Tornado Climatology of Turkey

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ABSTRACT

A climatology of tornadoes in Turkey is presented using records from a wide variety of sources (e.g., the Turkish State Meteorological Service, European Severe Weather Database, newspaper archives, Internet searches, etc.). The climatology includes the annual, diurnal, geographical, and intensity distributions of both mesocyclonic and nonmesocyclonic tornadoes. From 1818 to 2013, 385 tornado cases were obtained. The tornadoes range from F0 to F3, with F1 being the most frequently reported or inferred intensity. Mesocyclonic tornadoes are most likely in May and June, and a secondary maximum in frequency is present in October and November. Nonmesocyclonic tornadoes (waterspouts) are most common in the winter along the (southern) Mediterranean coast and in the fall along the Black Sea (northern) coast. Tornadoes (both mesocyclonic and nonmesocyclonic) are most likely in the afternoon and early evening hours.

1. Introduction

This paper presents what is believed to be the most comprehensive climatology of tornadoes in Turkey to date. [The only other known compilation is available on the Turkish Meteorological Services Web page (in Turkish) at http://www.dmi.gov.tr/FILES/arastirma/afetler/hortum.pdf. It consists of 31 tornadoes recorded between 1940 and 2010.] The climatology spans the years 1818–2013. Tornado climatologies recently have been published for several European countries, including Ireland, the United Kingdom, Lithuania, former Soviet Union, France, Germany, Austria, the Czech Republic, Hungary, Greece, Spain, Portugal, Italy, and the Balaeric Islands [see Rauhala et al. (2012) and the references therein for a comprehensive summary]. The lack of formal documentation of Turkish tornadoes is perhaps in part because they are regarded as extremely rare and exceptional weather events.

Tornadoes have been blamed for at least 31 fatalities and 204 injuries in Turkey. The killer tornadoes in Ankara in 2004, Ağrı in 2005, Balıkesir in 2011, Elazığ and Antalya in 2012, and Mardin and Mersin in 2013 are notable recent examples. Other major tornadoes in Turkey include the 1997 Kayseri tornado, which uprooted thousands of large trees; the 1988 Çorum tornado, which lifted a car a significant distance and killed two; and the killer tornadoes in Istanbul and Konya in 1914 and 1959, respectively. Though events such as these deservedly attract considerable public attention in their aftermath, the events tend to be quickly forgotten. There remains an overall lack of awareness of tornadoes, for example, media reports of "the first tornado in Turkey" abound. The purpose of this article is to document the geographical, annual, and diurnal distributions of tornadoes in Turkey. It is believed that tornado forecasting in Turkey would benefit from a better understanding and increased appreciation of the local tornado climatology.

The data collection process and methods used to construct the tornado climatology for Turkey are described in section 2. The results and summary are presented in sections 3 and 4, respectively.

2. Data and methods

Following Rauhala et al. (2012), the concept of tornado *case* is used, where a case potentially can include

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more than one tornado if the tornadoes occur in close proximity to each other. Rauhala et al.'s (2012) approach was adopted because the exact number, location, or timing of each individual tornado is not known in some cases. This is a particularly common issue for offshore waterspout cases, which can sometimes include a dozen or more tornadoes (these occurrences would dominate the database if they were counted as individual cases). On the other hand, for a regional outbreak of tornadoes occurring on a single day, multiple tornado cases may be tallied. In other words, separate tornado cases are identified if it can be determined that tornadoes were associated with different storms or the starting points of successive tornadoes can be resolved from the available reports.

Building a tornado climatology for Turkey proved to be a challenging task, as there is no official database of tornadoes such as *Storm Data* in the United States. It is likely that the climatology suffers from potentially significant underreporting given the low population density in many parts of Turkey (especially eastern Turkey), the absence (until very recently) of an operational radar network, and a lack of storm spotting (let alone chasing) activities.

One major source of data was the Turkish State Meteorological Service (TSMS), which operates meteorological stations in Turkey. The stations report exceptional weather events in addition to routine observations, which are archived separately. A total of 59 tornado cases were found by manually searching this archive from 1939 to 2012. The European Severe Weather Database (ESWD; Brooks and Dotzek 2008; Dotzek et al. 2009) was also a major contributor to the tornado records used in the development of the tornado climatology for Turkey; 118 cases were obtained from the database.

