

Interactive comment on “Scorched earth: how will changes in ozone deposition caused by drought affect human health and ecosystems?” by L. D. Emberson et al.

L. D. Emberson et al.

l.emberson@york.ac.uk

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General comments: While this is not the first study to consider the effect of dry deposition to vegetation on the concentration of ozone at the surface, the application of dose-response relationships to estimate the implications for human health and potential crop damage marks a substantive extension of previous work. The methodology employed is valid and builds on a significant body of research within the epidemiological and plant physiological communities. The results are discussed at length and the implications of the findings to policy-relevant questions explored. Overall, this is a well

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thought out, well conducted and well presented piece of research, and I recommend publication once the issues listed below are addressed.

Specific comments: 1. Confidence intervals: Epidemiological studies of the human health impacts of ground-level ozone routinely include estimates of the 95% confidence intervals for dose-response relationships, human mortality and morbidity. This is a relatively straight-forward calculation and I would expect at the very least that the confidence intervals for the health impacts are given here and discussed with the uncertainties, although the authors should also highlight how these figures have been derived and make clear that other sources of uncertainty (e.g. within the models used) would further widen the confidence intervals. (With a projected increase in mortality of at most 400, the confidence intervals could be of a similar order of magnitude, and if this is the case could the authors please comment on the implications of this to their conclusions.) Response: Agree with this comment, we propose to add CIs to the estimates of deaths brought forwards to the original Table 3 (CIs will be added, rounding again to the nearest multiple of 5). These will be discussed in light of concentration response function uncertainties (to which these CIs relate) and other uncertainties not captured within the CIs as suggested by the reviewer.

2. Threshold: Analysis of the health impacts of O₃ routinely employ a threshold concentration. While the authors are correct in their assertion that the validity of such a threshold is physiologically unlikely, epidemiological studies show that the correlation between O₃ concentrations and increased mortality is unconvincing below this level. As such, the authors' estimation of 16000 plus deaths attributable to O₃ is unconvincing (particularly in light of the (only) 22000 deaths estimated to be attributable to O₃ across all of Europe). Can the authors comment on why they have chosen to include these calculations? If the results of these calculations are to be included in the paper they should be put into context (i.e. by quoting the 22000 deaths across Europe). Response: Due to uncertainties associated with the threshold, and the likelihood of underestimation of O₃ effects using the threshold of 35 ppb, the 16 000 figure

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was included in the paper to indicate the margin of uncertainties in our calculation (as mentioned in section 2.4). We will ensure the text clearly describes this rationale for including the without threshold data.

The referee made a good point about the 22 000 EU figure. Our 16 000 is the estimate of the O₃ effect for the entire year 2006 whereas the EU estimate of 22 000 is for a much shorter time period (i.e., the heat wave 1-15 August 2003). It should be stressed that the calculation is very sensitive to changes of population, O₃ concentrations and thresholds. It is unfortunate that these input parameters are not quoted in the reference. Assuming the EU figure estimate is without a threshold, the estimates at its country level (e.g., ~2045 for England and Wales and ~3134 for Italy) are considered comparable with our June-July estimate of ~3500. We propose to make this clear in the paper.

3. Modelled vs. measured [O₃]: The authors have taken pains to demonstrate the agreement between modelled and measured ozone concentrations at a number of rural sites across the UK, and note that, in general, agreement is good. However, they also state that the model has a tendency to over-estimate O₃ concentrations by between 2 and 14 ppb (p27861). An over-estimation of 14 ppb in mean O₃ concentration at a rural site is substantial, particularly as these concentrations are then used to derive cumulative threshold-based metrics. The authors need to calculate and show the effect that these over-estimates have on the threshold-based metrics that they use to estimate the impacts. How do the modelled 8-hr ozone and POD metrics compare against those calculated from measured O₃ concentrations? Response: Firstly, we note with some embarrassment that the (p27861) “between 2 and 14 ppb” should be “2 and 14 $\mu\text{g m}^{-3}$ ”. However, the new O₃ metric site validation analysis (see Figure 1a and 1b in response to reviewer #1) clearly shows that the model is overestimating O₃ concentrations, especially in urban areas. To give some indication of the absolute magnitude of this overestimate we suggest to include a table/figures that show the range in premature mortalities and POD_y for beech calculated using both the modelled vs the

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measured data with an indication of the distribution of values within this range.

