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Interactive comment on "Declining risk of ozone impacts on vegetation in Europe 1990–2050 due to reduced precursor emissions in a changed climate" *by* J. Klingberg et al.

Anonymous Referee #1

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The authors have submitted an interesting manuscript focussing on the present and future decline in the exposure of European vegetation to ozone as based on modelled reductions in ozone precursor emissions and a changing climate during the time period from 1990 to 2050. The focus of the study is highly relevant from a scientific and policy-related point of view, since the future impacts of ozone on European vegetation are of ecological and socio-economic concern for the respective scientific community, policy makers as well as the public due to the various ecosystem service functions agro- and agro-forestry-systems provide.

The ozone exposure was characterised by use of the AOT40 and the average ozone concentration. Climate simulations and ozone precursor emissions were based on the

IPCC SRES A1B scenario and the RCP4.5 scenario respectively, and then fed into the Chemical Transport Model MATCH, which was applied to entire Europe (50 x 50 km grids). The authors specifically targeted the change in the a) AOT40 between 1990 and 2050, b) length of the growing season for European forest trees, and c) climatic conditions affecting the stomatal uptake of ozone.

The study is well thought through, but would benefit from changes to its focus; the manuscript also has some formal shortcomings. The reasons why a major revision is suggested are listed in the following:

It is rather unfortunate that the study focusses on AOT40 and not (accumulated) ozone flux (e.g. POD), especially because a) the main parameters required for the flux approach seemed to have been at hand and b) potential impacts of the meteorology/climate on stomatal conductance and hence flux are discussed in detail but are not applied. This feels like a step backwards, now that the scientific community is moving more and more to the flux approach. Is there a chance for the authors to apply a (simplified?) flux approach without too much hassle?

If applying the flux approach is not an option, there needs to be some sort of quantification of the effect of the change in VPD, temperature and SWC between 1990 and 2050 on the relative risk of the exposure of vegetation to ozone (AOT40) (e.g. a VPD-modified AOT40?), also in comparison with the benefits from the reductions of the ozone precursor emissions. It is rather hard for the reader to grasp why the authors believe that the positive effect of the predicted reductions in precursor emissions on the relative risk ozone will pose on European vegetation is larger than the negative effects of the potentially increased uptake of ozone in parts of Europe due to a changing climate.

The methods chapter is partly unclear and lacks some key pieces of information (see also specific comments below):

Spatial and temporal resolution of MATCH Why did authors use two different emission

scenarios (RCP4.5 and SRES) – why wouldn't have one been sufficient? The two different 10 year (RCA?) time periods are not being introduced It is not explained how VPD and SWC have been calculated The target vegetation is not explicitly described – why did you concentrate on forests trees and crops, but not on grasslands? Why use of the northern European conifer parameterisation for effect of SWC and VPD (on growing season and ozone uptake?) when study is covering entire Europe? Some results are presented in "Methods" – they should be shifted to "Results and Discussion"

Specific comments:

P. 626 (abstract) In general: Mention somewhere that you focussed on forest trees and crops Line 1: change emission to emissions Line 2: explain what AOT40 stands for

P. 627 (introduction) Line 8, comma after Royal Society ref. Line 12: exchange "amount" for "concentrations" Line 19: change to "The stomatal conductance (gsto) of plants. . .." Line 26: change to "more so in the south than in the north. . .." Line 28: change to "However, precursor emissions. . .."

P. 628 Line 4: change to "To handle this problem, four. . .." Line 11: give ref. for MATCH model Line 13: exchange emissions for emission Line 19: here AOT40 is mentioned the first time – describe what it stands for Line 23: SRES scenario: mention that this is an IPCC scenario and give ref. Line 25: ". . .in ways that are not included. . ." – describe what exactly you mean here Line 26: change to "length of the growing season for forest trees. . ."

