Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2019-55-RC2, 2019

Earth System Dynamics
Discussions

Interactive comment on "The impact of RCM formulation and resolution on simulated precipitation in Africa" *by* Minchao Wu et al.

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Received and published: 16 December 2019

In this study the authors introduce a procedure to separate the impact of model formulation from the impact of resolution on the dynamical downscaling results of regional climate models (RCMs) driven by observations (reanalyses). The procedure involves performing the downscaling at several horizontal resolutions. The coarsest RCM resolution is set to match the resolution of the reanalysis model that provides the driving data. This is referred to as the "no added-value experiment", which I will refer to as the NAVE. The authors make the point that the NAVE biases vs the reanalysis biases (relative to an independent observational dataset) result from "model formulation" differences and so are independent of added value. Once NAVE biases are defined, higher resolution RCM simulations are employed to document the evolution of NAVE

biases with resolution. It is argued that a reduction of NAVE biases with increasing resolution indicates added value in the RCM. The authors employ this procedure to precipitation biases in RCM downscaling results over the African CORDEX domain from two regional models.

The results of the authors' analysis of model formulation vs resolution is often mixed with few clear results. But this is overshadowed by the introduction of the NAVE procedure itself, which is highly publishable as it provides a tool to the RCM community to make progress on the complex issue of added value in RCM studies. In fact, the NAVE approach would seem to have a logical extension to the much more important issue of value added by RCMs in climate-change experiments. In my detailed comments, I suggest a generalization of the NAVE approach to the issue of value added by RCMs in climate-change experiments. It is my recommendation that this manuscript be accepted for publication with only minor revision.

General Minor Comments

1) NAVE procedure applied to Climate-Change experiments:

The NAVE procedure would seem to be equally applicable to climate change problems to help distinguish the impact of model formulation from the impact of resolution on RCM climate-change responses relative to those of its driving GCM. In the climate-change context, two sets of RCM runs would need to be performed - NAVE runs at the resolution of the driving global climate model (GCM) and the usual high-resolution runs used for downscaling GCM climate-change results. Consider a typical time-slice experiment over a CORDEX domain performed at the end of the 20th and 21st centuries. For a given climate index (eg screen-level temperature, precipitation, extremes etc.), one could construct the three climate-change responses:

R_GCM(X) = GCM_21st(X) - GCM_20th(X)

R_NAVE(X) = NAVE_21st(X) - NAVE_20th(X)

R_RCM(X) = RCM_21st(X) - RCM_20th(X),

where each term on the right is a time (and/or ensemble) average at a given spatial location "X".

In the above, R_NAVE(X) represents the climate-change signal associated with model formulation differences between the RCM and GCM. As for the authors' present-day analysis, the potential for value added due to the response associated with resolution changes may be expressed as:

R_RES(X) = R_RCM(X) - R_NAVE(X).

The NAVE analysis allows the decomposition:

R_RCM = R_NAVE(X) + R_RES(X)

Given R_RES(X), and R_NAVE one can ask interesting questions like:

- Where is R_RES(X) significant in the RCM domain?

- Do these location correlate well with where the authors found downscaling improvement in their NAVE analysis of reanalysis driven RCMs?

- Where is R_RCM appreciably different from R_NAVE? The appreciable difference analysis presented in Section 5 of Scinocca et al. 2015 (JClim p. 17-35) would seem like an ideal approach to address this question. In locations where there exists an appreciable difference, there exists the potential for added value. However, where there is no appreciable difference, there can be no added value - irrespective of how one chooses to define added value.

This is in line with the authors' stated goals (ll.116-118). Clearly such climate-change questions are outside the authors' present study but, they may want to discuss this potential application of the NAVE approach for future investigation.

2) Interpretation of the NAVE:

It is assumed here that differences in the NAVE and driving model results arise from differences the RCM and GCM model formulation. This would be strictly true only if the RCM were also run in a global mode. The one-way nesting approach introduces a number of potential artifacts which are most acute for large RCM domains and applications that do not use interior (or spectral) nudging - both of which are the case for the authors' present study (eg Section 2 of Scinocca et al. 2015 JClim p. 17-35). The authors should acknowledge this issue when introducing the NAVE.

3) RCM model tuning:

ll.183-185 "We note that in general, both regional models - RCA and HCLIM-ALADIN were developed to operate at a range of 10-50km resolution and their performance at 100 and 200km may not be optimal." This is a non-trivial point, given the philosophy of the authors' NAVE approach. Where there is systematic improvement of NAVE biases with increased resolution, the authors interpret this as a systematic increase in added value. However, The poorer results at the coarser resolutions may also be related to a lack of model retuning at these non-standard resolutions. Very few physical parameterizations are automatically scale dependent and an adjustment of their free parameters with changing spatial resolution should in principle be performed.

Retuning the RCMs at each spatial resolution would represent a significant undertaking and these added degrees of freedom would complicate the main point made in this study. Consequently, I would recommend that this issue be addressed by simply having it raised as a caveat.

4) Interior nudging:

In downscaling reanalysis products, the authors chose not to employ any constraints on the interior RCM solution such as spectral nudging (ll.185-186). In focusing on such evaluation experiments, one could argue that it is more appropriate to use spectral nudging to constrain the large scales to obtain the best downscaled results in their study. Any upscale influence produced by the RCM would serve only to degrade the

large scale flow as it is well observed and represented in reanalysis produces. By not constraining the RCM in this way, the authors leave open the possibility that locations of large biases in their high-resolution RCM results are due to the downscaling of the wrong large-scale flow rather than a lack of intrinsic added value. For more detail see Section 2 of Scinocca et al. 2015 (JClim p. 7-35).

Detailed Minor Comments

l.26 "Additionally to the two RCMs" perhaps change to "In addition to the two RCMs"

l.31 "the phase of the diurnal cycle is" perhaps change to "the phase of the diurnal cycle in precipitation is"

l.71 "However, added value from RCMs" should be changed to "However, perceived added value from RCMs" for the context of the sentence.

ll.141-147. It was unclear whether the difference between v1 and v4 was simply a change in a free parameter for an existing scheme or whether the difference was associated with a change in the equations of the scheme. The former might be considered "tuning" while the latter considered a "formulation" difference.

ll.176-178 It would be helpful to show these plots to see if the differences have any correlation with later results (perhaps in an appendix) - particularly the distribution of temperature differences.

ll.260-262 Fig 2b-p. It was often hard to associate the location of a particular bias with the full field in panel a. Expressing the bias as a percentage difference from the full field would be helpful in the West and central regions. However, where there is weak precipitation in the reference/obs data this may be problematic.

ll.350-352 Fig 4. It would be better to use the colour red for the reference GPCC7 curves in this figure. I had difficulty seeing the GPCC7 curves in a number of the model result panels in columns 2-4.

ll.558-560 "In general, model formulation related improvements cannot be considered as an added value of downscaling as such improvements are strongly model dependent and cannot be generalised." Also, such formulations could in principle be used in global models and so obviate the need for the RCM.

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