EGUSPHERE-2025-3345

Reply to Review Comments

Apr 17, 2026

We thank the reviewers for their comments. In particular, we thank Moritz Hanke for his comparison of different couplers, especially regarding performance. He has taken significant effort to test the performance of YAC with our setup - this is extremely useful and his experience with other couplers has helped us to take different perspectives on our adapters and to find weaknesses we had not been aware of.

To address the reviewers' concerns, beyond minor technical improvements, we have clarified statements in the introduction and expanded the comparison of couplers in the discussion section. We agree that our interpretation of the performance analysis was lacking and have improved it using the reviewer's suggestions. Our conclusions have been adjusted accordingly.

Detailed replies to the review comments follows below. In red, we repeat verbatim the comment from the reviewer. Continuing in normal font, we give our reply and revisions. Some comments have been split up to answer specific points and the order of some comments has been changed to reply to multiple related comments at the same time. Lines given for our changes refer to the author's tracked changes document of the revised submission.

We regret the many spurious highlighted differences in the author's tracked changes document that make the review more difficult, this is due to technical changes to avoid hyphenation of software library and other names.

Comments by Moritz Hanke

The paper compares preCICE primarily with the ESM couplers OASIS and YAC, which are, for good reasons, quite similar. However, several other relevant couplers are not considered in the discussion. As a result, any general conclusions about ESM couplers should be made with caution.

We have actually looked at more than the mentioned couplers, but did not reference them. After this review, we also looked at C-Coupler, but mostly in regards to performance (see below). We believe we included the most widely used and mature couplers. Also, as noted by the reviewer, the features of ESM couplers are generally quite similar, so we feel some general statements are possible.

We added a missing reference to ESMF (page 2, line 54). We also give a more complete picture of common features of ESM couplers and a few unique features (page 30, line 636).

I recommend avoiding sentences that begin with ”preCICE,” as this may conflict with language rules and, depending on GMD’s editorial standards, could result in the use of ”PreCICE.”

While this is true, it is hard to avoid without significant rewrites and repeating wording in the beginning of sentences. We have reworded some easy cases (page 2 line 53, page 4 line 88, page 5 line 102), but opted not to make the suggested change throughout the paper. We are open to making the appropriate changes if required by the style of the journal.

The manuscript does not provide a clear rationale for the choice of coupler in this setup. It appears that an ESM-specific coupler could have been used as well. A statement such as ”Any coupler would have sufficed and we selected preCICE,” or ”We chose preCICE specifically to demonstrate its applicability in an Earth System Modeling context,” would be a valid and transparent justification.

We have added a combination of the suggested statements, since both apply (page 2, line 55).

Additionally, ”Earth System Modeling” is typically capitalized.

“Earth” certainly needs to be capitalized. The other words are capitalized inconsistently in the literature. But we agree that capital letters are warranted.

Capitalized Earth and Earth System Model/Modeling (throughout the manuscript).

Line 51-54: ”Hocks and Uekermann (2026) compares the general data mapping of preCICE to those of specialized couplers using an ESM mapping benchmarks and concludes that preCICE is competitive. While specifically the radial-basis-function interpolation performs well for the considered smooth test functions, preCICE still lacks specialized conservative data mappings – a limitation that can, however, be overcome by bespoke pre- and postprocessing.” Hocks and Uekermann (2026) is currently under review, and I am one of the referees. The conclusions of that manuscript have received criticism from multiple reviewers, including myself. Therefore, I recommend refraining from citing these conclusions at this stage.

We feel the reference should not be removed entirely, since it adds relevant context to our work even as a preprint.

As its conclusions are contested, we refrained from using them as an argument here (page 2 line 62). We have removed the reference from the discussion (page 30, line 626).

Line 55-56: ”The missing ESM specialization of preCICE is less important in non-global ESM scenarios, such as the setup of this paper, or scenarios where more flexibility is needed such as adding further models.” This statement could be interpreted as: ”The missing ESM specialization of preCICE is less important in non-global ESM scenarios (such as the setup in this paper), but also in global ESMs if greater flexibility is required, for example, to add additional models.” If this is not the intended meaning, please clarify. As currently phrased, it is unclear why the need for more flexibility would make ESM specialization less important, especially in the context of global ESMs.

We agree the sentence is ambiguous and that the second part is not really connected to ESM specialization. It refers to flexibility provided by preCICE features.

Since the preCICE features are discussed elsewhere, we have opted to simply rephrase this sentence without the second part (page 3, line 65).

