

## ***Interactive comment on “Projected change in atmospheric nitrogen deposition to the Baltic Sea towards 2020” by C. Geels et al.***

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Projected change in atmospheric nitrogen deposition to the Baltic Sea towards 2020  
by C. Geels et al.

Answer to anonymous Referee #1:

General comment: This manuscript describes the results of a modeling exercise where the effect of the new stricter European legislation on national emission ceilings on nitrogen deposition to the Baltic Sea is studied. The main research instrument is the well documented Danish DEHM atmospheric dispersion model which has been widely used in air pollution studies. The manuscript is quite straightforward and the work as well as the results are presented in an efficient manner. The chosen strategy involves

C12016

the identification of a “representative” meteorological year during the period 1995–2004 whose meteorological data is then used to drive the model, first with the emissions of 2007 and then with the projected emissions in 2020. The contributions to the deposition load from the countries bordering the Baltic Sea and from shipping is assessed by using tagging techniques. Although some questions arise about their chosen approach, the authors argue their case rather well, and I also appreciate their discussion (in Chapter 2.4) on the uncertainties brought about by this approach (however, see also below). While this study considers the future nitrogen deposition caused by changes in anthropogenic emissions alone, it is my belief that also this type of simplistic model applications are needed, and may turn out to be valuable contributions to the evaluation of the effects of proposed environmental policies.

Reply: We appreciate the positive words about the manuscript and that reviewer #1 concludes that the study can be a valuable contribution to the evaluation of proposed policies. We are also thankful for the comments to the applied setup and the constructive suggestions to changes. Below we address each of the questions raised by the reviewer and describe the according changes we have made to the manuscript.

Specific comments: Introduction in general: References need to be included in several places where the authors discuss the atmospheric fate (chemistry, transformation, lifetimes, incorporation into aerosol, deposition etc.) of the nitrogen compounds. As it is now, the authors make specific claims and present several details which cannot be considered common knowledge.

Reply – we have now added a number of references in the text to support these statements

Please, be systematic in the introduction of the chemical compounds by their common names before using the chemical formulas to represent them (e.g. NO<sub>x</sub> and NH<sub>3</sub> are used on p. 21535, line 19 while NO<sub>x</sub> is introduced on p. 21535, line 24 and NH<sub>3</sub> seems not to be introduced at all).

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Reply: true, in line 19 we have now added this information.

Please, avoid using terms such as “N compounds” or “N components” instead of nitrogen compounds or nitrogen components (you might also keep in mind that you define N as “reactive nitrogen” on p. 21536, line 6-7). This comment also concerns the text of the manuscript in other places.

Reply – we have now rephrased this.

P. 21534, line 23: “(Krishnamurthy et al. (2010) and references herein)” – “herein” should probably be replaced with “therein”? Reply: True, we have now changed that.

P. 21536, line 17: The last sentence of this paragraph is confusing. Please, spell out the “etc.” at the end and maybe also consider rephrasing.

Reply: we agree that this is not very easy to understand this sentence. We have therefore rephrased the sentence:

FROM: This means that a comprehensive budget of atmospheric N depositions to the Baltic Sea must include a very large geographical area, high quality emission inventories, including projections for future development, chemical transformation, removal processes etc.

TO: This means that a comprehensive budget of atmospheric nitrogen depositions to the Baltic Sea must include at least the following four components: 1) a very large geographical area, 2) high quality emission inventories including projections for future development, 3) chemical transformation, 4) removal processes.

P. 21536, line 21: What does “Such” refer to?

Reply: We agree that this is not clear and we have reformulated the text:

FROM: Such future scenarios are most efficiently studied using state-of-the-art atmospheric chemistry transport models (CTM).

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TO: Projected budgets of nitrogen depositions are most efficiently studied using state-of-the-art atmospheric chemistry transport models (CTM).

