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The Cryosphere Discussions

Interactive comment on "Impact of Icebergs on Net Primary Productivity in the Southern Ocean" *by* S.-Y. Wu and S. Hou

Anonymous Referee #2

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Wu & Hou use net primary production (NPP; estimated from satellite observations), temperature, and iceberg occurrence frequency data to investigate the variation of NPP with temperature and/or iceberg frequency in the Southern Ocean. They apply multi-linear regression (MLR) where the logarithm of NPP is considered as response to temperature and iceberg frequency; the logarithm of NPP is used to obtain residuals that better fulfil requirements for linear regression. The MLR and calculation of various coefficients of determination (R2) is described in more detail than usual in the current literature showing the carefulness in application of these powerful methods. The authors claim that they found a small, however, statistically significant influence of icebergs.

The correlation coefficients (r) between the relative frequency of icebergs and (logarithm of) NPP and the corresponding coefficients of determination (R2) based on MLR

are small and would speak against an influence of icebergs on NPP. However, this negative result may be, at least in part, due to an inappropriate approach.

By considering the whole region south of 40°S, the authors include large areas that never see an iceberg and where thus icebergs cannot really influence NPP. On the other hand, temperature correlates with almost everything and is, at least on the large scales considered here, also a proxy for latitude, light and maybe other quantities. I'm convinced that large icebergs can have an influence on NPP, however, the question is which mechanisms are at work here (iron supply, upwelling of freshwater, increased mixing) and, depending on the mechanism, how large is the area of influence.

I suggest that the authors look at their results with open mind and discuss limitations of their approach in the light of known as well as speculative mechanisms.

General comments:

The terms 'iceberg probability of presence' and 'iceberg presence probability' should be avoided. I would prefer 'relative frequency of icebergs'.

The interpretation of correlation coefficients depends very much on the context (for example, high-quality measurements in branches of physics versus ecological observations with small sample sizes). A rule of thumb might be 'no or weak correlation' for $-0.3 < r < +0.3$, 'positive correlation' for $r > 0.3$. What's your interpretation of correlation coefficients? What is meant by 'significant' in this context?

'Correlation analysis shows that for all grid cells, NPP is significantly correlated with temperature ($r = 0.66$), but not with iceberg probability ($r = -0.03$). However, if only the cells with iceberg presence are considered, NPP becomes significantly correlated with iceberg probability ($r = 0.12$), whereas the correlation between NPP and temperature greatly weakens ($r = 0.27$) albeit still significant. When temperature is controlled, the correlation between NPP and iceberg probability increases significantly both in case of all grid cells and for cells with iceberg presence. In all cases, NPP is positively

correlated with iceberg probability, suggesting that the presence of iceberg tends to increase NPP in those places.'

When considering the whole oceanic area south of 40°S, many 1° x 1° cells have very low relative frequencies of icebergs and any variation of NPP in these 'low frequency' cell cannot be 'explained' by icebergs. Thus it is not surprising that correlation with iceberg frequency is low (r = -0.03). If restricting the area to cells where the relative frequency of icebergs is larger than zero (is zero really the threshold value), it is not surprising that the value of the correlation coefficient changes, however, r = 0.12 is still very small (-> rˆ2 = 0.01!!!). I don't understand what is meant by 'when temperature is controlled'. A correlation coefficient of 0.27 is in my opinion a borderline case.

p.6 'However, the effect of the iceberg probability on NPP increases as measured by both R2 (0.02) and standardized coefficient (0.15). This effect is statistically significant at critical level of 0.01.' I don't understand what the authors would like to convey here. R2 = 0.02 is small and thus iceberg frequency is not a good quantity for predicting or explaining variations in NPP. I do not know how the authors calculated a p-value below 0.01 and what it means in the current context. The conclusion is mainly based on these numbers (R2 = 0.02, p < 0.01):

'. . .our analyses show that iceberg presence has a small, yet statistically significant, positive impact on the SO NPP. . . . in places with iceberg presence, iceberg probability could independently explain 2% of the NPP'.

