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Biogeosciences Discussions

Interactive comment on "Contrasting responses of DMS and DMSP to ocean acidification in Arctic waters" *by* S. D. Archer et al.

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We thank Reviewer 2 for their useful, thought-provoking and positive comments; which are addressed below:

Introduction: we accept criticism of the structure and content of the Introduction and will reduce over-emphasis of the description of the role of DMS in the atmosphere and describe in more detail the strengths of the current study.

P12804, l 25: 'this' changed to 'the estimate by Lana et al. (2011)'

P12805, l 26: as stated above, we will reduce the emphasis on the atmospheric role of DMS generally in the introduction. Nonetheless, our intention was to clearly present the importance of understanding possible consequences of altered DMS emission to

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the atmosphere driven by ocean acidification, particularly in the Arctic atmosphere.

P12806, l 1: accepted, reference to Caldeira and Wicketts 2003 will be made.

P12806 l 5: accepted, the sentence will be altered to: 'The rapidity and scale of change of acidity and carbonate chemistry of the surface oceans has the potential to alter the physiology of microorganisms and impact on biogeochemical processes (Riebesell and Tortell, 2011); including the production and removal of biogenic trace gases such as DMS.'

P12806 l 12: 'conclusive evidence of the mechanisms involved' has not been achieved because previous studies have understandably concentrated on determining pH-associated variations in DMS and in some cases DMSP, over the course of mesocosm-type experiments. An improved understanding of the mechanisms behind alterations in DMS or DMSP concentrations requires a greater emphasis on measuring relevant process rates, an altered experimental design that includes a gradient of levels of acidity rather than contrasting only two levels, and as comprehensive an understanding of the composition and activity of the biological communities as possible. We will explain the advances in the approach used in the current study as part of the introduction, as suggested by the reviewer.

P12806 l 16-22: In order to clarify our point we will alter the sentence to: 'Changes in primary production may have a considerably larger influence on DMSP production if they involve alterations in the biomass of the principle DMSP producing taxa or are accompanied by changes in the proportion of the phytoplankton community that comprises DMSP-producing taxa.'

P12806 l26: we will restructure the paragraph in light of the reviewer's recommendation to briefly explain the DMS cycle and then outline which components may be susceptible to ocean acidification and how much is known about these components from previous studies.

BGD

9, C7269–C7274, 2013

Materials and Methods:

P12808 l5: altered to 't-7'

P12808 l5: we have added that the mesocosms were 'cylindrical' and added the following sentence to clarify that they were sealed: 'On 2 June ($t-5$), the mesocosms were closed, allowing no further exchange with the surrounding fjord water.'

P12808 l13: the reviewer is correct that the experimental set-up, including manipulation of pCO_2 and pH levels is described in detail in three manuscripts that are part of the Special Issue. However, we will include greater detail and clarify our description.

P12808 l14: correct and altered to '(t_{-1} to t_4)'

P12808 l17: and 12812 l20: as stated on P12808 l17, nutrients were added at t13 'to stimulate phytoplankton growth'. We have added the following point: 'The addition of nutrients to all mesocosms ensured that differences between mesocosms were driven primarily by variations in pH and pCO_2 rather than nutrient availability, while non-limiting conditions existed.'

P12809 l14: an 8-point calibration was carried out every second day throughout the experiment, with an r^2 for the resulting regression of ng sulphur versus square root of the peak area, typically >0.995. This will be made clear in the text.

P12809 l21: the following statement will be added: 'The addition of $NaH^{13}CO_3$ is estimated to have altered [H+] by <3 % in the incubated water; within the range of daily variations in individual mesocosms'.

P12809 l22: yes, the remaining sampled water was discarded.

P12809 l26 and P12810 l25: yes, because the incubations for DMSP synthesis involved sampling at 4 time points within the 24 h period they had to be incubated at a location that could be readily accessed.

P12811, l9: the brackets will be changed accordingly.

BGD

9, C7269–C7274, 2013

Results: we accept the reviewers point that autocorrelation may be a factor affecting our statistical approach and interpretation. In response we will i) include a section in the Materials and Methods that describes our statistical approach and addresses the question of autocorrelation; ii) have applied the Durbin-Watson test on lagged variables for each of the regression analyses that we have conducted in order to check for autocorrelation. The results of this analyses will be included in the Results section.

P12812, l12: if the comment is taken in the full context of the sentence then it seems clear we are referring to a DMS concentration that is high relative to the DMSP concentration (DMS:DMSPt ratio = 15 %).

P12813 l12: it is not clear what the reviewer is referring to by 'random fluctuations in the seed populations', however, steps were taken to ensure that the communities enclosed in each of the mesocosms at the start of the experiment were as similar as possible. This is confirmed by observations of the microbial community composition published in a series of the papers that make up the special issue.

P12813 l14: the rapid response by the picoeukaryote populations and subsequent succession by diatoms and dinoflagellates is addressed in the paper by Schulz et al. that is part of this Special Issue.

P12813, l22: by 'pervasive environmental forcing' we mean that alterations in extracellular [H+] are likely to have a direct impact on a greater proportion of the physiological processes that occur in bacteria and microalgae than changes in CO_2 availability per se.

P12814 l9: this sentence will be rephrased.

P12814 l 10: what a and b stand for will be made clear in a revised Table 1. We will also clarify that we do indeed fit all daily data for the 9 mesocosms and for each phase separately. See the earlier comment regarding autocorrelation. We will include in this Table the Durbin-Watson values for the tests of autocorrelation on lagged data.

BGD

9, C7269–C7274, 2013

P12815 l12: we will rephrase our explanation. Our point is that because DMSPt was the variable measured in the mesocosms rather than DMSPp, an estimate of μDMSPt is of more direct relevance that an estimate of μDMSPp would be.

P12816 l5-6: We have now included a section on our statistical approach. It is worth noting that we present the uncertainty in the daily estimates of Fv/Fm, this uncertainty is based on the propagated uncertainty from the measurements of Fo and Fm made in triplicate in each mesocosm each day, this level of assessment of uncertainty in variable fluorescence measurements is rarely presented. Our approach will be made more clear in section 2.5.

P12816: Figure 6c. Accepted, this will be made clear in the Figure legend.

P12817, L11 – accepted.

P12819, Figure 8: - accepted

Discussion:

P12823 l12: I accept that our study has limitations. Indeed the reviewer is right that obtaining a comprehensive understanding of the processes involved in determining DMS concentrations is a big undertaking and something that has been achieved on only a handful of occasions by relatively large teams. I do believe that in order to accurately predict changes in DMS emissions requires a mechanistic understanding and the application of process-based models. That said, our study adds two key elements to the issue of the controls on DMS concentrations in the face of ocean acidification by directly addressing: i) direct measures of DMSP synthesis rates in the face of altered pCO_2 and H^+; and ii) an in-depth assessment of which components of the phytoplankton contribute to the variations in DMSP accumulation between levels of pCO_2 and H+. More rate measurements would be desirable of course and should be an ambition of future studies of this type. Obviously, this information stems from one location and what is also required are more detailed studies regionally and seasonally. Continued

BGD

9, C7269–C7274, 2013

exchange between modelers and experimentalists will be needed to identify the key processes that need to be understood.

Conclusions: Yes, we accept the reviewer's point and will include a statement to that effect.

Interactive comment on Biogeosciences Discuss., 9, 12803, 2012.