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Atmospheric Chemistry and Physics Discussions

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11, C4129–C4136, 2011

Interactive Comment

Interactive comment on "Microwave Limb Sounder observations of biomass-burning products from the Australian bush fires of February 2009" *by* H. C. Pumphrey et al.

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For ease of comparison with Dr. Fromm's comments, we adopt his convention of writing PX, LY for manuscript page X, line Y.

1 Response to comments by M. Fromm

1.1 Substantial issues

P3, L8: Dr. Fromm suggests that we should not necessarily claim the BS event to be the first “such event” and that we should investigate December 2006 more closely. We have removed the wording describing the event studied as the first such event. As we describe below, we have examined the December 2006 event in more detail. It does appear to be a clear observation of an identifiable biomass-burning plume, but its altitude and duration are far less remarkable than is the case for the Black Saturday event.

P3, L8: Dr. Fromm suggests that we should say more about the obvious problems in the CH_3CN data. We now specify that the “problems” are large biases in the lower stratosphere when compared to earlier measurements and a large systematic difference between the 190 GHz and 640 GHz products.

Figure 2 and discussion on P4, L25ff: Dr. Fromm suggests that we should discuss why the number of affected pressure surfaces decreases as time goes on. This is really part of the discussion of Figs. 3-4 as well as Fig. 2. One contributing factor is likely to be the greater rate of mixing in the troposphere — this causes the enhancement at 215 and 147 hPa to disappear within a few days. The part of the plume in the stratosphere proper (100 hPa and higher altitudes) affects only two MLS levels for most of the time: 100 hPa and 68 hPa for the first week or so, 68 hPa and 46 hPa for the rest of the event. The signal drops into the noise a little earlier for the 68 hPa level. We add a note to the text about the stratosphere/troposphere distinction; we already state that the plume altitude appears to be increasing.

P5, L20: Dr. Fromm requests that we clarify where in the world the largest CO values are for the days when the plume is not present. They could be anywhere between 5°S

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and 60°S although they are most likely to be at a low latitude as can be inferred from Fig. 1. This isn't really important for Figs. 3 and 4 because when there is no plume the number of unusual points (Fig. 3) is always zero or very close to it. And the highest three values will always be about 4 standard deviations above the mean when there is not some event going on which is distinct from the roughly Gaussian distribution of a normal day's data. We add a clarification as to the latitude range covered.

P5, L23: Dr. Fromm requests a statement about the data quality of H_2O, HNO_3, SO_2, HCl and O_3. I would prefer not to add any detail on this as it is rather a digression. The information can be found in the MLS data quality document: this is essential reading for anyone using or interpreting the MLS data. A sentence has been added directing the reader to this document. I have, however, re-visited the water vapour, partly in order to help with explaining Fig. 7, partly on account of Dr. Fromm's request that I characterise the water vapour in the plume. Although the water vapour is not enhanced as clearly as the main biomass-burning products, the plume can still be seen to be noticably wetter.

P6, L12: Dr. Fromm remarks that the reader may not be familiar with the various species known to be common in biomass-burning fumes and suggests that we provide a reference. We have done so.

P6, L12 Dr. Fromm asks for more guidance on interpreting Fig. 7. He notes that there is a positive enhancement everywhere except for the region near to the water vapour line. This enhancement is partly due to water vapour; I have added water vapour to the calculated species in Fig. 7. Note that the calculated effect of a water vapour enhancement also shows the dip in the centre of band 2 which Dr. Fromm mentions. It may at first seem counter-intuitive that the enhancement is much smaller in the region immediately surrounding the water vapour line. This happens because water vapour absorbs so strongly: at frequencies near the line centre the atmosphere is opaque and all of the radiation observed by the instrument comes from an altitude far above the tangent altitude.

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P7, L12: Dr. Fromm asks specifically for a better characterisation of water vapour in the plume. I have added this to the previous section.

P9, L24: Dr. Fromm notes that Winker et al. (2010) discuss CALIPSO in general but not its observations of the Black Saturday event. He is correct — I have asked the CALIPSO PI if they have a paper in preparation that I could reference but I have not received an answer. Searches so far tend to turn up only conference abstracts — nothing that I could reference.

Figure 11: Dr. Fromm notes that Fig. 11 is far too cluttered and suggests some possible improvements. We have split each part of the figure into two separate panels, one for the upper troposphere levels and one for the lower stratosphere levels. This does indeed make the figure a lot clearer and shows much more dramatically how unusual the Black Saturday event was. We have not plotted the 31 hPa level as no biomass burning events affect CO at this level directly, not even the Black Saturday event.

Dr. Fromm also suggests that the event in late 2006 be investigated in more detail. As the new figure makes clear, this event affects only the 316—147 hPa levels: the Black Saturday event is unique in affecting the 100—46 hPa range. The December 2006 event occurs beteen 12 and 17 December and is located initially to the East of New Zealand, moving eastwards towards South America. It is probably associated with the Great Divide fires (also in Australia) which burned throughout December 2006 and January 2007 and which were particularly intense in 9-11 December 2006, shortly before the peak seen in Fig. 11. I have re-written the section of the paper that discusses Fig. 11 somewhat in order to mention this. I also note a couple of the more minor features of the time series.

1.2 Minor / Technical issues

Abstract / sec 2.1: The ascent of the plume is added to the abstract.

