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Unique solvability of a system of ordinary differential equations modeling a warm cloud parcel and avoiding saturation adjustment

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The representation of cloud processes in weather and climate models is crucial for their feedback on atmospheric flows. Since there is no general macroscopic theory of clouds, the parameterization of clouds in corresponding simulation software depends fundamentally on the underlying modeling assumptions. We present a new model of intermediate complexity (a one-and-a-half moment scheme) for warm clouds, which is derived from physical principles. Our model consists of a system of differential-algebraic equations which allows for supersaturation and thus avoids the commonly used but somewhat outdated concept of so called 'saturation adjustment'. This is made possible by a non-Lipschitz right-hand side, which allows for nontrivial solutions. In a recent effort we have proved under mild assumptions on the external forcing that this system of equations has a unique physically consistent solution, i.e., a solution with a nonzero droplet population in the supersaturated regime. For the numerical solution of this system we have developed a semi-implicit integration scheme, with efficient solvers for the implicit parts. The model conserves air and water (if one accounts for the precipitation), and it comes with eight parameters that cannot be measured since they describe simplified processes, so they need to be fitted to the data. For further studies we implemented our cloud micro physics model into ICON, the weather forecast model operated by the German forecast center DWD.