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The climatology of tornadoes and waterspouts in Italy

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Abstract

In this work 10 years of reports collected by weather amateurs are used to define a preliminary climatology of tornadoes and waterspouts in Italy. The results show behaviors different from those observed in other countries. Generally, tornadoes and waterspouts are more frequent in late summer and autumn than in the other seasons. The seasonality of tornadoes and waterspouts appears different for different Italian zones, in particular in the Po Valley and Friulian plain and coast (south to the Alps) tornadoes and waterspouts are more frequent in spring and early summer while in the Tirrenian and Ionian coasts (western and southern Italy), tornadoes and waterspouts are more frequent in late summer and autumn. As observed in other studies (Brooks, H., E. and Doswell, C. A. III, 2001. Some aspects of the international climatology of tornadoes by damage classification. Atmos. Res., 56, 191–201.) Italian tornadoes and waterspouts are statistically weaker than in other countries but this difference cannot be completely ascribed to the presence of waterspouts. The "CAPE Storm-Relative-Helicity diagrams" and "Shear Magnitude diagrams" obtained for Italian tornadoes and waterspouts show different characteristics than those obtained for US. The cause of these differences is still unknown, it can rely in the sample selection (problems with the concept of proximity sounding) or in a real climatic effect.

Keywords: Tornado; Climate

1. Introduction

The climate of the Italian peninsula is quite well known in its general features; nevertheless there is a general lack of knowledge concerning tornadoes, apart from a small number of pioneering works (Boscovich, 1749; Palmieri and Pulcini, 1978). In the past most of the work concerning tornadoes and related phenomena was placed into the realm of "amateurs" of meteorology and only recently, thanks to the Internet, the huge amount of information collected by those amateurs is made available. Using this information, the first goal of this work is to define the climatology of tornadoes in Italy, fixing their intensity distribution as well as their time and space distribution. The second goal of this work is to interpret the observed features according to the meteorological and geographical environment that characterize the area. These tasks are faced using the data collected by one of the authors (M. Giovannoni) from 1991 to 1999 using the news that appeared on the mass media as well as reports given to him by other Italian amateurs. Starting from 2000 thanks to the internet, this collection became systematic. Being different, the ways in which the samples have been collected, initially the year 2000 is not merged with the other years, but it is used as a check. In this work, tornadoes and waterspouts are considered as similar

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phenomena. This had been a forced choice because the distinction between the two classes was not present into all the reports collected. Recently, i.e. in the second half of the 1990s, thanks to the development in Italy of several regional meteorological services, the collection of information on tornadoes and waterspouts in some areas (Friuli Venezia Giulia, Veneto, Emilia-Romagna, among others) is taking advantage from a permanent monitoring of the territory and that could assure, even in the future, at least a major control on the correctness of the reports.

A characteristic of the database used in this work is that of "incompleteness," i.e. not all the tornadoes and waterspouts occurred over Italy are present in the database. This can be easily shown by plotting, as done by Tyrrell (2003), the number of reports as a function of the year (Fig. 1). In that figure, it is clear that the sample is surely not complete because the number of reports concerning tornadoes is growing from 1991 up to 1999. This feature is interpreted as a signal of the growing of people's attention and interest on these phenomena. Another characteristic of the database used is that of "incorrectness," i.e. not all the tornado reports are referring to a real tornado event. A source of incorrectness relies into the fact that the Italian expression "tromba d'aria" (namely "air trump") is generally used by mass media for both "tornadoes" and "downbursts." A percentage of wrong tornado reports had been evidenced and corrected into the database during the collecting activity, but surely some mistakes, whose percentage is difficult to quantify, still remain.

The tornado intensity was classified according to the Fujita scale. This choice is due to historical reasons; in fact the TORRO scale was not known at the time in which the collection started. The Fujita intensity was assigned to tornadoes and waterspouts quite soon after the occurrence of almost each event by one of the authors (M. Giovannoni) according to the reported damages. In any case, the evaluation of the intensity passed through the check of this author. For this reason, even if not complete or correct, at least under the point of view of intensity, the database should be considered as homogeneous.

