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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The impact of resolution on ship plume simulations with NO_x chemistry" *by* C. L. Charlton-Perez et al.

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We would like to thank Reviewer 2 for the careful reading of our manuscript, bringing our attention to a new article which we now include a reference to and the many suggestions which we have used to make the paper stronger and clearer.

0.1 Abstract

1. Please specify that the study refers to tropical conditions and include a brief description of the simplifications adopted in the chemistry scheme eg. NMVOCs.

   We have added to the abstract: "in a tropical location."

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We have also added to the text on the chemistry: “VOC chemistry is not included in the model. The primary reason is numerical efficiency, as the addition of VOC chemistry adds a significant computational burden to the model. A second reason is to simplify the experimental design, allowing the present experiments to focus solely on NO_x photochemistry, rather than attempting to map the more uncertain NO_x-VOC parameter space. Thirdly, in the conditions explored here the background VOC levels are low due to the remote nature of the atmosphere being simulated. At the low concentrations typical of the remote ocean the impact of VOCs on OH and O_3 production is small (Sommariva, et.al., 2006).”

2. P 8588 L 8 It would be interesting to know what happens to NOx and O3 concentration.

   We have now included this information in the body of the paper, but as we haven't made this the focus of the paper, we leave it out of the abstract. Domain mean NO_x concentrations decrease steadily as the model resolution is coarsened. O_3 concentrations do not change appreciably as resolution is changed, although the maximum domain mean O_3 is found at the coarsest (C48) resolution.

3. P 8588 L 12 What about mentioning the OH halo effect here?

   We think that the OH halo effect is interesting and worthy of discussion, but because it is not the main focus of the paper, we chose not to include it in the abstract.

4. P 8588 L 13-15 This sentence should be rephrased and clarified.

   We have clarified this sentence in response to this comment and to a comment by Reviewer 1.

5. P 8588 L 17-18 Some work on parametrizations has already been published (Franke et. al 2008).

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We have discussed this in the introduction and conclusions and have added a reference to this particular paper.

0.2 Intro

1. P 8589 L 4-6 Rephrase and be careful. Add a sentence on the Eyring et al (2007) ACP study.

   We have rephrased and added a sentence on the Eyring (2007, ACP) study.

2. P 8589 L 4-12 Consider moving this paragraph or L 9-12 to the end of the intro.

   Yes, we have rearranged as suggested.

3. P 8591 L 16 There seems to be a mismatch between resolutions and spectral truncations.

   Yes, indeed that was a mistake and has been fixed.

4. P 8591 L 21-23 Consider moving this sentence to the end of the intro.

   Having rearranged the introduction as suggested, two comments above this one, we think that this sentence can remain where it is linking the previous Esler (2004) study to ours.

5. P 8592 L 2-4 Rephrase and clarify your choice.

   We have restated and the sentence now reads: "Therefore, the ability of resolution to explain the perceived failure of global models to simulate ship NO_x emissions should and can be tested fully within a single model."

0.3 Section 2

1. Authors could consider merging the section into a single methodology section.

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We have not done this because we wanted first to set the stage with a description of the physical system we intend to model. We then wanted to take the reader through all the technical details in a separate section.

2. P 8592 L 10-11 This sentence could go into the final paragraph of the intro and could mention that this paper focusses on a tropical case.

   We added the word “tropical”. We think that leaving the sentence here provides a nice transition from the Intro. to this second section.

3. P 8592 L 21-23 Please rephrase and clarify your choice.

   We have done so according to Reviewer 1’s similar comment on these lines. We have added: “Explicitly simulating these stronger ground-relative winds (with a moving ship) would be expected to increase the shear-driven mixing in the turbulent boundary-layer, but since investigating the role of a variety of boundary-layer structures was beyond the scope of this study this effect was neglected.”

0.4 Section 3

1. P 8594 L 17-18 Please add to this sentence or else comment on the large-scale subsidence described in P 8595 L 21-23.

   We have added to this sentence to refer the reader to the description of subsidence in the next section.

2. P 8594 L 21 Is “reaching the domain boundary” what the authors meant with “exiting the box”.

   Yes, it is, we have changed the text from “box” to “domain.”

3. P 8595 L 2-3 The statement in the round brackets seems to say that this dependance goes beyond the scope of this study.

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Yes, the different types of boundary layer meteorology could be explored using this model and other LEM runs representing the meteorology, but is not explored in the current study.

4. P 8595 L 7 Is the hyphenation necessary here?

   No, we have removed it.

5. P 8595 L 11 please consider comparing here the LES model domain to the domain used in the CTM or referring to P 8596 L 7.

