Author's Response

Discussion on
Eichinger, R. and Jöckel, P. (2014): The generic MESSy submodel TENDENCY (v1.0) for process-based analyses in Earth System Models; Geoscientific Model Development

Reply to RC C396 by A. Grini

Thank you very much for your valuable comments and questions. Our answers are:

1. As it is now implemented, the submodel TENDENCY is directly portable only to other MESSy basemodels (i.e., models equipped with the MESSy infrastructure), since it utilizes two other MESSy infrastructure submodels: CHANNEL for memory management and I/O (Jöckel et al., 2010: Development cycle 2 of the Modular Earth Submodel System (MESSy2)) and TRACER for chemical constituents (Jöckel et al., 2008: Technical Note: Coupling of chemical processes with the Modular Earth Submodel System (MESSy) submodel TRACER).

   The *concept*, however, is portable to other model systems, as well. For this, large parts of the code can be reused as well, since only the CHANNEL based memory management and the TRACER infrastructure need to be replaced.

   In any case, the list of prognostic (non-TRACER) variables, which depends on the basemodel, needs to be adapted, which is, however, technically a minor modification.

   This comment was indeed very helpful, we will clarify this throughout the manuscript and add some text to Section 2.

2. This is apparently a misunderstanding mixing the "unaccounted" object with the closure test:
   - An "unaccounted" object (as explained in Section 3.1, User interface) is created for each user defined pair of *prognostic variable* and *corresponding list of processes or sums*. This is to ensure that the TENDENCY budget is always closed. For example, if the user defines only one specific process he/she is interested in, the "unaccounted" object will contain the sum of all other processes. The other way around, if the user specifies all processes explicitely, the "unaccounted" object will contain zero.
   - The closure test (as explained in Section 3.2) is completely independent of this and serves a different purpose: The closure test, if activated, checks if all submodels modify the prognostic variable tendencies correctly via TENDENCY. If, what can in Fortran technically not be prohibited, a submodel (as classically done!) USEs (by Fortran USE) a prognostic variable tendency directly and modifies it without calling the corresponding TENDENCY routines, TENDENCY will detect a discrepancy against its internal book-keeping at the end of the time step and create an error message.

We will recheck the manuscript, in order to detect, how this misunderstanding can evolve and clarify this point.

3. See previous point.
   The closure test will at the end of the time step detect a discrepancy between its internal book-keeping of correctly modified tendencies with the overall modified tendency, which contains also the contribution of the new submodel. This will trigger an error message.

4. TENDENCY is designed for the book-keeping of individual process tendencies, thus it is directly related to the "granularity" of the process descriptions. If a process can be subdivided into further sub-processes each calculating a distinct contribution to the tendency, those sub-process-tendencies can be handled by TENDENCY. This implies that intermediate tendencies within an implicit scheme cannot be captured by TENDENCY, unless they are explicitely calculated within the scheme.

   This is a limitation by design, and an important point. We will add an explanation to this at the beginning of Section 3.

   In order to follow production/loss rates from chemical schemes MESSy provides additional tools, based on the tagging principle, for instance:

   - Grewe, V., 2013: A generalized tagging method
   - Gromov et al., 2010: A kinetic chemistry tagging technique and its application to modelling the stable isotopic composition of atmospheric trace gases

5. See also our answer to your question 1. The set of prognostic variables is defined by the basemodel, including their units. If a basemodel can be operated, e.g., with different dynamical cores defining different sets of prognostic variables, this needs to be taken into account in TENDENCY. TENDENCY does not perform any unit checks.

   The example with the scaled and unscaled winds sharing the same memory (or variables) you are referring to, is an ECHAM inheritance of EMAC.

6. No, developers do not have to take parallelisation into account, because TENDENCY operates within the parallel decomposition, i.e., locally in each grid box.

