Review of
Climate assessment platform of different aircraft routing strategies in the chemistry-climate model EMAC2.41 : AirTraf 1.0

March 7, 2016

1 Introduction

The manuscript is well structured, and different aspects of AirTraf are explained by a nice equilibrium of description and examples. The motivation of the work is reasonably well explained. Figures and tables are informative. There is a substantial comparison with results from other studies to give confidence in the results obtained here.

Implementing aircraft routing strategies in a general circulation model or a numerical weather prediction model is not an easy task. Arriving at the status as described here in the manuscript is already a considerable achievement. However, as the tool is not finished, one wonders whether it is useful to describe the tool in its current status (with only 2 of the 7 optimization options implemented, fuel consumption due to climbing not included, the meteorological fields in the optimization are the ones at the start of the flight, ...).

Publishing the manuscript now shows the status of the work. It makes clear that for specific options the optimization works, and it can trigger discussion with other researchers/institutes on the approaches chosen (is the optimization working well, could other optimization routines be faster, ...).

I think the manuscript is worth publishing, but is should be considerably improved in several ways. A list of principal remarks is given below, followed by a list of more specific comments. I hope the authors will take them into consideration, and if not give a sound argumentation why they do not.

2 Principal remarks

Work in progress The manuscript describes a submodel in MESSy which works, but is not finished yet (only 2 of the 7 optimization options are in place). Why not waiting until all the work is finished? One has to guarantee that this manuscript remains valid and worth all the work once the remaining parts come into place, and that this document is therefore worth publishing.

Language There is a lot of improvement needed for the language. The use of articles (a/an/the/none) should be improved. Specific expressions (e.g., "trajectories as longitude vs altitude, trajectories as location" or "number of n_p", ...) should be modified.

CP in trajectories Concerning the treatment of CP points, I have several questions.

- As an example, 3 CPs have been used for the geographical location, and 5 for the altitude. Is this fixed? Do all flights use the same number of CPs?

- For the 103 flights, which were primarily zonal, rectangles around the CPs could be described by using a range in latitude and longitude. How is the choice around the CPs when flights cross the equator, e.g., at an angle of 45°? What if flights go from low to high latitudes and defining regions whit fixed ranges in longitude makes them very different in size?

- For a given trajectory (which is a B-spline curve), how are the waypoints found? Are they equally spaced along that trajectory between the CPs? I am wondering whether it is possible to find explicit expressions for equidistant waypoints on a B-spline curve?

- In the example used, 3 CPs were used for the geographical location, 5 CPs for for the altitude, and 101 waypoints. However, the condition $(101-1)\mathrm{modulo}(5+1) = 0$ is not fulfilled. One also gets the impression

that the waypoints for the altitude and longitude are not located at the same place (although the manuscript confirms it actually is). Could this be clarified?

GA algorithm This algorithm is explained to some detail, but I suggest that all terms used should be explained to some extent (e.g., mating pool). One should also be informed on how the final solution is derived from the population in the last generation. Finally, the abstract uses some terminology related to the optimization routine (e.g., population), which are too technical to be mentioned in the abstract.

Abstract, introduction, conclusion The abstract is sometimes too much a summing up of what has been done, with vocabulary/terms which have no concrete meaning without a concrete context. There is also much more overlap between these three parts (abstract, introduction, and conclusion) than needed. The abstract should be written differently, and considerably improved.

Sensitivity In the approach followed here, quite some assumptions and simplifications are introduced. It would be useful to give the reader an idea of the impact of these assumptions on the results. A list of some of the assumptions is :

- line 274 : $dh(t)/dt = 0$ in Eq. (270).
- M is set constant. Can this be varied slightly? Or have pilots only a very small envelope of allowed or possible speeds?
- What if weather not just from $t = 1$ is taken, but from the whole period of the flight?
- Leaving out the ascent and descend phase of the flight : how does this impact the optimization?

Mathematical formulas The mathematical expressions should be improved.

- In mathematical formulas, variables longer than one letter should be written straight.
- A lot of indices should be straight letters : V_{ground}, V_{wind}, ...
- After every equation, there should be a ”,” or ”.”, depending on the function of the equation in the sentence.
- Names of trigonometric formulas should not be italic : sin, cos, ...

Climate model, long/short time scales Why is this tool implemented in a climate model? To my opinion, the tool could also have been build such that it uses off-line 3-hourly meteo fields over the range of time it has flights which should be optimized : one thinks over a range of 1 to 10 days. The meteo data might come from a NWP, or a climate model.

Maybe the authors want to show that it is possible to have such a tool on-line in a NWP or GCM. However, in that case, I would have chosen for a NWP as that is the place where, if the tool is operationally used, might be most appropriate. What was the reason that the authors made the choice of implementing it in a climate model?

