Upper Tropospheric Temperature Impacts on Tropical Cyclone Structure and Intensity

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Potential intensity theory predicts that the tropopause temperature acts as a powerful constraint on tropical cyclone (TC) intensity and structure. The physical mechanisms by which the upper tropospheric thermal structure and radiative forcing impact TC intensity and structure have not been fully explored however, due in part to limited observations and the complex interactions between clouds, radiation, and storm dynamics. Idealized Weather Research and Forecasting (WRF) ensembles were conducted using a combination of three different tropopause temperatures (196, 199, and 202 K) with different radiation schemes (full diurnal radiation, longwave only, and no radiation) on weather timescales. The simulated TC intensity and structure were strongly sensitive to colder tropopause temperatures using only longwave radiation, but were less sensitive using full-radiation and no radiation. Colder tropopause temperatures resulted in deeper convection, increased ice species aloft, and when radiation was included more intense storms on average. Deeper convection led to increased local longwave cooling rates but reduced outgoing longwave radiation at cloud top, such that from a Carnot engine perspective, the radiative heat sink is reduced in the stronger storms. We hypothesize that a balanced response in the secondary circulation described by the Eliassen equation arises from upper troposphere radiative cooling/heating anomalies that leads to stronger tangential winds. The results of this study further suggest that cloud-radiative feedbacks may have a non-negligible impact on weather timescales.

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