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## Comment on gmd-2021-127

Anonymous Referee #2

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Referee comment on "TransClim (v1.0): A chemistry-climate response model for assessing the effect of mitigation strategies for road traffic on ozone" by Vanessa Simone Rieger and Volker Grewe, Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-127-RC2>, 2021

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### Manuscript Summary

The manuscript describes the development of parameterised source-receptor model (TransClim) to quickly and efficiently assess the climate impacts from changes in road traffic emissions. TransClim uses look up tables that have been built from simulations of the chemistry climate model EMAC. These look up tables define the relationships between different variables (including  $O_3$ ) and the change in  $NO_x$ , CO and VOC emissions from road traffic sources. This is then linked to radiative forcing to determine the climate impact from road traffic emissions. The specific contribution from road traffic emissions is further quantified by using a tagging method. The paper describes the development of TransClim and presents results of the evaluation against additional EMAC simulations.

I think the manuscript describes a useful new tool to assess the impact of road traffic emissions and I think it should be published once the comments below have been addressed. One of the main issues to be addressed is improvements to the clarity of the methods section. This will allow for a better flow to manuscript and make clearer how TransClim was developed.

### Major Comments

- I know the focus of this tool is the climate impact of  $O_3$  but one of the most important impacts of road traffic is on local air quality and health. This seems to be an equally if not bigger motivator for understanding the impact from road traffic emissions but is not mentioned in the introduction? Also would this method also be applicable to calculating

the impacts on surface O<sub>3</sub> and therefore an estimate of both the impact on climate and air quality could be obtained?

- If you are going to mention the methods in the introduction can you provide an improved explanation of what is used in this study (see further comments in minor section below) or just leave the details to the methods.
- I think significant improvements could be made to the methods to make the manuscript read better and provide a more logical flow. I found the structure of the methods section confusing as it appeared to be the wrong way round. The first section told us what TransClim does (which already occurred at end of introduction) before how you developed the response model. Also, the development of the look up tables and model simulations that were used to develop these should probably be discussed earlier as these are the key datasets that underpin the tool. Then the methods should discuss how the algorithm was built from these look up tables. Also Section 2.2 is not a list of requirements and needs to be changed to better reflect what you want to say here. Furthermore, in section 2 there was only a brief mention of the Tagging method but not how it fits in with the rest of the development process. Additionally, the workflow sections and Figure 5 could be improved to make it easier to follow how the tool works (see further minor comments below).
- The definition of the emission source regions seems slightly arbitrary to me. Why were these eleven regions chosen and is the future use of tool limited by the defined set of regions used to create it? The regions seem heavily weighted towards Europe and particularly broad over other areas like North America and Asia. Can you provide some justification for this choice and any limitations that might occur as a result of applying this tool to regions outside of Europe. Also could the regions be improved by only including land-only points, as currently there is a lot of oceanic parts considered in some regions (Fig. 3).
- The EMAC simulations are based on a single year, 2010, and use emissions for this year from a particular emissions inventory. What are the limitations of basing the tool solely on 2010 emissions, meteorology and background concentrations? How will changes to variables such as these effect the chemical relationships within TransClim and impact the predictions made by the tool?
- The EMAC emission variation simulations used to build the look up tables that form the basis of the TransClim tool are described in Table S4. These simulations seem disproportionately biased towards the emission source region of Germany and therefore are the results from the TransClim tool from other regions affected by this weighting of training data? Are you therefore assuming that the O<sub>3</sub> and emission relationships calculated over Germany can be applied around the world? There are hardly any emission perturbation experiments over Asia or North America for example. This seems quite limiting as I would have potentially thought they would be quite different emission relationships over India and China to those over Germany. For example, across these regions you are basing the O<sub>3</sub> response relationships on only a single perturbation simulation. This seem particularly limiting and depends heavily on your simulations over Germany.
- Whilst I agree that testing the performance of TransClim over Europe is needed, I was disappointed not to see further evaluation across other emission source regions. This would strengthen the evidence of the applicability of the tool in other world regions. I would expect the performance to be better over Europe given the number of EMAC simulations performed over this region to construct the Look Up Tables in Table S4. However, given the lack of EMAC simulations over other source regions e.g. Asia and North America, I would therefore feel it is even more important to evaluate the performance of TransClim for emission perturbations and response over these regions. Given the lack of evaluation over these regions I am not sure how TransClim currently performs on regions other than Europe.
- A description of the linear interpolation error is found in section 5 but probably this should be moved earlier towards the methods section as this is the first point it is mentioned in the manuscript. I also found there was little detailed quantification of this

