

## ***Interactive comment on “Tropospheric ozone and its precursors from the urban to the global scale from air quality to short-lived climate forcer” by P. S. Monks et al.***

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Received and published: 22 May 2015

This is a very interesting review paper. At first I was slightly daunted by its length, but it actually was a very easy and enjoyable read. It provides a very nice up-to-date review of what is a complex topic, simultaneously providing a good introduction to the subject, whilst exploring some of the latest research findings. I expect to use it as a recommended paper for my students (UGs and PGs).

I think the paper should be published subject to minor revisions.

We are grateful to the referee for the comments and insights on the paper. We have

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dealt with all the comments and list below (in brief) the changes made.

I thought the title of the paper was rather cumbersome and not quick to understand. I would suggest something more concise.

The title has been chosen to reflect scales and roles of ozone.

Throughout the paper, but particularly towards the front, ensure that all acronyms and chemical formula are defined.

Noted and checked.

P. 32712, lines 26-30. I believe that the reference to Bloss et al (2005) refers to the high OH concentrations in the tropical lower troposphere rather than the greater ozone production from long-lived HCs there. As it stands, this is not clear. Whilst it is expected that there will be greater oxidation of the long-lived HCs in tropical lower troposphere, the production of ozone does rather depend on the amount of NO<sub>x</sub> present. Fig. 2 relates to this. Whilst the plots indicate high ozone production in the tropical lower troposphere, the non-linear scale for the legends tends to hide some of the variation at the higher rates. Note axes labels are missing from the upper panels.

The Bloss paper shows fraction of methane loss by atmospheric region which is referred to in the context of the highlighted sentence. We agree that ozone production is a combination with NO<sub>x</sub> availability as mentioned.

P. 32716, lines 21-23. “Considering : : :”. This is not a sentence.

Sentence rewritten.

P. 32717, lines 5-6. I suggest including a reference to Reaction R3, for example, for the regeneration of OH.

Added

P. 32717, lines 6-8. This says that production of O<sub>3</sub> is shown schematically in Fig.

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3. Although Fig. 3 was not what I had expected which was a figure that would show schematically the reactions involved in the formation of ozone. I think this would be a useful additional figure.

New figure 3 added for methane oxidation cycle.

P. 32717 discusses Fig 3 including the transition from point A to B and from point C to B. I also think it is useful to discuss moving from point A towards the origin and from point C towards the origin.

Text has been revised to highlight the points and the transitions in differing ozone formation/destruction regimes.

P. 32718, line 12, suggest "which can be readily".

Done

P. 32718 discusses the impact of deposition in rural areas in such a way that it seems to suggest that deposition is not important in urban areas. Of course in urban areas there is the added impact of the NO<sub>x</sub> titration effect, but that doesn't mean that deposition isn't still an important ozone sink.

Having looked at this, we are not sure that we get the same inference from the text.

P. 32729, line 9. I didn't fully understand what was meant by "by treating the vegetation to fully close stomata". Please clarify.

This section of text has been rewritten.

Structure of section 2.1.2. This seemed a bit odd, with the end of section b introducing sections c, d and e, which all seemed to be sub-sections of b. Consider restructuring the headings.

These are all separate features of the uptake, though obviously interrelated. Sections kept as was.

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P. 32722, line 14, suggest "deposition rates to water"

Done

Structure of section 2.1.3. I suggest giving the sub-headings letters a, b, etc. I also suggest perhaps separating stratospheric-tropospheric exchange and summer monsoons. I don't see the need for them to be together.

Separate section headings made and STE separated from seasonal transport patterns as suggested.

P. 32733, lines 14-18. "this behaviour", which I take to be the decreasing trend in high percentiles is said to be in part due to increasing hemispheric ozone levels, but this would lead to reduced ozone. Please clarify.

Sentence modified to "This behaviour has been interpreted as resulting from the combined effect of regional pollution controls since 1990 (Vautard et al., 2006) and increasing hemispheric ozone levels (Derwent and Hjellbrekke, 2013)".

P. 32734, line 6, "non-significance of the trends". Urban or rural background?

Rural background added

Section 2.3.2 relates to "evolution" of emissions and yet, quite a lot of the text at the end of this section is on uncertainties, which might fit better in the following section 2.3.3. in uncertainties.

We feel though while this might be correct, that the benefits from such a major reorganisation might be counterproductive.

P. 32738, line 5, suggest "among these inventories".

Done

P. 32738, line 7, suggest "lowest and highest".

Done

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End of section 2.3.2.a is about shipping emissions. These do not seem to specifically relate to Europe or N. America, so I suggest some restructuring.

