Atmos. Chem. Phys. Discuss., 8, S12328–S12341, 2009
www.atmos-chem-phys-discuss.net/8/S12328/2009/

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.

J.-P. Cammas et al.

Received and published: 29 July 2009

We are grateful to referee 1 for the thoughtful and constructive comments that we generally agree with and have taken into account in writing the revised manuscript.

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

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

the paper.
As it can be checked with radiosounding data available at the Dept. of Atmospheric Sciences, University of Wyoming (http://weather.uwyo.edu/upperair/sounding.html) the tropopause (cold point temperature) over the area (Fort Nelson at 58.8N-122.6W, Whitehorse at 60.7N-135.1W, and Norman Wells at 65.3N-126.7W) from June 24th to June 26th was at about 12 km with an average temperature of 215K $\pm$ 3K. This is also the case in the Meso-NH simulation for which the temperature minimum at the tropopause is close from 215K and is near the 2 pvu isoline. Determining the cloud top heights with precision using GOES data is a difficult task. A crude estimate can however be obtained knowing the vertical profile of temperature and assuming cloud as opaque. A new and additional figure in the revised manuscript shows the time evolution of the brightness temperature minimum values over the model domain, both in the observation and the simulation. Minimum values are around 215 K suggesting that deep convective clouds reached the tropopause. These explanations and the corresponding figure have been added to the revised version of the manuscript.

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 different simulated outflow level (below/above the tropopause) would perhaps export the emissions to different regions depending on the wind at that level?
As shown by the new figure in the revised manuscript, the main outflow of the convective clouds (Fig. 9a) reaches temperatures characteristic of the tropopause region. The corresponding altitude level is difficult to assess with precision because the temperature lapse rate here is not as large as in the mid-troposphere. The latter may be a bit higher up than the maximum injection altitude in FLEXPART (Δ z=0-2 km). However, sensitivity for the long-range transport to the injection altitude in the 10-12 km altitude layer is not that large compared to the one in other layers in the mid- to upper-troposphere, and this is due to the less enhanced vertical wind shear over this altitude layer.

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?
As explained just above these differences in altitude are conciliable because the sensitivity to long-range transport differences is reduced in the 10-12 km altitude layer over the area and during the period of concern.

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?
The frontal uplift over the area happens later than June 26th and hence can not be associated with MOZAIC measurements shown in this work.

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.

The following description of how the emission inventory of biomass fires is done has been added to the Appendix and briefly mentioned in Sect 2.2 as requested by the reviewer: The Center for International Disaster Information (http://iys.cidi.org/wildfire/) publishes daily burn areas, burnt per province in Canada and fire province in the U.S. The resulting timeseries were smoothed by a 3-day running mean. As a second source of information, MODIS hot spot data were obtained from the NOAA Satellite and Information Service. Hot spots were counted daily on a 1x1 degree grid and for every 3-day period the maximum daily number of hot spots was taken in order to account for possibly missing hot spots during cloudy periods. Then, the daily area burned in Alaska and the Canadian provinces was distributed to those grid cells in these provinces contain-

ACPD
8, S12328–S12341, 2009

Interactive Comment

ing hot spots (weighted, according to the number of hot spots). The rest of the U.S. was treated as a single region instead of as different fire provinces. Sometimes, hot spots were detected when no area was given as burned in a province or vice versa. The missing area (about 10%) was distributed equally-weighted to all hot spots detected during the entire period. Finally, a constant emission factor of 4500 kg CO / hectare burned was used to obtain a daily CO emission inventory on a 1x1 degree grid.

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-O_3 correlation has frequently also been observed (e.g. during ICARTT and POLARCAT).
The reviewer is right. The modified text is now: Chemistry in the fire plumes may lead to formation of tropospheric ozone (Crutzen and Andreae, 1990 ; Forster et al., 2001), which may exert a significant climate forcing in downwind regions. However, fire plumes with a negative CO-O_3 correlation are also observed (e.g., Real et al., 2008 during the ICARTT campaign).

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.
More explanation is given in the revised version, as reported below: As for the connection between lidar observation at Wisconsin University (Fig. 3) and MOZAIC observations, we analyse backwards calculations of FLEXPART initialized along the MZ1 observations in the eastern Atlantic upper level trough. It is shown on Figure 7 the residence time distribution in the whole atmospheric column for trajectory particles initialized in small receptor boxes (0.5 latitude and longitude, 500m thickness) along the MZ1 MOZAIC aircraft route on 30 June 2004 within a 1-h time interval. Particles were released only from boxes where the measured CO exceeded 200 ppbv. Residence times were calculated from initialisation until 36 h back (valid on 28 June 2004, 15:00 UTC) which corresponds to the observing time period by the lidar. The westernmost part of the residence time distribution lies over Wisconsin, approximately at the time

ACPD
8, S12328–S12341, 2009

Interactive Comment

and the location for which lidar observations of the aerosol layer were performed (see Fig. 3). Thus, the transport model establishes a quasi-Lagrangian connection between the MZ1 MOZAIC observations and the lidar observations and confirms that smoke is associated with high CO observations.