The authors must further demonstrate that the use of these over-estimated concentrations does not significantly affect their estimations of mortality and vegetation impacts. I would like to see some exploration of the sensitivity of their results to more realistic O₃ concentrations (either by “correcting” the bias in model output data or by using the measured concentrations). The former could be applied over the whole domain; the latter extrapolated from the individual sites and closely adjoining areas. Response: We suggest that the analysis described in response to reviewers comment 3 addresses this issue since this directly assess the uncertainty between the modelled and observed estimates. It would seem risky to ‘correct the bias’ as although there is a tendency for the model to over-estimate O₃ concentrations there are also many instances where the model under-predicts O₃ levels, we can’t also not be sure that the measured data are truly representative of the entire modelling domain. Therefore, ‘correcting bias’ over the whole domain would seem likely to jeopardise the scientific sense of the model results as it is likely to add more bias in O₃ distribution and risk estimates as a consequence.

Furthermore, the failure to include any urban measurement sites is of concern here as the study goes on to calculate the impact on human health. In this context, the ability of the model to correctly simulate O₃ concentrations in urban areas is of more importance than rural ones. Can the authors demonstrate that agreement between modelled and measured O₃ is good in centres of population? Response: We agree with this and propose to include urban site observations in evaluation of the health metrics estimated using the model (see also response to reviewer #1 general comment 2b.)

4. Soil moisture status: The authors have stated that soil moisture is critical to stomatal g_s and deposition and that the available water content calculated by the CMAQDO₃SE model tallies with that from the Met Office (based on observations). However, there is a difference of 5% between the available water content calculated by the two models (i.e. DO₃SE over-estimates soil moisture by 20% if MORECS is taken as “truth”, thereby over-estimating stomatal conductance and hence uptake of

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O₃ by vegetation). How sensitive is the DO₃SE model of stomatal flux to soil moisture deficit? Please demonstrate that the 5% difference/20% over-estimate really does have a negligible effect on the projected impacts. Response: This issue was also raised by reviewer #1. We agree this is important and propose to include, in addition to the map provided in the original Figure 2, figures that show the seasonal profile of evolution of SMD for beech and grasslands. These figures will be used to indicate the sensitivity of the model to +/- 20% changes in SMD (since this is within the range of difference found between the MORECS and CMAQ-DO₃SE model) and resulting influence on stomatal O₃ flux (by indicating the values of SMD above and below which stomatal flux will be affected), see also response to reviewer #1).

5. AOT₄₀: The authors include a paragraph in the discussion section (p27868, L25 onward) specifically commenting on the use of the AOT₄₀ metric to assess vegetation damage. However, this metric has not been introduced, explained or discussed previously in this manuscript. If the authors wish to include it here they must explain what it is and how it is calculated. Furthermore they should explain why it would lead to increased rather than decreased O₃ concentrations. Personally, I would recommend removing this section, particularly as the authors choose not to show the data they refer to (the differing patterns of risk – p27869, L3-6). If they wish to retain this section I would urge them to include the figure referred to here. Response: We propose to condense this to a couple of sentences (and introduce and describe the AOT₄₀ index) and also include the AOT₄₀ RCL 'reference' case figure in the original Figure 6 since we feel this is an important point to make.

Technical corrections: At times, the style of the manuscript is rather ponderous and convoluted, making it difficult to follow and obscuring the important message it has to deliver to policy-makers. I would strongly urge the authors to give the revised manuscript to a colleague in a related field to read and comment on in this light. Response: Would agree and propose to make the manuscript more succinct and readable, there are sections reviewer #1 suggested removing which once addressed will

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also improve the text.