Line 57: ”The functionality of preCICE goes beyond communication and data mapping, as specialized ESM couplers typically offer.” The wording here is somewhat misleading. ESM couplers can also provide additional functionalities. Consider rephrasing, for example: ”Functionality not typically offered by ESM couplers, but provided by preCICE, includes, among others, ...”

We agree that the phrasing is misleading. The sentence was reworded in a similar way as suggested (page 3, line 68).

Line 58-59: ”Implicit coupling schemes including quasi-Newton acceleration (Mehl et al., 2016), time interpolation (Rodenberg and Uekermann, 2025), or multi-scale coupling (Desai et al., 2023) are all features that are relevant for ESM.”

Implicit coupling schemes are a niche area in the ESM community; explicit coupling remains the standard for ESM component interaction. One reason for this is the additional resource consumption required by implicit schemes, which is a significant consideration. YAC, for example, does not implement implicit coupling due to lack of demand, but this could be added if needed.

Similarly, time interpolation could be implemented in YAC, but until recently there was no demand for it.

Features can (almost) always be added, that’s not a reason not to mention them, and we do also note several features that preCICE does not currently provide. Niche features are still relevant. For example, we do discuss later in the manuscript that time interpolation may be used to increase temporal resolution of the coupling; CUAS is often computing much smaller time steps than ISSM and would benefit. But we also note that we have not found it necessary so far.

We have qualified our statement here to note the limited importance of the features (page 3, line 71).

See the following review comments for a wider discussion of the mention of missing features in the introduction.

Line 58-59 cont’d: The meaning of ”multi-scale coupling” is unclear to me. ICON, for instance, supports nested grids with different resolutions and timesteps, which could be

seen as multi-scale. However, exchanges between nests currently occur only at the largest timestep, not due to coupler limitations. YAC supports different timesteps and multiple grids with arbitrary resolution. Would this qualify as multi-scale coupling?

Multi-scale coupling refers to coupling of larger ("macro" scale) models to many small ("micro" scale) models. The cited reference presents a preCICE-based utility code for this to simplify the management of the micro scale models, which would be infeasible with manual setup. Just like the other features, there is no irremovable barrier to implementing the same with other couplers.

Since we do not discuss this feature further in the paper, we have removed it here instead of adding explanation, but mention it in Sect. 2.1 as an additional feature (Removed page 3, line 69; added page 5, line 124).

Line 58-59 cont'd: Overall, I do not agree with the argument that preCICE is superior to ESM couplers due to a lack of certain features, as these features may not be as important or may already be available in ESM couplers.

See the answer to the next reviewer comment.

Line 57-62: Whole paragraph

This paragraph appears to argue for the superiority of preCICE over ESM couplers, but omits counterarguments. Some of the points made are debatable: missing functionality may already be available or may not be relevant; the claim of limited documentation for ESM couplers is questionable; and the assertion of unsustainable software development is not convincing (OASIS, for example, has been maintained for over 30 years). The integration of OpenFOAM and FEniCS is certainly valuable, but its relevance to the ESM community should be clarified. As noted in the abstract, using a generic coupler versus an ESM-specific coupler has both advantages and disadvantages for the ESM community.

A balanced discussion of the pros and cons of both coupler types would be more appropriate in the discussion section. In the introduction, it would be better to focus on preCICE's strengths and unique features that make it suitable for coupling ISSM and CUAS. Additional features could be mentioned in the "2.1 preCICE" section, but unless you are sure that certain features are unique to preCICE, please choose your wording carefully.

We did not intend to argue for the superiority of preCICE in the introduction. We did include several advantages of specialized ESM couplers (but we also agree that some are missing). Instead, we argue for the strengths of preCICE in our use case, but also for the potential interest of the ESM community as a whole, since an evaluation of preCICE's use for ESM applications is one part of the motivation for the development and for this paper. This is also what the reviewer suggests, so there seems to be some contradiction in the comment. As the reviewer notes, detailed comparison can only be performed in the discussion section based on the presented results.

To the specific points raised:

- We argue for *potential* benefits of multi-disciplinary collaboration, not the current superiority of documentation and sustainable development. We do not believe these potential benefits to be controversial.

- We do not argue that development of specialized ESM couplers is unsustainable. But sustainability is not really a binary and multi-disciplinary collaboration can undoubtedly increase it, e.g., by avoiding unnecessary duplication.
- We do not claim that all the features mentioned are entirely unique to preCICE, but we have found them unique in respect to the couplers cited in the paper. So preCICE at least provides features that some of the most widely used ESM couplers do not provide.

