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## ***Interactive comment on “Improved modelling of atmospheric ammonia over Denmark using the coupled modelling system DAMOS” by C. Geels et al.***

**C. Geels et al.**

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Response to Anonymous Referee #1 on the Biogeosciences Discuss paper: Improved modelling of atmospheric ammonia over Denmark using the coupled modelling system DAMOS” by C. Geels et al.

We are grateful for the useful and valuable comments and suggestions for improvements and in the following we go through the comments by the reviewer point by point:

Reviewer: This paper presents a comparison of modeling studies carried out with the coupling of two model systems, a fine-scale Gaussian model and a regional model which has nesting down to about 6km. This comparison is interesting, as it emphasizes

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some important features of fine-scale deposition, and the ability (or lack of) large-scale models to capture this. I think that this paper can be a good contribution to the literature, but the authors should first take the opportunity to compare the effects of resolution in a more systematic manner. My main concern is the following. The authors present a good case that DEHM over predicts because the measurement sites are located in clean areas, and Fig. 7 sup-ports this case. This is also given as the reason why DEHM predicts more than DAMOS. I suspect that the authors are right, but I would like to see if they have excluded the possibility that simply DEHM over-predicts everywhere? I miss a sideby- side comparison of DEHM vs. DAMOS for regional averages, for example show DAMOS averages for the DEHM 6km squares. Present a version of Table 5 which is not just for one location, but an average over the domains. It would also be interesting to see the results from different nests of DEHM, showing how the scale issue affects deposition within one model system. DEHM might be different for many reasons, with the vertical dispersion assumptions also being a large source of model differences. How much does this matter?

Answer: First of all we are very pleased that the reviewer finds the comparison interesting and state that this paper can be a good contribution to the literature. We agree that a more systematic analysis of the effects of resolution will be interesting to include. As suggested we now include a side-by-side comparison of DAMOS (extracted from org. resolution of 400 m x 400m), DEHM (extracted from org. resolution of ca. 6 km x 6 km) and DAMOS as “regional averages” i.e. a mean value for a 6 km area. This is now included in fig. 4. From this it is clear that “DAMOS mean 6 km” in most cases is very similar to the DEHM results. This supports that a higher resolution is necessary in order to avoid the spatial averaging of emissions leading to a too high impact of the emissions at the sites. We have included a few lines on this in Section 3.2.1 (“In Fig. 4 the annual concentration from DAMOS is also included as an average over of a 6 km area centred at the measuring sites. This “DAMOS mean 6 km” is seen to be very close to the results from the DEHM model. ” and in Section 3.3 where the direct impact of local emissions are analysed (Fig. 7) . We have not analysed the impact of the

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differences in vertical dispersion in the applied models in detail. But as noted above the “DAMOS mean 6 km” and DEHM are quite similar at the five main sites - indicating that the impact of this difference is minor compared to the resolution of the emissions.

Table 5 have also as suggested been extended to include information from the 50 km grid of DEHM. The application of the DAMOS system is focused on the assessment of N load at specific nature sites and therefore we find it relevant to show examples of the different estimates of deposition to a specific location in table 5. We have extended the discussion on this in Section 5 to:

“The model results are extracted for the land-use category corresponding to the specific nature areas, which combined with the higher resolution in the DAMOS system gives a more precise estimate of the total N load. In order to illustrate this, the central estimate of the total N load at a specific coniferous forest as extracted from DAMOS and two different nests of the DEHM model (50 km grid and 5.56 km grid) are shown as an example in Table 5. The total N load would in the DAMOS system be estimated to about 22 kg N/ha at this forest site. The regional model estimated a load of ca. 29 kg N/ha in the 5.56 km grid and ca. 31 kg N/ha in the 50 km grid. If the load is based on an average over all the nature types within the 5.56 km x 5.56 km (or 50 km x 50 km) grid cell including the specific coniferous forest it would be ca. 17 kg N/ha (or 15 kg N/ha). The contribution from wet deposition of NH<sub>x</sub> and NO<sub>y</sub> (also given in Table 5) is not dependent on the land-use type; however, differences are seen for the calculated dry deposition. When extracting dry deposition to the forest, the regional model alone gives a very high estimate for NH<sub>3</sub>. Highest total load is obtained from the 50 km grid in DEHM. This is in line with Dore et al. (2012), who found greater area exceedance with coarser grid resolution in the UK. This is mainly because the heterogeneity in the emissions is not resolved in the coarser grid. When averaging over all the land-use types in the grid cell (5.56 km x 5.56 km or 50 km x 50 km), lower values of dry deposited NH<sub>x</sub> as well as NO<sub>y</sub> are obtained. Such average estimates for grid cells will be very dependent on the specific sharing of land-use types within the cell. In this

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example the mean load from the 50 km grid is ca. 15 kg N/ha as the part covered by forest is small compared to other land-use types. This type of estimates will hence not be very representative for an explicit nature types. ”

Reviewer: P.1, Abstract. Mention the horizontal resolution of the DEHM model. P.1, line 15. Quantify "locally". P.1589. This last paragraph is taken from Hertel et al.'s review, and should cite the original reference for this estimates. P.1590, line 9. Another relevant reference here would be Flechard et al. 2011. Answer: We have followed the above suggestions and modified the text.

Reviewer: P.1590, line 29. The Van Jaarsveld et al. reference is gray literature. There are plenty of published papers on this issue. Answer: We now refers to Fagerli and Aas instead.

