GESAMP
Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

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Agenda item 4

PLANNING OF GESAMP ACTIVITIES: ATMOSPHERIC INPUT OF CHEMICALS TO THE OCEANS

Report of the Co-Chairmen of Working Group 38

History, early meetings and their results

1 Working Group 38 was first formed in 2008 because of growing concern about the impact of atmospheric deposition of both natural and anthropogenic substances on ocean chemistry, biology, and biogeochemistry as well as climate. It has held meetings at the University of Arizona, Tucson, Arizona, United States, in 2008, at IMO in London in 2010, in Malta in 2011, and at the University of East Anglia, Norwich, UK in 2013 and 2017. Sponsors of those WG 38 efforts have included WMO, IMO, SCOR, SIDA, the European Commission Joint Research Centre, the University of Arizona, the International Environment Institute at the University of Malta, the University of East Anglia, and the US National Science Foundation. Following the initial terms of reference and the meetings through 2011, five scientific papers were published in the peer-reviewed scientific literature. These were as follows:

[1] Okin, G., A. R. Baker, I. Tegen, N. M. Mahowald, F. J. Dentener, R A. Duce, et al., "Impacts of atmospheric nutrient deposition on marine productivity: roles of nitrogen, phosphorus, and iron, Global Biogeochemical Cycles, 25, GB2022, doi:10.1029/2010GB003858, (2011).

[2] Hunter, K.A., P. S. Liss, V. Surapipith, F. Dentener, R. A. Duce, M. Kanakidou, et al., "Impacts of anthropogenic SO_x, NO_x and NH_3 on acidification of coastal waters and shipping lanes", Geophysical Research Letters, 38, L13602, doi:10.1029/2011GL047720 (2011).

[3] Kanakidou, M., Kanakidou, M., R. Duce, J. Prospero, A. Baker, et al., "Atmospheric fluxes of organic N and P to the ocean", Global Biogeochemical Cycles, GB3026, doi:10.1029/2011GB004277 (2012).

[4] Schulz, M., J. M. Prospero, A. R. Baker, F. Dentener, L. Ickes, P. S. Liss et al., "The atmospheric transport and deposition of mineral dust to the ocean - Implications for research needs", Environmental Science and Technology, 46, doi:10.1021/es30073ul, 10,390-10,404 (2012).

[5] Hagens, M., K. A. Hunter, Peter S. Liss, and Jack J. Middelburg, "Biogeochemical context impacts seawater pH changes resulting from atmospheric sulfur and nitrogen deposition", Geophysical Research Letters, 41, doi:10.1002/2013GL058796 (2014).

Nitrogen workshop in Norwich, United Kingdom, 2013

2 New Terms of Reference for continued work of GESAMP WG 38 were approved in 2011 to address issues related to the impact of the atmospheric deposition of anthropogenic nitrogen to the ocean. A highly successful workshop on "The Atmospheric Deposition of Nitrogen and its Impact on Marine Biogeochemistry" was held by WG 38 at the University of East Anglia in

February, 2013 to address the new terms of reference. 23 scientists participated in the workshop. As a result of the Norwich nitrogen workshop several papers have been published in the peer reviewed scientific literature on this nitrogen issue. These include:

[6] Kim, T.-W., K. Lee, R.A. Duce and P.S. Liss, "Impact of atmospheric nitrogen deposition on phytoplankton productivity in the South China Sea", Geophysical Research Letters, 41, 3156-3162, doi: 10.1002/2014GL059665 (2014).

[7] Somes, C., A. Landolfi1, W. Koeve1, and A. Oschlies, "Limited impact of atmospheric nitrogen deposition on marine productivity due to biogeochemical feedbacks in a global ocean model, Geophysical Research Letters, 43, 4500–4509, doi:10.1002/2016GL068335 (2016).