P. 21536, line 28: The first sentence of the chapter starting here seems to state that the aim of this work was to study the deposition for 2010 “as well as” the deposition from the present day emissions (2007). I would rather suggest emphasizing that your aim was to study the changes in the deposition if the new emission ceilings are adopted.

Reply: We follow the suggestion from the reviewer and have reformulated the text:

FROM: The aim of this study is to investigate the nitrogen deposition from projected emissions for 2020 following the draft to a new National Emission Ceilings (NEC) directive as well as from the emissions for present day conditions (2007). We use the Danish Eulerian Hemispheric Model (DEHM) to calculate the change in nitrogen deposition to the Baltic Sea towards 2020.

TO: The aim of this study is to investigate the changes in nitrogen deposition if the new National Emission Ceilings (NEC) directive for 2020 is adopted. We use the results from the Danish Eulerian Hemispheric Model (DEHM) to calculate these changes in nitrogen deposition to the Baltic Sea from present situation (2007) to the year 2020.

P. 21536, line 29: Here the abbreviation (NEC) is used while in other contexts the new legislation is referred to as NEC-II. Maybe this is intentional for some reason? However, it seems a bit confusing.

Reply: We have throughout the paper made changes so that there is now referred to NEC-II only.

P. 21537, line 1: I also don't like the statement that the DEHM model was used to calculate the change in the deposition – I would suppose that the model calculates the deposition(s) and the changes are inferred afterwards by comparing the model results for the different years.

Reply: We agree, see the changes at the text above.

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P. 21538: Several chemical formulas and/or abbreviations are used without proper introduction.

Reply – all species and abbreviations are now explained the first time they appear in the text

P. 21538: line 25: According to this last sentence of this paragraph several particle size classes were used in the model calculations. Are particle densities a factor in the deposition calculations and what densities were used? Reply: Yes particle density is included in the parameterisation of the dry deposition. We have included this information in the text now:

FROM: For the particles, dry deposition velocities are calculated for sulphate (SO<sub>4</sub><sup>2-</sup>), organic and inorganic NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup> and primary PM<sub>2.5</sub> assuming a particle diameter of 1 micro m, for ANIT, PM<sub>10</sub> and sea salt assuming a particle diameter of 6 micro m and for TSP assuming a particle diameter of 15 micro m.

TO: For the particles, dry deposition velocities are calculated for sulphate (SO<sub>4</sub><sup>2-</sup>), organic and inorganic NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup> and primary PM<sub>2.5</sub> assuming a particle diameter of 1 micro m. For ANIT, PM<sub>10</sub> and sea salt a particle diameter of 6 micro m are assumed while for TSP a particle diameter of 15 micro m is used. A density of 1800 kg/m<sup>3</sup> is used for all particles.

P. 21539: The resistance analogy method for the calculation of the deposition velocities of both gases and particles is described in one longish paragraph. The description is awkward to read, and the inclusion of the symbols for the various terms of the mathematical formulation only confuses the reader, as not a single equation is shown. Since deposition velocities are probably the most important detail in the model calculations of the deposition, it might be a good idea to present this in a more structured way: clearly separating the gases and the particles and including at least the most basic equations if their terms are discussed using the symbols.

C12020

Reply – the reviewer is of course completely right and we have accordingly removed the symbols from the text as these were only confusing for the reader. We have also tried to structure the text, so that it is easier to read.

P. 21541, line 3: In the last sentence a claim is made about the better accuracy of the tagging method compared to another. Are there any references for backing up this argument?

Reply: We have extended the text about tagging in order to include such references.

FROM: The tagging method gives a more accurate estimate of the contribution from the tagged emissions compared to the common applied method, where two different model run are subtracted in order to obtain the signal.

TO: Tagging methods have also been used in other recent CTM studies (e.g. (Fisher et al., 2010; Wu et al., 2011) as the method gives a more accurate estimate of the contribution from the tagged emissions compared to the common applied method, where two different model run are subtracted in order to obtain the signal (Brandt et al., 2011a).

