Author Comments 2 on "Spatial and temporal variability of solar penetration depths in the Bay of Bengal and its impact on SST during the summer monsoon"

We would like to thank Reviewer 2 who provided constructive comments and interesting questions that have improved the revised manuscript. Reviewer 2 comments have been reproduced in black with the authors response in blue and excerpts from the revised manuscript in italics.

Response to Reviewer 2

Specific comments:

1. Section 3.1: The glider measurements are discussed to explain the Chl-a variations in time vs. depth over the region of glider deployment. The BoB is known for having sharp horizontal gradients of properties (T, S, and maybe Chl-a). In the eddy region, these sharp gradients are likely to form. However, the results discussed in this section appear to assuming spatial homogeneity in the area covered by the glider trajectory. One possible solution could be to plot along-track profiles.

The reviewer is correct that we focus our discussion of spatial variations on the more widely spaced float data, and focus our discussion of temporal variability on the glider, which was occupying a time series site in virtual mooring mode. Along track profiles are not helpful since the glider spent the majority of it's time at one location. Of course any time series location is a mixture of temporal and spatial variability as eddies and fronts are advected past the glider. Nonetheless the KPP modelling in section 3.3 confirms the value of treating the glider data as a time series. We now make this clearer in the text.

> Line 243: *"Patches of surface chlorophyll, with concentrations of 0.1–0.4 mg m^{-3} (Fig. 1d), continue to be advected by the SMC into the region where glider SG579 is parked at a virtual mooring at 85° E until 19 July."*
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> Line 252: *"The temporal variability of h_2 in the SMC is large with a standard deviation of 4 m (Fig. 4a)."*

2. In Figure 2, What are causes of the measured (flagged) PAR values departing from the fit. Do we consider PAR values inaccurate in upper few meters or the double exponential fit method is not well-suitable close to surface? How would it affect the calculation of heat terms and SST (change in SST due to Chl-a)?

We would like to thank the Reviewer for their interesting questions. Flagged PAR values in the top 5 m depart from the fit due to (i) noise caused by wave-focusing and cloud shadows, and (ii) the double exponential function is not well suited close to the surface. This has now been added to Section 2.2. As mentioned in Section 2.2, the two-band model is only an approximation of the decay of visible radiation with depth across the full solar spectrum. Increasing the number of exponential terms would improve the fit to near-surface PAR, as the number of degrees of freedom increases. However, for the purposes of this study, we use the two-band model as it is commonly used in coupled ocean-atmosphere GCMs and we do not have confidence in fitting a higher band model to near-surface PAR as we would likely be fitting to noise. Due to the GCMs coarse vertical resolutions, all long wavelengths are absorbed within the first layer of a model ocean. The use of a higher band model would have little influence on the radiant heating rate and SST in these GCMs.

> Line 224: *"Generally, flagged PAR values in the top 5 m depart from the fit due to excessive noise caused by wave-focusing and cloud shadows, and the poor approximation of Eq. (1) representing the absorption of longer wavelengths near the surface."*

3. The glider and float 629 are very close in the first week of July (as seen in Fig 1) but their h2 values differ a lot and appears out of phase between these two measurements. Is it due to different sensors used on glider and float or a calibration issue, or due to any other process?

The distance between the deployment location of float 629 and SG579 is approximately 56 km, which is large enough for noticeable differences in chlorophyll concentration and h_2 values. SG579 is deployed in the middle of the SLD, whilst float 629 is deployed on the western side of the SLD. Conditions inside the SLD are conducive for increased biological activity, hence SG579 observes higher chlorophyll concentrations and correspondingly smaller h_2 values compared with float 629 on the outer edges of the SLD. Although the sensors are different on the glider and float, this has a minimal effect on final h_2 values. As mentioned in Section 2.2, line 215, the absorption rate of PAR with depth is independent of the absolute values of PAR.

4. Line 369-293: The effect of changing h2 depths on the SST is described here. A major concern is that the SST differences among different h2 values prescribed in model shows a progressively increasing differences in SST with the increasing time of simulation. At the beginning of simulation all the SST curves are aligned and by the end of July month, the difference is largest. This points to the possible issue with a drift in model. The precipitation events after 15th July changes the absolute magnitude of SST in all experiments but the difference in SST remains unaffected by precipitation.

We respectfully disagree with the reviewer. We observe no signs of drift in the KPP model when we initially 'spin-up' the KPP model for the month of June 2016. Differences in SST are caused by changes in h_2, or the absorption rate of blue light with depth, as determined from PAR measurements from SG579. These differences are due to different net heat fluxes that accumulate over time to cause the divergence noted by the reviewer.

5. Lines 63-74: Assimilation of satellite-derived Chlorophyll (Chl) concentration would improve the simulation of Chl on the surface. But the radiation attenuation occurs in the water column. How these climate models simulate the vertical profiles of the Chl? That would determine their ability to correctly representing radiation attenuation in the mixed layer and, therefore, the SST simulation.