P. 629 (Materials and Methods) In general: The link between the different models/scenarios is not very clearly described; explain why you need two different emission scenarios (RCP4.5 and SRES) – why wouldn't have one been sufficient? In general: Describe somewhere that and why you focus on forest trees and crops only Line 1: Maybe only call it Methods? Materials are not involved really Line 11f: Give detail about spatial (grid size) and temporal resolution of MATCH Line 12: Introduce here specifically the two 10 year periods Line 15: it is not clear where the tracer boundary

concentrations are coming from Line 17: change to "RCA3 has been described and evaluated by. . .. . .." Line 22: change to "studies of future O3 concentrations across Europe." Line 23: add comma at end of line after bracket Line 24f: explain why downscaling is important and why 3 m (too high for crops, too low for trees) – also, there is a mismatch of reference height for ozone concentration (3 m) and meteo. parameter (2 m) Line 25: Explain here (?) how VPD and SWC are being calculated

P. 630 Line 6: change to: "AOT40 is accumulated over a daytime window which differs with vegetation type." Line 10: use latest version of CLRTAP MM, 2010 Line 11: comma after brackets Line 13: change to "CLRTAP (2010) uses. . .." Line 17: add reference Line 19f: change to ".., expressed here as the water vapour pressure deficit (VPD), and soil water content (SWC), the water. . .." Line 21: change to "varying between 0 % at. . .." Line 23: get rid of both commas Line 24ff: why use of northern European parameterisation here, when this study is covering entire Europe? Wouldn't it have been better to use a central European parameterisation? Also, it is not clear whether you apply these VPD and SWC thresholds to check their effect only on potential ozone uptake or on length of growing season too? Is this test done only for trees and not for crops?

P. 631: Line 2: get rid of comma after uptake; low to moderate temperature range is too vague – what do you mean? Refer to typical bell-shape curve of temperature function Line 5: Does the growing season calculation method also refer to needle-leaf trees that might have a longer growing season than broad-leaf trees? Line 12: change to ". . .performance has been evaluated earlier and shown good. . .. Line 13: change to ". . .in Europe: In Langner. . .." Line 16: comma after (2011) Line 21: Which are these four sites (e.g. make them bold in Tab. 1). It is not clear that they are a subset of the 13 EMEP sites you introduce in the following sentence. Also, it is not clear where the difference is between "in-depth comparison" (4 sites) and normal comparison (9 or 13 sites?) Line 21: change "in depth" to "in-depth" Line 22: give reference for EMEP Line 23: change to "representing different European climatic regions" Line 26: Are

the EMEP hourly ozone data real measurements or modelled data? If the latter is the case, they can't be described as observations Line 28: change to "the European climate assessment dataset. . ."

P. 632 Line 1: pers. comm. by whom? From line 3 onwards: These are results and should be shifted to the results and discussion section! Line 10: change "in depth" to "in-depth" Line 12: change to ". . .to indicate the observed yearly and spatial variability.."

P. 633 First paragraph: Mention that this refers to the crop growing season! Also add this important piece of information to the caption of Fig 2! Line 9: change to "depends strongly on the credibility of the reduction of. . ." Line 14: change "emissions" to "emission" Line 14: change "are performed" to "will be achieved" Line 15: change "decline" to "declines" Line 16: add at end of sentence where in Europe the risk will not be reduced Line 25: change to " . . . time series of tree growing season AOT40 values. . ." Line 26: change to ". . . peaked before 2000, followed by a decline until 2100."