Another major source of records was historical newspaper archives. In Turkey, two mainstream newspapers, *Milliyet* and *Cumhuriyet*, maintain digitized archives. The *Milliyet* archive is accessible via a free membership and contains newspapers from 3 May 1950 to 30 June 2004. The archive was searched for the Turkish word *hortum* (which is literally translated as *hose*), and typographically similar words such as *hontum* and *horturn*, in order to reach possible lost records especially with older fonts owing to some of the deficiencies of digitalizing technology. This search resulted in 46 tornado cases. The *Cumhuriyet* archive, which requires purchasing a membership for access, contains newspapers from 1 January 1930 to almost the present date. A search of that archive identified 33 additional tornado cases. The online archives of two additional media sources, *Hurriyet* and the *Cihan News Agency*, which each span roughly the last decade, resulted in 13 more cases. Another 149 cases were found via the Google and Yahoo! search engines, mostly through additional news websites, video-sharing websites, and social networks. Newspaper and Internet records had to be scrutinized to ensure their reliability, and some records lacked essential information. In other cases, the information from these sources was further investigated, sometimes via interviews with locals who experienced the event. For example, some news stories were accompanied by photos that were not necessarily obtained from the event being reported. In other cases, damage was exaggerated, or what was clearly nontornadic straight-line wind damage was reported as resulting from a tornado. Moreover, words like *kasırga* (a word occasionally used for hurricanes and gale-force winds in Turkish, and sometimes for tornadoes as well), *fırtına* (refers to a storm or severe wind), or *siklon* (which means *cyclone*) have also been used in reports documenting some tornado events, which further complicated the compilation of historical tornado records.

Additional tornado reports were obtained from Gilbert (1823) and the Ottoman Archives. The two oldest tornado records for Turkey originate from these sources. A tornado in Çeşme in early December 1818 is described in Gilbert's work, and is also documented in Wegener's (1917) landmark publication on European tornadoes. A tornado that killed two people in Istanbul on 19 June 1914 is documented in the Ottoman Archives. This tornado is also discussed by Kocaturk (2012).

Cases were classified as "verified," "very likely," and "possible," depending on the credibility of the report and weight of the evidence. Of the 421 tornado cases, 77 cases (18%) were classified as verified, 308 cases (73%) were classified as very likely, and 36 cases (9%) were classified as possible. Existence of reliable video and/or photos of tornado cases, with credible timestamps and locations given, garnered a verified classification. The very likely classification was applied to cases for which photos or videos of the tornado *damage*, or a credible eyewitness report, were available. The possible category was used for cases in which considerable uncertainty existed regarding the veracity of the report(s); these cases were not included in the climatology.

When possible, tornado cases were classified as "likely mesocyclonic" and "likely nonmesocyclonic," depending on clues in radar imagery (available only in rare cases, even after the installation of operational radars, given the gaps in coverage that remain), satellite imagery, ancillary severe weather reports (e.g., very