Chapters 2.2 and 2.3: The “reference meteorological year” was not identified via the analysis of the meteorological parameters over the chosen period (1995-2004) and picking the most average or representative year with respect to them, as one might expect. Instead, the most representative “deposition year” was identified, using the 2007 emissions and the actual meteorologies during the 10-year period as the basis of the selection. Would the end result have been the same (i.e. year 1998) if the reference year had been chosen simply as the average “meteorological year” based on meteorology alone and if not, how would it affect the modeling results? In addition, understanding the reasoning behind this basic decision is complicated by the fact that it is not clear from the text which average of the full 10-year period is meant on p. 21541, line 17, the actual average deposition during 1995-2004 or the average from the runs with the 2007 emissions? The same applies to the statement on p. 21541, line 18, of the +/-17% variability in deposition – it is not clear from the text if what is meant

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is the variability of actual deposition or the variability of the 10-year simulations with 2007 emissions. What is the logic behind the selection of 1995-2004 for meteorology and then the “reference emission year” 2007 outside of this chosen meteorological averaging period? Furthermore, if the purpose of selecting a reference meteorological year was simply to reduce the number of required model runs, was it ever considered to pick a set of years to make the present day calculations with actual meteorologies and realized emissions? An obvious choice would have been the years 1997, 1999, 2000, and 2003 and averages based on them, as they correspond to the years of the Baseline Scenario of the Clean Air for Europe (CAFÉ) Programme.

Reply: The period 1995-2004 was originally chosen as it covers the reference period of BASP. Afterwards we found out that the official EMEP emissions from this period had been updated, while the expert emissions applied for model studies had not been updated. We therefore decided to use the most updated emissions data set (2007) where we know that the official and expert emissions agree. As our study is focused on the projected difference in N deposition due to changes in emissions from present day (2007) to 2020 the applied meteorology year is less important (we also do not use projected changes in meteorology). However, in order to analyse the year to year difference in N dep. due to meteorology alone and in order not to use a very extreme year we have chosen this method. We did consider running the model for several years as suggested by the reviewer, but since we here include tagged model runs for each of the countries around the Baltic as well as for Ship traffic for both current day and future emissions, we had to limit the study to one year. For this year we made 22 different model runs.

Due to the chosen method we agree that what we use is not a true “reference meteorological year” - we have changed the text so that we now use the term “reference deposition year” as suggested. To our opinion it would be very difficult to find a true “reference meteorological year” as there are so many meteorological components that should be included in the analysis. As we focus on the N deposition we believe that

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this is a valid method to use.

We have tried to make all this easier to understand by extending the text on p. 21541, line 17 and forward:

FROM: “As an alternative, we have made a 10-year model simulation with the same emissions applied for all years and identified the year where the nitrogen deposition to the Baltic is closest to the average for the full 10-year period. Within the period 1995-2004 the deposition varies by +/- 17% from year to year.”

TO: “As an alternative, we have made a 10-year model simulation with the same emissions applied for all years. Based on this we have calculated the average nitrogen deposition to the Baltic Sea and analysed the variations around this mean due year to year changes in meteorology alone. Finally we identified the year where the nitrogen deposition to the Baltic is closest to the average for the full 10-year simulation. The analysis also showed that within the period 1995-2004 the deposition varies by +/- 17% from year to year due to meteorology alone.”

P. 21553, line 5: The point of the sentence (“This supports that: :”) beginning on this line escapes me.

Reply: We agree that this sentence is not well formulated, so we have rephrased it to make it clearer:

FROM: This supports that the development in atmospheric input of N to the Baltic Sea and the projected deposition reductions from individual countries as described in the current study are taken into consideration in future updates of the Baltic Sea Action Plan.

TO: The current study demonstrates that future updates of the Baltic Sea Action Plan need to include two levels of detail: 1) development in overall atmospheric input of nitrogen and 2) the projected deposition reductions from individual countries.

