

## Review of EGUSphere-2025-5618: “Evaluation of preCICE (version 3.3.0) in an Earth System Model Regridding Benchmark”

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The manuscript is well written, but the presentation of the results is insufficient to adequately convince the readers that RBF schemes in preCICE can outperform (in both time and accuracy) the high-order, non-conservative implementations in SCRIP, ESMF and YAC libraries.

All major comments are provided below. The authors are requested to address them thoroughly.

1. P2. L26-28: “For example, preCICE operates solely on Cartesian coordinates, which may require additional pre- and postprocessing for geodesic ESM meshes.”
  - While the intent is correct here, it should be noted that many implementations of both conservative and quasi-interpolant schemes do not need to make explicit assumptions about whether the meshes are on a spherical manifold. It is also important to ensure that the pre and post-processing steps that are used in this manuscript do not introduce additional bias or improvements, as it can affect the conclusions in this study.
2. P2. L45: “Mappings in preCICE can be classified as consistent or conservative”  
P2. L48: “Thus, consistent and conservative mappings can be constructed from each other by transposing the mapping matrix.”
  - These are not mutually exclusive attributes of a linear map. For global ESM meshes, conservative meshes are also consistent. However, for culled meshes, conservation along a boundary interface (e.g., the land-sea coastal boundary) depends on the local definition of the metric. Rephrase your statements to clarify.
3. P2. L47: “Here, the sum of the data values should remain constant, which means that all columns of  $M$  sum up to 1.”
  - This is wrong. Given the definition for  $M$ , the column sum equates the source area contribution in the corresponding overlap region between source and target, since conservative schemes are area weighted. This will not sum up to 1.
4. P3: Equations (3) checks the global bounds of the projected field values against the source values, which implies checking for monotonicity in the remapping algorithm. However, I do not see any further discussion of this metric anywhere in the results. If this is not a metric used in the experiment, remove it from the description.
5. P4. L87: The nearest projection (NP) description sounds like it is actually a natural-neighbor interpolant based on Delaunay triangulation? The terminology is confusing here. If this is not the case, please provide references to where NP was introduced in preCICE, or briefly explain further how NP is achieved.
  - Sibson, R. (1981), A Brief Description of Natural Neighbor Interpolation. In Interpolating multivariate data, John Wiley & Sons, New York, 1981, pp. 21-36.
  - Watson, David F. (1981). Computing the n-dimensional Delaunay tessellation with application to Voronoi polytopes. The Computer Journal 24(2), p. 167-173.
6. P4. L96-L98: “Here, the results of a consistent mapping are globally scaled in a post-processing step to conserve integral values. To compute the scaling factor, connectivity information of both meshes is required.”

- Scaled normalization to achieve global conservation can yield unphysical non-monotone values, for example if fields are strictly bounded or constrained to be non-negative. How do you deal with that? Given that you do mention a bound checking metric in Equation (3) and since you use normalized post-processing to achieve global conservation, this will directly impact the quality of the remapped result. Elaborate.

7. Please refer to the MIRA intercomparison paper that introduces several metrics for the inter-comparison of remapping algorithms in ESM. This will help readers better understand the RBF reconstructions used in preCICE and how they compare against other implementations and algorithms as well. Disclaimer: I am one of the authors of the MIRA protocol.

Mahadevan, V. S., et al., Metrics for Intercomparison of Remapping Algorithms (MIRA) protocol applied to Earth system models, *Geosci. Model Dev.*, 15, 6601–6635, <https://doi.org/10.5194/gmd-15-6601-2022>, 2022.

8. P5. L114: "Meshes are provided in two forms: a) node-based including connectivity and b) cell-based, only containing cell centers"

- I do not understand the reasoning. If you have a node-based mesh with connectivity information, obtaining the cell-centers is trivial. Do you mean to say that the input grids are either cell-based or node-based?

