We are most grateful to the referee #2 for the very helpful and encouraging comments on the original version of our manuscript. Here are our replies:

- This paper presents a development of “module” adapted to the climate chemistry model ECHAM5/MESSY in order to calculate the climate impact of aircraft routes. Only one part of the module needed has been included in the model and presented in this paper: the part generating the route and only in the case of great circle (simple) or time-optimal route (optimisation). From these two routing the module calculates fuel use, and some emissions (H_2O and NO_x only), these parameter are assessed with real data. The module is tested over one winter day data over the North Atlantic corridor. In its present form I unfortunately cannot recommend the publication of the paper in Geoscientific Model Development for several reasons that I will be listing. I would strongly recommend the editor to request a severe revision before publication. The time-optimal calculation module may be of interest for modellers. The optimisation module description as well as the size of the population to be included in the optimisation to converge toward optimal time may be presented in a revised paper.

  Reply: We are grateful to the referee #2 for the critical comments and useful suggestions that have helped us to improve our manuscript. As indicated in the responses that follow, we have addressed all the comments and suggestions. We now state in the introduction that this development is a prerequisite for the investigation of climate-optimal routings. So that the motivation for this development is clear. And we are deleting this overall objective from other text passages, since we agree that they are misleading. We will reply to this point in the following (1). As the referee #2 noted, the descriptions of the time-optimal calculation module and the population sizing are included in the revised manuscript, as originally described.

- (1) My first problem is the presentation of the subject within most of the article (title, abstract and even structure of the manuscript). The focus seems to be in the “optimal routing for climate impact reduction” when you check the paper, however the reader is disappointed as the presented module is not doing that at all – only optimising for travel time. The manuscript needs to be reshaped completely to acknowledge that fact.

  Reply: As the referee #2 pointed out, the subject of this paper seems to be confusing. We should make clear that this paper introduces AirTraf submodel in its basic version, technically describes and validates the various components for first, simple aircraft routings (great circle and time-optimal). Eventually, we are aiming at an optimal routing for climate impact reduction. This will be a separate study, which requires a couple of developments beforehand, amongst which the present study is one of them. Here, we would like to make clear that the final purpose of the AirTraf is not to find “fastest routes.” For this, an Earth System Model (ESM) is not necessary. There are even better tools to answer this question. However, to find climate-optimal routes, the global air traffic simulation model coupled to the ESM, i.e. AirTraf submodel, is needed. And of course it has to be described and validated. The validation refers to standard aircraft applications in this paper, such great circle and time-optimal calculations.

  In the revised manuscript, we will revise the title, abstract, introduction and conclusion to be consistent with what is presented in the paper as follows: the title will be revised as, “~~Climate Assessment Platform of Different Aircraft Routing Strategies~~ **Air traffic simulation** in the Chemistry-Climate Model EMAC 2.41: AirTraf 1.0”.

  On page 1, line 9 in Abstract, the text will be revised as, “This study introduces AirTraf (version 1.0) ~~for climate impact evaluations~~ that performs global air traffic simulations on long time scales, including effects of local weather conditions on the emissions.”

  On page 3, final paragraph (line 84 – 87), “~~This study aims to investigate how much the climate impact of aircraft emissions can be reduced by aircraft routing. Here, we present a new assessment platform AirTraf (version 1.0, Yamashita et al., 2015) that is a global air traffic submodel coupled to the Chemistry-Climate model EMAC (Jöckel et al., 2010). Figure 1 shows the research road map for this study (Grewe et al., 2014b).~~ **This paper presents a new submodel AirTraf (version 1.0, Yamashita et al., 2015) that performs global**

air traffic simulations coupled to the Chemistry-Climate model EMAC (Jöckel et al., 2010). This paper technically describes the AirTraf and validates the various components for simple aircraft routings: great circle and time-optimal routings. Eventually, we are aiming at an optimal routing for climate impact reduction. The development described in this paper is a prerequisite for the investigation of climate-optimal routings. The research road map for our study is as follows (Grewe et al., 2014b): ~~T~~**t**he first step is to investigate...".

On page 26, final paragraph (line 870 – 873), "The fundamental framework of AirTraf has been developed to perform fairly realistic air traffic simulations. AirTraf 1.0 ~~is sufficient to investigate a reduction potential of aircraft routings on air traffic climate impacts~~ **is ready for more complex routing tasks**. ~~AirTraf is coupled with various submodels of EMAC to evaluate the impacts, and o~~**O**bjective functions corresponding to other routing options will be integrated soon, and AirTraf will be coupled with various submodels of EMAC to evaluate air traffic climate impacts."

- (2) I am also extremely disappointed in the fact that a part of the paper is dedicated in presenting and comparing "great circle routing" calculations. This is nothing new, and no advance in modelling or science presented. This part should be cut down and re-moved from the discussion. The more important difference could come from the fact the Earth is not a perfect sphere or maybe taking into account flight altitude. The table 4 is comparing calculation with decimal and no-decimal data when the difference is in the decimal value.

