Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2019-370-RC1, 2020

Geoscientific Model Development Discussions
Open Access
EGU

Interactive comment on "Can high-resolution GCMs reach the level of information provided by 12–50 km CORDEX RCMs in terms of daily precipitation distribution?" *by* Marie-Estelle Demory et al.

Anonymous Referee #1

Received and published: 30 March 2020

In the manuscript "Can high-resolution GCMs reach the level of information provided by 12-50 km CORDEX RCMs in terms of daily precipitation distribution?" Demory et al. evaluate precipitation distributions from an ensemble of regional climate model simulation with a novel ensemble of global high-resolution simulations. The authors aim to answer two questions: 1) If high-resolution GCMs can reach the quality of state-of-the-art RCMs in simulating precipitation over Europe? 2) Can climate modeling uncertainties be reduced by combining RCM and high-resolution GCM ensembles? The first question is well addressed and it is shown that precipitation from the new

Printer-friendly version

Discussion paper

high-resolution GCMs has a similar quality than precipitation from RCMs over Europe. This is a very promising result since it indicates that height-resolution GCMs might be able to provide high-quality precipitation simulations globally (or maybe at least in mid-latitudes). The second question is not addressed explicitly in the conclusion of the paper. The authors did an impressive job in evaluating a large number of models but the presentation and description of results are often vague and leaves a lot of room for interpretation. The novel part of this study is the comparison of RCMs with high-resolution GCMs and the paper would benefit from refocusing on this piece. The comparison of precipitation from 12 km and 50 km CORDEX simulations is already well documented and the sensitivity evaluation of the methods is important but takes up way too much space. Both topics draw the reader's attention away from the novel and innovative pieces of the manuscript. Furthermore, only precipitation intensity is evaluated and the simulation of precipitation patterns is neglected. I added more details about these and other issues and suggestions for improvements in the general and specific comments below. I am sorry that this review turned out to be so long but I see a lot of potential in this paper and sincerely tried to provide constructive guidance to help improve it.

General comments

1) I do not understand why the authors hypothesize that a high-resolution GCM should not have the same quality as an RCM downscaling a coarse resolution GCM. RCMs are tools that allow us to focus our available computational resources on a region of interest to derive higher-resolution climate information. The limiting factor here is the available computational resources. RCMs are not ultimately better in simulating regional climate than GCMs (although I agree that RCMs can be more tuned and are partly developed to perform well in a specific region). If we would have infinite computational resources we would not need RCMs anymore since a global high-resolution GCM should be able to outperform an RCM due to the potential to better simulate the global circulation and to close the water and energy cycle.

Printer-friendly version

Discussion paper

This is exactly the argument that Denis et al. (2002) used in their paper describing the so-called Big Brother Experiment (see section 2.1 in their paper). Therefore, I recommend rethinking the argumentation in your paper - starting with the title. One massive advantage of high-resolution GCMs, which is not discussed in the paper, is that they can provide high-resolution climate information globally. Therefore, the main conclusion of your paper for me (although you did not discuss this) is that we now have global models that have the potential of providing climate information that is on par with CORDEX downscaled datasets, which is a breakthrough.

This also shows that CORDEX has to evolve (which it does mainly through the flagship pilot studies) and explore new territory in climate modeling.

2) Related to the first comment, your paper reads biased. Especially in your introduction (e.g., L56), it reads like RCMs are superior tools compared to GCMs. However, RCMs have a major weakness, which is their dependence on lateral boundary conditions (LBC). Transitioning from a coarse-resolution GCM to a high-resolution RCM is not trivial and can cause problems. That is why RCMs use sponge zones and most studies typically do not show results close to the RCM computational domain due to massive biases, especially along the outflow boundaries. Furthermore, selecting an appropriate domain size and location is not trivial since too small domains cannot spin up higher-resolution features (e.g., Brisson et al. 2015) while too large domains can create unrealistic circulation patterns (Prein et al. 2019). A more unbiased discussion about the pros and cons of GCM and RCM modeling would be beneficial.

3) I suggest removing your "synthetic datasets" from your analysis. Simply multiplying observed precipitation by 1.2 is way too oversimplified to account for observational undercatch. If it would be that simple, the experts that create these observational datasets would have already done it. Precipitation undercatch is strongly dependent on the precipitation phase, intensity, the location of the stations (i.e., their exposure), and the type of gauge used (e.g., shielded vs. unshielded). It is fair to argue that observed precipitation is likely undercatched but adding 20 % more rainfall over the

entire distribution, in all regions, and all seasons is not scientifically justifiable.