A reason I can imagine is that one could do tests like : how would the optimal routing be in a year 2100 climate, when global climate is considerably different from nowadays?

Benchmarks Is proving that the great circle option works well worth publishing and/or mentioning in an abstract? In addition, I think that the word benchmark puts more importance on a test than it actually deserves.

Size of the document The files are so large (30 MB) that people will have problems printing the documents. To my opinion it is mainly related to the figures which show different flight trajectories. I assume that the figures contain all the information from all trajectories, while a large central part of the figure is just black. These figures should be made in such a way that they become much smaller in size, without loosing their precision.

3   Comments on the text

Page 1

p 1, l 1–5 : The sequence of the first three sentences is a bit strange. I would even skip the first sentence (as it says the same as the first 7 words of sentence 3).

p 1, l 3–6 : ”building a climate-friendly”, ”for a sustainable development”, ”is an important approach”. It makes me wonder whether this is not a too optimistic view on aviation.

p 1, l 9 : "stable" gas. This is not precise enough.

p 1, l 9 : "vary regionally". I would rather use something like "inhomogeneous distribution".

p 1, l 11 : "on long time scales". I assume that the tool takes into account climate impacts on long time scale, via e.g. the CCFs. However, the tool itself is an optimization of only the flights planned within the next few days. There should be no confusion about these very different aspects.

p 1, l 15 : were → are (because you describe the functioning of a tool).

p 1, l 15 : DLR. This abbreviation should be explained.

p 1, l 16–17 : "with respect to routing options" : vague.

p 1, l 17–18 : "two benchmark tests ... for great circle and time routing options" : sounds a bit strange → "benchmark tests ... for the great circle and time routing options".

p 1, l 19 : "by other published code" : vague, and inappropriate language for an abstract.

p 1, l 20 : "optimal solution" → "optimal solution found by the algorithm" (distinguish whether it relates to the real optimal solution, or to the best estimate found by the optimization routine).

Page 2

p 2, l 22 : "initial population" : as such, this is too technical for an abstract. I suggest to skip this from the abstract, or one could also choose to describe a bit better the optimization algorithm/methodology in the abstract.

p 2, l 22–23 : "We found that the influence was small (around 0.01 %)" : I suggest to combine this into one sentence with the former sentence.

p 2, l 24 : "function evaluations", "generation sizing" : too technical for an abstract.

p 2, l 27 "one-day AirTraf simulations are demonstrated ..." : vague.

p 2, l 27 : specific winter day → typical winter day.

p 2, l 29 : "for the two options" : it is a long time ago that these were mentioned. So maybe express them explicitly again.

p 2, l 30 : for all airport pairs : too vague for an abstract.

p 2, l 30–31 : "reflecting" local weather → taking into account (?).

p 2, l 31 : verified → confirmed.

p 2, l 32 : "comparable to reference data" : too vague.

p 2, l 34 : "with increasing the number " → "with the increasing number".

p 2, l 35 : "a major problem" : too vague.

p 2, l 35 : "At present" → Nowadays, currently, ...

p 2, l 35–37 : aircraft emission impacts contribute 4.9% of total anthropogenic radiative forcing : skip "impacts", as radiative forcing is an impact; 4.9 → to 4.9 ; of total → "of the total".

p 2, l 39 : will grow → might grow.

p 2, l 40 : the value of 4.9% → a value of 4.9%.

p 2, l 41 : indicates → implies.

p 2, l 41–42 : "and therefore environmental impacts from aviation increase" : try to avoid to have twice "increase" in this sentence.

p 2, l 42–43 : This sentence sounds more positive than one can possibly defend.

p 2, l 47 : contrail → contrails.

p 2, l 49 : depends → depends partially.

p 2, l 49–51 : What follows behind the ":" is not an explanation from what is said before ":".

p 2, l 50 : geographic → geographical (both are possible).

p 2, l 51 – p3, l 59 : "... and affect the atmosphere from minutes to centuries." Minutes probably refers to the time scale for disappearance of some chemical perturbations. However, every appearance (even if it is only a few minutes) of a GHG, has a century-timescale effect. Although I think I understand what the authors want to say, I think that the whole paragraph is rather inaccurate, and should be rewritten more precisely.