Section restructured and shipping pulled out as a separate section.

P. 32739 lines 21-22, suggest "For India, the range of values proposed by the different groups is even larger, : : :"

Done

P. 32739 line 26, suggest "Figures 7 and 10"

Done (with new Figure numbers)

P. 32740 line 13. When you say "deterioration" of emissions, do you actually mean "varying deterioration"?

Change made

P. 32740 line 21. "most countries".

Deleted "the"

P. 32741 line 1. "on a few".

Added "a"

P. 32741 line 6. "information on".

Added "on"

P. 32741 line 8. "uncertainties in".

Changed

P. 32741 line 20, says that Figure 14 also highlights the "growing" importance of emissions from Africa. It doesn't actually highlight this as it only shows 2005 data. It does however show that in 2005, African emissions are comparable to emissions from other

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regions.

Referee is correct removed "growing".

P. 32742 line 24-26. This is confusing as it says an example of "variability" is : : : :the "constant" high fire episodes.

Sentence rewritten

P. 32743 line 9. I would also suggest that Fig. 17 shows large differences for broad regions as well.

Agreed.

P. 32743 line 12. "limit in".

"limit to the accuracy" is OK

P. 32743 line 29. "remain in".

Done

P. 32744 line 6. "taken as constant".

Done

P. 32744 lines 18-19. "fire plumes".

Changed to from fires

P. 32744 line 23. "fire emissions".

Done

P. 32746, line 11, suggest "lowest and highest".

Done

P. 32747, line 16, should refer to Fig 21b not 22b.

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Done

P. 32750, lines 8-9, suggest "during a 2 year period".

Done

P. 32750, lines 13-15, I am not sure of the relevance of this within this section.

As this section deals with a climatological view, the impact of Saharan dust seemed to fit best here.

P. 32751, line 13, suggest "than would be".

Deleted "what"

P. 32752, line 1, refers to Figure 26. As well as ozone, this figure includes PM10, which is not discussed in the text and is actually not relevant.

Agreed (as per referee#3) - PM10 is present owing to source of data, thought best not to doctor figure. The figure caption has been expanded to explain significance of result.

P. 32752, line 10, suggest "coupling at the".

Left as is – two things can be a couple

P. 32752, line 20, "emission".

Done

P. 32753, lines 22-24. It is not clear why there is an interim target and the "High Level" maximum daily mean (one being 40 ppb than the other). Please clarify.

These are nomenclature used by WHO to indicate high and significant health impacts from ozone. Text added to indicate this.

P. 32756, line 18. It would be helpful to provide the definition of SOMO here. It is given later on page 32801.

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Cross referenced to section 5.

P. 32756, line 22. Surely this should be "calculated" increases in health effects?

Agreed and changed

P. 32757, lines 1-13. Again the comments here seem to refer to actual increases in ozone impacts depending on the choice of SOMO. Surely these should be calculated impacts.

Yes, these are indeed calculated impacts based on measurements and models.

P. 32758, lines 12-13. This could be defined as AOT40 as again this used later in the paper.

Added AOT40 and cross link to section 5.

Section 4 Topics. It is not clear to me why the various topics are ordered in the way they are. I would suggest ordering the topics something along the lines of emission sources, chemistry, specific regions, general topics (such as modelling and nitrogen cycle).

A new introduction has been added here to overview the selection of topics (as per referee #3).

P. 32763, lines 23, suggest "concentrations have been observed".

Done

P. 32765, Up until now ozone levels have been given as mixing ratios. I realise that here they are given as mass densities because of the units of the thresholds, but I think it would be helpful to be consistent with the earlier text to give the values in mixing ratios (even if this means giving the values in both units).

Units have been standardised.

P. 32765, line 20. The 3 needs to be a subscript.

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Done

P. 32765, line 22, suggest "avoided by such policies".

OK, as is

P. 32765, line 24. What is meant by "small but substantial"?

It means low fractions which have large health impacts.

P. 32768, lines 3-4, "Tropical biomass burning dominates : : :". It would be good to give the percentage contribution from this biomass to burning emissions to compare to boreal fires.

Page 32768, states in terms of carbon that only 9% is boreal, therefore 91% in tropical.

P. 32768, line 17. "boreal".

done

P. 32768, line 21. "BORTAS was to".

done

P. 32769, line 4. "drivers of the OPE".

done

P. 32769, line 26. "algorithms"

done

P. 32769, line 29 – p. 32770, lines 1-3. I am confused by the comment that boreal fires emit products up to 10 km, and then the subsequent comments which limit emission to below 4 km. Please clarify.

