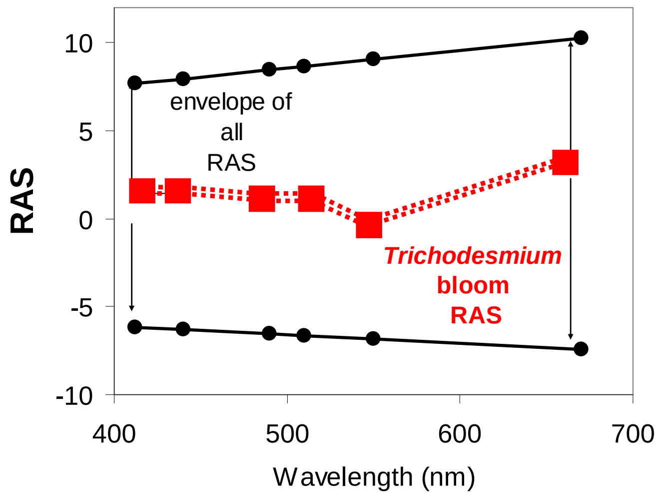

Fig. 2.

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Figure 3AB

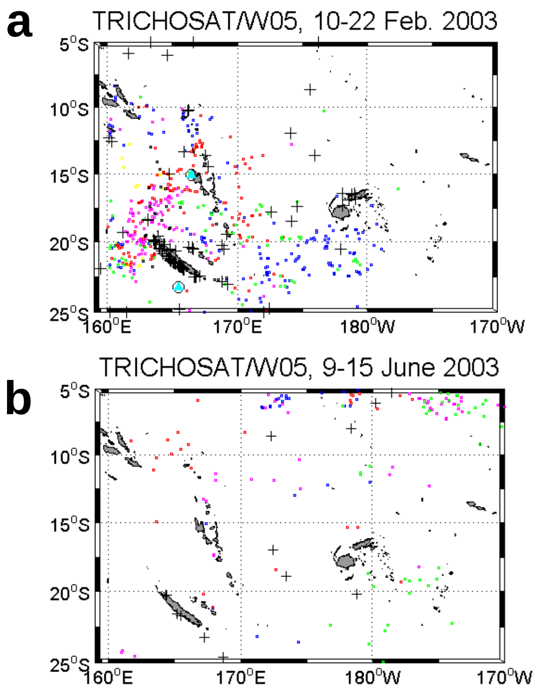

Fig. 3.

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Figure 4

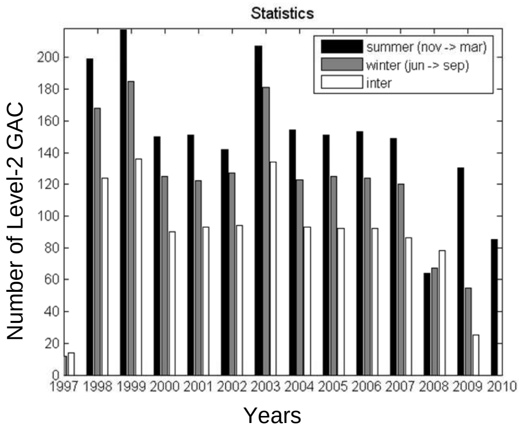

Fig. 4.

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Figure 5ABCD

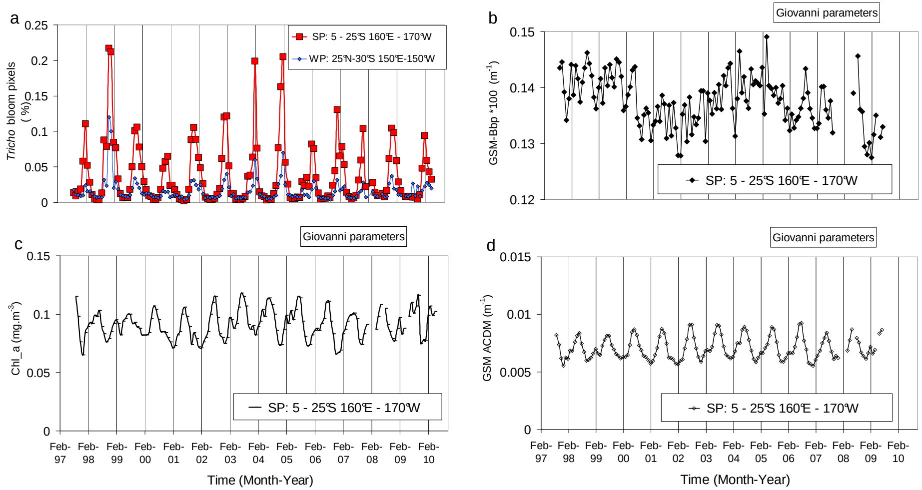

Fig. 5.

