

## ***Interactive comment on “Development of prognostic aerosol–cloud interactions combining a chemistry transport model and a regional climate model” by M. A. Thomas et al.***

**Anonymous Referee #1**

Received and published: 7 April 2015

The article from Thomas et al. (2015) presents the results from a regional climate model (RCA4) using cloud droplet number concentration (CDNC) calculated with a chemistry transport model MATCH, coupled with the aerosol dynamics model SALSA. The study describes an experimental setup, using existing models, which improves substantially the description of the cloud microphysical properties in the regional climate model RCA4, using as input the MATCH-SALSA derived CDNC, instead of the standard cloud RCA4 parameterization. The RCA4 model performance with the proposed experimental setup is evaluated with cloud liquid water path from MODIS and total TOA radiative fluxes from the CERES sensor onboard the Aqua satellite. They performed a second experiment to quantify the effects of a better CDNC description in

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RCA4 on the indirect aerosol effects due to present day anthropogenic aerosols. This work does not represent a new model development, but can be useful in particular to the RCA4 community, as it provides a description of a methodology and benefits by including a better aerosol-cloud interactions. The paper is well structured and written and the presentation of the results and conclusions is complete, thus I recommend publication after the authors address some comments.

Main comments:

- 1) As the authors stated in the introduction, a number of regional climate models coupled with chemistry and aerosols already exist, e.g. RegCM3-CAMx, WRF-Chem, and others. It would be interesting to summarize the assumptions in the existing models regarding the aerosol-cloud interactions, and their performances in reproducing CDNC, if some studies are available. This can help to highlight what is new in this study, e.g. is SALSA already implemented (offline/online) in any other regional climate model?
- 2) In Andersson et al (2014) on MATCH-SALSA model, it is stated that “The lack of ammonium nitrate condensation in the aerosol microphysics could cause underestimation of cloud droplet number concentration (CDNC).” I think a comment on this should be added also in your model description section and the possible impact on your results.
- 3) It is not clearly described in sections 2.3 and 4, how the first and second IAE are quantified separately. From Page 910, Lines 6-9, it seems that one or two more simulations were performed to turn off the individual IAEs by prescribing the fixed values for CDNC. This should be explained better, probably in Section 2.3. Did you run both PI and PD simulations turning off the IAEs? Did you turn off the first and second IAE at the same time or you had to perform two separate experiments?
- 4) In section 3.3 it is not very clear the last paragraph (Page 907, 6-10). It seems that in the standard RCA4 version (fixed CDNCs), large scale precipitations are not possible, due to droplet radius below the critical level of 10  $\mu\text{m}$ . At this point, a figure on the impact on precipitations due to the CTRL and MOD simulations could be added.

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5) Regarding the comparison with MODIS and CERES measurements, the authors showed improvements in the frequency distributions (Figure 10 and 12), but I would include when possible also a comparison of the spatial distribution of the measured and simulated fields, to evaluate eventually improvements in the spatial distribution of the simulated fields.

6) Is there a plan to directly implement SALSA into the RCA4 model, to have the online coupled aerosol-cloud interactions? It should be mentioned in the conclusions if such development is foreseen.

Minor comments:

Title: The word “development” in the title is not appropriate, as this work uses existing models doing an offline coupling between them.

Page 898, Line 1: remove comma after hence

Page 898, Line 6: “.. , RCA4, ...” or use parenthesis “(RCA4)”

Page 898, Line 9-10: I would replace with “In the stand-alone RCA4 version CDNCs are constants, distinguishing only between land and ocean surface.”

Page 898, Line 23: which months are included in summer half of the year and winter half of the year? Rephrase.

Page 898, Line 25: “.. reaching  $13\mu\text{m}$ , whereas in the stand-alone version the values reached only  $5\mu\text{m}$ .”

Page 898, Line 28: explicit SD.

Page 899, Line 5: “are estimated in the MOD simulation in comparison to pre-industrial aerosol emissions (1900)”

Page 899, Line 7: You could add in parenthesis the estimates for the first and second IAE.

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Page 899, Line 25-26: I would replace “The study of these ... great detail requires ..”, with “An accurate estimate of these effects requires the coupling ...”

Page 899, Line 27: use “due to their coarse resolution”, instead of lack of resolution

Page 900 Line 10-13: consider the following rephrasing: “Their study also showed that the inclusion of climate-chemistry/aerosol coupling led to significant improvements in climate models.”

Page 900, Line 21-28: The three points highlighted are not unique to your study. Other regional models exist, which have coupled aerosol-cloud interactions. The last point is also too general, in your case also you don't have online coupling between climate and chemistry, so you would have to run a further simulation with MATCH-SALSA using the meteorology from MOD simulation.

Page 901, Line 9: remove “through this coupling.”

