**Authors response to "Interactive comment on "The on-line coupled atmospheric chemistry model system MECO(n) - Part 5: Expanding the Multi-Model-Driver (MMD v2.0) for 2-way data exchange including data interpolation via GRID (v1.0)" by Astrid Kerkweg et al."**

Note: Referee comments are indicated in bold, answers are in regular blue font.

**Overview:**
**This manuscript documents new features of the MECO system (MESSyfied ECHAM and COSMO models nested). A new version (MMD v2.0) of the Multi-Model-Driver has been implemented and the capabilities of the 2-way coupling is illustrated. General Comments: a) The manuscript is well written and the achieved model improvements are clearly described.**
Thanks!

**b) A description of the time management during the 2-way coupling is missed. I would see a more detailed explanation in terms of coupling frequency, time slices considered to average (accumulate) fields before interpolation, etc.**
Usually people are aware of other couplings (e.g. ocean-atmosphere coupling) in which, for instance for mass conservation, fluxes need to be accumulated / averaged over the coupling interval. In contrast to this, our two-way coupling of two atmosphere models utilises a relaxation technique at the lateral boundaries for the parent-to-child exchange, and within the entire coupling domain for the feedback from child to parent, thus modifying the model results according to the finer resolved fields. Thus, since we do not couple fluxes for which mass conservation would be required, but correct the results directly, no accumulation or averaging is reasonable.
The coupling frequency can be changed per namelist, but to minimise the errors, it is strongly recommended to couple every parent model timestep. We add this information to the revised article within a newly added section "Model performance".

**c) An evaluation of the MMD v2.0 model performances (the increased computational cost quantification, etc) compared to the v1.0 could improve substantially the present work.**
Fig. 1 gives an impression of the costs of the coupling. A MECO(2) setup, similar to the hurricane case, was run for one day. During this simulation the wall clock time spent for the data transformation was measured using an internal tool utilising system clock counts. Because the child model does all the data transformations between the two grids, it consumes much more computing time than the parent model. The difference between the one-way coupled (black) and the only dynamically two-way coupled (red) simulation is small, as only six additional fields need to be transformed. Adding 139 chemical tracers to the one-way coupled setup (black dashed line) triples the processing time in the child model, while it requires the sixfold time, if they are two-way coupled (red dashed line).
In contrast to this, the number of coupled fields provokes no systematic increase of computing time in the parent model.
We add this to the revised article in a new section "Model performance".

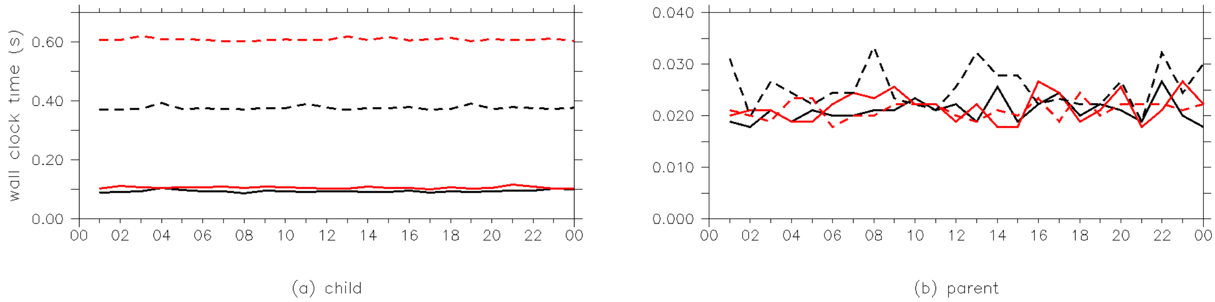



Figure 1: Hourly averaged wall clock time, spent for the processing of the coupling data in the submodels (a) MMD2WAY_CHILD and (b) MMD2WAY_PARENT for a MECO(2) setup, for different couplings between the two COSMO/MESSy instances: Black: One-way coupling, red: two-way dynamical coupling. The dashed lines are for the additional coupling of 139 tracers.