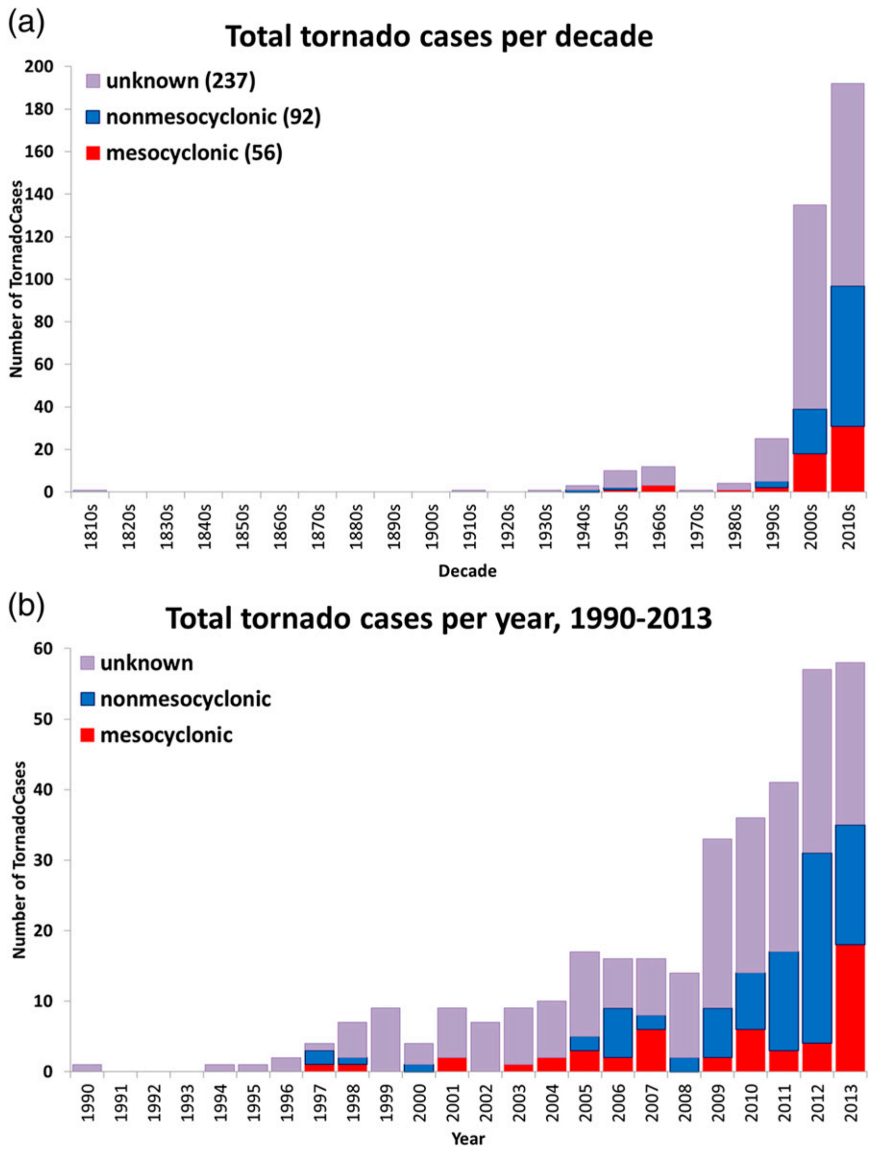

FIG. 1. Total tornado cases (a) per decade and (b) per year during 1990–2013.

large hail observed near the tornado would suggest a mesocyclonic tornado), or photographic/video evidence of the tornado, if it existed.

3. Results

The climatology of Turkish tornadoes consists of 385 verified and very likely cases from 1818 to 2013 (Fig. 1). More than half of the cases (225) are from the last 5 years. The recent upward trend in tornado cases is presumed to reflect technological advances in communications (e.g., Internet and smart phones), a growing awareness of tornado occurrences in Turkey, and the efforts of the lead author in documenting Turkish tornadoes,[1] rather than an abrupt change in the regional climate. The distribution of the cases throughout the years is greatly affected by the inhomogeneous sources and low probability of accessing old records, whether they exist or not (there is an overall lack of old records, likely because of a limited historical appreciation that tornadoes occur in Turkey).

The distribution of tornado damage intensity peaks at F1, though the distribution should be viewed with caution

[1] Approximately one-third of the ESWD reports of tornadoes from Turkey were submitted by the lead author.

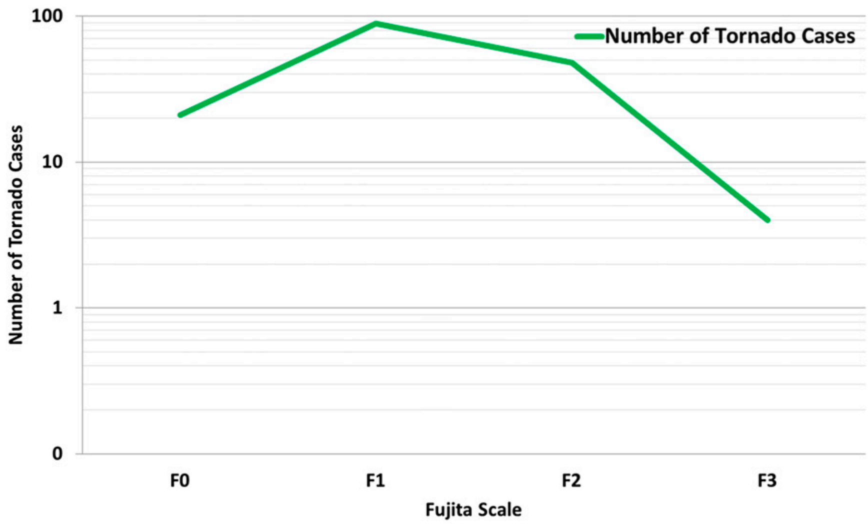

FIG. 2. Intensity distribution of tornado cases in Turkey.

