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Climatological analysis of tornado events in Bulgaria during the period 2001-2014

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INTRODUCTION

Tornadoes occur relatively rarely in Bulgaria compared to other parts of the world. These events may often remain unreported when they occur in remote and weakly populated mountainous regions of the country or if they leave no significant damage behind. The number of reports of tornadoes in Bulgarian in the last 10-15 years however has significantly increased thanks to the revolutionary development of the information technology. There exist even amateur websites where one can find up-to-date summary of suspect tornado cases in the country given either by description of the damage or by photos of the object. While some of them were indeed tornadoes others were rather downbursts or funnel clouds not touching the ground.
This study mainly summarizes general features of the tornado and waterspouts statistics such as the geographical, yearly, monthly and diurnal distributions. Characteristics concerning tornado intensity are also presented. The main thermodynamic parameters and instability indices related to tornado occurrence are also given.

METHODOLOGY

The present work is based on a collection of data of 55 tornados and waterspouts in Bulgaria between 2001 and 2014. Data originated from eyewitness reports, site investigations, media news, reports of the local administration of damage in crops and infrastructure. Press and TV are often the richest source of images of the tornadoes and waterspouts themselves or the damage they have caused. Data from site investigations of damage, scientific publications, the meteorological data base of National Institute of Meteorology and Hydrology (NIMH) and the archives of the Bulgarian Hail Suppression Agency (BAHS) are also included. The analysis of the vertical structure of the atmosphere at the location and the time of occurrence are based on the sounding data from the archives of NIMH. The tornado cases have also been classified by severity according the Fujita scale (Fujita, 1985).
The sounding data from the national (Sofia) or the closest foreign aerological stations (Thessaloniki, Belgrade, Bucharest) have been used to calculate some thermodynamic parameters and indices of instability at the environment of occurrence of the tornadoes. Surface data (pressure, temperature, humidity parameters, wind speed and direction) from the closest synoptic station have been fitted to the lower part of the vertical profile. All computations have been made by the upgraded in 2013 non-adiabatic empirical model presented in Simeonov, 1996.

SPATIAL AND TEMPORAL DISTRIBUTION OF TORNADO EVENTS

The above mentioned 55 tornado cases have occurred in 48 days. The average number per year in Bulgaria is 3.9 which therefore makes up a frequency of =0.35/104 km2year-1. The similar frequency was published for Austria (=0.3/104 km2year-1 – Holzer, 2000) while the one for Greece appears to be 4 times bigger (=1.1/104 km2year-1 - Sioutas, 2011).
Only 18 out of 28 administrative regions have registered tornadoes for the 14-year period. The Sofia-city region has the highest frequency of 2.1/104 km2year-1 followed by Dobrich (1.2/104 km2year-1) and Razgrad (1.1/104 km2year-1).The regions of Varna and Burgas (0.7/104 km2year-1) Plovdiv, Vratsa and Veliko Tarnovo (0.6/104 km2year-1), Targovishte and Kyustendil (0.5/104 km2year-1), and Smolyan (0.4/104 km2year-1) exhibit frequencies greater than the national average. Only waterspouts have been reported in the region of Dobrich which border the Black sea.
All documented tornado cases in Bulgaria from 2001 to 2014 have been classified by severity according to the Fujita scale and by the type of the topography and the land use of the terrain upon which they occurred. There are 14 cases upon mountainous or hilly terrain covered by shrub or grass; 8 cases upon wooded mountainous or hilly terrain; 14 cases over flat terrain (plain); and 17 waterspouts. More than half (above 40%) of all cases in Bulgaria therefore have occurred over mountainous or hilly terrain which contrasts with other parts of Europe

where tornadoes most often form and develop upon flat terrain or near water bodies (Giaiotti et al., 2007; Sioutas, 2011).
The classification by strength excludes the 17 waterspouts. The reason is that they left no damage and this inhibits the attempts to classify them according to the Fujita scale. Most of the tornadoes (73%) match or even do not reach the F1 level of the Fujita scale which means that they were weak. About 11% of all cases have been attributed with an intermediate class F1-F2 because the damage data corresponds to the higher class F2 but the wind data suggest only class F1. There have been no documented casess of a class higher than F2 in Bulgaria.
The diurnal ditribution of tornadoes and waterspouts in Bulgaria show that most of the cases (about 80%) occured within the afternoon hours between 14:00 and 18:00 Local time (East European Time (EET) which in summer is 3 hour ahead of the Universal Coordianted Time (UTC) and in winter – 2 h). The monthly distribution of tornado cases show that almost all cases (91%) occurred within the warm half of the year between April and September. The highest frequency of tornado events has occurred in June and July. This corresponds to the statistics for other countries in Central and Eastern Europe. Waterspouts in Bulgaria seem to occur between June and September. This matches the time of year when the sea water is the warmest.
In the list of documented tornadoes in the 14-year period there are 5 "winter" cases which occurred within the cold half of year: 3 of which in Southern Bulgaria and 2- in Northern Bulgaria. They were associated with strong thunderstorms which developed along rapid and intense cold fronts introducing cold and moist air masses in Bulgaria after a prolonged period of unseasonably warm and dry weather.

THERMODINAMIC CONDITIONS
Four instability indices as well as other thermodynamic parameters have been calculated. According to Siedlecki (2009) KI>25 and TT>49 indicate conditions favorable for the development of strong thunderstorms with hail and/or tornadoes. The means of KI (30.4), TTi (51.7), and LI (-5.4) are above the threshold values. The mean SWEAT (238.2) is greater than the one for Greece (Sioutas, 2011) but lower than 400 which were found to be a threshold value for summer tornado storms in the USA (David, 1976). The maximum value of updraft velocity (wmax), wind shear 300-700 hPa ([U+F044]v), altitude of 0ºC isotherm (H0) and lifted convective equilibrium level (LfcEL) have been also calculated. The values of [U+F044]v suggest that for 85% of all cases the maximum vertical velocity of the updraft is in the upper part of convective cloud. The values of LfcEL match those presented in series Bulgarian publications from previous years identified as being informative for the development of hail producing summer convective storms and are even greater than the one from literature.

CONCLUSSIONS
The analysed cases will enrich the NIMH database of severe storm events and can be used for further improvement of techniques and practices for severe weather warnings as well as for further studying the climate variability of such severe weather phenomena. Tornadoes in Bulgaria mainly occur in the north-central, north-eastern and south-central regions of Bulgaria over mountainous terrain but also over plains. There is a tendency of increase of the documented number of tornado events in Bulgaria during the last 14 years. The intensity analysis indicated that the majority of the tornadoes in Bulgaria can be classified as F0–F1 of the Fujita scale which is equivalent to "weak" tornadoes. The analysis of the selected thermodynamic indices and wind parameters showed values comparable to those found in the literature.
These results, although modest, will contribute to the enrichment of the tornado climatology of the Balkans and Europe. Further climatological research is needed for quantitative and qualitative improvement of the tornado and waterspout database.

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