Discussion 2nd review of Sophie Valcke:

2nd review of "ICONGETM v1.0 – Flexible NUOPC-driven two-way coupling via ESMF exchange grids between the unstructured-grid atmosphere model ICON and the structured-grid coastal ocean model GETM"

Major comment:
I consider that the authors have carefully analysed the remarks I formulated for the first review but I still think that my main remark about the impossibility to have a fully conservative interpolation with non-matching sea-land mask between the ocean and the atmosphere is not answered properly. Contrary to what the authors state in their reply (" Therefore, interpolation via the ESMF exchange grid guarantees global conservation ..."), the exchange grid ensures locally conservative data exchange but cannot ensure the global conservation if the sea-land masks of the two models do not match, and this should be clarified in the text.

We are very grateful for pointing again to the still unclear explanation in our manuscript. In terms of conservativity, we would like to stress the difference between *interpolation* and *flux exchange*, which we now clearly explain in the manuscript. The interpolation is only defined and performed over the area of the exchange grid. Therefore, *the interpolation is always conservative by definition.* However, in case the atmosphere and ocean models do not share the same common sea surface area, i.e. non-matching land/sea masks, the flux exchange can be non-conservative: When ICON applies air-sea fluxes in ocean areas that are represented by land in GETM, fluxes are not conserved in the atmosphere-ocean-system. Therefore, the differentiation between local and global only makes sense for flux exchange, but not for the interpolation. Throughout the manuscript, we have carefully double checked the correct terminology.

Furthermore, the authors seem to agree with my analysis when they write "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, see also next point." and when they discuss the possibility/difficulty to implement mixed land/ocean cells in ICON. Therefore, I strongly suggest that the following sentences be modified so not to mislead the reader:

- L.4 : *add "locally" before "conservative data exchange via ESMF exchange grids"*

  => For a more clear distinction between interpolation and data exchange, "conservative" has been removed in front of "data exchange". It is now correctly and more clearly written: "ICONGETM is built on the latest NUOPC coupling software with flexible data exchange and conservative interpolation via ESMF exchange grids.

- L.54-55: *at the end of the sentence, add: ", even if the exchange grid cannot force their global conservation if the sea-land masks do not match between the ocean and the atmosphere models.".*

  => We now write: "Moreover, the ESMF exchange grid considers the masking of the original grids, e.g. land/sea masks, and excludes fractions that are not required for the interpolation." We will elaborate on the missing global conservation of fluxes within the developed model system in detail in Sec. 3.4.1, see your next point, and in the discussion.

- L.220: *At the end of this paragraph: "It is also obvious that in case 2, a part of the flux calculated by the atmospheric cells will be lost as it cannot be attributed to any ocean cell in GETM; the global conservation of the fluxes cannot be ensured if the sea-land masks do not match between the ocean and the atmosphere models."*

  => The text has been adapted: "As sketched in Fig. 6, the interpolation of the mean sea level pressure (MSLP) from ICON to GETM is straightforward in principle, because ICON provides all quantities over the whole domain. However, in case sea surface fluxes are exchanged, there are two issues if the land/sea masks do not match between ICON and GETM. First, there is a physical inconsistency, when surface fluxes parametrized over land cells in ICON are transferred to ocean cells in GETM (case 3). Second, when ICON applies sea surface fluxes in ocean areas that are represented by land in GETM (case 2), the fluxes are not conserved in the global atmosphere-ocean-system. This latter case demonstrates that the conservative interpolation via the exchange grid is not sufficient to guarantee a conservative flux exchange.

- L.351-352: *Modify the sentence for "The applied ESMF exchange grid guarantees a conservative flux exchange, except in the case of non-matching sea-land masks between the ocean and the atmosphere."*

  => Modified.

- L.355-356: *Modify the sentence for "Their calculation directly on the ESMF exchange, even if it cannot solve the problem of different land-sea masks (Balaji et al., 2006) ensures physical consistency ..."*

  => Please see our reply to your next remark.

