2023 CMIP6 Sea ice Model Intercomparison Workshop: Lessons learned and observational needs for sea ice model evaluation

What: Workshop with around 25 participants to discuss the lessons learned from the sea ice intercomparison project (SIMIP)in CMIP6, needs for sea ice variables written out from climate models, as well as the observational needs to further advance sea ice -observation comparisons in the context of fully coupled climate models.

When: June 10 2023

Where: Bremerhaven, Germany

At the 4th SIMIP workshop, about 25 participants gathered for one day after the 2023 IGS Sea ice Symposium in Bremerhaven, Germany, to reflect on the lessons learned from SIMIP and to discuss needs for further improving model-observational intercomparisons in terms of sea ice. The workshop was sponsored by CliC-WCRP, which supported the attendance of 10 early career scientists at the workshop

Accomplishments and lessons learned from a decade of SIMIP

Reflecting on SIMIP's activities over the last 10 years, it was found that a lot has been accomplished. The expanded sea ice variable request for sea ice variables in CMIP6, which was one of the two core activities of SIMIP, enabled novel model analysis that was not previously possible, for example a sea ice mass budget intercomparison between models (Keen et al. 2021) and the use of melt-season transitions to diagnose model biases (Smith et al. 2021). However, many variables were only supplied by a few models, and some variables that were written out did not get analyzed by many as they were very specific to individual scientists interests. For CMIP7, it would therefore make sense to revisit the variable request to see which variables scientists in the SIMIP community actually downloaded and used, and put those into a higher priority, while moving less frequently used ones into a lower priority. Furthermore, in CMIP6 users were sometimes confused between sithick and sivol, despite the description in the variable definition paper (Notz et al. 2016) for the users. So whether both should be kept going forward is something to consider for CMIP7.

Building a sense of community within the sea ice modeling community and to coordinate model analysis and spark collaborations was the second overarching goal of SIMIP in CMIP6. This was also successful, and there now exists more of a sense of community among global sea ice modelers than before. This was achieved primarily through the series of previous SIMIP workshops (in 2014, 2017, 2019). The pinnacle of this newly built community was the joint writing of two community articles on sea ice in CMIP6 (SIMIP community 2020 and Roach et al., 2020), which was a very positive experience that really gathered the community and benefited from input from everyone involved. Furthermore, it removed duplicated efforts to write the first article on sea ice in CMIP6 and instead benefited from a truly collaborative approach to writing a community article, which allowed progress to be made on community agreed upon ways to compare models with observation, through detailed discussions over email during the writing of the article SIMIP community (2020). Despite a general sense of success of the community building

aspect of SIMIP over the last decade, areas for improvement were also discussed. Suggestions were generally centered around a wish for more frequent communications from SIMIP to the community. A lack of communication was noted in particular during recent years, since the previous workshop and the writing of the community papers in 2019/2020. Specifically, workshop participants suggested a quarterly webinar series focused on SIMIP activities and science, with updates from the various working groups that formed at the earlier workshops. That would benefit the whole community, but in particular early career scientists who may want to get involved in various working groups or learn about what has already been done as well as about what was attempted but didn't work (and hence wasn't published). In addition, a Slack-like discussion board where people could ask questions to others regarding sea ice model analysis was also suggested, as well as more frequent use of the SIMIP email list to provide updates and more frequent updates to the SIMIP website. Finally, another suggestion was to make SIMIP more widely known, in particular to early career scientists, by mentioning SIMIP at talks people give.

In addition, it was suggested to have a SIMIP website with links to derived CMIP6 data products community members have created and that are already archived somewhere, but not always easy to find. Similarly, a SIMIP git-hub or similar repository with example scripts to process sea ice output from CMIP6 would be very helpful, in particular to scientists new to the field. A wish for such a community collection of code or a SIMIP code-cookbook was voiced several times during the workshop.

Observational needs for sea ice model evaluation

Based on the experiences of the scientists in the room, it was discussed what is needed in terms of observational data products to improve sea ice model evaluation. For these discussions it was invaluable to have a representative of the remote sensing community in the room, who could answer questions from modelers as well as ask questions to the modelers.