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?
No additional forcing is necessary to trigger the convection in Meso-NH. The convection parameterization in Meso-NH has been developped on the basis of existing frameworks, essentially the rather general framework proposed by Kain and Fritsch (1993). The parameterization is intended to provide an efficient representation of atmospheric shallow and deep convection for both mesoscale and global applications. Numerical applications in different 1D, mesoscale and global contexts are discussed in Bechtold et al. (2001) and Mallet et al. (1999). Further 1D evaluations of the scheme and intercomparisons with other models/schemes are presented in Xie et al. (2002) and Bechtold et al. (2000) in the context of the international pro-gram GCSS (GEWEX Cloud System Study).

Bechtold, P., J. L. Redelsperger, I. Beau, M. Blackburn, S. Brinkop, J. Y. Grandpeix, A. Grant, D. Gregory, F. Guichard, C. Hoff and E. Ioannidou, 2000: A GCSS model intercomparison for a tropical squall line observed during TOGA-COARE. II: Intercomparison of single-column models and a cloud-resolving model. Quart. J. Roy. Meteor. Soc., 126, 865-888.
Bechtold, P., E. Bazile, P. Mascart and E. Richard, 2001: A Mass flux convection scheme for regional and global models. Quart. J. Roy. Meteor. Soc., 127, 869-886.
Kain, J. S., and J. M. Fritsch, 1993: Convective parameterization for mesoscale models: The Kain- Fritsch scheme. Meteor. Monographs, 46, 165-170.
Mallet, I., J.-P. Cammas, P. Mascart and P. Bechtold, 1999: Effects of cloud diabatic heating on a FASTEX cyclone (IOP17) early development. Quart. J. Roy. Meteor.

ACPD
8, S12328–S12341, 2009
Interactive Comment

Soc., 125, 3415-3438.
Xie, S.-C., K.-M. Xu, R. T. Cederwall, P. Bechtold, A. D. Del Genio, S. A. Klein, D. G. Cripe, S. J. Ghan, D. Gregory, S. F. Iacobellis, S. K. Krueger, U. Lohmann, J. C . Petch, D. A. Randall, L. D. Rotstayn, R. C. J. Somerville, Y. C. Sud, K. von Salzen, G. K. Walker, A. Wolf, J. J. Yio, G. J. Zhang and M. Zhang, 2002: Intercomparison and evaluation of cumulus parameterizations under summertime midlatitude continental conditions. Q. J. R. Meteorol.Soc., 128, 1095-1135.

Why are no compensating downdrafts visible in Fig. 10b?
Only positive values of the indicator of the characteristic time for convective masse fluxes to exchange air at the top of updraft are projected on the dynamical tropopause. The caption has been corrected.

Minor comments and technical corrections:

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

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

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

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

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

ACPD
8, S12328–S12341, 2009

Interactive Comment

Done

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

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".
When discussing the boreal fire activity in 2004, we have added the two references as requested: Real et al. (2007) describe the processes influencing O_3 levels in Alaskan forest fire plumes in 2004 from measurements in several biomass burning plumes over Europe and show that O_3 impact of Alaskan fires can be potentially significant over Europe. Pfister et al. (2006) show that on average the fires increased the O_3 burden (surface - 300 hPa) over Alaska and Canada during summer 2004 by about 7-9% and over Europe by about 2-3%.

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

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

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

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

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

ACPD

8, S12328–S12341, 2009

Line 20: "frontal profile": Profile of what?
Done, replaced by cold front.

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".
Done

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

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

Page 20929, line 11: "total odd nitrogen": Change to "total odd nitrogen (NO_y = NO+NO_2+HNO_3+PAN +....)" and add that PAN = peroxyacetylnitrate.
Done

Line 18: "research instrument": what kind of research instrument?
A description of the research instrument is added: research instrument using a gold converter and chemiluminescence as measurements principle (ECO-Physics instrument)

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

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

Page 20930, line 6: "ICARTT": Write out.
Done: International Consortium for Atmospheric Research on Transport and Transfor-

ACPD
8, S12328–S12341, 2009

mation

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

3. Observations of forest fire emission plumes
Page 20932, line 13: "stratosphere in flying": Change to "stratosphere by flying".
Done

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

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.
Done

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

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

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

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

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

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

ACPD

8, S12328–S12341, 2009

Interactive Comment

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

Line 9: "some maxima": Maxima of what?
Changed by: maxima of residence times of particles

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

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

Page 20938, line 2-3: "(red points) and deep convective cells": Hard to recognise.
The size of the figure has been increased to recognise the red points.