Page 3

p 3, l 61 : "150 km horizontally" : maybe distinguish two directions (is it perpendicular to the flight path, or along the flight path). Isn't this 150 km much too specific? Isn't there a very broad spectrum?

p 3, l 63 : There "are" two options ... : this sounds very optimistic.

p 3, l 64 : "approaches" → measures.

p 3, l 69 : "... are optimized with respect to time and economic costs." : if both are taken into account, how are they weighted?

p 3, l 69 : "fuel, crew, operating costs" : isn't fuel part of the operating costs?

p 3, l 72 : "systematic routing changes" : reading this, one gets the impression that there are different options. However, later it is reduced to just "i.e. flight altitude change". I suggest to just say "systematic flight altitude changes".

p 3, 74 : has a strong effect on the reduction of the climate impact → has a strong impact on climate. (From the original formulation it is not clear whether the increase or the decrease in flight altitude leads to a reduction of the climate impact.)

p 3, l 74–77 : "the" climate-optimized routing → climate-optimized routing.

p 3, l 79 : "the" climate sensitive regions → climate-sensitive regions.

p 3, l 80 : "This study" → "That study".

p 3, l 81 : by only small increase → by only a small increase.

p 3, l 80–81 : This study reported: "large reductions ..." → That study reported that large reductions ...

p 3, l 82 : useful : is useful what one wants to express?

p 3, l 85–86 : The current study wants apparently to investigate something (how much the climate impact of aircraft emissions can be reduced) that already has been investigated before (see lines 80–81 : large reductions in the climate impact of up to 25% can be achieved). One should be more specific of what the current study will do extra with respect to the former study.

p 3, l 84–87 : Do you mean by "this study" = "this manuscript"? Or is "this study" broader? After reading the manuscript, I have the impression that line 84–85 is not what is answered by this manuscript.

p 3, l 87 : The first step "is" → The first step "was".

p 3, l 87–89 : The first step is to investigate specific past weather situations, in particular the climate impact of locally released aircraft emissions → The first step was to investigate the influence of specific weather situations on the climate impact of aircraft emissions.

p 3, l 89 : "The resulting data are ..." : too vague. Maybe one could say : "This results in climate cost functions ...".

p 3, l 91 : Why is CO_2 in this list? I can understand that the impact of adding CO_2 depends on the altitude, but this comes a bit unexpected after formulating earlier that CO_2 is well-mixed.

p 3, l 91 : "They are specific climate metrics, i.e. climate impact per unit of emission" → "per unit amount of emission."

p 3, l 92 : "and are used ..." → "will/might be used".

Page 4

p 4, l 92 : "In a further step, weather proxies are identified for the specific weather situations." It is not clear whether this has been done.

p 4, l 102–104 : "A benchmark test for the great circle routing option is performed and ..." : the part before and after the "and" actually express more or less the same.

p 4, l 103 : "by other published code" : too vague.

p 4, l 103–104 : "Another ... also ..." : I suggest to skip one of these words.

p 4, l 103–105 : I would transform this into one sentence.

p 4, l 105–106 : This sentence is too technical with "population" and "generation sizing".

p 4, l 107 : "consistency" is too general. One has not enough background information at this point in the text to understand this.

p 4, l 108 : "states" : I suggest to use another word.

p 4, l 112–116 : This paragraph should be rewritten.

p 4, l 112 : "reasonable" : I think this is not enough as a motivation.

p 4, l 113 : "because we perform global air traffic simulations on long time scales considering local weather conditions." : I think this is a vague argumentation.

p 4, l 114 : "geographic location and altitude at which emissions are released should be also considered" : vague.

p 4, l 115 : This is maybe the main reason why the effort is done to implement AirTraf in a climate model, and not just in a NWP, or using off-line available weather forecasts. So make this more explicit, and give examples of which climate impacts can be evaluated.

p 4, l 117 : Explain what "entries" are.

p 4, l 121–124 : This sentence should be improved. You have to put "here PE is synonym to MPI task" possibly between brackets. I am also not sure whether "while" is the most appropriate word to use here.

p 4, l 125 : I think one should be more specific about what a "time loop" is : isn't rather meant "time step"?

p 4, l 125–126 : Thus, naturally short-term and long-term simulations consider the local weather conditions for every flight in EMAC. I think this should be explained more clearly.

p 4, l 126–127 : "(AirTraf continuously treats overnight flights)" : this is not logically related to the sentence it is attached to. What is meant by this? Because the weather patterns used in AirTraf are the ones at the time of take-off, it seems to me that there is no large complexity about it. Is it therefore still worth mentioning?

