

## ***Interactive comment on “Calcification and distribution of extant coccolithophores across the Drake Passage during late austral summer 2016” by Mariem Saavedra-Pellitero et al.***

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General comments:

Referee #1 (R#1): This manuscript is well written and of high quality. The authors present a valuable dataset with respect to observed coccolithophores. They present fantastic detailed plots of coccolithophore species in this Southern Ocean transect. This transect is slightly westward of the transects presented Charalampopoulou et al. (2016), which is a similar study. This manuscript offers more information on depth variations in coccolithophore abundances than previous studies in this region, which is great! This study reaches much of the same overall conclusions as previous tran-

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sects observing coccolithophores in the Southern Ocean, so it is not groundbreaking, but adds to a solid overall conclusion of coccolithophores transitioning from more calcified species/morphotypes in the subtropics to less calcified ones in the ACC region. The conclusion that temperature is a controlling factor on coccolithophore abundance agrees with previous studies (e.g., Charalampopoulou et al., 2016). I think this manuscript is in great shape and only needs minor revisions.

Mariem Saavedra-Pellitero et al. (MSP): We thank reviewer #1 for his/her insightful comments and we agree with most of them and made changes accordingly.

R#1: One piece that is missing is a bit more specific speculation about how coccolithophore abundance/calcification could change with climate change. The authors say that coccolithophores will be strongly influenced, but not how they will be influenced. I think it's important to hypothesize the direction of change, given current observations and relationships with environmental variables presented in the study. I also think that the positive relationship between temperature and coccolith mass needs to be emphasized a bit more. MSP: This point has been made also by reviewer #2. We included more information regarding the missing information at the end of section 4.3.

R#1: It is a bit of a shame that nutrients and carbonate chemistry parameters were not measured in situ, but I do not think that having these measurements would have changed the conclusions (it would have just added more strength to them). MSP: We absolutely agree with reviewer#1 and we are aware that it is a limitation we have face in this study.

R#1: I also think that the depth variations between the three different oceanic region clusters could be more emphasized (especially because this was not as well presented in previous studies, so I find it to be new information): maximum depth of coccolithophores decreases poleward. MSP: We added more details regarding depth variations for each of the clusters/zones in section 4.2. Additionally, we mentioned it now in the abstract, conclusions and also briefly in section 4.1.

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Specific comments: R#1: Page 1, Abstract: maybe add in something about the decreasing depth of coccolithophores as you go poleward (as shown in Figure 3a) MSP: We wrote: “We find that coccolithophore abundance, diversity and maximum depth habitat decrease southwards marking different oceanographic fronts as ecological boundaries” in the abstract.

R#1: Page 2, Line 6: extra “substantial”. MSP: The extra “substantial” was deleted.

R#1: Page 2, Lines 11-13: This sentence is awkward and a bit hard to understand. Maybe it would be best rewritten like this: “Coccolithophores produce up to 40% of open ocean calcium carbonate (Poulton et al., 2013) and are responsible for 20% of global net marine primary production (Malone et al., 2017). Therefore, how coccolithophores respond to changing oceanic conditions is of upmost importance for marine ecology and carbon cycling.” MSP: We rewrote this sentence (literally) using the suggestion from reviewer #1.

R#1: Page 2, Line 32: I think that it’s important to include that the Beaufort et al (2011) study includes both modern samples and paleodata from the last 40000 years. Maybe just add “over long timescales”: “A known positive correlation exists over long timescales between surface-ocean : :.” MSP: We agree and therefore we added “over long timescales” to the text.

R#1: Page 3, Line 6: replace “actually” with “recently” MSP: We replaced “actually” with “recently”.

R#1: Page 3, Line 15: Perhaps replace “species levels” with “overall coccolithophore calcification” since Beaufort et al. (2011) and Freeman and Lovenduski (2015) both have drawn conclusions based on overall coccolithophore calcification. While the Beaufort study has some species level information, the Freeman and Lovenduski study does not. MSP: Following the suggestion of reviewer#1 we made this sentence simpler, and wrote: “Even with a temperature-driven range expansion of coccolithophores in the SO, surface ocean carbonate chemistry is now capable of exerting a first-order

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control on the composition of coccolithophore assemblages as well as on overall coccolithophore calcification (Cubillos et al., 2007; Mohan et al., 2008; Beaufort et al., 2011; Freeman and Lovenduski, 2015)”.

