Review for: Biogeosciences Discussions

Title: The Southern Annular Mode (SAM) influences phytoplankton communities in the seasonal ice zone of the Southern Ocean
Authors: Greaves et al.
1st review

Summary

Greaves et al. hypothesize that a large-scale climate mode (the Southern Annular Mode; SAM) shapes phytoplankton communities in the sea ice zone of Antarctica through effects on ocean mixing, nutrient upwelling or sea ice cover. This sea ice zone is relevant to marine primary productivity and marine carbon export and constitutes an exceptionally dynamic and cold habitat. To quantify SAM, the authors use an index, defined as the zonal mean sea level air-pressure at 40°S minus the zonal mean sea level air-pressure at 65°S (Gong and Wang, 1999). This index has become more positive throughout the years 1979 to 2017 (i.e., weaker high-latitude pressure, relative to the mid-latitude pressure) and was linked to stronger winds and upwelling at 60°-70°S (latitudes of the sea ice zone). The authors use a 'time-window approach' to detect the possible imprint of SAM on phytoplankton community composition, and they study composition-environment relationships for an additional 13 variables (including sea surface temperature, nitrate concentration, and sampling day, among others). The authors report that a time-averaged SAM signal explains 13.3% of variance in phytoplankton community composition across 52 samples (spanning 22 taxa and 11 spring/summer periods from 2002/3 through 2012/3). This SAM signal is obtained by averaging daily SAM across two months and by centering it at March 11th prior to the sampling period. However, the most powerful predictor reported is sampling day (15.4% of variance explained). Furthermore, the authors report disparate responses in the relative abundance of small vs. large diatom species to increasing (time-averaged) SAM. It is concluded that SAM signals influence phytoplankton communities in the seasonal ice zone of Antarctica.

General evaluation

This study focuses on the intersection of sea ice and water in Antarctica. From an ecological and climate point of view, the quantification of patterns and predictors of phytoplankton composition in this large-scale habitat appears timely and important. The data collected appear useful to address this understudied habitat. However, I identified a serious lack of clarity in the writing and structure in many parts of the manuscript (i), and have a main conceptual critique point (ii).

(i) Key concepts (SAM or SAM index) are not clearly defined. The SAM definition leaves it open to the reader, how the sign of the SAM index is calculated, and whether atmospheric pressure or water pressure constitutes the SAM index. There is a problem with clarity of statements and consistency of word use (e.g., different expressions are used for the same thing), and a lack of clear correspondence between hypothesis, methods, and key results. I provide detailed examples on clarity below.

(ii) My main conceptual critique point is that the impact of the time-averaged SAM signal in autumn on phytoplankton community composition in spring to summer has

not been firmly tested by the data shown. The study demonstrates that it is possible to average the daily SAM index in a way that a significant part of the variation in community composition can be explained in next spring/summer, yet it is unclear why microbial species that live on timescales from days to weeks, would respond to the SAM signal with a time-lag of several months. I suggest that relationships between a more positive state of SAM in autumn and temperature, wind speed, mixed-layer depths, and nutrient levels in spring to summer—factors that may directly shape phytoplankton composition—shall be evaluated, to support the paper's message. In section 4 ('Other relationships'), there are several relationships presented between predictors, yet the results are not presented in a structured way to support the hypothesis that SAM-induced changes in temperature, wind-speed, mixed-layer depth or nutrient concentrations affect community composition. The current association between the SAM signal (or "SAM modes") described and community composition may not be causal. In the context of fast-lived organisms it seems crucial to test if the link between summer community composition and (preceding) SAM is plausible.

Recommendations

I suggest that the manuscript is thoroughly screened for clarity. Second, besides further testing the associations of the SAM signal of autumn with physicochemical factors known to affect phytoplankton composition (and whether these associations are in line with expectation), I suggest splitting the 22 taxa into ecological test groups, which are expected to respond differently to changing mixing-, wind-, and nutrient-patterns under a more positive SAM state. These expectations can be presented as specific hypotheses in the introduction. Such a biological approach has been partly implemented by comparing small diatoms (presumably better adapted to stable waters) with large diatoms (presumably better adapted to strong mixing). Yet the results of this test lack a graphical presentation in the manuscript, across all taxa. Species may be grouped further into warm, temperate, or polar species, depending on their global distributions (e.g. using observations from OBIS and GIBF; Righetti et al., 2019) and their responses may differ under SAM-induced warming/cooling. Similarly, R-strategist (fast growing, light stress tolerant species) and S-strategists (slow growing, nutrient stress tolerant species) may be grouped together (Brun et al., 2015), as they may respond oppositely to changing nutrient levels. Additionally, species with large vs. small cells may show opposite responses to changing turbulence and wind regimes (Margalef, 1997, 1978). Finally, predicting the response of siliceous vs. calcareous taxa to SAM constitutes an exciting hypothesis: these groups have shown opposite responses to deeper mixing or nutrient entrainment (Cermeño et al., 2008). With respect to the clustering techniques used to describe communities I cannot give detailed recommendations, as the metrics used are beyond my expertise.