Page 5

p 5, l 131–132 : What is meant by these "global fields"? Give examples.

p 5, l 132–134 : What is meant by the sentence "Other evaluation models ... on the climate impact"? I suggest to make this more concrete.

p 5, l 135–136 : "R_E=6371 km" : I don't know whether this level of detail should be mentioned in the manuscript.

p 5, l 137–138 : The Mach number is a ($\rightarrow$ "the") velocity divided by a ($\rightarrow$ "the") speed of sound.

p 5, l 138 : "true air speed" $\rightarrow$ "the true air speed". Maybe add to the sentence : "When an aircraft flies at a constant Mach number". Isn't "vary along flight trajectories" enough? I don't think that "latitude, longitude, altitude and time" should be added. If one really wants to be more specific, I would rather add temperature and wind speed as factors modifying the true air speed and ground speed.

p 5, l 142 : limits rates $\rightarrow$ limit rates.

p 5, l 142 : Explain "semi-circular rule", and "sector demand analysis".

p 5, l 144 : "mention" : I do not think this is the appropriate wording.

p 5, l 149 : What is meant by "interactions with human influences"?

p 5, l 153 : T42L31ECMWF-resolution $\rightarrow$ T42L31ECMWF resolution

p 5, l 159 : Can it exist out of more than one day? On page 6, line 163 : "Any arbitrary number of flight plans is applicable to AirTraf". So one can give flight plans for many days at once?

p 5, l 160 : of A330-301 $\rightarrow$ of an A330-301 aircraft.

p 5, l 162 : a departure time $\rightarrow$ the departure time.

p 5, l 162 : as values [-90,90] $\rightarrow$ as values in the range [-90,90].

Page 6

p 6, l 164 : the data are required $\rightarrow$ these data are required.

p 6, l 165 : "As for ..." $\rightarrow$ "Concerning ...".

p 6, l 166 : flows (plural) while index (singular).

p 6, l 168 : What is meant by an "overall" weight factor?

p 6, l 171 : are described "here" step by step.

p 6, l 172 : a flight status $\rightarrow$ the flight status.

p 6, l 178 : moving aircraft position $\rightarrow$ aircraft position calculation.

p 6, l 182–183 : differ to $\rightarrow$ differ from.

p 6, l 184 : can be used $\rightarrow$ can currently be used.

p 6, l 187 : for a selected option $\rightarrow$ for the selected option.

p 6, l 191–194 : Why adding these sentences? It makes the text confusing. In addition, it is not well defined how an optimization might work when one optimizes according to two criteria (time and cost). One should also mention then how to weight or compare both (trade-off between them).

p 6, l 197 : The CCF is $\rightarrow$ The CCFs are.

p 6, l 199 : "total" climate impacts versus "some" aviation emissions : this sounds strange.

Page 7

p 7, l 211 : $n_{wp-1} \to n_{wp} - 1$.

p 7, l 212–213 : calculation/calculation/calculate : try to vary the wording more.

p 7, l 218–219 : corresponding to time steps $\to$ corresponding to "the" time steps.

p 7, l 219–220 : "present" and "previous" is a bit vague : isn't it the position at the beginning of a time step of EMAC, and at the end of a time step?

p 7, l 220 : "a" present and previous position $\to$ "the" present and previous position.

p 7, l 221 : by real numbers of the waypoint index $\to$ by real numbers as a function of the waypoint index.

p 7, l 224 : I would rather say : "This means that the aircraft moves 100% of the distance between $i = 1$ and $i = 2$, and 30% of the distance between $i = 2$ and $i = 3$ in one time step."

p 7, l 233 : is used $\to$ are used.

p 7, l 233 : This is a little bit inaccurate (see also Fig. 4). Assess the impact of this inaccuracy.

Page 8

p 8, l 237 : "If $t \geq 2$ of the day" : express this better.

p 8, l 239 : without recalculating flight trajectory and fuel emissions $\to$ without recalculating the flight trajectory or fuel emissions.

p 8, l 240–241 : "For more than two consecutive days simulations" $\to$ "For simulations longer than two days".

p 8, l 243 : Twice "calculation".

p 8, l 246 : are used $\to$ is used.

p 8, l 246–247 : the first trip fuel estimation $\to$ a first trip fuel estimation.

p 8, l 247 : the second fuel calculation : a bit vague. Maybe mention that it is more detailed.

p 8, l 256 : mean flight altitude of the flight $\to$ mean altitude of the flight.

p 8, l 260 : it is assumed as $\to$ it is assumed to be.

Page 9

p 9, l 274–275 : "For an aircraft in cruise ..." : express this better.

p 9, line 276–278 : One should have a "," or a "." after most of the formula.

p 9, line 280 : The numerical value of ρ_i is not given in Table (2) (as for S, C_{D0} and C_{D1} in Table 1).

p 9, l 281 : a fuel flow $\to$ the fuel flow.

p 9, l 282 : I suggest to skip "for jet aircraft".

p 9, l 283–284 : "," after the equations.

p 9, l 287 : Oneday : I suggest to find another name for this variable in the manuscript. In addition, its units in Table 1 should be "sec day^{-1}".

p 9, l 289 : "reflects" $\to$ "incorporates" or "is impacted by".

p 9, l 290 : $(m) \to (m_i)$.

p 9, l 294 : next to the last $\to$ at the one but last.

p 9, l 296–297 : I do not think this last sentence gives new information. Or formulate it nicer.

