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Diurnal circulation adjustment and organized deep convection

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The diurnal cycle of tropical deep convection over open ocean is investigated to understand interactions between radiation, convection, and circulation in organized systems. Gravity wave phase speeds are invoked to estimate the time scales over which weak temperature gradient (WTG) balance is established. This estimation suggests that circulation adjustment towards WTG balance is achieved rapidly (<6 h) relative to diurnal diabatic forcing on horizontal scales typical of organized convection. Convection-permitting numerical simulations of self-aggregation in diurnal radiative–convective equilibrium (RCE) are conducted to explore this further. These simulations depict a pronounced diurnal cycle of convection and circulation in the organized (aggregated) state, which indeed maintains WTG balance to first order, and is consistent with the observed diurnal pulsing of the Hadley cell driven by the ITCZ. This diurnal cycle is characterized by vigorous nocturnal convection and strong bottom-heavy circulation, owing fundamentally to radiative cooling from cloud top. In daytime, shortwave cloud-top warming suppresses convection, although it additionally invigorates circulation at upper levels. The *direct radiation–convection interaction* (or lapse-rate) mechanism is of leading importance for the diurnal modulation of organized convection, and hence of circulation, although the *dynamic cloudy–clear differential radiation* mechanism amplifies diurnal precipitation amplitude by ∼30% and delays the nocturnal precipitation peak by ∼5 h. The differential radiation mechanism therefore explains the tendency for tropical heavy rainfall to peak in the early morning. In disorganized convection, the latter mechanism is of little importance. A principal conclusion is that the interaction of shortwave radiative heating with deep convection is highly important for both the structure and strength of tropical circulation.