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The VELD experiment: An evaluation of the ammonia emissions and concentrations in an agricultural area

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ABSTRACT

From July 2002until September 2003, a detailed ammonia emission inventory was carried out in concurrence with detailed measurements of the ammonia concentrations in air in a 3 × 3 km area in the East of the Netherlands. The main goal of the project was to validate the emission inventory by comparing modelled ammonia concentrations based on these emissions to the measured concentrations. It was found that the emissions from animal housings are the dominant source of ammonia over the year. Only incidentally, emissions of manure spreading were larger. The spatial and temporal variations in the concentrations over the year are well represented by the OPS model based on these emissions. For the entire period, the model shows an underestimation of the concentrations of about 15% (explained variance of the regression line of 76%). In the winter period, which is characterized by a dominance of the emissions from animal housings, the underestimation is only 5%. This most likely indicates that the emissions from animal housings, which in the area is mainly from pigs, are estimated correctly, as well as the modeling of the concentrations, for this period.

In both the Spring and August 2003 period, a gap between calculated and measured ammonia concentrations was found. Under spring conditions, this gap is most likely the result of an underestimation of the emission during manure spreading. A part of the underestimation may be attributed to a reduction in the dry deposition process in the successive weeks after spreading which is caused by a saturation of the grassland with ammonium. Taking into account the uncertainty in this dry deposition process, it was estimated that the underestimate of the emissions by manure spreading could amount from 15% to 60%. The gap in August 2003, which was a very warm and dry month, is most probably caused by re-emission of ammonia at a large scale in and around the VELD area. The re-emission of ammonia from grass and crop land in August 2003 has a typical density of 14 g/ha/day during daytime. On a national scale this would mean for the Netherlands a re-emission of about 1 Gg during these three weeks of August.

1. Introduction

The deposition of ammonia originating from agricultural activities may lead to eutrophication of ecosystems. Therefore, in national and international policy, measures are defined to reduce the ammonia emissions (e.g. EU NEC-directive). A major issue in several countries is the quality or accuracy of the (national) ammonia emission inventories and the possibility to derive the effectiveness of measures from these inventories.

In general, the ammonia emissions are calculated from an inventory or statistics on the agricultural

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activities and emission factors (Van der Hoek, 2002). Monitoring of the ammonia emissions has hardly been carried out because agricultural sources are widespread and varying much in time. Monitoring would, therefore, mean a very large effort in time and resources. Often measurements of the ammonia concentrations in air are used to validate the national emission inventories or to evaluate trends in the emissions. The validation process consists of calculating the ammonia concentration with atmospheric transport models on the basis of these emission inventories, and compare these calculations with measurements of ammonia concentrations. Sutton et al. (2003), give an overview of national efforts in this field. This overview shows that trends in the concentrations do not always follow the trends in emissions. Apart from the quality of emission inventories themselves, this discrepancy in trends can be caused by a variety of non-linear effects e.g. by chemical and deposition processes.

In the Netherlands also an evaluation of the emission inventory takes place using an atmospheric transport model, i.e. the OPS model (Van Jaarsveld et al., 2000a). The OPS model clearly underestimates the measured ammonia concentrations with about 30% (Van Pul et al., 2004). This underestimation is rather constant over time, from the early 90s until now. Much research has been carried out to try to unravel the reasons for this so called ammonia gap.

In this study we will present an experiment in the Netherlands that was carried out with the objective to get insight in the quality of the emissions in a relatively small area of 3 × 3 km. The quality of the emissions is evaluated by a detailed comparison of the measured concentrations with the concentrations calculated on the basis of the emissions. Here a short term version of the OPS model is used (Van Jaarsveld et al., 2000b), based on hourly emissions.

In this paper we present the set up of the experiment (Section 2), the results of the emission inventory (Section 3), an overview of the OPS model results and the comparison with the measurements, and conclusions on the quality of the emissions and modeling aspects (Section 4). The project is described in detail in Smits et al., 2005.

2. Outline of the experiment

The experiment was carried out in an area of 3 × 3 km around the village of Vragender (Eastern-Netherlands) from July 2002 to September 2003. In this area, the ammonia emissions and concentrations were inventoried in great detail. The area of Vragender is mainly an agricultural area with pigs breeding and to a lesser extent cattle and arable farming. The area is mainly covered with grass and corn, farms and animal housings and patchy nature areas. The area of Vragender was chosen since the relative contribution of local ammonia sources in the area to the concentration based on calculations with annual emission data was large, i.e. about 70%. This means that possible over- or underestimates of the emissions could be traced back from the comparison between measured and modelled concentrations. Besides, the willingness of the farmers to participate in the project was high.

In the following sections, we will present the methodologies used to assemble the emission inventory and the measurements and calculations of the ammonia concentrations.

2.1. Emission inventory

The research area was split into two areas in which the emission inventory was carried out at a different level of detail (Fig. 1). The first area was a circle with a radius of 1 km around a central concentration measurement site (see Section 2.2) in which farmers registered the number of animals, the application of manure and grazing during the course of the experiments. Outside this area up to approximately 1.5 km radius around the central concentration measurement site the inventory was carried out with less detail. Here, the animal numbers were based on a farmer's estimate of the average number of animals housed during the year or an official registration of the yearly counts per animal category and housing system.

The ammonia emissions of all sources were calculated on the basis of these data. The dependency of the emission on environmental factors such as temperature and wind speed, was taken into account in the emission calculation. In the following sections, we briefly address the used descriptions.

2.1.1. Emissions from animal housings

The emissions from animal housings were calculated per animal category and housing type. The parameters that are used in the calculations are depicted in Table 1.

The effect of temperature on the emissions for meat animal housings is summarized in Table 2. For several categories of pigs, the temperature effects were estimated on expert judgement by Aarnink (2004) based on the work of Van Ouwerkerk (2001) and Aarnink (1997).

The effect of animal age and temperature on the emission from veal calve and broiler housings, was based on studies from Beurskens and Hol (2004) and Hol and Groot Koerkamp (1998).

The exact geographic position of the animal housings was used. For specific housings close to the measurement sites a higher detail was obtained by considering the different outlets of the housings as individual sources.

2.1.2. Emission during manure application

The variation in the emissions in manure spreading was obtained by monitoring the manure spreading events, on which parcels the manure was applied and with what quantity. The emission during manure application can be split in emissions on arable land and grass land.

For arable land, the following techniques were applied: surface spreading including direct incorporation of the manure into the soil (SI_{0h}), surface spreading with incorporation in a second track with a time lag of approximately 1 h (SI_{1h}), and injection. The emissions were calculated according to the regression model of Huijsmans (2003) using the following parameters: