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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Injection in the lower stratosphere of biomass fire emissions followed by long-range transport: a MOZAIC case study" *by* J.-P. Cammas et al.

Anonymous Referee #1

Received and published: 13 January 2009

General comments:

This paper investigates a case of rapid convective uplift of emissions from boreal fires in Alaska and Canada in June 2004 and its downwind transport. Interesting is the especially high altitude that the emissions reached, the lower stratosphere (LS), and the long-lasting signatures of these fire plumes observed downwind as far as over the eastern Atlantic. In this region, observations during two MOZAIC flights, 5-6 days after emission, clearly show signatures in several trace gases from the fires. A Lagrangian particle dispersion model (FLEXPART) was used to trace back the polluted air masses and to identify the sources, and a mesoscale model (Meso-NH) was used to simulate

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the convective transport over the emission region.

The focus of the paper is well within the scope of ACP. The paper is in general clear and concise written, however at some places more information is needed (see specific comments below). A novel concept as the importance of a high emission height (up to 10 km) as input to the FLEXPART model to better fit observations is presented. Furthermore, it is shown that a combination of both FLEXPART and Meso-NH is necessary to explain the presented observations obtained from MOZAIC. Measurements of biomass fire emissions in the LS are still rare and therefore this paper adds valuable information to the community. The English language needs improvements at a few places (see technical corrections).

The results of the paper point out the importance of taking an injection height of up to 10 km into account for the FLEXPART simulations performed. The large extension in space and time of these fire plumes observed in the LS also has an important impact on the chemistry in this region. A statistical investigation of the whole MOZAIC data set (1994-2008) is planned in an upcoming study to investigate the overall impact of boreal fire emissions in the LS region, which is highly recommended by the reviewer.

Specific comments:

- Several results from the model simulations with Meso-NH show the penetration of the convection into the LS. However, it would also be important to show observed cloud top heights obtained from GOES data and if they agree with Meso-NH results. Are the clouds in Fig. 9a (GOES) really high enough to penetrate above the 2-pvu tropopause surface (which altitude/temperature?)? A time sequence of GOES images showing the development of convective clouds and their heights would add valuable information to the paper.

- For the long-range transport of the convective uplifted biomass burning emissions it would be very important to know if the main outflow levels (altitude) in Figs. 9a (GOES) and in FLEXPART (only up to 10 km considered, below tropopause) are similar. A

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different simulated outflow level (below/above the tropopause) would perhaps export the emissions to different regions depending on the wind at that level?

- FLEXPART backward simulations with a fire emission height up to 10 km fit the MOZAIC observations best. However, the Meso-NH simulations indicate that for an injection of fire emissions into the LS an altitude of at least 12 km must be reached. How can these differences in altitudes be explained?

- With Meso-NH only the convective uplift is investigated. What about the frontal uplift since the convective clouds in Fig. 9 seem to be imbedded in a larger synoptic-scale system?

- First in the Appendix it is very briefly mentioned that the FLEXPART fire CO emissions are based on a "self-made inventory of daily emissions from biomass burning". Explain more in detail how this inventory is done. Based on satellite hot spots? Which emission factors and references were used? Add this description to Sect. 2.2 (at least briefly) and to the Appendix.

- In the introduction it is mentioned that "Chemistry in the fire plumes leads to formation of tropospheric ozone". However, this is not always the case. Fire plumes with a negative CO-O3 correlation has frequently also been observed (e.g. during ICARTT and POLARCAT).

- The backward calculation shown in Fig. 7 needs some more explanation in the text paragraph (as partly given in the legend). It is difficult to follow the calculations shown.

- Is some kind of additional forcing necessary to trigger convection penetrating into the LS in Meso-NH or are the simulations just based on ECMWF data?

- Why are no compensating downdrafts visible in Fig. 10b?

Minor comments and technical corrections:

Abstract

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Page 20926, line 5: "is done using MOZAIC": Change to "is based on airborne MOZAIC".

Line 6: "(NOx and PAN)": Cut and specify first in Sect. 2.

Line 7-8: Cut the times given in UTC. Specify later.

Line 8: "in a vertical": Change to "on a vertical". "by lidar observations": Change to "on lidar observations".

Line 10: "of the plumes": Change to "of the observed CO plumes".

Line 21: "by MOZAIC over": Change to "by a MOZAIC airliner over".

1. Introduction

Add the references Pfister et al., JGR, 2006, "Ozone production from the 2004 North American boreal fires" and Real et al., JGR, 2007, "Processes influencing ozone levels in Alaskan forest fire plumes during long-range transport over the North Atlantic".

Page 20927, line 1: "too little": Change to "however only little.....(Wotawa and Trainer, 2000)".

Line 6-7: "leads to formation": Change to "may lead to formation".

Line 8: "which exerts": Change to "which may exert".

Line 8: "the Arctic and": Cut and leave only downwind regions.

Line 9: "lower latitudes": Change to "lower altitudes".

Line 20: "frontal profile": Profile of what?

Lines 24-28: Sentence too long, separate. "Small mixing processes": Change to "Small-scale mixing processes". "waves induced by the overshooting convection increase": Change to "waves, induced by the overshooting convection, increase". "where residence times": Change to "There the residence times".

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Page 20928, line 12-13: "CO mixing ratio": Change to "CO mixing ratios".

2. Data and model description

Page 20928, line 25 and Page 20929, line 9: "+-[2 ppbv + 2%]" and "+-5 ppbv +-5%": Unify specifications.

Page 20929, line 11: "total odd nitrogen": Change to "total odd nitrogen (NOy = NO+NO2+HNO3+PAN....)" and add that PAN = peroxyacetylnitrate.

Line 18: "research instrument": what kind of research instrument?

Line 22: "and the usually": Change to "The usually".

Line 24: "Peroxy Acetyl Nitrate": Change to "PAN".

Page 20930, line 6: "ICARTT": Write out.

Page 20931, line 13: "12:00 UTC 23 June": Change to "12:00 UTC on 23 June".

3. Observations of forest fire emission plumes

Page 20932, line 13: "stratosphere in flying": Change to "stratosphere by flying".

Line 23: "The strong values": Change to "The enhanced values".

4. Identification of the source region of forest fire emissions

Page 20935, line 17: Add that an injection height of up to 3 km is insufficient to explain the observations.

Line 27: "later": Change to "in Sect. 5".

Page 20936, line 14: "agent": Change to "mechanism".

Line 16: "airpaths": Change to "flight tracks".

Page 20937, line 4: "As for": Change to "For".

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Line 5: "backwards": Change to "backward".

Line 7: "airpath": Change to "flight track".

Line 8: "shows on": Change to "shows in".

Line 9: "some maxima": Maxima of what?

Line 14: "Lagrangian connection": Better "quasi-Lagrangian"?

Line 16: "smoke is associated with high CO observations": Change to "smoke aerosols are associated with high CO mixing ratios".

Page 20938, line 2-3: "(red points) and deep convective cells": Hard to recognise.

Line 12: "Lagrangian connections": Better "quasi-Lagrangian"?

Line 14: "18 June": Change to "28 June".

5. Meso-scale modeling over the source region and UTLS injection

Page 20938, line 20: "As detailed": Change to "As described".

Line 21: "Sect. 3, largest": Change to "Sect. 3, the largest".

Line 22: "span the period": Change to "span over the period".

Line 22: "24 June": In Sect. 2.3 "23 June" is given as start for the initialisation?

Line 23-24: "Therefore the initialization date of the mesoscale model Meso-NH over the boreal domain is chosen on 24 June": Change to "Therefore, this first date is chosen as initialization date of the mesoscale model Meso-NH over the boreal domain".

Page 20939, line 2: "with a model-to-satellite approach.... combining": Change to "A model-to-satellite approach.... combines".

Line 21: "at each time step": Which time steps were used?

Page 20940, line 1: "height of the convective clouds exceeding 12 km": Change to

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"height of convective clouds reaching up to 13 km".

Line 3 and 6: "anticyclonic ring": Replace by "anticyclonic flow"?

Line 4: What about the presence of GEOS deep convective cells in the region of FLEX-PARTs highest sensitivity?

Line 7: "We built": Change to "We developed".

Line 18: "go across": Change to "cross".

Line 18: Explain the location of the 2-pvu tropopause surface in comparison to the 335 K isentropic surface.

Line 23: In Fig. 11a the majority of the values across 2-5 pvu are between 0.5-0.75 (more than 5 h?).

Line 24-25: Why are downdrafts only in the BL?

Page 20941, line 9: "on Fig. 12": Change to "in Fig. 12".

Line 27: "1.4-1.8 ppmv": Are no surface CO measurements available for Yukon within the framework of ICARTT?

6. Conclusions

Page 20942, line 3: "we report in-situ observations of": Change to "we report on in-situ observations during MOZAIC flights of".

Line 4: "multiple plumes": Change to "multiple CO plumes".

Page 20951, Table 1: Add year "2004".

Page 20952, Fig. 1: It is enough to show only one colour bar. Increase the numbers on the axes in (b) and of the colour bar.

Page 20954, Fig. 3: Add "left" and "right" in the legend for (b). Numbers on x-axis in (b) (right) are hard to read. What does the header in (b) mean: mol / ref / aer?

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Page 20955, Fig. 4: "d) below 1000 m": Change to "d) below 150 m". Why show pollution from SO2 and NO2 when not discussed in the paper (also in Fig. 5)?

Page 20957, Fig. 6: The small numbers (daily position) are hard to recognise, increase and perhaps change colour. "The asterisk": Move this sentence to the end of the legend.

Page 20958, Fig. 7: Indicate the position of the lidar site. Add "°N" and "°E" to the numbers on the axes.

Page 20959, Fig. 8: Add a second latitude to (a).

Page 20960, Fig. 9: "Brightness Temperature": Change to "brightness temperature" (2x).

Page 20962, Figs. 11a-b: The irregular labelling of the x-axes is confusing (0, 2, 3, 5, 6, 8, 10, 11, 13, 14, 16 km).

Page 20964, Fig. 13: "blue line is the 335 K": Change to "black line is the 335 K". The irregular labelling of the x-axis is confusing (0, 2, 3, 5, 6, 8, 10, 11, 13, 14, 16 km).

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 20925, 2008.