error other than saying the evaluation of a TransClim simulation is similar to EMAC. However, looking at Figure 8 it appears that the linear interpolation error would increase at larger emission perturbations (e.g. 1.0 to 0.0 or 1.0 to 3.0). I think it would be useful to know for what emission scalings does TransClim have low errors and therefore performs best at. Also, it would be good to document for what size of emission perturbations do the relationships used in TransClim breakdown at. This seems a key aspect of confidence in TransClim and should be explored further.

### **Minor Specific Comments**

Page 1, Line 9 – change “bases” to “is based”

Page 1, line 23 – CO<sub>2</sub> is not carbon monoxide

Page 2, lines 24 – 27 – Could also mention the other impacts from road traffic here e.g. the emission of particulate matter and also the importance of O<sub>3</sub> and CH<sub>4</sub> for climate.

Page 2, line 27 – I think “In general” is quite a broad statement here. Would be good to mention what conditions are important here e.g. time of day, season, urban vs rural etc.

Page 2, lines 28-29 – “not linear”, why not just say non-linear?

Page 2, line 36 – any comment on winter changes?

Page 2, line 37-38 – what does these studies show?

Page 2, line 38 – remove “by”

Page 2, line 39 – Is this number global? Also would it be better to just show in K.

Page 2, line 42 – When explaining the perturbation method it is better to refer to the simulations as a control (all emissions) and an experiment (perturbed emissions).

Page 2, line 43 – Why does the perturbation method not account for non-linear interactions? I would have thought most chemistry models would do.

Page 2, line 43 – Replace use of “relations” here and in other parts of the manuscript with “relationship”

Page 2, line 44-46 – Why does this sentence talk about “only the impact of road traffic emissions on O<sub>3</sub>”, I think this is what you want? Why does changing emissions only from road traffic emissions effect O<sub>3</sub> production from other sectors? Should they have not been kept the same in these two different simulations? Please make this description clearer.

Page 2, line 44 – Change “As a variation of ...” to “As changes in ...”

Page 2, line 45 – Change “of” to “from”

Page 2, lines 48-50 – I see the benefit of tagging but I think the distinction between tagging and perturbation experiments need to be made clearer at this point. Also how does the “impact” differ from “total effect”. The use of language needs to be made clearer at this point and consistent throughout the manuscript.

Page 2, lines 52 – I would expect to read this statement earlier. Also there has been no mention about the impacts of O<sub>3</sub> on health and the environment until this point.

Page 2, Lines 53 – reword to “... reduce road traffic emissions to minimise their effect on climate”

Page 3, line 63 -64 – move “on climate” from end of the sentence to after “O<sub>3</sub> effect”

Page 4, line 79 – Is Figure 1 that useful? I understand that it is trying to convey the concept of TransClim but seems to lack useful detail and also other figures (2 and 4) seem to be showing a similar concept.

Page 4, lines 86-86 – All of the discussion so far has been on determining O<sub>3</sub> and its impact on climate. This is the first mention of other variables so could the above paragraph be talked of in more general terms or explain how the same method for O<sub>3</sub> can be applied to other chemical species.

Page 4, Section 2.2 – This is not a just a list of requirements but also what the algorithm does and also some results presented at the end. This needs to be sorted out to determine what you want to say here and this section reworded accordingly.

Page 4, line 91 – such as what other climate effect?

Page 4, line 93 – Do you also include the non-linear impact of CH<sub>4</sub>?

Page 4, line 94-95 – This again is a bit confusing referring to the total change in O<sub>3</sub> and also the contribution from Traffic. Won't just perturbing the emissions from road traffic give you both of these of these quantities together? Clearly explain the difference between O<sub>3</sub> and O<sub>3</sub><sup>tra</sup>.

Page 4, line 97 – Isn't the non-linear chemistry included within TransClim rather than considered?