**Specific Comments:**

**- Page 3 line 5: I suggest to uniform the syntax and to use coupling OR nesting throughout the paper.**

"Nesting" and "coupling" do not mean the same thing. The term "coupling" is much broader. In the context of model coupling, it describes the exchange of data between models (or components of those) in general. The term "nesting" is more specific. It describes the data transfer between two models of the same compartment (e.g. atmosphere), of which one typically resolves a larger domain and is used to drive the model with the smaller domain.

In order to explain the nature of our coupling correctly, we think, we need both terms in the abstract / introduction. In the remainder of the article (i.e. in two examples 4.2 and 4.3.2) we replaced the term "nested" by "on-line coupled" in order to unify the usage of nesting and coupling.

**Page 5 line 25: what do you mean with "longer simulation"? I assume this system as also available for climate simulations, thus "restarting feature" is a mandatory requirement. Is it the system designed considering this feature?**

"Check-pointing", which is the technical term for "restarting feature", is indeed considered for the reasons given in the text. We remove "For longer simulations" and rewrite simply "Check-pointing" (the technical term for restarting feature) is required (not only for climate simulations) to be able ...".

**Page 6 line 20: figure 3 labels (panel b) are not readable. Also please uniform the subpanel labelling [ a), b) .. ] in all of the manuscript figures.**

Labels are changed / updated.

**Page 7 line 5: is there any plan to add other remapping approaches?**

Yes. Especially, as SCRIP provides other horizontal remapping approaches, it is relatively straightforward to implement them as well. But there is no special need (and funding) to do so at the moment. Additionally, it is discussed whether to implement YAC (Hanke et al., GMD, 2016) into GRID.

**Page 7 line 10: you use "0. and 1." Instead of the "1. and 2." Approach used in the previous page. Why?**
Because the previous page gives just a list of steps which are processed, while here "0. and 1." are indeed the numbers, which can be set in the namelist to choose the "method". To avoid the confusion, we change the numbers on page 6 to bullet points and use quotes for the numbers on page 7.

**Page 8 line 15: figure 4 labels are not readable.**
Changed.

**Page 9 line 1: "as one central part" should be "as the central part"**
This seems to be a misunderstanding due to incorrect use of language. Grid transformation is only one of a number of important parts in a model infrastructure. Others are e.g., memory management or time and event handling. Therefore we rephrase to "one important part".

**Page 9 line 4: What does "ideally" means?**
"Ideally" means that in the best case, the GRID submodel provides all the listed functionalities. So far, not all of them are implemented. This will be clarifed in the revised article.

**Page 11 line 15: The remapping steps mentioned (first horiz. then vert.) are the typical ones. Not sure this is always the best way, depending on spatial resolution and fields considered. Is it possible to give the user the possibility to choose the interpolation order?**
With some considerable additional programming effort it would be somehow possible. However, as usually the biggest problem is the height correction required due to the differently resolved orographies of the child and the parent model, it seems to be a natural choice to first regrid horizontally and to perform the vertical regridding intertwined with the height adjustment as a second step. At the time being we are not convinced that the effort of code restructuring would be justified by the scientific gain. We explicitly state this in the revised article.

**Page 12 line 10: the last sentence of this chapter is a conclusion before results description. I suggest to move it after the discussion of the TC example.**
Done.

**Page 12 line 15: "For 2-way applications. . ..." please rephrase this sentence.**
We changed "For 2-way coupled applications the questions, if the aggregation of the subgrid-scale information provided by the smaller scale model to the larger scale model constitutes an added value for the larger scale model is still under debate." to "The question, if the aggregation of the subgrid-scale information provided by the smaller scale model to the larger scale model constitutes an added value for the larger scale model is still under debate and might be answered with the help of 2-way coupled applications."

**Page 12 line 25: "NO" must be typed explicitly.**
Done.

**Page 12 line 30: if I understand well, the only interpolation available is a conservative one. I suggest to add NO spatial integral values as obtained after and before the interpolation, to complement the information obtained by figure 5 and 6.**

The NO emission flux integrated over the coupled domain is 3.29 $kg(NO)/s$ and 2.63 $kg(NO)/s$ for the parent and the child model, respectively. Thus, the differences in the soil properties of the two models account for a difference of 0.66 $kg(NO)/s$. The integrated NO emission flux regridded from the child to the parent grid is 2.78 $kg(NO)/s$, providing an emission flux lower by $0.51 kg/s$ compared to the directly calculated integrated emission flux. The difference of 0.15 $kg(NO)/s$ between the flux on the regional domain and its integral on the global domain simply results from the not fully congruent areas (due to different grid box sizes and orientation) over which the integrals are taken in the rotated domain and the global domain, respectively.

