

A TORNADO AND WATERSPOUT CLIMATOLOGY FOR GREECE

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I. INTRODUCTION

Tornadoes were generally neglected in the climatological records of Greece, considered as very rare events or of an anecdotal character. Except some academic references and very few articles including reports of a waterspout case and a remarkable fish rain event, there was not any essential tornado research and literature (Livadas, 1954; Kanellopoulos, 1977; Flocas, 1992). A systematic recording of tornado and waterspout occurrence has been started in Greece from the year 2000, in an attempt to develop a reliable and possibly comprehensive database (Sioutas, 2002 and 2003; Sioutas and Keul, 2007). Data originate from various sources, including eyewitness, site investigations, mass media, administrations and damage reports to crop and infrastructure. This database has already completed 10 years of data, that are used to define a preliminary climatology of tornado and waterspouts for Greece.

II. PRESENTATION OF RESEARCH

A number of about 250 tornado and waterspout events were catalogued during the 10-year period 2000-09, in a total of 145 days, in Greece. These data result to a yearly average of 14.5 days of tornado and waterspout activity or a yearly number of about 1.1 day per 10,000 km², suggesting a rather high frequency of tornado events between European countries (Dotzek, 2001; Paul, 2001; Tyrell, 2003; Giaiotti et al., 2007).

As it can be seen in Figure 1, the number of tornado and waterspout days fluctuates largely from year to year of the examined data sample. An upward trend line is evident, primarily attributed to an increasing tornado reporting coupled with enhancing public awareness and systematic recording, rather than representing an actual increase in the annual frequency of tornadoes and waterspouts.



FIG. 1: Yearly distribution of tornado and waterspout days in Greece, upon 10-year data (2000-2009).

The geographical distribution of tornado and waterspout day number is plotted in Figure 2, where the total day number is indicated (circles) for greater than 3 days. Although tornadoes can occur everywhere, however the 10-year database reveals that they are more frequent over the

western Greece and the Ionian coasts with a maximum located over northwest Peloponnese. Over this area, namely the Elias prefecture, a total of 13 tornado and waterspout days was recorded in the 10-year period. Considering waterspout activity, although it seems also high for the Ionian Sea, however, a significant local maximum is located in the southern Aegean Sea, over north off coast of Iraklion, Crete Isl., with a total of 23 waterspout days and about 70 waterspouts recorded during the 10-year period. Considerable outbreaks with a total of 13 waterspouts on 5 September 2002 and more than 20 waterspouts on 21 September 2006 were also observed in this area (Keul, 2003; Keul et al., 2009).



FIG. 2: Tornado and waterspout day distribution in Greece for total number of occurrences above 3, upon 10-year data (2000-2009).

Geographical effect in tornado formation and intensification is expected, considering the complexity of Greek territory. Spatial analysis showed that tornadoes are more frequent in coastal and flat areas than over rough areas. Waterspouts are mainly recorded near or in small distances from the coasts that is primarily related to the ability to observe and record it, than in the open sea.

The monthly totals of tornado and waterspout days along with the tornado and waterspout numbers are graphed in Figures 3a,b. July is the highest frequency month in both tornado days and tornado number (Fig. 3a). Tornado days are similarly distributed from November to March, however, July, January and November is the monthly ranking for tornado number. July is a month characterized by atmospheric instability for northern Greece, while November and January are related with instability for western and southern Greece. Considering waterspout days (Fig. 3b), their majority is appearing in the fall months, with September dominating in both waterspout days and number, a feature primarily related to the warmer sea surface temperatures of this period.

