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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Transport of anthropogenic emissions during ARCTAS-A: a climatology and regional case studies" *by* D. L. Harrigan et al.

Anonymous Referee #3

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Review of "Transport of anthropogenic emissions during ARCTAS-A: a climatology and regional case studies" by Harrigan et al., submitted to ACPD

The authors present a trajectory-based analysis of the transport characteristics to the Arctic region during the ARCTAS-A campaign. They focus on the transport pathways of anthropogenic pollution to the Arctic, and present several case studies of pollution plumes encountered by aircraft. I believe the study can be a valuable contribution to research in the field, but the results need to be presented more clearly, partly by improving the presentation quality, but also by more concise writing. The method also needs clarification and additional work.

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Discussion Paper

Major issues

1. It is not clear why the authors go through the exercise of double nesting the WRF simulations, this is never discussed. It is also not clear why those particular nests are chosen, they do not coincide with the trajectory starting locations.

2. A major limitation of the study is the use of 1x daily trajectory calculations on a 2x2 degree grid. This weakens the statistics, and could bias results by examining one particular time of day only for each area. The analysis of general transport characteristics should be redone with at least 4x daily trajectory calculations. Considering that the WRF model output is hourly, this should not be difficult.

3. It is unclear what is shown in Fig. 2, panels b,d,f. The CGRER data set is supposed to show anthropogenic CO emissions. But over Borneo for instance Fig. 2b shows as high emissions as for Japan. On panel 2f there are large CO emissions over equatorial Africa, higher than over central Europe, which is rather counterintuitive since these are not heavily industrialized areas. More details on the data set should be given, and a comparison with some other emission inventory be made.

4. There is a significant amount of redundancy in Figs 6, 11, 15: Panels a,b can be condensed into one, and the boundary layer segments indicated by symbols or a more distinct color. This would provide space for bigger, more readable figures.

5. The sea level pressure figures in Fig. 7,8,12,17 are not very useful because they cover a too large area. It would be much more useful to show just one panel for each case when the air parcels supposedly are lifted up in a WCB, zoomed to a reasonable region. Other variables than SLP, for example cloud cover or precipitation, could be shown to strengthen the point of a WCB being present in the WRF simulation.

6. The writing should carefully distinguish between air parcels, air masses and trajectories. In the manuscript these terms are wrongly used interchangeably.

7. The method description of the trajectory calculations needs more details and clarifi-

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cation.

8. It should be more clearly stated in the manuscript that the paper is focused on case studies. I don't think that the term "climatology", even though in quotation marks, can be used justifiably for a one-month period. In particular the title of the manuscript is misleading in that sense, and the word climatology should not appear here. You could describe the month-long analysis as "mean transport characteristics during the ARCTAS campaign", or something along those lines.

9. It should be discussed that the present setup does not take into account that air masses can leave the Arctic again right after having crossed the 70°N boundary. Whether air masses actually remain in the Arctic for an extended period of time could be assessed with forward trajectories from the aircraft locations.

10. The authors suggest that in all three cases of interception of polluted air masses WCBs played a decisive role in the vertical transport behavior. While this may be a coincidence, this aspect should be discussed in more coherence in a separate discussion section. Is there actually at all a mechanism that could bring mid-latitude polluted air to the altitude of the aircraft within a handful of days, other than WCB uplift?

11. The WCB criterion is explained 3x in each case study. Instead, it should be described 1x in the methods section. A table would be helpful to summarize the WCB criterion results.

12. A table would be helpful to summarize the results presented for each case study on the fraction of trajectories entering the Arctic.

13. The Summary and Conclusions section should be condensed by 50% and the main conclusions more clearly brought forward.

Detailed comments:

Abstract

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Pg. 5436, L. 13: Trajectories can be calculated but not released, air parcels can be released and traced. Use consistent wording throughout the manuscript.

L. 14: historically significant: not clear what you mean, rephrase. This applies at all instances of this term throughout the manuscript.

L. 12-20 can be shortened

L. 20: the term climatology, even though in quotation marks, does not apply for the mean characteristics over a one-month period

Introduction

Pg. 5437, L. 7: citing Stohl (2006) and Law and Stohl (2007) in that location sounds as if those papers would argue for seeing the Arctic as a clean location - rephrase!

