

# **The Atmospheric Input of Chemicals to the Ocean - GESAMP Working Group 38**

## **Introduction and History**

Recognition continues to grow concerning the impact of the atmospheric input of both natural and anthropogenic substances on ocean chemistry, biology, and biogeochemistry as well as climate. In the 1980s, GESAMP formed a working group sponsored by WMO, UNESCO/IOC and UNEP that developed a comprehensive review of the input of atmospheric trace species to the global ocean (GESAMP Reports and Studies 38, 1989). That benchmark effort led to a scientific publication in Global Biogeochemical Cycles that for more than 15 years was the state-of-the-art reference in this area, leading to over 700 citations in the literature. However, the information in those reports is now over 20 years old, the documents are clearly out of date, and much new information on this topic is now available. A number of important environmental issues persist in this area and in many cases are considered to be more serious than previously thought, and new issues have arisen.

The atmospheric input of chemicals to the ocean is closely related to a number of important global change issues. For example, it has recently been shown that the increasing input to much of the ocean of atmospheric anthropogenic nitrogen species, including nitrate, ammonia, and water-soluble organic nitrogen, may cause a low level fertilization of the ocean that could result in an increase in marine 'new' productivity of up to ~3%. This in turn could cause a possible sequestering of up to 0.3 Pg C/yr of atmospheric CO<sub>2</sub> in the ocean, which would affect the radiative properties of the atmosphere and thus climate. The atmospheric input of this anthropogenic nitrogen may also lead to the increased oceanic production and emission of N<sub>2</sub>O, a powerful greenhouse gas that could offset as much as 2/3 of the decrease in radiative forcing from the increased drawdown of CO<sub>2</sub>. In addition, the recognition that much of the oceanic iron, which is a limiting nutrient in many areas of the ocean, originates from the atmospheric input of minerals as a result of the long-range transport of sand and dust has catalyzed an intense interest in the atmospheric and marine chemistry of iron, its chemical form, and rate of input to the ocean. The transport of mineral dust and iron affects the large areas of the global ocean where iron is the limiting nutrient. There is also a close connection with climate here, as a windier and dryer climate would result in increased quantities of iron entering the ocean, with its consequent impact on marine productivity and thus both CO<sub>2</sub> drawdown and dimethyl sulfide release, both of which in turn would provide a climate feedback. In both of these examples (nitrogen and iron), the fates of these substances and changes in their fluxes in the future are potentially related to climate and climate change. While the atmospheric input of nitrogen species and iron are currently topics of great interest, the input of other nutrients that may have an impact on the ocean, such as phosphorus, may also be of concern, but have had little focused study to date. In addition, there is little information about whether inputs of sulfur dioxide and nitrogen oxides from the atmosphere can add to the ocean acidification occurring by rising levels of carbon dioxide. These gases may be particularly critical in heavily trafficked shipping lanes and/or offshore of industrialized land areas. And our understanding in general about the atmospheric input to the ocean of the organic forms of carbon, nitrogen, and phosphorus is minimal.

## **Terms of Reference of the Working Group**

To address these and other important issues related to the transport of chemicals via the atmosphere to the ocean, GESAMP formed Working Group 38 in 2008. The Terms of Reference were as follows:

1. Assess the need for the development of new model and measurement products for improving our understanding of the impacts of the atmospheric deposition of nitrogen species and dust (iron) to the ocean;
2. Review the present information on the atmospheric deposition of phosphorus species to both the marine and terrestrial environments, considering both natural and anthropogenic sources, and evaluate the impact of atmospheric phosphorus deposition on marine and terrestrial ecosystems. Consider whether such a review of any other substance would be useful.
3. Work with the WMO Sand and Dust Storm Warning and Assessment System and with the WMO Precipitation Chemistry Data Synthesis and Community Project to evaluate the needs of the marine community and assist in clearly articulating them in the development of these WMO efforts.

### **Activities of the Working Group**

#### **First Meeting of the Working Group**

The first meeting of the Working Group took place at the University of Arizona, Tucson, Arizona, USA from 10-14 December 2008. This meeting was organized and supported by the Global Atmosphere Watch (GAW) and World Weather Research Programme of the World Meteorological Organization (WMO), with additional support from the Swedish International Development Agency, the International Maritime Organization, the international research program SOLAS (Surface Ocean/Lower Atmosphere Study) of the International Geosphere/Biosphere Program (IGBP), EU Joint Research Centre, and the University of Arizona.

