

## ***Interactive comment on* “The effect of climate and climate change on ammonia emissions in Europe” by C. A. Skjøth and C. Geels**

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Received and published: 3 December 2012

We are pleased that reviewer 2 considers the manuscript to be of relevance to ACP. We have addressed the specific comments raised by reviewer 2. Furthermore, the ACPD manuscript has been proof-read by a fellow scientist with English as mother tongue. Below we have answered each of the questions by reviewer 2 and also provided a full list of changes due to both the proof reading and the requests from reviewer 1. This full list is available below the reply to reviewer 1, but can also be obtained as a separate document if this is needed.

Note that we are having technical problems in the upload of pdf-files in the reply to reviewer 2. Currently the system does not accept our pdf files. The reply to reviewer 2 is therefore below this message and as a result the reply has a different format than

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the reply to reviewer 1. The full list of corrections can be found in the pdf-file in the reply to reviewer 1.

Highly regards Carsten Ambelas Skjøth and Camilla Geels

REPLY TO REVIEWER 2:

General comments from reviewer 2:

This is a nice paper clearly highlighting the importance taking the climate and meteorological conditions into account when estimating and reporting NH<sub>3</sub> emissions. It is also quantitative thereby bridging the gap between "knowing that it should be taken into account to How that could be done". I favor publications but have several remarks/demands for improvement and correction.

Specific comment from reviewer 2:

The policy relevance could be stressed more clearly. In fact not only relevance, it will also complicate policies as the climate dependence of the emissions will remove the "level playing field" in Europe for NH<sub>3</sub> emissions. Still, this is reality and should be discussed – if ignored that should be a deliberate policy choice, not hidden. Or the other way around, warm countries could be allowed to emit more NH<sub>3</sub> per animal unit? This should not be solved in the paper but in the discussion should be at least be mentioned what the impact might be on the EU NEC directive and that harmonizing such an adjusted emission reporting with the NEC is not trivial (as agriculture is by far dominating NH<sub>3</sub> emissions in Europe).

Answer to the specific comment from reviewer 2:

We agree that estimated impact of variations in meteorology and climate on NH<sub>3</sub> emissions is relevant in relation to European policy on emissions. This has not been stated clearly in the manuscript. We therefore now include the following new paragraph in the section, 4.1 line 16, page 23414: "In Europe the emission of NH<sub>3</sub> is regulated through the National Emission Ceiling directive (NEC 2001/81/EC), where the countries have

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agreed on legally binding emissions ceilings to be met in 2010. An evaluation made by the European Environment Agency in 2012 (Acid News 2012, No 1, March 2012) show that only two countries fail to meet the NH<sub>3</sub> directive limits. It is, however, expected that the current review of the EU policy will lead to stricter emissions ceilings in the future in order to improve the protection of the human health as well as the environment. For the evaluation of such international agreements a harmonized emission reporting from the countries is crucial and the climate dependent uncertainty described in this paper complicates the evaluation of the NH<sub>3</sub> ceiling. Furthermore the fact that a given agricultural activity will lead to larger emission in a warmer country or year than in a colder country/year, in spite of using identical production methods, could lead to a discussion on the fairness of the used approach with emissions ceilings. Our results indicate for example that the emissions from our test storage in 2010 in North-western Europe were lower than in 2007. Thereby it would be easier for countries in this region to meet the ceiling for 2010. “

Specific comment from reviewer 2:

The MS should be checked for English spelling, especially the verbs. Often plural is used when should be singular or the other way around. Example line 11 abstract "vary" should be "varies" (although this reviewer would prefer there "would vary", Sometimes "-ing" is used where the verb should be active. Example line 5 Abstract "investigating" should be "investigate". It is advised to give the MS a read-over by a colleague or editor not on content but on this issue. Related to this is the very frequently used word "here" and "then" where it is often not necessary . Example first line of the abstract or line 11 of the introduction. Important note: I have reviewed - and made my notes in - the original manuscript as submitted to ACP, this means my line numbers and page numbers correspond to that pdf, it had a much longer abstract - which is improved now . My page & line nr. are not in line with the online version. However, it takes me too much time find the corresponding numbers in the new version. I'm afraid the authors may have to puzzle a bit. I did review the new abstract (see end).

