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Biogeosciences
Discussions

Interactive comment on "Can we trust simple marine DMS parameterisations within complex climate models?" *by* P. R. Halloran et al.

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Response to comments by Anonymous Referee #1

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We thank the referee for what we see as a very fair and considered review. We agree with all of the referee's points, and specify in the following text how each has been addressed with additions and modifications to the manuscript and supplementary materials. We are grateful that the referee recommend publication subject to acceptance of the following corrections.

Referee point 1

The paper by Halloran et al. investigates the important question whether we can relay on parameterisations derived from empirical data fitting in future climate predictions. This topic is well studied by applying two empirical DMS parameterisations within the context of an Earth System model (ESM). The performance of these parameterisations in reproducing global mean DMS values as well as seasonal and inter annual DMS variability is investigated. The authors present a well structured and clearly written paper, with strong emphasis on the limitations of their study. Nevertheless that a similar testing of one of the empirical parametrisation has already been published by Kloster et al. (BG, 2006) the present study extends the scope to DMS variations on seasonal and inter annual time scales.

Response 1

Although this was not a criticism, we thank the reviewer for highlighting the Kloster et al. (2006) manuscript and acknowledge the complimentary analysis undertaken within that study by adding the Kloster et al. (2006) reference in section 4.2 (page 1310 line 22 of the original manuscript).

Referee point 2

From my point of view the authors made one assumption that has to be discussed in greater detail. When applying the DMS parameterisation the authors neglected chlorophyll concentrations of the phytoplankton functional type referring to diatoms. In general, it is certainly correct that diatoms are low DMS producers and could, therefore, be excluded from a first order DMS production formulation. However, this is not what Anderson et al. or Simo and Dachs did in their studies. They used the monthly composites of SeaWIFS chlorophyll concentration without any corrections. Chlorophyll concentration is, to first order, negatively correlated with the local nitrate concentration which is part of the Anderson et al. approach. Thus, to consider only non-diatom phytoplankton in the DMS parameterisation might on one hand conceal the mismatch between simulated and observed chlorophyll but on the other hand might obscure the interpretation of the results. Especially the simulated seasonality of DMS might be corrupted by this assumption. The authors must definitely add more information about the

effects of disregarding diatom chlorophyll on their findings.

Response 2

We acknowledge that by using only non-diatom chlorophyll in the DMS calculation when looking at DMS concentrations calculated within the model, we are not directly testing the published parameterisations, rather we are looking at an interpretation of these parameterisations in the context of our model. As justified in the original manuscript (page 1300 lines 3-18), we make this decision because unfortunately (but not unsurprisingly) the model simulation of surface chlorophyll is not directly comparable to that used by Simo (2002), and Anderson (2001) (i.e. satellite observations) to derive their parameterisations - the simulation of vertical mixing in the model's upper ocean results in a poor vertical distribution of near surface chlorophyll, consequently over-predicting chlorophyll in the surface model layer. We could have addressed this by either scaling the chlorophyll concentration used in the calculation, or as we did, by examining the chlorophyll produced by just the plankton functional type known to produce DMS. One problem with scaling down the chlorophyll concentrations would be that when we run simulations into the future and much of the surface ocean stratifies, the vertical profile of chlorophyll will change and that scaling factor may no longer be applicable. The issues arising from the decision we have made are in part addressed by figure two and the associated text, where we present a side by side analysis of the DMS as simulated by the model (using chlorophyll from just the non-DMS producing phytoplankton group), and DMS as calculated using climatological values for all of the variables (and therefore an equivalent chlorophyll field to that used in the original studies by Simo (2002), and Anderson (2001)).

We agree with the referee that the choice of chlorophyll data used within the DMS calculation is very important, and therefore, in addition to the information already included in the manuscript (and discussed above), we have added an analysis and discussion of the difference in the DMS fields calculated using all phytoplankton, and just non-diatom phytoplankton, to the supplementary material and referenced this with an insertion of text 'A' (below) into page 1300, line 16 of the originally submitted manuscript (the supplementary material text is included below (text 'B'), and additional figures provided alongside this response). The additional analysis we have done has demonstrated that the primary consequence of rejecting the chlorophyll contribution from the diatom group is, as we intended, a downward scaling of the global chlorophyll value being fed into the DMS calculations (reducing from a global annual average of 0.93 mg m^{-3} to 0.51 mg m^{-3} in the Simo and Dachs model run, and 0.92 mg m^{-3} to 0.51 mg m^{-3} in the Anderson model run), without a major impact on the spatial (Supplementary Material figure 1) or seasonal (Supplementary Material figure 2) distribution.