Besides precipitation undercatch, there is another error source that affects specifically heavy rainfall in gridded observations, which is the soothing of intense rainfall over larger regions. This occurs in all gridded precipitation datasets that are purely based on gauges and results in dampening extreme precipitation peaks by smoothing the heavy rainfall and redistributing it larger regions. You can find more details about this in e.g., Haylock et al. (2008), Hofstra et al. (2009), or Prein and Gobiet (2017).

4) You are frequently using "resolution" when you refer to "horizontal grid spacing". E.g., the horizontal grid spacing of the CORDEX-44 simulations is roughly 50 km while their resolution is on the order of 2-8 time coarser (e.g., Skamarock 2004). The same concept applies to gridded observational datasets. Isotta et al. 2014 discuss that their precipitation dataset over the Alps has a grid spacing of 5 km while 10-15 km is a lower bound for the effective resolution of the dataset.

5) I appreciate that you performed a lot of sensitivity analysis to test the robustness of your results to various parameters. However, it takes you 1 ÂňΩ pages and two figures to show that your results are robust. Simply stating this in your method section and adding the figures to the supplement would be sufficient and would remove the distraction from your main results since you are not writing a methods paper but rather address impact researchers that want to use these climate simulations.

6) It is okay to assess the added value of simulated precipitation in the EURO-CORDEX-11 compare to the EURO-CORDEX-44 in this paper but I suggest to shorten this comparison since multiple papers have investigated this before and come to the same conclusions as you do (Kotlarski et al. 2014, Prein et al. 2016, Casanueva et al. 2016). This would allow the reader to focus more on the novel part of your analysis, which is the comparison of EURO-CORDEX with PRIMAVERA results.

7) You only evaluate precipitation distribution characteristics and neglect the spatial patterns of precipitation. Cutting back on the comparison between EURO-CORDEX

12 km and 50 km simulations and moving the sensitivity chapter to the supplement would free up enough space to add additional analysis that assesses the simulation of mean, and extreme (or light, moderate, and heavy) precipitation patterns. You could look at spatial correlation coefficients and standard deviations and create summary plots in the form of e.g., Taylor diagrams (Taylor 2001).

8) You do not directly address the two questions that you pose in L151-155 in your conclusions. Especially a discussion on your 2nd questions is missing.

9) The paper could be overall shortened, would benefit from restructuring, and can be in many places more precise. Also, a careful review of the language and style would improve the paper. I added multiple suggestions to the specific comments, which aim to address these issues, but I certainly did not capture everything.

Specific Comments:

L1: I suggest to use EURO-CORDEX instead of CORDEX in your title to make it clear that your analysis focuses on Europe.

L25: At this point in your paper it is not clear what you mean with rainfall bins. It would be better to talk about the contribution of various rainfall rates to total rainfall or something similar here.

L26: high-quality

L28: CMIP5 GCMs cannot capture because

L30: moderate-rainfall

L32-33: This is overly complicated. How about: Extreme precipitation simulated in PRIMAVERA GCMS agrees better with observations while CORDEX overestimates precipitation extremes.

L35-36: Please be careful with such broad statements since you do not assess any benefits for impact studies in your paper but you assess the simulation of precipitation.

L38: representation of the land-sea

L39-40: I think this is a misconception. I agree that it would be beneficial to better coordinate GCM and RCM efforts but RCMs will always be able to run at higher grid spacings than GCMs when using the same computational resources. RCMs should continue to explore the benefit of grid spacings that are out of reach for GCMs (e.g., kilometer-scale grid spacings), which can, in turn, inform GCM development.

L44: It would be good to add some references for RCM modeling here (e.g., Giorgi and Mearns 1991, Giorgi 2019).

L46: RCMs are also designed to balance the same resources.

L49: RCMs are not cheaper to run than atmosphere-only GCMs but they allow to focus resources on a region rather than having to simulate the entire globe.

L56: sample many different

L56-58: Your point 4 is more a disadvantage than an advantage. The need for RCMs introduces another layer of uncertainty, which is hard to quantify unless you downscale a large number of GCMs by a range of RCMs. Running high-resolution GCMs such as in the PRIMAVERA project should be an advantage especially since you show that the simulated precipitation quality is similar to the one from CORDEX without the extra need of downscaling.

L61: There are also regional earth system models, that can be as complex as ESMs (Zhang et al 2020).

