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 black and bold, answers are in regular blue font, and changes to the revised manuscript are highlighted in lightblue.

Dear Referee,
thanks for the careful reading of our manuscript and valuable hints on shortcomings in its original form.

R1: **This manuscript is part 5 of the documentation of the MECO(n) online coupled atmospheric chemistry system. It presents an update of the Multi-Model-DriverMMD from v1.0 to v2.0, which introduces the option of 2-way (as opposed to 1-way) coupling, and describes a new submodel GRID v1.0 for grid translations between the coupled model systems. Online coupling of different model systems running on different grids, with different input and output requirements, different time steps, etc. and running as separate executables is a challenging task. The authors have done a marvelous job in accomplishing such a coupling between a global and a regional model and even between different instances of the regional model. The work is obviously not yet complete, and thus this publication should be seen as another update or extension. The manuscript is composed of a main part and comprehensive user manuals of MMD and GRID as supplements. The supplements provide all the details that are important for users. While I did not have time to look at them in detail, they seem to be well organized and comprehensive with detailed information on data structures and routines and the overall logic. The main body of the manuscript is a high-level description of MMD and GRID and, in addition, presents a few example applications of the coupled system. To me this looks like an appropriate approach for a GMD publication.**

General/major points:
An important general question for a journal like GMD seems to me at what stage an update of a model deserves to be published. In my view only major updates that add significant new functionality should be published, and such updates should be in a mature stage. While the first criterion is clearly fulfilled by the present manuscript (a 2-way coupling is certainly a major update), the second point is much less clear, as detailed especially in point 1 of my main concerns below.

A1: We do not share the referees concern about publishing the system in the current state for several reasons: First of all, major parts of the described 2-way coupling, in particular for atmosheric chemistry related applications and diagnostics are technically complete and already in use. These applications deserve a proper reference, which can be cited if it comes to publications. Second, the current development step was released with the release 2.53 of our model system (see Section "Code

Availability") to a wider user community. This requires a proper reference and documentation, including a clear description of the current limitations.

R2: **Although the manuscript is reasonably well structured and written and the topic is relevant and suitable for GMD, I have some major reservations: 1. The 2-way coupling is still in a pre-mature stage**

A2: As above, we disagree. The 2-way coupling is technically complete and the updated model system is already in use, in particular for atmospheric chemistry related applications. These are in the focus of our work. Thus, we think, publication of the current stage of the developement is justified, despite the fact that the dynamical 2-way coupling, which is a specific challenge on its own, requires further development.

R3: **because a) dynamical 2-way coupling (of meteorology) seems not yet possible between EMAC and COSMO and even between instances of COSMO only seems to work reasonably well over flat terrain (an example is presented over the ocean). The main reason for this seems to be inconsistencies in the vertical grid transformations, especially because different methods are used for the partent-to-child (int2lm) and the child-to-parent (GRID v1.0) transformations.**

A3: This is correct for the EMAC-COSMO coupling. However, for the COSMO-COSMO coupling the vertical interpolation routine of INT2LM is used for both directions. We have to admit that this is not clear in the paper, but well documented in the supplement.
We add this information to the revised manuscript. The major problem for both, EMAC-COSMO and COSMO-COSMO couplings, is that INT2LM does not only perform a vertical remapping, but makes a crude assumption of keeping the boundary layer (i.e. up to 850 hPa) as it is, however, moving it to the height of the target orography and remapping only the remaining part of the vertical column. This procedure, as it is implemented in INT2LM, is not reversible and thus introduces spurious effects for different orographies, which are always present because of the different horizontal resolutions of the nested models.

R4: **b) as just mentioned, the COSMO pre-processor tool int2lm is still used for the parent-to-child transformations, which seems redundant since GRID should provide all functionality required for this, and using GRID for both up- and down-scaling would provide much more consistency. It remains unclear why this issue has not been resolved.**

A4: INT2LM provides much more functionalities than only remapping. It reads and processes the external data required as input for the COSMO model (especially for the initialisation of the model). Moreover, it performs some field adjustments concerning inconsistencies between the land-sea-mask of the COSMO model and the in-coming data.
We add this information to the introduction of Sect. 2.
Therefore, it is not possible to completely eliminate INT2LM. One could, however, indeed exchange the horizontal and vertical interpolation routines. We started to test this, but in the first place the performance (w.r.t. the results) of the child model was downgraded. As explained above, the main problem is the extra treatment of the boundary layer, which for the off-line nested COSMO model is the preferred way, as this makes physically more sense compared to a simple vertical

interpolation. But in terms of reversibility of the height adjustment procedure this unfortunately causes problems.