During the Arizona meeting the Working Group addressed these three charges in detail. Charge 3 in the Terms of Reference was addressed by the development during the meeting of two letter reports, including recommendations. **These letter reports address the issues outlined in Charge 3 and were submitted by GESAMP to WMO in April 2009, thus satisfying Terms of Reference #3.**

Terms of Reference #1 and #2 were addressed by gathering information for three separate papers/documents that the working group would develop in the areas of phosphorus, nitrogen, iron and organic matter deposition from the atmosphere to the ocean. The titles of these three papers are:

- a) Impacts of atmospheric nutrient deposition on marine productivity: roles of nitrogen, phosphorus, and iron
- b) Impacts of anthropogenic SO<sub>x</sub>, NO<sub>x</sub> and NH<sub>3</sub> on acidification of coastal waters and shipping lanes
- c) Atmospheric organic material and the nutrients it carries to the ocean

#### **Second Meeting of the Working Group**

Work progressed on these papers during the intersessional period. The second meeting of Working Group 38 took place in London at IMO from 12-15 January 2010. This meeting was supported by

WMO, IMO, and SIDA. During the meeting working group members broke up into three sub-groups, each addressing the drafts of the three papers outlined above. At the completion of the meeting significant progress had been made on finishing the three papers.

Paper a) has now gone through more than six drafts, and it is estimated that it will be submitted for publication to Geophysical Research Letters before the end of February, 2010.

Paper b) has gone through at least three drafts and it is expected that it will be submitted for publication in Geophysical Research Letters by the end of February, 2010.

Paper c), which is a much longer and more detailed paper than the other two, should have a comprehensive draft completed by the end of February, with plans to submit it for publication in Global Biogeochemical Cycles by the end of March or early April, 2010.

**Thus we expect that all three papers will be submitted to journals within the next 2-3 months, with publication likely in very late 2010 or 2011. When these papers are completed and submitted, this will satisfy Terms of Reference #1 and #2.**

### **Proposed Future Activities of the Working Group**

In order to more specifically elaborate the role of chemicals carried by dust which are responsible for marine biological production, WMO proposes the extension of Working Group 38 activities for another year or two beyond 2010, with the aim of achieving a more detailed description of the atmospheric transport and deposition process of iron- and phosphorus-carried minerals to the ocean. GESAMP Working Group 38 would establish a close cooperation with the WMO Sand and Dust Storm Warning and Assessment System (SDS-WAS) in order to exploit the already existing modelling and observational capabilities of the SDS-WAS project, and a meeting in the spring of 2011 would be joint between Working Group 38 and SDS-WAS. This meeting in the spring of 2011 would have a tentative title "Expert Workshop on Modelling and Observing the Impacts of Dust Transport/Deposition on Marine Productivity".

The proposed specific themes of the joint activities to be discussed at this workshop would be:

- Specifying test-bed regions for studies (Central Atlantic; North Pacific; Indian Ocean; possibly others);
- Employing dust/iron/phosphorus models with resolutions as high as possible;
- Improving quantitative estimates of geographical distribution of mineral fractions;
- Long-term (re-analyses) and case-study assessment of mineral ocean input and marine response provided by dust/Fe/P and ocean modelling and by remote-sensing and in-situ observations; and
- Environmental and climate consequences.

WMO/GESAMP will seek to get co-sponsorship from other interested partners, such as ESA, NASA and others, and it is hoped that IMO and SIDA will continue to support the working group's activities as well. This third meeting of Working Group 38 would likely take place in Malta.

### **Membership of the Working Group**

The membership of GESAMP Working Group 38 is as follows:

#### Co-Chairs:

Robert Duce, USA

Peter Liss, United Kingdom

#### Members:

Alex Baker - United Kingdom

Frank Dentener - Italy

Keith Hunter - New Zealand

Maria Kanakidou - Greece

Nilgun Kubilay - Turkey

Natalie Mahowald - United States

Greg Okin - United States

Joseph Prospero - United States

Manmohan Sarin - India

Vanisa Surapipith - Thailand

Ina Tegen - Germany

Mitsuo Uematsu - Japan

Tong Zhu - China

At both meetings of the working group all but two of the members were able to attend - different people for each meeting. For the second meeting both of the two individuals who could not attend did participate by phone during the meeting.