Thank you for your question. Generally, ocean GCMs do not explicitly model the vertical profiles of chlorophyll concentrations because of the computational expense. Instead, satellite-derived chlorophyll concentration values are assigned to each ocean grid point, representing the average chlorophyll concentration between the surface and one scale depth. Using the chlorophyll-dependent parameterisations, the satellite-derived chlorophyll concentrations are converted into a solar penetration depth, which can then be used in the solar radiation scheme of the ocean model. This has now been better explained in Section 1.

> Line 69: *"Both GCMs have the capability to assimilate satellite-derived chlorophyll concentrations. These chlorophyll concentrations can then be converted into a solar penetration depth using chlorophyll-dependent parameterisations. Satellite-derived chlorophyll concentrations have revolutionized our understanding of how chlorophyll-induced heating affects ocean dynamics and the climate system (Murtugudde et al., 2002; Sweeney et al., 2005; Wetzel et al., 2006)."*

6. Lines 196-201: Radiation penetration is wavelength dependent and its attenuation is a function of Chl-a concentration and water quality. Red wavelengths are absorbed in top 1-2 m but there are other intermediate wavelengths between red and blue. Only red and blue wavelength bands are referred. What

happens to other intermediate wavelengths? How these are treated? Would it affect the overall estimate of SST change?

We do refer to the two-band model as "red" and "blue" light, but these two bands together encompass all wavelengths of visible light. As mentioned in Section 2.2, line 206, The two-band model is the simplest approximation of the full solar spectrum.

7. The water types are determined dynamically in space and time? Can we consider water type (h2 value) to be same for a period of one month?

The reviewer is correct to point out that the value of h_2 may vary temporally as the plankton blooms wax and wane. However, the point of our idealised modelling experiments is to demonstrate quantitatively the impact of different values of h_2, rather than to simulate exactly the observed variations; that would require a much more complex numerical model. We now make these caveats more explicit by including the word 'idealised' throughout Section 3.3.

8. Line 241: 'The position and velocity of the SMC relative…..south-central BoB'. There could be some contribution to the Chl-a in the south-central BoB from the productive southwest coast of India (apart from the source in the south of Sri Lanka).

The Reviewer is correct in suggesting that biologically productive water along the southwest coast of India also contributes to the chlorophyll concentrations in the south-central BoB. The following sentence has been edited:

> Line 248: *"The position and velocity of the SMC relative to the biologically productive southern coast of Sri Lanka and southwest coast of India determines how much surface chlorophyll is entrained and advected into the south-central BoB (Vinayachandran et al., 2004)."*

9. In Figure 3(d), Chl-a increases in near-surface layers during 16-17 July. What are possible reasons for this increase? Is it advection-driven due to a chance of upwelling (noticing a decrease in Chl-a just below the thermocline in the corresponding period).

The increase in chlorophyll concentration in the top 30 m during 16-17 July is likely due to horizontal advection of fresher and more biologically productive water. Upwelling is unlikely as Fig. 1d shows that the SLD has weakened by the end of July and there is no indication that the thermocline is doming, leading to upwelling and increased salinity. The vertical distribution of chlorophyll concentration is affected by additional factors that are not investigated in this study, such as nutrient supply, light limitation, grazing, mortality and sinking rates (Thushara et al., 2019). Thus, it is difficult to identify the direct cause(s) of increased chlorophyll concentration.

10. Line 360: Apart from the varying h2 values (14 m, 17 m, 19 m, 21 m and 26 m), you also have changing R values in different experiments? Since the two parameters are being changed in each sensitivity expt, one should be careful in checking that it should not affect the inferences drawn from the experiments (i.e. relating to only h2 variations).

The Reviewer is correct in that we vary the value of R and h_2 in our idealised KPP simulations. Sensitivity experiments, not in the present study, have shown that variations in h_2 contribute to the largest changes in SST, whereas variations in R contribute to small, non-negligible changes in SST. Therefore, we conclude that it is primarily the variations in h_2 that are responsible for the SST changes in our idealised experiments.

> Line 351: *"Initial idealised KPP sensitivity experiments, not presented in this paper, show that the influence of R on SST is not negligible but the influence of h_2 on SST is the largest out of all optical parameters."*

11. In Abstract: Chlorophyll influences regional climate through its effect on solar radiation absorption and thus sea surface temperature (SST) --- Chlorophyll affects climate through other processes as well (e.g. air-sea gas exchange, CO2 uptake).

The Reviewer is correct in that chlorophyll does affect air-sea gas exchange such as CO2 drawdown. This has now been highlighted in the Abstract.

> Line 13: *"Chlorophyll has long been known to influence air-sea gas exchange and CO_2 drawdown. But chlorophyll also influences regional climate through its effect on solar radiation absorption and thus sea surface temperature (SST)."*

12. Mention in figure caption- what do the error bars indicate in figure 4?

The error bars indicate the uncertainty of derived values of h_2. We have clarified this by adding an additional sentence to the figure caption.

> Fig. 4 caption: *"The error bars indicate the uncertainty of derived values of h_2."*