Responses to Reviewer #1

We have written a very long manuscript, so we would first like to thank reviewer #1 for taking the time to review our paper and for giving a lot of very useful criticism on different aspects of the paper. We believe that their comments will lead to a significant improvement in its quality. We have quoted the relevant text from the review (shown in italics) and have responded below each comment in times new roman. In addition, we have prepared a revised manuscript showing the revised text in red.

Major Revisions

First, I suggest an effort to shorten the paper and limit the number of tables and figures for more clarity.

We thank the reviewer for identifying this concern. We have attempted to address this issue in a number of ways:

- First by filtering the entire document to check for material that can be removed.
- Simplifying the style of the writing as much as possible.
- Section 2.4 (previously 2.3) now relies more on Table 3 to present the information and all repetitions are removed between the text and table and all duplicate information has been removed from the text.
- By following the specific comments of the reviewer about Sect. 4.1.3: we have removed this entire section and all of its associated figures.

My second main concern is about the meteorological drive of EPISODE. I understand that the 3D part of EPISODE is a CTM and I think it is necessary to explain how the meteorological inputs are provided to EPISODE and at which temporal frequency. I guess that several options are available. However, Only two are briefly described and one in an obscure way (I don't know what is TAPM).

We thank the reviewer for identifying this problem. Having reviewed the manuscript we completely agree with their comment that the manuscript lacks enough detail on this point. We have therefore modified the manuscript in several locations to correct this problem. The relevant sections in the new document are:

- There is a new section '2.3 Meteorological Inputs' that details the information relevant for the input meteorology.
- Within section 2.3 we have now properly referenced TAPM and also given specific direction to consult Part Two of this paper where TAPM is more thoroughly described and discussed in a specific implementation example.
- Also, in section 2.3, we have now more clearly explained the AROME meteorological fields are available from Met Norway's THREDDS server. We give a clearer link to the supplement that describes these data in detail. In addition, we clearly explain the frequency at which the data are available.
- We also describe the use of the WRF meteorological data.

Third, in my opinion, the assumption of PSS could explain some discrepancies between simulated results and observations. However, this is not discussed except in the last part on future work.

We thank the reviewer for identifying this issue. Although we did try to highlight the limitation of the PSS during summer in Sect 4.1.2 (lines 21-27, page 21) in the original manuscript this was perhaps not made clear enough. We now state this more clearly. Indeed, reviewer #2 has made similar criticisms, and we therefore have drafted a common response to both sets of comments. We have modified the manuscript text in several locations to expand the discussion of the PSS and how it affects our results. The new discussion aims to justify the PSS assumption, yet also highlight its limitations both in the

Nordic context and in other locations. These discussions are in Sect. 4.1.2 (lines 26 onwards, page 20) and in the summary.

Specific Revisions

Introduction

The discussion on LES modelling is very short and lacks from citations and examples of obtained results with such models.

We have now added appropriate description of microscale modelling methods and have provided literature examples discussing LES methods.

Others models using the same concept than EPISODE have been cited but no comparison is done between them and EPISODE. In particular, the originality of EPISODE compared to these previous models should be assessed.

We have now added a sentence explaining that EPISODE was originally developed at a similar point in time (i.e., 1980s) to models following a similar philosophy, e.g., AirGIS, and that therefore at the point of its original inception it was consistent with the state of the art at that time.

Part 2

2.1

I understand that no chemical evolution of PM2.5 and PM10 is implemented in EPIDOSE but I wonder if microphysical processes (coagulation, sedimentation) are taken into account. At which time-step, the meteorological inputs are given to EPISODE?

We are currently at the early stages of implementing sedimentation and below cloud wet scavenging into EPISODE. In order to improve the representation of the physical removal processes, we will also implement size bins to capture the different physical processes affecting the washout of different size modes of particles, e.g., impaction, diffusion, and interception. Although coagulation and other types of particle growth are not currently planned in this round of work, these are processes that we would wish to add in the future. These planned/in-progress developments are now described in the section describing future work.

2.2.1

I understand that horizontal and vertical resolutions are flexible depending on the choice of the user. Could you please give the available range of horizontal resolutions and the typical number of vertical levels?

We have now included a description of the ranges in horizontal and vertical resolution that we typically use in Sect 2.2.1.

Page 7, lines 16-18: the information about topography should be moved page 5 in the first paragraph after 2.2.1 when the vertical grid is detailed.

We have followed this advice and moved the text to the suggested location.

Page 8: equations are hard to read, the font is too small. In equation (2), I guess it is K(z) and not K(z).*

We have increased the font size to 11 pt to make the equations more readable.

Page 9, lines 7-10: could you please explain that the surface roughness is needed to compute the friction velocity?

We have now added this as a note in the description of u*.

In table 2, it is indicated that constant concentration profiles are given as ASCII files while it is mentioned in the text (page 10, line 3) that they have to be specified in the EPISODE run file.

The constant concentration profiles have to be specified in separate ASCII files that are referenced from the runfile. We have now correctly described the text to reflect this.

