

Interactive comment on “Relative impact of aerosol, soil moisture and orography perturbations on deep convection” by Linda Schneider et al.

Anonymous Referee #2

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The manuscript “Relative impact of aerosol, soil moisture and orography perturbations on deep convection” investigates different aspects that affect precipitation stemming from deep convection in numerical weather forecast simulations for six cases with different synoptic forcing. The study includes the impact of cloud condensation nuclei (CCNs) concentration and distribution, soil moisture content and distribution and the smoothing of orography. The analysis comprises domain averaged precipitation sums, time development of precipitation averages, time averaged values of the structure, amplitude and location parameters and time resolved values of the amplitude parameter. Furthermore, convective parameters and cloud conversion rates are analysed. This analysis showed that the introduced soil moisture and CCN concentration modifications affect precipitation amounts stronger than the applied changes in orography. While soil

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moisture causes a positive feedback on precipitation, CCN concentrations affect precipitation unsystematically. The study is very comprehensive and covers many aspects which can affect precipitation rates in numerical model simulations. Despite the effort which was put in the model simulations, the motivation for the conducted simulations is not clear and the analysis methods need to be improved. Thus I recommend the study for publication after major revisions.

General comments: The results from simulation with varying soil moisture, orography (including other external data) and CCN concentrations were compared to each other and conclusions that soil moisture and CCN concentration can affect precipitation significantly were drawn. However, it is not clear to me, how the variation in the initial model conditions compare to each other. Soil moisture differences compare to differences which can occur between observed and modeled soil moisture content. CCN concentrations are described as varying between maritime and polluted conditions. How does this compare to observations? Modification in the orography are based on smoothing to coarser model resolution. How strong do these changes vary eg. compared to variation which can be achieved by tuning the orographic smoothing? Instead of addressing the question on how the resulting precipitation differs, I would rather ask the question how much one variable (eg. aerosol) needs to be changed to achieve the same model spread in precipitation as by a change in soil moisture content by eg. 25%. In the end the fact that soil moisture affects precipitation strongest can also be a result of the strength by which the soil moisture was modified. Preferable to do this an independent ensemble spread would provide a first estimate or the comparison to observational data which are present from the previous study from Schneider. Also possible to use the coarse scale simulation as reference comparison. While a lot of effort was put in conducting a very comprehensive model study, the analysis is lacking and often confusing. For example, mean values of the SAL score are calculated which are later revised as the A value is not representative. Page 10 Line 13 to 22 describe why the previously used values of A are not representative

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Specific comments:

Abstract: Page 1 Line 13: correct initial values are much more important than the spatial distribution ... What is meant by correct initial values? I think what is meant is something like: The amount of soil moisture affects precipitation stronger than its spatial distribution.

Page 1 Line 18: ... that the structure component is highest in the soil moisture ... Are structure values really higher for all soil moisture and CCN simulations or is structure most sensitive to changes in soil moisture (content) and CCN concentration. Also, I would avoid talking about structure in the abstract as the concept of SAL is not clear to the reader yet. What does structure mean? – Intensity of precipitation?

Page 1 Line 19: ... dominant mechanism for convection initiation ... trigger mechanism
What are these mechanisms?

Page 1 Line 20: Location and amplitude parameters are both much smaller. Change to: Location and amplitude parameters both vary over a much smaller range.

Introduction: Missing explanation about the soil moisture precipitation feedback. Missing: The conclusion of the study is to include soil moisture and aerosol variation in ensemble forecast to achieve a sufficient model spread? An overview of how ensemble spreads are generated in current ensemble setups would be beneficial.

Page 2 Line 26: What is meant by soil moisture assumptions? Assumptions in the formulation in the couple soil model or assumptions about the soil moisture content?

Page 3 Line 17: Aerosol or CCN? I think the study is constrained to changes in the CCN concentration while the freezing /nucleation scheme remains untouched?

Methods:

Why chess board like structure to modify soil moisture field. That looks like a very artificial change and could cause artificial circulation. Is the domain average soil moisture

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content the same? How are the random perturbations generated?

How exactly are the inhomogeneous CCN concentration generated? Even though, CCN concentration can vary spatially I would assume they are advected similar to the clouds (at least in strong forcing cases). Clouds which travel through region with strongly varying aerosol conditions seem to be rather unrealistic to me and I fear this causes unphysical affects? In weak forcing cases I would assume the effect of this CCN perturbation is randomly depending on where convection is triggered with respect to the CCN modification.

I assume the changes in the smoothing of external data affecting the orography is only relevant in regions with complex topography, while the modifications in soil moisture and CCN concentrations are applied across the whole model domain.

Page 4 Line 24: Change to homogenous soil moisture is done for all model levels. From that it is not clear if all soil moisture perturbations are applied on all soil layers.

Table 1: Maybe I missed it: what is the aerosol concentration in the reference run? In the text it says simulations with modified terrain and soil moisture run with 1700 cm⁻³. Is this also the case for the reference run? If so, I wonder what the difference to CON is.

The simulations were compared to radar observations in a previous study. The present study would highly benefit from including this comparison eg. also by using SAL analysis. This provides a reference deviation for a better quantification of the variations in precipitation that occur from different model settings.

Results: For the analysis SAL was used. While the A value mainly describes the changes in precipitation amount, it does not give much more information as the comparison of the precipitation amount. However, the S value gives information of whether precipitation becomes more intense and locally constrained (deeper convection) or increases in size. For that it is important to have A as comparison in order to derive if a

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change in structure is caused by a change in the area or intensity. This connection was not drawn in the analysis. Further, the averaging over SAL values over time diminish some effects. I'm not sure what the worth of an averaged SAL values are. Especially later the relevance and correctness of the A-value is often questioned.

Page 6 Line 17: ... the sensitivity to terrain forcing always shows the smallest spread. As already mentioned above, I find this hard to judge as the sensitivity highly depends on the strength on variation.

Page 6 Line 25: How does stratiform precipitation match the title?

Page 8 Line 2-3: Change small to negative Change too small to smaller. Too smaller sound as if this is wrong but it is just different to the reference case. Change large to positive.

Page 8 Line 11: Are the SAL values smaller compared to other studies because of the model to model comparison or because of the averaging?

Page 8 Line 29: On weak forcing days, there are simulations, in which the amplitude does not reflect the precipitation sum? So, what is the sense of the previous analysis than. This makes it really difficult to follow. Also on Page 10 Line 21.

Page 10 Line 7: Change especially to only.

Page 10 Line 24: Bowen ration not introduced yet. What does Bowen ration above 1 mean? Higher latent or sensible heat?

Page 10 Line 28: What is the relation between CAPE and A-component? Why does precipitation increase with reduced CAPE? (If my interpretation of positive A is correct). In Line 30 the argument is, that enhanced CAPE enhances precipitation. In this argumentation I miss arguments about the changed moistening of the atmosphere, what is needed to trigger, convection, destabilize the atmosphere and also to provide enough moisture for precipitation. Showing some more results about convective parameters such as surface temperature, CAPE or LCL developments may support the

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argumentation.

Page 12 Line 1: What kind of precipitation is found below cloud base (rain or snow). Is it only a size argument what makes them less susceptible to evaporation (or sublimation)?

Page 12 Line 20: What are correct initial values?

Technical comments: Page 2 Line 10: the state of the atmospheric Atmosphere or atmospheric condition

Page 11 Line 27: switch 28 July and 11 September as in the text above 28 July is also mentioned first

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