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A simple derivation of tropical mean precipitation and circulation changes

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Using just a few simple assumptions and a widely used radiative transfer scheme, we try to explain why rainfall increases in a warming climate and predict how the tropical mean circulation changes to accommodate this. We use konrad, a 1D radiative-convective equilibrium model, in which convection is handled simply by specifying the tropospheric lapse rate and enthalpy conservation (similar to Manabe and Wetherald 1967). Considering energy balance at the surface or equivalently in the whole of the atmosphere, evaporation or condensation rates can be calculated (as in Jeevanjee and Romps 2018), giving precipitation increases of 2.0-2.7% per Kelvin increase in surface temperature. The direct radiative effect of carbon dioxide results in a decrease in precipitation, but the warming it induces leads to an overall increase in precipitation at the new equilibrium state of 1.4-2.0%/K. Thus, in agreement with global modelling studies (eg. Flaeschner et al 2016), we expect that the continual increase in atmospheric carbon dioxide in the real world is suppressing the increase in mean precipitation that will occur in the long term. To derive the convective mass flux as well as the downwelling and upwelling velocities and area fractions from our single column model output, we think of the atmosphere as two distinct regions, a saturated moist region of upward motion and a non-saturated region where adiabatic motion balances radiative cooling. The mass flux decreases in a warming climate as the increase in water vapour available for condensation is larger than the increase in condensation rate required to balance radiative cooling. Further, using our simplistic approach we find an increase in upwelling area in a warming climate. This has implications for convective aggregation and how it may change with climate change.