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Structural and Environmental Characteristics of Extratropical Cyclones that Cause Tornado Outbreaks in the Warm Sector

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The differences in structural and environmental characteristics of extratropical cyclones (hereafter, ECs) that cause tornado outbreaks and those that do not were examined through composite analyses of the newly-released Japanese reanalysis data (JRA-55) and idealized numerical experiments. ECs that developed in the United States in April and May between 1995 and 2012 are categorized into two groups: ECs accompanied by 15 or more tornadoes (hereafter, outbreak cyclones (OCs)) and ECs accompanied by 5 or less tornadoes (non-outbreak cyclones (NOCs)). 55 OCs and 41 NOCs that are of similar strength as OCs are selected in this study.
The composite analyses show significant differences in convective environmental parameters between OCs and NOCs. For OCs, convective available potential energy (CAPE) and storm relative environmental helicity (SREH) are larger and the areas in which these parameters have significant values are wider in the warm sector. The larger CAPE in OCs is due to larger amount of low-level water vapor, while the larger SREH in OCs due to stronger southerly wind at low levels. A piecewise potential vorticity (PV) diagnostics (Davis and Emanuel, 1991) indicates that low- to mid-level PV anomalies mainly contribute to the difference in the low-level winds between OCs and NOCs. On the other hand, the low-level winds associated with upper-level PV anomalies are not the major contributor to the difference.
The results of the idealized numerical experiments for OCs and NOCs (hereafter, referred to as OC-CTL and NOC-CTL, respectively) using WRF ver. 3.4 show that the characteristics of the low-level wind fields and SREH distributions for the simulated ECs in OC-CTL and NOC-CTL are similar to those for OCs and NOCs, respectively. In OC-CTL, SREH and low-level winds in the east-southeast region of the EC center is larger than those in NOC-CTL, respectively. It is suggested that these differences are due to the structures of jetstream. The structure of jetstream in OC-CTL has larger anticyclonic horizontal shear in the southern side of the jet axis than that in NOC-CTL. Larger horizontal anticyclonic shear of the jetstream in OC-CTL causes more meridionally-elongated structure of the EC, resulting stronger low-level winds and larger SREH in the southeast region of the cyclone center.