Biogeochemistry (2012) 110:1–4
DOI 10.1007/s10533-012-9759-3

PREFACE

Special Issue of the 5th International Symposium on Biological and Environmental Chemistry of DMS(P) and Related Compounds, Goa, India, 19–22 October 2010

Jacqueline Stefels · Damodar Shenoy · Rafel Simó · Gill Malin · Maurice Levasseur · Sauveur Belviso · Dileep Kumar

Published online: 4 August 2012

This Special Issue of Biogeochemistry contains a selection of papers presented at the 5th International Symposium on Biological and Environmental Chemistry of DMS(P) and Related Compounds, organized at the National Institute of Oceanography (NIO) in Goa, India, 19–22 October 2010. This symposium is one of a series that started in 1995 in Mobile, USA (Kiene et al. 1996). These symposia have greatly stimulated the exchange of research results and ideas, in an open and collaborative atmosphere across the interdisciplinary community that investigates the biogeochemical processes underlying the production of the climate-cooling gas dimethyl sulfide (DMS). Since the first symposium in 1995 (Kiene et al. 1996), we have met roughly once every 4 years: in Groningen, The Netherlands in 1999 (Stefels et al. 2000); Rimouski, Canada in 2002 (Levasseur 2004) and Norwich, UK in 2006 (Malin 2007). The date for the 6th symposium, which will be held in Barcelona, Spain, will be announced soon.

Two major publications in the 80s stimulated the work of this truly international DMS research community. Shaw (1983) was the first to propose a link between ocean biota and Earth's radiation budget through the emission of DMS. The CLAW hypothesis (Charlson et al. 1987) extended this concept by proposing a feedback between Earth's temperature

J. Stefels (✉)
Laboratory of Plant Physiology, Centre for Ecological and Evolutionary Studies (CEES), University of Groningen, P.O. Box 11103, 9700 CC Groningen, The Netherlands
e-mail: j.stefels@rug.nl

D. Shenoy · D. Kumar
National Institute of Oceanography (CSIR), Dona Paula, Goa 403 004, India

R. Simó
Institut de Ciències del Mar-CSIC, Pg. Marítim de la Barceloneta, P.O. Box 37-49, 08003 Barcelona, Catalunya, Spain

G. Malin
Laboratory for Global Marine and Atmospheric Chemistry (LGMAC), School of Environmental Sciences, University of East Anglia, Norwich Research Park, Norwich NR4 7TJ, UK

M. Levasseur
Département de biologie, Québec-Océan, Université Laval, Quebec, QC G1V 0A6, Canada

S. Belviso
IPSL/Laboratoire des Sciences du Climat et de l'Environnement, UMR 8212, CEA/CNRS/UVSQ, CE de Saclay, Bât 701l'Orme des Merisiers, 91191 Gif-sur-Yvette, France

and DMS production. Since these publications, many marine biologists, chemists and physicists have worked together to try to understand the complex ecosystem pathways and the various controls that constrain the production and emission of DMS. This has resulted in many important discoveries, some of which extend beyond the topic of DMS emission per se, but the major question of whether and how the feedback upon global climate change operates is still to be answered.

The papers presented in this Special Issue cover all aspects of DMS marine production, from its physiological role in microalgae to global emissions and climate. Several of them focus on the response of algae and bacteria to abiotic stresses which are expected to change in the near future. Contrary to what is expected when a global ocean thermostat is active, increased temperature or CO_2 concentrations do not always result in increased DMS or DMSP production (Kerrison et al., McLennon & DiTullio, Jones & Fisher). The study by Shenoy et al. illustrates the potential for high DMS emissions associated with seasonally anoxic waters off the coast of Goa. This could be an important area for future work given that anoxic zones are increasing across the world. The work by Ruiz-Gonzalez et al. shows that the effects of sunlight, and particularly UV radiation, on the assimilation of DMSP by polar bacterioplankton vary among taxonomic groups. Salinity appears to have a regulatory role in the emissions of DMS, methanethiol and N_2O from estuarine sediments (Magalhães et al.).

