

Interactive comment on “ICONGETM v1.0 – Flexible two-way coupling via exchange grids between the unstructured-grid atmospheric model ICON and the structured-grid coastal ocean model GETM” by Tobias Peter Bauer et al.

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Received and published: 9 February 2021

Discussion review of anonymous referee #2:

This paper describes the implementation of the coupling between the atmospheric ICON model and the ocean GETM model using the ESMF/NUOPC coupling technology. It describes in particular the remapping between the unstructured atmosphere grid and the ocean structure grid, and vice-versa, using ESMF exchange grids available in ESMF regridting package. The impact of the two-way coupling is then analysed comparing in detail the results of two simulations of the central Baltic sea, one imple-

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menting two-way coupling and the other implementing only one-way coupling from the atmosphere to the ocean. It shows it particular that two-way coupling better represent the surface temperature as compared to the one-way coupling. The paper is clearly written and easy to follow, and explanations are well illustrated. It represents a nice description of a coupled application and would deserve publication in GMD, but only, I think, if the following major comment is addressed.

Many thanks to the Reviewer for his motivating criticism.

Major comment:

In many places, you write that you implemented conservative interpolation between ICON and GETM, but from what I understood, I think this is not the case because of the non-matching sea-land masks in the two models. Let's take Figure 5 but considering fluxes exchanged from the atmosphere to the ocean. One problem is how to calculate the flux, for example, for the lower left GETM cell. If one normalizes the flux calculation by the whole lower-left cell area ("destarea" option in ESMF and SCRIP), then local conservation is ensured but non-physical values may result; if one normalizes by the intersected area ("fracarea" option in ESMF and SCRIP), then values will be physically sound but local conservation will not be ensured.

In ICONGETM, the interpolation is carried out via the ESMF exchange grid. This two-step procedure from the source to the exchange grid and further to the destination grid is a combination of the mentioned individual interpolation methods for a direct interpolation from a source to a destination grid. Therefore, interpolation via the ESMF exchange grid guarantees global conservation and physically reasonable interpolated quantities.

For example, in Figure 5, it is clear that fluxes coming from the atmosphere in "case-2" regions would be lost as there is no corresponding ocean cell in GETM. The other problem is for the flux coming from case-2 atmosphere region; this part of the flux will not be transferred to any ocean cell and again local conservation will not be ensured.

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A conservative interpolation ensures that e.g. the energy exchanged through a **common** area is conserved. For the data exchange between the atmosphere and ocean in ICONGETM, this is guaranteed by the implementation and use of the ESMF exchange grid. Of course, fluxes leaving the atmosphere not towards a common area with GETM are not further accounted in the atmosphere-ocean-system. A conservative atmosphere-ocean-system requires the surface area of the sea water fraction in an ICON cell being identical to the corresponding area in the exchange grid with GETM, see also next point.

The only way to set up a consistent atmosphere-ocean system and have a well-posed coupled problem, is to adopt the following best practice to defining coherent sea-land masks and sea fractions but it is applicable only if the atmosphere model can consider at least water and land sub surfaces. The original sea-land mask of the ocean model should be taken as is. For the atmosphere model, the fraction of water in each cell should be defined by the conservative remapping of the ocean mask on the atmospheric grid. Therefore, the atmospheric coupling mask should be adapted associating a valid/active index to cells containing at least a fraction of sea. This method ensures that the total sea and land surfaces are the same in the ocean and atmosphere models, allowing global conservation of sea or land integrated quantities. Can you please comment on these important issues and clarify this in your manuscript?

We absolutely agree with the reviewer. We double-checked the ICON code whether it is possible to implement this treatment, but modifications are far from trivial, at least for us, who are no developers of the ICON core. In the new Discussion section we now write: "Another feature missing in ICON is mixed land/ocean cells. However, for a fully coherent treatment of land/sea masks in the coupled system, ICON needs to consider the water fraction area of GETM from the exchange grid."

Minor comments:

- *p.1, l.20-21-22: I don't understand why you give the example of the precipitation*

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over sea, while you start by talking about precipitation over land. I would just remove the “e.g. by precipitation over sea” which is confusing, I think.

You are absolutely right. This sentence is now removed from the introduction.

(After reorganizing the introduction, this part is now removed.)

- *p.2, l.43: for the OASIS reference, please use also: Craig A., Valcke S., Coquart L., 2017: Development and performance of a new version of the OASIS coupler, OASIS3-MCT_3.0, Geoscientific Model Development, 10, pp. 3297-3308, doi:10.5194/gmd-10-3297-2017*

Added reference.

- *p.5, Table 1 captions: You write “If graupel, ice and hail are activated in ICON, then the corresponding contributions to precipitation must also be considered.” but these are not explicit in Table 1 right? Maybe you should clarify this.*

The sentence has been rephrased for clarification: "The corresponding contributions to precipitation from graupel, hail and ice are only considered for the coupling if they are activated in ICON."

Graupel, ice and hail have been added to the table.

- *p.5, Table 1 captions: You write “The humidity quantity is correctly identified by the name of the exchanged ESMF field” but I don’t understand what this means. More on this should be provided in the text?*

It is now clearly written:

"The **exchanged** humidity quantity (**dew point or relative humidity**) is correctly identified by the name attribute of the connected ESMF field".

- *p.5, Table 1 captions: You write “The exchange of flux data (3rd block) or state variables (last block) offers the comparison of different coupling strategies within*

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the same model environment” but I don’t understand what this means. More on this should be provided in the text?