In the revised manuscript, to clarify our argument and avoid the appearance of imbalance, we have qualified and reworded the statements in this paragraph. In particular, we state the limited relevance of the missing features (as mentioned above), mention benefits of specialized software development, and added clarification of the benefits of the mentioned numerical frameworks/libraries. We reworded the argument about sustainability to make it clearer that it is about potential, not actual/current, community and sustainability (page 3, line 74).

We also expanded the comparison part of the discussion section to evaluate the potential benefits mentioned in this introduction as the reviewer suggests. We discuss the balance of features in more detail than we have so far done. While in our earlier submission we did not hide the fact that we have not yet used the advanced preCICE features mentioned in the introduction, we made sure to highlight this. We also took care to make a clear distinction between our use-case and other ESM applications, such as global models (page 30, line 620-642).

Line 78-80: ”All preCICE configuration options can be set at runtime in a configuration file that is shared by the participating solvers, via which the respective algorithms for communication, data mapping, and time stepping are selected.”

This wording could be misunderstood as: ”During runtime, participants generate a configuration file, which is then read by preCICE and shared with other participants.” Is this what you intended? Or did you mean: ”Configuration options such as the communication algorithm and data mapping are specified in a configuration file, which is read by preCICE during initialization and then shared with all participants.”

This is true, the wording is not clear. preCICE reads the configuration file at runtime that is provided by the user, the configuration file is not generated at runtime by the adapter. We have reworded the sentence to clarify (page 4, line 95).

Line 111-114: Whole paragraph

Just a remark: The CalculiX-preCICE adapter uses what is often called a ”library approach” in the ESM context, while the CAMRAD II-preCICE adapter is an example of a ”framework approach.”

We feel that using these terms here is potentially misleading since preCICE itself is always used as a library, never as a framework. Frameworks (e.g. ESMF) also typically use a common interface to call the solvers, while preCICE adapters directly call the normal solver API.

Unchanged (page 6, line 129ff).

Figure 3

Remark: The figure clearly illustrates the design and dependencies of the ISSM preCICE adapter. Since the ”Adapter” is the entry point, I would have placed it at the top-left or top-middle, but this is just a personal preference.

We think the placement of the adapter between the solver and the coupler makes its role as an intermediary clearer. However, we have added an indicator of the entry point to this figure (page 10, fig 3) and the corresponding CUAS figure (page 13, fig 4).

Line 185-186: ”Mesh connectivity is added to support mapping schemes like linear cell interpolation (Chourdakis et al., 2022).”

I could not find a reference to linear cell interpolation in Chourdakis et al. (2022). You may want to cite https://mediatum.ub.tum.de/1685618 instead.

Remark: In 2D, this method is likely similar to YAC’s ”average with barycentric coordinates” 2 or OASIS’ linear interpolation.

We thank the reviewer for checking this. The feature was added after the current version of the preCICE paper was published and an updated preCICE paper is not available yet.

We added the reference as suggested (page 10, line 208). We also added “barycentric coordinates” as context to the manuscript when using linear cell interpolation in experiments (page 26, line 526).

Line 189-190: ”For best results, this would require multiple coupling interfaces for different finite element types, and mesh connectivity would not be available.”

Remark: Alternatively, you could provide a callback mechanism for a weight computation function. This function, set by the user, would compute the interpolation weights for a given target point. Such an approach has already been used successfully with YAC.

There are multiple different ways to add improved support for FEM meshes to preCICE. Here, we are mostly interested in how to handle this from the point of view of a preCICE user/adapter developer without modification of preCICE.

Unchanged (page 10, line 211).

Line 195-196: ”But it may be beneficial for, e.g., ice-ocean coupling to only couple over floating ice.” Or, for example, when coupling with a globally defined atmosphere model.

We have added this as a further example (page 10, line 219). In addition, masking is noted as a desirable feature for ESM couplers in the discussion section (page 30, line 637).

Line 420: ”No energy is wasted”

Remark: Even in an idle state, the power consumption of HPC nodes is non-negligible.

This is true. The argument remains valid, but requires qualification. We have rephrased the sentence accordingly (page 21, line 454).

Line 436-437: ”In earth system models, initialization of the coupled setup is often a significant part of the runtime, see for example the runtime analysis of the OASIS3-MCT coupling library in Craig et al. (2017).”

The phrase ”initialization of the coupled setup” is ambiguous. It could refer to the setup of the coupling library (including weight computation, reading weights from file, and establishing communication patterns) or to the entire setup, including model initialization. Please be more specific.

We agree this is ambiguous. This was only intended as a general introduction to the section. Later in the section we discuss specific parts of initialization. However, we reworded to clarify that we are investigating both coupler and solver initialization in this section (page 21, line 470).