We add this information to the article.

**Page 13 line 30: I think it could help to see in the present work also the model deficiency induced by topography.**

Differently resolved topography heights in the coupled models cause a displacement of the tracer with height. To visualise these differences, a MECO(2) simulation with a passive tracer was performed. The initial tracer distribution is horizontally homogeneous and vertically increasing. Fig. 2 displays at four different locations, the height profiles of the tracer in the parent domain (black, triangles), in the child domain (blue, circles) and the coupled field (red, upside down triangles). The annotation gives the surface height in the parent and the child domain, respectively. The blue and the black line are always on top of each other indicating the tracer is initialised with exactly the same height profile in both COSMO instances. With increasing surface height difference, the difference in the vertical profiles increases. The second row of Fig. 2 displays the differences of the black and the red line, i.e., of the original profile and the profile given by the coupling field.

We will add this explanation to the supplement of the paper and add a reference to the supplement to the paper.

**Page 14 line 10: what do you mean with "performed without any scaling of the emissions" ?**

Dust emission schemes heavily depend on soil properties, soil wetness and wind speed. All these factors vary with model resolution. Therefore, our dust emission scheme needs to be optimised by scaling the simulated flux for a given horizontal resolution, in order to yield the same integrated emitted dust mass. In this example we used the same scaling factors as for the global model in T42 also for the regional model.

We change the sentence to "without any resolution dependent optimisation of the emission scheme"

**Page 15: are we looking (figures 10 and 11) at daily or 6hourly (or model time step snapshot) values? Is it possible to see the same as figure 10, but based on 10 meter wind speed?**

These are 6 hourly values. We add this to the caption of the figure.

Fig. 3 shows the maximum 10m wind speed. As these figures do not provide any additional insights, we are hesitating to include them into the revised manuscript.

**Page 15: I think it is really important to highlight the role of the coupling frequency when coupling components/models to improve the representation of certain features such as TCs (see Scoccimarro et al. 2017 and Zarzycki et al. 2016). Thus please add some comment on the coupling frequency you used and some information on sensitivity tests (if any).**
Due to technical reasons, the frequency of data exchange between the child and the parent model must be the same as for the parent-to-child data transfer. For the latter, the two slices of the boundary fields, for which COSMO performs a linear time interpolation, are filled with the data of the actual time step of the parent model. This was required to enable the two-way coupling in which parent and child instances are running concurrently (and not sequentially). This approach enables an improved parallel scaling, but limits the (reasonable) choice of the coupling frequency. To minimise errors, the coupling frequency should be chosen as small as possible, i.e., the smallest common multiple of the parent and the child model time step. For this reason a sensitivity analysis of different coupling frequencies is not provided here. We add this information to the new section "Model Performance".

**FIGURES: Figure 1 and 2 can be also smaller: I suggest to leave more space to enlarge figures as figure 4.**
We reduce the figure size for the revised version. However, the production office might do different things.

