

Interactive comment on “Cloud, precipitation and radiation responses to large perturbations in global dimethyl sulfide” by Sonya L. Fiddes et al.

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Response to Reviewer 2

We would like to thank Reviewer 2 for their extensive comments. We acknowledge that there are a number of recent studies examining the role of DMS in the climate system. Our study provides a thorough end-to-end analysis of all aspects of the chemical, aerosol and meteorological impacts of large DMS perturbations in the current climate. To our knowledge, previous studies have not considered the entire system, and typically only considered short time periods (1yr) or future projections.

We have taken the Reviewer's advice and have strengthened not only our problem statements in the introduction but also the points mentioned above in the introduction

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and conclusion. We agree that just using a different model does not provide sufficient novelty to a study. We have now included some more information about why ACCESS-UKCA, but more particularly GLOMAP-mode, is a desirable tool, and further elucidated the novel aspects of the study in the manuscript

We also agree that the experiments performed here are extreme cases. However, there are significant insight into the DMS-climate system gained from these experiments that will serve to inform more targeted, realistic scenario experiments. Specifically, our large scale perturbations allow quantification of the overall contribution of DMS to the climate system.

We would also like to thank Reviewer 2 for bringing to our attention the two Tesdal et al. 2016 papers. They have provided a useful reference for discussion around DMS climatology and flux uncertainties.

Specific comments:

The introduction provides relevant background regarding the role of aerosols in the global radiation budget. It would benefit from more background information regarding the uncertainty in DMS concentrations in the ocean. See for example: Belviso et al. (2004), Tesdal et al. (2016a).

We have included further background information regarding the uncertainties surrounding the DMS climatology and flux as suggested by the Reviewer. We thank the Reviewer for their recommendations.

(page 2 line 9): Additional support for the use of DMS fields in climate model are given in Belviso et al. (2004) and Tesdal et al. (2016a), and it is recommended to include these references. Hopkins et al. (2016) is not an appropriate reference for the uncertainty around observed DMS concentrations. Royer et al. (2015) is suggested.

We have revised this section and included more appropriate references.

(page 2 line 10) Charlson et al (1987) is not an appropriate reference for the role of

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DMS in climate systems being subject to debate, as this is the paper that introduced the hypothesis. The debate came later. A more appropriate article that also serves as an review of the CLAW hypothesis is Ayers and Caine (2007).

We have included the recommended citation as the Reviewer has suggested

(page 2 line 16) Add "s" to "contribute"

Typo amended

(page 2 line 23) Add "in certain regions" following "...local DMS concentrations" (page 2 line 29) Add "in order" between "... a one year simulation" and "to quantify its importance. . ."

Sentence amended as suggested

(page 2 line 32) Replace "for example" with "e.g."

Sentence amended as suggested

(page 2 line 34) Is ocean acidification meant to be an example of "anthropogenic climate change"? Please clarify.

This sentence has been clarified to reflect that ocean acidification is caused by anthropogenic emission of CO₂.

(page 3 line 3 and throughout manuscript) Both Celsius and Kelvin temperature units are used throughout. Please use one or the other (preferably Celsius) for consistency.

We have made all temperature units consistent throughout the text

(page 3 line 10) Replace "low-mid level" with "low- and mid-level" (page 3 line 26) Add "analyzes" after "Section 4"

Sentence amended as suggested

(page 4 line 23) Replace "of" with "detailed in"

Sentence amended as suggested

(page 4 line 28) " A full description of the scheme can be found in Mann et al. . ." Here it would be appropriate to mention the study by Bellouin et al. (2013), who

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compared GLOMAP-mode and CLASSIC and determine that GLOMAP-mode is more sophisticated and accurate.

We have made reference to the Bellouin et al. (2013) paper, as well as the Mann et al (2012) paper. We have retained the Mann et al. (2010) citation as this is the model description paper.

(page 5 line 1) "Significant sampling biases...Northern Hemisphere (Lana et al 2011)" This sentence is not entirely clear. Is the point that the data is biased towards spring-summer and towards Northern Hemisphere?

Yes, we have clarified this sentence to reflect this.

(page 5 line 2) Replace "spring-summer" with "spring through summer"

Sentence amended as suggested

(page 5 line 5) "The Liss and Merlivat (1986) parameterization. . ." There should be justification for why this parameterization is used. Several different parameterizations of the piston velocity in terms of wind speed have been used in modelling studies (e.g., Liss and Merlivat, 1986; Wanninkhof, 1992; Nightingale et al., 2000), leading to substantially different flux fields for a given concentration field (Tesdal et al., 2016a).

We have made reference to the alternative flux parameterisations as well as the modelling studies that detail their uncertainties in the introduction. Of the parameterisations available within ACCESS-UKCA, we chose the Liss Merlivat (1986) method because it agrees more closely with the latest generation of DMS flux parameterisations, e.g. Vlahos Monahan (2009), Bell et al. (2017), which were specifically derived for DMS, unlike the above parameterisations.