R5: **c) The GRID submodel seems to be still in a fairly rudimentary stage. E.g. only "conservative remapping" is implemented (see P7, L6), whereas the description of the GRID submodel in Section 3 also mentions "interpolation" as a final goal (see P9, L15). Also vertical grid transformations seem to be implemented only in a pre-mature way (see next point).**

A5: This is obviously a misunderstanding that we need to clarify. Please do not mix up GRID with the applied interpolation procedure for the 2-way coupling in MMD2WAY. GRID is fully functional, it includes two remapping packages: NREGRID and SCRIP, implying that all interpolation / remapping routines provided by NREGRID and SCRIP can be used with the GRID submodel.
For the 2-way coupling (MMD2WAY), however, only conservative remapping is utilized so far, for mainly two reasons: First, an improved run-time performance can be achieved by efficiently exploiting the given horizonal domain decompositions of the models, because the data exchange between the local domains could be minimised in comparison to other remapping or interpolation schemes. And second, conservative remapping is the first choice for atmospheric chemistry applications, since fluxes (e.g. emission fluxes) are conserved.
We are more precise about this in the revised manuscript.
We change the sentence on page 7 from "For the time being, only conservative remapping is implemented as horizontal transformation method" to "For the time being, only the conservative remapping, as provided by GRID, is utilized as transformation method in MMD2WAY_CHILD."

R6: **Some parts of the manuscript are lacking clarity and detail. I am particularly missing details regarding the grid transformations and the separation into horizontal and vertical transformations. In particular, COSMO is a non-hydrostatic model running on a geometrically fixed grid, whereas EMAC is hydrostatic and formulated on a hybrid-pressure grid. Although I understand the motivation of the authors to keep the descriptions generic, the transformation between these fundamentally different vertical representations is essential and should be much better described.**

A6: The revised manuscript contains a more detailed description.

R7: **Furthermore, COSMO variables are represented on a staggered (Arakawa-C type) grid, which requires different transformations for variables like temperature or concentrations defined on grid cell centers, and variables like wind or tendencies defined on grid cell interfaces. Neither the main body of the manuscript nor the documentation makes any reference to the issue of staggered variables.**

A7: The only variables defined on the staggered grid in the COSMO model are the wind components. For the COSMO-EMAC coupling the COSMO wind components are first interpolated to the cell midpoints, and afterwards transformed to the EMAC grid. For the COSMO-COSMO coupling the wind components are interpolated directly between the staggered grids, i.e., they are always defined on the box edges. This information is added to the revised manuscript and the MMD User Manual.

R8: **The manuscript talks about a "geo-hybrid-grid" without explaining this structure** [...]

A8: The Fortran data structures of GRID are based on those of NCREGRID as published by [Jöckel(2006)]. This article provides an extensive explanation of the definition of a geo-hybrid grid. Therefore, we did not repeat it in the current article.
[Jöckel(2006)] introduces the geo-hybrid grid as follows: *The horizontal grid space of a geo-hybrid grid usually comprises geographical latitude and longitude. Especially in 3-D global atmospheric models the vertical pressure (p) coordinate is often defined by hybrid levels (with index i) of the form*

$$p(i, x, y, t) = h_a(i) \cdot p_0 + h_b(i) \cdot p_s(x, y, t), \tag{1}$$

where p_s is the surface pressure, p_0 is a constant reference pressure, and h_a and h_b are the dimensionless hybrid coefficients. This representation in a curvi-linear coordinate system (dependent on longitude x, latitude y, and time t) allows a terrain following vertical coordinate, if $h_a = 0$ and $h_b = 1$ for the lowest level (surface level)."
Thus, dependent on the choice of p_s and p_0 GRID is capable to handle all cases of vertical pressure axes, such as

- hybrid pressure axes ($h_a \neq 0$, $h_b \neq 0$),
- constant pressure axes ($h_b = 0$) and
- sigma levels ($h_a = 0$).

