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Tornadogenesis within a Supercell Storm near a Meiyu Frontal System in Eastern China: Dynamical Analyses based on a Tornado-Resolving Real-Data Simulation

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A tornado of estimated EF2 intensity occurred in Gaoyou County, Jiangsu Province in eastern China in the afternoon of 7 July 2013, within a supercell storm near a Meiyu frontal system, producing destructive winds at the ground for about 20 minutes, injuring 50 people and damaging over a thousand houses. Data from a nearby operational S-band Doppler radar are assimilated using a 4D ensemble Kalman filter at 5 minute intervals into the Advanced Regional Prediction System (ARPS) at 1 km horizontal grid spacing. Forecasts are run with a nested 50-m grid, capturing the tornado embedded within the supercell storm with reasonable agreement with observations.

The tornadogenesis processes within the simulation are analyzed in detail. Backward trajectories are calculated based on model output at 2 second intervals, and equations for streamwise, crosswise and vertical vorticity components are integrated along the trajectories and contributions from source/sink and conversion terms in the questions are quantitatively calculated. Origins of the parcels feeding the intensifying tornado vortex are identified, and vertical profiles of the mass and vorticity fluxes into the core of tornado vortex are examined. Furthermore, circulations along circuits enclosing the tornado vortex at different levels are integrated backward in time, and contributions of baroclinic and surface frictional generation to the circulation are evaluated. The calculated trajectories show that a cold surge within the rear flank downdraft region plays a key role in instigating tornadogenesis when the leading edge of the cold surge approaches a low-level convergence center located underneath the main updraft, while the tilting of cross-wise horizontal vorticity that has been primarily generated by surface friction is the main source of tornadic vorticity near ground at the genesis stage. The circulation analyses show that surface drag acting on the nearly horizontal portion of the circuit that is close to the ground is the primary contributor to the final circulation converging into the tornado vortex, while baroclinic generation of circulation associated with the vertical portion of the circuit has opposite signs in the ascending and descending branches of the circuit, resulting in small net circulation generation from baroclinicity. These results provide further evidences on the key importance of surface-friction-generated vorticity/circulation in tornadogenesis, a theory advanced by the lead author's research group in recent years, and in this case, for a realistically simulated tornado in a different part of the world.