We are most grateful to the referee #1 for the very helpful and encouraging comments on the original version of our manuscript. Here are our replies:

- Summary: This paper describes a new model which will eventually be used in calculating the climate impact of aircraft routes. There are several different parts to the model, which are detailed in the paper, including generating the route either by calculating a great circle or time-optimal route (the two constraints which are described and tested here), calculating the fuel use along the route, and the emissions for example of water vapour and NO_x along the route. A thorough assessment is made of the model and its ability to generate the routes and calculate the various parameters; the model performs well and appears to be fit for purpose. The paper is generally clear and the different components of the model are well-described. My only major concern regards the vertical flight profiles, please see the major comment below. I recommend the paper for publication after revision.

  Reply: We thank the referee #1 for these positive comments. We will reply to your major concern regarding the vertical flight profiles in the "General comment" section.

- General comment: In the calculation of the time-optimal flights, the flight altitude is allowed to vary freely between FL290 and FL410. Some of the resulting time-optimal flight profiles display significant altitude changes during the flight, as shown in Figure 14 (b), where the flight altitude profile along the flight is 'm' shaped (i.e. increases, decreases, increases and then decreases again). This is in contrast to the familiar stepped profiles, where the aircraft altitude increases are done as step climbs when enough fuel has been burned off, or alternatively a gradual increase in height to a maximum cruising altitude, followed by a descent. It is difficult to see how (or why) an aircraft would do this 'm' profile in real life, given air traffic constraints, for example. Given how unusual these profiles are, some justification or explanation for why these profiles are allowed in this study should be given, as well as a comment on how realistic it would be for an aircraft to fly this profile.

  Reply: In this paper, we have confirmed that the 'm' shaped flight profile effectively takes advantages of the wind fields and leads to the time-optimal solution (please see on page 20 line 647 – 657).

  As the referee #1 pointed out, AirTraf allows aircraft to vary flight altitudes freely between FL290 and FL410. Here, the AirTraf submodel is used to investigate an optimization strategy of aircraft routing for minimizing the climate impact of aircraft emissions and to show its mitigation gain for the future. The regions with high climate impacts, e.g. regions where contrail form, are often very shallow (vertically). In order to investigate how such regions can be avoided more flexibility in the routing options is required. Hence, in this approach it is necessary for aircraft to have a high flexibility for flight profiles to explore widely the possibility of minimizing climate impact by aircraft routing.

  If the optimization strategy is found, it will be proven by a more realistic air traffic simulation model, considering realistic air traffic constraints. The "m" shaped flight profile will be modified to adapt to the constraints (probably stepped profiles). The development of the realistic air traffic simulation model is addressed by research groups of DLR-Hamburg and DLR-Braunschweig in the DLR Project WeCare.

  We will add this information in the revised manuscript: on page 14 line 472, "Here x_7 to x_{11} indicate altitude values**; these values vary freely between FL290 and FL410 to explore widely the possibility of minimizing climate impact by aircraft routing.**"

  Further, we will add the text: on page 19 line 635, "..., while that for west-bound showed large altitude changes, i.e. it climbed, descended, climbed and **then descended** again."

- Minor comments:
  (1) p3 L61 – the Spichtinger et al (2003) study referenced by the authors analyses the vertical distribution of ice-supersaturated regions. The mean length of 150 km is from Gierens and Spichtinger (2000), as stated in

the Spichtinger paper.

Reply: Thank you very much. We will refer the paper in the revised manuscript: on page 3 line 61, "... extend a few 100 m vertically and around 150 km horizontally with a large spatial and temporal variability (**Gierens et al., 2000,** Spichtinger et al., 2003)." We will also add the paper to References in the revised manuscript: on page 27, "**Gierens, K., and Spichtinger, P.: On the size distribution of ice-supersaturated regions in the upper troposphere and lowermost stratosphere, Annales Geophysicae, vol. 18, No. 4, 499–504, 2000.**"

- (2) p3, final paragraph (L84 – 99). As I understand it, the aim of the study presented in the paper is to introduce, describe and validate the AirTraf model, not to investigate 'how much the climate impact … can be reduced by aircraft routing' – that is a separate study which would use AirTraf. This paragraph is therefore confusing to the reader, and there is extra detail here which is not all necessary to understand this paper. Please rephrase the aims of the study to be consistent with what is presented in the paper, remove unnecessary detail about future studies and I also suggest removing Figure 1 which is not needed here.