2. Space and time distribution of tornadoes in Italy

The sample 1991–1999 and the sample 2000, even if collected in different ways, both draw a similar picture for the spatial distribution of tornadoes in Italy (Fig. 2a and b). This characteristic was observed even in previous historical analysis (Palmieri and Pulcini, 1978). Tornadoes and waterspouts mainly occur in flat terrains and in coastal areas, that is in the Po Valley, in the Friulian plain and coast, in the Tirrenian coast, in the Tiber Valley and in the Ionian coast. The predilection of tornadoes for flat terrains was, however, already observed even by previous works referring to other parts of the world (among others, Dessens and Snow, 1989, 1993; Dotzek, 2001; Leitão, 2003; Sioutas, 2003; Holzer, 2001; Tyrrell, 2003). Quite surprisingly, the medium Adriatic coast shows a low frequency of tornadoes. This area has quite a high density of inhabitants, generally higher than the Tirrenian coast and, on average, everywhere equal or higher than 50 people/km^2. Moreover, the population density of this area grows in summer because of the tourism. These

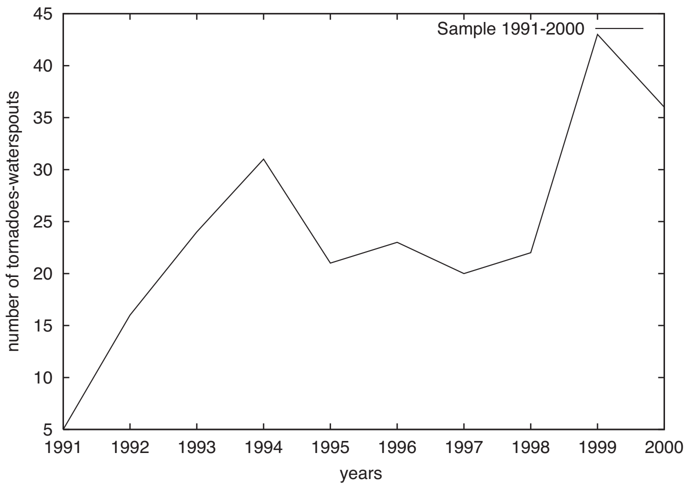

Fig. 1. The number of tornado and waterspout reports in the database as a function of the year. The increasing in the number of reports is interpreted as a growing of interest in these phenomena.

