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Interactive comment on "Optimization of Biological Production for Indian Ocean upwelling zones: Part – I: Improving Biological Parameterization via a variable Compensation Depth" *by* Mohanan Geethalekshmi Sreeush et al.

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We are thankful to the reviewer for acknowledging the importance of our work and highlighting the point that spatially and temporally varying compensation depths in the surface restoration models are indeed important. The reviewer also gave important comments to further improve the manuscript. We sincerely thank the reviewer for recommending our paper for accepting but with minor modifications. As per his/her comments, modifications/revisions have been and more analysis have been done and reported as below. We have revised the manuscript by taking into account all the com-

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ments by the reviewer. A point-by-point reply to reviewer's comment is as follows. For clarity the comments are shown in blue fonts.

1. The introduction is too long with too many unnecessary narrations. I generally have a feeling after reading introduction several times, the paragraphs are not carrying a 'specific message per paragraphs'. Introductions required to be synchronized.

We thank the reviewer for a thorough reading and understanding of the manuscript. We agree to some extend to the reviewer's opinion that the introduction could be trimmed a bit for more clarity and avoid too long unnecessary narrations. This has been resolved in the revised manuscript.

2. The biogeochemical model used in the study requires a little more details.

We kindly request the reviewer to go through the appendix –A of the manuscript where we have given the entire details of the model.

3. Author(s) may explore the possibility of quantifying both the biological and solubility pumps which play an important role in the Indian Ocean upwelling zones.

This was a very valuable suggestion, to further highlight our claim that the biological pumps are better represented by the new parameterization. Though this was already given in the earlier version of the manuscript an explicit quantification and narration was missing. In the revised form we have resolved this issue.

As per the reviewer's suggestions we have conducted two additional simulations to quantify the impact of varying compensation depth in the biological and solubility pumps over the upwelling zones. The simulations were carried out from 1961 to 2010, however for further analysis; the data from 1990 to 2010 is utilized as done in the previous version of this manuscript. In these new simulations more model diagnostics were saved such as explicit profiles of biological pump in terms of DIC and calcite. We have adopted the methodology of Louanchi et. al., 1996 for the computation of the dissolved inorganic carbon tendency caused by the biological and solubility pumps.

The biological effect on dissolved inorganic carbon is calculated from the biomass production and calcite formation in the production zone expressed as below:

(δDIC/δt)_b=((δPO_4)/δt)_b*R_(C:P)- J_Ca (1)

The total tendency due to DIC in the mixed layer depth is the sum of both the pumps (Louanchi et al., 1996).

(∂DIC/∂t)_total=(∂DIC/∂t)_b+ ∫_x ∫_yΦdx dyãĂŮ (2)

Where (δDIC/δt)_b is evolution of dissolved inorganic carbon due to the impact of biology. ((δPO_4)/δt)_b is the rate of change of phosphate which represents the biological production in the model multiplied by the Redfield ratio (R_(C:P) = 117:1) calculated in terms of carbon and J_Ca represents the calcite formation in the model. The solubility pump is calculated by integrating the surface fluxes. Results are discussed as below.

Effect of varZc parameterization in strengthening the pump intensity over the selected upwelling regions are shown in Figure 1 (a-d) of this response note. The spatially and temporally varying compensation depth (varZc) strengthened the biological pump and solubility pump in the model as compared to constant Zc simulations.

Figure 1a shows the comparison of both solubility and biological pump over the western Arabian Sea (WAS). The analysis proves that draw down of dissolved inorganic carbon(DIC) from the production zone due to biological effect is increased by the varZc thereby strengthening the biological pump in the model.

The annual mean DIC variation due to biological effect in constZc simulation is 45.49 ± 14.3 g C m-2 yr-1. However varZc parameterization increased the DIC variation due to biological effect to 126.6 ± 24.3 g C m-2 yr-1. This is clear that the varZc has increased the strength of biological pump as evidenced by the increase in DIC variations of the production zone due to biological effects.

The above analysis clearly shows that the spatially and temporally varying compensation depth significantly affects both solubility and biological pumps in the upwelling

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zones.