   We have added the following text: “Because the LEM simulation has periodic lateral boundary conditions, we use the domain to create a longer domain for the chemical and dynamical plume model in this study. This extended domain is described later in this section.”

6. P 8595 L 17-19 Please comment on this possible caveat or consider moving the sentence in P 8596 L 11-13 into this paragraph.

   We have moved the sentence as suggested.

7. P 8596 L 21-23 Please consider adding a citation to this statement - if you have done these tests yourself please clarify.

   We performed these tests and clarified the text to reflect this.

8. P 8596 L 23-25 Please consider adding a comment about the time step over which the interpolation takes place.

   The timestep and interpolation are mentioned in the lines above: “The LEM winds are supplied at 1 minute intervals; we interpolate in time to match our advection time step of 3 seconds...”

9. P 8597 L 21-24 Please consider moving these sentences into the previous paragraph.

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We think that the sentences reflect the link between the ideas in the two paragraphs, but have rewritten the text in this section to improve this link.

10. P 8598 L 10 Please comment on your choice to exclude important NMVOCs from the chemical scheme.

    After the paragraph starting "Table 1 summarizes the chemical reactions we use to model" we have now included a new paragraph:

    "We do not include VOC chemistry in the model. Primarily we have done this for numerical expediency. The addition of a VOC chemistry scheme would have added a significant computational burden to our simulations. Secondly, since the emissions of VOCs from shipping are even more uncertain than the emissions of VOC, it was felt more appropriate to focus on the photochemistry of NO_x rather than attempt to map the highly uncertatin NO_x-VOC space. Thirdly in the conditions explored here the background VOC levels are low due to the remote nature of the atmosphere being simulated."

0.5 Section 4

1. Please consider merging section 4 and 5 into a single results section.

   We have done this, and created 2 subsections in order to treat the results of the study in two stages.

2. P 8598 L 18-19 Please consider moving this sentence into the previous section.

   We have followed this suggestion.

3. P 8598 L 21-27 Please consider adding that Figures 1 and 2 refer to the C1 simulation.

   We have followed this suggestion.

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0.6 Section 5

1. P 8599 L 4-8 There seems to be more in this section than what is described in this paragraph. Is it really necessary?

   We have expanded this summary paragraph.

2. P 8599 L 20-25 Please consider merging this paragraph with the previous one.

   We have merged.

3. P 8600 L 10-11 I highly suggest that the authors include mean absolute values on NOx and O3 as they do for OH in Figure 5.

   We have now included these values in the results section.

4. P 8600 L 13 Please define NOx lifetime here rather than in P 8601 L 13-15.

   We have moved the definition.

5. P 8601 L 2 Is the first round bracket in the right place?

   No. We have fixed this error.

6. P 8601 L 20 Please add "each time the resolution is halved" at the end of the sentence.

   We have added this phrase.

7. P 8601 L 25 Is this a caveat of your model or a conclusion from your interpretation of the model results? What is chicken and what is egg?

   Good point. Because in our model chemistry the NOx loss rate is defined exactly as the production of HNO_3, this must be attributed to the NOx lifetime being anti-correlated with OH. We have now stated this in the definition of NO_x lifetime: "We define the NO_x lifetime as ratio of concentration of NO_x to rate of loss of NO_x,

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where, in our model, the NO_x loss rate is exactly equivalent to the production rate of nitric acid (HNO_3)."

8. P 8602 L 12 Why do you use the present tense here? What about "suggested"?

   The tense has been changed.

9. P 8602 L 16 The verb "are" is missing.

   Indeed, we have fixed this typo.

10. P 8602 L 29 Please consider starting a new paragraph with "When the ship emission...".

    Paragraph has been split.

11. P 8603 L 1-5 This point is fairly interesting and deserves more attention. I found it surprising to see the OPE dependence on resolution increase when emissions are halved. I would appreciate if the authors would comment more on this and suggest some mechanism.

    Having read Franke et. al. (2008), Figure 11 described in section 6.4 could be relevant, if I understand it correctly. The figure plots the change in O_3 as a function of relative emission strength and shows that there is a linear relationship for the instantaneous dilution model, but a nonlinear relationship in the case of the parametrised plume model. Thus, if a plume is included in the model, we should expect a nonlinear relationship between emission strength and the production of ozone over a given time. Perhaps there is a link between the results of our OPE-resolution relationship and this fact? However, we cannot explain why the OPE-resolution slope changes as it does when the emission rate is halved in our model and so have removed this sentence from the paper.