Reply: The referee is right that a "great circle calculation" is commonly used method. However, we are hesitating to remove the discussion on that part for the following three reasons.

First, the final purpose of the AirTraf is to investigate "optimal routing for climate impact reduction." We will compare AirTraf simulation results among several aircraft routing options. As a climate-optimized route will be evaluated in the light of the detour that would be necessary to avoid "climate-sensitive" areas with respect to the reference (trade-off), i.e. great circle or time-optimal route. Thus, the great circle routing option is used as reference of our comparisons (note that the great circle is the optimal solution for "minimum flight distance"). In addition, we would like to refer to a future Air Traffic Management system, which aims at having aircraft fly more direct routes, so called user-preferred routes without being constrained to Air Traffic Services routes and waypoints any longer. These future user-preferred routes would be great circle segments in the ideal case (without wind). Hence, AirTraf is developed with the objective to evaluate routing options for the future and the great circle is still an important route in reality. We think that a thorough assessment of the great circle routing module should be made in this paper to demonstrate its ability to generate the routes and working well if coupled to the ESM. The "great circle calculation" is suitable for the validation of AirTraf, because it is the widely used method (the benchmark test of the great circle calculation is described on page 12 – 13, Sect. 3.1.2).

Second, the above-mentioned assessment of the great circle routing module is also indispensable to showing the correct implementation and applicability of the genetic algorithm (GA) approach. Because the validated great circle routing module provides the analytical solution (f_{true} = 25,994.0 s) for the benchmark test of flight trajectory optimization with GA (i.e. the single-objective optimization for minimization of flight time from MUC to JFK). This point is described on page 16 line 530, "...the f_{true} equals the flight time along the great circle from MUC to JFK at FL290: f_{true} = 25,994.0 s calculated by Eq. (23) with h_i = FL290 for $i = 1, 2, \cdots, 101$." That the GA reproduces the analytical solution is an important milestone towards other routing optimizations. The part of the great circle routing module supports the discussion of the flight trajectory optimization with GA. Hence, the description of the great circle routing module should be included in this paper.

Last, we would like to stress that AirTraf submodel, which contains the combination of a routing module (including GA) with an Earth System Model, is unique. That is, the great circle routing module described in the paper is a unique model, which works coupling with the ESM. For example, a flight trajectory consists of waypoints arranged by the waypoint index i ($i = 1, 2, \cdots, n_{wp}$). The geographical and meteorological values, which are used regarding the great circle calculation (e.g. latitude, longitude, altitude, temperature, wind speeds), are provided by the ESM to individual waypoint i. It is important to show correctly how the great circles are calculated through waypoints in the ESM. For this, Eqs. 21 – 27 (on page 11 – 12) include the terms with the index i.

As the referee #2 noted, an influence of the asymmetric nature of the Earth is an interesting topic. However, we think that this is a separate study. On page 5 line 135, we describe the assumption for AirTraf (version 1.0) as, "a spherical Earth is assumed (radius is R_E = 6,371 km)," corresponding to the ESM. On page 11 in section 3.1, Eqs. 22 and 23 present in detail how to take into account the flight altitude in AirTraf. This part is included in the revised manuscript.

In addition, as the referee #2 pointed out, the decimal and no-decimal data are compared in Table 4. This is indeed a very important point, which we completely overlooked. We will revise Table 4: on column 4, "**d_{MTS}, km; 6,481.1; 10,875.0; 16,312.1; 8,895.6; 13,343.4**". On column 6, "**$\Delta d_{eq23, MTS}$, %; –0.0005; –0.0028; –0.0036; –0.0008; –0.0019**". On column 7, "**$\Delta d_{eq22, MTS}$, %; 0.0000; 0.0000; 0.0000; 0.0000; 0.0000**". We will also revise the caption in Table 4 as, "...column 4 (d_{MTS}) shows the result calculated with the Movable type scripts (MTS),~~ which output only integer values~~ **using the Haversine formula with a spherical Earth radius of R_E = 6,371 km**."

Related to this matter, we will revise the manuscript as follows: on page 1 line 18, "The first test showed that the great circle calculations were accurate to ~~within~~ **–0.004 %**...". On page 11 line 354, we will revise the word "Harvesine formula" into "**Haversine** formula." On page 13 line 406, "The results showed that $\Delta d_{eq23,eq22}$ **and** $\Delta d_{eq23,MTS}$ varied between −0.0036 and −0.0008 %, and between ~~−0.0435~~ **−0.0036** and ~~0.0054~~ **−0.0005** %, **respectively, while $\Delta d_{eq22,MTS}$ showed 0.0 %** ~~and between −0.0463 and 0.0046 %~~." On page 13 line 408, "The great circle distances calculated by Eqs. (22) and (23) were accurate to ~~within~~ **–0.004 %**...". On page 25 line 832, "The accuracy of the results was ~~within~~ **–0.004 %**." On page 26 line 876, we will add the text as, "**The authors thank Mr. Chris Veness for providing great circle distances that have been calculated with the Movable type script.**"

- (3) Concerning the "optimisation routing" for flying time the validation over the North Atlantic is interesting but what would happen with a case of congested space or restricted space (military)? Please do tests in different part of the world or at different season.

