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Biogeosciences Discussions

Interactive comment on "Testing the relationship between the solar radiation dose and surface DMS concentrations using high resolution in situ data" *by* C. J. Miles et al.

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We would like to thank all three reviewers for their considered and constructive comments regarding our manuscript. We welcome the support for publication offered by reviewer 2 and feel able to answer the concerns raised by the reviewers. We are grateful for the chance to clarify some issues raised by reviewer 1 where we may have been misunderstood (specifically their concerns about the uncertainty attached to I0 and that we have selected only some of the data collected during AMT to make our point). We strongly refute the main objection made by reviewer 3 that this work offers too few new insights into how DMS varies in the open ocean.

The aim of this work is to calculate a SRD using in situ data sampled concurrently with [DMS] for all of its component variables including for the first time the light attenuation coefficient, k. This is then compared to a SRD calculated using climatological data (SRDclim after Vallina and Simo 2007) and again for the first time, to a SRD restricted to the narrower spectral band of UVA at 380nm (UVRD). We also add to the present literature by calculating in situ SRD's for the previously unrepresented equatorial and south Atlantic regions sampled by the AMT transect. The regional studies of Vallina and Simo (2007) (V&S07) and Belviso and Caniaux (2009) (B&C09) are from the coastal northwest Mediterranean (Blanes Bay 41o3N, 2o48E), Sargasso Sea (32o10N, 64o30W) and northeast Atlantic (16oW - 22oW, 38oN - 45oN) respectively. Analysing regional, in situ data from different locations is vital to advance understanding of this reported global relationship that has only been tested with in situ data in a limited number of locations.

Reviewer 3 appears to misunderstand or overlook some aspects of this work. We will make these points more explicit in the revised manuscript. Reviewer 3 comments that "This whole exercise seems a bit silly without altering the light attenuation coefficient in response to known variations in chlorophyll and colored DOM distributions which alter light attenuation. Variations in k are as big as MLD in this game.". We agree with reviewer 3 that variations in light attenuation are important. An aim of this work is to calculate in situ k values from the 1 % light depth. This is in contrast to other work which uses fixed, estimated values for k (V&S07, B&C09)). We show that a variable, in situ k within the SRD calculation decreased the correlation between SRD and [DMS] when compared to the use of a fixed value. To our knowledge this is the first time this has been done and represents a new addition to the literature. Reviewers 1 and 2 congratulate us on calculating the UVRD. Reviewer 3 appears to confuse the TOA I0 data used by V&S07 (not cloud adjusted) with the UV product used to calculate the UVRD suggesting that "daily UV radiation rates at the sea surface are available from NASA. So, I believe that the full problem could be done correctly.". The data used in this study is a surface, cloud adjusted satellite UV product from NASA.

Reviewer 1 (comment 2) requests clarification regarding the number of AMT DMS data points used and their geographical location. To calculate SRDinsitu it is necessary to not only have a [DMS] measurement at a sampling point but to also have concurrent data for the components of the SRD (MLD, I0 and the1% light level depth (Ze) to calculate k). It was this need that led to some of the AMT [DMS] data being excluded. It was possible to calculate SRD's using climatological data (SRDclim) for these excluded AMT [DMS] data points but it was decided to restrict the analysis to the same data to enable a fair comparison. The same reasoning was applied to the UVRD. The [DMS] data (along with the concurrent in situ data used to derive SRDinsitu) come from 3 AMT cruises spanning 44.63oN to 38.89oS (AMT-12, AMT-13, AMT-14) not just AMT-12 and AMT-14 as suggested by the reviewer. We made a grammatical error indicating that AMT-12 and AMT-14 were undertaken in the northern hemisphere autumn rather than spring which could have led to some confusion. We have amended the methods section to make this more explicit. We refute the suggestion (reviewer 1) that because the number of data points utilised is low relative to the work of V&S07 and B&C09 that it offers only a modest contribution. Although the number of data points is less than B&C09 the spatial coverage is considerably more and includes data from previously unreported areas as outlined above. This combined with the use of an in situ k and the derivation of a UVRD provides genuine new insights.