R#1: Page 3, Line 23: Break this sentence up into two sentences for clarity: “Accordingly, we calculated extant coccolithophore species numbers at different stations between 10 and 150 m of the water column and evaluated the coccolith mass variations of *E. huxleyi*. We compared these observations with in situ conductivity–temperature–depth (CTD) measurements, carbonate chemistry parameters, as well as to previously published Southern Ocean coccolithophore and calcification datasets.” MSP: We split the sentence into two shorter ones.

R#1: Page 3, Line 28: no need to capitalize “stations” MSP: We changed it to “stations”.

R#1: Page 6, Line 7: instead of “a taxon” say “one taxon” MSP: We use “one” instead of “a”.

R#1: Page 7: Line 22: Add references to Figures 4 and 5: “: : , grouped into A (Figure 4) and B (Figure 5) according to Young et al. (2019). Also, by “Young et al., 2019” do you mean Nanotax3 website? It is unclear what reference this is referring to in the bibliography. MSP: We added the references to Figures 4 and 5 as suggested. Yes, as pointed out by reviewer#1, we unclearly referenced Nanotax3 website in the previous version. To ensure that we cite it correctly this time, we double checked in <http://www.mikrotax.org/Nannotax3/pages/ntax-citation.html> and referenced accordingly.

R#1: Page 7, Line 30: Type A overcalcified and Type R seem very similar to me. How are they different exactly? MSP: They are indeed similar and showed similar distribution, but they still show slightly different morphologies, as shown in Plate 1. In *E. huxleyi* type R the slits between distal shield elements are almost or totally closed, and the tube is usually thick (Plate 1 a) giving a Reticulofenestra-like appearance, while type A overcalcified shows just a closed or nearly closed central area (Plate 1 b, c), but

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not almost closed slits. Since this information can be found in the original sources mentioned in the section 2.1, we simply added the references to the specific pictures of the different morphotypes displayed Plate 1, e.g., “Type R (Plate 1 a)...”

R#1: Page 8, Line 23: When you say that *Syracosphaera* dominates in the SAZ, do you mean that it dominates among the rare coccolithophore assemblage or among coccolithophores overall? Please modify to be more specific. MSP: We specify now that it dominates among the rare coccolithophore assemblage.

R#1: Page 9, Line 7: Take out the extraneous “the” before 77.4%. MSP: “The” was deleted.

R#1: Page 10, Lines 25-29: Could silica be becoming more limiting north of the PF, opening a niche for coccolithophores? Perhaps competition among phytoplankton is another possibility of coccolithophores increasing in abundance at the PF. MSP: This is a likely possibility, as far as we know from other papers in the Atlantic sector of the Southern Ocean (e.g., Smith et al., 2017). However, we do not have in situ silica measurements or diatoms counts, so we decided to avoid speculation and did not to include this suggestion in the new version of the manuscript. Future research could usefully address the interesting shift in dominance from coccolithophores to diatoms across the PF (also mentioned by reviewer #2) and assess the interrelationship between both groups, even at a sub-species level.

R#1: Page 11, Line 10: rather than saying “up to 61.7\_S”, maybe it’s more appropriate to say “down to 61.7\_S” MSP: We changed it to “down to”.

R#1: Page 11, Line 21: misspelling of the word “coastal”; and instead of saying “: : increasing towards oceanic regions” maybe say “: : increasing towards open ocean regions” MSP: We made both changes

Page 12, Line 12: change “communities” to “community” MSP: We could not find the word “communities” in page 12 line 12, so we assumed that reviewer#1 was referring

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to page 12 line 3. We changed “communities” to “community” in that sentence.

