Mapping Nitrogen Loads of Coastal Marine Waters

A contribution to subproject CAPMAN

Ole Hertel[1], Carsten Ambelas Skjøth and Lise Marie Frohn

National Environmental Research Institute (NERI), Department of Atmospheric Environment (ATMI)
P. O. Box 358, Frederiksborgvej 399, 4000 Roskilde, Denmark

[1] *Corresponding author: e-mail: Ole.Hertel@dmu.dk,*
Tel. +45 46301148, Fax. +56 46301214

Summary

The ACDEP model has for the last eight years been used as an operational tool for calculations of atmospheric nitrogen depositions to Danish marine waters. Furthermore the model has been applied for the North Sea and the Baltic Sea. The results have shown the importance of atmospheric nitrogen depositions compared with other loads from run-off and point sources. An example is that for Danish marine waters the calculations for 1999 have shown that on a yearly basis the atmosphere contributed with a nitrogen input of similar size as the river run-off. The high atmospheric loads in 1999 were partly due to high frequency of precipitation events leading to significant wet deposition of especially aerosol bound nitrogen compounds. During the same period the Danish wastewater treatments have improved, leading to decreased contributions from river run-off.

There are considerable uncertainties in currently used operational models for calculation of atmospheric nitrogen deposition. These uncertainties concern input data as well as parameterisations of the physical and chemical processes. Large uncertainties are known to be associated with the temporal and spatial distributions of emissions. Concerning the parameterisations of the various processes in the model, main focus is currently devoted to the treatment of aerosols. Detailed field studies of chemical composition in size distributions are crucial for the development and test of new parameterisations of aerosol processes in the next generation of operational atmospheric transport-chemistry models.

Aim of the research

The aim of the project is to improve current atmospheric transport-chemistry models developed for assessment of loads and impacts of nitrogen deposition to coastal marine waters. Furthermore to apply the developed models for calculations to specific coastal waters and try to link atmospheric nitrogen loads to observed effects on the marine ecosystems. The main part of the work has been devoted to improving the performance of the Danish variable scale Lagrangian model ACDEP (Atmospheric Chemistry and Deposition) model (Hertel et al., 1995). The ACDEP-model is applied for calculations of nitrogen depositions to Danish marine waters, and in a number of research projects for similar calculations for the North Sea and the Baltic Sea. A part of the work is devoted to improvements of the description of aerosol processes in the ACDEP-model. The long-term goal of the project is the development of REGINA (REGIonal high resolutioN Air pollution model) a Eulerian nested grid model (Frohn et al., 2001), which in turn will substitute the Lagrangian model. REGINA will to some extent be built on best parts from various transport-chemistry models at NERI-ATMI.

Procedures for sensitivity studies, validation and evaluation of the model will be outlined as a part of the project, together with some recommendations for experimental studies needed for improving the performance of current models.

Activities during the year

A new version of the ACDEP-model was developed in 2000 and applied within the Danish Background Programme. This new version uses meteorological input from the Eta model operated as a part of the NERI pollution forecasting system THOR (Brandt et al., 2000). Another modification concerned the treatment of chemistry and vertical diffusion/deposition, which in the new version is solved using the same numerical scheme. A first evaluation of the new version of the model indicated a considerable improvement of the model performance.

Calculation grids with a resolution of 30 km x 30 km have been established for the North Sea area, the Baltic Sea and the Adriatic. A web site with calculation grids, and results presented in figures and tables has been established at: www.dmu.dk/AtmosphericEnvironment/ACDEP. This site will be continuously updated with new results when available.

Principal results

Calculations are performed on a routine basis within the Danish Background Monitoring programme (Ellermann et al., 2000; Hertel et al., 2001). The model was updated in connection with the change to a new set of meteorological input data from the Eta-model running under the THOR system and the new numerical handling of chemistry, vertical diffusion and deposition in the same scheme.