L. 9: There are also pollution sources well within the Arctic from natural gas and oil extraction and other heavy industry

L. 20: citing Stohl (2006) and Warneke et al (2009) in this context is wrong, these studies actually do note the importance of non-anthropogenic pollution for Arctic air pollution

Pg. 5438, L. 11: cold potential temperature -> should be low, potential temperature is a measure of energy

L. 21: Stohl and Law (2006) does not seem to be peer-reviewed literature, is it necessary to cite this?

L. 23: "lifted over the Arctic front": not clear what you mean, rephrase

Pg. 5439, L. 10: could remove Jacob reference here

Data and methodology

Pg. 5440, L. 20: motivate using the limited nests, and using WRF over GFS in the first place

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Pg. 5441, L. 4: Trajectories -> 3D kinematic trajectories

L. 8: Mention specifically what advantages particle dispersion models have, and why you think trajectories are more appropriate for your study

L. 15: clarify how you specify starting locations from the emissions inventory. How is the emissions inventory different to e.g. EDGAR?

Fig 2: How were release locations specified? In Fig. 2e it appears that France has been left out from the analysis, why? Also, why have Turkey and the Iraq been included but not the European part of Russia and the Ukraine?

L. 16: "release" -> starting

L. 20: at what level where the trajectories released?

L. 26: What distance did the aircraft cover during that time interval?

Fig. 4, 9, 13: Maps in panels b and c should be rotated to the same center longitude

Pg. 5444, L. 23: "hot spots" -> secondary maxima

Pg. 5445, L. 5: combine this information into a table for all regions

L. 18: standard techniques: please include more information here on how this has been done

Pg. 5446, L. 2: mention the sources of biomass burning here

Pg. 5447, L. 27: formulate more carefully here, it is likely/probably a source in China, but I don't see why you could rule out for instance a source in Japan

Pg. 5448, L. 8: constant pressure analysis: not clear what you mean, sea level pressure?

L. 11-15: rewrite, it is confusing to describe the backward calculation as a "release from the aircraft"

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L. 20: how does the uncertainty of trajectory calculations, that can amount to thousands of km after a few days, affect your interpretation of this transport pattern?

Pg. 5449, L. 1: Branches should be labeled or otherwise made distinguishable in Fig. 6

L. 28 onward: place into method section once for all cases, add table for results.

Pg. 5450, L. 23 onward: remove summary paragraphs here and in the other case studies, they contain unnecessary repetition.

Pg. 5451, L. 7: "the distribution of Arctic arrivals. . ." unclear, rephrase

Pg. 5452, L. 16: list the species here

Pg. 5454, L. 9: again, how reliable is it to follow individual trajectories over 10 days given the considerable errors individual trajectories may have?

Pg. 5455, L. 11-18: delete summary section

Pg. 5456, L. 5: releases were made in Turkey and the middle east, it appears that this is rather responsible for the apparent transport maximum.

L. 7: "middle and upper levels": are not all trajectories released at the surface? Unclear.

L. 17: "Thus, considering the combination. . ." Not clear what is your point here. Asia, America and Europe span a range of longitudes, and so do the entry regions. This should not be surprising.

L. 25: To what extent is this due to the more northerly starting locations in Europe compared to the other regions?

Pg. 5458, L. 16: remove summary section

Pg. 5459, L. 2: It appears as an over-interpretation to rely on the accuracy of trajectories calculated several days backward in time to the degree needed for your interpretation. In particular in the vicinity of the boundary layer the concept of conserved air

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parcels becomes increasingly questionable due to turbulent mixing. To fully exclude a biomass burning influence in your airmass you would need the information from a specific tracer, such as levoglucosan.

Pg. 5460, L. 11-20: remove/condense summary section

L. 22: The proximity of the "entry location" to Asia makes it very likely that this airmass was indeed a mix of air masses, that may have included European pollution, but unlikely undiluted (by, for instance, Asian pollution sources, as encountered earlier in the flight) over such a long travel distance.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 5435, 2011.