In the case of $h_b = 0$, $h_a \cdot p_0$ could also be a height coordinate. The grid transformations require that source and destination grids are both defined in the same vertical representation, i.e. either with pressure or with height coordinates.
We add some more information to the revised Sect. 3.1 (which also required a slight reordering), with a specific reference to the corresponding section in the revised GRID User Manual, which contains the complete information.

R9: [...] **and later about the "basegrid".**

A9: "basegrid" is a short cut for one specific geo-hybgrid grid, namely the 3-D grid of the basemodel (see Sect. 3.2 in the GMDD version of the manuscript).

R10: **GRID seems to expect a hybrid pressure grid (see line 14 on page 10), but how COSMO variables are transformed to hybrid pressure levels is never explained.**

A10: The COSMO model still provides the possibility to define the vertical grid by pressure levels. This option was still frequently used when our model development started. Thus, for the definition of the hybrid pressure grid, we currently use the routines provided by INT2LM.
Nevertheless, in the meantime GRID is further developed to deal with the requirements of the ICON model, which only features height axes. Thus, we are going to implement the possibility to use the actual (time-dependent) 3-D pressure field for remapping between height and pressure grids, since this will be required for the MESSy infrastructure submodel IMPORT connected to ICON.
We discuss this issue more in the revised Sect. 2.2.

R11: **Furthermore, if GRID only supports hybrid-pressure levels, it will be little suited for transformations between two instances of COSMO, as these are both operating on geometric grids.**

A11: As explained in answer A8, height - height interpolations are possible as well. Anyhow, as stated in answer A3, for the back-transition between two COSMO instances the procedure of INT2LM is used.

R12: **I am also missing information on details of the coupling, especially with respect to the frequency of the coupling: Are fields exchanged at every model time step? Are the parent and child models forced to use the same time steps? Is the frequency of coupling the same for the upward and the downward directions? Such information my be added in Section 2.2. 3.**

A12: Parent and child model do not need to use the same time step lengths. However, the parent model time step length needs to be a common multiple of the child model time step length. The coupling frequency can be changed in the namelist, but to minimise the deviation of the child model from the parent model state at the boundary, it is strongly recommended to couple every parent model timestep.
This information is provided in a new subsection "Model performance" of the revised manuscript.

R13: **The authors emphasize the need for developing computationally efficient interfaces and submodels (e.g. line 19 on page 9), but no information is provided that would allow the reader to judge the efficiency of the coupling that is ultimately achieved. What is the computational overhead introduced by the coupling in terms of additional memory usage and computation time? Maybe this has been addressed in previous publications, but if so, this should be referenced. Otherwise, I would strongly encourage the authors to benchmark the model system (e.g. for one of the simulation examples in Sect. 4) with detailed timings of the individual model components and additional diagnostics, as this is a fundamental first step towards identifying bottlenecks and improving efficiency.**

A13: It is not clear to us, to which reference this "overhead" and additional computation time should be compared to? An off-line 2-way nesting is hardly possible, and the show-stopper would obviously be the tremendous I/O required to write and read the files with coupled fields in every model time step. The required memory (for the 2-way nesting) increases linearly with the number of variables that need to be exchanged. And the run-time performance depends first and foremost on the specific model setups (e.g., on the complexity of the chosen chemistry representation etc.). But most important, the overall performance is at the end determined by the "degree of balance" of the distribution of parallel tasks among the different model instances. We discussed this in detail in Part II of our series (Kerkweg and Jöckel, 2012) for the 1-way nesting case. The same principles hold for the 2-way exchange, except for the complication that communication waiting times depend now on bidirectional data exchange. Thus, it is up to the user to find (experimentally) the optimum task distribution to minimise communication waiting times.
We add a brief discussion on this to the new Section "Model performance" and additionally assess the dependency of the simulation time on the number of coupled fields in order to check, whether an increasing number of fields shows discontinously prolonged simulation times caused by the 2-way exchange.

