The mean air flow as Lagrangian dynamics approximation and the thermodynamic analysis of convective systems

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A new technique, the Mean Air Flow As Lagrangian Dynamics Approximation (MAFALDA), is introduced here to analyze the thermodynamics transformations associated with convective systems. This approach rely first on defining an isentropic stream function by sorting the vertical mass transport in terms of different value of the equivalent potential temperature. This makes it possible to separate the gravity waves from irreversible convective motions while ensuring that the recovered mass transport is indeed associated with the total convective energy transport. The isentropic streamfunction analysis is then used to identify a set of mean air trajectories. The value of the different thermodynamic state variables along these trajectories can be determined, which makes is possible to analyze thermodynamic transformations undergone by air parcels.

This technique is then applied to analyze radiative-convective equilibrium simulations with the System for Atmospheric Modeling (SAM). It is found that a large portion of the convection is limited to relative shallow overturning, with very low mechanical efficiency, while more infrequent and deeper convective motions produce the bulk of the mechanical work. For all cases, the mechanical work is significantly less than that produced by a comparable Carnot cycle. This reduction of the mechanical output of convection can be directly tied to the thermodynamic impacts of moist processes, as captured in an idealized thermodynamic steam cycle.