Line 436-437 cont'd: "Craig et al. (2017)."

Using this paper as a general reference for initialization in ESMs is not ideal. Other couplers have demonstrated much faster initialization. The referenced paper is also rather old and may not reflect the current state of the art. While this was a significant issue in the past, such measurements remain relevant.

We agree. We have removed the reference here since it's not really required (page 21, line 471) and have added more up-to-date references in the discussion section for comparison with our results (page 29, line 603).

Figure 9:

This figure suggests a potentially serious issue in the initialization of preCICE. For this problem size and these process counts, I would have expected a nearly linear decrease in runtime as the number of processes increases.

We share the concerns of the reviewer and discuss them in detail below (see review comment for line 578-579).

Line 440: "For comparison, Fig. 10 and 9 show the time required to initialize the solver."

You may have referenced the wrong figure for the CUAS data here.

Changed to reference Fig. 10 and 11 (page 21, line 477).

Figure 12 and 15:

Consider presenting both diagrams side by side in the same figure.

We feel this would require two y-axes, since a single y-axis makes the graphs too flat to clearly see the minimum of each series. Figures with multiple y-axes can be hard to understand. We opted instead to put the two figures side by side for easier comparison (page 23, fig. 12).

Figure 18: Out of curiosity: can you explain the long runtime of LCI? Based on the method, I would have expected only a minor increase compared to NN. Perhaps a detailed performance analysis is warranted. In YAC, a similar method is among the fastest in terms of runtime.

Based on the profile output of preCICE it seems to be mostly due to slower repartitioning. This is expected to some degree, as cell-based partitioning is a bit more complicated, but should not make this large difference. But this is conjecture at this point, and the necessary detailed analysis of preCICE internals is out of scope of this paper.

We make note of this in the revised manuscript when discussing the initialization performance in general (page 29, line 606).

Line 574: "We believe preCICE is at least on par regarding the basic functionality."

This statement directly contradicts the following from the manuscript: Line 581-582: "However, we have identified several missing features (spherical coordinate systems,

masking, specialized mapping methods) that may be highly relevant for other ESM applications."

I would consider these to be basic functionality. Furthermore, as discussed later, performance also does not appear to be on par.

We agree the word "basic" is ambiguous. We did not consider the mentioned missing features "basic" for our use-case. In the revised manuscript, we avoid this term and also make a clearer distinction between our use-case and other ESM applications (page 30, line 622ff).

The issue of performance is discussed below (see review comment for line 578-579).

Line 577-578: "The regridding benchmark by Hocks and Uekermann (2026) already demonstrated that numerical performance is equivalent."

As mentioned above, I would not cite this paper in its current form as a reference here.

As mentioned above, we removed the citation here but kept it in the introduction as relevant context but with phrasing that avoids contested conclusions (page 30, line 624).

Line 578-579: "The results in Sect. 3.2 are in line with those reported for other libraries (Craig et al., 2017; Hanke et al., 2016)"

Using Craig et al., 2017 as a performance reference is misleading. The measurements were performed on a slower machine, and the version used in that study contained a bug that negatively affected initialization performance. After fixing this bug, performance improved significantly.

Note that in Hanke et al. (2016), the x-axis is "number of nodes per component." To get the total number of processes, multiply by 48 (two components times 24 processes per node). This was also on an older machine. Nevertheless, Figure 3b should represent values for a problem size similar to that in Figure 9 of the preCICE paper. At high scales (4096 processes), YAC initialization time is about 1s, while preCICE is roughly 100s. The scaling behavior is also quite different. (As a side note, the YAC paper used version 1.2; the latest version is much faster.)

Therefore, I do not support the statement that preCICE's performance is in line with the couplers mentioned here. When taking my comparative measurements (see above) into account, it seems to be quite the opposite.

We share the concerns of the reviewer regarding the initialization performance and agree that our comparison was incomplete. We are not able to explain the slower initialization at this point, as it would require detailed analysis of preCICE internals. This probably requires a paper of its own.

We have added a paragraph to discuss the performance in more detail, including citations of more up to date references. We state some possible reasons based on indicators from our benchmarks (in particular, the mesh repartitioning algorithm). We suggest to investigate and optimize this in the future. (page 29, line 602ff and page 30, line 639)

Line 583-585: "The main advantage of preCICE due to its generic nature is the potentially much larger community, collaborating in the development of adapters and the coupling library itself."