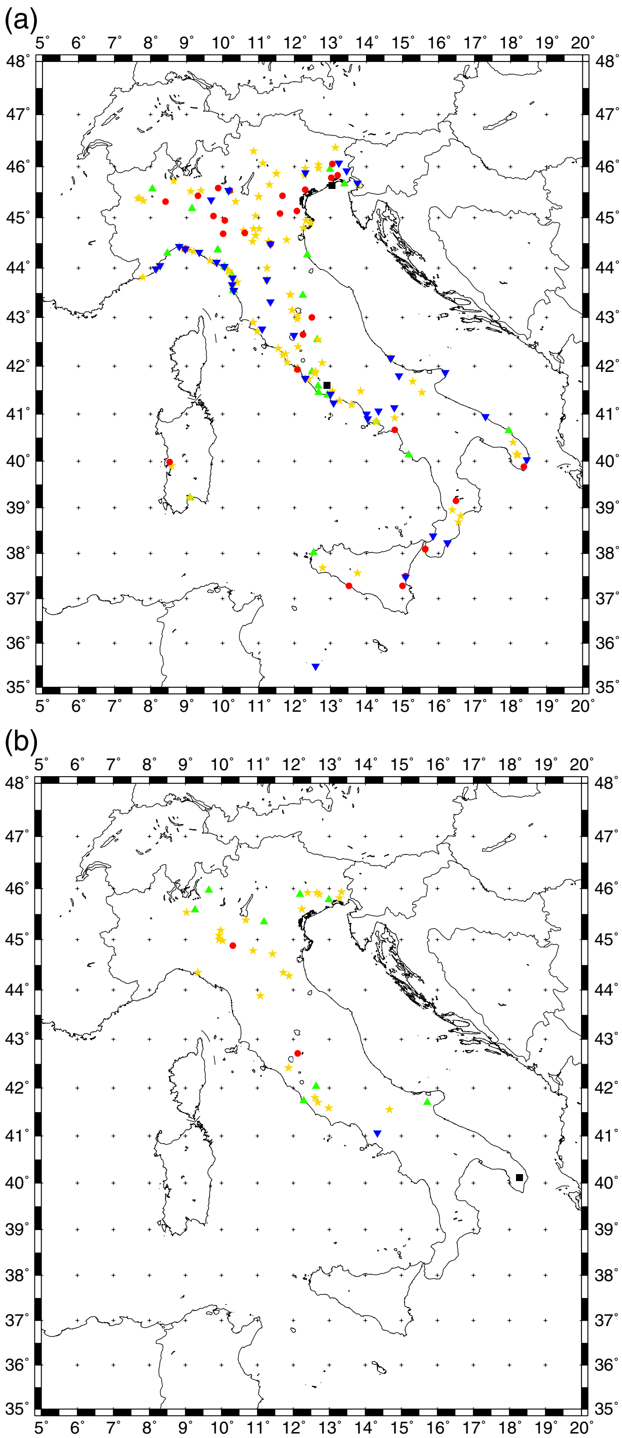

Fig. 2. (a and b) Tornadoes and waterspouts observed in the years 1991–1999 (panel a) and in the year 2000 (panel b). Intensity of events is reported as well and measured according to the Fujita scale. F0 events are represented by triangles, F1 by stars, F2 by filled dots, F3 by filled squares, uncertain intensity events are represented by reversed triangles.