Page 4, line 98 – "Road traffic emissions from different regions are accounted for" not regarded

Page 4, line 101-102 – reword sentence to talk about local and remote response.

Page 4, line 105-106 – How would you take into account future changes in background O<sub>3</sub>? Also would this include effects of CH<sub>4</sub> and surface temperature on O<sub>3</sub>? If this is not being done in the current study why mention it here as a requirement. Wouldn't it be better to say what the current tool is able to do and then propose future improvements in a different section?

Page 4, lines 108-109 – This is not a requirement but a result.

Page 5, line 113 – In Figure 2 are the two response fields identical for the two different regions? If this is only a schematic then why not show actual results from two regions to give the reader an idea of how the tool actually works?

Page 5 line 114-115 – I know the emission scaling factors are mentioned further in the

manuscript but on first reading this I didn't know what these were or how they had been decided to generate the algorithm. I think this is another point where reordering the methods would be beneficial.

Page 5, line 118 – I think this equation needs a label if it is going to be kept. Also if  $\Delta x$  is provided by the look up table directly then I am not sure this equation is necessary in its current form. I think it would be better just to describe this in words like you have and then include the meaning of  $\Delta x$  in what is currently labelled as equation 1. Also it would be good to say where the basis of these look up tables have been derived from (e.g. the perturbation simulations).

Page 5, line 119 – Specify what variable  $x$  can be.

Page 6, line 125 – I am a bit confused about what  $x^{\text{ref}}$  is. Is this the background values onto which the response to road traffic emissions are added onto? Should this not also be on a per region or per grid box basis? Also is  $x^{\text{ref}}$  not also included in the calculation of  $\Delta x$ ? Why is it in both calculations or are these different values?

Page 6, line 127-128 – This is not obvious how the regionally derived values can be used to derived changes in global mean values or across the whole troposphere. Further explanation if required here of how this is done.

Page 6, line 130 – surely your approach is applicable to other emission perturbations? It is just utilised here for road traffic emissions?

Page 6, line 135 – I think section 3 definitely needs to come earlier as reading section 2 first just left me with lots of unanswered questions.

Page 6, line 138 – “eleven source regions”?

Page 6, line 151 – label emissions for relevant year e.g. high road traffic emissions in 2010

Page 7, line 163-166 – What is the impact of using global model simulations at 2.8 x 2.8 degrees to try and understanding the effect from road traffic emissions which normally take place at much finer resolution? Do the use of emissions at this resolution also impact the effectiveness of the model simulations to capture model the response to road traffic emissions?

Page 7, line 166 – I am surprised to see these simulations are free-running. Does this not introduce a potential additional problem of meteorological variability by using multiple simulations of the same model? Has this been accounted for or the impact of it calculated?

Page 7, line 168 – change “trop-” to “troposphere”

Page 8 - What do you mean by Tg(VOC)? Which VOCs? How is this different to Tg(C) presented next to it? Surely you only need one definition of VOC emissions unless there is something different?

Page 8, line 172 – I am not sure I understand what you mean by prescribing climatologies for radiation and the hydrological cycle. How does this impact the results? Can perturbations in emissions not therefore impact the radiation or meteorology?

Page 8, line 178 –  $O_3^{tra}$  is mentioned here but you have not said yet how you have calculated this or what exactly it is.

Page 8, line 178-179 – Is this the  $O_3$  field in the model from the road traffic emission perturbation experiments? Or is this just the  $O_3$  radiative fluxes from switching on the chemistry scheme?

Page 8, line 180-182 – What is the third call to the radiation scheme doing that is different to the second? I think some clarification of what the radiation scheme is actually calculating in each step would be useful so it is easier to follow the process. I am a little confused about what is the second and third steps.

Page 8, line 183 – are these radiative fluxes equivalent to instantaneous radiative forcings e.g. excluding fast and slow feedbacks on climate through adjustments to clouds?

Page 9, line 189 – Is this  $O_3^{tra}$ ? Can you provide a very brief summary of what the tagging is doing and how it is different to the perturbation method here rather than just referring to the appendix?

