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Biogeosciences Discussions

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Interactive Comment

Interactive comment on "Predicting and partitioning ozone fluxes to maize crops from sowing to harvest: the Surfatm-O_3 model" *by* P. Stella et al.

P. Stella et al.

patrick.stella@grignon.inra.fr

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Dear Referee#1,

We acknowledge you for your valuable comments on this manuscript. We answer to your comments in the following. Major part of your comments and questions are taken into account in the revised paper in order to improve the quality and understanding of the study presented here.

In details, we have provided here the answers to each item specified in your comment.

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Interactive Discussion

Discussion Paper

Page 6702, lines 11-13. This comment refers to the comment Page 6714, second paragraph of Section 4.2. We address this issue in the following.

Page 6702, lines 18-21. This issue is the subject of an other paper that will be submitted in the next weeks to "Environmental Science and Technology" ("Stomatal, cuticular, and soil ozone budgets of winter-wheat and maize crops", Stella, P., Lamaud, E., Personne, E., Loubet, B., and Cellier, P.), so it will not be treated here. However, we estimated that for the maize crop of Grignon, the soil deposition represented 70% (32 kg O3 ha-1 y-1) of the annual ozone deposition to the ecosystem.

Page 6703, second paragraph of Introduction. We added the following discussion concerning the O3 effect on air-quality in the manuscript: "Indeed, O3 is responsible for damages on polymeric materials such as rubbers, but also on textiles, dyes, surface coatings, metals and buildings materials (Lee et al., 1996; Massey, 1999; Ahmad et al., 2000; Almeida et al., 2000; Boyce et al., 2001) and causes deleterious impacts to human health, including lung inflammation, reduction in lung function, respiratory diseases, and mortality (Rastogi et al., 1991; Uysal and Schapira, 2003; Bell et al., 2005; Ito et al., 2005; Levy et al., 2005; Targer et al., 2005; Hazucha and Lefohn, 2007)."

Page 6704, line 26. Two main issues are addressed in this answer. First of all, if we well understand the Referee's comment, he suggests that non-stomatal resistances (i.e. soil and cuticular resistances) are dependent on roughness length. In our approach, the roughness length for the canopy is taken into account by the canopy boundary layer resistance Rbl, and for the soil, it is calculated from the ground surface boundary layer resistance Rbs (see Figure 1 in the paper and Personne et al 2009 for the details). With the approaches specifically calculating the transfer resistances in the quasi-laminar layers, in the current parameterizations, (i) cuticular resistances are expressed as functions of relative humidity like in Simpson et al. (2003) and Lamaud et al. (2009) and leaf area index (Simpson et al., 2003; Bassin et al., 2004; Massman, 2004) and (ii) soil resistance is only expressed as a function of soil water content (Bassin et al., 2004) or relative humidity (Stella et al., 2011). The second point concerns the LAI. We defined LAI as a parameter of the canopy structure in page 6704, lines 13-17. Here, we talk about climatic parameters. We understand that this sentence could be unclear for the reader and proposed the following formulation: “Finally, non-stomatal resistances, in particular cuticular resistance, are expressed as functions of air climatic variables (such as air relative humidity) and not as a function of climatic variables at the leaf surface. This issue could have a strong impact especially during growing season when the difference between measurement and canopy heights changes, leading to differences between relative humidity at the measurement height and the leaf surface.”

Page 6706, line 16-20. We acknowledge the Referee to have pointed out this issue. Effectively it was an error. We corrected the parameterization of the cuticular resistance in consequence. The new results do not change significantly concerning the comparisons between measured and modeled ozone fluxes for the three sites (Table 3 and Figures 3, 4, 6a, and 7). Indeed, the conditions corresponding to RH = 100% are typically nighttime conditions during which (i) the fluxes are very weak and (ii) it is the aerodynamic resistance that mainly controls the total ozone deposition. Nevertheless, the modification of the parameterization of cuticular resistance has a significant impact on the ozone flux partitioning during daytime (Figures 8c, 9c, and 10c), by increasing the contribution of cuticular deposition. The figures and related text were changed in consequence. In addition, we showed that there was a mistake concerning the x-scales and y-scales of Figures 4 and 6a that was also corrected.

Page 6707, the last paragraph. This issue was not investigated, so we can not provide an absolute response. However, the use of the efficient leaf area index to up-scale leaf stomatal conductance to canopy level was already satisfying (i.e. see Section 4.2, Page 6715, lines 3-11). In addition the principle of using the efficient leaf area index instead of leaf area index reflects that all parts of the canopy do not contribute in the same extent to total canopy conductance due to in particular radiation inside

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the canopy. Finally, the model presented here was based on the Surfatm-NH3 model (Personne et al., 2009) which also uses the principle of up-scaling with efficient leaf area index.