R14: **The manuscript may be acceptable after addressing my main concerns 2 and 3 (plus the minor points below), or it may be postponed until a**

more mature version of coupling is available (i.e. main concern 1 is also addressed).

A14: See our answers A1 and A2.

R15: **Minor points: - Introduction: The reasons for the external coupling mentioned on P2/L20-30 are not entirely clear. Why is it good to "prevent the patches approach"? What are the "limitations of the Fortran95 namespace"?**

A15: Maybe we were not precise enough here. The "patches approach" is usually a feature of regional grid-refinements, which is directly embedded in (or part of) the model code, as for instance in WRF or ICON, in which the user can specify the number of patches and their corresponding domains flexibly at run-time. For such a feature, however, the entire model code needs to be "aware" of a(n arbitrary) number of grid-refined patches. Thus, this needs to be implemented "by design". To equip legacy code (as COSMO or ECHAM) supplementarily with such a feature would basically mean to rewrite the entire code from scratch. The reason is that all prognostic (and diagnostic) variables need to exist on each patch (technically independent of each other). How this is technically achieved depends largely on the applied programming language. In fully object oriented languages, overloaded "sets" or "instances" of the same variable(s) could be defined, however, the Fortran95 language standard does not allow to have the same variable with the same name in the same name-space more than once. Thus a complete recoding, e.g., replacing arrays by structures of arrays is required.

The first /second part of this answer is added for clarification to the first / second bullet point in the introduction of the revised manuscript.

R16: **On the other hand, an advantage not mentioned is that this external coupling allows testing the influence of the coupling of different (individual) variables, which would likely be more difficult with internal coupling. The introduction should also emphasize the disadvantages and challenges of the external coupling, e.g. the challenge of transforming between different vertical grids.**

A16: First of all, thank you very much for this important hint on variable testing.

We add this point to our revised list of advantages.

Indeed, in our current applications we do exactly this (e.g., chemical 2-way nesting with dynamical 1-way nesting).

Concering the challenges: The need to transform between different vertical grids is not necessarily connected to the way of (internal or external) coupling. Nevertheless, the patch (or grid-refinement) approaches are usually implemented as "internal" coupling and do keep the vertical grid between different patches in order to avoid vertical interpolation. But also in an external coupling approach the vertical grid between different model instances can be the same. In both cases, however, the issues due to the horizontally refined orography information remain.

To expand the discussion, we add some statements about the disadvantages and challenges of external coupling to the revised introduction, right after the list of reasons for choosing external coupling:

"Apart from these advantages, the external coupling proves to be more challenging than the internal coupling. Horizontal and vertical interpolation errors are expected to be larger, depending on the relations between the different grids and differences in the orography. From these, the adaption to the higher resolved orography of the nested simulation causes the largest error. An additional disadvantage of all external coupling approaches is the need for the user to optimise the distribution of the available parallel tasks among the different model instances, in order to achieve an optimal run-time performance with minimized waiting times between the model instances."

R17: **Footnote "2" on MPI-ESM seems little relevant in the context of this manuscript and could easily be deleted in my view.**

A17: We want to provide references for each model.
Instead of the web-site, we now cite Giorgetta et al. (2013).

R18: **P3, L8: Sentence "This article documents the development of the . . .". No, this article is only part of a documentation.**

A18: We change the statement to "This article documents a major achievement in the development of the ... "

R19: **The following lines are presented in italics, which I found confusing until I realized that this is a citation. It would be clearer to present the references at the beginning and then the quoted text, e.g. "As described in Jöckel et al. (2015), Baumgaertner et al. (2016) and the MESSy homepage (..), the Modular Earth System Model (MESSy) is "a sofware providing . . .".**

A19: Thanks for this suggestion! Indeed, the reordering enhances the readability a lot.
Changed.

R20: **P4, L3: Delete the bracket "(Messyfied ECHAM . . .)", this was already explained earlier.**

A20: Done.

R21: **P4, L14: "update of MMD" → "update of MMD presented here"**

A21: Changed.