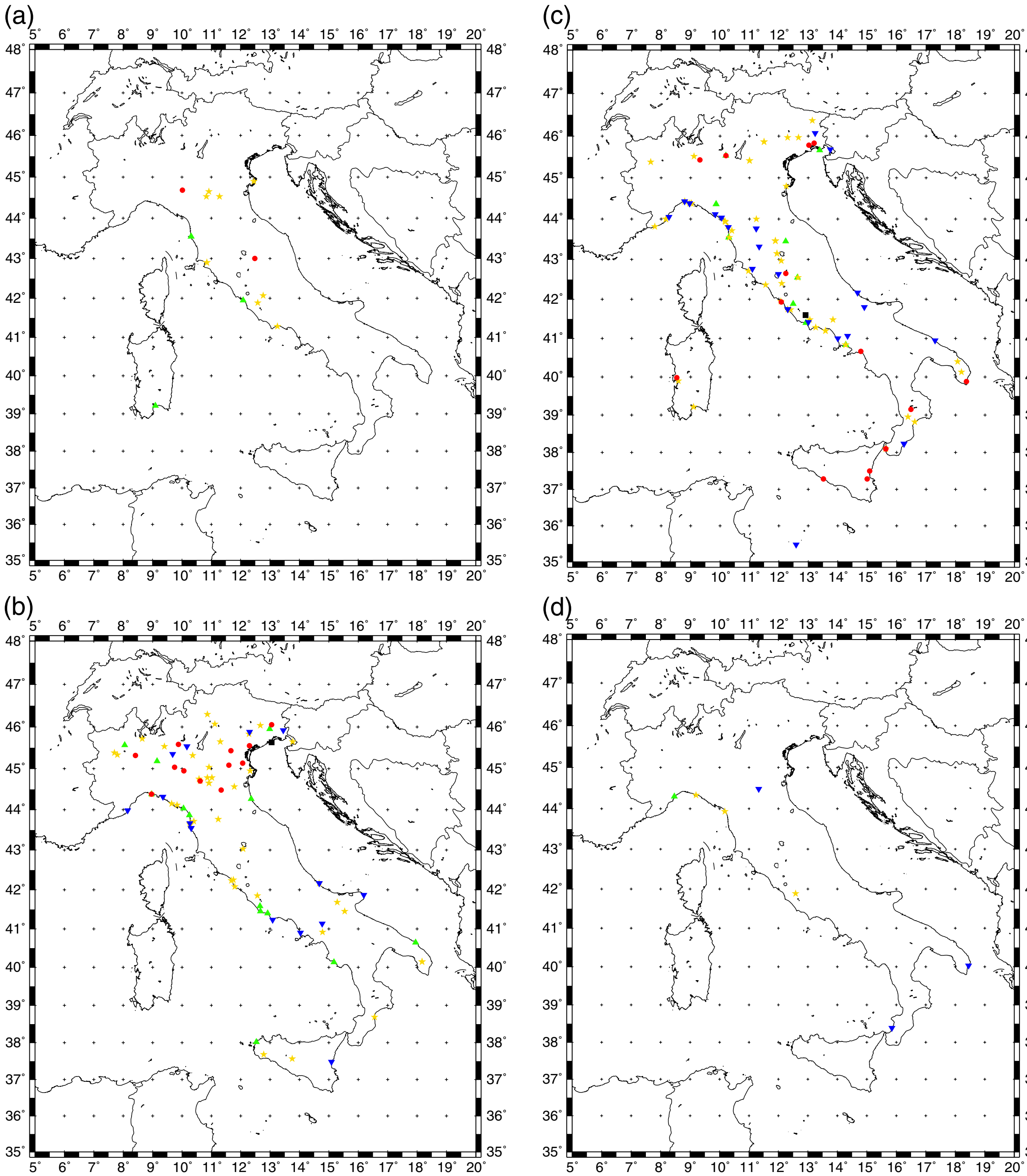

Fig. 3. (a–d) Tornadoes and waterspouts observed in the years from 1991 to 2000 stratified according to the seasons (spring panel a, summer panel b, autumn panel c and winter panel d). Intensity of events is reported as well and measured according to the Fujita scale. F0 events are represented by triangles, F1 by stars, F2 by filled dots, F3 by filled squares, uncertain intensity events are represented by reversed triangles.

Table 1
Percent frequency of tornadoes and waterspouts stratified according to the various seasons and intensity

%	MAM (Spring)	JJA (Summer)	SON (Autumn)	DJF (Winter)
F0	23	21	13	25
F1	62	56	58	75
F2	15	20	27	–
F3	–	3	2	–
Yearly percentage	10	42	45	3

The last row of the table shows the percentage of tornadoes and waterspouts reported in the various seasons.

considerations push the interpretation of the result against the hypothesis of an observational bias due to a lack of the attention or number of observers, and in favor of a real climatic effect. The increase of the sample could presumably solve this doubt.

Tornadoes and waterspouts in the Po Valley and in the Friulian plain and coast are more frequent in spring (Fig. 3a) and summer (Fig. 3b), while in the Tirrenian coast (western coast), in the Tiber Valley and in the Ionian coast, they are more frequent in summer (Fig. 3b) and in autumn (Fig. 3c). Globally, tornadoes and waterspouts are more frequent in autumn than in spring and, even if slightly, higher in autumn than in summer (see Table 1). In general the month in which they are most frequent is August followed by September, October and November (see Fig. 4). This behavior, quite different from what observed in other countries (Brooks and Doswell, 2001; Dotzek, 2001; Tyrrell, 2003; Sioutas, 2003; Dessens and Snow, 1989), can be explained keeping into account the effects of Alps and Mediterranean Sea on the synoptic circulation. Especially in late summer and autumn, synoptic troughs interacting with Alps give origin to cold "cut-offs" over the Mediterranean Sea. These low-pressure areas are then fed by the warm and moist environment they find in the Tirrenian and Ionian sea. This interpretation is supported by the observation that the major contribution to the number of tornadoes in autumn is indeed given by the Tirrenian and Ionian coasts. The main contribution to spring and summer tornadoes and waterspouts in Italy is given by the Po Valley and by the Friulian plain and coast. These observations can be interpreted keeping into account the interactions between cold fronts and orography (Morgan, 1973). Cold fronts approaching the Alps produce leeward of the ridge, in the lower levels, the right shear for the onset of mesocyclones. Future studies will confirm or reject the hypothesis that in the Po Valley and Friulian plain, tornadoes are essentially mesocyclonic. If this behavior will be confirmed, the monthly distribution of tornadoes in Italy could be decomposed as a sum of the "continental distribution" similar to that observed in the European continent (Dessens and Snow, 1993; Dotzek, 2001) that peaked between June and July and of a "maritime distribution" similar to that observed by Sioutas (2003) with a peak between August and September.