Most of all, a sea ice volume product is needed for the next round of model assessments. In the community papers for CMIP6, only sea ice area was used as it was too hard at the time (in 2019) to justify a choice of sea ice volume product without expert guidance from the remote sensing community. An intercomparison of the available sea ice thickness and volume products by the remote sensing community would therefore be very valuable for sea ice modelers to better understand the strengths and weaknesses of each product, so that a well funded decision on which product(s) to use for a given purpose could be made for future model assessments. Furthermore, currently the global sea ice modeling community is lacking an understanding of the uncertainties of the different sea ice thickness and volume products, in particular on how to translate uncertainties between different spatial and temporal scales of the observations and the models, due to the fact that many spatial uncertainties are correlated and/or have decay rates. Ideally, the evaluated sea ice thickness and volume products with available uncertainties included should be made available in one netCDF file (or a series of netCDF files at one data portal if too large otherwise) for the historical period (for CMIP7 the historical period will go to 2021), to facilitate the usage by the modeling community for comparisons to observations. Furthermore, the sea ice thickness distribution is also very valuable for model comparisons. It was also discussed that the SIT records are now starting to be long enough to be useful for the

evaluation of sea ice in climate models. Nonetheless, extensions of SIT observations into the future and efforts to extend the records back into the 1990s and before as well as to providing year-around SIT products are very valuable to make SIT products even more useful, with the goal of eventually being able to use SIT and SIV for the full range of comparisons that we can use SIA for already.

In addition to sea ice thickness/volume, the freeboard as well as the snow field used to derive the observational sea ice thickness/volume would be very useful for the sea ice modelers to have. Sea ice freeboard was a requested variable in CMIP6, and for understanding the causes of biases in sea ice thickness in models it is crucial to be able to assess whether the bias stems from the sea ice or the snow cover on sea ice. Snow thickness is also a highly relevant variable for many other analyses, such as biogeochemical cycles, due to its effect on light penetration, assessments of the sea ice seasonal evolution, and its effect on sea ice growth. Thus, a high quality observational datasets at daily resolution for snow thickness on sea ice is a high priority for model comparisons.

For sea ice drift, a long monthly observational record exists that is very useful for model evaluation. At the workshop, a lot of discussion was focused on whether daily or monthly products would be more useful. The request for a monthly observational product is motivated by a desire for a longer record that has been processed to remove the offsets between observational instruments/processing algorithms. A request for a long and high-quality daily drift dataset would only make sense if we are able to get daily sea ice velocity output from CMIP7, but would then allow a better assessment of actual ice-movement that is often averaged out in monthly data.

Sea ice age was also discussed. And while the observational dataset of ice age was found to be very important to characterize the change in the sea ice over the last decades, comparisons with models are challenging as the definitions of ice age do not agree between models and observations, and the details of when sea ice moves to the next age category has implications on the sea ice age product, as was shown during the IGS meeting. In models, on the other hand, ice age is often tracked in days, rather than years, so different thresholds for sea ice age in terms of years can be applied to the output. However, averaging of ages from different sea ice thickness categories as well as young ice added through bottom ice formation can lead to challenges working with the average ice age from models, in particular when comparing to observations that trace only the surface of the ice motion and determine age based on that. Due to these challenges, it was discussed that for comparisons with observations and some analysis needs, for example emulators and snow on sea ice, first year versus multi-year sea ice fraction is arguably more important than a more detailed ice-age product, and likely more robust to differences between how models and observations trace ice age.

A high quality and continuous melt ponds dataset for model evaluation is highly desirable, as models now write out melt pond parameters (in CMIP6, area fraction, melt pond mass, and thickness of refrozen lid). So far no model assessments have been done based on melt pond characteristics, so it would be desirable to be able to start that. This would also be important to

assess different melt pond parameterisations currently being used and developed in sea ice models, as we heard about at the IGS meeting.

Albedo is not a variable that is not well suited to model-observation comparisons of sea ice, due to the many issues around defining it and the high likelihood that different groups will make different decisions on those issues (e.g., related to albedo for different wavelengths if models includes that, grid cell averaging, what is the albedo in winter when there is no shortwave radiation coming in, how to handle shoulder seasons when sunlight returns). The discussion ended with the conclusion also arrived at for SIMIP in CMIP6, that it is best to provide the shortwave fluxes so that scientists interested in albedo can calculate it themselves, ensuring they understand what went into the calculation and it is applied consistently across all assessed models.

For surface temperature, daily data is needed. It was discussed that it is important to consider when the temperature is measured (time of day), and hence care must be taken when averaging. One alternative to mean daily surface temperature would be to use/request maximum daily temperature, but would also need a corresponding dataset.

In-situ measurements were also briefly discussed. However, as they are primarily used for model development or data assimilation, and not much for climate model evaluation, the discussion was brief. This should not be taken as indications that in situ measurements are not valuable, but for large scale climate model sea ice model evaluation they are just by their nature less useful than large scale gridded sea ice products. Nonetheless, it was discussed that a large network of ice mass-balance buoys that measure fluxes both in the atmosphere and the ocean would be very valuable for the assessment of physical processes in large scale models, as those data currently only exist for a few locations, and is hence hard to generalize. Furthermore, there is work at modeling centers to use MOSAiC data to assess single column sea ice models physics, which can ultimately lead to improvements in global sea ice models.

