Review of: *Particulate matter air pollution offsets ozone damage to global crop production*

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Summary:

The paper presents the results of a numerical modelling exercise which combines a base crop production model (GAEZ) with a chemistry transport model (GEOS-Chem). This framework is used to examine the response of managed vegetation (i.e. Maize, Wheat and Rice crops) exposed to different air quality assumptions (PD, RCP4.5 and RCP8.5). The modelling is done at the global scale but the reported results also discuss the main regions of production individually. Air quality here is characterized by Ozone and particulate matter (PM), the latter being represented by aerosol particles. Ozone is a pollutant with a well-known armful effect on plants physiology (i.e. it decreases their productivity). PM reduces the amount of global radiation available for plants photosynthesis (i.e. ir decreases productivity as well) but it also promotes higher level of diffuse radiation (i.e. it increases productivity). Overall the increase in diffuse fraction (DF) is assumed to enhance vegetation light use efficiency despite a reduction in global radiation. Considering both ozone and PM impacts on crop production, the authors claimed that PM offsets the ozone damaging effect for most of the regions and type of crops considered for present days emission levels (ca 2010). The authors also conduct additional experiments to evaluate the impact of future air quality policies assuming both RCP4.5 and RCP8.5 emission trajectories. They highlight that a reduction in pollution from particulate matter may result in a net negative effect on food production.

General comments:

Linking climate-composition with the terrestrial carbon is an active field of research. Few studies so far have considered the combined impact of PM and Ozone on the global carbon budget. Even lesser have analysed these impact on crop production specifically. The paper brings novel insight and help to appreciate the potential role of climate-composition on food production, highlighting interesting implication for air quality policies. This makes the paper absolutely relevant for publication in ACP.

The paper is well structured and reads nicely. The figures are clear and produced with great attention to details. I strongly support its publication in ACP after addressing these few comments.

Specific comments:

- Modelling the impact of aerosol on the radiative/energy budget and consequently on vegetation productivity is difficult and remains poorly constrained. Intermediate complexity models such as those used in the present study are a good step toward assessing these relationships. However, such framework may overlook some critical feedbacks (e.g. temperature change induced by the aerosol cooling which may shift/bring closer vegetation from its optimum productivity regime, change in cloudiness, change in the hydrology cycle / soil moisture, …). I would recommend softening the title which makes a strong statement, especially when considering that the main results reported in the abstract are based on the most sensitive DF assumption (ΔRUE=100%) and that the framework is not fully coupled.

- As the authors acknowledge, the present study does not consider the secondary feedbacks associated with clouds or reduced radiation reaching the surface (e.g. hydrology, temperature). In a recent study, Unger et al. (2017) argue that the aerosol cooling impact over the Amazon drives a net primary productivity (NPP) increases that is 5–10 times larger than estimates of diffuse radiation fertilization by biomass burning aerosol in this region. These estimates may well be specific to the location, the type of biome considered and the numerical representation of the processes involved but would you believe that PM may then still be able to offset ozone damage in future climate if you were considering these cooling effects?

- Suggestion: To make an even stronger point in the abstract/conclusion, could you provide an estimate of the associated economic cost ($$) attributed to the effect of AQ on crop production?

- In your RCP4.5 and RCP8.5 experiment, do you also modify the meteorology to be representative of 2050 or are you just modifying the PM emissions?

- Along the same lines, in 2050, do you assume the same Land Use (i.e. vegetation distribution) as in PD or do you consider a different distribution for crops?

- Has the growing season changed for the 2050 period?

- Do natural aerosols change in your future climate projections (e.g. Allen et al. 2016)? Could that have an implication for assessing the impact of anthropogenic aerosols on crops?

- How does the representation of diffuse light fertilization used here compares with more mechanistic approach such as those used in CLM (Bonan et al., 2011), YIBs (Yue et al., 2017) or JULES (Mercado et al., 2009)? Is it particularly sensitive? Are crops more susceptible to DF than more vertically developed canopies?

- Same question about the representation of the Ozone damage. How does it compare with representation such as the one of Sitch et al. (2007)?

- Is the representation of the impact of DF on RY based on observations? If so, is it considered to be robust globally or was it derived for a specific type of plant/crops at specific location?

- How the ΔRUE function is applied? Is it function of DF that provides a multiplying factor to adjust RY? Does the reduction in radiation due to PM impact RY as well?

- Page 9 – L18-20 can move/add in methods. So, do I understand correctly that the impact of Ozone on Pcarb and the impact of PM on RY are calculated individually?

- Although there are properly defined in the method, state explicitly what the AOT40 and M12 acronyms stand for in the introduction.

- Page 6, L30: Comparison of SW/DF → add: not shown.

References:

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