

Interactive comment on “Simulation of polar stratospheric clouds in the chemistry-climate-model EMAC via the submodel PSC” by O. Kirner et al.

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Dear referee,

thank you very much for your efforts to create this detailed review of our manuscript. We will try to incorporate your suggestions in our paper and hope that we answer satisfactorily most of your requirements.

Here are our answers to all your comments:

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GENERAL COMMENTS

- *This paper presents a thorough and in-depth summary of the PSC submodel in the EMAC chemistry-climate model. It is well suited for publication in GMD. While it may look like there are many comments below, almost all are minor in nature and many are intended to improve the clarity of the writing. I recommend this paper for publication in GMD once the issues detailed below have been addressed.*

Thank you very much for the recommendation of our manuscript for publication.

- *What is missing from this paper is a quantitative assessment of the improvements of PSC representation in EMAC achieved through implementing the PSC submodel described here compared to previous incarnations of the PSC submodel used in EMAC. This is valuable documentation of how the PSC calculations in EMAC are performed but the reader comes away from the paper with no idea whether this scheme is likely to result in better performance of EMAC in simulating e.g. ozone destruction. Does this scheme improve the performance of EMAC over previous schemes? Surely that is a question that this paper should address?*

We can understand very well the need of this suggestion. It is in our opinion that there should be a quantitative assessment of the new and original PSC scheme of the submodel PSC. We intend to do this in a second paper which is currently still in preparation but will be submitted in approx. two months by ACP:

Kirner, O., Ruhnke, R., Höpfner, M., Jöckel, P., and Fischer, H.: A new parameterisation of polar stratospheric clouds (PSC) based on the efficient growth and sedimentation of NAT particles in the chemistry-climate-model EMAC

This paper will include amongst others:

1. A detailed description of the time depend PSC development in the Antarctic and Arctic region by using the new PSC scheme

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2. A detailed comparison of the new and original PSC scheme with focus on NAT, ice, HNO_3 , H_2O and O_3
3. A detailed comparison to satellite observations of PSCs, HNO_3 and ozone columns
4. A detailed comparison of the different sedimentation schemes and their influence to the new and original PSC schemes
5. A recommendation which PSC parameterisation should be used in different cases

We think that the quantitative assessment of the original and new PSC scheme is in content and scope beyond the aim of the current paper. The aim of our current paper is to introduce the new NAT parameterisation and to give a comprehensive description of the submodel PSC.

SPECIFIC COMMENTS

- *Page 2072 line 11: This reference to 'namelist switches' is very specific to the software used to code this model and will only be familiar to those readers familiar with this software. I would advise against referring to such technical specifics, at least in the abstract for the paper.*

You are right; this is too specific in the abstract. We will improve this sentence and avoid technical specifics.

- *Page 2072 line 16: Polar stratospheric clouds are not only necessary for understanding polar ozone depletion, they are also actually necessary for ozone depletion i.e. they are not a means by which understanding of polar ozone depletion is achieved, they are real objects that are central to ozone depletion processes.*

We will change this sentence.

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- *Page 2073 line 14: And then what happens after the temperature drops below the ice frost point?*

We will add a sentence with respect to this point.

- *Page 2073 line 21: You start this sentence by saying that two assumptions are made regarding the formation of NAT particles but after reading the sentence I still didn't know what these assumptions are. 'the heterogeneous formation of NAT on ice particles' is not an assumption unless you mean that it is assumed that NAT particles coalesce onto ice particles? You need to state much more clearly in this sentence exactly what it is that is assumed in current theories related to the formation of NAT particles.*

OK, the formulation of this sentence is incorrect. We will skip the expression "two assumptions" and change the sentence.

- *Page 2075 line 3: How much is 'some Kelvin'. I think that you need to find a better way to express this.*

We will skip "some Kelvin".

- *Page 2077 line 19 to page 2078 line 10: What purpose does it serve listing all of these submodels that constitute EMAC? None are the subject of this publication and providing this list of submodels seems to serve no purpose for the reader.*

Here we are not sure. We think that is a part of the model description. Maybe the editor can decide this.

- *Page 2078 line 15: It would be useful to know some details about what sort of PSC scheme was included in versions of EMAC before version 1.9 so that the reader can assess the value of the new PSC scheme, detailed in this paper, compared to earlier schemes.*

OK, that is true. Only the new kinetic growth NAT parameterisation is new in version 1.9. We will try to make this more clearly in the paragraph.

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- *Page 2078 line 22: So at this stage I am left wondering what was included in EMAC before Kirner (2008), what improvements then occurred through the implementation of Kirner (2008), and what additional improvements are now being implemented through this 2010 publication? This paragraph needs to provide the reader with that information and to make very clear what advancements in the PSC scheme used in EMAC were achieved at each stage.*

OK, this is a good point. In fact the new kinetic growth NAT parameterisation was only preliminary implemented in the submodel PSC at the time of the dissertation by Kirner et al. (2008). There have been many changes and improvements in the code in the last two years. Finally the new NAT parameterisation had to be adapted to the MESSy infrastructure, so that it was possible to release this new parameterisation in the submodel PSC in EMAC version 1.9 (released 2010).

As the new NAT parameterisation was not complete in 2008 and so not entirely implemented by Kirner (2008) we changed this accordingly in the paper.

- *Page 2078 line 24: This sentence doesn't make sense to me at all. First it doesn't make sense to say that you 'calculate STS droplets'. Please reword this sentence for better clarity.*

We will change this sentence.

