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Interactive comment on "The non-hydrostatic global atmospheric model for CMIP6 HighResMIP simulations (NICAM16-S): Experimental design, model description, and sensitivity experiments" *by* Chihiro Kodama et al.

Anonymous Referee #1

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The paper describes the new version of the global non-hydrostatic could-system resolving model, NICAM. The goal of the paper is twofold (1) evaluate several recent updates which brought the model from version NICAM.12 to the newest NICAM.16; (2) describe additional developments that were made necessary to adapt the model to the HighResMIP (CMIP6 endorsed MIP) protocol and that were introduced in the specific configuration NICAM16-S. The description and evaluation of those changes is valuable, and the paper will undoubtedly serve as a reference for NICAM16-S in studies analysing HighResMIP models. However, the paper does not investigate the impact of

model resolution on the model climatology or only marginally. The reader understands only at the end of the paper that it is a deliberate decision and that the impact of resolution will be presented in another paper in preparation. This is a surprising choice, as most people would expect a reference paper of a new model configuration participating in HighResMIP to have horizontal resolution as its main focus. This makes me wonder if the present paper should not be limited to the description of the new model NICAM.16, leaving the developments for CMIP6 to another HighResMIP paper in which the impact of resolution would be investigated in more detail? The quality of the writing in unequal, some sections (e.g, abstract, introduction of section 3 and section 3.1) fall short of meeting the standards of a journal such as GMD, while other sections (e.g. 3.2, 3.3) are written in a very good english. I would recommend a collective effort to improve and homogenise the quality of the text throughout the manuscript. I believe the paper requires major revisions before being published and I would like the authors to answer more specifically the following comments :

Main comments :

1) Could you please clarify both in the abstract and in the introduction to which MIP of CMIP6, NICAM will participate? Am I right to understand that they will only participate to HighResMIP and they will not submit simulations to the DECK? The author is left long to speculate about that. The confusion also arises from the fact that CMIP6 and HighResMIP are sometimes used interchangeably (e.g. abstract line 16 vs line 19). I would recommend to use HighResMIP as often as possible, as it is more specific.

2) My main issue is that the paper describes a new set-up for HighResMIP but there is absolutely no description of the impact of a change in resolution on the simulated climate. Even section 4, whose title announces an investigation of the dependency to horizontal resolution has only three lines about resolution (l. 7 to 10). Is there a convergence of those statistics when horizontal resolution is increased? I believe you need to inform the reader in the abstract that you do not discuss the impact of resolution.

3) The HighResMIP protocol stipulates : "For a clean evaluation of the impact of horizontal resolution, additional tuning of the high-resolution version of the model should be avoided. The experimental set-up and de- sign of the standard resolution experiments will be exactly the same as for the high-resolution runs" (Haarsma et al., 2016). Have you performed specific retuning at each resolution? Please mention explicitly which resolution has been tuned first and what was the procedure and the parameters which were adjusted. In addition, mention any additional tuning specific of each resolution.

4) You do not comment on the effect of changing the time step of the radiation scheme in NICAM16-7S to 9S (from 40 to 10min) and changing the time step of the dynamics from (240 to 60s) will have on the climatology (precipitation for instance in Table 6 and figure 11). In addition, and related to the previous question, how will changes in the time step be distinguished from the direct impact of increasing horizontal resolution in HighResMIP? Have you done additional sensitivity experiments? I believe the paper should address this issue.

5) There are four levels of labelling in the paper which makes it sometimes difficult to follow : (1) the different versions of NICAM.12 and 16, (2) the configuration for HighResMIP NICAM16-S, (3) the various resolutions 7S, 8S, 9S, (4) and the sensitivity experiments (g, f, …). Labels are sometimes redundant NICAM16-S and g for instance refer to the same simulations. I believe you might need to keep both (to remain consistent with the naming already communicated to CMIP6) but you need to refer consistently to those different labels throughout the paper and I feel it is not always the case. -> NICAM.16-S rather than NICAM16-S is used in many places. -> Most sensitivity experiments are listed in Table 2 but not all. Could you give an experimental id to simulations described in section 3.5 and column Table 2e? -> The experimental id are not mentioned in the text after section 3.4 (only in tables and captions) whereas they are used in the text before section 3.3. Please can you at least recall once what they are (maybe when you list the sensitivity experiments at the beginning of the section).

6) You make the choice not to use a convection scheme. This has been tested

in several models at resolutions where convective processes are not yet resolved : please cite references which have tested a similar approach (see for instance Hohenegger et al 2020, https://www.jstage.jst.go.jp/article/jmsj/98/1/98_2020-005/_html/-char/en and references therein). You explain that not having a convective parameterisation results in more patchy precipitation (page 6, line 27) and it would be interesting to illustrate that (see for instance Figure 2 in Maher et al, 2018, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017GL076826)

7) The beginning of the introduction is a bit confused, both climate sensitivity and climate impacts are mentioned and it is unclear why. What not saying from the beginning that the accurate treatment of cloud requires high-resolution cloud resolving models. You could also cite the review paper by Bony et al. 2015, https://www.nature.com/articles/ngeo2398) in this paragraph.