Page 10

p 10, l 302 : first → First.

p 10, l 310–311 : corresponding sea level values → corresponding values at sea level.

p 10, l 314–315 : ”,” after equations.

p 10, l 327 : ”... and q_i is the specific humidity at h_i” : mention units of q_i ($\mathrm{kg\,kg^{-1}}$, $\mathrm{g\,kg^{-1}}$, ...).

p 10, l 329 : pre-calculated → calculated.

p 10, l 330–331 : ”,” after equations. I do not think it is a good idea to have variables whit names as $NO_{x,i}$ and H_2O_i. I would rather use names like m_{NO_x}.

Page 11

p 11, l 339 : one-day → one day of.

p 11, l 343 : works → works only.

p 11, l 351 : arctan, sin, cos, ... should not be italic.

p 11, l 351 : ”,” after equation.

p 11, l 362 : Why mentioning ”km” here? Better to write on line 355 : d_i (km).

p 11, l 363 : i.e. the → i.e.

p 11, l 365 : ”based on Polar coordinates”? Explain this better.

p 11, l 365 : therefore → in that case.

Page 12

p 12, l 370 : of the i-th waypoint → at the i-th waypoint.

p 12, l 371–372 : ”,” after equations.

p 12, l 374 : where M is ”the” Mach number.

p 12, l 378–379 : Although it is mentioned that V_{TAS}, V_{wind} and V_{ground} are scalars, Eq. (25) on line 372 is actually a vector equation.

p 12, l 386 : ”reflects” : this is not the only aspect which is reflected. I suggest to use ”incorporates”.

p 12, l 390 : for the five → for five.

p 12, l 393–395 : 180 → 180° (while ”deg” on line 397).

p 12, l 398 : Missing deg?

p 12, l 399 : ”;” → ”,”.

Page 13

p 13, l 403 : varying n_{wp} in "the range" [2, 100].

p 13, l 404 : and the MTS → and MTS.

p 13, l 406 : I do not think that $\Delta d_{\mathrm{eq23,eq22}}$, etc. are appropriate choices for variable names. As these are difference, I think they should not not have a specific variable name attributed.

p 13, l 409–410 : "shows" versus "showed".

p 13, l 413 : I would not call it linear interpolation : one goes straight whereas the other follows an arc. Shouldn't you also add that n_{wp} maybe should depend on the length of the flight?

p 13, l 417 : with respect to the flight time routing option → with respect to the flight time.

p 13, l 418 : algorithms → algorithm.

p 13, l 422 : The ARMOGA → ARMOGA.

p 13, l 424–425 : With a routing option → For each routing option (except ...). I also suggest to skip "on the selected routing" in the second part of the sentence.

p 13, l 427 : Explain what an objective function in this context is.

p 13, l 432-433 : "Is called "an" optimal solution" and "is called "the" true-optimal solution".

p 13, l 434 : Say what is meant by converge : larger initial population, or just more generations?

p 13, l 435 : Will every flight have the same size for its initial population, and the same number of generations? Is that independent of the length of the flight?

Page 14

p 14, l 440–441 : I do not think that "definitions" is the appropriate word to be used here.

p 14, l 441 : of objective functions → of the objective function.

p 14, l 444 : used interchangeably to mean a flight trajectory → used interchangeably to flight trajectory.

p 14, l 445 : $n_{dv} = 11$ should not be here.

p 14, l 456 : centering → centered.

p 14, l 463–464 : how are these waypoints calculated? Will the arc lengths be equal?

p 14, l 458–459 and 470–471 : "GA provided the values" : Do you mean already the final optimal values?

p 14, l 462 : Explain a little bit more a B-spline curve.

p 14, l 464 : Are the waypoints on the B-spline curve still equidistant?

p 14, l 461 and 472 : "Here x_1, ... indicate longitudes/latitudes/altitude values". Shouldn't this be mentioned earlier in the paragraphs, i.e. on lines 452 and 466?