Fig.2: I doubt that comparison of zonally averaged NPP & relative frequency of icebergs yields much insight (please drop figure).

The text needs a bit polishing by a native English speaker (examples: 'planktons', 'which is much contrasted in the three ocean basins')

Specific comments:

- Southern Ocean is defined in the manuscript as the oceanic region south of 40°S

(which is fine with me): you don't have to repeat this definition several times

- abstract: 'NPP in the SO is largely influenced by temperature . . .' I suggest reformulation because MLR only shows variation of NPP with temperature and not (direct) 'influence'. Temperature is co-varying with many other quantities in the SO and thus it is not clear by what mechanism NPP is 'influenced' by temperature.

- page1, line 27: planktons -> plankton

- page1, line 30: 'in either natural or artificial settings′ you might cite here: Blain, S., Quéguiner, B., Armand, L., Belviso, S., Bombled, B., Bopp, L., ... & Christaki, U. (2007). Effect of natural iron fertilization on carbon sequestration in the Southern Ocean. Nature, 446(7139), 1070-1074.

- Smetacek, V., C. Klaas, V.H. Strass, P. Assmy, M. Montresor, B. Cisewski, N. Savoye, A. Webb, J.M. Arrieta, U. Bathmann, R. Bellerby, G.M. Berg, P. Croot, F. d'Ovidio, S. Gonzalez, J. Henjes, G.J. Herndl, L.J. Hoffmann, H. Leach, M. Losch, M.M. Mills, C. Neill, I. Peeken, R. Röttgers, O. Sachs, E. Sauter, M.M. Schmidt, J. Schwarz, A. Terbrüggen, & D. Wolf-Gladrow, Deep carbon export from a Southern Ocean iron-fertilized plankton bloom, Nature, 487, 313-319, 2012. doi:10.1038/nature11229

p.2 total dissolved Fe in SO: you cite more recent work: Klunder, M. B., Laan, P., Middag, R., De Baar, H. J. W., & Van Ooijen, J. C. (2011). Dissolved iron in the Southern Ocean (Atlantic sector). Deep Sea Research Part II: Topical Studies in Oceanography, 58(25), 2678-2694.

Klunder, M. B., Laan, P., De Baar, H. J. W., Middag, R., Neven, I., & Van Ooijen, J. (2014). Dissolved Fe across the Weddell Sea and Drake Passage: impact of DFe on nutrient uptake. Biogeosciences, 11(3), 651-669.

p.2, lines 9-11: Fe from sediments has to be mixed up or upwelled; Fe source from hydrothermal vents is missing

German, C. R., Legendre, L. L., Sander, S. G., Niquil, N., Luther, G. W., Bharati, L.,

... & Le Bris, N. (2015). Hydrothermal Fe cycling and deep ocean organic carbon scavenging: Model-based evidence for significant POC supply to seafloor sediments. Earth and Planetary Science Letters, 419, 143-153.

p.2, line 16: drop 'Thus'

p.2 'Raiswell and Canfield (2012) recently even suggested that icebergs could supply more than 90% of total colloidal and filterable Fe in the SO.' Raiswell and Canfield (2012) write: 'The model indicates that the rate of delivery of bioavailable Fe from icebergs to the Southern Ocean is at least as large as that by wind-blown dust. However estimates of all the main aqueous, nanoparticulate and colloidal (and potentially bioavailable) Fe inputs to the ocean are poorly-constrained.'

p.4, lines 8-9 'μ is the mean of the variable and σ is the standard deviation of the variable' -> 'm is the mean and s is the standard deviation of the sample' & change eq. accordingly, i.e. z = (x – m)/s

p. 4, lines 26-27 'NPP is relatively high near the coast of Antarctica, largely because of nutrient input from the continent.' I suggest replacing 'nutrient' by 'iron'.

p.4 -60 °S -> 60°S [drop minus sign: S already indicates 'negative' latitudes; no space between degree symbol and S]; please change everywhere in manuscript

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