The lack of unifying principles within or between microbial taxonomic groups involved in the marine S-cycle is amongst the most difficult problems to tackle. The contribution of algae to DMSP production and cleavage into DMS is highly heterogeneous even within specific taxonomic groups (Caruana et al.). The burst in use of molecular biology tools in microbial ecology has also reached the DMS(P) research field, and has opened fascinating and complex research paths we are only just beginning to walk. These techniques, either alone or combined with measurements of metabolic transformations, have revealed that multiple DMS producing enzymes can coexist within a single bacterial species (Todd et al.), have allowed the identification of bacterial DMSP transporters (Johnston et al.) and have shown how the associations between bacteria and algae can affect DMSP and DMS turnover (Hatton et al.).

A major achievement in DMS research was the initiation of a global DMS database (Kettle et al. 1999; http://saga.pmel.noaa.gov/dms/), which provides modellers with the means to include DMS in global ocean models. In its turn, new models have revealed quantitative and qualitative knowledge gaps, stimulating further targeted research. This was reflected in the Goa Symposium with emphasis on new instrumentation that allows continuous underway measurement of DMS. Currently several groups around the world are doing such measurements and deposit their data in the DMS database, which calls for standardisation of methodology and calibration (Bell et al.). A new and fast DMS sensor was presented for DMS measurements in algal cultures with potential for measurements in the field (Green et al.).

Now that modelling of the marine sulphur cycle is a maturing topic, collaboration between modellers and experimentalists has resulted in new and sometimes contradicting insights. Previously it has been suggested that the main parameter triggering high DMS concentrations in summer when chlorophyll-*a* is minimal, a pattern often referred to as the DMS "summer paradox", is increasing irradiance leading to light stress-induced DMS release from phytoplankton cells. A re-examination of the newly expanded global DMS data and its relationships with other parameters has confirmed the positive correlation between surface seawater DMS concentrations and solar radiation dose in the upper mixed layers, whereas the correlation of DMS with chlorophyll-a appears to be dependent on latitude (Lana et al.). In support of this global analysis, a study conducted at the scale of the Northwest Atlantic by Lizotte et al. shows a clear difference between the factors that correlate with the production of DMS (depth of the upper mixed layer and solar radiation) and of its algal precursor dimethylsulfoniopropionate (chlorophyll a, phytoplankton community structure and bacterial activity). A meta-analysis of data for the North and South Atlantic further confirms a major role for solar irradiance, but indicates that adding a variable representative of biological processes (such as primary production rate) gives a better relationship with the variance in DMS concentrations (Miles et al.). On the other hand, the Belviso et al. study highlights the danger of drawing generalizations regarding what determines DMS distribution across the globe; they find different results with three approaches (station, province and model based) to studying the DMS summer paradox in

Fig. 1 1. VVSS Sarma; 2. Stephen Archer; 3. Andrew W B Johnston; 4. Jack DiTullio; 5. Graham Jones; 6. Damodar M Shenoy; 7. Anil Chandrashekar A; 8. Jacqueline Stefels; 9. Gill Malin; 10. Maurice Levasseur; 11. Rafel Simo; 12. V Damodara Rao; 13. Sunita S Pandey; 14. Sarah-Jeanne Royer; 15. Subina NS; 16. Jasna Vijayan; 17. Jagadish Patil; 18. Andrew Mogg; 19. Parvathi A; 20. Seshadri Reddy Ankireddy; 21. Bikkina Srinivas; 22. Karthik Reddy; 23. Vaattovaara Petri; 24. Kameyama Sohiko; 25. Arlene Rowan; 26. Gauthier Carnat; 27. Grant Humphries; 28. Hendrik Schafe;r 29. Olga Lage; 30. Hiroshi Tanimoto; 31. Dinesh K Sharma; 32. Surendra Kadam; 33. Jose Mathew; 34. Akhil P Soman; 35. Subha Anand; 36. Durga Rao; 37. Sujatha CH; 38. Jesly Araujo; 39. Luca Polimene; 40. Arancha Lana; 41. Martine Lizotte; 42. Philip Kerrison; 43. Christa Marandino; 44. Mark Breckels; 45. Sam Kamalesan; 46. Michael Steinke; 47. Sardar Patil; 48. Michelle Fernandes; 49. Eyice Ozge; 50. Marti Gali; 51. Jonathan Todd; 52. Michal Bochenek; 53. Angela Hatton; 54. Prasanna Kumar C; 55. Benjamin Green; 56. Cathleen Zindler; 57. Sauveur Belviso; 58. R Viswanadham; 59. Chris Miles; 60. Sujith KB; 61. Tom Bell; 62. Dayala VT