Reviewers 1 and 2 enquired about the in situ I0 used in this study and its influence on the SRD values which both reviewers observe to be high. (reviewer1; comment 1, reviewer 2; comment 1 and 3). As reviewer 2 correctly assumed (comment 3), our in situ SRD values were too high as we had calculated daily average light differently to V&S07. We have recalculated the situ I0 data more appropriately taking the average irradiance over the 24hrs previous to sampling time be that 0300 (pre-dawn sample) or late morning (1100). High SRD values resulted from not averaging the in situ I0 data over the full 24 hours but rather just over the light hours not from any obvious error in Io sensor (reviewer 1, comment 1). Reviewer 1 also requests details of the I0 sensor used, we are happy to provide this information and have included it our methods

section. (Two Kipp & Zonen SP Lite 0339-900 TIR Pyranometers were positioned on the ships foremast 22m above sea level. The average of the two sensors was used. The same instrumentation was used on all three AMT cruises). In addition, the climatological values of I0 had not been multiplied by 0.5 and this had an impact on our SRDclim values and the slope of the relationship (but made no change to the strength in correlation).

Reviewer 2 (comment 2) noted that the MLD criteria used by V&S07 (0.1°C difference from the temperature at 5 m) is different to that used in this study (0.2°C difference from the temperature at 10 m). We have altered our MLD criteria to match that used by V&S07 with a minimal effect on the calculated SRD/UVRD values. The recalculation did cause us to remove Figure 2. The observed relationship between the MLD, penetration depths of UVA and UVB and [DMS] concentrations we had previously observed no longer held. We are pleased to note that the changes in MLD and I0 have not completely altered our results such that the general interpretation and conclusions we present are broadly the same. We include the revised versions of all Figures and Table 1 in our response. We have also changed small portions of the text to reflect these new results. In particular, the last sentence of the SRD section (Results, Page 3075, Lines 5-9) has been changed to: "The SRD permutations offer some improvement, albeit small, upon the simpler relationships between [DMS] and MLD (40/MLD) (= 0.65). There is little difference between the SRD correlation strengths and the I0 that is derived from a TOA value and does not account for cloud (= 0.76)."

In response to comments by reviewer 1 (comment 2) and reviewer 2 (comment 5) that we should refer more explicitly to the regional studies of V&S07 and B&C09 we have added regression lines for the two regional studies of V&S07 (Blanes Bay and Sargasso Sea) and the study of B&C09 to Figure 1. Additional commentary will be provided. Reviewer 2 also comments that we "take too long to underline that the VS07 study (or the part of it they use the most) is a global approach". We intend to change the introduction section to make the point that V&S07 conduct regional studies with non-climatological data earlier in the manuscript.

Reviewers 1 and 2 congratulated us on the inclusion of the UVRD analysis. Due to changes in MLD criteria and the suggestion by reviewer 2 that we use a value of k more appropriate for UVA (comment 4c) we have recalculated the UVRD (see Figure 2 previously Figure 3). This has had little effect on the correlation between UVRD and [DMS] and our subsequent interpretation and conclusions. Reviewer 2 (comment 4a) requests some clarification of the satellite UV data: "It is not clear to me if the authors used noon UVA irradiances measured by TOMS on the very same days (and year) of the DMS sampling, or those extracted from a climatology (average of several years)". The UV data comprises date specific (day and year) noon irradiances at a 1o x 1o degree grid box resolution at the surface in mW m-2 nm-1 at 380nm (UVA) and is not from a climatology in the sense that it does not represent an average of different years. Reviewer 2 (comment 4b) also enquires about how the noon irradiance data is used within the SRD/UVRD framework"(b) The authors use the noon UVA irradiance and make no daily averaging of it, parallel to what they do for I0. That is, they do not take into account the differences in day length as they change latitude and season." . The reviewer is correct in pointing out that the noon irradiance used is not adjusted for day length and in that sense is different to the SRD/I0 data. We suggest that the noon value gives a reasonable indication of the daily UVA flux at the surface but concede that a daily average would be more desirable . Reviewer 1 requests that the UVRD analysis be extended. The decision was made to limit the UVRD calculation to those DMS data points included within the SRD analysis to enable a fair comparison between results.

We would now like to address some of the more specific points made by the reviewers.

Specific comments: reviewer 1

Reviewer 1 comments that the data was not collected with high resolution. The use of "high resolution" terminology is a relative term, V&S07 use monthly averaged data whereas this study uses daily data and it was in that sense that high resolution was

intended but we accept that it could be misleading and are happy to change the title accordingly.

