Environmental fields associated with tornadoes relative to their genesis points

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In order to improve understanding of environmental factors associated with tornado occurrence and maintenance in Japan, a statistical analysis of tornado-favorable environments characterized by key thermodynamical and dynamical indices is conducted. Previous studies have examined large-scale environments favorable to tornadoes in association with typhoons (Sueki and Niino 2016) or extratropical cyclones (Tochimoto et al. 2019). However, statistical analyses of environmental indices explicitly referenced to the time and location of tornadogenesis have been limited. This study addresses this gap by applying composite analysis centered on tornado genesis points.

The environmental indices considered in this study include Convective Available Potential Energy (CAPE) and Storm-Relative Helicity (SReH), which represent thermodynamic instability and dynamical shear-related rotation, respectively. In addition, a recently-developed K-index for torrential rainfall (KT-index), which considers degree of conditional instability and mid-tropospheric moisture, is also examined to assess its applicability to tornado environments.

Using tornado cases in Japan between 1961 and 2023 obtained from the Japan Meteorological Agency (JMA) gusty winds database, we perform composite analyses of CAPE, SReH, KT-index, and related environmental fields with respect to the time and location of tornado genesis. Environmental indices are calculated from ERA5 reanalysis data, which has a horizontal and temporal resolution of 0.25˚and 1 hour, respectively. The results show that SReH and the KT-index exhibit pronounced maxima near the location of the tornado genesis point. Furthermore, by subtracting the climatological mean of all tornado cases from the indices for each event prior to compositing, the maxima in the composite distributions, including CAPE, become more clearly. Although the overall effectiveness of these indices is maintained across different seasons and synoptic conditions, the spatial structures of the composites differ substantially. Lag composite analysis is also performed to examine the temporal evolution of environmental fields. These result show how favorable environments for tornadoes are established and how different the tornado-producing and non-producing environment are.

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