[8] Kanakidou, M., S. Myriokefalitakis, N. Daskalakas, G. Fanourgakis, A. Nenes, A.R. Baker, K.Tsigaridis, and N. Mihalopoulos, "Past, Present, and Future Atmospheric Nitrogen Deposition", Journal of the Atmospheric Sciences, 73, 2039-2047, doi:10.1175/JAS-D-15-0278.1. (2016).

[9] Sharples, J., J. J. Middelburg, K. Fennel, and T. D. Jickells, "What proportaion of riverine nutrients reaches the open ocean", Global Biogeochemical Cycles, 31, 39–58, doi:10.1002/2016GB005483. (2017).

[10] Jickells, T.D., E. Buitenhuis, K. Altieri, A.R. Baker, et al., "A re-evaluation of the magnitude and impacts of anthropogenic atmospheric nitrogen inputs on the ocean", Biogeochemical Cycles, 31, 289–305, doi:10.1002/2016GB005586. (2017).

[11] Baker, A.R., M. Kanakidou, K. E. Altieri, et al., "Observation- and model-based estimates of particulate dry nitrogen deposition to the oceans", Atmospheric Chemistry and Physics, 17, 8189-8210, https://doi.org/10.5194/acp-17-8189. (2017).

One final nitrogen paper will be submitted this fall:

[12] Suntharalingam, P., L. M. Zamora, M. M. Sarin, et al., "Increasing inputs of anthropogenic nitrogen to the Northern Indian Ocean and its impacts on marine N_2O fluxes" to be submitted by fall, 2017 to Environmental Research Letters.

3 Following the completion of the publication of the papers resulting from the 2013 workshop on the impacts of atmospheric nitrogen deposition to the ocean, WG 38 has prepared a synthesis of the results from the scientific papers derived from that workshop as part of the GESAMP Reports and Studies series. That draft report is now being reviewed by GESAMP, and hopefully it will be published in the fall of 2017.

Activities in 2017

4 For the fourth year in a row WG 38 organized a session on atmospheric input of chemicals to the ocean for the 2017 European Geosciences Union meeting, held in Vienna, Austria in April – "Air-sea Exchanges: Impacts on Biogeochemistry and Climate". A number of oral and poster papers at this session were presented by a combination of WG 38 members and other scientists. The initial outcomes from the 2017 Norwich workshops (see 8 below) were also presented at this EGU session.

5 Tim Jickells represented WG 38 (via a remote connection) at the GAW workshop on Measurement-Model Fusion for Global Total Atmospheric Deposition February 28 – March 2, 2017, Geneva, with a presentation on "Observation and Model based Estimates of Atmospheric Inputs to the Oceans".

6 Tim Jickells represented WG 38 and GESAMP at the GAW Symposium 10-13 April 2017 in Geneva giving one presentation to the plenary session on the activities of GESAMP and then a presentation on “Observations and Modelling Needs to Understand the Impacts of Nitrogen Inputs to the Oceans at a side event on “How can GAW contribute to the N cycle assessment?”

7 Tim Jickells represented WG 38 and GESAMP at The Third Informal Meeting of the International Law Commission (ILC) on the Protection of the Atmosphere as part of the Dialogue with Scientists meeting in Geneva on May 5, 2017 giving a presentation entitled “Linkages between the oceans and the atmosphere” and participating in the subsequent discussion.

Current Activities of Working Group 38

8 At the meeting of GESAMP 42 at IOC in Paris in September, 2015, GESAMP approved two new workshops for WG 38. These two simultaneous workshops were related to the changing acid/base character of the global atmosphere and ocean and the impact of these changes on certain air/sea chemical exchange processes. Funding was obtained for these workshops from the US National Science Foundation (through SCOR), from WMO, and from IMO. SOLAS also sponsored these workshops. The workshops took place at the University of East Anglia (UEA) in Norwich, United Kingdom from February 27 through March 2, 2017. The topics of the two workshops were as follows:

Impact of Ocean Acidification on Fluxes of Atmospheric non-CO_2 Climate-Active Species

9 Earlier investigations of the impact of ocean acidification (OA) have primarily focused on changes in oceanic uptake of anthropogenic CO_2, the resulting shifts in carbonate chemical equilibria, and the consequences for marine calcifying organisms. Very little attention has been paid to the direct impacts of OA on the ocean sources of a range of other gaseous and aerosol species that are influential in regulating radiative forcing, atmospheric oxidising capacity (via OH and O_3 cycling) and atmospheric chemistry.