(page 5 line 16-17) Following Eq. 4, Replace "Where" with "Here," . Insert "is" before "determined following the method of Saltzman.."

Sentence amended as suggested

(page 5 line 20) "seawater" should not be

hyphenated Typo amended

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(Section 2.2 Model Evaluation) The evaluation should include comparison to observation of atmospheric concentration of DMS and other sulfur species, for example as described in Tesdal et al. (2016b).

We appreciate that an evaluation of atmospheric DMS and other sulfur species is desirable, as done in the Tesdal et al. (2016b) study. However, we have limited this evaluation to meteorological data sets that are globally available from satellite products. We are confident in the use of this model for DMS studies due GLOMAP-mode being extensively evaluated against observations in many previous studies (Mann et al. 2010, 2012, Woodhouse et al 2010, 2013, 2015).

(page 6 line 1) add "between" between "medium" and "440-680 hPa" and between "low" and "680-1000 hPa"

Sentence amended as suggested

(page 6 line 17) Add period at end of sentence that begins "The Australian region..."

(page 6 line 24) Replace "that" with "the one"

Sentence amended as suggested

(page 6 line 30) "By providing this radiative effect. . ." The text appears to imply that FAIR is a tool that provides estimates of climate response, given a simple value of radiative effect. Thus, by feeding estimates of radiative effects to FAIR one can analyze the effect on temperature and other climate variables. The text would benefit from more elaboration regarding the relationship between the radiative effect and the FAIR climate component.

We have included some more information on how the FAIR emulator links radiative forcing changes to temperature and we have included some additional references for readers to pursue.

(page 7 line 12) Add comma after "e.g."

Sentence amended as suggested

(page 8 line 12) "...instead reflecting more sunlight thus enhancing the albedo..." This

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clause is confusing. What is it that is reflecting more sunlight?

We have restructured this sentence to be clearer: 'Over the Antarctic ice sheets, both TOA outgoing and surface incoming SW radiation are overestimated, due to an underestimation of low clouds which allows the high albedo to reflect too much incoming SW radiation back out to space.'

(page 8 line 20) Replace "...low clouds allowing.." with "...low clouds, which allows. . ."

Sentence amended as suggested

(page 8 line 24) "This estimation is slightly greater. . ." Greater than what?

We have amended this sentence to say greater than the CMIP5 GCMs

(page 9 line 20) Replace "representing" with "which is due to" or "which represents" to avoid awkward verb-gerund construction ("...representing lofting...").

Sentence amended as suggested

(page 9 line 23) Use appropriate subscript formatting for H₂SO₄.

Typo amended

(page 9 line 25) Replace "...in new particle formation, forming secondary sulfate aerosol. . ." with "...in formation of secondary sulfate aerosols..."

Sentence amended as suggested

(page 9 line 26) Correct formatting of H₂SO₄.

Typo amended, this has been checked throughout the text

(page 10 line 5 and throughout manuscript) Replace "Whilest" " with "While"

This has been amended throughout the manuscript as suggested

(page 10 line 26) Replace "cloud condensation nuclei" with "CCN"

Sentence amended as suggested

(page 10 line 26-33) "Fig. 8d-e show the number. . ." The paragraph does not clearly describe the figures; sentence structure is awkward. Consider revision as follows:

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Fig. 8d-e show the number concentration of CCN with dry diameters greater than 70 nm (CCN70) for the Ctl and the differences resulting from Exp.1. The largest absolute differences are in the tropics, which, similarly to the N3, have the highest concentration. Relatively, there is a global decrease of 5%, whilst decreases of 7% were found over the Australian region, decreases of 8% over the SO and decreases of 20% over the SEP. Differences in cloud droplet number (CDN) are shown in Fig. 8g-h. The relative differences in CDN (Exp.1-Ctl) show a similar spatial pattern to that of the CCN. Global mean CDN decreases by 5%. A decrease of 5% is also found for the Australian region, whereas the SO shows an 8% decrease, and the SEP shows an 18% decrease. In both the CCN70 and CDN, the marine Southern Hemisphere mid-latitudes have the largest decreases of 14% (averaged between 5-35°S) despite the SO having some of the larger decreases in SO₂ and H₂SO₄.

The figure caption has been amended as suggested by the Reviewer.

(page 10 line 30) "Exp 1- Ctl" Is this explaining the ratio for relative difference? It is not given elsewhere when talking about relative difference.

The 'Exp 1- Ctl' notation simply implies Experiment 1 minus the Control. We have removed it to avoid confusion.

(page 11 line 1) Replace "tropics mid-latitudes" with "mid-latitude tropics".

Sentence has been amended

(page 11 line 13) "Similar CCN sensitivities are reported in the Woodhouse et al. (2010) study." State actual values reported in the reference.

Actual values have been provided

(page 11 line 24) "...radiation scheme via aerosols and some (see Section 2.1.1)." Missing word/phrase following "some".