Reviewer 1 comments:

"The manuscript also investigates the relationship between DMS and the depth of the MLD (Fig. 2) in a similar way to Bell et al. (2006). I think that there is not much improvement since a smaller number of data points is used and the non-linear relationship still demonstrates considerable scatter."

The point of figure 2 was not to reiterate the findings of Bell et al (2006) but to illustrate that the DMS data showed an interesting relationship to the light penetration depths of UVA and UVB. However following comments from referee 2 and the subsequent recalculation of the MLD to correspond with the criteria utilised by V&S07 we decided to remove this figure.

Reviewer 1 comments:

"In Figure 1a, the in situ data is compared with the V&S07 relationship obtained at the global scale (Remark: plots are correct but in the legend of Fig. 1a, the authors report for the global scale the equation obtained for Blanes Bay, this is a mistake!)."

We have corrected this error and are grateful to the reviewer for pointing this out.

Reviewer 1 comments:

"Are the number and quality of references appropriate? Page 3077 - line 3-5: The authors use unpublished informations contained in a manuscript under consideration in another journal (Derevianko et al. Geophys. Res. Lett., submitted 2009). The consent of the author should be asked."

Consent was gained before submission.

Specific comments: reviewer 2

"7. P. 3066, lines 25-26. It is not exactly like that. Reduced S demand does not lead to reduced DMS consumption, as it has been shown that DMS does not supply much S to its consumers, but the S ends up as DMSO and sulfate. The suggested effects of UVB on DMS as far as the bacteria are concerned are:

(a) UVB damages cells, lowers bacterial production, lowers bacterial S demand, lowers bacterial DMSP-S assimilation (all this proven), increases bacterial DMSP cleavage, increases DMS production (unproven).

(b) UVB damages cells, lowers bacterial production, lowers bacterial DMS consumption (proven: e.g. Toole et al. Deep-Sea Res. I 53:136-153 (2006)."

We thank the reviewer for this comment and are grateful to them for pointing out that we had not communicated this point effectively. We will make the necessary amendments.

"8. P. 3067, lines 9-10. Kniveton et al. indeed demonstrated that extreme increases in UV can cause a reduction in atmospheric DMS but they could not attribute that to underwater effects. Direct (UV mediated) photodestruction in the atmosphere seems a more plausible explanation."

We agree, this was our intended point. We will make the necessary amendments .

"9. P. 3068, line 22 and throughout the manuscript. Montegut et al. 2004 should read de Boyer Montégut et al. 2004."

We thank the reviewer for this correction. We will make the necessary amendments .

"10. P. 3072, line 13. Better cite Toole et al. (2006) than Herndl et al. (1993), since the latter does not link DMS and incident UVR."

We thank the reviewer for this suggestion. We will make the necessary amendments .

"11. P. 3073, line 23. The approach is not "the same" unless the authors correct for the MLD criterion and the SRD calculations."

We have recalculated the MLD to conform with the definition used by V&S07 (see above)

"12. P. 3076, lines 19-23. It seems appropriate to cite Toole & Siegel 2004 (who found a relationship between DMS and UVR) here and comment accordingly."

We thank referee for this suggestion. We will make the necessary amendments .

"13. Is Derevianko et al. an accepted/published manuscript?"

This work is "submitted".

Revised Table and Figure captions

Table 1: Spearman's rank correlation coefficients () between [DMS] and the outcome of the 3 equations on test (SRD (Eq.(1)), UVRD (Eq.(2)), 40/MLD (Eq.(3)) with various combinations of the available climatological/in situ data as input variables (I0/UV380nm, MLD and k). Bold coefficients indicate that an appropriate fixed value of k is used (0.06 for I0100-1000nm, 0.10 for UV380nm). Plain text indicates that the in situ value for k is used. The simpler DMS α 40/MLD coefficients (italics) does not utilise a k value. All coefficients significant at p<0.01 unless marked with * (in which case, result is significant at p<0.05).

Figure 1:[DMS] (nM) versus SRD (W m-2) calculated using: (A) in situ data (SRDinsitu, squares); and (B) climatological data (SRDclim, triangles), for MLD, k and I0. On both plots, solid line is linear best fit regression of the data. Dashed lines a –d are the relationships between [DMS] and SRD reported by Vallina and Simo (2007) and Belviso and Canaux (2009) (a = V&S07 Blanes Bay; DMS=0.138 + 0.028.SRD, b = B&C09 North Atlantic: DMS= 0.492 + 0.019.SRD, c = V&S07 Global: DMS=0.492+0.019.SRD, d=V&S07 Sargasso Sea: DMS=0.51+0.017.SRD)

Figure 2:[DMS] (nM) versus UV radiation dose (UVRD, mW m-2 nm-1) calculated using in situ MLD, a constant k (0.10) and satellite derived UVA (380nm) at the surface.

