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# Numerical issues associated with compensating and competing processes in climate models: an example from ECHAM-HAM

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Abstract. The purpose of this paper is to draw attention to the need for appropriate numerical techniques to represent process interactions in climate models. In two versions of the ECHAM-HAM model, different time integration methods are used to solve the sulfuric acid ($H_2SO_4$) gas evolution equation, which lead to substantially different results in the $H_2SO_4$ gas concentration and the aerosol nucleation rate. Using convergence tests and sensitivity simulations performed with various time stepping schemes, it is confirmed that numerical errors in the second model version are significantly smaller than those in version one. The use of sequential operator splitting in combination with a long time step is identified as the main reason for the large systematic biases in the old model. The remaining errors of nucleation rate in version two, related to the competition between condensation and nucleation, have a clear impact on the simulated concentration of cloud condensation nuclei (CCN) in the lower troposphere. These errors can be significantly reduced by employing solvers that handle production, condensation and nucleation at the same time. Lessons learned in this work underline the need for more caution when treating multi-timescale problems involving compensating and competing processes, a common occurrence in current climate models.

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