P. 21553, line 10: I find the sentence (“It is therefore necessary to include: :”) some-

C12023

what contradictory with the approach chosen in this study since, unless I have misunderstood the previous chapters, actual multi-year deposition time series were not used as the 10-year simulation was carried out using emissions of 2007 only.

Reply: The first step in this study has been to run the model with constant emissions and meteorological data for the ten year period 1995-2004. Based on this we have 1) analysed the variability in the deposition to the Baltic Sea due to year to year variation in meteorology and 2) found the year were (1998) the yearly deposition is closest to the average 10-year deposition. For the next series of model runs we have then applied 1998 as a “standard” meteorological year So the sentence the reviewer is referring to: “It is therefore necessary to include multi-year deposition time series or analyses to find a representative meteorological year (like in this study) when e.g. the effect of reduction plans is to be evaluated.” Simply refers to these analyses of the impact of meteorology alone that we have made.

Referencing: The status of some central references is “in preparation” or “submitted” which makes it somewhat cumbersome to evaluate the manuscript properly. Hopefully this situation is improved at the time of the publication of the paper. Reply: We will update this information in the final version of the paper.

Table 3: It is stated that the changes in N emissions (rightmost column) are taken from Table 1. However, this cannot be the case as Table 1 does not have any decimals, but obviously the origin of both sets of numbers is the same. One wonders if the percentual changes in Table 3 could be given as integers also?

Reply: We agree that in order to be consistent the numbers in table 3 should also be integers, so we have changed the table.

Table 4: The “N input reduction” in the caption should be N emission reduction.

Figures in general: I would suggest including, as the first figure, a map of the Baltic Sea with the bordering countries (preferably entire countries, not just some fragments)

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as well as other discussed areas and basins clearly identified. Latitude and longitude information would also be advisable. While there is a map of the area included in the Supplement, it would improve the reading experience of this article if one was spared from bouncing back and forth between two separate documents for central information like this. Furthermore, the map in the Supplement is smudgy, with some important countries (Germany, Denmark) not even identified. The scale of the map also seems a bit weird (0-407 kilometers ?!) and the (obviously) web graphics quality is much inferior to what should be expected from graphics in print versions of scientific articles.

Reply: We agree and have now included two new maps. An overview map is now included as Fig. 1 and a more detailed map is included in the Supplement.

Figure 1: What are the deposition velocities “appropriate” for land and water surfaces? Could they be explained in the text in 2.4? Note the typo in the second “appropriate”, on the last line of the caption.

Reply – this is now rephrased in the figure caption to dry deposition velocities for the specific land surface type and dry deposition velocities for water.

Figures 2 and 3: Please, replace “Simulated total deposition” with “Simulated total annual deposition” in the captions. Should “commen” be spelled common? The figures are too small - both at the web site and especially in the “printer-friendly” version. The legends are illegible, but appear to be the same in both panels of each figure and thus only one legend should be enough per figure.

Reply: We have made the suggested changes to the captions and the figures have been made larger.

Figure 4: Why must the pies be 3D as this causes a visual effect that distorts the contributions from the countries on the front and far sides of the cake? I would suggest using 2D-pies, with the same order of countries on both years. Then also the colors of the countries would remain the same from pie to pie and be easier to compare visually.

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Reply: We have followed the suggestions by the reviewer and now include 2D pies with the same colour for each country. Part of the caption has been changes:

FROM: Note that the order of the top-four contributing countries change from 2007 to 2020 (see the legend).

TO: Each contributing country has the came colour in the two pies.

Supplement: Figure S1: I was not able to locate this figure in the address [www.helcom.fi](http://www.helcom.fi). See also the comment on figures in general above. Tables S2-S5: "Aaland Sea" should be replaced by the proper name, Sea of Åland – or at least by Åland Sea which is used in the map.

Reply: As described above, two new maps are now included. We have also corrected the name in Tables S2-S5.

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