Accurate simulation of the temperature profile in actively convecting regions of the tropics using a convective parameterization

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The mean temperature profile of strongly convecting regions is a fundamental property of the tropics, but continues to be a challenge for convective parameterizations to accurately simulate. The observed temperature profile exhibits three layers of enhanced stability: near 2 km, near the melting level (roughly 5 km), and above 13 km (associated with the tropopause). We use a convective parameterization, implemented in the CAM4 climate model, to show that the melting level stability feature is generated by melting level downdrafts. Below the melting level, the observed variation in lapse rate can be simulated by assuming that the melting and evaporation of ice contribute to the formation of air parcels with negative buoyancy, and which subsequently descend multiple model levels, within a convective timestep. To avoid a cold bias in the lower troposphere, we implemented a leaky pipe model of convective mixing. Rising convective air parcels entrain at a rate as required to sustain particular values of prescribed positive buoyancy. They may also partially detrain into the background atmosphere, depending on the background relative humidity. With this approach, convective air parcels retain a larger positive bias in moist static energy, with respect to the background atmosphere. The detrainment of convective air parcels gives rise to a larger source term in the local moist static energy, and contributes to a warming of the lower troposphere.