R22: **At the end of the introduction section I was wondering whether GRID is now used for both directions replacing INT2LM entirely or not. It should already be explained here that the present implementation of GRID is only used for the child-to-parent transformation.**

A22: We change the sentence "Sect. 3 introduces the newly developed GRID submodel, which provides the required mapping functionalities" to "Sect. 3 introduces the newly developed GRID submodel, which provides the required mapping functionalities used for the child-to-parent data exchange.". Furthermore, the last sentence of the prior paragraph reads now "GRID can be used for all grid mapping operations required during a simulation." instead of "GRID is used for all grid mapping operations required during a simulation."

R23: **P6, L15: What does "imprints its time settings" mean? Start and end of the simulation, time step, or something else?**

A23: These are the start-date (only if a model instance is newly started), the end-date, and the restart trigger.
Item changed to "the parent imprints its time settings on the child model, i.e., end-date, restart trigger and, at the very first start of a model instance, the (re-)start-date as start-date of this instance."

R24: **Does "imprint" mean that the child model has to use the same time step as the parent?**

A24: No. Forcing the coarsest instance to use the same short time step length as the finest resolved model instance would downgrade the performance of the system dramatically. Nevertheless, the time step lengths of all model instances need to be common multiples.
For respective changes in manuscript: see A12.

R25: **P6, footnote 9: It would be better to include this information in the main text rather than as a footnote. Is it really necessary to distinguish between INT2LM and INT2COSMO in this manuscript?**

A25: We prefer to keep the differentiation between INT2LM and INT2COSMO to keep the manuscript consistent with Part II of the article series about MECO(n).
We inline the footnote in the revised manuscript. The sentence reads: "Afterwards the data is transformed from the in-grid to the child grid using the expanded version of the preprocessing software INT2LM for the COSMO model (INT2COSMO). See Kerkweg and Jöckel (2012b) for further explanations."

R26: **P7, L9-16: What is the difference between Option "0" and Option "1a"? On line 16, shouldn't it be Option "0" rather than "(a)", since (a) was introduced as an option available only for prognostic variables?**

A26: With option "0", as explained in the text, the memory for the target field is allocated within MMD2WAY_PARENT and can afterwards be accessed by other MESSy submodels. For option "1", however, the variable needs to exist in the parent model and will be modified directly.
In the revision, we change the wording from "the field is used to modify an existing parent model field." to "the exchanged field is used to directly modify a parent model field." Additionally, as the explanations below belong all to option "1", we moved the end of the enumeration to the end of the section.

R27: **P8, L17: The weight functions should remain the same during the simulation, at least the horizontal weights. Are the functions nevertheless transformed at each time step, i.e. the same transformation is repeated over and over again?**

A27: Indeed, our sentence is misleading. We change it to:
"They are once, during the initialization phase, transformed in the same way as the data and sent to the parent model for application during the integration phase."

R28: **P8, L28: The statement "for all required grid transformations" is not correct, since int2lm is used for partent-to-child transformations.**

A28: This needs indeed to be clarified. GRID is independent of MMD2WAY. The MESSy infrastructure component GRID provides the basis for all required grid transformations. However, in the MMD2WAY_CHILD submodel we decided to use the INT2LM software instead of GRID. One of the reasons is that the 1-way online coupling was implemented prior to GRID.
This sentence is skipped in the revised manuscript anyhow, see A29.

R29: **P8, L29: I didn't understand this sentence. "Ideally" points at an ideal state not yet reached and should therefore be followed by "would be implemented" rather than "is implemented".**

A29: Yes. “Ideally” means that in the best case, the GRID submodel provides all the listed functionalities. So far, not all of them are implemented. This is clarified in the revised article. We change “is” to “would be”.
Moreover, we see that the first sentence of this subsection is misleading. Therefore we skip it and add a more general introduction, fitting better the following more general statements. The new sentence reads: “Due to the increasing complexity of Earth System Models, grid transformations at run-time of the model, (e.g., remapping from an atmosphere grid to a higher resolved land grid and vice versa) are more and more commonly required. To avoid individual implementations throughout the code, such an on-line transformation functionality should be implemented as one important part of the model infrastructure, providing a common grid processing functionality.”