Missing words was 'gases'

(page 11 line 28) "...slightly removed from the coastline." Not clear. From the Southern Hemisphere's coastline? Recommend revising the whole first sentence, ending with a

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period after "(Fig. 9a)" and then beginning a new sentence. This would help to clarify what difference is seen in the SH generally and would parallel the structure used for the rest of the paragraph.

We have revised this sentence and removed the confusing reference to the coastline.

(page 11 line 32) "...see Section 3 in comparison to other areas. . ." Confusing. The author is comparing all of Section 3 to the areas of low cloud formation?

A typo has been amended in the sentence (a missing bracket after Section 3) which resolves the clarity of this section.

(page 11 line 35) "...biases exacerbate this. . ." Clarify what "this" refers to.

We have clarified what 'this' refers to (the differing responses of areas of low cloud formation).

(page 12 line 4) Complete parentheses for "shown in Fig. 10a-b"

Typo amended

(page 12 line 8) Capitalize "Southern Hemisphere"

Typo amended

(page 12 line 13) Add "the" before "Ctl"

Sentence amended as suggested

(page 12 line 25) Delete the comma after

"magnitude" Sentence amended as suggested

(page 12 line 28) Revise text to "...the SEP: increases of 42%, 172%, and 89% respectively."

Sentence amended as suggested

(page 12 line 29) Insert "occurs" after "...a decrease of 37%"

Sentence amended as suggested

(page 12 line 33) Insert "respectively" after "...increases by 6%, 4% and 5%"

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Sentence amended as suggested

(page 12 line 34) Insert "the" before "...SEP of 14%"

Sentence amended as suggested

(page 13 line 2) Replace "showing" with "which show"

Sentence amended as suggested

(page 13 line 2) Suggest "Incoming surface SW radiation" rather than "Surface incoming SW radiation. . ."

Sentence amended as suggested

(page 13 line 6) Replace "analyzed under" with "which analyzed"

Sentence amended as suggested

(page 13 line 8) Replace "south east" with "southeast"; Replace "these results presented" with "the results presented here"

Sentence amended as suggested

(page 13 line 10) Insert "however" between "...the surface," and "the precipitation. . ."

Sentence amended as suggested

(page 13 line 18) Delete "Although"; insert "and" between "...warming" and "we. . ."

Sentence amended as suggested

(page 13 line 21) Delete comma after "...study"

Typo amended

(page 13 line 26) Replace "on" with "in"

Typo amended

(page 13 line 30) Delete duplicate "the"; insert "that" between "...this study is" and "the model. . ."; replace "underestimation of" with "underestimates"

Sentence amended as suggested

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(page 14 line 1) Replace "rather a multitude of theories" with "multiple theories have been proposed"

Sentence amended as suggested

(page 14 line 7) "representation" should be plural

Typo amended as suggested

(page 14 line 13) Change "Figure 1" to "Fig. 1" for consistency with rest of manuscript

Sentence amended as suggested

(page 14 line 14) Delete comma after SO₂

Sentence amended as suggested

(page 14 line 32) Break run-on sentence: Period after "importance". Next sentence: "Instead, the studies highlighted SO (Thomas et al., 2010; Mahajan et al., 2015)." Highlighted the SO in terms of what parameter(s)?

These studies have focused on cloud feedbacks, which we have clarified in the text.

(page 14 line 35) Revise sentence as: "...slightly lower than the estimation of 2.03 Wm⁻² by Thomas. . ."

Sentence amended as suggested

(page 15 line 1) Replace "are" with "were"

Sentence amended as suggested

(page 15 line 5) Revise reference format: (Albrecht, 1989)

Sentence amended as suggested

(page 15 line 16) Revise placement of subordinate clause in the sentence beginning "The cause of the discrepancy. . ." as: "Without further information, it is difficult to speculate on the cause of the discrepancy. . ."

Sentence amended as suggested

(page 15 line 18) "Suggest" should be plural; delete comma after constraints

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Sentence amended as suggested

(page 15 line 22) Replace "Whilst" with "Though"

Sentence amended as suggested

(page 15 line 23) Replace the colon after "For example" with a comma; replace "an as of yet" with currently; replace "for" with "as a"

Sentence amended as suggested

(page 15 line 31) Replace the semicolon after "Six et al (2013) with "and"

Sentence amended as suggested

(page 16 line 3) "coral-reef-derived" (2 hyphens), or "DMS derived from coral reefs"

Sentence amended as suggested

(page 16 line 5) Replace semicolon after "Hopkins et al. (2011)" with a comma

Sentence amended as suggested

(page 16 line 8) Insert "those" between "than" and "found"

Sentence amended as suggested

(page 16 line 12) Make example given in this sentence parenthetical: "...increases (e.g., via solar radiation management) may have a short term cooling effects, however, without. . ."

Sentence amended as suggested

(page 16 line 13) Delete the "a" between "...may have" and "short term..."; insert comma after "...however"

Sentence amended as suggested

(page 16 line 14) Delete "on" between "...impact" and "marine life. . ."

Sentence amended as suggested

Interactive comment on Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2017-1141>,

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