

Interactive comment on “Impact of resolution and air temperature on Large Eddy Simulation of mid-latitude summer time convection” by Christopher Moseley et al.

Anonymous Referee #1

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This article discusses the impact of resolution on the organisation of convection in a LES of summer time convection over Germany, as well as the sensitivity of precipitation to 2m temperature in simulations with 625m grid spacing.

It concludes that there is a benefit in using a simulation with 156m grid spacing as compared to 625m in terms of the diurnal cycle of convection and some of the measures of convective organisation, and that the model underestimates the sensitivity of rainfall to 2m temperature.

Most of the analysis is a valuable analysis of ICON-LEM's representation of summer-time convection. I have some questions about both the methodology and the conclu-

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sions, and some revisions will be required to make the manuscripts suitable for publication.

The writing is mostly clear, although some of the sentences are rather long and the language could be more concise at points (I have suggested some changes here, but more could be made). There are also places where e.g. including hyphens would make the text more readable.

General comments:

- Title: "resolution and air temperature" -> I find this a bit confusing, as resolution is determined by the model configuration, but air temperature is not a model parameter (it impacts the simulated convection, rather than the simulation itself). Maybe mention "sensitivity to 2m temperature" specifically?
- It would be good to add some further information about earlier studies that have looked at sensitivity of convection to resolution. One term that has come up in recent years is so-called bulk-convergence (i.e. the convergence of larger-scale mean properties) as opposed to structural convergence (e.g. Langhans et al 2012, <https://journals.ametsoc.org/doi/full/10.1175/JAS-D-11-0252.1>, Panosetti et al 2019, <https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/qj.3502>).
- p4, l26: The authors mention they have resampled their results on a larger grid. Although such a resampling is a good idea, it is important to be aware that the method used may influence the results. For example, it is likely that the cloud fraction increases due to the resampling, because some grid cells will only partially meet the threshold (this is certainly the case if non-zero liquid water would be used as the mask). It is not fully clear to me how this can be prevented, but it may be worth describing the possible effects. One alternative strategy for regridding would be to randomly sample one of the columns: this would keep the cloud fraction the same (statistically). This may also be relevant to the track statistics (section 3.3.)

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- Section 2.4: It would be good to add some more information on the interpretation of and differences between some of the indices of convection, such as SCAI and COP. It is not clear to me what the advantages of using one metric over the other would be from the current description.
- One of the metrics which is currently missing, and may be helpful in terms of the interpretation of the other indices, is a probability distribution function of object sizes in each simulation and the radar. This could potentially be plotted both for the original data and the resampled data.
- One potential issue with some of the metrics, e.g. I_{org} , may be that it can give disproportionately high importance to smaller objects. One option here would be to consider a measure of organisation that considers objects of the same size (see e.g. Neggers et al 2019, <https://journals.ametsoc.org/doi/full/10.1175/JAS-D-18-0194.1>). It would be good to mention this in the text.
- In section 3.4, there seems to be a significant difference between all simulations and the radar in terms of the organization indices. It would be good to investigate the cause of this in more detail, for example by looking at object size distributions, or the original fields from which the indices were derived.
- One striking feature of figure 3 is that the development of SCAI looks different between different days. The other metrics seem to have a very similar development on different days, and for COP and I_{org} , the differences between radar and simulations are of the same order as the differences between the development of the indices on different days. This may point to the SCAI being more useful than some of the other indices.
- One aspect of SCAI that I am wondering about is the fact that it seems to be consistently low at night. This may partially be due to organised propagating systems, but I am also wondering how the SCAI behaves when convection is (almost) absent? Is there a strong correlation between SCAI and cloud cover?

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- What explains differences in night-time behaviour between cool and warm days?
- The results should likely be interpreted in the context of a given configuration. It would be worth stressing that changes to e.g. the microphysics scheme, as well as further changes to the turbulence scheme mentioned already, will impact on the results. - In figure 8, again there seem to be differences between radar and ICON in terms of I_{shape} and COP, which are bigger than the differences between warm and cool days. Do you understand what causes these differences?
- p19, l11: "larger clusters". I am not sure if this can be said on the basis of the statistics provided. Can you clarify?

Minor/editorial issues (these are mostly easy to address, but could improve the presentation quality):

- p1, l4-5: "showing a considerable..most of the days" -> this is a long clause, maybe it can be broken up?
- p1, l8: "showed that"
- p1, l14: diurnal cycles -> "the diurnal cycle" is clearer, I think.
- p1, l16: "CRMs" (plural)? Or refer to the technique instead.
- p1, l16: "necessary" -> I would simply say "suitable", possibly a well-designed parametrisation could also have the correct diurnal cycle.
- p1, l21: it would be good to explain the differences between LES and kilometre-scale modelling in terms of the turbulence scheme.
- p2, l1: this sentence is on the long side.
- p2, l10: the cumulus scheme would be worth mentioning here as well.
- p2, l16: the presence of super-CC scaling may de-

- p2, l16-17: "even" occurs twice here.
- p2, l20: there are earlier references on the dynamic and thermodynamic components of this sensitivity.
- p2, l22: "air temperature" is a somewhat vague term. I would probably mention 2m temperature specifically, unless a different level/set of levels is used.
- p2, l24: "above-mentioned"
- p2, l27: "object-oriented"?
- p3, l5: "by" -> "of"?, "suited to provide" -> "provides"
- p3, l9: remove "applied"
- p3, l10: 165 -> 156?
- p3, l15: remove "implemented".
- p3, l22: place a comma after "work".
- p3, l26: it may be good to mention something about the surface layer parametrization and the (absence of?) a subgrid-scale cloud scheme. For the turbulence scheme, it would be good to mention how grid anisotropy is dealt with.
- p3, l29: "down scaled" -> I am not sure if this is the right verb.
- Section 2.2: it would be good to spend some text on model initialisation and spin-up of convective structures for the inner nests.
- p4 l4: article "the" missing before billions
- p4, l5: do you mean "the first days"?