because intensities are unavailable for 223 tornado cases (Fig. 2). The most extreme tornado damage observed in Turkey is F3 (four cases). As in all assessments of tornado damage, the usual caveats apply concerning the relationship between wind speed and damage (Fujita 1971; Doswell et al. 2009; Feuerstein et al. 2011; Edwards et al. 2013). Moreover, as in the sparsely populated Great Plains region of the United States, the intensity of many tornadoes occurring in low-population-density regions of Turkey is likely underestimated.

The longest-lived tornado is reported to have persisted for 30 min. The longest-confirmed path is 20 km; however, a 60-km path in one case is possible, which is presently reported as two different tornadoes. Information about path widths is difficult to obtain, given that damage widths are usually not reported. Of the cases for which path widths are known (25 cases), the widest tornado had a diameter of 400 m.

There are 56 cases identified as likely mesocyclonic and 92 cases categorized as likely nonmesocyclonic. Taking only last 5 years into account (considering these data to be the most representative), the annual average number of tornado cases in Turkey is 45, of which 7 are likely mesocyclonic. This equates to 0.57 tornado cases per 10 000 square kilometers per year, which is comparable[2] to the tornado densities that have been estimated in prior European tornado climatologies (e.g., Holzer 2001; Sioutas 2011). However, the spatial distribution of reported tornadoes in Turkey is extremely heterogeneous, such that a much higher tornado density is found along the coast, and a significantly a smaller tornado density exists in the interior, where low-population densities may have contributed to underreporting (Fig. 3).

The tornadoes along the Mediterranean (MED; southern) and Aegean (EGE; western) coasts (MED+EGE; Fig. 3) dominate the tornado climatology (207 of the 385 cases). Tornado cases are most numerous along the southern coast between Antalya and Anamur. Along this ~210-km segment of the coastline, roughly a dozen tornado cases per year have occurred on average in the past 5 years, implying a tornado density of approximately 19 tornado cases per 10 000 square kilometers (within a 30-km-wide corridor along this segment of the coastline). Comparisons to previously published tornado climatologies for European countries (e.g., Dotzek 2001; Holzer 2001; Gayà et al. 2001; Tyrrell 2003; Marcinoniene 2003; Sioutas et al. 2006; Bissolli et al. 2007; Szilárd 2007; Sioutas and Keul 2007; Giaiotti et al. 2007; Sioutas 2011; Gayà 2011), as well as plots of tornadoes that are recorded in the ESWD (http://eswd.eu), suggest that this stretch of Turkish coastline is among the most tornado-prone regions of Europe, though many of these vortices remain offshore as waterspouts. The EGE has nearly the same climate as the MED, but with a considerably lower tornado frequency.

Within both the southern and western coastal regions (MED+EGE), tornadoes are predominantly nonmesocyclonic, weak (F0–F1), and are most frequently observed in the winter months, having a peak in December and January (Fig. 4a). Although a significant fraction of the ''unknown'' tornadoes are likely waterspouts not associated with mesocyclones, supercellular

[2] The comparison to other studies is not a direct comparison given that tornado cases (this study) are being compared to tornadoes (other studies).