According to a survey on the OASIS3-MCT website, at least 67 modeling groups are using it. Comparing actual community sizes is challenging. Additionally, ESM couplers often benefit from institutional funding. For example, ESMF receives substantial support, and there are dedicated national and international projects (such as natESM) that provide professional support for coupling infrastructure development. DKRZ, for instance, exists solely to provide compute power and services to the ESM community.

The advantage of being generic may be offset by these other factors. Thus, the argument as stated is one-sided and should be revised.

We are deliberately not trying to compare current community sizes. As the reviewer states, doing so would be challenging. It is also irrelevant, since clearly preCICE is currently not able to replace ESM couplers in many applications. We are instead arguing that, if preCICE (or another general-purpose coupler) is further developed and widely adopted, in the long term the *potential* community (as we write in the quoted line; this includes potential institutional support) of a multi-disciplinary coupler would obviously always be greater than that of a specialized one. The current community size does not counter this argument. And we believe this justifies continued research and development effort.

This whole paragraph has been reworded, also due to the other concerns noted by the reviewer (page 30, line 620ff). We do (here and in other places in the manuscript) note the benefits of specialized software development/libraries and have expanded it further in the revised manuscript. We believe the revised text is balanced and adequately reflects our argument as stated here.

Line 596-597: ”We found preCICE to be competitive in all aspects.”

Considering the information presented in the manuscript and my comments above, I reach a different conclusion.

As noted above and in the discussion section of the revised manuscript, we share the concerns of the reviewer and have reworded this conclusion accordingly (page 31, line 656)

Line 598-599: ”We also provided arguments that either approach is superior in the long run to integrating different models into the same monolithic code.”

This sentence seems out of place in this context.

This refers back to the introduction where we make the argument that coupling with an external coupling library is superior to (or at least has clear advantages over) monolithic model development.

Since this is relatively trivial and we do not discuss this much further in the rest of the text, we have opted to simply remove the statement. (page 31, line 659)

Comments by Basile de Fleurian

Line 23 : Replace "formed by " by "fed by"

Changed (page 2, line 25).

Line 30 : Parenthesis for the reference should be modified

Changed (page 2, line 32).

Line 41 : The sentence starting by "We use an internal..." could be clarified, for example, "To couple these two model, we use..."

Changed (page 2, line 46).

Line 51 : Should be "compare" not "compares"

Removed due to other comments (page 3, line 59).

Line 121 : As this paper is not specifically aimed at ice dynamics modellers I would add the references for the different approximations to the momentum balance.

We feel the ISSM citation in this sentence gives a good overview over the different approximations for the purposes of this paper.

Unchanged (page 6, line 140-142).

Line 144 : I don't think that "aligned" is the best term to use here.

Changed (page 7, line 165).

Line 254 : You may want to add a reference for the equivalent porous medium approach (Teutsch, G., 1990. An extended double-porosity concept as a practical modelling approach for a karstified terrain. IAHS PUBLICATION, pp.281-281.)

We agree that a reference is warranted. We think Teutsch & Sauter, 1991 is the more fitting reference here since we use a single-layer equivalent porous media approach rather than double-layer.

We added that reference and reworded the statement accordingly (page 12, line 279).

Line 259 :"at each" rather than "in each"

Changed (page 12, line 285).

Line 333 : I am not sure of what the inequality on this line is representing

The sentence was excessively shortened and hard to understand with inline inequalities.

The revised sentence contains some repetition, but should be more understandable (page 15, line 362-364).

Line 339 : As CUAS is a variable conductivity model it should be clarified here that the channel opening is represented by an increase in conductivity.

Added the clarification to the sentence (page 15, line 370).

Figure 5 and following: I am unsure what the dark grey shading is representing in the ice thickness panel. I expect that those region are either cold based or with no ice but if they are cold based then I think their thickness should appear on panel (a).

Dark grey regions are cold based. We also agree that it is informative to see ice thickness everywhere.

We amended the figures and their captions to clarify the coloring (page 17 Fig. 5, page 19 Fig. 7, page 20 Fig. 8).

Line 360 : "masal" should be removed.

Changed (page 16, line 394).

Figure 7 and 8: It might be easier to compare if Figure 7 and 8 are merged with just a quarter of the domain shown.

We feel the figure would be overcrowded with so many panels.

We opted instead to make the figures less wide (by only showing quarter domains as suggested) and single-column so that they can be more easily set on the same page in the final layout (page 19 Fig. 7, page 20 Fig. 8).

Line 374 : The sentence starting on this line should be rephrased

Changed (page 16, line 399-400).

Line 440 : Isn't it figure 10 and 11

Changed (page 21, line 477).