Text A: 'The implications of considering only non-diatom chlorophyll within the model's DMS calculation are discussed in the supplementary materials.'

Text B: 'As described in section three of the main text, it has been necessary to modify our use of the Simo (2002) and the Anderson (2001) parameterisations to account for the Earth System model's inaccuracies in predicting the near-surface vertical distribution of chlorophyll. The model simulates a global annual average surface chlorophyll concentration of 0.93 mg m^{-3} and 0.92 mg m^{-3} in the Simo (2002) and Anderson (2001) model runs respectively, approximately twice that predicted from SeaWiFS imagery (Yoder and Kennelly, 2005). To prevent the simulated high chlorophyll causing an over-prediction of surface ocean [DMS], we choose to exclude diatom chlorophyll from the calculations, on account of their low DMS production (Yoch, 2002; Keller et al., 1989). Considering just non-diatom surface chlorophyll our model simulates a global annual average surface chlorophyll concentration of 0.51 mg m^{-3} in both the Simo (2002) and the Anderson (2001) experiments, comparable with globally averaged SeaWiFS chlorophyll data (Yoder and Kennelly, 2005). Excluding diatom chlorophyll from our calculations of DMS using both the

Simo (2002), and the Anderson (2001) parameterisations does not have a major impact on either the spatial (Supplementary Material Figure 1) or seasonal (Supplementary Material Figure 2) distribution of DMS production. Although future shifts in the non-diatom to diatom ratio simulated by the model would be amongst the most robust indications that we might expect future changes in surface ocean [DMS], we have been unable to test how realistic the interactive calculation of surface ocean [DMS] would be under these situations.'

Supplementary Material Figure 1 caption: 'A) Annually averaged surface ocean DMS concentrations calculated using the Simo (2002) parameterisation from model non-diatom surface chlorophyll and mixed layer depth fields. B) Annually averaged surface ocean DMS concentrations calculated using the Simo (2002) parameterisation from model total surface chlorophyll and mixed layer depth fields. C) Annually averaged surface ocean DMS concentrations calculated using the Anderson (2001) parameterisation from model non-diatom surface chlorophyll, nitrate and solar radiation fields. D) Annually averaged surface ocean DMS concentrations calculated using the Anderson (2001) parameterisation from model total surface chlorophyll, nitrate and solar radiation fields. Figure parts a and b have been calculated from the eight year model simulation in which surface ocean [DMS] was interactively calculated using the Simo (2002) scheme, parts c and d of the figure have been calculated from the eight year model simulation in which surface ocean [DMS] was interactively calculated using the Anderson (2001) scheme. Although both model simulations included an interactive DMS scheme, the data presented in this figure have been calculated off-line using monthly mean data for the parameterisations' input fields, and therefore the specific [DMS] presented here does not feed-back on the model's climate. Furthermore, because calculations have been undertaken using monthly mean data, rather than instantaneous data from each model time-step (i.e. each hour), the averaging of extreme values means that the exact values presented in this figure differ from those presented elsewhere in the paper. Broad agreement in the spatial distribution of surface ocean [DMS] between a and b, and c and d respectively indicates that only issues associated with using just non-diatom chlorophyll in the model [DMS] calculations (rather than total surface chlorophyll) can be regarded as second order relative to the disparity between observed (Yoder and Kennelly, 2005) and modelled chlorophyll.'

Supplementary Material Figure 2 caption: 'Mean seasonal cycle of surface ocean [DMS] calculated using the Simo (2002) parameterisation (red) and Anderson (2001) parameterisation (green) from monthly mean model fields of non-diatom surface chlorophyll (solid lines), total surface chlorophyll (dashed lines), mixed layer depth, surface nitrate concentrations and daily mean shortwave irradiance. The Simo (2002) data have been calculated from the eight year model simulation in which surface ocean [DMS] was interactively calculated using the Simo (2002) scheme. The Anderson (2001) data have been calculated from the eight year model simulation in which surface ocean [DMS] was interactively calculated using the Anderson (2001) scheme. Broad agreement between the shape of the seasonal cycles for the two Simo (2002) curves and the two Anderson (2001) curves respectively indicates that using just non-diatom chlorophyll in the model [DMS] calculations (rather than total surface chlorophyll) can be regarded as a second order issue relative to the disparity between observed (Yoder and Kennelly, 2005) and modelled chlorophyll. Although both model simulations included an interactive DMS scheme, the data presented in this figure have been calculated off-line using monthly mean data for the parameterisations' input fields, and therefore the specific [DMS] presented here does not feed-back on the model's climate. Furthermore, because calculations have been undertaken using monthly mean data, rather than instantaneous data at each model time-step (i.e. each hour), the averaging of extreme values means that the exact values here differ from those presented elsewhere in this paper.'