Detailed comments

There are too many comments to be listed. I therefore give examples for selected paragraphs, with comments on clarity, for each:

Abstract:

- Line 3: How many variables were tested?
- Line 6: How many species (genera, higher taxa) were included among the 22 taxa?
- Line 7: I do not understand 'CAP'. This term has not been introduced.

- Lines 8, 9, 11, 17: The following terms are used: taxonomic community composition, taxa composition, phytoplankton community structure, taxonomic composition of phytoplankton. While I understand that the authors strive to include stylistic variation, the reader is confused by the multiple expressions. Do they denote the same thing or not? I recommend using use the same expression for the same thing. Else, once an expression is clear, an abbreviation of the latter may be used therein, as long as it denotes the same thing.
- Line 10: Unclear to me, if the correlation is significant or not.
- Line 13: Unclear to me, if "response" means a response of abundance or not.
- Line 15: Before, the expression "SAM index" was used, not "higher SAM". Does "higher SAM" refer to a more positive state of the SAM index?
- Line 17: Confusing, as taxonomic composition of phytoplankton is not the same thing as a standing stock (or a "pasture") of biomass of phytoplankton.
- Line 16: It is unclear to me, if the expression "pelagic ecosystem" is suitable in the context of a sea ice transition zone.
- Line 16: It is unclear, how many of the total species that were studied, responded significantly to SAM. Thus, it is unclear, if this result is important or general.
- Line 10 ff: It is surprising that 'day of sampling' explains more variation in community composition than any other locally sampled environmental factor (SST, nutrients, etc). An interpretation on why this is the case would help the reader to assess the plausibility or importance of this result.

Introduction:
- Line 21-23: The first two sentences are partially repetitive.
- Line 21 ff: The paragraph wants to establish the importance of phytoplankton productivity in the study area for global phytoplankton productivity. While the reader understands that a larger fraction (~30%) of carbon fixed by phytoplankton is exported in the study region, relative to the global average (~ 20% exported) it remains unclear, if the study region is globally important. What is the area-weighted contribution of the study region to global phytoplankton C-export?

1.2 The Southern Annular Mode
- Line 58 ff: Clarify the definition of SAM (see above). The reader cannot grasp how the sign of SAM is calculated or linked to changing pressure gradients, and thus how it is associated with physicochemical changes in the study system.
- Line 64 ff: SAM vs. SAM index vs. SAM state vs. SAM mode. Please use consistent expressions throughout the manuscript. (In addition, "taxon" could always refer to both a species and a group of species, and the use of "mode" in both the context of SAM and community composition may confuse the reader).

2.1 Phytoplankton composition and abundance
- Line 116: One reads as if the abundance of phytoplankton communities was sampled. As much as I understand, the abundance of species or taxa was sampled. (Then, an abundance-weighted community composition was calculated?).

2.3 Statistical analysis
- Line 151 ff: The methods section needs clarification, structurally and through editing. In this section, I have difficulties to understand whether three or more sets of analyses were performed based on the phytoplankton field data, and which of

these analyses is most important to test the key hypothesis of the paper, and at what temporal resolution the analyses were performed.

- Line 152: Has "community structure" really been correlated to "environmental covariates"? If I understand correctly, the abundance data was related to possible environmental drivers, per species. In this case, please specify: e.g. …and *species* abundance between samples…
- Line 151 ff: It is not clearly motivated, why clustering of community-level samples is suitable to identify the effect of SAM on community composition. To me, the number of 52 samples seems rather low already, and each degree of freedom may be valuable.

3. Results

- The first results presented to the reader are abundance-distributions of taxa across samples. Yet, the reader might expect that the most important piece of evidence to elucidate the role of SAM for phytoplankton composition is first presented.
- Line 206 ff. Can P, n, and R^2-values be provided for the correlations?
- Table 1: I do not understand, why nutrients are excluded in this table.
- Figure 5. The caption remains vague. What are the "several underlying assumptions" of linear regression? Relevant to be discussed in the caption?

Overall, the manuscript requires a clear structure in order to show to what degree the SAM signals may matter to community composition, based on (ecological) hypotheses tested and data. The support in the data for this message, and the evaluation of the manuscript are complicated at current and warrant further attention.

Damiano Righetti, November 20, 2019

References

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