Response to Reviewers

Reviewer 3 - Mark Baldwin

1) I think that an important addition for most readers would be to add a brief discussion explaining that the RT flight time will always increase if there is an increase in the background wind speed in either direction. *(details of mechanism omitted here but available in original review online)*. This would help to explain a lot of your results and may help at the end of the paper to explain differences with previous publications. Of course, actual flight paths attempt to mitigate this.

Absolutely correct - thank you for this clear explanation. An explanation of the concept has been added to Section 3.3 where the round-trip methodology has been introduced, and the concept has been integrated into our discussion of the results later in the paper.

2) Limited data set. I looked up approximately how many Europe - US flights actually took place between August 1994 and March 2024. There were approximately 7-9 million direct transatlantic flights operated between Europe and the United States. This estimate is based on analysis of available flight data, historical trends, and consideration of major aviation disruptions during this 30-year period.he data used in this study neglects 99.8% of the actual transatlantic flights. This makes me wonder how the results might differ if all the flights were available for analysis. You do mention this in 8.2 L461, but I think that you should state how small the fraction of flights available to analyze was compared to the number that took place.

Firstly, we concur on the relatively small proportion of total flights considered in this study. To provide more precise numbers in aid of discussion: after filtering for flight type and aircraft size as described in Appendix D2 (now E2), the US Bureau of Transport Statistics dataset we use contains 3.79 million (one-way) flights for the period January 1994 to July 2024, i.e. it is in the same order of magnitude as your quick estimate but slightly smaller. Our 16 327 flights therefore represent 0.43% of total similar flights.

Even assuming the flights are fully independent statistically, which they are likely not, this would be an important factor. Therefore, it is important to strongly caveat our results, which we now do in Section 2.1, and refer back to in several other places.

3) The underlying question is: how does the atmosphere change with the 4 indices (plus trend) and how does this affect the optimal flight times for round trip transatlantic flights? ... I suggest a comparison to a very simple theoretical flight. The basic idea would be to select several city pairs, and simply assume that flights were at some constant altitude and air speed. Using reanalysis (4X daily?) simply calculate the great circle flight path time in both directions at the reanalysis times. This comparison might reinforce the results you have obtained. I expect annual, ENSO, and NAO results to be verified. But trends would be very interesting. This approach could help sort out the Honolulu results that differ from previous publications (Discussion, L444). Stronger winds should increase the RT flight times.

This is a really good suggestion, and we agree that an atmospheric-only benchmark is useful. However, we worry that adding material on this topic would introduce significant overlap with the work of Kim et al. 2020, who applied this approach to 28 years of wind-optimal simulated flights on the JFK-LHR and HNL-SFO routes based on ERA-Interim winds, considering only the ENSO and NAO indices. Their results were briefly mentioned in our original discussion, but as this reviewer comment identifies this was clearly understated and should be better integrated into the text. Accordingly, in the revision we have mentioned this prior

work more prominently in the introductory material, hopefully addressing the Reviewer's concerns. We are very happy to reconsider this and repeat the analysis ourselves for the same time period as our current study and for our full set of climate indices if the Reviewer/Editor feel this would enhance our study further.

4) Please convert the solar cycle altitude result to meters different (not just standard deviation) in the Abstract Line 12. On line 415 you do discuss this, but I am left wondering if this effect is real.

In response to Reviewer 2's concerns, this material has now been removed. Nevertheless, we do agree with this comment, and if we had not removed the material would have made this change as suggested.

5) This suggestion is probably for a future paper, since it would be fairly involved: Use reanalysis to calculate millions of idealised RT flights, assuming all flights are optimised to minimise flight times. That way you would eliminate all the operational issues and address only the atmosphere. It would focus on how the atmosphere changes for ENSO, NAO, TSI etc.

This would indeed be a very interesting study, and builds well upon other studies in the literature (e.g. the aforementioned Kim et al. 2020, but also to some degree Boucher et al. 2023) which provide the methods needed for such optimal-route sampling. As you say, it would be fairly involved, but maybe not too unmanageable - if the synthetic flights were outputted to the same format as the IAGOS ones then the existing code could be used for the remainder of the analysis. However, a larger issue is that adding this would make the narrative much more complex. Accordingly, we concur with the Reviewer that this is better suited for future work.

References

Boucher, Olivier et al. (Aug. 2023). "Comparison of Actual and Time-Optimized Flight Trajectories in the Context of the In-Service Aircraft for a Global Observing System (IAGOS) Programme". In: *Aerospace* 10.9, p. 744. DOI: 10.3390/aerospace10090744.

Kim, Jung-Hoon et al. (Oct. 2020). "Impact of climate variabilities on trans-oceanic flight times and emissions during strong NAO and ENSO phases". In: *Environmental Research Letters* 15.10, p. 105017. DOI: 10.1088/1748-9326/abaa77.