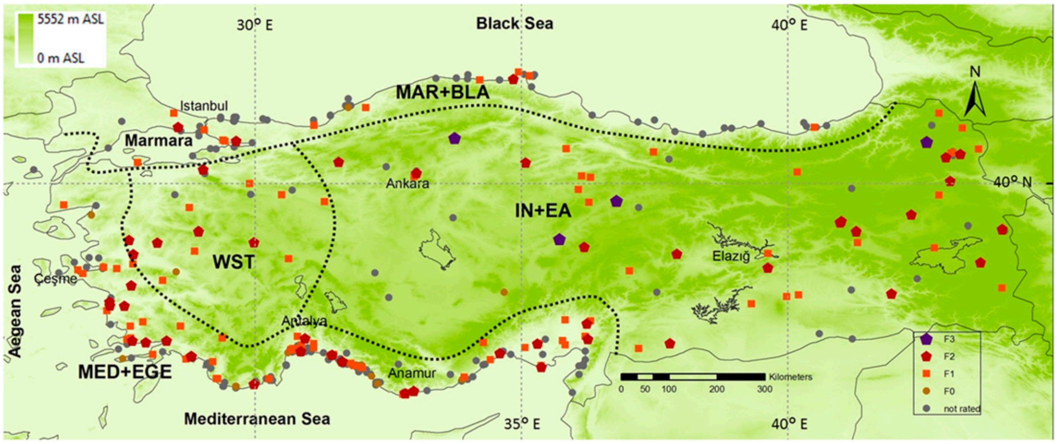

FIG. 3. Geographical distribution of tornado cases over Turkey. "MAR+BLA" and "MED+EGE" refer to the coastal regions around the Marmara and Black Seas and Mediterranean and Aegean Seas, respectively. The central and eastern inlands of the Anatolian Peninsula are labeled as "IN+EA," and the western inlands are labeled as "WST."

convection also occasionally occurs in this region in winter. Therefore, it is likely that at least some of the unknown cases are tornadoes associated with mesocyclones. The summer months are the least favorable time of the year in this region, likely owing to the region being under the influence of subsidence associated with the Azores anticyclone.

A third coastal region comprises the Black Sea coast in the north (BLA) and the Marmara coastal region in the northwest (MAR; Fig. 3). Waterspouts during summer and autumn dominate the dataset here, though three mesocyclonic tornadoes have also been observed (Fig. 4c). In winter, the frequency gradually decreases, and practically vanishes in April and May.

Tornado cases are less common in the interior of Turkey [westernmost inlands (WST) and central and eastern inlands (IN+EA)] than along the coastlines (MED+EGE and MAR+BLA; Fig. 3), especially the southern and western coastlines (Figs. 4b,d). Most tornadoes in the inlands are believed to be associated with

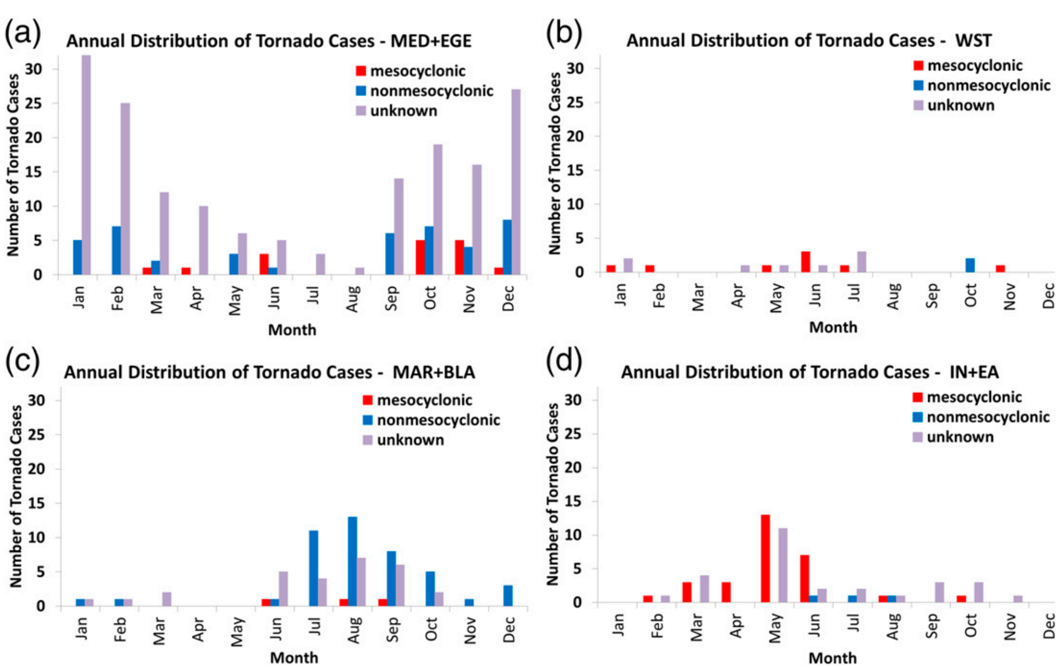

FIG. 4. As in Fig. 3, but for the number of tornado cases for each month and region.

