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Towards multiscale simulation of moist global flows with soundproof equations

Wojciech W. Grabowski (1), Marcin J. Kurowski (2), and Piotr K. Smolarkiewicz (3)

(1) NCAR, Boulder, Colorado, USA (grabow@ucar.edu), (2) On leave from Institute of Meteorology and Water Management, Warsaw, Poland (kurowski@ucar.edu), (3) NCAR, Boulder, Colorado, USA (smolar@ucar.edu)

This presentation will discuss incorporation of phase changes of the water substance that accompany moist atmospheric flows into the all-scale atmospheric model based on soundproof equations. Specific issue concerns developing a theoretical basis and practical implementation to include pressure perturbations associated with atmospheric circulations, from small-scale to global, into representations of moist thermodynamics. In small-scale modeling using soundproof equations, pressure perturbations are obtained from the elliptic pressure solver and are typically excluded from the moist thermodynamics. For some small-scale or mesoscale extreme weather events such as a tornado or a hurricane, pressure perturbations are significant and neglecting them in the moist thermodynamics is no longer justifiable. We show through the theoretical analysis that, in larger-scale flows, at least the hydrostatic component of the pressure perturbation needs to be included because pressure variation in synoptic weather systems may affect moist thermodynamics in a way comparable to the temperature variations. As an illustration, we compare numerical solutions to the problem of moist thermal rising in a stratified environment obtained with a fully-compressible acoustic-mode-resolving model and with two versions of the anelastic model, either including or excluding small-scale pressure perturbations in moist thermodynamics. A range of initial temperature perturbations is considered. Model results show that small differences between anelastic and compressible solutions exist only for the largest initial temperature perturbation of 50$\sim$K. This paves the way to include pressure perturbations from the elliptic pressure solver in the larger-scale moist problems that will be considered in the future.