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

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

5. Meso-scale modeling over the source region and UTLS injection
Page 20938, line 20: "As detailed": Change to "As described".
Done

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

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

Line 22: "24 June": In Sect. 2.3 "23 June" is given as start for the initialisation?
The error was in Sect. 2.3: The simulation is initialized at 12:00UTC 24 June for a duration of 60 hours. Error corrected.

ACPD
8, S12328–S12341, 2009

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".
Done

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

Line 21: "at each time step": Which time steps were used?
The time step of the model is 20s, and the convection scheme is called every 300 s (i.e. every 15 time steps). This information has been added in Sect. 2.3

Page 20940, line 1: "height of the convective clouds exceeding 12 km": Change to "height of convective clouds reaching up to 13 km".
Done

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

Line 4: What about the presence of GEOS deep convective cells in the region of FLEXPARTs highest sensitivity?
This deviation to FLEXPARTs results inside the Meso-NH section was indeed not opportune. We have just moved it at the end of the section for more clarity: Note finally that the outflow above deep convective cells over the area of interest is embedded in the anticyclonic flow, which is in agreement with FLEXPART retro-plume calculations.

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

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

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

ACPD

8, S12328–S12341, 2009

K isentropic surface.

The following explanation has been added to the revised version: Over the area of interest, the 2-pvu tropopause surface is mostly slightly below the 335-K isentropic surface in the model outputs, except nearby some of the deep convective cells where it is slightly above this surface (see also vertical cross sections in Figs. 11 and 13).

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

Yes, the reviewer is right: it is a bit more than 5h. On average the convective indicator across 2-5 pvu is closer from 0.75 than from 1. as it was suggested. It leads to a characteristic time of 7.5h, which is still a time period compatible with the convective diurnal cycle. This is corrected here, as well as in the conclusion and in the abstract.

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

The reason why downdraft are only in the boundary layer comes from the design of the convection scheme (Bechtold et al., 2000, 2001) used in Meso-NH. The downdraft originates within the cloud at the level of free sink and extends down to the downdraft base level. All downdraft mass is detrained over a fixed 60-hPa thick mixed layer extending above the downdraft base level which is defined as the level where the equivalent potential temperature of the level of free sink becomes larger than its saturated environmental value. With this method motivated by the fact that the amount of downdraft mass flux is dependent on the total downdraft evaporation rate, the downdraft base level is most of the times in the boundary layer. The complete documentation of Meso-NH is available at http://mesonh.aero.obs-mip.fr/mesonh/

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

Done

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

ICARTT was not originally set up to study the long-range transport of plumes of

ACPD

8, S12328–S12341, 2009

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

biomass fires from Alaska and Yukon. The ICARTT network of ground sites that has operated for air quality monitoring was settled up in northeastern United States and the Maritime Provinces of Canada. The only measurements we have found come from NAPS, the National Air Pollution Surveillance network of Canada (http://www.etc-cte.ec.gc.ca/NAPS/). CO surface measurements at Yellowknife (capital of the Northwest Territories on the north shore of Great Slave Lake) indicates (not shown) summer monthly means of 0.6ppm, 0.8ppm and 0.9ppm in June, July, and August 2004, respectively compared to less than 0.1ppm for all summer months in 2005. This information has been added in the revised version.

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

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

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

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.
Done

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?
Done. The figure has been redrawn, and only the backscatter ratio from the aerosols is shown.

Page 20955, Fig. 4: "d) below 1000 m": Change to "d) below 150 m". Why show pollution from SO_2 and NO_2 when not discussed in the paper (also in Fig. 5)?

ACPD
8, S12328–S12341, 2009

Done. Graphs with pollution from SO_2 and NO_2 have been removed.

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.
The small numbers showing the daily positions of the retroplume centroids were inessential, i.e. did not important informations for the understanding which is given by the biomass fire CO source contribution itself. Accordingly, the sentence has been removed from the caption. Sentence with asterisk has been moved to the end of the caption.

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

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

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

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).
Figures have now a regular labelling (0, 2, 4, 6, 8, 8230;) for the altitude axis.

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).
Done.

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

ACPD

8, S12328–S12341, 2009

Interactive Comment