Discussion about needs for sea ice output

In CMIP6, SIA and SIE and SIV were requested as integrated variables, as those are the most commonly used sea ice variables. Calculating them is not always straightforward due to different model grids and missing grid information. Not all models supplied them though, and some were incorrect. It would be good to ensure these are made available, if not from the CMIP output directly then as community resources. As reported at the IGS Sea ice Symposium, Dirk Notz at Univ. Hamburg is currently leading an effort to compile SIA data from CMIP6, and ultimately also CMIP5 and CMIP3, for the community to use. For that, it would be useful to also provide regional timeseries of SIA/SIV. For the Northern Hemisphere, that should use the recently updated Arctic regional mask, based on accepted standards by J. Scott Stewart and Walter N. Meier, NSIDC (2021, https://insidecires.colorado.edu/rendezvous/uploads/Rendezvous_2021_1448_1619668996.pdf). In the southern hemisphere, further discussions are needed as to which region mask to use. Some suggestions to consider are the longitudinal regions of Parkinson and Cavalieri (2012) or the regions defined by Raphael and Hobbs (2014) based upon geographical sectors in which the sea ice cover varies coherently.

For CMIP7, the current draft list of priority 1 sea ice variables does not include the variables the community feels are crucial to obtain from all mode simulations. So a task for the next few months will be to provide input on the CMIP7 variable request task time to ensure the community needs for output from the CMIP7 models will be met. Important to highlight there is that sea ice variables are small, as 2D, and hence take not very much storage space. For example, both daily sea ice and snow thickness are needed for many applications. As a community, we also need daily surface temperature, as monthly is not of any use for that variable, so if it can not be daily it can be skipped as priority 1. The need for daily sea ice drift speeds was also discussed. If daily output of a variable is desired but not feasible, it should be considered whether monthly max and min for some variables make sense, instead of/in addition to the monthly means, to study certain events (e,g., polynya, extreme drift speeds, other extreme events). To determine a new ranking of priority variables, the goal is to perform a community survey in the coming weeks, to gather information on which variables people actually used from CMIP6 and prioritize those.

Another point discussed was that if model centers only provide some of the variables needed for a heat or mass budget, these can't really be used. So it would be important to somehow indicate that certain variables need to be written out together or not at all. For that it would also be useful to get the full information from CMIP6 on which variables were provided by how many models, as well as information on how often variables were downloaded. However, as people also share data or use data centers that download the data once for a large community of users, download counts are of limited value, and would mainly be useful to detect variables that were not downloaded at all, or only a few times.

One other suggestion discussed was to ask CMIP7 whether it would be an option to ask the modeling centers to have one historical and one agreed upon SSP simulation with priority 1-3 output from all components, to allow detailed process studies across domains. And then reduced priority 1 output for additional runs, as we understand that storage space and processing are real concerns.

The future of SIMIP

At the end of the workshop, the future for SIMIP was discussed. There was a clear sense that SIMIP should continue to exist, as it really helped with building a sense of community and that for CMIP7, SIMIP should once again coordinate the first-look papers about sea ice to turn that exercise into a collaboration rather than a competition. With planning for CMIP7 already ongoing, things that were discussed were whether SIMIP should again be an officially endorsed MIP for CMIP7, and if so, if it should be a diagnostic MIP or propose experiments. For experiments, at the workshop there was a consensus that experiments would make the most sense to better understand the model-observation mismatch in Antarctic sea ice, but no clear ideas for experiments were immediately put forward. Furthermore, some participants had heard about Southern Ocean freshwater forcing experiments potentially planned by another group. As an alternative to being an official CMIP7 MIP, it was discussed that SIMIP could exist separate from CMIP7 as a community group that can provide input to the variable request task force for CMIP7, but is not an endorsed MIP. To include the wider SIMIP community in the definition of what SIMIP should look like in the future, no decisions were made at the workshop, but will be made after, using the SIMIP mailing list to solicit input.

The current leadership of SIMIP, Alexandra Jahn and Dirk Notz, is planning to step down after this workshop, as the goals they had for starting SIMIP for CMIP6 in 2014 have been achieved and so this is a good time to change leadership and bring new voices and visions into SIMIP. The leadership of SIMIP will be handed over to Patricia DeRepentigny, François Massonnet, and Martin Vancoppenolle, which will mean the new co-chairs will be two previous SIMIP steering committee members and one attendee at the 2023 SIMIP workshop.