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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Contributions of Nordic anthropogenic emissions on air pollution and premature mortality over the Nordic region and the Arctic" *by* Ulas Im et al.

Anonymous Referee #3

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In this modelling study, PM and O3 exposure and associated premature mortalities in the Nordic countries have been attributed to anthropogenic emission sources (sectors) in each of the countries. The attribution is based on the tagging methodology which is more accurate than linearized source-receptor relations, commonly used under conditions of limited CPU resources.

General comments:

The material obtained from the modelling is potentially relevant, however my feeling is that the results are not optimally evaluated and presented, and too much attention is given to less relevant issues. In my opinion, the major conclusion of this study is

that 80-85% percent of the air pollution impacts in the Nordic countries are coming from sources outside that region. This observation is reported in the abstract and in the conclusions, however without giving any further consideration on the (policy) relevance of this finding. It basically means that national air quality measures in the Nordic country apparently barely can contribute to improving air quality. Given this outcome, one can wonder what is the relevance of making a detailed discussion of individual other Nordic countries contributions by sector to PM2.5 in the receptor country (i.e. attribution by country and by sector of the tiny orange part in the bar graphs of Fig. 4). Based on Figure 4, the key question is: which source regions and sectors are then contributing to the gray portion of the stacked bars? Hence, if the aim of the study is "to identify emission sectors that should be targeted for mitigation to decrease air pollution levels in the Nordic countries" (L108) the authors have clearly overlooked the major contributing factors. If the authors still want to focus specifically on the Nordic countries' contribution only, this should be better motivated and framed in the introduction. (Besides, I also wonder what is the motivation for a separate health impact assessment for specifically the low-populated Arctic region >67°N).

Specific comments:

1. Throughout the text: use subscript in chemical names and PM2.5

2. L34 – 37 and throughout the paper: please use consistent naming for the sectors in text and figure legends; "non-industrial" and "residential" are interchanged. It is better to use just one consistent name (preferably "residential"). Same for "Agriculture and Waste" and "Others" (preferably use "Agriculture + Waste")

3. L33: '. . .80% of the PM2.5 concentration was attributed to transport from outside. . .'

4. L34-35: If 80% of PM2.5 comes from outside, how can residential combustion (inside the country) be responsible for 60% of total PM2.5 mass?

5. L38 OC is said to be the major contributor. In the main section however nothing

has been mentioned on the chemical mass balance of the PM2.5 in each country, and further ammonium nitrate has never been mentioned. Was this compound considered as a PM2.5 constituent? Earlier studies have suggested that ammonium nitrate is the dominant PM2.5 component in NW Europe (e.g. Lelieveld et al., 2015).

6. L39: if the tagging method was used, the contribution of the residential sector should not be 'suggested' from the chemical composition but result directly from the tagged species & sector?

7. L62: in Sweden originates

8. L66: instead of 'geographic' maybe better use 'spatial'?

9. It is unclear to me how a country contributes to x% of European PM2.5. Do you mean that the European-wide population-weighted PM2.5 concentration (i.e. exposure) contains x% PM2.5 emitted in that country (L77-79)? Please formulate more precisely.

10. L94: Can you be more quantitative on how 'low' air pollution levels are, e.g. relative to WHO target levels? Does 'low' refer to country-area-mean or population exposure? Does this also apply to urban locations?

11. L96-104: not sure if the climate impact of BC is relevant in this context. Define 'SLCFs' (L103)

12. L109 'decrease'

13. DEHM: What is the time resolution of the model output for the pollutants? Are O3 values produced at 1h time steps? Does the model include natural PM components (in particular seasalt)?

14. L151: Actually the large contribution of NH3 in 'Others' is due to Agriculture (only).

15. Figure 1 is difficult to read and would benefit from a different layout (e.g. stacked bar plots, and using a different Y-scale for each component). Alternatively, as the

total values are already given in the table, the plot could show the different relative contributions by sector (stacked bar or pie plots).

