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Formation and Quasi-Periodic Behavior of Outer Spiral Rainbands in a Numerically Simulated Tropical Cyclone

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The formation and quasi-periodic behavior of outer spiral rainbands in a tropical cyclone simulated in the cloud-resolving tropical cyclone model version 4 (TCM4) are analyzed. The outer spiral rainbands in the simulation are preferably initiated near the 60-km radius, or roughly about three times the radius of maximum wind (RMW). After initiation, they generally propagate radially outward with a mean speed of ∼5 m s-1. They are reinitiated quasi-periodically with a period between 22 h and 26 h in the simulation. While the inner spiral rainbands, which form within a radius of about three times the RMW, are characterized by the convectively coupled vortex Rossby waves (VRWs), the formation of outer spiral rainbands, namely, rainbands formed outside a radius of about three times the RMW, is much more complicated. It is shown that outer spiral rainbands are triggered by the inner-rainband remnants immediately outside the rapid filamentation zone and inertial instability in the upper troposphere. The preferred radial location of initiation of outer spiral rainbands is understood as a balance between the suppression of deep convection by rapid filamentation and the favorable dynamical and thermodynamic conditions for initiation of deep convection.
The quasi-periodic occurrence of outer spiral rainbands is found to be associated with the boundary layer recovery from the effect of convective downdrafts and the consumption of convective available potential energy (CAPE) by convection in the previous outer spiral rainbands. Specifically, once convection is initiated and organized in the form of outer spiral rainbands, it will produce strong downdrafts and consume CAPE. These effects weaken convection near its initiation location. As the rainband propagates outward further, the boundary layer air near the original location of convection initiation takes about 10 h to recover by extracting energy from the underlying ocean. Convection and thus new outer spiral rainbands will be initiated near a radius of about three times the RMW. This will be followed by a similar outward propagation and the subsequent boundary layer recovery, leading to a quasi-periodic occurrence of outer spiral rainbands. In response to the quasi-periodic appearance of outer spiral rainbands, the storm intensity experiences a similar quasi-periodic oscillation with its intensity or intensification rate starting to decrease after about 4 h of the initiation of an outer spiral rainband. The results provide an alternative explanation or one of the mechanisms that are responsible for the quasi-periodic (quasi-diurnal) variation in the intensity and in the area of outflow-layer cloud canopy of observed tropical cyclones.