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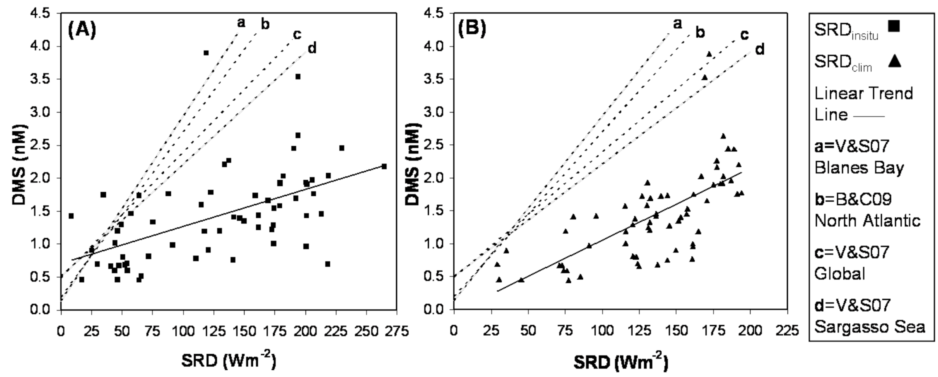

Fig. 1. Revised figure caption above

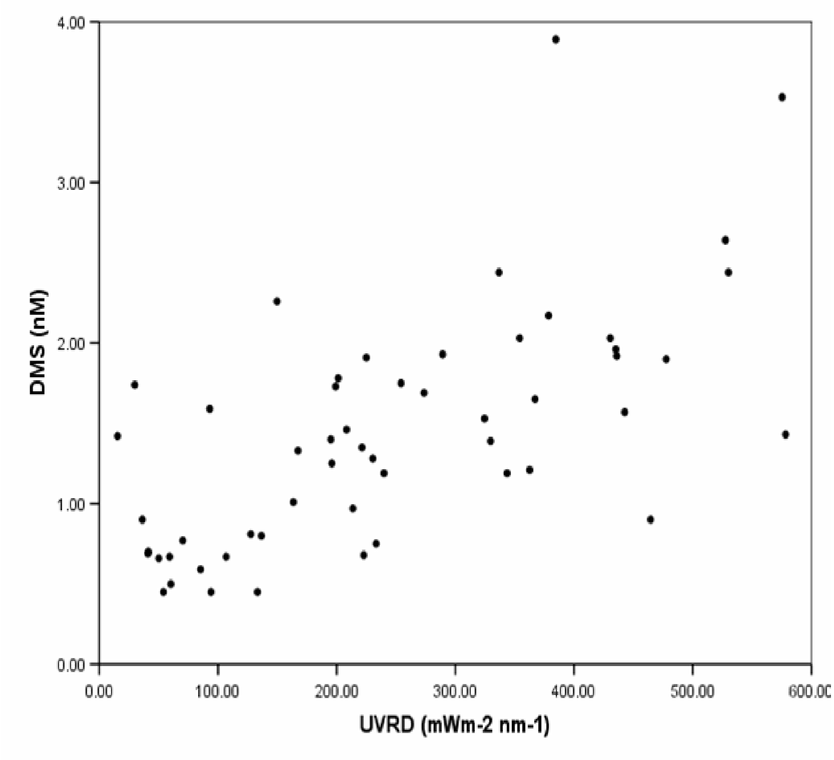

Fig. 2. Revised figure caption above

	I_0 In situ	I_0 Climatology	I_0 Fixed	UVA	40/MLD
MLD In situ	0.51 **0.68**	0.64 **0.70**	0.54 **0.65**	n/a **0.65**	*0.65*
MLD Climatology	0.54 **0.64**	0.61 **0.76**	0.45 **0.69**	n/a **0.67**	*0.67*
MLD Fixed	0.51 **0.51**	0.75 **0.76**	n/a n/a	n/a **0.30***	*n/a*

Fig. 3. Revised figure caption above