9. P6: Table 1 is very confusing. I assume the authors are describing 3 rows: nearest-neighbor, linear and high-order methods. Do the conservative and non-conservative columns specify variants of the scheme used in Valcke et al., (2022)? It was introduced before that preCICE does have a normalized version of the remapper that can retain conservation. In that sense, you can make any non-conservative scheme conservative by choosing an appropriate normalization.

10. P10: In Section 3.5, RBF mapping algorithm is being discussed. The details are terse and do not give the reader the full picture of how the algorithm is used. Please elaborate a bit more about the algorithm, its properties, compactness, applicability to unstructured topology, and computational complexity. The note about the parameter indicates that for both the fine to fine and fine to coarse remaps use the same value of  $2E6$  for support radius. Does this adversely affect the results? How about performance? Please provide a better discussion.

Please also highlight that the scripts that perform the different stages of the workflow shown in Figure. 2 have been provided in Hocks, 2025a, to improve reproducibility of the results presented here.

11. P11-12: Section 3.7 deals with meshing issues, but specifically in the Delaunay triangulation algorithm. This seems like a problem that needs to be fixed in the algorithm implementation. How did you verify the Delaunay triangulation algorithm implemented here in the manuscript?

12. In Figure 6 and Figure 8, how can the nearest-neighbor be different in any implementation? There is a unique point on the source mesh that is always closest to any given target point. The mean misfit shows this, but why are global conservation values different?

13. In the Section (2.2.1) L95-98, it is stated "Also regarding the  $\ell$ -min and  $\ell$ -max metric, pre-CICE yields similar results as the reference without much deviation."

- It will be interesting and important to analyze the impact of the normalization by measuring bound-checking metrics. This can add additional value to the manuscript.

14. Figure 8: In the gulfstream high-order comparison plot, please explain why torc-icos and icos-torc grid combinations yield a much lower RBF reconstruction error as opposed to the bicubic or HSBB interpolants in SCRIP and YAC respectively?

15. Figure 8: I was under the assumption that the normalization was applied for all preCICE schemes in the study. But the results in Figure 8 do not hint at this. So why is the normalization not used here?

**Comment:** For non-conservative schemes, it makes no sense, nor does it add any value to measure the conservation error. Please either use normalized/scaled projections or just define it as non-conservative, and not worry about the net bias introduced in preserving the global integrals. In an ESM, whether an algorithm introduces  $1E - 4$  or  $1E - 8$  conservation error, they are still both non-conservative. Please remove these conservation error results from the manuscript for all non-conservative methods.

16. Comparing Figure 9 and 10 misfits, it is clear that the RBF reconstruction performs much better on smooth solutions and is only as accurate as a nearest-neighbor solution when applied to a case with strong gradients. Please highlight this and provide comments on the behavior or approaches to make the high-order scheme perform better in such scenarios.

17. L279-282: "An example of such transfer is the RBF mapping method, widely used in fluid-structure interaction (Chourdakis et al., 2022). In our tests, it outperformed ESM-specific second-order methods by an average of two orders of magnitude for smooth test functions while also showing robustness: The same setup worked across all considered ESM meshes."

Given the results presented, these statements should be modified to reflect the overall conclusions. Smooth analytical functions make excellent candidates to measure properties of the remapping algorithm. However, I strongly encourage the authors to measure convergence rates, dissipation characteristics, effect of the radius parameter in the scheme, and then provide a comparison against the other schemes in ESMF, YAC, and SCRIP. This provides better validation of the quasi-interpolation algorithm and its accuracy behavior for both smooth and non-smooth solutions.

**Comment:** Additionally, the authors do not provide any comparison or even hint at a discussion about the performance implications of solving a large number of linear problems at every target point site. How will this compare against the generation and application of linear maps created out of the ESMF, YAC, and SCRIP implementations? Please dedicate a section to discuss the performance of the remap scheme and provide a plot of time to remap vs accuracy against, say, both the vortex and Gulfstream solutions. If possible, comparing this efficacy chart with those generated for ESMF, YAC, and SCRIP would be a nice contribution to the community.