Answer to the specific comment from reviewer 2:

The manuscript has been proof read by a native English speaking scientist. We will include the suggested changes to the abstract.

Specific comment from reviewer 2:

Throughout the MS the authors find it necessary to explicitly list if a citation is from "Nature" or a similar journal. This reviewer is against this, it is unnecessary and suggests that because it is published in e.g. Nature cannot be wrong. It is enough for any scientist to look in the ref list and values that work as seen fit. For example p. 3, l 4: " although the Nature commentary by Sutton et al. (2011b) highlights the high uncertainty on health effects that are related to ammonia emissions. " should be : "although Sutton et al. (2011b) highlight s the high uncertainty on of health effects that are related to ammonia emissions. " : Please change all these references including the journal name accordingly.

Answer to the specific comment from reviewer 2:

We have removed this type of referencing. We have provided a full list of the changes in the reply to reviewer 1.

Specific comment from reviewer 2:

p3, l 28: These gridded emission inventories are often based on national reported emissions - not on emission factors. Of course emission factors are used by national agencies but they do not go directly into the grid.

Answer to the specific comment from reviewer 2:

According to the emission reporting guidebook, then each country is supposed to use activity data (e.g. animal numbers, manure application, application of mineral fertilizer, grazing animals, etc), which is then multiplied with a country specific emission factor in a similar methodology as given in Appendix B in Gyldenkærne et al (2005). As such

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most countries that deliver gridded inventories within the CLRTAP reporting mechanism, use animal numbers that are gridded but emission factors than are not gridded. To make this more clear we have therefore changed the text on page 23406, line 20 from:

“These gridded emission inventories are often based on national emission factors”

into:

“These gridded emission inventories are often based on national emission factors combined with gridded activity data like e.g. animal numbers .”

Specific comment from reviewer 2:

p6, l 20: Please be a bit more specific: at what resolution? using what distribution proxy? (land use? animal numbers?) or simply splitting EMEP cells?’

Answer to the specific comment from reviewer 2:

The emission model also use an inventory of gridded NH<sub>3</sub> emissions (e.g. EMEP, EDGAR or national inventories), in combinations with information on agricultural activities. On European scale the inventory is based on a redistribution of the officially reported EMEP emissions and national numbers for a distribution of agricultural activities that contributes to the overall ammonia emission load. These numbers are obtained from Table 2 in Skjøth et al. (2011) to provide a gridded estimate for all 15 source categories. Change to: “The emission model also use an inventory of gridded NH<sub>3</sub> emissions (e.g. EMEP, EDGAR or national inventories), in combinations with information on agricultural activities. In the current setup the officially reported EMEP emissions on 50 km x 50 km grid resolution have been redistributed directly into the applied model domain with a resolution of ca. 16.67 km x 16.67 km. Afterwards the gridded totals have been divided into different agricultural categories that are present in the emission model. This distribution is obtained from Table 2 in Skjøth et al. (2011) as it provides the national split between the different categories. The final result is a

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gridded estimate for all 15 source categories.

Specific comment from reviewer 2:

Results p7 l24-30 (Fig. 2 shows, not show). More important, I would like to see this more clearly explained. If I understand correctly for every grid cell you calculate what the NH3 emission would be for a pig stable similar to the standard as in Tange. If that is correct than it is confusing to actually place / mark Tange in the maps, it is irrelevant. At first I thought the maps showed the distribution of emission coming from Tange as it was marked so prominently.