3. Tornado intensity and environmental variables

The distribution of tornadoes and waterspouts intensity for the merged sample 1991–1999 and 2000 is obtained using the Fujita–Pearson scale. The distribution obtained is different from those found in other countries (Brooks and Doswell, 2001) in particular because the frequency of strong tornadoes (i.e., stronger

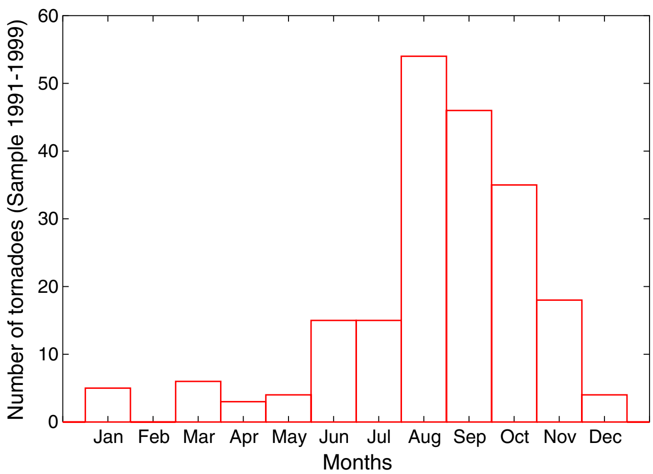

Fig. 4. Number of tornadoes and waterspouts in the years from 1991 to 2000 stratified according to the various months.

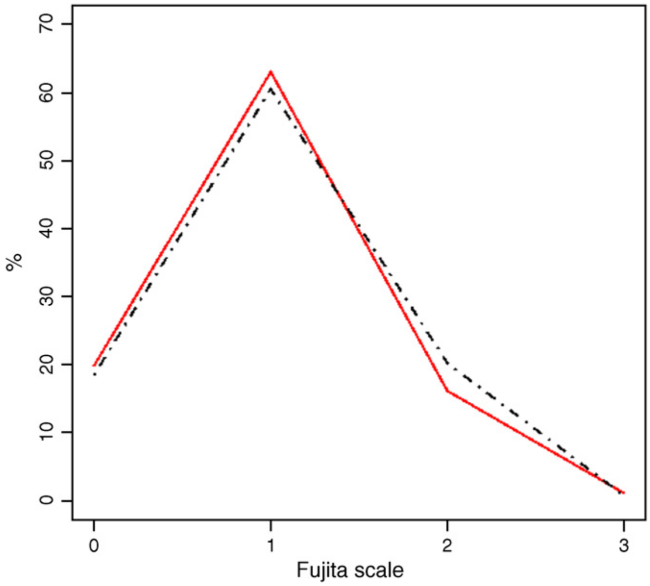

Fig. 5. Percent distribution of tornado and waterspout intensity observed in Italy using the database from 1991 to 2000. Intensity is reported according to the Fujita scale. The solid line reports the distribution obtained for the whole sample. Dotted line shows the distribution obtained without the Tirrenian and Ionian events.

or equal than F3) in Italy is lower (Fig. 5, solid line). To test if this result is mainly due to the contribution of waterspouts, an intensity distribution is computed without the Tirrenian and Ionian reports. Even without these reports, the observed distribution shows a lower frequency of strong tornadoes (Fig. 5, dotted line). If these results will be confirmed with an enlarged sample, Italian tornadoes and waterspouts shall be considered as statistically weaker than those observed in other countries (e.g. in USA).

