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Spatial–Temporal Clustering of Tornadoes

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The standard measure of the intensity of a tornado is the Enhanced Fujita scale, which is based qualitatively on the damage caused by a tornado. An alternative measure of tornado intensity is the tornado path length, L. Here we examine the spatial–temporal clustering of severe tornadoes, which we define as having path lengths $L \geq 10$ km. Of particular concern are tornado outbreaks, when a large number of severe tornadoes occur in a day in a restricted region. We apply a spatial–temporal clustering analysis developed for earthquakes. We take all pairs of severe tornadoes in observed and modelled outbreaks, and for each pair plot the spatial lag (distance between touchdown points) against the temporal lag (time between touchdown points). We apply our spatial–temporal lag methodology to the intense tornado outbreaks in the central United States on 26 and 27 April 2011, which resulted in over 300 fatalities and produced 109 severe ($L \geq 10$ km) tornadoes. The patterns of spatial–temporal lag correlations that we obtain for the 2 days are strikingly different. On 26 April 2011, there were 45 severe tornadoes and our clustering analysis is dominated by a complex sequence of linear features. We associate the linear patterns with the tornadoes generated in either a single cell thunderstorm or a closely spaced cluster of single cell thunderstorms moving at a near-constant velocity. Our study of a derecho tornado outbreak of six severe tornadoes on 4 April 2011 along with modelled outbreak scenarios confirms this association. On 27 April 2011, there were 64 severe tornadoes and our clustering analysis is predominantly random with virtually no embedded linear patterns. We associate this pattern with a large number of interacting supercell thunderstorms generating tornadoes randomly in space and time. In order to better understand these associations, we also applied our approach to the Great Plains tornado outbreak of 3 May 1999. Careful studies by others have associated individual tornadoes with specified supercell thunderstorms. Our analysis of the 3 May 1999 tornado outbreak directly associated linear features in the largely random spatial–temporal analysis with several supercell thunderstorms, which we then confirmed using model scenarios of synthetic tornado outbreaks. We suggest that it may be possible to develop a semi-automated modelling of tornado touchdowns to match the type of observations made on the 3 May 1999 outbreak.