

SOLAS Open Science Conference 2009
Discussion Session Report:
Towards a better representation of DMS emissions in global climate models – Status of measurement issues and model parameterisations
Tuesday 17th November 2009

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The key questions addressed during this session were:

- What is the current status of Global Climate Models (GCM), and how is the sulphur cycle represented in GCMs?
- How are DMS ocean emissions parameterized in GCMs? What is really important and what can we ignore?
- What data is needed to improve DMS ocean emission in GCMs?

This well-attended session started with a short presentation by Nadja Steiner (IOS/CCCma Fisheries & Oceans, Canada) and Gill Malin (University of East Anglia, U.K.) on the status of DMS modelling into GCMs and understanding of the upper water column processes leading to DMS. GCMs mostly use the Kettle et al. 1999 (Global Biogeochemical Cycles 13(2): 399–444) climatology to estimate the sea-to-air DMS flux. Some models use empirical relationships of chlorophyll and mixed layer depth, light, nutrients or Fp-ratio which show large regional differences. This is not adequate to properly represent the full spatiotemporal variability observed in the DMS distribution in the ocean, to reproduce ocean-atmosphere retroactions, and to explore how ongoing and future changes in ocean properties (temperature, nutrient, pH, etc.) will affect DMS ocean production. Thus there is an urgent need to include a mechanistic representation of the ocean DMS cycle in GCMs. There are already few existing mechanistic 1-D and 3-D DMS Ocean models which can reproduce with some success the regional and seasonal variations in DMS production. Most of these models are however too complex to be incorporated into GCMs given current computing capability. In the short term, the challenge is to define the key players and processes sensitive to climate change that need to be included. This is not a trivial task given the complexity of the ocean DMS cycle as we currently know it.

So, what should we do? The importance of improving spatial and temporal coverage was mentioned several times because this would help to better constrain existing models. High frequency measurement methods like MIMs show potentially important and previously ignored high frequency variations at the temporal (e.g. diurnal increases in DMS around midday) and spatial (few meters) scales. More of these high frequency measurements would be valuable, preferably they should be coupled to high frequency measurements of DMS_{Pt} and supporting biological parameters (e.g. FlowCam, fluorescence, nitrate analysers, etc.) to enable in-depth data interpretation.

Participants highlighted that some seasons and regions remain under-sampled (e.g. Southern Ocean, South Pacific, Arctic). It was also noted that in addition to the averaged distribution, a map of the raw data is available for model calibration so misconceptions due to data extrapolation can be avoided. Most models have a surface layer 20-50 m which reflects the “surface information”, whereas surface data are represented in the climatology. This was also viewed as a potential limitation of the use of the climatology for model validation. Finally, the unresolved question of the potential role of the microlayer on gas exchange was also briefly addressed. The microlayer is currently ignored in models.

Measurements done so far are inconclusive in that the gradient of DMS between the microlayer and the subsurface can be positive or negative. It is clear that more research is needed on this topic, including on the persistence of the microlayer versus wind state.

The session included 4 invited 5-min talks. Aranza Lana, (ICM-CSIC, Barcelona) presented DMS-GO (Dimethylsulphide concentrations and emission fluxes in the Global Ocean). The new data base consisting of 47,313 data points is available for model calibration and validation. This is a significant improvement on the 15,000 data points used previously. Significantly, there are more data for the Indian Ocean and the flux (estimated with the Nightingale et al 2000 parameterisation (Global Biogeochem. Cycles 14(1): 373–387) is 28-46 Tg S y⁻¹, 20% higher than Kettle & Andreae 2000 (J. Geophys. Res. 105D (22): 26793–26808).

Dave Kieber (State University of New York) presented new information on the origin of DMS in phytoplankton cells which have no measureable DMSP-lyase. DMSO can be reduced to DMS in algae through an MSA reductase. So, instead of the known 'cleavage' pathway, direct production of DMS may take place from DMSP in the presence of light, with 25% of DMSP potentially going to DMS (10%) and DMSO (15%) after reaction with OH radicals. Should we parameterize this new source of DMS in models?

In the third invited talk Hendrik Schäfer (University of Warwick) showed 2 new sink pathways for DMS through the bacterial DMS oxidation. The gammaproteobacterium *Methylophaga thiooxidans* assimilates carbon from DMS via a novel pathway to tetrathionate and thiosulphate. The alphaproteobacterium *Sagittula stellata* uses DMS as an auxiliary energy source by oxidising it to DMSO.

Finally, Tessa Vance (Australian Antarctic Division) presented an example of how a rapid change in light intensity (UV + PAR) – in this case due to the vernal loss of the ice cover – might stimulate DMS and DMSP production. She exposed an under ice Antarctic phytoplankton communities to surface light and UV and found a 160-fold increase in the DMSP to chlorophyll a ratio within 24 to 48 hours. Sea ice can break up rapidly in spring and light stress could result in spring pulses of DMS, CCN and MSA.

In the open discussion the reliability of measurements of the dissolved DMSP pool (DMSPd) and the need to have this pool represented in DMS models was addressed. Even the more gentle methods can enhance DMSPd levels and it is likely that many of the DMSPd data measurements made and published so far overestimate in situ concentrations. Participants with experience in measuring DMSPd generally agree that the dissolved pool is very small (< 2 nmol L⁻¹). Given that DMSPd also has a short turnover time (few hours) there is doubt as to its relevance for modelling. Adding boxes (pools) to models increases computing time substantially, so the general consensus was that DMSPd should not be explicitly included in models at this time.

The importance of including a bacterial box was then discussed. It is recognised that bacteria are a key component of the system: they play a pivotal role in DMS production, act as a sink for DMSP, and a source and a sink for DMS. On the other hand, the inclusion of the end product of DMS bacterial consumption was not viewed as critical. Our current understanding of what is controlling bacterial DMSP and DMS metabolism is rather limited. It is important to know what is controlling the bacterial uptake of DMSP (loss rate constant) and the proportion of the DMSP taken up converted into DMS (DMS yield). For implementation into models we need to know more about these rates, how they vary in the field, and their sensitivity to the chemical and environmental conditions.

The need for a 2-stage modelling approach was also discussed. There was general agreement that it would be useful to begin with a more complex ecological model, progress through to adding the DMS and then use this to make decisions as to the key processes to include in the full scale global models.

In conclusion, the session did not provide concrete answers to all the key questions, but it did achieve the goal of providing some guidance to modellers and experimentalists for further useful research. Future IPCC runs will use Earth System Models which tend to provide an integrated view of the climate system. The challenges for the research field are the big steps that are needed to implement a simplified but realistic representation of the ocean DMS cycles in these models.