R30: **P9, L1: What exactly do you mean by ”as one central part of the model infrastructure”?**

A30: 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, for instance, memory management or time and event handling.
Therefore we rephrase to “one important part”.

R31: **P9, L5-8: I don’t agree with the definition of regular and irregular grids. A ”lambert conformal” grid as often used e.g. in WRF is also a regular orthogonal grid. A grid is usually regular in one projection but irregular (non-orthogonal) in another projection. Here it sounds like any non-lat-lon grid would be irregular (same issue in Section 3.1).**

A31: Indeed, it was definitely not our intention to name every non-lat-lon grid irregular! Following the grid classifications of Bowler and Clegg (2011), we decided to change the grid classification to

- rectangular grids, which are either orthogonal in geo-coordinates (rectilinear grids) or curvi-linear grids,
- non-rectangular structured grids, and
- unstructured grids.

The second sentence of Sect. 3.1 is changed accordingly to “Four different grid types are distinguishable: (1) rectangular grids, which are orthogonal in geo-coordinates, (2) curvi-linear grids, (3) non-rectangular, structured grids and (4) unstructured or irregularly geo-located grids.

R32: **Equally important as the horizontal grid transformation (and actually more challenging) is the vertical transformation. This needs more attention in section 3.**

A32: We provide additional information on the vertical remapping in revised Sect. 3. by introducing a new subsection “3.1.4 Application of GRID in MMD2WAY_CHILD”.

R33: **P10, L11: What is a ”geo-hybrid grid” structure?**

A33: A geo-hybrid grid structure is the Fortran type definition (= structure), which contains all data required to define a geo-hybrid grid (for the definition of a geo-hybrid grid see answer A8.)
We change the sentence to “The definition of the Fortran structure, which contains

all components required for the definition of a geo-hybrid grid, was extended and generalised for the usage in GRID."

R34: **P10, L13: Why is a grid "defined by geographical longitude and latitude and vertically by hybrid pressure coefficients"? Is this a design choice for the GRID submodel?**

A34: Yes it is. See answer A8.

R35: **Does that imply that for a COSMO-COSMO nesting the COSMO grids (which may share the same projection) have to be first converted to geographical coordinates and then back to rotated ones? It would seem much more logical to me that GRID would translate everything to the same projection (e.g. the one used in the parent model), irrespective of whether it is a geographical coordinate system or not.**

A35: The referee comments R35, R37 and R39 point to an additional misunderstanding: In our article the term "grid transformations" refers always to data "remapping", "regridding" or interpolation between different model grids based on geographical coordinates. We never intended to use it in the meaning of "grid translations" or "map projection".
Independent of the computational grid of the model, the grid structure in GRID contains the data of the grid vertices and / or cell centers always in geographical coordinates. This information is – in all cases – provided by the respective base-models (ECHAM5 and COSMO) and does not need to be determined by the GRID submodel. Thus, GRID does not need to perform "grid translations" or "map projections". The remapping weights of geo-located data between two different grids are always calculated in geographical coordinates.
We change the term transformation to remapping at some location in the article to avoid the above misunderstanding. Additionally, the information about the geographical coordinates is added to the revised Sect. 3.1.

R36: **How is the COSMO vertical grid transformed to hybrid pressures?**

A36: Until now, the hybrid pressure coefficients calculated by INT2LM or the COSMO model are used. See answer A10.

R37: **Section 3.1.1 GRID_TRAFO: Grid transformations have been implemented in standard libraries like gdal (http://www.gdal.org/) and proj.4 (http://proj4.org), which also support rotated grids as used in COSMO. Why did you not choose to link to such a library that could provide a great level of flexibility? The SCRIP software seems to offer comparatively little flexibility. In my view one should strictly distinguish between coordinate translations (as can be accomplished by such libraries) and the final mapping between grids, which can be done by linear, cubic, or spline interpolation of any other (possibly conservative) mapping, and may be implemented as separate routines in GRID.**

A37: As far as we understand the functionalities of these libraries, they would not help, as it is not coordinate translations (or map projections) we need, but the actual remapping of data between different geographical coordinate systems.