8) Section 2.2: Please be more specific on the initial land conditions in NICAM16-7S and NICAM16-8S. Are they derived in a similar way as NICAM16-9S? this is not clear.

9) The change of SICCRT between the AMIP and slab experiments is very large (a factor 5!). Could you please explain if there is any resulting inconsistency between the AMIP and slab experiments for SIC, which I believe is a standard diagnostic of CMIP6?

10) Page 15 : you indicate that you will share regridded data with CMIP6 at resolution of 1degree or coarser. Will you be able to provide higher-resolution fields on demand? HighResMIP has a special focus at fine scale features, such as tropical cyclones, extreme precipitation, for which high-resolution data might be needed.

Specific comments : page 1, line 2 : Experimental -> experimental page 1, line 6 : the Coupled Model Intercomparison Project Phase 6 page 1, line 17 : the land surface model (and everywhere thereafter) page 1, line 18 : an improvement of the coupling page 1, line 19 : and the radiation schemes; ... to follow the protocol of the CMIP6 High... page 1, line 21 : the impacts of the various model updates page 1, line 23 : over Africa and South Asia page 1, line 29 : redistributes mass page 2, line 22 : non-

sphericity of ice particles page 2, line 26 : "That is, the interfaces" => unclear, please rephrase page 3, line 9 : NICAM17-nS -> NICAM16-nS. page 3, line 15: including tropical cyclones page 3, line 31: using -> with page 4, line 4: The initial land conditions . . . were page 4, line 6: under present-day conditions . . . the last 5 years of data page 4, line 14 : are derived from "g" . . . 1 une 2004 to ensure consistency with previous NICAM studies page 4, line 19 : Is SST an external forcing? I don't think it is what people mean by external forcing. page 4, line 32 : fixed SST conditions ere used in the 56km meh run page 4, line 33 : was used in the 14 km mesh runs page 5, line 4 : Future change in SST is somewhat similar to the El Nino pattern => personally I don't think so, there is a warming everywhere! You could mention with a larger warming in the equatorial Pacific. page 5, line 9 : ICE is nearly page 5, line 11 : prescribed in the model page 6, line 8 : a smoother is applied -> a spatial filter is applied to smooth page 6, line 18 : could you give a reference for the various schemes? page 6, line 21 : sentence is too long. page 6, line 32 : global means -> global mean climate page 7, line 10 : We used . . . -> the sentence is unclear. Do you use it to show improvements or because it shows improvements? page 7, line 13 : was originated -> originated page 7, line 21 : is the key -> represent a significant change page 7, line 26 : comparing -> compared page 7, line 32 : accounts for the snow category [this is a typical example where a simple grammar mistake can loose the reader. I thought a new special category was created.] page 8, line 5 : midlatitude storm-track page 8, line 7 : 399%, respectively page 8, line 10 : the accretion page 8, line 15 : In addition, the decrease page 8, line 21 : The low cloud amount is increased as a result of a compensation . . . in medium and thick clouds and a decrease in thin clouds. page 8, line 28 : check punctuation page 8, line 31 : consistent assumptions of coupling . . ... can reduce the model biases page 10, line 8-9 : reference needed. page 11, line 5 : capital letters for the model name. page 11, line 7 and line 10 : the model name is NICAM16-S not NICAM.16-S (the same mistake occurs in other places) Figure 9 : is it possible to have an idea of the fractional reduction of the bias? page 12, line 5 : The depth of the slab End of section 3.6 : please mention when a result is not shown. page 13, line 2,3 : the precipitation

-> precipitation; line 5 : remove coma page 13, line 8 : is tested -> is used / or / introduced in the model (and please mention that no gravity wave drag was used in NICAM.12) page 13, line 21 : it may not be a wise choice -> introducing such a gravity wave drag scheme will not necessarily lead to an improvement of the simulated climate. page 14, line 3-7 : this is a repetition of things which have already been introduced in previous sections. page 14, line 9 : NICAM-7S -> NICAM16-7S page 14, line 19 : greater than SYPD ??? How many? page 14, line 20 : please mention the number of cores per node (I guess 4 from the table 9?) page 15, line 2 : in an icosahedral grid -> on the model's native icosahedral grid ? page 15 : Summary section : no capital after " : " in this section page 15, line 28 : describe ... model description => this is a bit redundant page 29, line 4 : hygroscopity -> hygroscopicity page 30 : ocean model -> ocean / or / ocean treatment (this is because you mostly use SST) page 32 : global mean impacts -> difference of global mean variables between control "g" and sensitivity experiments page 32 : it would be nice if you could highlight in bold where the difference is statistically significant? page 33 : NICAM.16-S -> NICAM16-S and phrase the legend similarly to Tab 5. page 34 : NICAM.16-S -> NICAM16-S page 34 : line 5, rephrase the end of the sentence. What does ad hoc mean here? page 36 : what does Output size in latitude-longitude grid per year TB means here? page 38 : The same as -> Same as page 39 : prescribed in the model ; decadal running mean page 40: NICAM16-7 -> NICAM16-7S. Could you add a reference in this figure? page 41 : line 3 : "g3 and g, respectively". page 41 : units of the vertical axis?