Page 15

p 15, 477 : where longitude-coordinate of waypoints → where "the" longitude of the waypoints.

p 15, l 476–478 "where longitude-coordinate of waypoints is the same for the two curves." Is this true in the example here? The lon-lat curve contains 3 CPs and thus 4 intervals. The the lon-altitude curve contains 5 CPs and 6 intervals. The number of waypoints is 101, so 100 intervals. This is however not a multiple of 6, so I don't see that the longitude of the waypoints for both B-spline curves are automatically identical.

p 15, l 479 : "provides initial values by random numbers" : this is too cryptic.

p 15, l 481 : "The operator creates divers solutions defined by a fixed population size n_p." : This is a complicated way to say : "The operator creates n_p different solutions (where n_p is the population size)."

p 15, l 481 : "a random set" : do you mean the random set which is just described (then I suggest to use "the"), or is it even another random set? I would put the sentence "GA starts it search with a random set of solutions (population approach)" at the beginning of the paragraph.

p 15, l 483 : By summing the flight time for flight segments → by summing the flight time over all flight segments.

p 15, l 483–484 : "The .. optimization solved here" : too cryptic and vague.

p 15, l 485 : "Minimize" and "Subject to" should not be italic.

p 15, l 490 : What is meant by "solutions that dominate it"?

p 15, l 489–491 : Why is "rank" written in italic, but "fitness" not?

p 15, l 493 : made → makes (because "are identified" on line 488).

p 15, l 492 : What is meant by a "mating pool"?

p 15, l 500 : "This operator was applied to each design value." : Isn't this said already in the sentence before?

p 15, l 504 : "added a disturbance to the child solution." : It does if for both child solutions I presume.

Page 16

p 16, l 515 : the population of "the" solutions → the population of solutions.

p 16, l 517 : "an optimal solution is output." : How is that solution found based on the last generation?

p 16, l 518 : "corresponding to the routing option" : I don't think this has to be repeated here.

p 16, l 518 : "the best" : one cannot guarantee that it is the best I think.

p 16, l 519 : "naturally" : is this the appropriate wording?

p 16, l 521–522 : can be applied to any routing option (I thought that was not possible yet in version 1.0?) → could.

p 16, l 529 : "As V_{TAS} and V_{ground} were set to $898.8 \, \text{km} \, \text{h}^{-1}$" : Isn't it better to mention first explicitly that we have set $V_{\text{wind}} = 0$, and from that it follows that V_{TAS} and V_{ground} are $898.8 \, \text{km} \, \text{h}^{-1}$ (and not set).

p 16, l 531 : Maybe one should say why flying at FL290 will be faster than at other altitudes. I assume that this depends on the value of T. Are the initial and final points at FL290? Mention that $M = 0.82$.

p 16, l 537 : total 1000 independent → a total of 1000 independent.

p 16, l532–538 : Isn't the first experiment also included in the second setup?

Page 17

p 17, l 540 : generation number n_g → number of generations n_g.

p 17, l 541 : Is "confirmed" the appropriate wording?

p 17, l 542 : sufficiently come close → come sufficiently close.

p 17, l 542, 543, 545 : the f_{true} → f_{true}.

p 17, l 545 : Δf : you do not need an extra variable name for something you express only once.

p 17, l 547 : What is meant by "diversity" of GA optimization?

p 17, l 547–548 : we focus on the optimization results, which found the best solution → we focus on the optimization setup which gave the best solution.

p 17, l 548 : "all the solutions" : Are these the $100 \times 100 = 10000$?

p 17, l 548–549 : solutions explored by GA as longitude vs altitude (top) and as location. This should be worded correctly.

p 17, l 552 : "To confirm the difference" : I don't think confirm is appropriate to be used here.

p 17, l 554–555 : Isn't this conclusion too fast? What if the trajectory is not so zonal, but the trajectory crosses the equator at an angle of $45°$: how would the CPs and regions around be defined?

p 17 , l 552 : "confirm" is not appropriate here.

p 17, l 552 : To confirm the dependence of optimal solutions on initial populations → To "analyze" the dependence of "the" optimal solution on "the" initial population, ...

p 17, l 552–553 : I don't think one should use words like "best-of-generation".

p 17, l 558–559 : corresponding to → for.

p 17, l 653 : "there is a small degree of variation in the objective function". Stated like this, it gives the impression that a different objective function is used. Probably, what is meant is that the value of the objective function for the final flight is different.

p 17, l 564 : Writing $f - f_{\text{true}}$ is a bit strange. For me, f and f_{true} are solutions, i.e. flights defined by x_1, ... x_{11}. Here, f and f_{true} seem to indicate the value of the flight time.

p 17, l 569 and 570 : "number of n_p and n_g" and "size of n_p and n_g". One should use : "the value of n_p", or "the size of the population", not something hybrid like "the number of n_p".

p 17, l 569 : "discover" : I suggest to use a different word.

p 17, l 570 : "is problem dependent, e.g. weather situations" : this should be formulated properly.

p 17, l 571 : "estimating appropriate n_p and n_g could be different" : I suggest to formulate this differently.