oligotrophic regions. Belviso et al. and Polimene et al. suggest that the 'summer paradox' can be explained through two different dynamic processes: (1) the succession of phytoplankton types in surface water and (2) the spatial and seasonal variation in bacteria-mediated DMSP(d) to DMS conversion, as a function of nutrient limitation.

Aeolian delivery of soluble iron that exhibits considerable spatio-temporal variability (Srinivas et al.) can also influence DMS production in iron-limited oceanic regions. Model simulations are able to reproduce the effects of natural aeolian iron fertilization on surface water plankton dynamics and mixed layer DMS accumulation in the subarctic Pacific (Steiner et al.). When ecological modelling techniques used for describing species distributions are applied to examine the relationship between surface seawater DMS concentrations and various environmental data, they highlight the major role of the mean sea ice extent and surface nitrate concentrations in the Arctic Ocean (Humphries et al.). Digging deeper into the complexities of ecosystem responses, Lewis et al. used a multitrophic plankton model to show how grazing induced production of DMS can stabilize food-web dynamics and promote the formation of phytoplankton blooms in the ocean. This is a nice example of how models can contribute to our understanding of complex systems with multiple interactions that are difficult to identify in nature.

This Symposium could not have been organised without the support of the National Institute of Oceanography (NIO, Dona Paula, Goa, India), the Council of Scientific and Industrial Research, India, and the Indian National Science Academy. The staff of the NIO did an excellent job in hosting the 86 participants from 14 countries (Fig. 1). We are also indebted to all colleagues from around the world who helped in reviewing the manuscripts for this special issue.

References

Charlson RJ, Lovelock JE, Andreae MO, Warren SG (1987) Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate. Nature 326:655–661

Kettle AJ, Andreae MO, Amouroux D, Andreae TW, Bates TS, Berresheim H, Bingemer H, Boniforti R, Curran MAJ, Ditullio GR, Helas G, Jones GB, Keller MD, Kiene RP, Leck C, Levasseur M, Malin G, Maspero M, Matrai P, Mctaggart AR, Mihalopoulos N, Nguyen BC, Novo A, Putaud JP, Rapsomanikis S, Roberts G, Schebeske G, Sharma S, Simo R, Staubes R, Turner S, Uher G (1999) A global database of sea surface dimethylsulfide (DMS) measurements and a procedure to predict sea surface DMS as a function of latitude, longitude, and month. Global Biogeochem Cycles 13(2):399–444

Kiene RP, Visscher PT, Keller MD, Kirst GO (eds) (1996) Biological and environmental chemistry of DMSP and related sulfonium compounds. Plenum Press, New York 430

Levasseur M (ed) (2004) Proceedings of the third international symposium on DMSP and related compounds. Can J Fish Aquat Sci 61(5):673–856

Malin G (ed) (2007) Special issue—biological and environmental chemistry of DMS(P) and related compounds. Aquat Sci 69(3):289–426

Shaw GE (1983) Bio-controlled thermostasis involving the sulfur cycle. Clim Change 5(3):297–303

Stefels J, van Rijssel M, Hansen TA, Dijkhuizen L, Gieskes WWC (eds) (2000) Special issue—biological and environmental chemistry of DMS(P) and the role of Phaeocystis in marine biogeochemical cycles. J Sea Res 43(3–4):179–392