Reviewer: P.1595. I find it hard to believe that an ammonia emission inventory can be accurate to within 5-10%, or farm/field level uncertainties kept within 25-35%. There are usually significant difficulties associated with estimating NH<sub>3</sub> emissions, have these all been overcome in Denmark? No references are given for these assertions. Answer: Denmark has a strict environmental regulation. Every year updated nitrogen excretion rates are compiled for all animal species within different age classes. The normative figures give furthermore guidelines for the ammonia loss for different housing types. These normative figures are based on actual feeding plans and efficacy controls at farm level. The Danish farmers have a very high education and efficacy level giving that almost all farmers are making these plans. The normative figures are collected among the farmers by the extension service. In total data from approximately 15-20% of the cattle herd is included in the normative figures and for pigs it is 25-30%. For poultry and fur animals it is even higher because they get their feed from factories. The standard deviation in the feed consumption between the farmers is +- 20-25% and we do not expect any larger differences between the animals. The number of animals on each farm is taken from the Central Husbandry Register at the 31. Dec of that year. There is public access to these numbers (www.glr-chr.dk). The database is updated

daily. For ruminants, the number is exact due to the single registration of ruminants and for pigs and poultry the error is small too as the farmers shall make a nitrogen accounting where the N-excretion is estimated either based on the normative figures or on actual farm data combined with the actual housing type. The nitrogen accounting from each farmers is public available ([www.pdir.dk](http://www.pdir.dk)). As the farmers are fined if there are errors in their accounting (due to EU cross compliance), the difference between the number in the CHR and the actual number is very likely small.

In 2007 we did not have access to the precise housing conditions on farm level (slats, solid floor, etc.). Therefore the emission factor on farm level is based on the total emission from each animal subcategory (dairy cows, beef cows, heifers etc.) in the Danish ammonia inventory, divided by the number of animals in that category. The distribution in the housing types at the national level is known very well, so here the error is relatively small, especially where the same housing type is dominant within an animal group. From 2009 we have access to the housing type on farm level from the nitrogen accounting system combined with the farmer's correction of Nex to the actual feeding level on that farm. This is expected to improve the precision further.

As pointed out by the reviewer references to work describing the emission inventory are missing. We have now included references to reports to UNECE where also the uncertainty related to the different components of the NH<sub>3</sub> emission are described in more detail.

In the discussion of why the models in DAMOS in general overestimates the NH<sub>3</sub> concentration at the Danish sites we have also extended the part on uncertainties related to emissions to:

“- an overestimation of the national ammonia emissions. As described in Section 2.2 the inventory for Denmark is based on a number of detailed activity data and highest uncertainty is assumed to be connected to the applied emission factors. A recent study indicates that the emission from agricultural fields might be overestimated in current

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inventories, but also concludes that new systematic measuring campaigns are needed in order to lower the uncertainty (Sintermann et al., 2011).”

Reviewer: P.1597. The word "validated" is anyway controversial, and here wrong. No model can be properly evaluated, let alone validated, against just one site. Answer: We acknowledge that the use of the term “validate” can be problematic. We have therefore changed the text to: “This version of the model has e.g. been tested in connection with a measuring campaign around a poultry farm in Denmark. . . . .”

Reviewer: P.1597. Does OM-DEEP have wet-deposition? If not, how does this affect the comparison? Answer: Wet deposition of ammonia is not included in OML-DEP. We have now included this information in Section 2.3.2. Seen as an average over time it only rains ca. 5% of the time in Denmark. So it is fair to assume that only a very small part of the locally emitted NH<sub>3</sub> is removed within the 16 km x 16 km model domain. In the comparison we focus on the concentration of NH<sub>3</sub> as simulated by the two models. When we use the coupled system DAMOS to estimate the total N deposition we include wet deposition of NH<sub>3</sub> as simulated by DEHM.

Reviewer: Fig. 9. This figure is said to be shown in Hertel et al. 2012. Why? The authors should decide whose paper it fits into best, rather than publishing the same material twice. Answer: Based on comments from the second reviewer we have now modified this figure, so that the model estimate includes uncertainty interval. Hence, the plot now includes extra information compared to the Hertel et al. 2012 paper. The plot illustrates how the DAMOS system can be used in relation to management and Natura 2000 areas and we therefore think it is appropriate to include this extended version of the figure in the manuscript.

Reviewer: English, etc. P.1588, line 24 and elsewhere. Use 1990s, not 1990ties

P.1589, line 11 deals can be singular P.1589, line 12 omit "the" management P.1591, line 12. The paper by Dore et al. in the same special issue is also relevant in this context, although Lagrangian rather than Eulerian. P.1596, spelling "DEMH", "Shults"

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Table 3: The use of m:, bias:, r: prefixes is not helpful. Add another header line with this information. Table 4. The units should be as kg (N), no need for NH<sub>3</sub>-N. Fig. 5. Mention also Table 3, where the statistics associated with this Figure are given. Fig. 7, "give at" should be given at. Answer: all the suggested corrections have been made.

Reviewer: In general, the Figures were very small and captions hard to read. This may be a result of the ACPD formatting, but in the final version the authors should make sure these figures are readable. Answer: We agree with the reviewer and will if necessary increase the size of the figures for the final version of the paper.

Reviewer: References Flechard, C. R., Nemitz, E., Smith, R. I., Fowler, D., Vermeulen, A. T., Bleeker, A., Erisman, J. W., Simpson, D., Zhang, L., Tang, Y. S. & Sutton, M. A. Dry deposition of reactive nitrogen to European ecosystems: a comparison of inferential models across the NitroEurope network Atmos. Chem. Physics, 2011, 11, 2703-2728 Answer: This reference have been included now. We also include a more detailed description of the results from this paper in a discussion of the uncertainties related to modelling of dry deposition (as asked for by the other reviewer).

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Interactive comment on Biogeosciences Discuss., 9, 1587, 2012.

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