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Volume 7, issue 4 | Copyright

Development and technical paper | 31 Jul 2014

The generic MESSy submodel TENDENCY (v1.0) for process-based analyses in Earth system models

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Received: 20 Feb 2014 – Discussion started: 08 Apr 2014 – Revised: 12 Jun 2014 – Accepted: 13 Jun 2014 – Published: 31 Jul 2014

Abstract. The tendencies of prognostic variables in Earth system models are usually only accessible, e.g. for output, as a sum over all physical, dynamical and chemical processes at the end of one time integration step. Information about the contribution of individual processes to the total tendency is lost, if no special precautions are implemented. The knowledge on individual contributions, however, can be of importance to track down specific mechanisms in the model system. We present the new MESSy (Modular Earth Submodel System) infrastructure submodel TENDENCY and use it exemplarily within the EMAC (ECHAM/MESSy Atmospheric Chemistry) model to trace process-based tendencies of prognostic variables. The main idea is the outsourcing of the tendency accounting for the state variables from the process operators (submodels) to the TENDENCY submodel itself. In this way, a record of the tendencies of all process–prognostic variable pairs can be stored. The selection of these pairs can be specified by the user, tailor-made for the desired application, in order to minimise memory requirements. Moreover, a standard interface allows the access to the individual process tendencies by other submodels, e.g. for on-line diagnostics or for additional parameterisations, which depend on individual process tendencies. An optional closure test assures the correct treatment of tendency accounting in all submodels and thus serves to reduce the model's susceptibility. TENDENCY is independent of the time integration scheme and therefore the concept is applicable to other model systems as well. Test simulations with TENDENCY show an increase of computing time for the EMAC model (in a setup without atmospheric chemistry) of 1.8 ± 1% due to the additional subroutine calls when using TENDENCY. Exemplary results reveal the dissolving mechanisms of the stratospheric tape recorder signal in height over time. The separation of the tendency of the specific humidity into the respective processes (large-scale clouds, convective clouds, large-scale advection, vertical diffusion and methane oxidation) show that the upward propagating water vapour signal dissolves mainly because of the chemical and the advective contribution. The TENDENCY submodel is part of version 2.42 or later of MESSy.

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How to cite: Eichinger, R. and Jöckel, P.: The generic MESSy submodel TENDENCY (v1.0) for process-based analyses in Earth system models, Geosci. Model Dev., 7, 1573-1582, https://doi.org/10.5194/gmd-7-1573-2014, 2014.