Text modified to "Depending on the fire radiative power (FRP) and size of the fire, Freitas et al., (2007) have shown that plumes from fires are likely able to reach 10 km

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altitude. Based on a statistical analysis of 5 years of satellite observation by MISR over North America, Val Martin et al., (2010) have shown that the median altitude of plumes is found below 3 km altitude for boreal forest fires. A significant fraction (4-12%) of those plumes are thus injected above the boundary layer and are more spread-out vertically depending on the stability conditions. In comparison, tropical biomass burning plumes are mostly limited to the first km of the atmosphere."

P. 32770, line 16. "have a strong impact on meeting air : : :".

Section removed owing to unpublished results.

P. 32770, line 17. "Figure 30".

Figure changed

P. 32770, line 18. "July 2012 in the frame"

Removed

P. 32770, lines 23-24. "and given plume age : : :..pathway apparently)." I really don't understand the point being made here. In fact I am really not very sure what message is trying to be conveyed with respect to Figure 30.

Removed

P. 32772, line 20. "of its key".

Done

Section 4.4 Halogens, first paragraph. I would prefer to see the reactions given on separate lines rather than integrated within the text.

Done

P. 32777, line 20. "to O3".

Done

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P. 32777, line 28. "Bromine is twice as important as chlorine as an ozone sink".

Done

P. 32782, lines 8 and 9. "reported for the tropics".

Done

P. 32785, line 1. "At the continental".

Done

P. 32786, line 8. "can be a significant".

OK

P. 32787, lines 22-23. If the power is given for over the land, why not for over the ocean? Having said that, the rest of the paragraph suggest that other parameterisations may be better, so perhaps there is no need to give any values (i.e. remove the bit in brackets).

Done

P. 32798, line 16. What is the Advanced Light Source?

Added synchrotron - <http://www-als.lbl.gov/>

P. 32799, line 23. "in its excited".

Done

P. 32802, line 2. "100s".

Done

P. 32805, lines 2-5. "even if : : . penalty". This is confusing. Please clarify.

Sentence rewritten.

P. 32805, line 16. "deaths".

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Done

P. 32806, first paragraph. Comments relate to 20% emission changes. The emissions of exactly which chemical species were changed?

In all precursors

Section 5.4. Most of the material on page 32807 is about the science of the impact of climate change on ozone and it is not until the next page that this section really deals with the policy context, which is what section 5 is about.

Agreed, there are some blurry lines between these sections. It was aimed that one would look at policy and the second at the science of the situation.

P. 32808, line 9. "impacts".

Done

P. 32812, last paragraph. I think it would be good to mention personal exposure monitors here.

References and a sentence added for personal exposure methods.

P. 32813, lines 3-6. It seems a bit odd to add this bit about the whitefly in the conclusions when it hasn't been mentioned before.

The aim here was to give a broad perspective on future directions and new slightly left-field directions, hence the inclusion of the whitefly.

Throughout the paper, but particularly towards the front, ensure that all acronyms and chemical formula are defined.

Noted and reviewed throughout manuscript.

Be consistent with the use of upper case letters, particularly when referring the specific regions, e.g. polar regions, boreal regions, tropics. Also stratosphere-troposphere exchange, chlorophyll, dissolved organic matter, background ozone

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Noted and reviewed throughout manuscript.

The text on a number of figures was rather small. Please make sure it is legible in the final paper.

Noted

Fig. 4. Although the RC terms are defined in the text, none of the other terms are. They should either explained in the text or figure caption.

Added link to nomenclature in text

Fig. 7. According to the figure headings some of these emissions are for the USA and others for N. America. The caption should reflect this.

Figure redrawn to ensure consistency.

Fig. 8. "data for Canada".

Done

Fig. 17. "see Fig. 17-1b" makes no sense.

Cross reference updated

Fig. 18. "of the mass"., "from Sofiev et al. (2013)."

Corrected

Fig. 21. In the caption please indicate for the right hand panel whether "This study" is a bottom up or top down study.

The "This study" from the Tohjima paper is a top-down estimate, figure amended.

Fig. 27. The two panels would be more comparable if they were both either daily maxima or annual means.

This may well be true, but this is as they are published in the paper.

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Fig. 29. Define MMM and T which are used in the title.

Done

Fig. 32. States that the values plotted are losses. However as the values are negative, they are actually negative production terms. The x-axes labels are rather unclear.

The negative terms represent loss terms.

Fig. 35 need more explanation.

More commentary has been added to the figure legend.

Fig. 37. "emission increases", "leakage rates".

Done

I didn't see Figure 39 referred to in the text.

Added

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Interactive comment on Atmos. Chem. Phys. Discuss., 14, 32709, 2014.

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