L72: would be complementary

L76: focused its effort on downscaling

L79: I suggest to remove CORDEX CORE since it is not relevant for your analysis. You could mention it in the discussion.

L94: high extreme fall / also, what are Mediterranean events? Do you mean extreme precipitation events here?

L97: A discussion of one of the main results of Kotlarski et al. (2014) is missing which is "For seasonal mean quantities averaged over large European subdomains, no clear benefit of an increased spatial resolution (12 vs. 50 km) can be identified."

L101: RCMs are strongly constrained by

L105: should uncertainty be quality here?

L108: GCMs contribute to a lesser extend

L110-116: I do not understand why you introduce convection-resolving RCM simulations here. The discussion section would be a better place for this. Also, what do you mean by recently developed 2-step nesting convection-resolving simulations? 2-step nesting is not specific and not necessary for convection-resolving simulations and can also be applied in coarser resolution RCM simulations.

201: You mention IPCC already earlier.

L201: What is the grid spacing that you mention here? Some CMIP5 models already had 100 km horizontal grid spacing.

L225: atmosphere only

L130: You could mention the 25 km CAM experiments by Bacmeister et al. (2014) and Wehner et al (2014) here.

L131: What do you mean by "weather-type systems that feedback" here? I assume you mean the upscaling of local-scale features on the large-scale simulation.

L141: Similar to the above, what do you mean by "weather-type processes". The term weather type has a very specific meaning and refers to a specific weather pattern (see e.g., Philipp et al 2010).

Printer-friendly version

Discussion paper

L153-154: what do you mean with "spread of information"?

L168: which method are you talking about?

L176: "one per model" which one did you choose?

L179: should the statement "please refer to" be removed?

L198: "the best" it is unclear what you mean by this. This could mean various things. Did you mean "observations with the highest station density"?

L199: The ALPS-EURO4M dataset is not a national dataset and also CARPACLIM includes several countries.

L247: What is this EUR-44 rotated pole grid?

L250: It would be good to tell the reader what you are bootstrapping here.

L254: for the difference

L315: I suggest to move the discussion of Fig 8 and Fig. 8 here. Also, it would be interesting to remap the observations to a 12 km, 50 km, 100 km, and 200 km grid to understand if these differences are purely based on the coarser grid spacing or if the high-resolution models can add additional value.

L319: I would not say that deep convection schemes are more appropriate in RCMs since many of these schemes were developed for tropical convection in GCMs.

L321: reduced compared to DJF suggesting that such a resolutionâĂŽ

L331-332: similar compared to

L346-349: This text could be removed since it should be covered in the figure caption.

L354: "when the strict criteria" please be more specific here. E.g., remains true at the 99 % confidence level.

L361-362: central or eastern Europe

L366: ensembles differ most from theâĂŽ Also, winter is the season with the largest precipitation undercatch in snow-dominated climates.

L440-441: This is a classic example where it is important to differentiate between model resolution and grid spacing. A model with semi-implicit semi-Lagrangian numerics might have the same grid spacing than a model with an e.g. split-explicit 3rd order Runge-Kutta time integration scheme but the latter will have a higher effective model resolution.

L459-460: I suggest to remove this sentence since it is very speculative.

L465-471: Relate to my general comment 5; This paragraph can be easily shortened to something like: "Our results are not sensitive to âĂŽ"

L551-552: Why are you highlighting this? Many studies investigate the impact of aerosols on climate change.

L505: A clean comparison would only be possible if you would downscale a PRIMAVERA GCM with an RCM at the same grid spacing.

Literature:

Bacmeister, J.T., Wehner, M.F., Neale, R.B., Gettelman, A., Hannay, C., Lauritzen, P.H., Caron, J.M. and Truesdale, J.E., 2014. Exploratory high-resolution climate simulations using the Community Atmosphere Model (CAM). Journal of Climate, 27(9), pp.3073-3099.

Brisson, E., Demuzere, M. and Van Lipzig, N., 2015. Modelling strategies for performing convection-permitting climate simulations. Meteorologische Zeitschrift, 25(2), pp.149-163.

Casanueva, A., Kotlarski, S., Herrera, S., Fern√°ndez, J., Guti√©rrez, J.M., Boberg, F., Colette, A., Christensen, O.B., Goergen, K., Jacob, D. and Keuler, K., 2016. Daily precipitation statistics in a EURO-CORDEX RCM ensemble: added value of raw and

bias-corrected high-resolution simulations. Climate dynamics, 47(3-4), pp.719-737.

