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Multiscale asymptotics and analysis of moist atmospheric flows

Abstract:

Model reductions in meteorology by scale analysis are inevitable and therefore have a long history. The key technique for a systematic study of complex processes involving the interaction of phenomena on different length and time scales is multiple scales asymptotics. Due to their major contribution to the energy transport of particular interest are hot towers, which are large cumulonimbus clouds that live on small horizontal scales. In comparison to existing studies we in joint work with R. Klein not only incorporate moisture into the model via balance equations for water vapor, cloud water and rain, but also refine the thermodynamics by taking into account the different gas constants and heat capacities for water in contrast to dry air. This refined setting is demonstrated to be essential by leading to different force balances. These deep convective clouds furthermore constitute the building blocks of larger scale convective storms. Incorporating the setting of organised convection into the multiscale approach requires the introduction of systematic averaging procedures, allowing in particular to quantify the modulation of the larger scale flow by the moisture processes in the cloud regions. While the just described multiscale asymptotics are purely formal, also results from joint work with R. Klein, J. Li and E. Titi on the rigorous analysis of the atmospheric flow models with moisture and phase transitions are presented. The global existence and uniqueness of solutions for the moisture model building the basis for the above expansions will be demonstrated, where at first the flow field is assumed to be given. The moisture dynamics are then further coupled to the primitive equations, which result from the full viscous compressible governing equations by making only one simplification, namely the assumption of hydrostatic balance. These primitive equations have been demonstrated to serve in general as a good approximation for the flow field and thus build the basis for weather forecast and climate models. A rigorous analysis for this set of equations is therefore of particular interest not only from a mathematical point of view.