Review comments to manuscript: gmd-2021-232

Robustness of simulating aerosol climatic impacts using regional model (WRF-Chem v3.6): the sensitivity to domain size

by Wang et al.

General comments:

The manuscript seeks to investigate the impact of domain size in the regional simulations of aerosol climatic feedbacks. Specifically, the authors focus on China and seek to identify discrepancies in the simulations of precipitation spatial patterns related to the East Asian Summer monsoon (EASM) and attribute them to discrepancies in the simulations of aerosol properties. An ensemble of WRF-Chem simulations is thus generated, where the runs differ by the size of the simulated domain, by the anthropogenic emission levels and inclusion of aerosol feedbacks. The manuscript thus investigates the important and debated question of how to set up regional model simulations to properly account for aerosol impacts on meteorological variables and ultimately on the regional climate. Although the presented topic is relevant to the GMD readership, the following specific and technical comments need to be addressed to consider it suitable for publication.

Specific comments:

- The manuscript should be fully and carefully revised to fix the English grammar. Several sentences are either not clear, missing verbs (e.g. first sentence in the Abstract), or contain typos. Support from an English editor is needed. I will not highlight in the technical comments all the mistakes as they are too many and major rewordings are needed.
- Significant restructuring to the manuscript is needed. For example, the data used for model evaluation is not mentioned until the result section. A separate section discussing the data used should be included before/after the simulation setup. Also, more details are needed about the simulations (see technical comments below).
- The objectives of the study are not clearly stated, as initially the manuscript is presented as a pure sensitivity study, while the result section starts with a model evaluation. Do the authors want to identify which setup plays a major role in simulating different aerosol and meteorological properties or do they want to identify which setup allows for a better representation of observations? If the latter is the case, a sensitivity on the spatial resolution and/or chemistry/aerosol schemes applied needs to be also included.
- While there is prior literature evidence that boundary conditions significantly impact the spatio-temporal patterns of aerosol properties within regional model simulations, varying the domain size is only one of the possible approaches. Multiple literature studies have addressed this issue by analyzing the sensitivity to the spatial resolution applied. The authors should comment on this and expand the literature review to better characterize the ongoing research on the topic (some references are provided below).
- A spatial resolution of 30 km is applied to both the large and small domain. Is this a proper resolution to capture the spatial variability and dynamics of aerosols over the region? A discussion on why 30 km is chosen should be included. Further, simulating a larger domain implies higher computing costs, as it would occur if the author would choose a finer spatial

resolution over a smaller domain. The author should discuss the quantified biases in terms of the resources (e.g. computing cost) needed for such simulations and how the bias can be minimized based on computing costs and the domain size and resolution applied.

Technical comments:

- The title could be improved/reworded. The expression "robustness of simulating" is not very clear.
- Key point #2: it is not clear if a bigger or smaller domain is associated with a weaker EASM moisture transport (similarly at line 39).
- Line 41: it is not clear what is the pattern +-+-+.
- Line 76: it would be clearer to specify the time frame when these air pollution episodes have occurred.
- Line 84: what do you mean by "extraterrestrial natural forcing"?
- Line 113: This paragraph should be revised. What is the impact of the much more simplified aerosol representation in GCMs? Aerosols scales of variability are generally not reproduced by GCMs, so regional simulations may be expected to perform better.
- Line 130: add "lateral boundary conditions".
- Line 131: other literature studies addressing the issue of spatial resolution and parameterizations applied are:
    - Di Luca, A., de Elía, R., and Laprise, R.: Challenges in the Quest for Added Value of Regional Climate Dynamical Downscaling, Curr. Clim. Change Rep., 1, 10–21, doi:10.1007/s40641-015- 0003-9, 2015.
    - Crippa, P., Sullivan, R. C., Thota, A., and Pryor, S. C.: The impact of resolution on meteorological, chemical and aerosol properties in regional simulations with WRF-Chem, Atmos. Chem. Phys., 17, 1511–1528, https://doi.org/10.5194/acp-17-1511-2017, 2017.
    - Diaconescu, E. and Laprise, R.: Can added value be expected in RCM-simulated large scales?, Clim. Dynam., 41, 1769–1800, doi:10.1007/s00382-012-1649-9, 2013.
    - Crippa, P., Sullivan, R. C., Thota, A., & Pryor, S. C. (2019). Sensitivity of simulated aerosol properties over eastern North America to WRF-Chem parameterizations. Journal of Geophysical Research: Atmospheres, 124, 3365– 3383. https://doi.org/10.1029/2018JD029900

- Line 142: which horizontal and vertical resolution did that study apply?
- Line 202: there is no mention of the applied resolution in the description of the simulation setup. Also, the authors do not specify the chemical scheme applied which is also important for the simulation of aerosol properties. Finally, in the result section there is mention of runs performed without aerosol feedback on, so those simulations should be included when presenting the ensemble.
- Line 219: it is not clear how initial conditions are changed. Is the 12-16 May the spin up time? How do you initialize the runs on June 1st? This sentence needs to be rephrased and clarified.

- Line 257: observations should be introduced in the data and methods part and the manuscript's objectives should be revised to include the model evaluation component.
- Line 273: is the underestimation due to the role of aerosols and the fact that lower emissions are provided as input to the model? How do observations compare to the simulations with "real" emissions? It is not clear why the CLEAN scenarios are used for model evaluation instead of the "real" ones.
- PM2.5 needs a subscript through the all manuscript.
- Section 3.2. There was no mention that $PM_{2.5}$ and AOD would be used as metrics for model evaluation, so this idea should be anticipated earlier in the text. Also, it is not clear why the authors compare $PM_{2.5}$ against AOD instead of performing a proper evaluation against observations from the ground.
- Line 371: the NoRA experiments were never introduced before, but they are part of the ensemble setup.
- Line 416-421: what is the role of aerosol composition on the radiative impacts?
- Line 430: the pattern +-+-+ is not clear