Page 9, Figure 4 - whilst I appreciate showing 3D variables on a 2D plain is hard I wonder if you could also mark up the emission factors used in some of the different simulations so it is easier to see what has been perturbed. It is hard to tell from Figure 4 what some of

the values are that have been used for each of the factors. It looks like you have done some experiments to reduce emissions but it is hard to tell what values these take for each emission used. If the information presented on this figure could be made clearer then it would improve its use. Perhaps a table might be better?

Page 9, line 198 – “separately” implies that you have performed one a time tests, but I do not think this is what you have done?

Page 9, line 203-204 – If you are varying two emissions at the same time then you are not really separating out their individual impacts. Are there are non-linear effects that need to be considered and mentioned here? Does this impact the use of TransClim when for example a perturbation of NO<sub>x</sub> emissions is applied but the results are based on changes from NO<sub>x</sub> + CO.

Page 10, Figure 5 – I think improving this figure along with the other changes to the methods section would help the understanding of how TransClim works. For example if radiative fluxes are calculated separately then does this need to go in parallel to the other variables on the workflow? Need to put in  $\Delta x$  earlier on work flow diagram. How are the radiative forcings calculated for O<sub>3</sub> and O<sub>3</sub><sup>tra</sup> separately?

Page 11, line 210 – I found the end of this sentence confusing “it is necessary to define an emission scenario as well as a reference scenario to which the emission scenario is compared to.” This is suggesting you are comparing the emissions scenario to itself?

Page 11, line 216 – Could defining the radiative flux due to O<sub>3</sub> as “flxn(O<sub>3</sub>)” be a bit misleading and potentially confused with the actual flux of O<sub>3</sub> concentrations. Would it be better to label it as RadFlxn(O<sub>3</sub>)?

Page 11, lines 216 – 218 – Similar to other points above, I am a bit confused of the double use of O<sub>3</sub> here in the calculations e.g. subtracting flxn(O<sub>3</sub> – O<sub>3</sub>tra) from flxn(O<sub>3</sub>). Please clarify this and in other parts of the manuscript.

Page 11, lines 219-220 – The LUTs are based on the emission variation simulations using EMAC so you could state this here. I assume this is for all variables apart from the radiative fluxes which are treated separately?

Page 11, line 220 – number 8.110.080 needs correcting.



Page 11, line 221 – This is the first mention of CH<sub>4</sub> lifetime which needs further explanation of how it is used as it won't be the same as other variables.

Page 11, line 224 – linearly interpolated between what, the response of a variable to two different emissions?

Page 11, line 225 – Do the LUTs just give  $\Delta x$ ? If so just say this and do refer to earlier. I do not think you need to define it again here.

Page 11, line 229-232 – I am confused about the calculation of radiative forcings. Surely having a reference and perturbation radiative flux with TransClim is sufficient to calculate a forcing? What is the EMAC reference scenario and how is it different to the other reference scenario mentioned? Also how is the additional stratospheric-adjusted forcing different to that defined in the previous sentence?

Page 12, line 244 – I assume Table 2 shows the emission scaling factors applied in TransClim and also in EMAC for evaluation purposes? What about CH<sub>4</sub>?

Page 12, line 244-247 – I agree that this is a good test for TransClim but am disappointed not to see the performance evaluated over other regions (see major comment for more details).

Page 12, Table 2 – A question for these evaluation simulations is how is a LUT generated for Eastern Europe for 1.3 scaling of all emissions whereas the EMAC simulations used to build TransClim for this region (Table S4) only contain reductions? I am not sure how TransClim would work for this type of emission perturbation or similar perturbations across other regions.

Page 12, line 249 – State what O<sub>3</sub> this is.

Page 12, line 255 – Why is there an overestimate over the Mediterranean? Could this be due to the way the experiment in Table 2 has been setup with reduction in O<sub>3</sub> precursors over Southern Europe?

Page 13, line 263-264 – If the southern hemisphere response is not significant and due to very small perturbations then is it worth showing this on Figure 7? Or is it better to show absolute changes? Can you change this Figure to only show the Northern Hemisphere of Europe as in Figure 6 where you would expect the effects of changes in European road

traffic emissions to be more important. Also is the tropospheric O<sub>3</sub> response on Figure 7 the same as on Figure 6, is so why show it twice?