Page 10, line 13: what are the NBV and BedreByLuft projects?

We have now included a clearer link to the NBV project and have provided a reference to the BedreByLuft project.

Page 10, lines 17-18: it is indicated how the background concentrations are provided to EPISODE in the example presented in part two of the article but not for the one presented in part one.

A discussion of the background data was included in Sect. 3, but we now try to make this clearer. We have now included a short description of how we download the data for the background concentrations in Sect 2.4 as well.

Page 11, line 6: please indicate how J(NO2) is computed, in particular the actinic flux.

We do not calculate the JNO2 values using actinic flux from a radiative transfer model. Rather, here we use a 2-parameter scheme to calculate the photolysis rate. The two parameter scheme is already described within the supplement S2 in equation S2.2b. The value of theta in S2.2b is calculated using time of day, date in the year. In addition, the meteorological input variable, cloud fraction, is also used to adjust JNO2. We have now added a reference to this equation in the supplement and main text. We also describe the future work we have planned to upgrade this calculation of JNO2.

Concerning the PSS via R4, the authors should specify that it is adequate in polluted Nordic wintertime conditions especially during the day. Indeed during the night, the NxOy (including N2O5, NO3 and HNO3) chemistry should be dominated.

We thank the reviewer for identifying this issue. Although we mentioned briefly our intention to consider N2O5 in the future, we did not give this adequate discussion throughout the paper. We have now added in order to clearly state that this is a limitation.

2.2.2

Page 11, lines 28-31: I do not understand how the location of the road links is given to the model.

The location of the road links is specified in a separate ASCII file giving the UTM coordinates of the road link beginning and end points, and the width, and height at the beginning and end points. We have now made this clearer in the text.

2.3

This section should be carefully read, it is difficult to understand, for instance: o UECT is described in two separated paragraphs.

We have now removed most of the text here since it was duplicated within Table 3 including the text relating to UECT.

What is TAPM? o I do not understand how it is possible to use 3D meteorological fields from AROME or WRF in EPISODE. I guess it implies a pre-processing of these fields to use then in EPISODE. Could you please clarify this point? Also at which temporal resolutions, meteorological fields have to be provided to EPISODE? See also major comment for this point.

We have now described TAPM more clearly (in Sect. 2.4) and have directed readers to Part Two of this paper (Karl et al., 2019) where a more thorough description of TAPM and its uses is given. The details regarding the spatiotemporal resolutions of the input meteorology are also explained in the new Sect. 2.3 on meteorological inputs.

Part 3

The information about the temporal frequencies of meteorological outputs given to EPISODE from AROME is missing.

We thank the reviewer for identifying this error. We have now added relevant text describing this.

Why do you not use point source emissions? Could you please justify?

We did use point source emissions in the case of the Grenland and Nedre Glomma simulations, but this was not properly explained. Both areas have a particular concentration of industry, and the emissions from the point sources happen to be relatively well characterized. We have now altered the text to describe the point sources in Grenland.

In the cases of the other cities, while there are point sources there in reality, in these cases we lacked the detailed information on the point sources (e.g., stack height, gas flue speed and temperature) to be able to represent these sources with this method.

I suggest adding a figure showing the location of the chosen urban areas including each domain of simulations if possible. The information about the vertical grids and the horizontal domain extend should be given at the beginning of the part and not at the end (table 6).

We thank the reviewer for this suggestion. We have now created a new figure (Fig. 3) that plots the locations of the different urban areas on a map of the southern half of Norway.

Part 4

4.1.1

I'm not sure that this part provides interesting information regarding the aim of the paper. I suggest deleting it to shorten the paper. If the decision is to conserve it, could you please discuss the interest to provide annual mean concentration maps? Maybe this information could be relevant for abatement strategy?

The annual mean NO_2 concentration is one of the EU limit values for this pollutant and so we therefore wish to keep these maps as part of the model analysis and evaluation.

4.1.2

The limitation due to the PSS hypothesis should be discuss in regards to the NxOy chemistry occurring during night (see comments on part 2.2.1).

We thank the reviewer for raising this point. We have now added relevant discussion here and highlight the limitations.

4.1.3

I am not convinced of the interest to look at these kinds of differences. In particular, the use of mean values makes it difficult to separate processes that may explain differences between simulations and observations. Moreover, again, the effect of the PSS hypothesis and of the non-linearity of atmospheric chemistry, which is not taken into account, is not discussed.

We have now removed this section and the relevant figures. Thank you for this recommendation.

4.2.1 and 4.2.2

Could you please give some possible reasons for this polluted event?

And… *Same comment as 4.2.1*

We have now included a comparison of the meteorology in the supplement and we use this to provide a more detailed context of the conditions leading to the worsening of pollution during these events, i.e., cold conditions with low wind speeds.

Parts 5 and 6

I suggest combining parts 5 and 6 in a part called "conclusion and future work".

We respectfully disagree with the reviewer. We think that this allows a clearer connection between certain arguments made during the paper regarding the limitations of the PSS and chemistry and the future work that we outline.