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Interactive comment on "Value-added by high-resolution regional simulations of climate-relevant aerosol properties" *by* P. Crippa et al.

Anonymous Referee #1

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Review of "Value added by high-resolution regional simulations of climate-relevant aerosol properties" by P. Crippa, R. C. Sullivan, A. Thota, S. C. Pryor

The study by Crippa et al. assesses possible improvements in high resolution simulations of aerosol by comparing aerosol optical depth (AOD) and aerosol precursor gases in two otherwise identical WRF-Chem simulations at 12 and 60 km horizontal resolution over eastern North America to MODIS for AOD and OMI/IASI for the precursor gases. The agreement of the simulations to observations in spatial patterns and extreme values are analyzed. This topic is well within the scope of Atmospheric Chemistry and Physics and the relatively long simulation period of one year could give insights whether improvements in high resolution simulations depend on season. Due

to the large differences between the 12 km and the 60 km simulation, which are not aerosol related, the very low precipitation rates in the 60 km simulation and a problem with one of the analysis methods publication can only be recommend after major revisions.

General comments:

1) Differences in meteorological variables, in particular relative humidity are identified in the paper as the main source of difference in the AOD simulation between 12 km and 60 km horizontal resolution. As the focus of the study is on improvements in the simulations of the aerosol at high resolution, the differences in meteorological variables would need to be as small as possible. Otherwise the quality of simulating meteorology is analyzed rather than aerosol. Assessing AOD and precursor gases in cloud free scenes may prove useful if the differences in meteorological variables can be minimized.

2) While the 12 km resolution simulation agrees fairly well with reanalysis data, the 60 km simulation shows large anomalies, in particular precipitation is very low. The annual mean precipitation in the studied region should be around 800 -1200 mm with a standard deviation of 180 – 260 mm (Groisman and Easterling, 1994). The precipitation of the 60 km simulation in Fig. S3 is significantly below these values in many areas. It needs to be checked if this is due to internal variability (e.g. by varying initial conditions), resolution dependent model parameters or whether one of the parameterizations used is not applicable for the resolutions used in the study.

3) In the computation of the Brier Skill Score (BSS) MODIS is used as the climatological mean and WRF60 as the current observation. This means if for example WRF60 would simulate unrealistic values, the ability of WRF12-remap is tested in this case to reproduce the unrealistic values, which is meaningless. Rather two BSS should be computed for each of the two simulations (WRF60 and WRF12-remap) where MODIS is used as the current observation and seasonal or annual mean values of MODIS are used for the climatological mean.

4) The climatological relevance of the results is not shown although the study is motivated by the uncertainty in aerosol forcing. A better accuracy for simulating the regional distribution and extreme values of AOD is important for air quality. If the same is true for effects of aerosol on radiation, clouds or precipitation is not straightforward and it would be a valuable addition if this would be assessed.

Specific comments:

P4, L73: Other studies that quantify the impact of model resolution on AOD should be discussed here e. g. Qian et al. (2010), Gustafson et al. (2011). In parallel to this study also a paper by Weigum et al. appeared on ACPD for discussion.

P4, L93: Table S1 gives relevant details of the simulations and should be moved into the main text. References for the parameterizations should be added in Table S1.

P5, L124-L130: According to Tomasi et al. (1983) alpha is often not proportional to ny-2 in the atmosphere. Furthermore, the Junge power law used in Eq. (3) is mainly interesting for historical reasons (Schuster et al., 2006) and the atmospheric aerosol size distribution is rather described by four log-normal size distributions (modes), where not all modes are present all the time in the atmosphere. But this is not particularly relevant here and the information in this paragraph should rather be that fine mode particles have smaller AOD at shorter wavelengths (e.g. 440 nm) than at longer wavelengths (e.g. 865 nm) whereas for coarse mode particles AOD is similar at shorter and longer wavelengths. This is reflected in the Angstrom parameter and the Angstrom parameter can therefore be used as a proxy for the fine mode fraction or fine mode radius (depending on the definition, see Schuster al. 2006).

P6, L144: For which year are the anthropogenic aerosol emissions, 2005, 2008, 2009? If not 2008, why is 2008 simulated and not the year corresponding to the aerosol emissions?

P6, L152: Are the cells at the outer boarder of the domain excluded from the analysis?

In some Figures e. g. Fig. 4, Fig. 6, Figs. S1-S3 one can clearly see the effects of the boundary conditions.

P6, L157-160: This is not clear. Is a single, instantaneous value used at the time of the satellite overpass or are several time steps averaged around the time of the satellite overpass. If the latter: how many time steps, in which time period?

P7, L172-175: Given the uncertainty of MODIS observations is there a minimum value for AOD used for the analysis? BSS incorporates the uncertainty in the observations but what about the other methods used?

P8, L198: Different definitions are used in the literature for planetary boundary height (PBLH), which can result in large differences in PBLH (e. g. von Engeln and Teixeira, 2013). Are the definitions for PBLH in MERRA-2 and WRF-Chem the same?

P11, L314: No explanation is given why BSS is so small in September and October (Fig. 5). Also in Fig. 1 d)-f) the standard deviation of September and October of WRF12-remap is much larger than for the other months. What is the reason for this?

P13, L370-375: How does AOD without AOD from aerosol water compare between WRF12-remap and WRF60?

P13, L377: What is the reason of the dry bias (also over the ocean) in WRF60?

P24, Fig. 3: Why are monthly values shown and not seasonal values as in the other Figures?

-, -: It should be mentioned clearly in the text that the analysis is conducted only over land and discussed why this is done.

Technical corrections:

P1, L1: The relevance for climate of the results is unclear so the title should rather be “Value-added by high-resolution regional simulations of aerosol properties”

P3, L51-52: References for the forcing estimates are missing.

P4, L76: Diaconescu and Laprise (2013) note that “the main added value of an RCM is provided by its small scales and its skill to simulate extreme events, particularly for precipitation.” As this is relevant for the current study it could be mentioned in the text.

P5, L118: Eq. (2) can be derived from Eq. (1) by integration over the atmospheric optical path. It would be clearer if lambda_1 and lambda_2 are also used in Eq. (1) instead of lambda and lambda=1 micrometer.

P5, L121: Define Dp.

P6, L128: Which geometric standard deviation is used for the coarse mode?

P6, L132-160: The model description should be expanded, in particular the part relevant for the aerosol simulation.

P6, L139: The total number of layers should be mentioned here as well.

P7, L162-L183: Give more details about the satellite products used e.g. resolution, coverage etc.

P7, L173-174: Give the right uncertainty values i.e. (+-0.05 +15%) and (+-0.05+15-20%).

P7, L184-L187: Reformulate to explain better how the regridding is done.

P7, L190: Standard scores could be shortly explained.

P8, L206-207: The root mean square difference is not shown in Fig. 1 a)-c).

P9, L225-239: This could be explained better. In Murphy and Epstein it is noted that the first term would be the skill if the second and third term were small. The second term is small if for all points F’ is linear to P’ (conditional bias). The third term gives the overall/mean bias. The fourth term is a correction and should be small.

P23, Fig. 2: It would be useful to add the number of cloud-free data points for each

season and each of the three datasets (WRF12-remap, WRF60, MODIS).

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