12. P 8603 L 19 This comparison seems to refer to the experiment with full emissions. Please state this explicitly.

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Yes, we now state that we are looking at cases with emissions.

13. P 8603 L 7-11 Please consider moving this paragraph to P 8602 before the paragraph with the halved emission rate.

    We think that it is logical to provide the no emission results after fully discussing the cases with ship emissions and we have now removed the cases with halved emission results as well.

0.7 Section 6

1. P 8603 L 13 Please specify tropical or subtropical before MBL.

   To be precise, the chemistry of the MBL is not tropical, but the setting (i.e. the LEM winds) is tropical, so we have left the sentence as it was.

2. P 8603 L 16 Please consider starting a new paragraph here.

   We have started a new paragraph.

3. P 8603 L 22-24 Please consider rephrasing taking into account possible model limitations.

   We have added a caveat to take into account model limitations: "NO_x lifetime is anti-correlated with OH levels which is in agreement with the results of Chen (2005) and could be seen as evidence that the reaction of OH with NO_2 is the key to loss of NO_x, although our model does not include the loss of NO_x due to the formation of PAN."

4. P 8604 L 2-6 These seem to be potential improvements to this study which as such go beyond the scope of this study. Please clarify this.

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The other reviewer also commented on this. Although this asymptote at small-scales is not important for our conclusions about the coarser scales, we mentioned this because given more available computational resources, this might be an interesting exercise.

5. P 8604 L 12 This is a good point for the authors to speculate on how the results might change under extratropical conditions.

   We have expanded the text here to include some speculation on NO_x lifetime.

6. P 8604 L 16 What about the implications for eg aircraft plumes?

   The chemistry is different in the upper atmosphere where aircraft spend the majority of their time. Our model chemistry may not be sufficient to speak to the aircraft plume problem. Also, the meteorology in our experiments is specific to the marine boundary layer. Plumes in the lower atmosphere such as from power plants appear to be a more promising application for future research with our model.

7. P 8604 L 17-20 I think that the authors should be more careful at this stage. The recent Franke et al (2008) Met Z Study should be mentioned too. Itf the authors wish to make a plea for particular approach, then they should motivate this.

   Now that we are aware of the Franke et al study, we have included it in the text and bibliography: "Finally, our results suggest that better parametrisations of ship emissions in global models need to be designed using, for example, the "equivalent emissions" concept introduced in Esler (2003) or the "effective emissions" method developed by Frank et. al. (2008)."

0.8 Appendix A: Two-way exchange of concentrations

1. Why not give a name to this interesting appendix?

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Appendix A: Two-way exchange of concentrations

2. P 8604 L 22 If Eq. A1 is the same as Eq. 1 why not simply refer to Eq. 1.

   We think that this choice makes the appendix self-contained and easier for the reader.

3. P 8604 L 24 I understand that the authors are referring to a "concentration flux" and I would recommend them being more specific.

   We have added to the text.

4. P 8605 L 17 please consider substituting "Another method" with "The method employed in this study."

   We have modifed this phrase.

5. P 8606 L 10 Actually, all the lines seem to be solid.

   Yes, we made an error here and have fixed this. The lines are all solid, but are thick and thin.

6. P 8606 L 12-16 Please specify that you are comparing the high resolution case with the C8 case.

   We have changed the text to be more specific: "Using the example of a passive tracer in the C8 resolution case,..."

0.9 Table 1

Please double check the contents of Table 1. In particular some equations are missing either the right or left hand side.

None of the equations are missing; this is just the table format. For some of the rate constants on the right side there are several parameters that need to be defined and

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this takes more than one line of text to accomplish. Three reactions have such lengthy rate constant definitions.

0.10 Figure 1

1. The gray between 316 and 1000 is a bit too light. The upper and lower boundary of the color bar could be triangles.

   The intent here was to increase the contrast between the 316-1000 and 1000-3162. The lowest contour line is clearly the 316 line which marks what might be considered the plume edge from the background. However, we admit that defining a plume edge is a subjective exercise.

2. Why not invert the labelling of the x axis with 0 either in the centre or at the right boundary of the grid cell with the ship emissions?

   Because we are only showing a part of the long, tiled domain of the plume model, we wanted to give a sense of the distances covered by the 3D model and have kept all the figures consistent.

0.11 Figure 2

Should the label of the horizontal axis not be y?

Yes, it should. We have corrected this error.

0.12 Figure 5

The last sentence in the caption could go into the main text.

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This fact is already mentioned in the text. We have put this sentence in the figure caption to make it easier for the reader to compare the clean case with the ship emissions case.

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