According to the observation that tornadoes develop in unstable and sheared environments, the diagram in

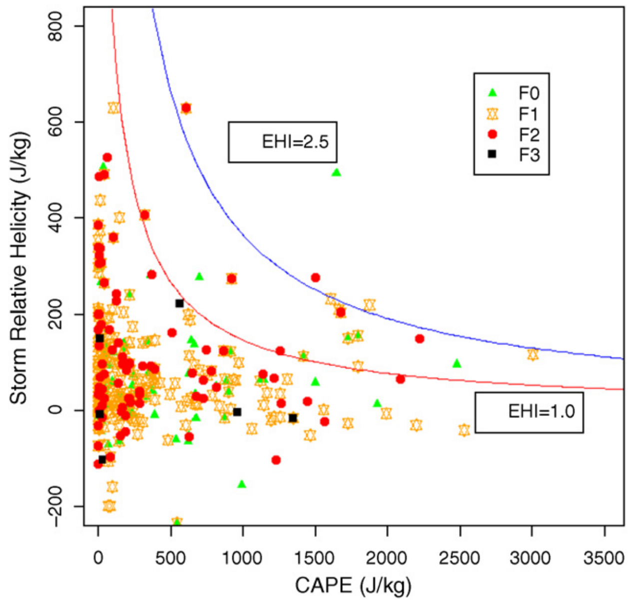

Fig. 6. CAPE Storm-Relative-Helicity diagram obtained using all the reports from 1991 to 2000. Intensity of the events is reported in symbols according to the Fujita scale. F0 events are represented by triangles, F1 events are represented by stars, F2 events are represented by filled dots, F3 events are represented by filled squares.

Fig. 6 shows the relationship between CAPE and Storm Relative Helicity for the merged sample 1991–1999 and 2000. Solid curves show the trend of EHI (Energy-Helicity Index). The definition of CAPE and EHI is deeply dependent on the lifted-parcel theory, then it depends highly on the decision of which parcel to lift. In this work, the reference parcels are chosen following what was written by Manzato and Morgan (2003). The sounding data, necessary for the computation of CAPE, SHEAR and EHI, were withdrawn from the web site of the Wyoming University and they all refer to launches carried out every day at 00 and 12 UTC by the Italian Air Force (16044 Udine/Campoformido, 16080 Milano/Linata, 16113 Cuneo/Levaldigi, 16560 Cagliari/Elmas, 16245 Pratica di Mare, 16320 Brindisi, 16429 Trapani/Birgi) and by French Meteorological Service (07761 Ajaccio).

As can be seen in Fig. 6, Italian tornadoes do not show a clear trend; that is, there is no stratification of tornado intensity according to the isopleths of EHI. A comparison with other analogous diagrams obtained for the US (Brooks et al., 1994) show that in Italy, CAPE