R38: **Please make clear from the beginning that NREGRID is only implemented in GRID for vertical transformation, while SCRIP is used for**

all horizontal transformations, not only at the end of Section 3.1.3 (and more explicitly in the conclusions). Otherwise the reader - like myself - is confused about the role of NREGRID.

A38: Sorry! Obviously we have to be more clear about the separation of GRID and the MMD submodels. NREGRID was originally implemented for horizontal and 3-D spatial remapping. This is still the standard way for the data import in the EMAC model (i.e., with ECHAM5 as basemodel).
In the COSMO model, some of the requirements of NREGRID w.r.t. the grid structure are, however, not fullfilled. Therefore, we had to introduce a second remapping option for horizontal grids, which can deal with rotated grids, such as the COSMO grid. We decided to use the very well known and commonly used SCRIP software package.
Therefore, MMD2WAY_CHILD uses SCRIP for the horizontal interpolations, and NREGRID for the vertical remapping, as SCRIP does not provide remapping along the vertical axis.

R39: **P11, L1: Why is NREGRID recursive? Is this information relevant here? It sounds strange to me to have a recursive algorithm for grid translations.**

A39: NREGRID is not for grid translations. It is for the rediscretisation of "gridded" geo-scientific data between n-dimensional (usually n = 2 or 3) orthogonal grids. The conservative rediscretisation of extensive or intensive variables is based on the calculation of the overlap (area or volume) matrix between source and destination grid boxes. For orthogonal grids these overlap matrices can nicely be calculated recursively, since the overlap area / volume is zero as soon as at least the overlap interval along one axis (dimension) is zero. For details see Jöckel (2006). Since the recursive nature of this algorithm limits its application to orthogonal grids it cannot be applied for rediscretisations between the (in geographical coordinates) orthogonal Gaussian grid of ECHAM5 and the rotated (in geographical coordinates non-orthogonal) COSMO grid. This is why we needed to implement SCRIP as well. Thus, the information is relevant.
We add this information to Sect. 3.1.2.

R40: **P12, L16: "For 2-way applications" → "For 2-way coupling applications"**

A40: Changed.

R41: **P12, L21-26: A missing important point why size matters in atmospheric chemistry is that this chemistry is highly non-linear.**

A41: This is indeed what we meant.
We rephrase the last sentence to "Especially in highly polluted regions, or more generally near emission sources, this might influence the simulated chemical regime, as atmospheric chemistry is highly non-linear."

R42: **P13, L7: dry deposition velocities do not only depend on soil type but also on turbulence, which could be another difference between the models.**

A42: Thanks for this remark.
We change the last sentence from ", which is most propably due to different soil properties in that region." to ", which is most propably due to different soil properties and also due to the different turbulence schemes employed by the two basemodels. "

R43: **P15, L8: Is really only the pressure perturbation exchanged, i.e. the deviation from a reference pressure profile?**

A43: For the COSMO-COSMO coupling only the deviation of the pressure from the reference atmosphere is exchanged during the integration. During the model initialisation phase all information required for the definition of the parent grid are exchanged. The definition of the reference atmosphere itself is part of this onetime data exchange. The term "pressure perturbation" seems to lead to a misunderstanding.
Therefore we change "pressure perturbation (pp)" by "the pressure deviation from the reference atmosphere (PP)".

Typos and grammar:
- P4, L30; "software as" → "software such as"
Corrected.

P5, L5: "reasonable" seems not the right word here.
"This is reasonable," is replaced by "This was required,"

P7, L6: "At the time being" → "For the time being"
Corrected.

P7, L17: "For both option" → "For both options"
Corrected.

P12, L4: "handy" is not a good word in a scientific publication
Replaced by "useful".

P12, L6: "tools, can" → "tools can"
Corrected.

P12, L31-32: Change to "If COSMO/Messy were 2-way coupled into EMAC and EMAC were using the NO emissions .."
Corrected.

P13, L2: "what is mostly" → "which is mostly"
Corrected.

P13, L5: "pervious" → "previous"
Corrected.

P13, L6: I would say "slightly but systematically" rather than "systematically"
Done.

P14, L4: "good" → "well"
Corrected.

P23, Fig. 5: "been mask" → "been masked"
Corrected.

Best regards,
Astrid Kerkweg and co-authors

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