Calculations of nitrogen depositions to the Baltic have been performed for 1999 with the new version of ACDEP. Another set of calculations has been performed for 1999 for the North Sea. These calculations are conducted as a part of the EU programme ANICE. The calculated annual atmospheric nitrogen depositions to these two waters are shown in *Figure 1*.

Main conclusions

Atmospheric nitrogen deposition is becoming increasingly important for the nitrogen budgets of the coastal marine waters, but the impact on algae blooming is still only poorly determined. The algae blooming may be linked to events with high atmospheric loads mainly in connection with rain episodes. In order to resolve such events with transport-chemistry models considerable improvements are needed. There will be a need for high quality input data concerning meteorology and emission inventories at higher spatial and especially temporal resolution compared to the data sets currently available.

Furthermore, the current treatment of aerosol processes needs to be improved. For this purpose there is a great need for experimental data concerning chemical composition of aerosols in different size fractions. Such data are currently only available for short time periods and with highly limited time resolution – typically 24 hours or even longer sampling times.

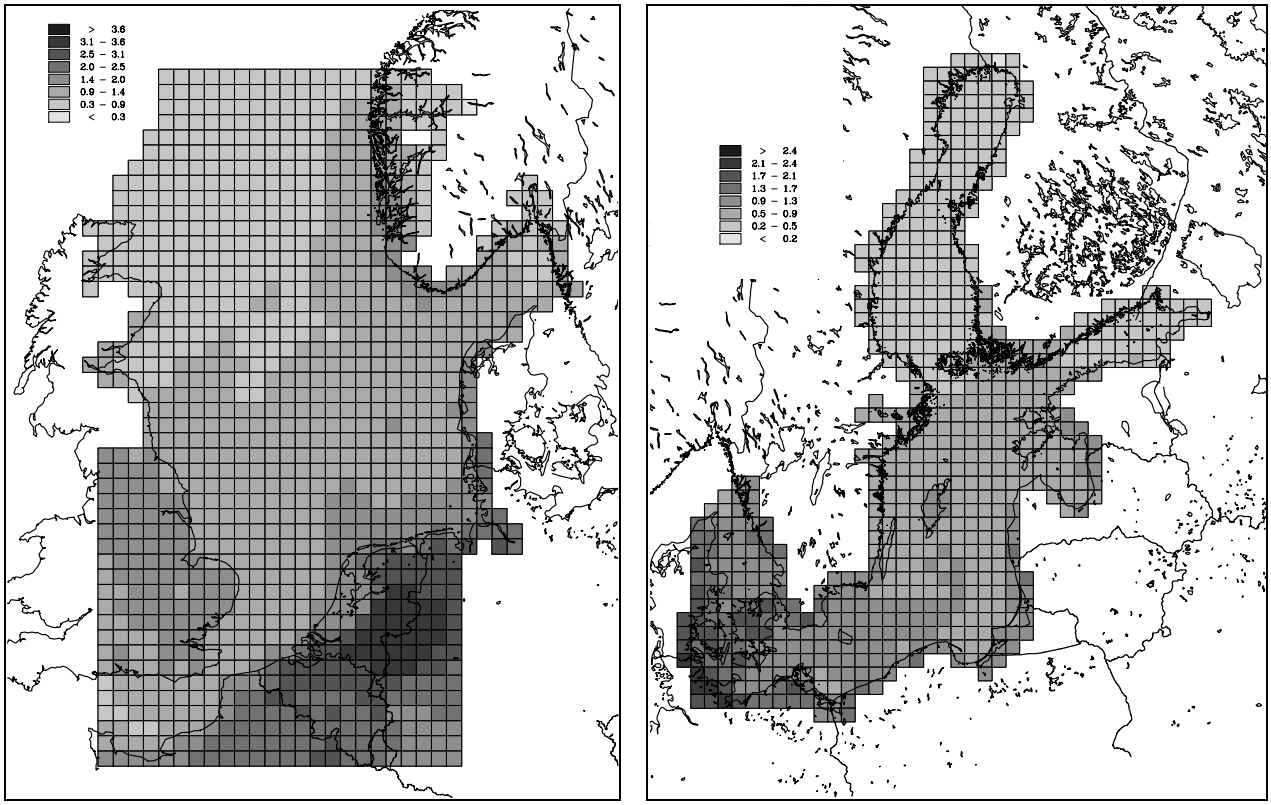

Figure 1. Calculated annual nitrogen deposition (ktonnes N/km^2) to the North Sea (left figure) and to the Baltic Sea in 1999 (right figure).

Aim for the coming year

One of the main aims for the year 2001 will be the development of an operational version of ACDEP for (semi) automatic calculations of nitrogen depositions to the Danish marine waters and the Baltic Sea. In the same way as for the previous years, calculations of nitrogen depositions to Danish marine waters will be carried out within the Danish Background Monitoring Programme. Similarly, calculations for the Baltic Sea will be carried out as part of a project for the Nordic Council of Ministers.

The developed aerosol module will be fully implemented in ACDEP, and the model will be tested versus measurements from Denmark and from EMEP monitoring stations over Europe.

