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Interactive comment on "Vertical distribution of chlorophyll in dynamically distinct regions of the southern Bay of Bengal" *by* Venugopal Thushara et al.

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Please find our replies to comments by Dr. E. Boss.

We thank the referee for carefully reading the manuscript and offering the comments and suggestions. We have addressed each of them below.

Q. This paper is concerned with the dynamics of chlorophyll concentration in the Bay of Bengal, and uses observations from glider, a ship, satellite and a numerical model to describe it and attempt to understand it. The paper's English is good. However, the English used is often not clear when it comes to the description of phytoplankton and

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their evolution. Bloom is never defined, sometime it seems to mean a relatively elevated chlorophyll concentration while in other time it denote a positive change in time. The paper may be of interest to readers of BG but I feel that it could be of significant more value if the authors addressed the following. I am also returning an annotated PDF (I stopped towards the end due to exasperation. Sorry.). I think addressing these will do a lot to make this paper significantly more useful.

A. We thank Dr. E. Boss for carefully reading the manuscript and offering the comments and suggestions. The term 'bloom' was used to refer to a condition of elevated chlorophyll concentration which is clearly distinguishable in space and time. During the study period, satellite observations of ocean color showed patches of high chlorophyll (0.3-0.7 mg m-3) in the regions of the Sri Lanka Dome (SLD) and the summer monsoon current (SMC), whereas the surrounding regions, outside the influence of these features, exhibited lower surface chlorophyll levels (< 0.2 mg m-3). These details will be included in the revised manuscript. The term bloom will be replaced by increase in chlorophyll appropriately.

Q. The author adopt the classical view that phytoplankton dynamics are all determined by nutrients and light with physics modulating their availability. This view is not consistent with the fact that phytoplankton do not double in concentration daily even though they, on average, divide daily in most of the oceans (see review in ARMS by Ed Laws). This bottom up view is understandable given the lack of measurements to constrain losses, but the author should be very careful in their interpretation of temporal dynamics. In fact, in the height of the bloom, the maximal concentration, is when loss = growth. The recent paper by Behrenfeld and Boss, 2017, may make this point of view clearer to the writers. Yes, productivity=growth rate x biomass, and hence when there is more chlorophyll there is likely more productivity.

A. Yes, chlorophyll distribution is determined by both physical and biological processes. In the present study, our main objective is to document the physical controls on the chlorophyll distribution, associated with the monsoon dynamics. In the southern BoB, high chlorophyll concentrations were observed in the regions of strong dynamics, including the SLD and the SMC, indicating that the distribution of chlorophyll is largely dependent on the upper ocean dynamics. The biological controls are equally important. However, lack of observations on loss terms including mortality and sinking rates, and grazing by different zooplankton groups restricts a detailed investigation on their relative importance with respect to the physical processes during different stages of the chlorophyll bloom evolution. These limitations will be mentioned in the revised manuscript.

Q. The issue of photoaclimation is very important in stratified waters as chl/C can vary by factors as high as 5. The fact that the glider measure bbp as well as chlorophyll could be use to study this question. Similarly, the model you use should have variable Chl/C, unless you use bbp to estimate C_phyto (e.g. Graff et al., 2015)

A. We agree that photoacclimation is important. Considering the variability in available light as a function of depth, the physiological adaptation of phytoplankton through photoacclimation has a significant control on the chlorophyll concentration. The observed vertical distribution of chlorophyll does not necessarily represent the phytoplankton biomass distribution, since the chlorophyll to carbon ratio (Chl/C) can vary. The relation between chlorophyll and bbp has been examined using observations from SG620 at the time series location (Figure 1). This shows a linear relationship between chlorophyll and bbp, which indicates that the Chl:C ratio did not vary much in the region during the observational period.

The ecosystem model incorporates the effect of photoacclimation on the simulated chlorophyll distribution (Dunne et al., 2010). The model calculates a variable Chl:C which is dependent on light availability following Geider et al. (1997).

Q. If Fcdom is available (not clear what the 3rd channel of the triplet is) it could also be useful to understand light availability to phytoplankton.

A. Fcdom is not available at the time series location.

Q. Chlorophyll is a limited descriptor of biology (we don't know the species and the associated ecosystem from it). Limiting the text to describe its dynamics rather than talking about the 'biology' will make your text more palatable to some. In addition, the value you are estimating for it based on 'factory calibration' is likely biased by a factor of 2 (e.g. Roesler et al., 2017).

A. Thanks to the referee for the suggestion. The text will be modified accordingly in the revised manuscript.

Q. The term 'bloom activity' is used over and over. What does that mean? Changes in chlorophyll concentrations? Try to be more precise.

A. The term bloom activity was used indicate elevated levels of chlorophyll that is clearly identifiable in space and evolving in time. Generally, the surface layers of the southern Bay of Bengal exhibit oligotrophic conditions with chlorophyll concentrations below 0.2 mg m-3. During the summer monsoon, patches of enhanced chlorophyll concentrations (0.3-0.7 mg m-3) are observed in the dynamically active regions of the SLD and the SMC. By the end of the summer monsoon, chlorophyll levels decrease considerably. For clarity, the term 'bloom' will be replaced by 'chlorophyll' appropriately in the revised manuscript.

Q. Phytoplankton primary productivity is driven by PAR, which means they care about absorbing a photon in the visible but not about the energy of the photon (blue photons have about twice as much as red one). Your light model should be in PAR not W mËĘ-2 and should take CDOM into account ('compete' with phytoplankton by absorbing blue photons).