Reply: As the referee #1 noted, this paragraph is confusing. On the other hand, we think that the information of this paragraph is helpful for readers to understand the motivation and background for the AirTraf development. To improve the manuscript, we will remove Fig. 1 and rephrase the aims of this study: on page 3, final paragraph (line 84 – 99),

"**This paper presents 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). Here, we describe the AirTraf in detail and validate it. The AirTraf will eventually be used to investigate how much the climate impact of aircraft emissions can be reduced by aircraft routing. The research road map for our study is as follows (Grewe et al., 2014b).** The first step is to investigate ...".

- (3) p4 L121, p5 L159 and caption of Figure 3 – "one-day flight plan". It is not clear what you mean by this phrase (it sounds like you are referring to a single flight on a single day, rather than many flights on a single day). It would be helpful to give a short description the first time you use the phrase.

Reply: We will add the text in the revised manuscript: on page 4 line 121, "As shown in Fig. 3, the one-day flight plan**, which includes the flights of a single day,** is decomposed for a number of processing elements (PEs)."

- (4) p4 L126 – "AirTraf continuously treats overnight flights". What does this mean?

Reply: Some international (long-distance) flights fly over two days. For example, NH215 departs at MUC on 21:35 and arrives at Tokyo on 15:50 + 1day. AirTraf can simulate the flight correctly. We will rewrite the text in the revised manuscript: on page 4 line 125, "Thus, naturally short-term and long-term simulations consider the local weather conditions for every flight in EMAC (AirTraf continuously treats overnight flights **with arrival on the next day**)."

Further, from the referee #3 comment on "p 4, l 126 – 127", the text of the sentence "(AirTraf continuously treats overnight flights **with arrival on the next day**)" will be moved from the current position to an appro priate position in the manuscript, which is related logically: finally, on page 4 line 125, "Thus, naturally short-term and long-term simulations consider the local weather conditions for every flight in EMAC (AirTraf con tinuously treats overnight flights with arrival on the next day)"; and on page 7 line 225, "pos_{new} and pos_{old} are stored in the memory and the aircraft continues the flight from pos_{new} = 2.3 at the next time step **(AirTraf continuously treats overnight flights with arrival on the next day)**."

- (5) p7 L201 – "local weather conditions provided by EMAC". Specifically, the wind field is used?

Reply: Specifically, temperature and wind fields are used here to calculate a flight trajectory. On pages 6 – 8

in section 2.4, we describe the overview of calculation procedures briefly. Thus, we describe on page 7 line 201 as, "For all routing options, <u>local weather conditions provided by EMAC</u> at $t = 1$ (i.e. at the departure day and time of the aircraft) are used to calculate the flight trajectory."

In the following section, this trajectory calculation method is described in detail. For great circle routing option, on page 12 line 375 in section 3.1.1, "Temperature T_i and three dimensional wind components (u_i, v_i, w_i) of the ith waypoint are available from the EMAC model fields at $t = 1$." For the time-optimal routing option, on page 15 line 487, "... where d_i and $V_{ground,i}$ are calculated by Eqs. (23) and (25), respectively ($V_{TAS,i}$ and $V_{wind,i}$ are calculated as described in Sect. 3.1.1)."

- (6) p8 L260 – You assume that the sum of the alternate, reserve and extra fuel is 3% of the total fuel. Is there any justification for this number? I acknowledge that this kind of data is almost impossible to get from airlines, but have other studies used a similar number, for instance?

  Reply: According to general fuel planning regulations, e.g. JAR-OPS 1.255[1], an additional 3% of the total fuel is considered as contingency fuel in the fuel planning assuming an en-route alternate aerodrome can be found on any mission whereas alternate, final reserve, additional and extra fuel are neglected as their contribution to the overall fuel amount is very small on long-haul flights. Although the fuel planning process of Air Traf, which is described on page 8 – 9 in section 2.5, is not exactly the same as JAR-OPS 1.255, the 3% assumption (calculated by Eq. (2) on page 8) as the entire reserve fuel is not far from reality.

  Further, we will delete the sentence related to this matter: on page 8 line 265, "**A refined fuel estimation will be employed for calculating m$_{nwp}$ in future.**" will be deleted in the revised manuscript, since the sentence is not necessary for our argument here.

  [1] The Joint Aviation Authorities Committee, "Joint Aviation Requirements: JAR-OPS 1, Commercial Air Transportation (Aeroplanes)", 1-D-4.