Page 6714, second paragraph of Section 4.2. We agree with the Referee that we could expect a good agreement between modeled and measured fluxes for the Grignon site. However, it must be noted that only the parameterization of the soil resistance and cuticular resistance were obtained on Grignon but: (i) the parameterization of soil resistance proposed by Stella et al. (2011) was obtained on a range of conditions including other datasets from Grignon in 2007 and 2008 and (ii) the parameterization of cuticular resistance of Lamaud et al. (2009) was on the one hand obtained for a maize crop in Grignon in 2002 (not in 2008) and on the other hand was modified to take into account the evolution of LAI and expressed as a function of relative humidity at the leaf surface (see Section 2.2). In addition, this point is already discussed in Section 4.3, Page 6717, lines 9-13. We clarified this by adding the following paragraph: “The model was tested against measurements of ozone deposition performed in the Grignon site. Although the model was partially built using parameterizations obtained on the same site, they were not necessarily obtained using the dataset presented here and significantly modified. Indeed, the parameterization of Rsoil was established by including other datasets from Grignon in 2007 and 2008 (Stella et al., 2011). In addition, the parameterization of Rcut proposed by Lamaud et al. (2009) was obtained for an other maize crop in an other field in Grignon in 2002. This parameterisation was further modified to be expressed as a function of relative humidity at the leaf surface instead of relative humidity at the reference height and to take into account the evolution of leaf area index along the cropping season (see Section 2.2)”.

Page 6717, lines 10-12. This is a sound remark and we particularly acknowledge the Referee for this issue improving this study. We carried out a sensitivity analysis of the model to chosen parameters: ksoil, Rsoilmin, kcut, Rcutmax and gmax. Four contrasted climatic conditions crossed with three development stages were considered.

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The results were included in the Table 4 and a new section was added (Section 4.4) between “Model validation on La Cape Sud and Lamasquère sites” and “Ozone flux partitioning” as follows: “The sensitivity analysis was carried out on ksoil, Rsoilmin, kcut, Rcutmax, and gmax. In order to take account of the influence of environmental variables on resistances to ozone deposition, four representative climatic conditions were tested (sunny day, overcast day, clear night and overcast night). In addition, because the weight of each deposition pathway is different according to the phenological stage (see Section 4.5), for each climatic condition three development stages with different canopy height and leaf index area were simulated. The results, expressed as relative difference from the reference case (i.e. with parameterisations indicated in Section 2), are summarized in Table 4. The sensitivity to parameters of soil resistance decreases with canopy development while the sensitivity to parameters of cuticular and stomatal resistances increases with canopy development. Indeed, the contributions of stomatal and cuticular sinks to total ozone deposition increase with leaf index area whereas this latter provokes an increase of in-canopy aerodynamic resistance, which lowers the contribution of the soil pathway in the O3 sink. The impact of climatic conditions is less clear. Indeed, we have chosen to performed this sensitivity analysis using micrometeorological classes (sunny day, overcast day, clear night and overcast night) implying that several climatic variables changes simultaneously (e.g. wind speed, temperature, relative humidity and radiation). Moreover, any variation in these climatic variables not only changes soil, cuticular and stomatal resistances to ozone deposition, but also transfer resistances (i.e. aerodynamic resistance, quasi-laminar boundary layer resistance and in-canopy canopy resistance). However, patterns can be distinguished. Overall, the sensitivity to soil parameters is greater during overcast conditions and the sensitivity to cuticular parameters is greater during nighttime. For bare soil periods, the model is particularly sensitive to ksoil. A change of 25% of ksoil can lead to up to 50% increase when ksoil decreased in modelled ozone flux. The sensitivity to Rsoilmin is smaller: 25% of variation of this term lead to a change of modelled flux of around 30% during bare soil to less than 1% during fully developed canopy, the

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flux increasing when Rsoilmin decreased. The sensitivity to the cuticular resistance parameters is the largest during nighttime when canopy is fully developed. The model is mostly sensitive to Rcutmax which is also the term with the greatest uncertainty. The flux increased when Rcutmax decreased. Its variation in the range reported by Massman (2004) can lead to a change of 65% during clear night. The sensitivity to kcut is comparatively small: in the range of uncertainty reported by Lamaud et al. (2009), kcut induces changes of modelled ozone flux between less than 1% and 34% for the cases considered. The stomatal resistance parameter gmax is responsible for a weak variation of modelled ozone flux: 25% of variation of gmax lead to a maximum 11% variation of modelled flux. However, only this parameter was tested here and several others can lead to variation of stomatal resistance such as the parameters of the attenuation functions described in Section 2.3 and Table 1. According to this sensitivity analysis, weak changes in ozone resistance parameters induce large deviations of modelled ozone fluxes. However, the variability of modelled fluxes is strongly dependent on canopy development stages and to a lower extent to climatic conditions. Thus, the fact that the model reproduces ozone fluxes whatever the development stage and whatever the climatic conditions provide evidence of the robustness of the Surfatm-O3 model."

Section 4.4. As for the second comment of the Referee, this issue is the subject of an other paper that will be submitted in the next weeks. However, we estimated that the Grignon site in 2008 was a sink of 46 kg O3 ha-1 y-1.

Abstract and Conclusion. The abstract and the conclusion were modified according to the additional results obtained.

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