Denis, B., Laprise, R., Caya, D. and C√Âët√©, J., 2002. Downscaling ability of one-way nested regional climate models: the Big-Brother Experiment. Climate Dynamics, 18(8), pp.627-646. Giorgi, F. and Mearns, L.O., 1991. Approaches to the simulation of regional climate change: a review. Reviews of Geophysics, 29(2), pp.191-216.

Giorgi, F., 2019. Thirty years of regional climate modeling: where are we and where are we going next?. Journal of Geophysical Research: Atmospheres, 124(11), pp.5696-5723.

Haylock, M.R., Hofstra, N., Klein Tank, A.M.G., Klok, E.J., Jones, P.D. and New, M., 2008. A European daily highâĂŽÄêresolution gridded data set of surface temperature and precipitation for 1950-2006. Journal of Geophysical Research: Atmospheres, 113(D20).

Hofstra, N., Haylock, M., New, M. and Jones, P.D., 2009. Testing EâĂŽÄêOBS European highâĂŽÄêresolution gridded data set of daily precipitation and surface temperature. Journal of Geophysical Research: Atmospheres, 114(D21).

Isotta, F.A., Frei, C., Weilguni, V., PerÆŠçec TadiÆŠá, M., Lassegues, P., Rudolf, B., Pavan, V., Cacciamani, C., Antolini, G., Ratto, S.M. and Munari, M., 2014. The climate of daily precipitation in the Alps: development and analysis of a highâĂŽÄêresolution grid dataset from panâĂŽÄêAlpine rainâĂŽÄêgauge data. International Journal of Climatology, 34(5), pp.1657-1675.

Kotlarski, S., Keuler, K., Christensen, O.B., Colette, A., D√©qu√©, M., Gobiet, A., Goergen, K., Jacob, D., L√∞thi, D., Van Meijgaard, E. and Nikulin, G., 2014. Regional climate modeling on European scales: a joint standard evaluation of the EURO-CORDEX RCM ensemble. Geoscientific Model Development, 7, pp.1297-1333.

Philipp, A., Bartholy, J., Beck, C., Erpicum, M., Esteban, P., Fettweis, X., Huth, R., James, P., Jourdain, S., Kreienkamp, F. and Krennert, T., 2010. Cost733cat-A

database of weather and circulation type classifications. Physics and Chemistry of the Earth, Parts A/B/C, 35(9-12), pp.360-373.

Prein, A.F. and Gobiet, A., 2017. Impacts of uncertainties in European gridded precipitation observations on regional climate analysis. International Journal of Climatology, 37(1), pp.305-327.

Prein, A.F., Bukovsky, M.S., Mearns, L.O., Bruy√®re, C. and Done, J.M., 2019. Simulating North American Weather Types With Regional Climate Models. Frontiers in Environmental Science, 7, p.36.

Prein, A.F., Gobiet, A., Truhetz, H., Keuler, K., Goergen, K., Teichmann, C., Maule, C.F., Van Meijgaard, E., D√©qu√©, M., Nikulin, G. and Vautard, R., 2016. Precipitation in the EURO-CORDEX $ $0.11^{\circ} $$ and $ $0.44^{\circ} $ $0.44âĂŽàò simulations: high resolution, high benefits?. Climate dynamics, 46(1-2), pp.383-412.

Skamarock, W.C., 2004. Evaluating mesoscale NWP models using kinetic energy spectra. Monthly weather review, 132(12), pp.3019-3032.

Taylor, K.E., 2001. Summarizing multiple aspects of model performance in a single diagram. Journal of Geophysical Research: Atmospheres, 106(D7), pp.7183-7192.

Wehner, M.F., Reed, K.A., Li, F., Bacmeister, J., Chen, C.T., Paciorek, C., Gleckler, P.J., Sperber, K.R., Collins, W.D., Gettelman, A. and Jablonowski, C., 2014. The effect of horizontal resolution on simulation quality in the Community Atmospheric Model, CAM 5.1. Journal of Advances in Modeling Earth Systems, 6(4), pp.980-997.

Zhang, W., D√∂scher, R., Koenigk, T., Miller, P.A., Jansson, C., Samuelsson, P., Wu, M. and Smith, B., 2020. The Interplay of Recent Vegetation and Sea Ice Dynamics-Results From a Regional Earth System Model Over the Arctic. Geophysical Research Letters, 47(6), p.e2019GL085982.

2020.