- (7) p20 L647 – 656. The explanation of why the flight altitude profiles are optimal is that the flight changes altitude to benefit from changes to the true airspeed and to increase its tailwind or reduce its headwind. The argument is currently not well supported by the figures (Figure 16, and S5 and S6) which show the altitude distribution of the true airspeed and tailwind indicator. The variations in these quantities at flight altitude are hard to see, since the vertical scale on the plots is 0 – 15 km. The case might be made much clearer simply by re-plotting these figures with a limited altitude range (i.e. only plot the range of altitudes relevant to the aircraft), and re-scaling the colour bar.

  Reply: We think that the referee's suggestion is right. On this matter, we have a reason why we used the vertical scale on the plots as 0 – 15 km. In Figs. 16, S5 and S6, we would like to show clearly that we start with the trajectory at FL290 and concentrate on the cruise mission only. In fact, we optimize flight trajectories within the general cruise flight altitude of commercial aircraft in [FL290, FL410], as shown in Fig. 7 (top), and the altitude of the airports are located at FL290 (not ground at 0 ft). We have seen situations many times that people assumed the start/end point of the time-optimal flight trajectories (in Fig. 16) as "the ground at 0 ft," when we plotted the same results in the range of altitude relevant to the aircraft. To avoid this situation, we plotted these figures in 0 – 15 km including the ground (just like Figs. 9, 14 and 18).

- (8) p22 L727 – 729 and Figure 22. "The maps show the time-optimal case has low values of the fuel use" (compared to the great circle case). The great circle case at FL290 clearly has a lower fuel use, as shown in Table 11. However, I do not think this is clear from Figure 22; the flights in the time optimal case are spread over a larger area than in the great circle case therefore it is difficult to assess objectively whether the fuel use is higher or lower in the time-optimal case. I do not think that this figure adds any weight to your argument. I suggest removing it.

  Reply: As the referee #1 suggested, we will remove Fig. 22 in the revised manuscript. In addition, we

will remove the sentences related to Fig. 22: on page 22 line 726 – 729, "**To confirm this intuitively, Fig. 22 shows the global distribution maps of the fuel use (in kg(fuel)box−1s−1, 2 hour averages) for these cases. The maps show that the time-optimal case has low values of the fuel use.**"

- (9) p25 L824. I cannot find AirTraf or any status information for it on the list of submodels on the MESSy website (accessed on 24/02/2016).

  Reply: On the basis of the MESSy Consortium Steering Group Policy, a status information for a new submodel is generally provided on the MESSy website after its publication. Nevertheless, we have provided the status information for AirTraf on the website. In the revised manuscript, we will rephrase the sentence related to this matter: on page 25 line 824, " The status information for AirTraf including the licence conditions **is** ~~will be~~ available at the website."

- (10) Figure 15, 16, S4 – S6 – Please add units to the colour bar and/or text.

  Reply: Thank you very much. We will add units in the captions for Figs. 15, 16, S3 – S6. In Figs. 15, S3 and S4, we will add the unit in the captions as, "The contours show the zonal wind speed (u **in ms^{-1}**)." In Figs. 16, S5 and S6, we will add the unit in the captions as, "Altitude distributions of the true air speed V_{TAS} **in ms^{-1}** (a and b)." The wind indicator is dimensionless quantity.

- (11) Table 8. It is difficult to compare the flight time for the time-optimal with the great circle at different altitudes, since the mean flight altitude of the time-optimal flights is given in m and the altitude of the great circle flights in feet. Please add either the mean flight altitude in feet for the time-optimal flights, or the flight altitude in m for the great circle flights to aid the comparison.

  Reply: Thank you very much. In the revised manuscript, we will add the mean flight altitude in feet for the time-optimal flights on column 6 in Table 8: "Mean flight altitude h, m **(in ft)**; 8,841 **(29,005)**; 8,839 **(29,000)**; 8,839 **(29,000)**; 10,002 **(32,815)**; 10,829 **(35,527)**; 9,311 **(30,546)**."

- (12) Table 11, Caption. 'sum of flight time, fuel use, NO_x and H_2O emissions...'. This implies that the table shows the quantity flight time + fuel use + NO_x + H_2O, when in fact they are displayed separately. Please rephrase.

  Reply: Thank you very much. In the revised manuscript, we will remove the word "**Sum of**" from the caption: on page 59 in Table 11, we will rewrite the caption as "**Flight time, fuel use, NO_x and H_2O emissions for the time-optimal and the great circle cases**…".