16. L165: The tagging method keeps track. . .

17. L167: What do you mean by "background concentrations"? Usually this refers to concentrations in absence of anthropogenic emissions. L168: not clear what is meant by "in parallel". In general this paragraph is rather difficult to understand for those not really confident with the tagging method. Would it be possible to include some mathematical equation(s) that express the basic principle(s)?

18. Model evaluation: L181: these data are not shown in the supplemental material (I presume they are presented in Tale 3 instead). Is the model resolution of 50kmx50km high enough to reproduce urban background concentrations? Does the model include a sub-grid treatment to simulate the urban increment (for PM) or titration decrement (for O3)? Table S1 should include as well station data for PM2.5, SOMO35, SO2 (i.e. all the metrics used for the health impact assessment). The references to data sources for the 4 countries can easily be moved to Table S1 so the section from L184 – L214 can be shortened.

19. Section 2.2 (EVA) could contain some more information on the exposure-response functions and RRs used both for PM and O3. Table S2 should be explained better. ERFs are commonly expressing the relative risk. It is strange to see the exposure-response coefficient expressed as mortalities per concentration unit. There must be an underlying calculation, involving exposed population number and baseline mortalities. Please expand this. Why is SO2 included as a risk but not NO2? WHO (2013, HRAPIE project) recommends PM, O3 and NO2 as major risk factors, but not SO2 and CO. It is not clear if CO was considered here: CO ERF is not mentioned in Table S2, but section 2.2 mentions it is included in EVA.

20. L225: "EVA calculates and uses annual mean. . ." change to: "EVA uses annual mean. . ."

21. Are natural PM components included in the PM2.5 exposure? L235: “full range of anthropogenic concentrations”?

22. L247-248: not clear if the perturbations were done for each individual SNAP sector, or for the combined sectors in case of Industry and Others

23. L253-255: what is the outcome of this comparison between 100% and scaled 30% perturbation?

24. Table 3 should also include the mean values for O3 and PM2.5. What about the model evaluation for SO2 and NOx?

25. Use consistent symbols for the correlation coefficient (either r or R)

26. Do the Taylor diagrams add essential new information to what is given in Table 3? What can be concluded from the diagrams that is not emerging from the table? Is model performance better/worse for specific station type?

27. L270-274: the discussion does not correspond to what is given in Table 3: r is not >0.7 for Norway. If the % overestimation refers to the NME, then for O3 it is rather 20% for Denmark, Finland and Sweden, not 10%. For PM2.5, the R for Norway in the table is 0.35, not 0.7. A relatively good R does not necessarily imply a good model performance: mean biases of the order of -3μg/m^3 are significant as can be seen in the NME (underestimation of 40 to 50% for all countries). Could this be due to a natural component in the measurements that was not considered in the model? What can be concluded from this model evaluation in the context of the further analysis? How robust are the model results?

28. L301: “near de ground surface”: change to “near the surface”

29. L301: ‘Caused by the..” change to “Based on the prevailing . . .”

30. L305 eacvh: each

31. Why does Fig. 4 not include NH4 and NO3? The sum BC+OC+SO4 is much lower

than total PM2.5. What makes up the remaining PM2.5 mass? If NO2 and CO are not used in the impact evaluation why show the values?

32. Why is the same analysis not made for O3 or SOMO35?

33. L307-308: this is a very important observation and raises immediately the question about the sources of this major rest contribution. This observation should not be left undiscussed.