Referee point 3a

More information is also need about the setup of the experiment. The title suggests the application of several climate models, which is not the case. The level of complexity of the used ESM is not described in the paper ("HadGEM2-ES, at a development stage").

Response 3a

We absolutely agree that the paper could benefit from more background information about the model and experimental setup. To address this, we have extended the description of the experimental setup (see text A below) in section 3 (with reference to a new supplementary materials figure - caption text B below), and added a reference to a publicly available Met Office Hadley Centre technical note describing and validating the Earth System model HadGEM2-ES (http://www.metoffice.gov.uk/publications/HCTN/HCTN_74.pdf). The referee's thoughts regarding the title is addressed in Point 4. Additionally we correct a mistaken value in section three, changing the cited model mean surface chlorophyll concentration from 1.03 mg m^{-3} to 0.51 mg m^{-3}.

text A: 'The Earth System model was run for two periods of ten model years. Both model runs were initialised with a preindustrial climate state spun up using the Kettle et al. (2000) DMS climatology. The first model run interactively calculated surface ocean [DMS] using the Simo (2002) parameterisation, the second run calculated surface ocean [DMS] using the Anderson (2001) parameterisation. Switching between the Kettle et al. (2000) climatology and the interactively calculated DMS schemes caused minimal disruption to the model climate, however we avoid sampling the model when in disequilibrium by rejecting the first two years of each ten year model run, and undertake all analysis on the remaining eight model years (see Supplementary Material).'

text B: 'Model experiments using the Simo (2002) (red) and Anderson (2001) (green) parameterisations were run for ten model years each, starting from a pre-industrial climate spun up using DMS fields from the Kettle et al. (2000) climatology. An initial drift in the simulated DMS data resulted in the first two model years of data being discarded from subsequent analysis.'

Referee point 3b

Why was it necessary to use an ESM for this study? E.g. are atmospheric feedback mechanisms? via the sulphur cycle included?

Response 3b

As made clear within the technical note referred to in point 3a, and now cited in the manuscript, DMS was calculated interactively within this model before being passed to the atmospheric model, where it was processed using the model's atmospheric chemistry scheme, influencing climate through its direct radiative effects and impact on cloud formation. To further address the reviewers point, and avoid confusion, we have added the text 'Within the earth system model, oceanic DMS emissions are processed by the atmospheric chemistry scheme (O'Connor et al., 2010, 2009), where DMS oxidation products have the potential to interact with the model's climate and feed-back on marine DMS production.' within section 3.

Referee point 3c

The author should describe and motivate the experiment setup in part 3. How long was the simulation with HadGEM2-ES?

Response 3c

For additional information about the experimental setup see our response to point 3a.

Referee point 3d

Global averages and monthly mean values should be provided with standard deviations, if possible.

Response 3d

We agree that it is useful to include standard deviations with this data, and have modifies figure 1 and its caption appropriately.

Referee point 4

The authors should reconsider the title. I agree that any empirical DMS parameterisation is a simplification of our current understanding of the marine DMS cycle and certainly of the reality. As mentioned in the paper, process based DMS models that have been developed in the past and are continuously improved will hopefully enhance the DMS future predictability. To clearly differentiate between the empirical approaches, used in this study, and process based DMS models, I suggest to change the title from "Can we trust simple marine DMS parameterisations within complex climate models?" into: "Can we trust empirical DMS parameterisations?".

Response 4

We absolutely agree that this should not be confused with an analysis of process-based DMS models, and therefore welcome the suggested modification to the manuscript title, however we also feel it is important to highlight that this is an assessment of the parameterisations within the contact of a climate model - which as discussed at length in point 2, would be very different from an assessment of those parameterisations done independently from a climate model. We have therefore changed the title to 'Can we trust empirical DMS parameterisations within projections of future climate?'

Referee point 5a

p1302 line 20: delete extra "of a"

Response 5a

Done

Referee point 5b

p1302 and 1304: replace "Lana et al, 2010" by "Lana pers. comm." as the paper is only in preparation according to the reference list.

Response 5b

Lana (2010) manuscript now submitted, so reference updated.

Referee point 5c

p1306 line 6: delete extra "and the"

Response 5c

Done

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