Modified sentence:

"The possibility to exchange either flux data (3rd block) **or** state variables (last block) offers the comparison of different coupling strategies within the same model environment."

- *p.5, Table 1 captions: The last block is never exchanged as nothing appears in the last column? If so, why does it appear in the Table?*

Because in Tab. 1 all quantities are listed that can be exchanged with the developed model system, not only the ones considered in the demonstration example.

- *p.13, l.239-240: Can you provide more precise numbers on the load balance obtained with 864 processes for ICON and 384 processes for GETM?*

The optimal load-balancing was estimated empirically in terms of minimum idle/waiting times for the single model components. A systematic analysis was not conducted, because it would be applicable only for this specific setup anyway.

- *p.14, l.251: can you describe and locate the “upwelling regions” more precisely?*

The text was expanded accordingly:

“In July 2012, the simulated SST ranged around 289 K, with values below 282 in the upwelling areas south of the coast of mainland Sweden and the islands of Öland and Gotland.”

- *p.13, l.254: It could be relevant to mention Figure 9 when you write about the RV Meteor.*

Added figure reference to text.

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- *p.13, l.255: It would be helpful to locate the island of Gotland on one figure.*

The white frames in Figs. 2 and 9 are showing the island of Gotland.

- *p.13, l.256-258: You state that “the values from the two-way coupled ICONGETM run are in the same range as the measurements and the temporal development also agrees much better with the observations“. I agree this is obviously the case after 10 days but not so obvious for the first days; can you better quantify the improvement, maybe by providing a correlation coefficient.*

A short statistical evaluation is now added to Sec. 4.2.1:

"The average deviation from the modelled and measured temperature is about $1.6\text{ K} / 1.5\text{ K}$ and $1.9\text{ K} / 2.0\text{ K}$ for the two-way coupled and uncoupled simulations from 01 / 10 July 2012 onward, respectively. This is a significant improvement of about 15%/ 25%, respectively. However, the Pearson correlation coefficient is only slightly improved, i.e. $0.7158 / 0.7487$ and $0.6996 / 0.7336$ for the two-way coupled and uncoupled simulations from 01 / 10 July 2012, respectively. The more reduced average deviation and higher correlation of the two-way coupled simulations after 10 July 2012 is related to the spin up of the model, since GETM is initialized as hot start while ICON uses the IFS reanalysis data."

- *p. 15, Figure 9: Which area is more precisely concerned, when you write “Eastern Gotland Basin”? Could you give the latitudes and longitudes of the region and maybe show it on one of the figures?*

The ship track is now presented on the right panel of Fig. 9.

- *p.15, l.269: Can you locate more precisely the “area east of Öland”?*

Added reference to marker in Fig. 8.

- *p.16, l. 274: can you give a definition of “central” and “upper” part of the boundary layer in meters so to refer to Fig. 12?*

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It is now clearly written: "... in the central to upper part of the boundary layer, between 900 *m* and 2400 *m* in the left panel of Fig. 12. Due to reduced evaporation, it is less in the lowermost part, below 500 *m* in the left panel of Fig. 12."

- *p.16, l.277: you write "to the strengthening of the local land-sea circulation (cf. Fig. 11)". I don't clearly see this, can you describe this in more details?*

The description has been reworded:

"In addition, there is less momentum mixed downwards (not shown), which is a likely explanation for the locally reduced wind velocity in the upwelling regions at Sweden's mainland coast and the Öland and Gotland islands, shown by negative differences in the central panel of Fig. 11. In the coupled case, the temperature gradient between land and sea is increased in the area of the upwelling, cf. Fig. 8, with almost the same land temperatures but significantly lower SSTs, which locally increases the onshore wind component and thus weakens the overall more easterly wind in Fig. 11."

- *p.17, l.295: You could refer to Figure 15 C and D.*

Done as suggested.

- *p.18, l.305: What does "cannot be switched off by minor changes" mean?*

We now write:

"In ICONGETM v1.0, the air-sea fluxes are taken from the atmosphere model ICON. Their calculation in ICON is very complex and deeply nested in the model code."

Therefore, the flux calculation cannot easily be moved to the mediator.

- *p.18, l. 310-312: These sentences describe what should be implemented ideally. You should replace "can" by "could" (l.310) and "is done" by "should be done" (l.312)*

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The whole part of the discussion on flux exchange via a mediator has been modified.

Other comments:

- *p.1, l.4: replace “The work achieved the development ...” by “We present here the development ...”*

Modified sentence.

- *p.1, l.19: add “but” before “later”*

After reorganizing the introduction, this part is now removed.

- *p.1, l.20-21: Start the sentence with “However, for most ...” and remove it on line 21.*

After reorganizing the introduction, this part is now removed.

- *p.2, l.31: Replace “show” by “have”*

After reorganizing the introduction, this part is now removed.

- *p.2, l.34-35-36: These sentences use “The latter” and “They” and “them”; I suppose these designate the “coastally trapped waves” but it could be made more explicit for clarity.*

After reorganizing the introduction, this part is now removed.

- *p.4, Figure 1 captions: replace “by arrows” with “by horizontal arrows”?*

No, all arrows represent generic NUOPC operations.

- *p.4, l.95: consider rewriting the last part of the sentence as “... and only individual specification routines need to be implemented for the model and coupler components.”*

Rephrased sentence.

- *p.16, l.284: you talk about the surface heat flux, but these are not shown in any figure right? If so, you should add "(not shown)".*

Added "not shown".

Interactive comment on Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2020-269>, 2020.

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