Further, the results are consistent with the export production profile which is indirectly a measure of biological pump in the model. These are added to the revised manuscript.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2017-114/bg-2017-114-AC1-supplement.pdf

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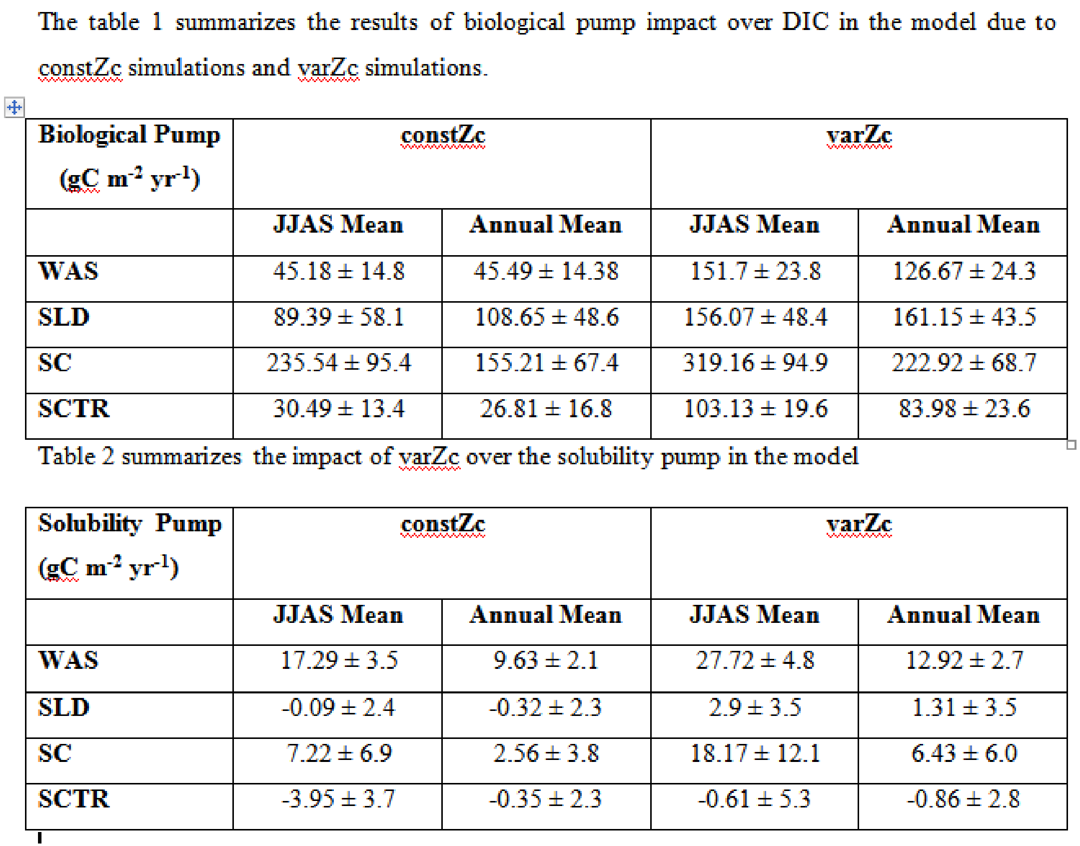

The table 1 summarizes the results of biological pump impact over DIC in the model due to constZc simulations and varZc simulations.

Biological Pump ($gC\ m^{-2}\ yr^{-1}$)	constZc		varZc	
	JJAS Mean	Annual Mean	JJAS Mean	Annual Mean
WAS	45.18 ± 14.8	45.49 ± 14.38	151.7 ± 23.8	126.67 ± 24.3
SLD	89.39 ± 58.1	108.65 ± 48.6	156.07 ± 48.4	161.15 ± 43.5
SC	235.54 ± 95.4	155.21 ± 67.4	319.16 ± 94.9	222.92 ± 68.7
SCTR	30.49 ± 13.4	26.81 ± 16.8	103.13 ± 19.6	83.98 ± 23.6

Table 2 summarizes the impact of varZc over the solubility pump in the model

Solubility Pump ($gC\ m^{-2}\ yr^{-1}$)	constZc		varZc	
	JJAS Mean	Annual Mean	JJAS Mean	Annual Mean
WAS	17.29 ± 3.5	9.63 ± 2.1	27.72 ± 4.8	12.92 ± 2.7
SLD	-0.09 ± 2.4	-0.32 ± 2.3	2.9 ± 3.5	1.31 ± 3.5
SC	7.22 ± 6.9	2.56 ± 3.8	18.17 ± 12.1	6.43 ± 6.0
SCTR	-3.95 ± 3.7	-0.35 ± 2.3	-0.61 ± 5.3	-0.86 ± 2.8

Fig. 1.