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New Figure 6

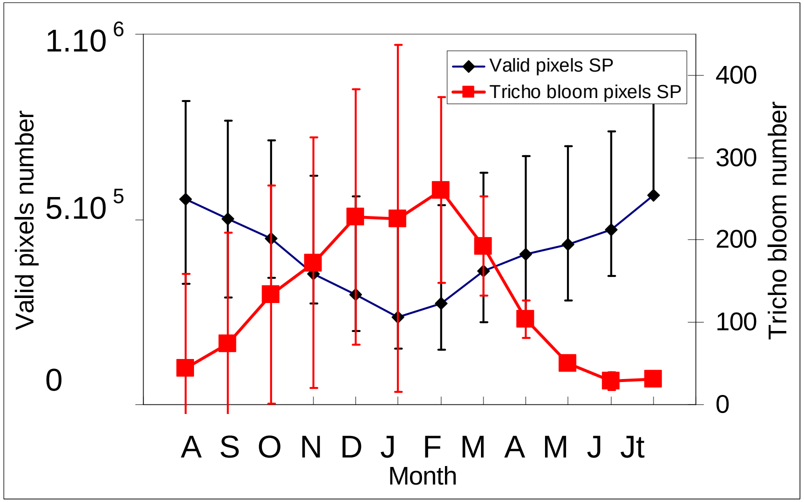

Fig. 6.

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New Figure 7ab

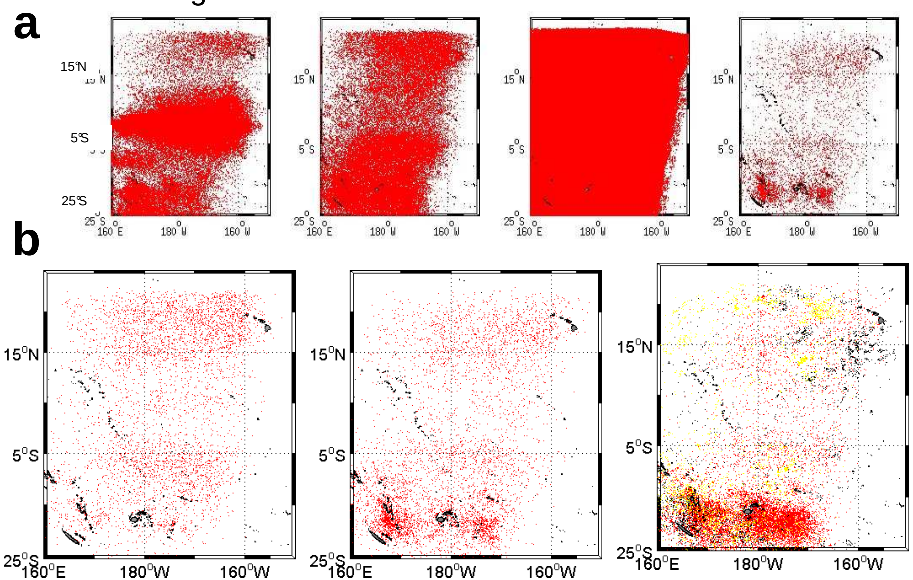

Fig. 7.

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New Figure 8

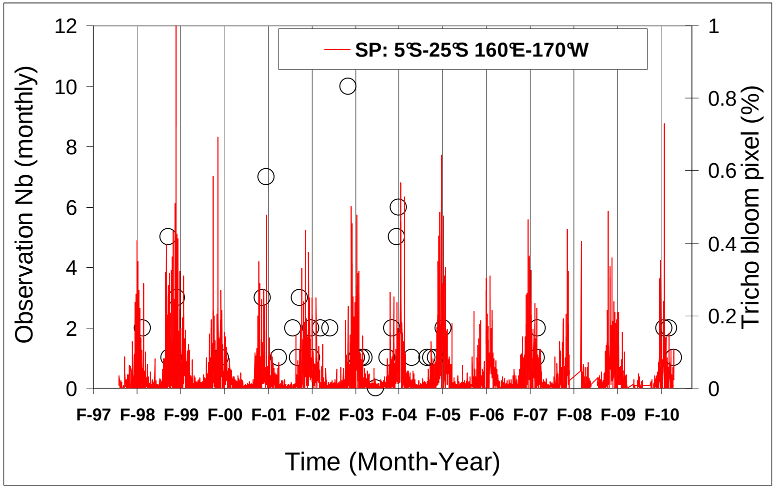

Fig. 8.

Figure 1c
Additional material

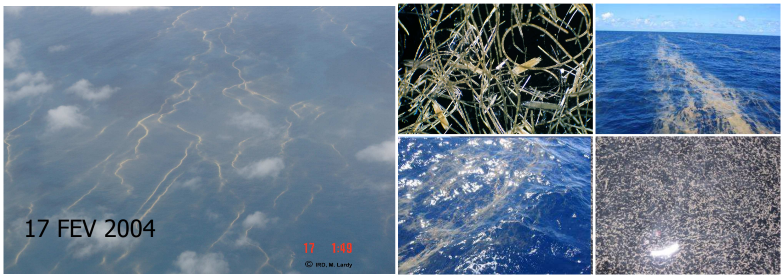

Fig. 9.

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