10 The oceanic processes governing emissions of these species are frequently sensitive to the changes in pH and ocean pCO_2 accompanying ocean acidification. These processes include, for example, metabolic rates of microbial activity, levels of surface primary production, ecosystem composition, and photo-chemical and microbially mediated production/loss pathways for individual species. The direct and indirect influences of these factors on oceanic fluxes of non-CO_2 trace-gases and aerosols, and the subsequent feedbacks to climate remain highly uncertain.

Changing Atmospheric Nutrient Oceanic Solubility

11 Atmospheric deposition of nutrients to the ocean is known to play a significant role in the marine carbon cycle. The impact of such deposition is dependent on the identity of the nutrient in question (e.g., N, P, Fe, Co, Zn, Ni, Cd), the location of the deposition, and the bioavailability of the deposited nutrient. Bioavailability is largely governed by the chemical speciation of a nutrient and, in general, insoluble species are not bioavailable. For Fe and P (and perhaps the other nutrient trace metals) solubility increases during transport through the atmosphere. The causes of this increase are complex, but interactions of aerosol particles with acids appears to play a significant role.

12 Emissions of acidic (SO_2 and NO_x) and alkaline (NH_3) gases have increased significantly since the Industrial Revolution, with a net increase in atmospheric acidity. This implies that Fe and P solubility may also have increased over this time-period, potentially resulting in increased marine productivity. More recently, pollution controls have decreased emissions of SO_2 from some regions and further reductions in SO_2 and NO_x are likely in the future. Emissions of NH_3 are much more difficult to control however, and are projected to stabilise or increase slightly to the end of

this century. Future anthropogenic emissions are thus likely to change the acidity of the atmosphere downwind of major urban / industrial centres, with potential consequences for the supply of soluble nutrients to the ocean.

13 The workshops took the form of rather informal presentations from experts followed by very lengthy discussion sessions exploring multiple issues and feedbacks evident in these complex air-sea interaction issues. The invited scientists were selected for their expertise and interest in these areas, and also to provide a wide spectrum of expertise from modellers to experimentalists. We drew 34 scientists from 16 countries and also from a wide range of career stages, from senior scientists through to graduate students. The participants all seemed to leave Norwich full of enthusiasm for the process and the new scientific insights the groups had developed. The aim now is to write a series of papers synthesising these conclusions. At the present time roughly 12 papers are being developed from the workshop discussions.

14 A potential additional upcoming activity of WG 38 is an assessment of the impact of nitrogen on the marine environment as a contribution to the Integrated Nitrogen Management System (INMS). INMS is a global targeted research project with the aim to provide clear scientific evidence to inform future international nitrogen policy development. INMS's core funding will come from the Global Environment Facility (GEF) (the environment funding mechanism of the United Nations System) with the United Nations Environment Program (UNEP) as the Implementing Agency and the UK Natural Environment Research Council (Centre for Ecology and Hydrology) as the Executing Agency acting on behalf of the International Nitrogen Initiative (INI). INMS has had no involvement with groups with concerns about nitrogen in the marine environment. They are particularly concerned about certain regional areas, such as the Black Sea and the South China Sea. WG 38 has extensive experience in both regional and global ocean issues with regard to nitrogen. WG38 has approached the INMS secretariat and made clear that we are ready to help in their work where we can.

Action requested of GESAMP

15 GESAMP is invited to consider the information provided and take action as appropriate.