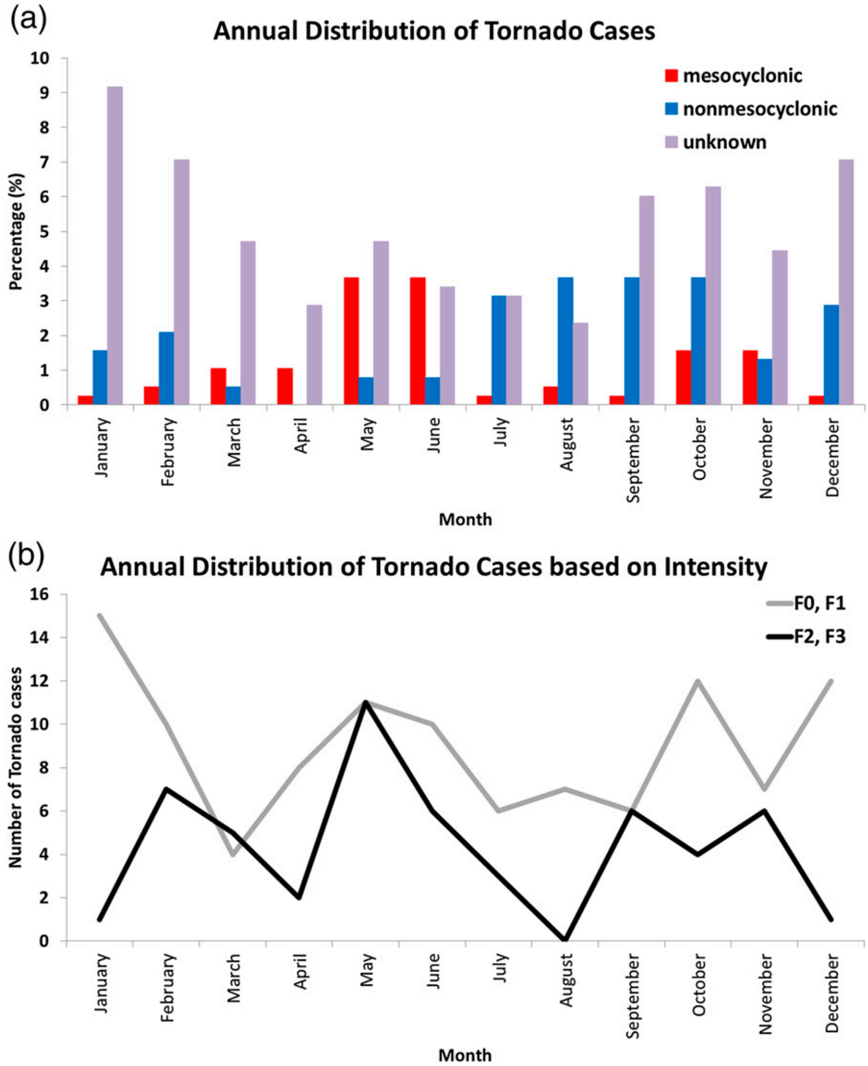

FIG. 5. Annual distribution of tornado cases in Turkey.

the mesocyclones of supercells. Turkey's most intense and deadly tornadoes have occurred in the IN+EA (Fig. 3), with all four F3 tornadoes occurring here. It seems likely that the tornado frequency is underestimated here owing to the general low-population density of this region. It is also possible that tornadoes have been able to inflict greater damage in this region owing to substandard construction of dwellings. A distinct maximum in tornado cases in the IN+EA occurs in May, followed by June (Fig. 4d), and no tornado observations exist for December and January. In the WST (Fig. 3), the peak months are June and July.

May and June are the peak months for mesocyclonic tornadoes, with a secondary peak in October and November (Fig. 5a). The secondary maximum for mesocyclonic tornadoes in October and November can be attributed to the return of extratropical cyclone passages (which are largely absent in the summer months) and the severe weather ingredients they tend to bring together (e.g., strong vertical shear and significant convective available potential energy). Nonmesocyclonic tornado frequency (which mainly reflects the occurrences of waterspouts on the Mediterranean, Aegean, and Black Sea coastlines) is a maximum from July to October and a minimum from March to June (Fig. 5a). For the relatively small sample of strong tornadoes (F2+), such tornadoes are most likely to occur in May, though there is a secondary maximum in February (most of these occur along the southern coast) and during September–November (Fig. 5b). Tornadoes are most likely in Turkey in the afternoon [local standard (daylight saving) time is 2 (3) h ahead of UTC]. Mesocyclonic and strong tornadoes