Reply: We think that the topics, which the referee #2 noted here, are important and interesting. However, we think that they are application studies which would probably use AirTraf, but which are beyond the scope of this technical documentation and first evaluation. The aim of this paper is to introduce, describe and validate the AirTraf submodel, as replied to the comment (1) above. We believe that this paper shows a substantial comparison of AirTraf simulation results to other studies to validate the model.

- (4) Moreover I am unsure of the complete philosophy of the inclusion of the "optimisation" module in the ECHAM5/MESSY model. I understand well the impact of local weather and composition on the impact the aircraft routing will have on climate change. However I am short in understanding the need of the online optimisation as I don't see the effect of "climate optimal routing" on the climate model – would a simple offline calculation not enough to determine this potential "climate optimal routing" (the day the full module will be ready) as well as making the "optimisation" easier to be adapted to other climate-chemistry model output?

Reply: As replied to the comment (1) above, our final purpose is to investigate the mitigation gain of the climate impact by climate-optimal routing. We would like to make clear that it is not our final purpose only to find climate-optimal flight trajectories for a specific weather condition. This was achieved, e.g. in Grewe et al., 2014. We eventually want to go one step further and apply an optimization on a daily basis for daily changing weather situations. To investigate then the mitigation gain, multi-annual (long-term) simulations are required (e.g. for ten years). In the simulations over the ten years, each flight trajectory is optimized with respect to a selected aircraft routing option, considering local weather conditions, and emissions are released. AirTraf can perform such air traffic simulations with the inclusion of the on-line optimization module and the optimal routes will change day by day. We think that the inclusion of the optimization module in EMAC is an appropriate approach for our purpose.

[Reference] Grewe, V., Champougny, T., Matthes, S., Frömming, C., Brinkop, S., Søvde, O. A., Irvine, E. A., and Halscheidt, L.: Reduction of the air traffic's contribution to climate change: A REACT4C case study, Atmospheric Environment, 94, 616–625, 2014a.

- (5) Finally I am unhappy with the fact that the only simple "time optimal routing" (optimising only for one variable) the weather situation if fixed for the entire flight. What would happen in the case of multi optimisation when you have to trade-off between time, fuel use, and different emissions? Could you comment on the impact on contrail formation from long flights? "-For all routing options, local weather conditions provided by EMAC at $t = 1$ (i.e. at the departure day and time of the aircraft) are used to calculate the flight trajectory. The conditions are assumed to be constant during the flight trajectory calculation-"making the model as simple as an offline module but complicated as an inside module of an already complex model?

Reply: In this paper, we would like to confirm whether AirTraf works well and is fit for our purpose. Particularly, the ability of the optimization module (GA) to optimize flight routes must be confirmed. For this, we tested the simple "time-optimal routing." The referee actually points at many interesting future investigations, which are far beyond the scope of this paper. As soon as we really start with climate optimized trajectories in EMAC/AirTraf, we will investigate whether it is necessary to re-optimize the trajectory during long flights. It is clear that a weather forecast, which would be required to optimize not only for time $t = 1$, is not feasible within the climate simulation. To cover all effects, such as NO_x effects, an offline calculation on the other hand is not feasible.

In addition, the contrail formation is one of the important factors on climate impacts. For example, Schumann, et al. 2011 noted in the literature: "…contrails are expected to cause the largest contribution to global radiative forcing of the Earth-atmosphere system, and hence, the largest contribution to aviation-induced global climate change…", and "Contrails and thin cirrus in general warm the Earth atmosphere by reducing terrestrial (longwave, LW) radiation loss into space and may cool the Earth atmosphere by reflecting part of the solar (short-wave, SW) radiation back to space. During night, contrails are always warming. The largest climate impact by contrails comes from thick, wide, long and long-lasting contrails. Hence, with respect to climate, optimal routes during night are those which form contrails with minimum longwave warming. During day time, contrails may cool. This may be the case for thick contrails, over dark and cool surfaces, in particular in the morning and evening times when cirrus is more reflective than during mid day. Hence, with respect to minimum contrail warming impact, optimal routes may be those causing contrails with maximum shortwave cooling."

Those contrail effects will be considered as one of the routing options in AirTraf, by coupling with another submodel of EMAC. AirTraf on-line simulation (coupled to the ESM) is a suited model for taking these complicated effects into account on long time scales and this is a difference from off-line models. In this context, as the referee #2 noted, local weather conditions are assumed to be constant during flight trajectory optimization. We think that this assumption is appropriate to perform such AirTraf on-line simulation for long-term to reduce the computational costs.

[Reference] Schumann, U., Graf, K., and Mannstein, H.: Potential to reduce the climate impact of aviation by flight level changes, in: 3rd AIAA Atmospheric and Space Environments Conference, AIAA paper, vol. 3376, pp. 1–22, 2011.