Answer to the specific comment from reviewer 2:

The reviewer has understood the results very precisely. Based on the recommendation we have therefore removed the Tange point on the maps. We have also changed the sentence, page 23411, line 11-12 from “Figure 2 show maps of gridded annual emission of NH3 from storage facilities for the years 2007 and 2010.” Into “Figure 2 shows maps of gridded annual emission of NH3 from our test storage facility for the years 2007 and 2010 if it was placed at any location in the model domain exposed to the local meteorology during the study years.”

Specific comment from reviewer 2:

p 8, l10 replace a difference with "range" Table 1. I have a fundamental problem with this table (and possibly how some of it is used in the paper). Given the range you present for small e.g. mountainous countries like Switzerland, Austria - I suspect that the methodology is applied everywhere but surely no pig stable with 1000 pigs is located high in the mountains (inaccessible, very cold). This creates a completely artificial range in the emission variation. If my impression is correct I would ask for some sort exclusion of unlikely altitudes or ecosystems because the created range is unrealistic. This would probably also change the lower boundaries of France and Germany? Later on you state that the biggest range is found for big countries - based on Table 1,

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I don't agree Austria, Switzerland show equal ranges and of course on a much smaller land area.....

Answer to the specific comment from reviewer 2:

The reviewer has pointed out a practical problem with the setup we have used. It is correct, that since many mountainous regions are not used by agriculture, we should not include the regions without any agriculture in the analysis. We have therefore analysed the recent Corine Land Cover 2006 with respect to this problem. Here we have identified 3 grid cells in Austria/Switzerland that does not contain agriculture and 59 grid cells in Norway. The issue here is that nearly all of the 16x16km grid cells contain valleys in the alpine region that contains either agricultural or urban land (see attached figure). To some degree this also highlights the importance of having a high grid resolution in mountain areas if models take into account climate dependency and meteorology in the emission calculation. In fact, a large number of grid cells would have been without agricultural land if we have applied a model grid with a similar resolution (5km x 5 km) as the one the nested DEHM model use over Denmark within the DAMOS system. This is also the reason why the COSMO-ART system that use used to forecast bioaerosols over Switzerland use a model grid of about 7km x 7km (Vogel et al., 2008). We have therefore updated Table 2 to take this into account and following to the results section by changing line 10-11 on page 23412 from

“In Table 1 the maximum and minimum emission rates within the countries are given for the warm years 2007, 2047 and 2087.” Into “In Table 1 the maximum and minimum emission rates within the countries are given for the warm years 2007, 2047 and 2087, where we have excluded those grid cells in the Alpine region that does not contain built-up and agricultural land by using the Corine Land Cover data set.” And we have also added following to page 23412, line 22: “Note that especially the minimim numbers in the mountain areas such as the Alpine region are highly dependendt on the grid resolution of the meteorological data set.” And added following to page 23413, line 17: “Furthermore, mountain areas such as the alpine region also show large variations.

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Here it should be noted, that this area is particular sensitive to the meteorological data set and that the chose grid resolution might be to coarse for an accurate assesment in that region.” And following to table 1: “Note that minimum numbers for Austria, Italy and Switzerland should be treated with caution due to the dependency of the meteorological data set that were used in the calculations.”

Specific comment from reviewer 2:

discussion p9. 23-26. not taking climate fully into account... That is correct but based on my previous comment - are the authors exaggerating it by taking unlikely places (like mountain regions) into account? If correcting this would reduce the range, that would not make the paper and the outcome less valuable - the range is big enough. In this same section a reference to the NEC (national emission ceiling) directive could be made. The NEC for NH<sub>3</sub> is dominated by agriculture and is an absolute ceiling. If in the target year 2010, the temperatures in several countries would be above average – these countries may exceed their ceiling. Is that fair? or should based on the methodology for e.g. NEC purposes a correction to a meteorological average year be made? Some discussion on this aspect would be useful.

Answer to the specific comment from reviewer 2:

Based on a new map and a new table excluding the mountainous regions this discussion has been updated. Regarding the NEC directive, we have as mentioned above included a discussion on this issue now.