R#1: Page 12, Line 19: The widely used *E. huxleyi* strain NZEH (morphotype R) and *E. huxleyi* strain RCC1216 (morphotype R) were both isolated from around New Zealand so I believe that would count as “observing” it there too. For example, see Methods in Iglesias-Rodriguez et al. (2017) and Langer et al., (2009): Iglesias-Rodriguez, Maria Debora, Bethan M. Jones, Sonia Blanco-Ameijeiras, Mervyn Greaves, Maria Huete-Ortega, and Mario Lebrato. “Physiological responses of coccolithophores to abrupt exposure of naturally low pH deep seawater.” *PloS one* 12, no. 7 (2017): e0181713. Langer, Gerald, Gernot Nehrke, Ian Probert, J. Ly, and Patrizia Ziveri. “Strain-specific responses of *Emiliania huxleyi* to changing seawater carbonate chemistry.” *Biogeosciences* 6, no. 11 (2009): 2637-2646. MSP: We thank reviewer#1 for those interesting papers. They are cited now in the new version.

R#1: Page 12, Line 30: change “up to ca. 6\_C” to “down to ca. 6\_C” MSP: We changed it to “down to ca. 6\_C”.

R#1: Page 13, Line 20: change “decreases” to “decrease” MSP: We changed it to “decrease”.

R#1: Page 14, section 4.3 in general: I think that the temperature as a controlling factor needs to be discussed more. It’s in the abstract (Page 1, Line 28/29) as a greater limiting factor than carbonate chemistry, which I totally agree with, but I think it needs more discussion in the paper. MSP: We included more information regarding this point at the end of section 4.3.

R#1: Are colder temperatures in the poleward direction selecting for lightly calcified species/morphotypes? Or could it be a physiological change induced by colder temperatures? MSP: These are in fact very interesting questions that we will keep in mind for future work. However, we believe that we would need more data in order to properly answer them. In the new version of the manuscript, we highlighted the relevant role of temperature, and mentioned the degree of adaptive potential of coccolithophores (last

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sentence in section 4.3), but we did not want to speculate more.

R#1: I think a bit more speculation (perhaps bringing in some laboratory experiments) would be nice in this section. MSP: We added more speculation (and more references citing culture experiments) in section 4.3.

R#1: There's a summary of the effects of temperature on coccolithophore calcification in Krumhardt et al. (2017): Krumhardt, Kristen M., Nicole S. Lovenduski, M. Debora Iglesias-Rodriguez, and Joan A. Kleypas. "Coccolithophore growth and calcification in a changing ocean." *Progress in oceanography* 159 (2017): 276-295. MSP: We thank reviewer#1 for suggesting this paper. We cited it in the new version in section 4.3.

R#1: Page 14, Line 20: misspelled the word "mass" MSP: We corrected it.

R#1: Page 14, Lines 20 – 25: It's good that you pointed out the fact that the carbonate chemistry parameters have been estimated, rather than measured. However, the latitudinal gradients in carbonate chemistry parameters are pretty well established and I don't think it would affect the relationships you're seeing. MSP: We thank reviewer#1 for this positive comment.

R#1: Page 15, Line 3: misspelled the word "Striking" MSP: We corrected it.

R#1: Page 15, Line 10. Here is where it would be good to speculate on the direction of change in coccolithophore abundance/calcification (or latitudinal species/morphotype shifts) with ongoing climate change. You could bring up the positive correlation with temperature shown in Table 4 and the PC analysis. MSP: We speculated about possible future scenarios in section 4.3.

R#1: Figure 13: I like that you included this comparison to the Charalampopoulou et al. (2016) paper. Is the direction arrow on the right hand side of the figure supposed to say "East" rather than "West"? I thought the Charalampopoulou transects were to the east of the present study. : : MSP: We thank reviewer#1 for spotting this mistake. We modified Figure 13 and wrote "East", because those transects are east of our study.

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R#1: Table 1 and Plate 1: I like that you grouped the E hux morphotypes into 2 main groups. There seems to be a fluidity between all these morphotypes and grouping into only 2 groups makes the information much more digestible. MSP: We are glad that reviewer#1 appreciate our approach.

R#1: Table 4: misspelling on the line HCO<sub>3</sub>- CO<sub>2</sub>Sys MSP: We corrected it.

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