As a part of a MSc thesis work, a nested grid version of the forecasting model Eta will be developed and applied with a high resolution for an area surrounding Denmark. The main aim is to achieve a more precise description of the meteorology for this domain such as coastal effects, wind fields and distribution of precipitation amounts.

Calculations of nitrogen depositions to the Adriatic Sea have been proposed. In case funding is obtained, ACDEP will be applied for these calculations.

The mathematical framework of the new REGINA model is in place and tested (see Frohn et al., 2001). Currently the model is being validated with measurements from the EMEP measurements stations network.

Acknowledgements

The work under the Danish Background Monitoring Programme is carried out in close co-operation with Thomas Ellermann at NERI. In the ANICE project, Elisabetta Vignati, currently at Joint Research Centre ISPRA, ITALY developed the aerosol module for implementation in ACDEP. The Nordic Council of Ministers funded the application of ACDEP for the Baltic Sea. Jørgen Brandt and Jesper Christensen are acknowledged for providing meteorological data from the Eta-model.

References

Brandt, J., J. H. Christensen, L. M. Frohn,, R. Berkowicz and F. Palmgren (2000). The DMU-ATMI THOR air pollution forecast system – system description. Technical report from NERI no 321, National Environmental Research Institute, P.O. Box 358, Frederiksborgvej 399, DK-4000 Roskilde, Denmark, 60 p.

de Leeuw, G., L. Cohen, L.M. Frohn, G. Geernaert, O. Hertel, B. Jensen, T. Jickells, L. Klein, G. Kunz, S. Lund, M. Moerman, F. Müller, B. Pedersen, K. von Salzen, H. Schlüenzen, M. Schulz, C.A. Skjøth,, L.L. Sørensen,, L. Spokes, S. Tamm and E. Vignati (2001). Atmospheric input of nitrogen in the North Sea: ANICE project overview, Submitted for Nearshore and Coastal Oceanography (Continetal Shelf Research), ELOISE special issue.

Ellermann, T., O. Hertel and C. Ambelas Skjøth (2000). NOVA 2003, Atmospheric Deposition of Nitrogen 1999 (In Danish: NOVA 2003, Atmosfærisk deposition af kvælstof 1999). NERI, Technical Report, no. 332, 120 p.

Frohn, L.M., J.H. Christensen, J. Brandt and O. Hertel (2001). Development of a high resolution air pollution model - The numerical approach. Submitted for Journal of Computational Physics.

Hertel, O., C. Ambelas Skjøth, T. Ellermann, H. Skov and L.M. Frohn (2001). Atmospheric Nitrogen Deposition to Danish Waters 1999. 10 pp. Submitted for publication in Pure and Applied Chemistry.