- L.365-366: *Modify the sentence "Their calculation directly on the ESMF exchange grid also solves the problem of different land/sea masks (Balaji et al., 2006) and ensures physical consistency in the sense that no fluxes calculated over land, i.e. not influenced by the sea surface temperature, are provided to the ocean." by something like: "Even if the ESMF exchange grid does not solve the problem of different land/sea masks (Balaji et al., 2006), it ensures physical consistency in the sense that no fluxes calculated over land, i.e. not influenced by the sea surface temperature, are provided to the ocean. Regarding the problem of matching land/sea masks between the atmosphere and the ocean, it is worth mentioning here that the only way to have a well-posed coupled problem, is to adopt the following best practice, which is applicable only if the atmosphere model can consider 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. Then, 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. ICON mask was not defined following this best practice (and it would involve some non-trivial*

modifications to do so, so the global conservation of fluxes cannot be fully ensured in the current coupled model.“

=> We agree with the reviewer that in the present implementation the flux exchange between the atmosphere and ocean is not fully conservative, which is now stated more clearly. We also agree with the outlined approach with mixed land/ocean cells to obtained identical sea surface areas and improved its description. However, following [2] and [1], we also extended and clarified our original argumentation for a conservative flux exchange via the ESMF exchange grid. The paragraphs now read:

"Ideally all fluxes, air-sea and land fluxes, should be calculated directly on one unique ESMF exchange grid in the mediator and applied as boundary conditions to the corresponding individual models [2]. On the exchange grid, a unique land/sea mask of the coupled system can be defined. If the land/sea mask of the exchange grid is adjusted to the mask of the ocean model [1], the associated sea surface areas will be identical. In this case, the conservative interpolation between the exchange and model grids finally offers a fully conservative flux exchange between the atmosphere and ocean, despite originally non-matching land/sea masks in the individual models. Moreover, physical consistency will be ensured in the sense that only air-sea fluxes, i.e. fluxes influenced by the sea surface temperature, are provided to the ocean. If the sea surface area on the exchange grid does not cover the one of the ocean model, creep, nearest neighbor or other extrapolation methods are required to avoid the application of land fluxes to the ocean [see e.g. 4, 3, 5]. In any case, fluxes provided by the mediator can be applied in the atmosphere and ocean over the same period until new fluxes are calculated in the next coupling time step. The flux calculation on the ESMF exchange grid in a central mediator component also offers the most straight-forward extension of the coupled system by models for e.g. waves and sea ice. One drawback of the flux calculation outside the individual models can be stability issues for explicit time stepping schemes or complex coupling implementations for implicit time stepping schemes.

Alternatively, a conservative exchange of air-sea fluxes calculated in the atmosphere model is possible, if the mask of the exchange grid can be emulated in the atmosphere model due to mixed land/ocean cells. For this, the water fraction in each cell must be obtained by conservative interpolation of the sea surface area from the ocean model via the ESMF exchange grid.

In its present state ICON does neither support the described ideal modular coupling nor the alternative. Both approaches require non-trivial modifications to the ICON code. It is expected that they will become available in future releases of ICON, such that the full potential of ICONGETM for a flexible conservative flux exchange via the ESMF exchange grid can be exploited."

Other important comments:

- p.14, l.272: *I don't understand what “a good concurrent load-balancing with minimum idle/waiting times for the single model components was empirically ...” means. Do you mean that the elapsed time for running*

ICON as single model on 864 processes was almost the same as the elapsed time for running GETM as single model on 384 processes, and therefore you suppose that using these number of processes for each component in the coupled system will lead to minimum idle/waiting time? If so, it should be rephrased for something like "For the present set-up, ICON was run on 864 processes and GETM on 384 processes. It is supposed that this distribution leads to minimum idle/waiting time of any of the component as the elapsed time for running ICON as a single model on 864 processes was about the same than the elapsed time for running GETM as a single model on 384 processes."

=> No, the load balancing was not predicted based on separate single model runs. From coupled model runs with different processor numbers, we analysed empirically the waiting times of both model components based on the log-files written by ESMF on a higher verbosity level. We now write "For the present setup, a good concurrent load-balancing with minimum idle/waiting times for ICON and GETM was empirically obtained through the log-file time information resulting in 864 and 384 processes, respectively."

- p.15, l.292-293: *The statistics presented are extremely difficult to understand. I suppose that 1.6K/1.5K are for the two-way coupled simulation and that 1.9K/2.0K are for the uncoupled simulation. But e.g. for the two-way coupled, I don't understand what the two numbers (1.6 K and 1.5K) relate to; are these for different averaging periods (maybe 01-10 July and 10 July onward?)? What does "01/10 July 2012 onward" stand for? I have the same remark for the Pearson coefficient. This remark about the need to better quantify the improvement brought by the two-way coupling was done by myself and by the other reviewer. I consider that the answer brought by the author is not satisfying, at least under the current form.*