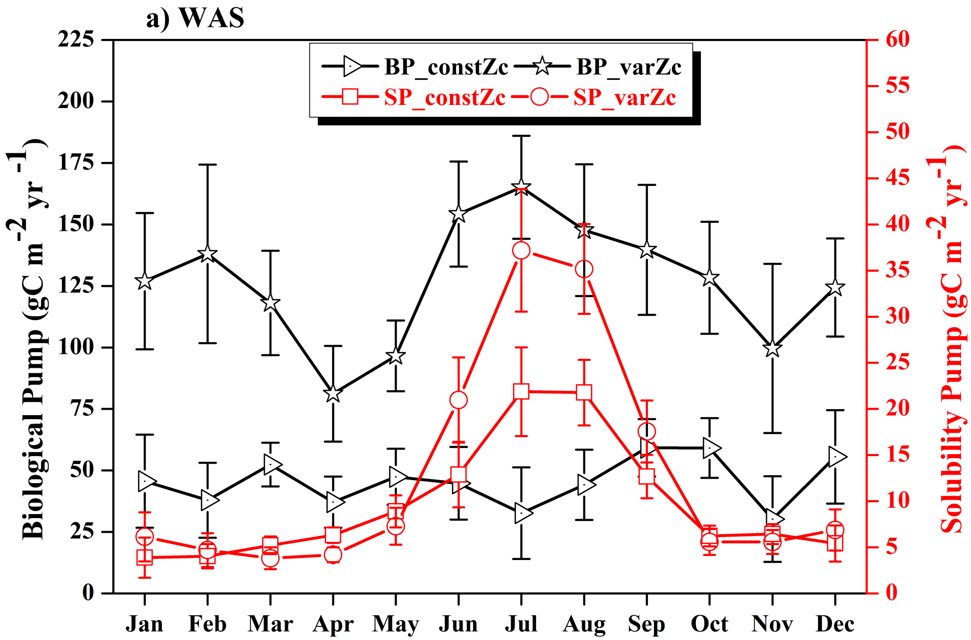

Fig. 2.

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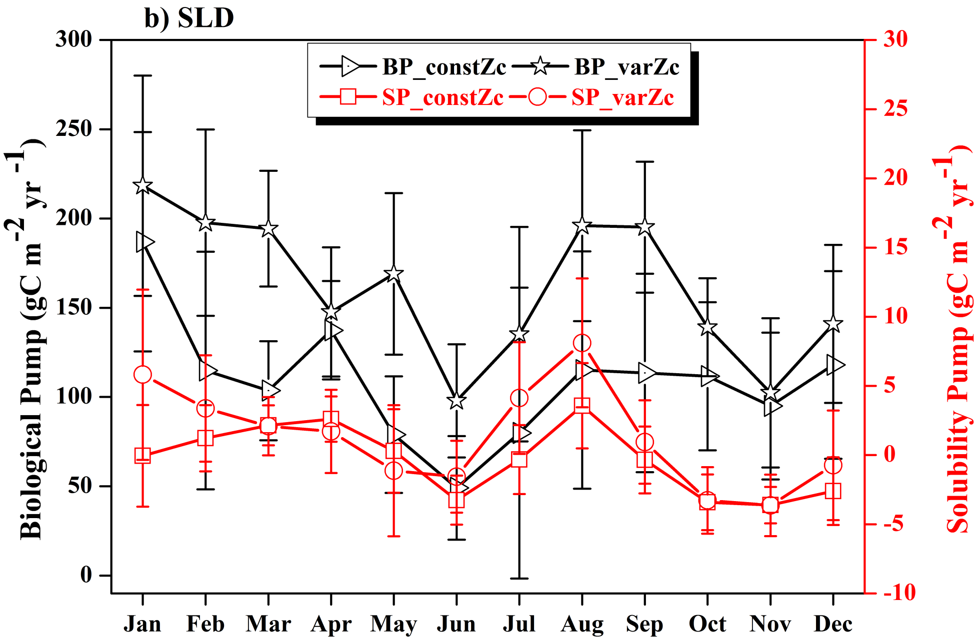
b) SLD
BP_constZc
BP_varZc
SP_constZc
SP_varZc
Biological Pump (gC m-2 yr-1)
Solubility Pump (gC m-2 yr-1)
300
250
200
150
100
50
0
30
25
20
15
10
5
0
-5
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Fig. 3.

