Geoscientific Model Development Discussions

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Comment on gmd-2021-315

Anonymous Referee #2

Referee comment on "PARASO, a circum-Antarctic fully coupled ice-sheet–ocean–sea-ice–atmosphere–land model involving f.ETISh1.7, NEMO3.6, LIM3.6, COSMO5.0 and CLM4.5" by Charles Pelletier et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-315-RC2, 2021

General comments

This manuscript presents the novel coupled regional climate model PARASO covering the Antarctica and the Southern Ocean, comprising model components of atmosphere and land surface, ocean and sea ice and land ice. The aim of this development is to provide a model system which can explicitly represent the complex interactions which are defining the polar climate of the Southern Hemisphere on multi-decadal timescales. A distinguishing quality of PARASO is that it explicitly resolves ice-shelf cavities with evolving geometry and sub-shelf melt while the incorporation of high resolution regional models for the ocean and atmosphere component open up the potential to realistically represent the climate of the Southern Ocean and the Antarctic continent.

The authors provide a thorough model description which is mostly pleasant to read. The manuscript transparently demonstrates (i) that the model is technically complete and ready to produce first results and (ii) that the coupled model system does not yet demonstrate a skill similar to its respective stand-alone sub-components and extensive tuning and adjusting of the coupling interfaces will be necessary.

The manuscript is clearly a valuable contribution to Earth system modeling and it presents both an exciting and an ambitious project. The manuscript is generally well written and I recommend it for publication in GMD after minor revisions.

Specific comments:

Introduction**:** you make a good point about the need to simulate the Antarctic and Southern Ocean climate in a coupled model to capture the various complex interactions. I would recommend to also mention the typical spatial resolution which is needed to capture characteristics of the climate (e.g. global climate models usually do not provide a decent Antarctic surface mass balance). This could serve to highlight the potential of PARASO.

P4, l.9: to avoid confusion change to "*ice-shelf cavities"* or "*representation of ice-shelf cavities in the ocean model"*

P4, l. 105: maybe provide the specific ice-thickness ranges

P6, ll. 140ff: please add some more information such as: "…provides NEMO with updated ice information about the geometry of the ice shelves. " Also it could be mentioned here already that the coupling allows ice shelves to change in thickness but not in extent.

P7, ll. 162ff: here it would be interesting to know the typical forcing frequency of the stand-alone models

P11, l. 229, 235: I would recommend to refer to the boolean variable with a dedicated name such as "ice type"

P14, ll. 287ff: please already state here that icebergs are part of the forcing.

P15, l. 338: I am not sure if I understand this: a longer relaxation period would have generally thinner ice shelves and eventually ice-shelves of minimum thickness? What is the time scale of this thinning? It took me a while to understand that this drift will not impair the dynamics of the climate system as only basal melt is coupled to the ocean model.

P.15, l. 342: This is a bit confusing, especially, since so far the experiment PARASO and its forcing was not yet introduced. Maybe: "…NEMO stand-alone, using consistent forcing with the subsequent coupled experiment. Specifically, this is ORAS5 forcing at its lateral boundaries and an ERA5 forcing which has been processed by the NEMO-CCLM2 coupling interface." And another question came to my mind here: is this forcing which is coming out of the coupling interface identical with the forcing which is used in the coupled experiments outside of the CCLM2 domain? From P17 and the discussion I take that this is

not the case- so is the coupling interface also used outside of the CCLM2 domain for the spin-up? Maybe it would be interesting to show the difference between ERA5 derived surface forcing fluxes from the coupling interface and from the CORE bulk formula.

P16, l. 344: Please specify the forcing of the NEMO stand-alone run (which ERA5 years).

P17, l. 375: also here: is the CORE bulk formula producing fluxes different to what the coupling interface would produce?

P18ff., Results: I wonder why there is no PARCLIM experiment (a coupled atmosphere-ocean experiment)? This could provide the forcing for the PARCRYO experiments, as it seems that the model drift is to larger parts related to the atmosphere-ocean interface, which makes it difficult to compare the PARCRYO and PARASOL experiment.

P18, Table 4: please also introduce PARATMO and PAROCE in the figure caption.

P19, section 5.1: this section is hard to read. I think it could be more clear and better structured if the purpose of the different experiments and comparisons would be formulated before respective paragraphs (eg.: comparison to observations, identifying the drift of ice thickness after ice shelves are allowed to evolve , illustrating the effect of SMB coupling, illustrating the effect of ocean coupling, illustrating synergy in the fully coupled system).

P20, Fig. 6a: this figure is too busy and the observation cannot be distinguished. I would recommend to only display yearly means in a table or in a simple bar chart with the different basins on the x-axis.

P21, Fig. 7j: why is there no dashed blue line?

P21, Fig. 7j: please discuss this figure a bit more. The integrated surface mass balance anomaly is almost constant in the first 2.5 months- while VAF is slightly negative- was the SMB forcing of the preceding model year of opposite sign? What is the interannual variability of SMB from ERA5 or VAF by comparison?

P23, Fig. 8a: colors are not ideal here, as it is difficult to identify the blue line. I recommend to use a thick or dashed black line for observations instead. Same applies for Figs 9 c-n and 10 c-n.

P23, Fig 8c-h: These panels are too small.

P24, Fig. 9c-n: Is it possible to highlight the sub-basin specific range of grounding line depths ?

P24/25, Fig. 9/10: It would be nice to show the whole NEMO domain here.

P27, Fig. 12: This figure is not very impressive- maybe increase contrast or use a non-linear colorbar with discrete color levels.

P34, Fig. A5: titles seem to be wrong