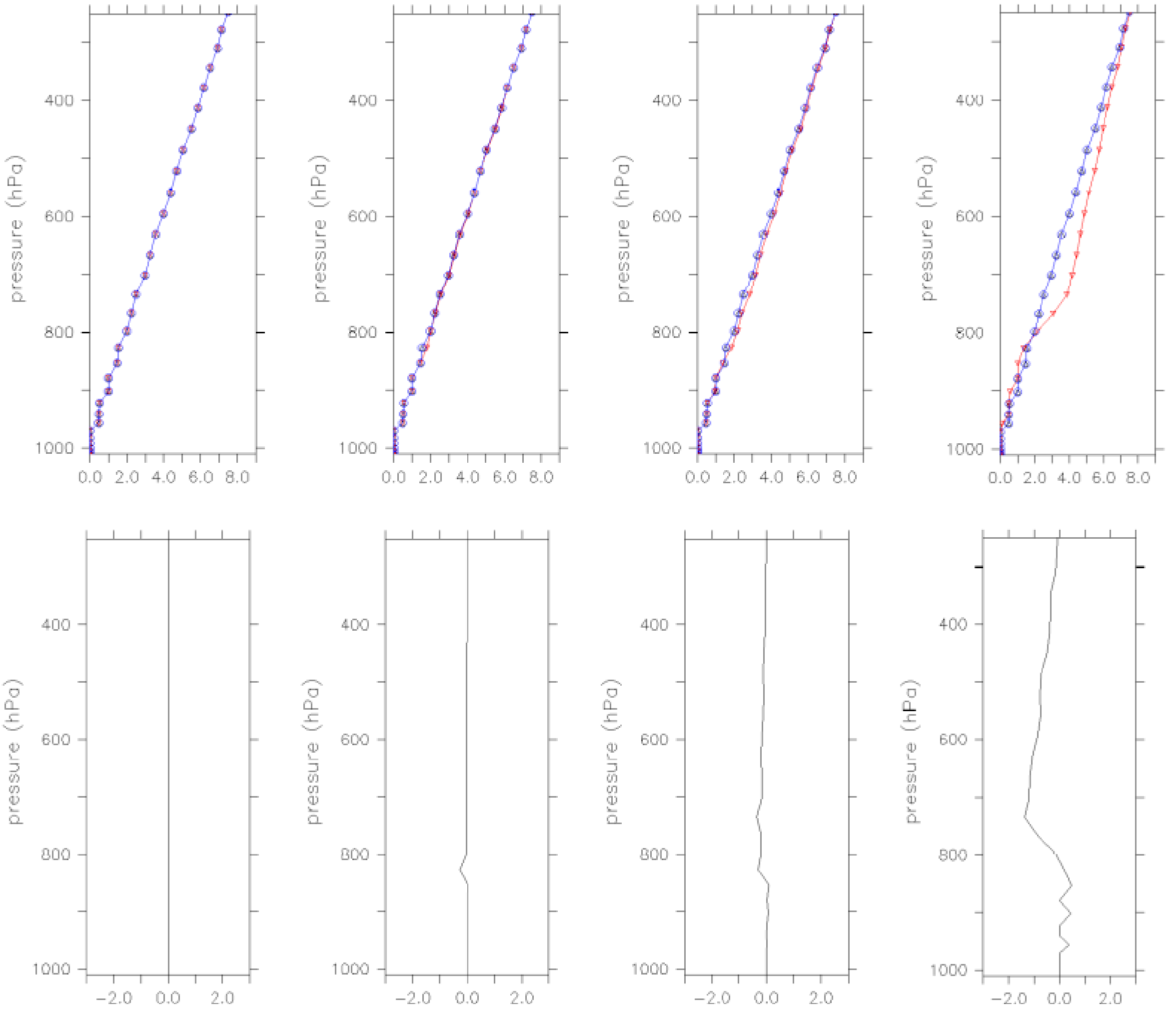
**Labels are not readable in figure 3a, 4, 10 and 11.**
Improved.

**Please uniform subpanels labelling (also add it to figure 10 and 11. I suggest to set white colour for near 0 values in figures 3a, 4 and 9.**
We added the subpanel labeling to Figs. 4, 7, 10 and 11.
We changed the color to white for near 0 values in Fig. 9 and to grey for Figs. 4 and 5 as the model domains should be distinguishable in the figures. However, for Fig. 3a there are no 0 values, as pink symbolises the EMAC domain.

Best regards,
Astrid Kerkweg and co-authors

Literature:

Hanke, M., Redler, R., Holfeld, T., and Yastremsky, M.: YAC 1.2.0: new aspects for coupling software in Earth system modelling, Geosci. Model Dev., 9, 2755-2769, doi:10.5194/gmd-9-2755-2016, 2016.




(a) 0 m / 0 m (b) 52 m / 52 m (c) 330 m / 260 m (d) 2041 m / 2249 m

Figure 2: Vertical profiles of passive tracer (upper row) and their differences (lower row) for different topographic heights in the two COSMO/MESSy model instances (in $10^{-10} mol/mol$). The title gives the topographic height in the parent / child domain, respectively. Black line (triangles): initial profile in the parent model; blue line (circles): initial profile in the child model; red line (topdown triangles): coupled tracer profile in the parent model. The lower row displays the differences between the black and the red lines.