A. We agree with the referee that PAR is the appropriate parameter to explain primary productivity. At the time series location (89E, 8N), in situ observations of the vertical distribution of PAR is not available. Spatial and temporal coverage of attenuation coefficients derived from satellite data are also insufficient during the study period. The light model presented in the analysis (Morel and Antoine, 1994 and Manizza et al., 2005) uses surface irradiance as input, instead of PAR. Hence, we preferred using the observed irradiance from the shipboard measurements to calculate the light penetration. The model considers light partioning into infrared and visible bands. Attenuation coefficients in the visible range were calculated seperately for two averaged wavelength bands (red and blue/green) at each depth levels as functions of chlorophyll profiles obtained from the glider (SG620), following Morel (1988). The vertically varying attenuation coefficients in the visible band will take into account the self-shading effect caused by the presence of phytoplankton in modulating the penetrative radiation into the subsurface layers, thereby influencing the DCM distribution.

PAR (E m-2 s-1) was estimated from the calculated penetrative radiation using the conversion,

PAR(z) = I_vis(z) * 2.75e18 / 6.023e23,

where I_vis(z) is the penetrative radiation (W m-2) in the visible range at depth z calculated using the light model, 2.75e18 quanta s-1 W-1 is the conversion factor obtained from Morel and Smith (1974), and 6.023e23 quanta E-1 is the number of photons corresponding to one mole. The depth of euphotic zone (Zeu) was calculated as the depth at which light reduces to 1% of the surface PAR value. Considering the fact that phytoplankton sees the absolute light level and not the percentage (Banse, 2004), the depth of threshold isolume (Z0.415), taken as the depth where PAR is 0.415 E m-2 day-1 below which light is insufficient to support photosynthesis (Letelier et al., 2004; Boss and Behrenfeld, 2010), is also shown (Figure 2).

Both Zeu and Z0.415 decreased during days with elevated surface chlorophyll (06-07 July) and deepened during days with weaker surface chlorophyll levels. This shows enhanced (reduced) light availability in the subsurface layers during days with low (high) surface chlorophyll, consistent with our results. Figure 10 in the manuscript and the corresponding text in Section 3.2.3. will be modifed in the revised manuscript following the above calculations. The location of study region is away from the coastal ocean indicating less turbidity and relatively lower concentrations of CDOM, except those associated with the phytoplankton blooms. Hence we believe that exclusion of CDOM effect in the present light model will not affect the results significantly.

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Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2018-300/bg-2018-300-AC2-supplement.pdf

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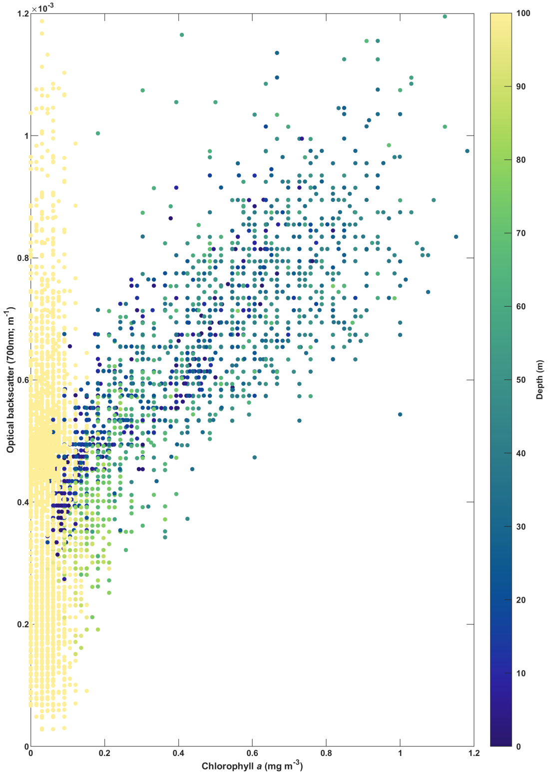

Fig. 1.

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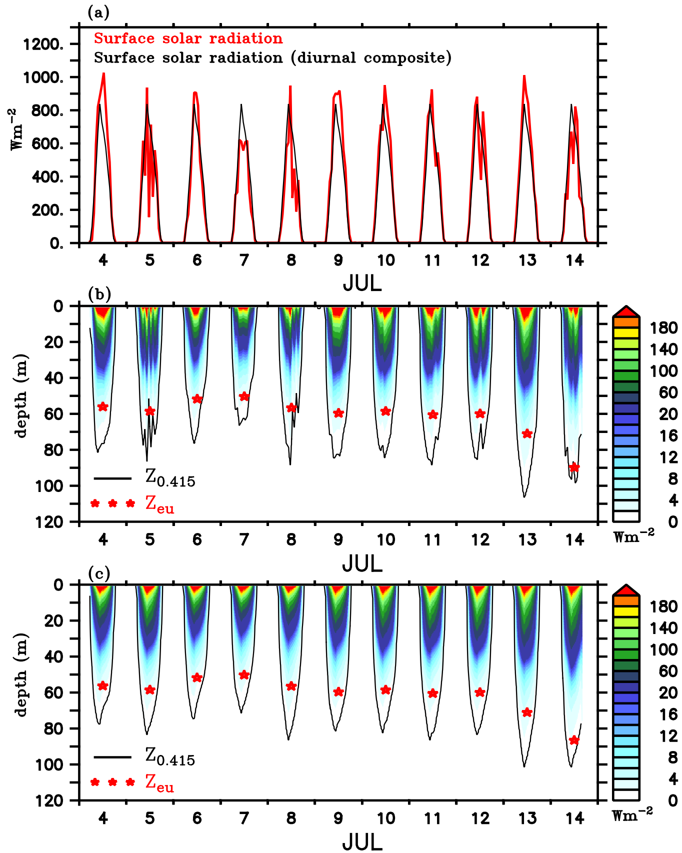

Fig. 2.

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