Page 18

p 18, l 573–574 : unclear sentence. What is, e.g., the difference between accuracy of GA optimizations and variation in the optimal solutions? I also had the impression that the impact of the initial population was already studied in Sect. 3.2.5.

p 18, l 574 : Skip "calculated".

p 18, l 581 : the variation of the Δf and the $s_{\Delta f}$ → Skip "the".

p 18, l 582 : the Δf → Skip "the".

p 18, l 589 : that reduction → a reduction.

p 18, l 591 : "by selecting n_p and n_g for different purposes." This should be formulated differently.

p 18, l 595 : for demonstrations → for demonstration.

p 18, l 596, 598 : Calculation conditions : too vague.

p 18, l 598–599 : simulation"s" and simulation.

p 18, l 605 : "On the other hand" → "In addition".

p 18, l 606 – p19, l 607 : in [FL290, FL410] → in the range of ..

p 18, l 607 : "and therefore" : I think V_{ground} also varies for other reasons, e.g., due to varying wind speed and direction.

Page 19

p 19, l 615 : Does "case" refers to just one flight, or to all 103 flights together?

p 19, l 616 : It is initially unclear what "it" refers to.

p 19, l 617 : "right" : This is maybe not the most appropriate wording.

p 19, l 618 : by a small → by "using" a small.

p 19, l 618 : "a small number of n_p" → "a small value of n_p", or "a small population size"

p 19, l 619 : with sufficient accuracy → with "still" sufficient accuracy.

p 19, l 620 : I think the title of Sect. 4.2 does not describe well the content : only one airport pair is discussed (Amsterdam - Minneapolis) really in depth. I suggest something more general.

p 19, l 623 : trajectories : Is meant the final trajectories?

p 19, l 627 : we have selected "the" three airport pairs → we have selected three airport pairs.

p 19, l 633 : in [FL290,FL410] → in the range of [FL290,FL410].

p 19, l 633–634 : "when calculating for the selected solutions" : This should be formulated better.

p 19, l 634 : in the supplements → in the supplementary material.

p 19, l 638–639 : east and west direction → eastern and western directions.

p 19, l 639 : major wind component : What is meant by this?

p 19, l 640–641 : at the h → at h.

Page 20

p 20, l 646 : Supplements → Supplementary material.

p 20, l 647 : the behaviour of altitude changes → the behaviour of the altitude changes.

p 20, l 647 : Fig. 16 plots → Fig. 16 shows.

p 20, l 650–651 : this means tail winds (≥ 1.0) and head winds (< 1.0) to the flight direction : Formulate better.

p 20, l 655, 662 : "reflects" → "takes into account", or "accounts for".

p 20, l 658 : confirmed → compared. Skip "quantitatively".

p 20, l 659 : as indicated → as shown.

p 20, l 659–662 : decreased → is lower.

p 20, l 664 : "sufficiently" : I think this is a bit vague.

p 20, l 667 : that the reduction → a reduction.

p 20, l 668 : "sizing" → "reducing" or "choosing properly".

p 20, l 671 : This is not a nice first sentence for a paragraph.

p 20, l 673–674 : trans-Atlantic Ocean → Atlantic ocean.

p 20, l 675 : of "the" region → of "that" region.

Page 21

p 21, l 681 : plot → show.

p 21, l 683 : with linear fitted lines : be more precise.

p 21, l 683 : increased → is higher.

p 21, l 688–689 : which had high V_{TAS} values → with high V_{TAS} values.

p 21, l 691 : increases → is larger.

p 21, l 696 : increases → is larger.

p 21, l 700 : Supplement → Supplementary material.

p 21, l 703 : correctly selected the airspace : improve this formulation.

p 21, l 705 : This behaviour of altitude changes → These altitude changes.

p 21, l 705 : affects the variation in fuel consumptions → affects the fuel consumption.

p 21, l 705 : the terms are used interchangeably to mean fuel flows : improve the formulation.

p 21, l 708 : increases → is higher.

p 21, l 708 : the mean value → the mean value of the fuel consumption.

p 21, l 714 : increases → is higher.

Page 22

p 22, l 718 : corresponding to "the 103" individual flights.

p 22, l 718–719 : the similar figures → similar figures.

p 22, l 720 : showed → show.

p 22, l 720 : in the right-hand domain : choose a better expression.

p 22, l 721 : decreases → is lower. Put "for all airport pairs" at the end of the sentence.

p 22, l 723 and 725 : increased → increases.

p 22, l 740–741 : "Consistency" : just by reading the section title, it is not clear what is meant by this.

p 22, l 742 : were → are.

p 22, l 742–743 : The data → Data.

p 22, l 744 : "they" is ambiguous.