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- p4, l8: comma after "costs"
- p4, l11: the differences are also partially due to the inherent unpredictability of convection
- p4, l14: "wide spread" -> "widespread"
- p4, l14: can you give some more information on the presence of cold pools during these days.
- p4, l23: "large scale" -> "large-scale"
- p5: l4 "time-interpolated"?
- p6, l25: note that l-shape is sensitive to discretisation: for example, as far as I can tell, a circle that is approximated by a large number of squares would have a shape ratio of $\pi/4$, rather than 1.
- p6, l27: "contour"
- p7, l4: "defined...results" -> this a very long clause, it would be better to split it.
- p7, l31: "different resolutions" (plural)
- p7, l32: "the" (capitalisation)
- p8, l1: are you referring to June 6, instead of June 3, here?
- p8, l1-5: the later onset in the simulations with higher resolution appears to be consistent on June 3 and June 6. However, some of the other differences may be due to individual large storms. It would be good to mention this at least (running ensemble forecasts of the lowest resolution run would help to establish this internal variability, though I am aware this may be a major effort).
- In section 3, the terms organisation and clustering are used somewhat interchangeably (it may be good to make explicit which of the measures identify clustering in particular, I thought this was mainly l-org).

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- p8, l16: "somehow different" -> remove "somehow", explain the differences for June 6.
- Caption fig. 3: 165 -> 156
- p9, l10: "We now how...tracks" -> I would rephrase this sentence, to tell more about the kind of additional information provided, rather than the fact that additional information is provided.
- p9, l10: "are provided" -> "is provided"
- p10, l2: there is an issue with the parentheses here.
- p10, l5 "even" -> "event"
- p10, l15: remove italics here (m) for consistency (same applies to e.g. p11, l16 and p13, l12/18)
- p10, l17: could the relative percentages be affected by the regridding method?
- p10, l20: "composites"
- p10, l24: "sizes" (capitalisation) #
- p11, l1: "at" -> "in"
- p11, l4 "(g-i)"
- p11, l9: it would be good to add a subscript to the areas, and put "A" in italics.
- p11, l20: "including" -> "and for"
- p11, l30: it would be good to refer back to the concept of bulk-convergence here.
- p12, l8: in terms of differences between precipitation between model and forecast, some of these may be due to the uncertainty in boundary conditions.
- p13, l4 "added value" (no article)

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- p13, l10: "6-day period"
- p13, l14: "introduction" (capitalisation)
- p14, l9: "than for the mean"
- p14, l12: "introduction" (capitalisation)
- p14, l14: is an underestimation of sensitivity to temperature sensitivity consistent with previous findings? It is not clear to me if this result is significant, given that only a few rain cells may have a big impact on the 99th percentile rainfall. The sensitivity test here is not a very strong one, as the bulk of the underlying data stays the same. One option would be to look at how much this differs between (subsets of) individual days in each category (looking at the diurnal average 99th percent rainfall).
- p15, l10: "similar to the larger period" -> "similar to that in the larger period"
- p16, l1: "a stronger degree"
- p17, l2: "there" (capitalisation)
- p17, l2: the trend is consistent, but the actual number of solitary tracks is very different. The differences between "cool days" and "all days" also seem more pronounced in the radar data.
- p17, l3/l5/l9: "there", "instead", "while" (capitalisation)
- p17, l4-19: may this impact on the interpretation of the 3-domain days as well (in the light of the remark about regridding in the general introduction)?
- p17, l20: "Similar as" -> replace by a construction with "similar to"
- p17, l24: "temperaure" -> "temperature"
- p18, l2: "the longer durations tracks above 1 hour life time" -> "the tracks with a life time longer than 1 hour"

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- Figure 5 and 9 have intensity with units km. This should likely be mm/hr.
- p18, l4: "on warm days" is repeated here.
- p19, l4: see my comments on the title. These are different kinds of sensitivities (to the model configurations, to the atmospheric state).
- p19, l15: it could be good to cite some work on turbulence schemes for the boundary-layer grey-zone here.
- p19, l18: "should be left" -> "will be left"
- p19, l19: "similar as" -> "similar to"
- p19, l20: "fewer and larger objects"
- p19, l23: "as to compared to" -> "as compared to"
- p19, l31: "at least simulated qualitatively" -> it would be good to rephrase this (the word choice/order here is odd: you could say the sensitivity to temperature has the same sign)
- p20, l3: "we", "in" (capitalisation)
- p20, l7: "objects" (plural)
- p20, l8: "may be left" -> "is left"
- p20, l11: "higher-resolved" -> or change formulation?
- p20, l28: "in May and June 2016" -> "for May and June 2016"
- p20, l30: but to a smaller degree. -> the sentence construction needs to be changed here (see also my previous comment on significance).
- p21, l1: Remove "However"
- p21, l5: place a comma after "Overall".

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