Page 901, Line 10: Section title, “Models description and experimental setup”

Page 901, Line 11: Section title: “Models description”

Page 901, Line 14: “an Eulerian CTM”

Page 901, Line 25: remove “precursor”

Page 902, Line 1: which year of EMEP emissions is used?

Page 902, Line 1: Is there a reference for the PM chemical speciation, vertical distribution and in which aerosol size bins the anthropogenic emissions are injected?

Page 902, Line 11: consider replacing with “..Ghan (2002), specifically designed for aerosol representation with sectional bins, is embedded ...”

Page 902, Line 13: remove “the” in “the efficiency of the an aerosol particle”

Page 902, Line 18: “model, RCA4 (...), that provides us ..”

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Page 902, Line 21-25: "the total number of cloud particles were set to constant values over the whole domain, based on .. vertically. These constant values were further used ... ( ... rain). In this work the 3D CDNC fields obtained from the cloud activation model in MATCH-SALSA are now used in the RCA4 simulation."

Page 903, Line 3: why you use 6-hourly CDNC to re-run RCA4? IN principle you can provide CDNC at higher time resolution (1 hour?). Is RCA4 interpolating between 6-hour values? Higher time frequency could improve the RCA4 simulation?

Page 903, Line 18: remove "precursor"

Page 903, Line 19: what is meant for physiography files?

Page 903, Line 25-27: should be better explained how the first and second IAEs can be estimated separately, see also comment above.

Page 904, Line 6: Section 3.1, how is the monthly distribution of SO<sub>2</sub> and PM total emissions?

Page 904, Line 17: To which figure do you refer with summer half of the year? JJA only? You should check throughout the text this expressions, you use summer or winter half of the year in other points, but the figures shows JJA DJF seasonal means.

Page 905, Line 1-2: It is not clear if you are commenting on the summer or autumn/winter distributions. The reference Yttri (2014) is not appropriate here, but you should check the EMEP emissions used in this specific study, to see which anthropogenic sector is mainly contributing to aerosol distribution in different seasons.

Page 905, Line 3-5. I would move this sentence at the beginning of the section.

Page 905, Line 6-12. Would be good to have also a comparison of MODIS vs simulation CDNC geographical distribution, to have a better understanding of the model performances.

Page 905, Line 14: replace with "Northern Atlantic" (also from Caption of Figure 5)

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Page 905, In the text and in the caption of Figure 6 it is not explained what is shown with the colorscale.

Page 906, Line 2-4: the authors claim the impact of transported pollution on the clouds in the North Atlantic, citing the HTAP project report. On the other hand, how the boundary conditions are simulated in the MATCH-SALSA for the aerosol and gases? This should be maybe added in the simulation setup description. Is the main pollution transport pathways from North America to Europe located at such North latitudes, where R4 is also located?

Page 906, Line 22: Also for Figure 8 caption and in the corresponding text, it is not explained exactly what is shown with the colorbar (Normalized frequency?).

Page 908, Line 8-14: would be helpful to compare also the geographical distribution of simulated and observed LWP in order to see if the differences in the lower tail (50-100) is located are a specific region?

Page 909, Line 15: consider rephrasing: "The present day (PD) perturbed case climate scenario is using the MOD simulation setup"

Page 909, Line 17: remove parenthesis from "(PD-PI) case" and replace with "PD-PI differences"

Page 909, Line 18-19: use "from the response" instead of "due to the response" In the same sentence, it is not clear what you mean by response of the land surface without other climate feedbacks.

Page 909, Line 21: "PI simulation" instead of "PI emissions"

Page 909, Line 26: "present day (PD)" instead of "present climate"

Page 909, Line 27: "The spatial distribution of these differences are reflected .."

Page 910, Line 6-9: The separate estimation of the first and second IAEs should be explained better as commented above.

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Page 910, Line 14: a better reference should be included instead of “IPCC models”, from which AR?

Page 910, Line 24-27: consider rephrasing of the sentence. It is long and difficult to read.

Page 911, Line 11: consider rephrasing “a more sophisticated representation of aerosol distribution (emissions, transport, and microphysical processes) can be included at a higher resolution ...”

Page 911, Line 6, point 1, consider rephrasing “Investigate the improvements in a regional climate model simulation of the cloud microphysical properties, using spatially and temporally resolved 3D CDNC fields from a detailed aerosol and cloud activation model.”

Page 912, Line 7-8: you should include the estimated numbers in parenthesis for the first and second IAEs.

The panels in Figures 3, 4, 7, 8, and 9, are small and should be enlarged in the figure

The resolution of Figure 2 is not very good, and difficult to read the text inside.

The resolution of Figure 8 is also low, and the axis labels and titles are difficult to read.

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