Page 23

p 23, l 723 : I would not say explicitly that the table shows "a comparison".

p 23, l 758 and 764 : literature → write the correct reference.

p 23, l 758 : indicated → indicates.

p 23, l 758–759 / 764–765 : Is it worth mentioning this?

p 23, l 764 : "indicate" : I don't think this is the appropriate word.

p 23, l 765 : "close" → "close to".

p 23. l 769 : reference data → the reference data.

p 23, l 774 : indication : shouldn't one use a different word?

p 23, l 778 : decreased → is lower.

p 23, l 783 : installed → contains.

Page 24

p 24, l 787 : "duplicates" : What is meant by this?

p 24, l 790 : for 103 flights → for "the" 103 flights.

p 24, l 792 : safety flight operations → flight operations safety.

p 24, l 794 : constrains to → constraints

p 24, l 800–801 : This sentence should be improved.

p 24, l 802 : to prevent "the" structural damage → to prevent structural damage.

p 24, l 803 : "aircraft has" → "aircraft have" or "an aircraft has".

p 24, l 803 : "to reduce below" → "to reduce until" or "to bring below".

p 24, l 808 : Why not using $\leq$?

p 24, l 806, 810 : of A330-301 → of an A330-301 aircraft.

p 24, l 812 : more → higher.

p 24, l 814 : Skip "calculations".

p 24, l 816 : an submodel → a submodel.

p 24, l 817 : "applied" : shouldn't it be "used"?

Page 25

p 25, l 823–824 : What is meant by this sentence?

p 25, l 829 : the benchmark test → a benchmark test.

p 25, l 831–832 : by other published code : this is too vague.

p 25, l 832 : the benchmark test → a benchmark test.

p 25, l 836 : dependence on the initial population.

p 25, l 835 and 838 : The fact that both values are 0.01 % is maybe not a good sign. I would think that you want the second one to be much smaller than the first one.

Page 26

p 26, l 860 and 866 : Please be more specific about what "reference data" is.

p 26, l 862 : close → (very) similar.

p 26, l 869 : fuel use calculation model → fuel use model.

p 26, l 871 : "is sufficient" : But some things do not work yet?

p 26, l 871 : "a" reduction potential → "the" reduction potential.

4 Remarks on figures

Figure 1 : I presume parts of this are already done in other optimized studies. Mention what is already done, what is part of this manuscript, and what shall be done in the future.

Figure 7 : Bizarre first sentence in caption. Consisting of → determined by. $\Delta\lambda_{airport} \to \Delta\lambda_{\mathrm{airport}}$.

Figure 8 : Conclusions/observations/interpretations should not be written in figure captions. I would not use the word "discovers".

Figure 9 : Change the first sentence. "The population size $n_p = 100$ ..." : This is not a good sentence. Replace "=" by "is".

Figure 10 : Skip "Comparison of".

Figure 11 : Don't use expressions like "Best-of-generation". "vs function evaluations" → "vs number of function evaluations". $f_{true} \to f_{\mathrm{true}}$. Change "On the ... and ...".

Figure 17 : Don't use expressions like "Best-of-generation".

Figure 22 : Shouldn't one have as unit for the emissions : $\mathrm{kg(fuel)\,m^{-2}\,s^{-1}}$? The figures are 2-hourly averages. However, the ranges are not clear from just mentioning 14:00:00, 16:00:00, 18:00:00, 20:00:00. Is it 14:00:00–16:00:00, 16:00:00–18:00:00, ..., or rather 12:00:00–14:00:00, 14:00:00–16:00:00, ...

5 Comments on tables

Table 1 101.325 → 101,325. Why is there "(jet)" at the end of the line with C_{f1}? There should be a small space between "kg" and "min". I would not give a variable the name "Oneday". P_0 and T_0 are not total pressure or temperature, but reference pressure and temperature.

Table 2 : $n_{wp-1} \to n_{wp} - 1$.

Table 4 : I think it makes no sense to introduce all these new variable names. Put in the heading (first row) of the table just : "Eq. (22)", "Eq. (23)", ...

Table 5 : For population size and generation number : "$\cdots$" → "$\ldots$".

Table 9 : "that of" → "average of". Why "medium"?

Table 12 : Skip "Comparison of".

Table 14 : "Constraints on" → "Constraints from". Why not just using $\geq$ and $\leq$? Why have on all the four lines A330-301 after some "." at the end of the line?

6 Supplementary material

Fig. S1 and S2 : including "the" time-optimal flight trajectories.

Fig. S3 and S4 : Skip "Comparison of".

Fig. S7 : Skip "that".