  => This part of the text has been rephrased: "The average deviation between the modelled and measured temperature in the period from 01 July till 21 July 2012 is decreased from 1.9 K for the uncoupled to 1.6 K for the two-way coupled simulation. This represents an improvement of about 15%. On the other hand, the Pearson correlation coefficient is only slightly improved from 0.7 for the uncoupled to 0.72 for the two-way coupled simulation. Fig. 9 indicates that the coupled ICONGETM system needs some spin-up time to adapt to the coupling, before the improvement with respect to the uncoupled simulation becomes visible. Within the period from 10 July till 21 July 2012, the average deviation between the modelled and measured temperature decreases from 2.0 K for the uncoupled to 1.5 K for the two-way coupled simulation. Thus, after the spin-up, the model results are significantly improved due to the coupling by 25%. The removal of the spin-up period also increases the correlation coefficients to 0.73 for the uncoupled and to 0.75 for the two-way coupled simulation."

Minor comments:

- p.2, l.26: *I suppose that the sentence "The atmosphere model WRF ...with MCT." describes COAWST? If so, it would be clearer by linking the two*

sentences with something like: "is COAWST (Warner et al., 2010) into which the atmosphere model WRF ... with MCT."

=> The second sentence has been modified to link the individual models in a more clear way to COAWST.

- p.2, l.27: *"the ocean model" is missing before "ROMS"*

  => Added.

- p.2, l.37: *consider changing "... are the coordinated execution of and the data exchange between the individual models." with "... are the coordinated execution of the individual component models and the data exchange between these models."*

  => The sentence has been rephrased to "... are the coordinated execution of the individual model components and the data exchange among them.".

- p.2, l.39: *It looks like you are doing a distinction between "coupling libraries" and "coupling frameworks" which is fine to me. But ESMF is mentioned as an example of both categories. In the coupling library list, you should replace OASIS by OASIS3-MCT (which has been introduced just above), you should remove "ESMF" and maybe replace it with "YAC (Yet Another Coupler, Hanke et al., 2016)" and put the reference to YAC there in the text (and remove it at l.97).*

  => In order to avoid misleading interpretations, "coupling libraries" is replaced by "coupling software" and "OASIS" by "OASIS3-MCT" as suggested.

- p.2, l.47: *consider changing "from the models are received during runtime" for "are received during runtime from the models"*

  => Changed.

- p.2, l.52: *I don't think that Balaji restricted his definition of an exchange grid to two rectangular grids. Therefore, please consider changing the two sentences for "They have been introduced in Balaji et al. (2006). ESMF implements this functionality to unstructured grids, ..."*

  => Changed.

- p.3, l.66, and p.22, l.372: *why do you call ICON a "next-generation" atmosphere; ICON exists today so it is not a next-generation" model; please consider changing "next-generation" for "state-of-the-art" or something similar.*

  => Modified.

- p.3, l.85: *I think a verb is missing in "can be configured to various models", maybe "can be configured to produce various models"*

  => It is now written: "The atmospheric component of ICON allows various user-configurations for different modelling scenarios, e.g. LES, NWP or climate simulations, by coupling a common dynamical core with different physics packages."

- p.4, l.100: *the link under www.getm.eu does not work (at least for me). Should it be "https://getm.eu" ?*

  => Thanks a lot for this hint. On our side, the link with the http protocol works fine. Maybe your browser only accepts the https protocol. We now changed all links to https and hope that they work for you as well.

- p.6, Table 1 captions: *consider adding "although exchange of state variables is not activated in the simulations reported in this paper" after "same model environment."*

  => Added a similar sentence at the end of the caption.

- p.7 l.133: *consider adding ", although exchange of state variables is not activated in the simulations reported in this paper" after "the exchange of flux data". Make a new sentence for "See Tab. 1 for a list ..."*

  => Modified and added.

- p.7, l.139: *replace "will be used" by "are used".*

  => Changed.

- p.7, l.142: *add "the" before "Initialization phase".*

  => Added.

- p.7, l.159: *why do you write "compare with Fig.1" and not simply "see Fig.1"?*

  => Changed.

- p.8, l.182: *replace "domain distributing" by "domain distribution"*

  => Changed.

- p.13, l.234: *add a comma after "Baltic Sea setup"*

  => Added.

- p.14, l.272: *add a comma after "For the present setup"*

  => Added.

- p.20, l.346: *add "see" before "Fig. 15 D"*

  => Added.

- p.20, l.347: *add "see" before "Fig. 15 A and C"*

  => Added.

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