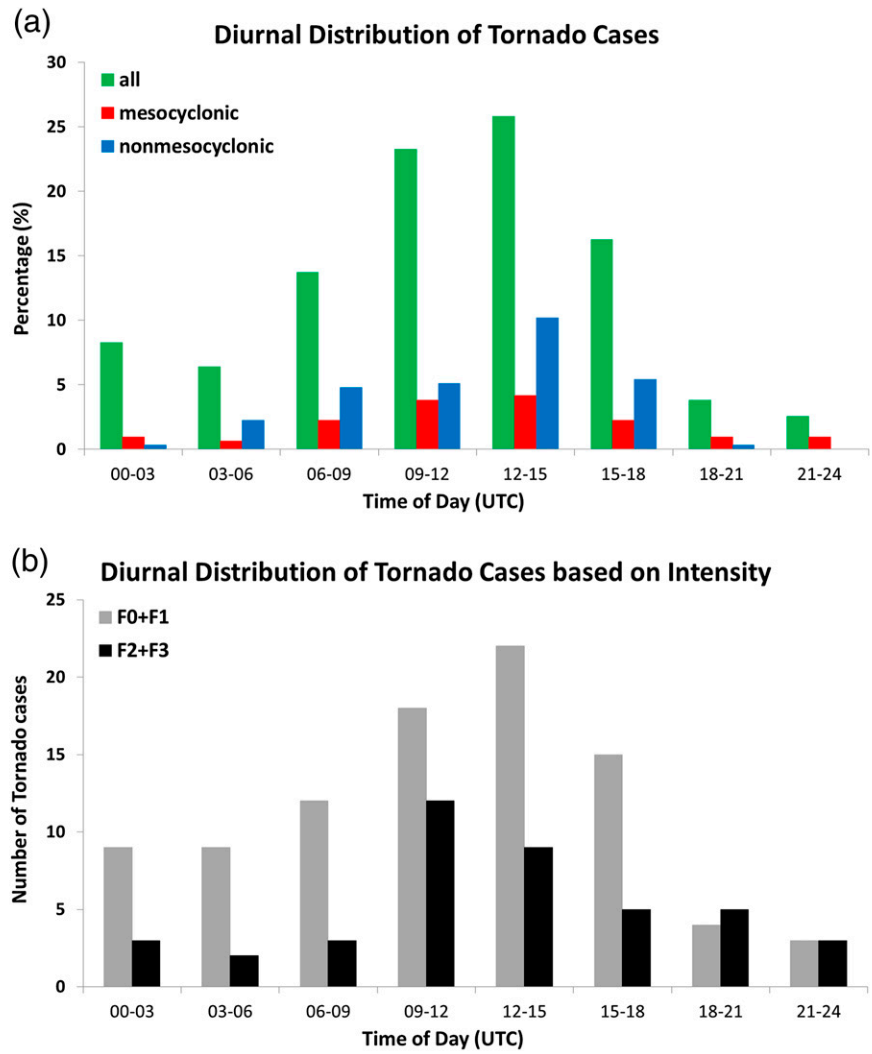

FIG. 6. Diurnal distribution of tornado cases in Turkey.

are most likely between 0900 and 1500 UTC (1200–1800 local time, except in winter; Figs. 6a,b).

4. Summary

This article is believed to be the most comprehensive climatology of tornadoes in Turkey to date. Tornado reports in Turkey historically have been sporadic and difficult to obtain, but reporting has improved in recent years for a number of reasons.

Nonmesocyclonic tornadoes (waterspouts) are relatively common in the fall and winter along the Turkish coastlines, especially the southern and western coastlines of the Mediterranean and Aegean Seas, respectively. In fact, the southern coastline from Antalya to Anamur is likely among the most tornado-prone regions of Europe. Tornadoes in interior Turkey are less common, or at least reported less often. However, Turkey's strongest (and deadliest, despite a relatively low-population density) tornadoes have occurred here, most often in late spring, and are associated with supercells.

The "next step" in studying tornadoes in Turkey is to investigate the characteristics of the environments of the tornadic storms, as well as the synoptic-scale and mesoscale processes responsible for the development of the environments.

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