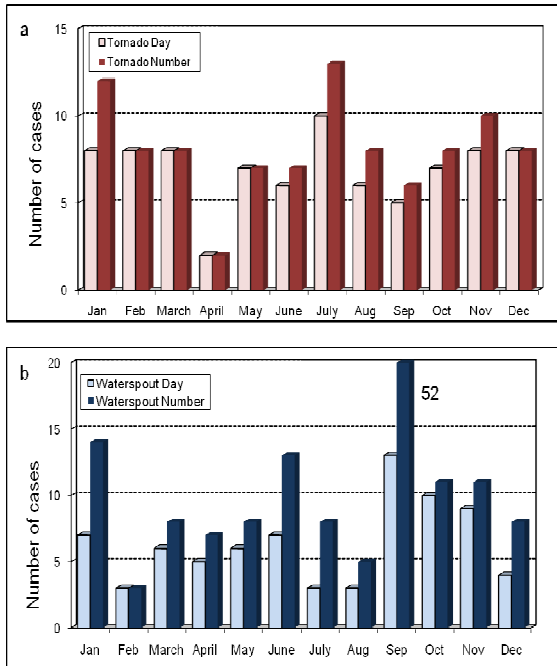


FIG. 3: Monthly tornado and waterspout activity distributions upon 10-year data (2000-2009) for Greece: a) tornado days and tornado number, and b) waterspout days and waterspout number.

Considering seasonal distributions as they displayed in Figure 4, tornadoes and waterspouts are recorded in all seasons of the year in Greece. A clear tendency is evident, for waterspout days to be maximized in fall, while tornado days appear their maximum activity in winter and summertime.

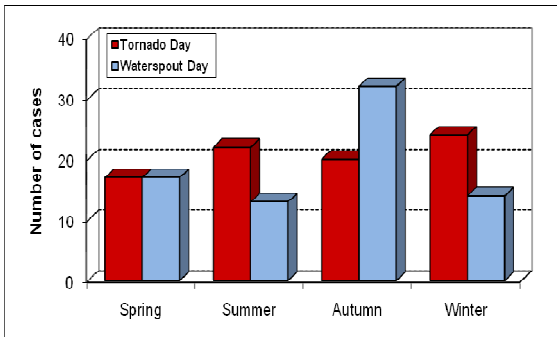


FIG. 4: Seasonal distribution of tornado and waterspout days for Greece, upon 10-year data (2000-2009).

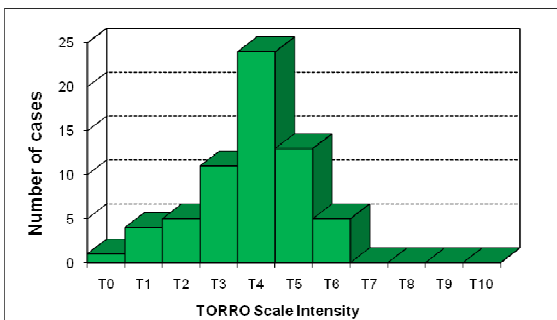


FIG. 5: Intensity distribution for Greek tornadoes by using of the T-scale, upon 10-year data (2000-2009).

Intensity analysis based on a data subset for which tornado intensities could be assessed (Fig. 5), indicated that, the majority of about 39% of the cases, reached at T4 of the TORRO scale or F2 of the F-scale.

III. RESULTS AND CONCLUSIONS

A preliminary climatology of tornadoes and waterspouts for Greece is defined in this work, based on a 10-year database (2000-2009). These data suggest to a yearly average of 1.1 tornado/waterspout days per 10.000 km². Spatial distribution showed that tornadoes are more frequent over the western Greece and the Ionian coasts with a local maximum of tornado days located over northwest Peloponnese. Waterspout maximum activity is located over north off shore of Iraklion, Crete. Monthly and seasonal distributions showed some differences for various parts of Greece, with winter as the most active tornado season for western Greece and summer for northern Greece. July is the highest tornado frequency month, in both tornado days and tornado number observed. Waterspouts occur in the Aegean and the Ionian Sea mostly in late summer and autumn, with a peak in September.

Analysis based on intensities as assessed by damage data, indicated that the majority of tornadoes reached at T4 of the TORRO scale or F2 of the F-scale. Further climatological research is necessary, with the effort for quantitative and qualitative improvement of Greek tornado database remaining as a challenge and priority.

IV. AKNOWLEDGMENTS

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