Ozone dry deposition through plant stomata: Multi-model comparison with flux observations and the role of water stress as part of AQMEII4 Activity 2

Khan et al., EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-3038

General comments

Dry deposition is an important removal process of trace gases and aerosols from the atmosphere to the Earth's surface. This paper reports on an intercomparison study of 18 dry deposition schemes used in current air pollution and atmospheric chemistry transport models, as part of the Air Quality Model Evaluation International Initiative 4 (AQMEII4), Activity 2. The paper is part of a Special Issue on AQMEII4.

This paper by Khan et al. follows on from a preceding paper in the same Special Issue (cited paper by Clifton et al., 2023), which evaluates the overall dry deposition process for ozone (O_3), through comparisons of modelled and observed deposition velocities. Clifton et al. found "models can disagree with respect to relative contributions from the [stomatal and non-stomatal] pathways, even when they predict similar deposition velocities, or agree with respect to the relative contributions but predict different deposition velocities". This paper extends the analysis, considering the stomatal component and investigates through two case studies how the stomatal uptake of ozone responds to moisture stress.

This is a very detailed paper, with a focus again on ozone (O_3). There are measured O_3 deposition fluxes, albeit from a limited number of sites (Figure 2 in cited paper by Clifton et al., 2020). The analysis is based on six of these sites in the Northern Hemisphere: boreal, temperate, and temperate-boreal transition forests (4 sites), together with an eastern Mediterranean shrubland (1) and a temperate grassland (1) site.

The authors aim to address the performance of the different schemes, process representation and sensitivity to parameter values. The paper reads wells and is likely to be of wider interest. The process-based approaches for stomatal conductance are used in land surface models (which form the land surface component of climate and Earth System models). I recommend publication after addressing the following comments.

Specific Comments

1. Dry deposition schemes

   The authors group the deposition schemes into 4 main types:
   - net photosynthesis coupled models (NP:SM/VPD/RH)
   - Jarvis-type models that include both soil and air moisture impacts (J:SM/VPD/RH)
   - Jarvis-type models that only include VPD_{air} (J:VPD)
   - Jarvis-type models that do not include soil moisture or air moisture impacts (J:NoSM/VPD/RH)

   Details of the dry deposition schemes are provided in the preceding paper by Clifton et al. (2023). While Table 2 and Figure 1 do have relevant information, it would be helpful to have a short summary table in this paper, to list the dry deposition schemes and the scheme 'type' to which it belongs.

2. Comparison to observations and/or observation-derived parameters

   The approach taken by Clifton et al. (2023) is also used here, i.e. the dry deposition schemes are run as point versions using measured meteorological and environmental variables from the 6 sites.

   The authors use two approaches to derive estimates of O_3 stomatal conductance from the observed fluxes of latent heat and the net ecosystem exchange of CO_2: inversion of the evaporation-resistance form of the Penman-Monteith (PM) equation and fitting the stomatal conductance model of Medlyn et al. So far, this is 'standard' analysis of flux data. Is there a reason why the O_3 flux observations could not be used to give the stomatal O_3 component? It is usually assumed that the night-time measurements give the non-stomatal component.

   I could understand the approach used here if the intention is an evaluation of stomatal conductance schemes in general and not of O_3 stomatal conductance specifically. Further, with the approach adopted, more FluxNet sites could be used and for a wider range of site/vegetation types. Some comment or justification is needed.

   From Figure 1, the model ensemble central range seems to reproduce observations at the forested sites, although the peak conductance appears to occur later in the year at Hyytiälä (Figure 1). There are greater differences at the grassland and shrubland sites. There seems to be some evidence that the net-photosynthesis type models perform better. Is this the case?

3. Case studies

   Two case studies are investigated to understand the impact of moisture stress on stomatal conductance, using observations from the Borden Forest and Ramat Hanadiv sites. Sensitivity studies are then undertaken, varying the values of parameters that control moisture stress. The analysis indicates the need to include more processes in the deposition schemes, e.g. inclusion of rooting depth. These are a valuable part of the study.

4. Conclusions and wider interest

   While areas for future development are Identified (inclusion of rooting depth), there are no recommendations about the relative merits or performance of the different types of deposition schemes (i.e. NP:SM/VPD/RH, J:SM/VPD/RH, J: VPD and J:NoSM/VPD/RH). Arguably, some of the Jarvis type schemes do not include all the factors that control stomatal exchange, but this may well be compensated by calibration and choice of parameter values. Can the authors say or give some indications if one type is preferable?

   O_3 vegetation damage is mentioned. This needs some clarification. Presumably, the authors are implying that parameter values may need adjusting to account for O_3 damage. I am aware that at least one leading land surface model (the UK model JULES) includes O_3 vegetation damage (Sitch et al., 2007; Oliver et al., 2018).

   The feedback between increased CO_2 concentrations leading to changing plant physiology and climate has long been known (e.g. Seneviratne et al., 2010; Betts et al., 2007). Further, vegetation water and drought stress are of current interest to the land surface modelling community (Williams et al., 2019, Harper et al., 2021). Therefore, I agree that "ongoing developments in land surface modelling of stomatal conductance and vegetation responses to water stress will likely benefit components of tropospheric O_3 modelling". There needs to be more engagement between the air pollution and land surface modelling community.

Technical Corrections

- Line 201: missing definite article in “from observed CO2 flux” -> “from the observed CO2 flux”.
- Line 465: delete duplicate “depth” in “soil moisture at 50 cm depth ~~depth~~ might”
- Lines 552-553: delete duplicate “the” in “most important driver of the ~~the~~ seasonal variability

Data availability

Information is provided.

Additional references:

Betts et al., 2007: Projected increase in continental runoff due to plant responses to increasing carbon dioxide. Nature 448, 1037-1041, https://doi.org/10.1038/nature06045.

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Seneviratne et al., 2010: Investigating soil moisture-climate interactions in a changing climate: A review. Earth-Science Reviews, 99, 125-161. https://www.sciencedirect.com/science/article/pii/S0012825210000139.

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Williams et al., 2019: How can the First ISLSCP Field Experiment contribute to present-day efforts to evaluate water stress in JULESv5.0?, Geosci. Model Dev., 12, 3207–3240, https://doi.org/10.5194/gmd-12-3207-2019.