Page 13, line 268-269- This is just for one emission and one region? Are these errors consistent over different emissions and source regions?

Page 13, line 270-276 – Why mention the interpolation and show Figure 8 here? Would this not be better in the methods section instead of the results section? Also I found that stating the interpolation errors are small is a bit misleading, especially when referring to Figure 8. For example the error gets worse if you go from say 1.0 to 3.0 or say 1.0 to 0.0. So it appears that for some emission perturbations errors will increase? I am not sure these are so small (see major comment).

Page 14, line 277 – Underestimation of what?

Page 14, line 278 – TransClim reproduces EMAC results for emission perturbation over this one region

Page 15, line 287-288 – move “The transport demand was determined” to the front of the sentence

Page 15, line 288-289 – change sentence to “Emissions were generated from road traffic, railways and inland shipping as well as passenger and freight transport.”

Page 15, line 292-293 – What do you mean by baseline scenarios? Is 2008 the baseline and 2020 and 2030 the future perturbation scenarios?

Page 15, line 294 – What is the set up for EMAC?

Page 15, line 297-298 - How does future emissions in other European countries evolve? You have said how German emissions change but it is not clear what happened for other countries that will clearly have a different mix and magnitude of transport emissions.

Page 16, line 299-301 – How is the radiative forcing downscaled? Also how are the CH<sub>4</sub> lifetime changes determined?

Page 16, line 306 – How have the emission scaling factors for other regions of Europe been calculated and are these for a particular year?

Page 16, line 306 – Is NO<sub>x</sub> a combination of NO + NO<sub>2</sub> here?

Page 16, line 315 – replace “found” with “transported”

Page 16, line 317-318 – TransClim reproduces the concentrations very well compared to what?

Page 17, Figure 9 – Can you convert some of these concentrations into more useful units e.g. ppb

Page 17, line 320-321 – Yes the emission inventory can make a difference but what about meteorological differences for these future scenarios. Could this also make an impact on the response of the variables in Figure 9?

Page 18, line 323 – Which years?

Page 18, line 325 – Change start of sentence to “TransClim also determines ...”

Page 18, Figure 10 – NO<sub>x</sub> changes not shown on figure

Page 19, line 334 – How much does German road traffic emissions increase by?

Page 19, line 335 – Change sentence to “A decrease in OH occurs in the free troposphere due to German road traffic emissions.”

Page 19, line 336 – Increase in OH due to increase in NO<sub>x</sub>?

Page 19, line 348-349 – What do you mean by downscaling here?

Page 19, line 349-351 – Are these global changes? Sentence Is a bit confusing so please reword.

Page 20, line 355 – is this not just a consequence of scaling the forcing by decreasing future traffic emissions?

Page 20, line 357-360 – How can the radiative forcing due to road traffic emissions be twice as large as the total? I think this needs more explaining and better descriptions of what you mean.

Page 20, line 269-270 – Yes the LUTs do account for the non-linear chemistry but the linear interpolation does introduce errors in this.

Page 21, line 293 – replace “bases” with “based”

Page 21, line 293-294 – also mention tropospheric O<sub>3</sub>

Page 21, line 297 – First time that it has been stated that emissions of 0-200% can be used in TransClim but not sure this has been tested thoroughly.

Page 21, line 211 – Change to “This enables the global and regional atmospheric response to be calculated.”

Page 22, line 414 – change “base” to “are based”

Page 22, line 415-416 – Also meteorological and transport patterns are an issue in different years. Why say that new LUTs need to be created when you use the current set of LUTs for different years and shown that they suitable? This statement is undermining the work presented in the manuscript.

Page 22, line 420 – Change start of sentence to “It is easy to extend ...”

Page 22, line 424-425 – You mention traffic emissions and then quote studies on aviation emissions.

Page 22, line 436- replace "base" with "are based"

Page 22, line 438-439 – What do you mean by "it does not regard the contribution of O<sub>3</sub> precursors" when referring to TM5-FASST? I think TM5-FASST does include the effect of O<sub>3</sub> precursors.

Page 22, line 442 – remove "reliably"

Page 22, line 444 – change "regarded" to "included"

Page 22, line 444-445 – reword sentence