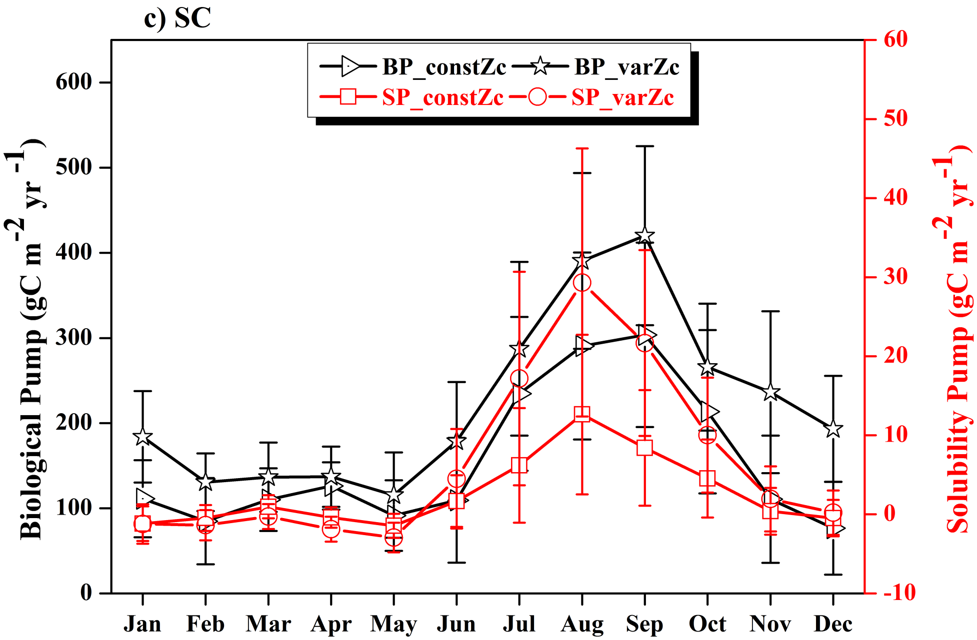

Fig. 4.

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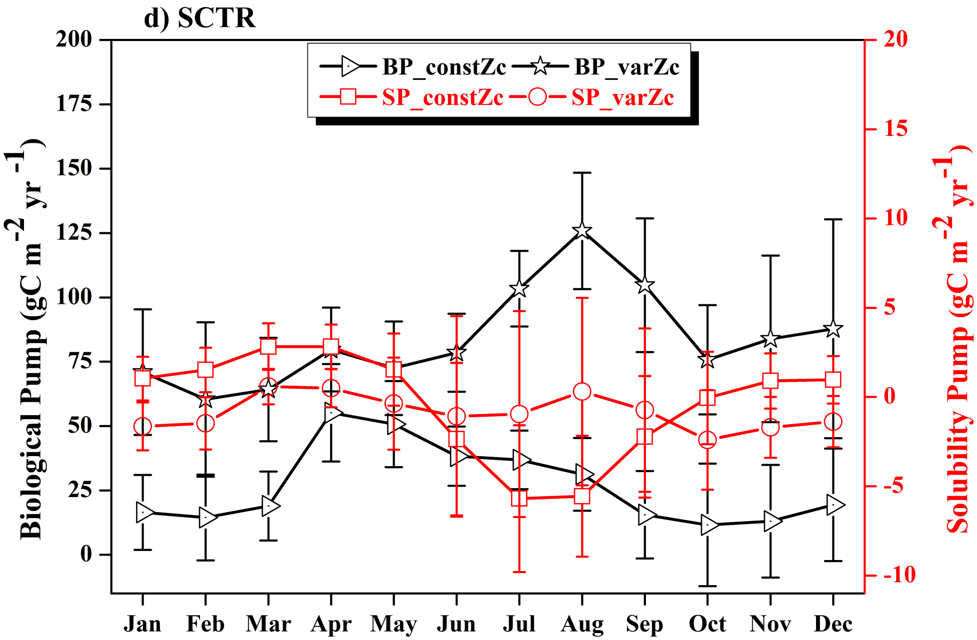

Fig. 5.

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