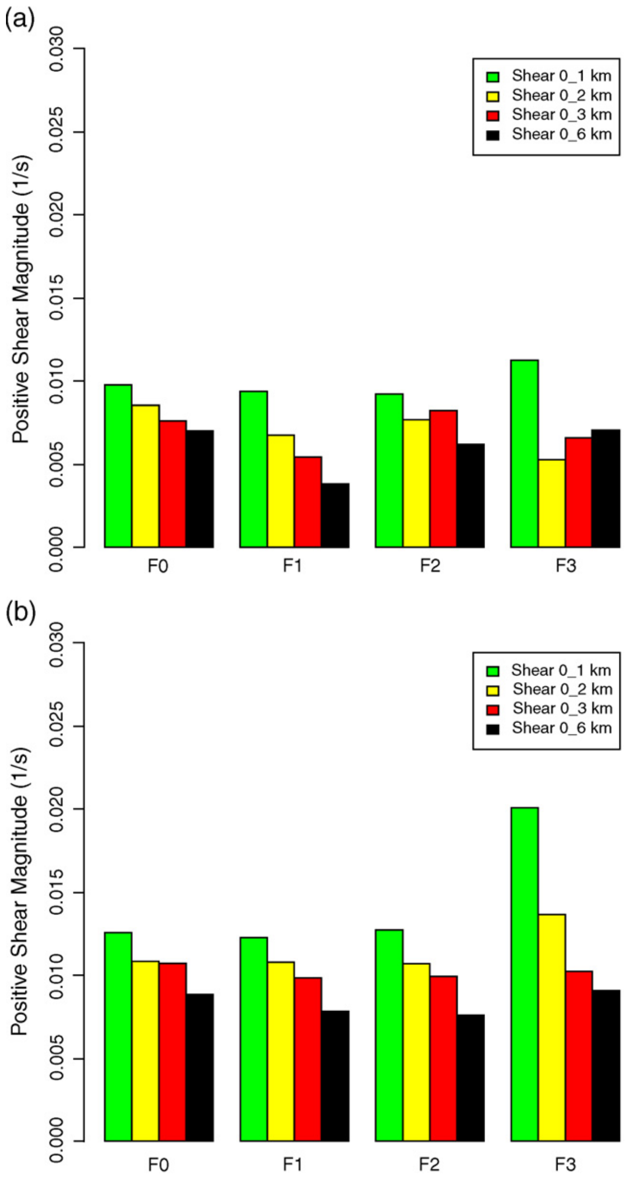

Fig. 7. (a and b) Shear magnitude diagrams obtained for the sample 1991–1999 (panel a) and for the sample 2000 (panel b). Histograms show the average value of the wind shear computed for different heights and for different classes of tornadoes, stratified according to the Fujita scale of intensity.

values are definitely lower than those observed in the US.

The importance of wind shear in tornadic environment is evaluated for both the samples 1991–1999 and 2000 by means of the diagrams shown in Fig. 7a and b. Both the samples show that the highest values of wind shear are reached in the lower troposphere. Wind shear intensity decreases with height. The different behavior experimented in the 1991–1999 sample and the noticeable increase in the 0–1-km shear value, both related to F3 tornadoes, is bound to the limited number of such cases: only five for 1991–1999 and one for 2000. It is important to observe that the outline is similar to the results obtained in Monteverdi et al. (2003) for California–US.

4. Conclusions

In this work 10 years of data, from 1991 to 2000, are used to define a preliminary climatology of tornadoes and waterspouts in Italy. The analysis of these data shows that tornadoes and waterspouts are more frequent in the flat areas than on the rough orography. Tornadoes are more frequent in late summer and autumn than in winter, spring and early summer. The seasonal effect is different in different areas. In particular in the Po Valley and Friulian plain, tornadoes and waterspouts are more frequent in spring and early summer, while in the Tirrenian and Ionian coasts, tornadoes and waterspouts are more frequent in late summer and autumn. This behavior is interpreted as due to the interplay between perturbations (essentially cold air advections) and Alpine ridge for the Po Valley and Friulian plain and between the occurrence of Mediterranean lows for the Tirreniana and Ionian coasts. Italian tornadoes and waterspouts seem to be weaker than those observed in other countries and this behavior seems to be a common feature of all the Italian areas. Shear magnitude diagrams obtained stratifying the data according to the tornado intensity show characteristics similar to those observed in other countries, in particular the higher shear intensity in the lowest levels. CAPE Storm-Relative-Helicity diagrams show behaviors different from those observed in the US, in particular CAPE values are lower in Italy than in US. This fact is interpreted as due to the mildness of the Mediterranean climate which, even if moist, does not show the abrupt transitions between air masses observed in the USA. This fact is considered as the reason for the statistical weakness of Italian tornadoes, as revealed by the intensity distribution.

Acknowledgments

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