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Mean Precipitation Change from a Deepening Troposphere

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Global climate models robustly predict that global mean precipitation should increase at roughly $2-3\%\ \mathrm{K}^{-1}$, but the origin of these values is not well understood. Here we develop a simple theory to help explain these values, in the simplified context of cloud-resolving simulations of the tropical atmosphere. Our theory combines the well-known radiative constraint on precipitation, which says that condensation heating from precipitation is balanced by the net radiative cooling of the atmosphere, with a novel universality of radiative cooling profiles when expressed in temperature coordinates. These two constraints yield a picture in which mean precipitation is controlled primarily by the depth of the atmosphere, when measured in temperature coordinates. This yields quantitative insight into the $2-3\%\ \mathrm{K}^{-1}$ increase in mean precipitation exhibited by our simulations. The relevance of our results to global climate simulations is also assessed.