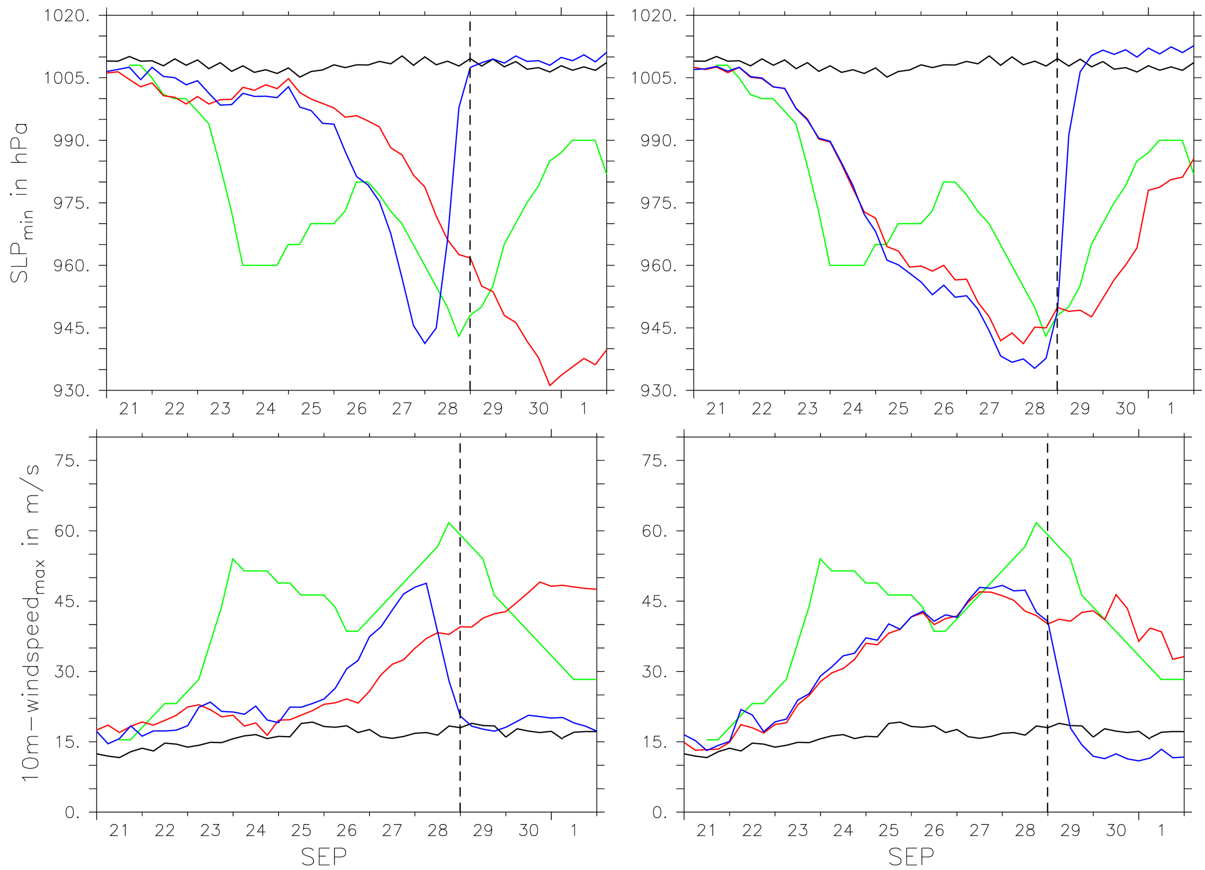



Figure 3: Time series of $SLP_{min}$ (upper row) and 10 m wind speed (lower row) (in the area of 10°N-50°N and 65°W-25°W) in the one-way (left) and 2-way (right) coupled simulation for EMAC (black), COSMO/MESSy$_{0.22°}$ (red), COSMO/MESSy$_{0.11°}$ (blue) based on 6-hourly data. The best-track intensity from HURDAT is shown as reference (green). EMAC is nuged until 29 September (dashed line, s. manuscript for details).