- *Page 2080 line 7: Why 'thermodynamical' and not 'thermodynamic'?*

We will change "thermodynamical NAT parameterisation" in "thermodynamic NAT parameterisation" in the whole manuscript

- *Page 2081 line 3: Do these lower and upper limits refer to altitude limits? If so, you should say so.*

We will change "lower and upper limits" to "lower and upper altitude limits"

- *Page 2084 lines 3-4: Is this something that the reader really needs to know? I would suggest deleting this sentence. It is extraneous detail.*

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We think this sentence is relevant for the understanding of this paragraph. Maybe the editor can decide this.

- *Page 2089 line 18: It is not clear to me what you mean by 'through the gases phase concentration'? Do you mean 'by the gas phase concentration'?*

We will replace "through" through "by"

- *Page 2093 line 15: I think it would greatly aid the readability of this paper if you provided a table of the fundamental constants used throughout the many equations in the paper. This would prevent you from repeating statements such as 'with g the acceleration of gravity (9.80665ms⁻²)' which appear more than once in the paper. A similar table could provide the units for all quantities so that you don't need to pepper the manuscript with this information. The numerous use of parentheses throughout the paper really detracts from the smooth reading of the text and I think that shifting some of this secondary detail into tables would help a lot.*

We support the idea of the table with the constants used in the submodel PSC and will create this table. But we think that a table with the units of all quantities would not make the paper more clear. Here we think that it is useful to have the description of the unknown variables and units directly related to the formula. But we will try to skip some of the parentheses throughout the paper.

GRAMMAR AND TYPOGRAPHICAL ERRORS

- *Page 2072 line 8: Replace 'first one is based' with 'first is based'.*

OK

- *Page 2072 line 9: Replace 'second one (new implemented by' with 'second (newly implemented by'.*

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OK

- Page 2072 line 10: Replace 'with aid of' with 'with the aid of'.

OK

- Page 2072 line 13: Replace 'the goal to simulate realistic PSC' with 'the goal of simulating realistic PSCs'

OK

- Page 2072 line 17: You should use the grammatical construct 'On the one hand X ... One other hand Y' only when X and Y are in some way in opposition to each other. This is not the case in the sentence you have written. I would therefore suggest that you rewrite this sentence in a more straightforward way.

OK

- Page 2072 line 22: Replace 'and the' with 'such that the'.

OK

- Page 2073 line 1: Replace 'are still matter' with 'are still a matter'.

OK

- Page 2073 line 2: The phrase 'profound suggestions of their formation and existence in the polar atmosphere exist' doesn't make sense to me. Our knowledge of PSCs is far more than a set of 'profound suggestions'. I would suggest rewording this as 'but a large body of scientific evidence exists that support a number of theories related to their formation'.

OK

- Page 2073 line 6: Replace 'or Luo' with 'and Luo'.

OK

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- Page 2073 line 10: Replace 'during cooling' with 'during cooling of STS' and delete the 'forming STS' at the end of the sentence.

OK

- Page 2073 line 12: Replace 'After' with 'As shown in'.

OK

- Page 2073 line 14: Delete 'also' and the on the next line replace 'particles is strongly increasing' with 'particles also strongly increases'.

OK

- Page 2073 line 17: Replace 'are changing' with 'change'.

OK

- Page 2073 line 21: Delete 'Mainly'.

OK

- Page 2074 line 6: Replace 'Former' with 'Earlier'.

OK

- Page 2074, line 14: Replace 'and it is possible to explain' with 'thereby explaining'.

OK

- Page 2074, line 19: Replace 'with approx' with 'at approx'.

OK

- Page 2075 line 14: Why not 'polar stratosphere' instead of 'polar stratospheric atmosphere'?

OK

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- Page 2075 equation R2: The 2 on the CINO₂ needs to be subscripted and again a few lines later.
OK
- Page 2077 line 10: Replace 'as for instance' with 'such as'.
OK
- Page 2079 line 3: It's not clear to me why there is a paragraph break here?
OK
- Page 2079 line 7: Delete 'thereby' since it is not used grammatically correctly here.
OK
- Page 2079 line 21: I think this would read better if instead of 'the difference of 1.0 to the calculated mass fractions' you said '1.0 minus the calculated total mass fraction of the other constituents.'
OK
- Page 2080 line 7: Replace 'called in the following' with 'referred to hereafter'. Likewise in the next sentence.
OK
- Page 2081 line 8: Delete the comma after 'set to 3'. Likewise a few lines below.
OK
- Page 2082 line 16: I think that what you mean to say here is 'the dependence of the surface growth factor on the...'
OK

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- Page 2082 line 22: Delete the comma between increase and through.
OK
- Page 2083 line 23: Replace 'containing in' with 'contained in'.
OK
- Page 2085 line 16: Replace 'as difference' with 'as the difference'.
OK
- Page 2089 line 7: Delete 'thereby' since it is not used grammatically correctly here.
Here we will change the whole sentence.
- Page 2089 lines 9-10: This sentence does not make grammatical sense and needs to be rewritten.
Yes, that is true. We will improve this sentence.
- Page 2090 line 3: Delete the comma between possible and as.
OK
- Page 2090 line 3: Replace 'much higher as the' with 'much higher than the'.
OK
- Page 2090 line 15: Replace 'details of' with 'details on'.
OK
- Page 2091 line 16: Replace 'through the gas phase' with 'by the gas phase'.
OK

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- *Page 2093 line 11: Not clear to me why the '1' is needed here?*
We will delete the 1.
- *Page 2097 line 11: Replace 'lower as the model temperatures' with 'lower than the model temperatures'.*
OK
- *Page 2097 line 15: Delete 'thereby' since it is not used grammatically correctly here.*
OK

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