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P4, L14 : Single line paragraph fixed.

P4, L25: Text description now mentions the pressure levels.

Fig. 5: Axis ranges tuned to prevent legend obscuring data.

Fig. 7: The referee asks "What determines the frequency resolution of the measurements[...]?" The channel positions and widths are hard-coded into the design of the MLS instrument: see Waters (2006) (which we already reference) for details.

Fig. 7: Dr. Fromm notes that the radiance data are reported on altitude surfaces while the mixing ratio data are reported on pressure surfaces. That is the way MLS works: the fundamental co-ordinate for radiance is the tangent altitude, which is set by where you point the antenna. But the fundamental co-ordinate for the retrieved products is a fixed set of pressure levels. The tangent heights in a single scan are actually 300 m apart in the lower stratosphere and are slightly different for every scan. To average them together you have to interpolate to a fixed vertical grid. I chose a 1 km spacing for this as it is closely-spaced enough to give a clear view of how things change with height but does not clutter the plot up with too many lines. Dr. Fromm notes that this spacing is smaller than the 2.7 km spacing between the pressure levels. (The effective resolution of the retrieved products is different again and varies from one product to another. Data users should consult the MLS data quality document for details.) I have added a sentence to clarify the averaging process.

Fig. 7: Dr. Fromm asks: 'What is meant by "intermediate"? ' The MLS radiometers (with the exception of the 118 GHz radiometers which we do not discuss in this paper) are double-sideband radiometers, so each spectrometer channel is sensitive to two different bits of the spectrum, at equal distances above and below the local oscillator (LO) frequency. The intermediate frequency (IF) is the difference in frequency between the LO and the two bits of the true spectrum being measured. For example, band 6 of MLS is fed by radiometer 2, which has an LO frequency of 191.9 GHz and is at an IF of about 14.2 GHz. It is therefore sensitive to both the 206 GHz Ozone line in its upper

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sideband at $191.9 + 14.2$ GHz and to the HCN line at 177.2 GHz which is not far from $191.9 - 14.2$ GHz. I have added a sentence to the figure caption to define IF.

Dr. Fromm raises an issue of style in axis labelling. Suppose we have an axis where the numeric labels are frequencies, given in GHz. Fundamentally, the axis ticks should say
100 GHz 200 GHz 300 GHz 400 GHz
with an overall title that says "Frequency". To avoid writing "GHz" in every tick label you divide both the tick labels and the overall title by the units, "GHz", to give
100 200 300 400
with an overall title that says "Frequency / GHz" Now I can not remember which of my mentors told me to label axes like this but it must have made a strong impression because I have done it like that ever since. I will change it for the final version if the editor directs me to do so.

P7, L12: The referee asks "To what is the reference "Latter effect"?" The intended reference was to the spectrally flat[ish] enhancement in the previous sentence. I have re-written the sentence in a manner which is hopefully clearer.

Fig. 8: The referee notes that the altitude grid in the top panel is slightly different from the lower panels. This is a side-effect of the way the radiative transfer model works: it takes as input

- Profiles of temperature and mixing ratio on a fixed pressure grid
- The *pressures* of the tangent points
- The geopotential height of *one* pressure level

As output, it produces

- The *altitudes* of the tangent points

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- The radiances

It is designed like this because the radiances and the tangent altitudes are the quantities that are measured by the instrument and are present in the level 1 data. Everything else has to be inferred by the MLS L2 retrieval code and is present in the level 2 data.

Figs. 9 and 10: UTC added to times in figure captions as requested.

2 Referee 2

This referee requests the addition of more references. We have added an introductory paragraph containing the references he requires. The referee asks the specific question: Could CH_3OH be an operational MLS product? To do this, I think one would require a retrieval phase that used band 5 (sensitive to ClO but NOT CH_3OH) and the band 10-11 region (sensitive to ClO AND CH_3OH). With both spectral regions used at once the two species should become separable and we have added a sentence to this effect to the paper. This is on the list of things to be attempted for version 4 of the MLS data but it remains to be seen whether it is achievable in practice.

The reviewer thinks that the "wider context" section could be extended. I have had to add a certain amount of extra detail to this section in response to comments from Referee 1.

P5534, L6: The referee asks for more information on the errors in the CH_3CN and HCN data. I have attempted to do this.

The referee asks whether the section on trajectories (currently sec. 3) should come immediately after section 2.1. and before the current sec. 2.2. While I see his point, I am not convinced that the required major re-organisation of the paper would result in a significant improvement. So I have taken no action on this point.

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The referee asks (again) whether a retrieval of CH_3OH would be possible. I address this above.

The referee asks whether the polluted airmass increases in altitude. We have altered the paper to state this explicitly in response to referee 1.

Like Dr. Fromm, referee 2 requests that figure 11 be clarified and the rest of the mission be discussed in more detail. As noted in our response to Dr. Fromm, we have done this.

3 Other changes made

P3, L2: “Almost flawlessly” changed to “with little interruption” to reflect the several weeks of data lost in spring of 2011.

Sec 2.2.1: Statement added describing the negative mixing ratios of ClO that appear in the plume at 100 hPa and noting that these are a systematic error that decreases rapidly with increasing altitude. We didn't feel that it was appropriate to show this feature in Fig. 6 and not to make a statement about it.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 6531, 2011.

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