Reply to RC C416, by Anonymous

Thank you very much for your valuable comments and questions. Our answers are:

1. Yes, TENDENCY could indeed be used for such studies. The relevance of solar activity can for instance be investigated by comparing the radiation tendencies of two model simulations, one with and one without variations in solar activity.
   The level of detail that can be investigated with TENDENCY is only limited by the specific process formulations: if the process submodel calculates various contributions, they can be examined individually with TENDENCY.

   We will add a paragraph at the end of Section 5, about possibilities and the limitations of further studies. Thank you for this advice. About the limitations, please also refer to our answer to question 4 from the other referee (C396).

2. Yes, some of the points are repetitive, though very brief. However, the mentioned point is very important for the motivation of the development and hence we think it should be

kept.
Other redundancies are included for the sake of readability of the manuscript. Specific points can be discussed about, though.

3. The namelist discussion is not only a pure description of the parameters, but is always in context with explanations of TENDENCY. Moving it to the supplement would hence increase the redundancy of the manuscript. Since this paragraph is not too long, we would like to keep it for easier understandability.

4. To our knowledge, there are no such tools available in other model systems, however, we cannot tell for every model. Commonly users hard-code quick, error-prone solutions, mostly if specific process tendencies are desired.

5. This is a very good point, we forgot to include this. We will add it in Section 2 and in the Summary.

Changes in the manuscript

1. Abstract:
   Changed *"TENDENCY is applicable to other model systems"*
   to *"the concept of TENDENCY is applicable to other model systems"*

2. Section 2.1:
   Changed *"The TENDENCY module operates in all three phases of the model:"*
   to *"The TENDENCY module is written in Fortran 95 programming language. It operates in all three phases of the model:*

3. End of Section 2.1:
   Added: *"As it is implemented now, the submodel TENDENCY is directly portable to other MESSy basemodels (i.e., models equipped with the MESSy infrastructure), since it utilises the two other MESSy infrastructure submodels CHANNEL (for memory management and I/O, Joeckel et al., 2010) and TRACER (for chemical constituents, Joeckel et al., 2008). Still, for porting the concept to another model system, large parts of the code can be reused, as well. The list of prognostic variables, however, needs to be adapted to the respective basemodel in any case. "*

4. Chapter 3:
   Added: *" The limitations of the book-keeping of process tendencies, by design, is the partitioning of the individual processes, according to the operator splitting concept. If a process can be sudivided into further sub-processes, each calculating a distinct contribution to the tendency, those sub-process-tendencies can be handled by TENDENCY. This also implies that intermediate tendencies within an implicit scheme cannot be captured by TENDENCY, unless they are explicitely calculated within the scheme. "*

5. Section 3.1:
   Changed: *"*`l_closure` *enables the internal closure test and creates the additional channel "tendency_clsr" with objects required for the closure test"*
   to *"*`l_closure` *enables the internal closure test and creates the additional channel "tendency_clsr" with the two objects required for the closure test"*

6. End of Chapter 5:
   Added: *A variety of studies can be carried out by means of TENDENCY. The relevance of certain processes as drivers for changes in the dynamical or chemical state of the atmosphere can be analysed. However, the limitations described in Sect. 3 have to be considered. The relevance of solar activity for a temperature change over time, for instance, can in the EMAC radiation scheme only be investigated by comparing the temperature tendencies from the radiation scheme of two model simulations, one with and one without variations in solar activity. The level of detail, that can be investigated with TENDENCY is limited by the specific process formulations. If one process calculates several contributions to a variable, though, these can be examined individually with TENDENCY.*

7. Summary:
   Changed: *"Implemented in the EMAC model this enables us"*
   to *"Implemented in the EMAC model this Fortran 95 module enables us"*

8. Summary:
   Changed: *"Due to the independence of the time integration scheme TENDENCY is also applicable to other basemodels."*
   to *"Due to the independence of the time integration scheme, the concept of TENDENCY is also applicable to other basemodels. "*