Title: Please consider revising the title slightly, perhaps to "Scorched Earth: How will changes in the strength of the vegetation sink to ozone deposition affect human health and ecosystems?", to make it easier to read/interpret. Response: OK

Abstract: p27848, L19-20: Is this the actual number of exceedances days or the difference between scenarios again? Response: Response: Will clarify that the exceedance is the differences between scenarios.

p27848, L23-25: Please make it clearer that when you refer to "protection" you are, in contrast to the previous sentence, now considering damage to vegetation. Perhaps "... of vegetation damage, will lead to a reduction in the impact of O₃ on vegetation across the UK." Response:OK

1 Introduction: p27849, L6: Please revise "loss of atmospheric O₃ concentrations" to "loss of atmospheric O₃" or "reduction of atmospheric O₃ concentrations". Response:OK

p27849, L17: Please break this sentence between (SMDs) and these. Response:OK

p27849, L23: Put the increase in O₃ concentrations of 25-30 ppb into context either by giving the % increase or the baseline O₃ concentration for comparison. Response:OK

p27850, L1: The Solberg citation should not be in parentheses -> "... regional modelling of Solberg et al. (2008) ..." Response:OK

p27850, L10: To demonstrate that this association is well established requires more than one reference. Please provide more references. Response:OK

p27850, L17-20: Please provide references for the non-linearity and species dependent increase in biogenic emissions with temperature, and the possibility that high temperatures combined with drought could decrease emissions. Response: OK

p27851, L10: Is this really 2.5 to 80%; if so, perhaps writing as 80.0 would make it look

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less like a typo. Response: It is 2.5 to 80% so can change as suggested

p27851, L25-26: "This metric is capable sensitivity of O3 to vegetation" Surely the metric measures the sensitivity of vegetation to O3? Response: Will modify

p27851, L29: Consider replacing the word "events" with "factors" or "conditions". Response: OK

p27852, L2-5: It also requires development and application of finely resolved process-based predictive bVOC emissions models. Response: OK..will add

2 Methods: p27853, L8: Punctuation required: ".../CMAQ model" . "Central to this" Response: OK

p27853, L22: Punctuation required: "into CMAQ's MCIP." p27854, L6: Move (Rgs) to go between "surface/soil" and "resistances" Response: OK

p27854, L7: Insert (rext) between "external" and "resistances" Response: OK

p27855, L25-27: From what initial resolutions were the land cover data aggregated? Response: Will add that this was from 1 km resolution.

p27856, L9: Insert "and" between "50 km" and "the". Response: OK

p27856, L25: Sanderson (2002) reference is incomplete. Response: Will correct

p27858, L26: Typo: "fromed" -> "formed" Response: Will correct

3 Results: p27860, L25: Too many parentheses: (R)) -> (R). Response: Will correct

4 Discussions: p27868, L25: Consider splitting this into two paragraphs between "... O3 deposition." and "The study ...". OK

p27871, L3: Punctuation required: "... DO3SE model's ...". Response: Will correct

References: p27878, L1-2: Sanderson reference incomplete. Response: Will correct Sanderson, M. G.: Emission of isoprene, monoterpenes, ethene and propene by veg-

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etation, UK Met Office, 2002.

Will also update a reference describing the EMEP model to Simpson et al (2012) ACP.

Figures: Fig 3 – Fig 6: Please improve the position of the scales on all of these figures. The scale for each map should be closest to the map it refers to. The scales would also be better to the right of each map so that the colour bar is immediately beside the map and the numbers are to the right of that. Furthermore, I would recommend the use of a single bar for all maps in Figures 3 and 4 as the scales are the same for all three. I also suggest that you make clear in the captions of Figures 5 and 6 that the scales for wheat and "stress" scenario respectively are different from those for the other maps in each figure. OK will change Response: We will change the maps and legends as suggested.

Supplement (S1): Formatting: Please ensure that the formatting (use of subscripts) is correct and consistent when referring to the terms in the equation in the text (e.g. p1 rsto should read rsto, p2 fphen -> fphen, etc). Parameters: Please ensure that all the parameters in the equations are clearly defined in the text. For example, on p1, what are LAIs and LAle, on p2 what are fphen_a, etc, ...) Response: Will correct, also need to add a reference to table S2 from p. 27855 ln 14.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 27847, 2012.

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