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Consistent Modelling of Non-Equilibrium Thermodynamic Processes in the Atmosphere

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Approximations in the moist thermodynamics of atmospheric/weather models are often inconsistent. Different parts of numerical models may handle the thermodynamics in different ways, or the approximations may disagree with the laws of thermodynamics. In order to address these problems, we may derive all relevant thermodynamic quantities from a defined thermodynamic potential; approximations are then instead made to the potential itself — this guarantees self-consistency. This concept is viable for vapor and liquid water mixtures in a moist atmospheric system using the Gibbs function but on extension to include the ice phase an ambiguity presents itself at the triple-point. In order to resolve this the energy function must be utilised instead; constrained maximisation methods can then be used on the entropy in order to solve the system equilibrium state. Once this is done however, a further extension is necessary for atmospheric systems. In the Earth's atmosphere many important non-equilibrium processes take place; for example, freezing of super-cooled water, evaporation, and precipitation. To fully capture these processes the equilibrium method must be reformulated to involve finite rates of approach towards equilibrium. This may be done using various principles of non-equilibrium thermodynamics, principally Onsager reciprocal relations. A numerical scheme may then be implemented which models competing finite processes in a moist thermodynamic system.