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# Impacts of meteorological situations and chemical reactions on daily dry deposition of nitrogen into the southern North Sea

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**Abstract**

The impact of the meteorological situation and chemistry on dry deposition to the southern North Sea is investigated. The studies are performed using a high-resolution meteorology/chemistry model system of different complexity for a five-day period in June 1998. The simulations consider passive tracer transport (Case I), gas phase chemistry (Case II), gas phase plus simple aerosol chemistry (Case III), gas phase plus size dependent aerosol chemistry (Case IV). The results show a very good agreement of meteorology model results with measured data and a reasonable agreement for the concentrations. The dry deposition to the southern North Sea differs a factor of three to seven within the investigated five-day period. Differences are larger for a more complex chemistry. The average dry deposition increases by a factor of three when including gas phase reactions or adding a simple aerosol model and up to a factor of eleven when considering a sectional aerosol model. The input composition depends on the chemistry considered.


*Keywords:* Coastal regions; Dry deposition; Mesoscale modelling; Nitrogen; High resolution

## 1. Introduction

About 184 million people live in the catchments' area of the North Sea with the highest population density in the southern and south-eastern part of the region (OSPAR, 2000). As most marginal seas, the North Sea is intensely used and truly multifunctional: it serves as a source for minerals, energy and food, it is a platform for transport and traffic, and the coastal regions are a place for settlement and recreation. In addition, the North Sea is used for dumping human waste in many ways: the North Sea is polluted and fertilized from shipping, pipelines, oil and gas industry (to name a few sources), by dumping, and receives high pollutant and nutrient loads from rivers and the atmosphere (Fig. 1). Based on OSPAR (2005), the anthropogenic nitrogen input from the atmosphere ranges from 29% (1995_O) to 43% (1996_O) for years 1995–2000 (Fig. 1). Using the mean deposition value calculated with ACDEP for 1999 ($902\,kg\,N\,km^{-2}\,yr^{-1}$; de Leeuw et al., 2003b), the atmospheric input results to $\sim 680\,kt\,N\,yr^{-1}$ for the Greater North Sea, when using the same area size ($750\,000\,km^2$) as used in OSPAR (2000). The atmospheric input amounts to 42% of the total input (1999_A in Fig. 1), compared

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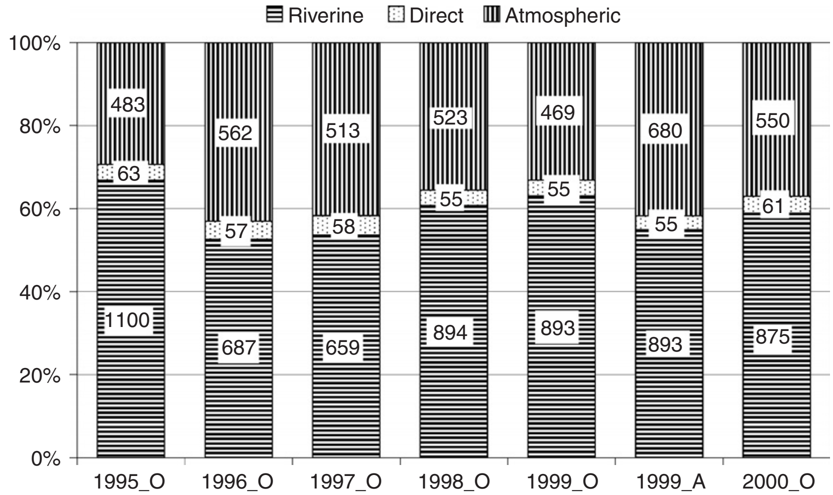


Fig. 1. Anthropogenic nitrogen input into the North Sea for 1995–2000. Based on OSPAR (2005) are 1995_O to 2000_O data. 1999_A uses atmospheric input data from de Leeuw et al. (2003b), all other data from OSPAR (2005).

to 33% resulting from OSPAR data (1999_O). These comparisons show the variability of the atmospheric input data from year to year, which is mainly caused by changes in meteorological conditions (precipitation) and partly a result of changed emissions. The difference of 469 kt N $yr^{-1}$ (1999_O) to 680 kt N $yr^{-1}$ (1999_A) found for 1999 can be attributed to differences in the models used for the calculation itself.

For the atmospheric inputs, results of the EMEP-model (Sandnes and Styve, 1992; Simpson et al., 2003) are available with five-year increments (years 1980, 1985, 1990) and on an annual basis for 1995–2001 (OSPAR, 2005). With a horizontal resolution of 50 km, the data can well be used to calculate annual and monthly input data. However, for the heavily loaded southern North Sea the resolution would be too coarse, since UK and the Netherlands are only about 200 km apart, corresponding to about 4 grid points in the EMEP model. Higher resolving model results are available from Hertel et al. (2002) for 1999. They used a resolution of 16.67 $km^2$ for the emission data and calculated 96-h backward trajectories by using hourly ~800 m wind speeds for column advection in the Lagrangian transport-chemistry model ACDEP (Hertel et al., 2002). As stated by de Leeuw et al. (2003b), who used the ACDEP results, the resolution of the meteorological data has a considerable impact on the calculated concentration and deposition values. Very relevant is also the vertical resolution, which is 10 layers in ACDEP with a model top at 2000 m (Hertel et al., 2002). The lowest level in ACDEP is at 2 m using 10 m winds for calculating deposition velocities (Hertel et al., 1995). In EMEP 10 levels are used in the lowest 2000 m with an additional nine layers above and a model top at about 14 km. Dry deposition is calculated at a height of ~45 m (Berge and Jakobsen, 1998).

In the current investigation, a high-resolution mesoscale model system is applied (Fig. 2). The model components that simulate meteorology (METRAS) and chemistry (MECTM) are both of Eulerian type and use a horizontal resolution of 8 km with a well-resolved atmospheric boundary layer. The lowest model level is at 10 m. A non-uniform grid is used in the vertical with 15 grid points in the lowest 1000 m of the atmosphere and an additional 18 levels above, with a model top at 11 km. This resolution allows simulating differences in the boundary layer heights over the water and resolves the coastal effects. In addition, the meteorology is calculated by METRAS in a 3D manner on the same grid that is used for the chemistry calculations with MECTM.

The studies are performed for the southern North Sea (Fig. 3), where the atmospheric nitrogen input is very high (de Leeuw et al., 2003a). The area was intensely studied in the EU-project ANICE (Atmospheric Nitrogen Input into the Coastal Ecosystem; de Leeuw et al., 2001, 2003a, b), and thus comparison data are available from a field campaign. These data include measurements of concentrations and