P. 634 Line 1: overestimate and underestimate are mixed up! Line 3: change "and" to "to" Line 8ff: the two last sentences feel a bit detached from the earlier sentences of this paragraph – blend them in better? Line 10: change to " . . . as part of a changing climate. . .." Line 19ff: the paper would benefit here from a quantification of the drought effect on the length of growing season, e.g. by applying an uncertainty analysis; this should be possible because SWC data seem to have been available for entire Europe? If this is not possible, then at least some references should be added that justify the statement of the drought effect on growing season length in southern Europe Line 24ff: please rephrase sentence – it is difficult to understand

P. 635 Line 11: How meaningful is the given difference between north and south Europe, if the soil moisture effect is not being taken into account? Line 12: General comment: this section is rightly pointing at the potential influence of the climate on the stomatal conductance and hence relative risk of plants' exposure to ozone (AOT40);

however, no quantification of the effects of various climatic variables on stomatal conductance and hence the relative risk is given, which not only compromises the significance of the study, but also – unintentionally - highlights the shortcoming of not having applied the flux approach; could a set of relative risk maps based on a VPD-modified and/or SWC-modified AOT40 be added, if the flux approach is not an option? See earlier comments Line 17ff: this paragraph needs some references that have discussed the effects of VPD on stomatal conductance Line 26: "High VPD occurs at high temperature. . ." – not necessarily, because it is a function of temperature AND relative humidity; be more precise here Line 27: comma after bracket

P. 636 Line 1: here the spatial resolution is mentioned for the first time – move to methods section Line 5: change to ". . .time when the estimated SWC was below. . .." Line 5: see earlier comment: how was SWC estimated? Line 8f: ". . . low SWC reduced stomatal conductance 10-60% of the time and up to 90% of the time . . .. " This is strictly speaking not what can be seen in Fig 8 – please rephrase Line 11: replace "in" by "by" Line 12: change "vary" to "varies" Line 15ff: This paragraph needs references Line 20: it might be preferable to show the relative rather than the absolute increase in Fig. 9; this would also be in accordance with the 20% figure given here Line 20: "increase the leaf O3 uptake to some extent" – this is too vague Line 21: Can a (AOT40) value have a phytotoxicity? Please rephrase here and in the following Line 21ff: explain your statement given in the last sentence of the paragraph Line 25: change to ". . .concentrations, by potentially increasing. . ." Line 29ff.: Here the lack of a quantification of the effects of VPD, temp. and SWC on stomatal conductance and hence ozone flux is very obvious;

P. 637 Line 3f: change to ". . .projected large decline in precursor emissions and hence AOT40." Line 4f: The statement in this last sentence is bold and somewhat speculative, given that no quantification of the relative risk current and future levels of ozone pose on European forests and crops is presented in paper Line 11: "how VPD, SWC and temperature are influenced by climate change.." this is difficult to grasp since you never clearly define what you mean by "climate change" → Methods section Line 13ff: give

reference Line 14: Last sentence → see earlier comments Line 20: give reference(s) Line 28: see earlier comment about use of two different emission scenarios (RCP4.5 and SRES)

P. 638 Line 8: change “is” to “are” Line 16f: change to “..to strongly reduce the exposure of plants to O3 in Europe. . ..” Line 19: all true, but what about O3 uptake?

P. 639 Line 3: change to “Drier conditions characterised by higher VPD and lower SWC . . .” Line 19: General: check plant species name for italics

P. 640 Line 13: use updated reference (2010) Line 15: change PM10 (0 not subscripted) to “PM10”

Table 1: indicate which are the “intensive analysis” sites the Mediterranean is only represented by one site; could for example a Spanish site be added?

Table 2: RMSE row: make sure all figures are given with one decimal

Fig. 1: Refer in the caption to the sites shown in map a and link it to Tab. 1

Fig. 2: Add to caption that this is referring to crop growing season Maybe add sites again to be consistent with Fig1?

Fig. 4: Change caption to “. . .. of O3 concentrations from 1990-2012 at these sites”.

Fig. 6: Change caption to “. . .. of temperature from 1990-2012 at these sites”.

Fig. 7: Change legend of figure a so that the category 0 to 10 % is included: It is not clear whether blank areas are excluded or have a 0 – 10 % time fraction Change caption to “Modelled time fraction when daytime VPD was above. . .”

Fig. 8: Change caption to “Modelled time fraction when SWC was below the CLRTAP Mapping Manual threshold of 15 % by. . ..”

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