34. Please increase text font in Figures 5 to 7.

35. L324: 7 μg m-3

36. L328: again: what is the contribution of ammonium nitrate?

37. In Section 3.2.1, the text is quite repetitive, basically repeating for each combination of source country x and receptor country z the contribution for each chemical component. How relevant is this separation in components in the context of the formulated scope of this study (i.e. to identify the emission sectors that should be targeted for mitigation)? To answer this question it is more relevant to show for each of the receptor regions how much is being contributed (1) from the country’s own emissions (2) from other Nordic countries (3) from the rest of the world (by difference). I would suggest to move Figs. 5-8 to the supplemental information. Instead, for each relevant exposure metric (PM2.5, O3 and maybe SO2, NO2, CO in the supplemental material), a figure could then be presented for each receptor country (DK, NO, FI, SE), with each bar representing a sector, and within each (stacked) bar a contribution from within the country, from other Nordic countries, and from the rest of the world (and maybe an additional bar for the sum of all sectors) as in attached figure 1 (made up with arbitrary numbers).

38. Similar comment for the Arctic (Fig. 9) where a graph could show the contributions by sector from each Nordic country and the rest of the world. But what is the relevance of considering specifically the >67°N area for health impacts? The contribution from

the Scandinavian countries are very low, also here it would be interesting to see what the major contributors to this receptor region are.

39. Are the concentrations and % shown in Figs 4 – 8 referring to exposure (i.e. population-weighted concentrations) or grid-area-weighted mean? To answer the formulated scientific question it should be exposure. For SE, NO and FI which have large portions of uninhabited area there could be a significant difference between area and population-weighted average.

40. If the graphs are produced as suggested, including PM2.5 and O3, the grid maps Fig 10 and 11 add little new information and they could be omitted (or transferred to the supplemental information)

41. If the grid maps are kept, please adapt the color scale of the O3 grid maps. Use the same range for the 4 maps, and make an upper limit that extends further above zero (now it seems that everything is colored red because the scale is cut off at a too low limit).

42. L405: what do you mean with "...are mainly calculated in the source country itself."

43. L 406 "Zealand region" has no meaning to a readership not familiar with the regional naming details.

44. L405 – 407 ("Danish anthropogenic. . .towards south") I can't follow the reasoning here: titration leads to a -4 to -5% contribution, but also to a +1% increase south? Also, as the scale stops at 0, this cannot be observed in graph 10a.

45. What is the share of O3 and SO2 in the acute mortalities?

46. L469: Given the fact that PM2.5 is the major risk factor in mortalities, why is the contribution of AGR so dominant in DK (compared to the small share in Fig 5)? Is this because the population exposure was taken into account? How is the share of sectors in the mortalities evaluated? By using the same proportion as in the population-weighted PM composition? In table 5 it would be useful to put in brackets which share

in total mortalities in each receptor country the numbers represent - e.g. 422 (13%).

47. L503 – 510: this is no new information because the costs are proportional to the mortalities for which it was already stated which sectors are dominating (L496 - 474). Further, when making recommendations on which sectors to address in order to "substantially reduce the costs of air pollution", the authors seem to have overlooked that 80 - 85% of the pollution health impact is imported from other regions.

48. L566 It is not 50% of total but 50% of premature deaths caused by the Nordic countries (the latter being 16% of total premature mortalities).

49. L579 -578: To my opinion this is the most relevant conclusion of this study. It leaves the reader with the feeling that the less relevant part of the data has been analyzed in too much detail, leaving this essential part untouched. . .

References

Lelieveld, J., Evans, J. S., Fnais, M., Giannadaki, D. and Pozzer, A.: The contribution of outdoor air pollution sources to premature mortality on a global scale, Nature, 525(7569), 367–371, doi:10.1038/nature15371, 2015.

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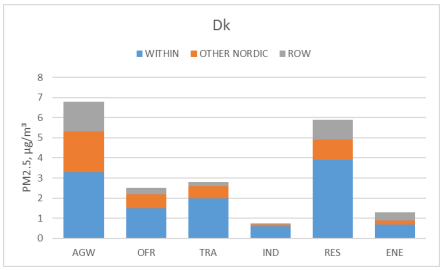

Fig 1 Fictitious example for alternative format for Figs 5 - 8

Fig. 1.