Specific comment from reviewer 2:

p.12, l31 "although several Nature papers have stated" - please give real references and remove the journal. Also in the conclusions - the above discussion on impacts on the NEC directive and level playing field in Europe should come back even if just very briefly. If we make European rules for air pollution should Denmark than have (proportionally) more pigs than Spain just because the temperature is lower and les

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NH3 is emitted?

Answer to the specific comment from reviewer 2:

We have included the relevant references here. We also agree on the relevance for emission policy here and have included some extra text on this in the conclusion:

“Therefore evaluations of future abatement strategies for ammonia need to take the possible effect of a general temperature changes into account as well as the associated cascade of effects in the nitrogen cycle, which is initiated with the emission.”

Changed to

“In relation to the NEC directive and a new emission ceiling for ammonia is should for example be evaluated if the use of a specific target year is desirable. If the target year (currently 2010) is a year with above/below average temperatures in a given region it will be harder/easier to meet the ceiling. In a future climate with a general warming trend and potentially more frequent extreme years this issue will be even more relevant. The analysis and subsequent negotiations leading to a revised NEC directive should somehow include the climate sensitivity of NH3 emissions”

Minor remarks from reviewer 2:

Minor remarks introduction, (can be shorter, quite some repetition) p2, l25 "here" should be removed p2 l31: "source to emissions of ammonia" -change to "source of ammonia emissions" p3 l29 remove "then" p4 l 6-11 this has been mentioned before methodology p5, l6: both the p5 l14 remove : "has in this study" Note that throughout the paper there are more of this kind of not wrong but unnecessary additions - it is too time consuming to type them all here. However removing them makes the text more direct. p6 l14 : the ... model uses not use - see earlier remark about the verbs p13, l17 remove "of" C7576 p13, l31 Pouliot

Answer to the specific comment from reviewer 2:

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We have corrected the identified technical errors including the technical corrections in the abstract that are available in the supplement (<http://www.atmos-chem-phys-discuss.net/12/C7573/2012/acpd-12-C7573-2012-supplement.pdf> )

## REFERENCES

Gyldenkærne, S., Ambelas Skjøth, C., Hertel, O., and Ellermann, T., 2005, A dynamical ammonia emission parameterization for use in air pollution models: J. Geophys. Res. , [Atmos. ], 110, 1-14.

Vogel, H., Pauling, A., and Vogel, B., 2008, Numerical simulation of birch pollen dispersion with an operational weather forecast system: Int. J. Biometeorol., 52, 805-814.

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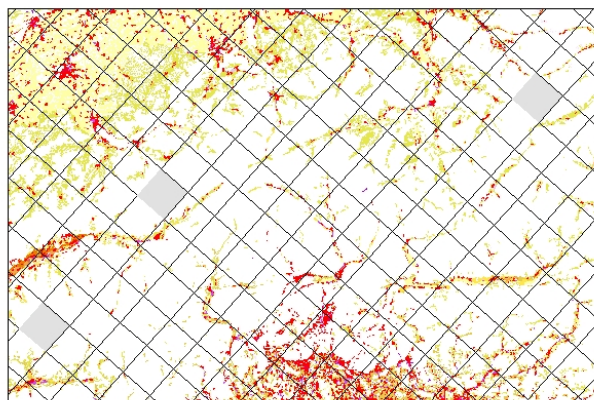
Interactive comment on Atmos. Chem. Phys. Discuss., 12, 23403, 2012.

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DEHM grid cells

agricultural areas or artificial surfaces
  non-agricultural areas (forests, bogs, glaciers, water areas etc)

Corine Land Cover 2006 ID codes and location

111	124	142	222	243	321	332	412	512	990
112	131	211	223	244	322	333	421	521	995
121	132	212	231	311	323	334	422	522	
122	133	213	241	312	324	335	423	523	
123	141	221	242	313	331	411	511	999	

**Fig. 1.** Figure 1. Grid cells used by the DEHM model, the MM5 model and the emission model in combination with areas that are available for agricultural production in the alpine region. Grey cells does not con

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