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e-mail: kasiagra@uw.edu.pl**ANNUAL AND DAILY CHANGES
OF THUNDERSTORMS IN TEMPERATE CLIMATE
IN LONDON, WARSAW AND MOSCOW**

Abstract: The aim of the study is to show and compare variation of the annual and daily course of thunderstorms in selected European cities in 2005-2009. Data on thunderstorms originate from dispatches METAR for three airport stations: London Gatwick, Warsaw Okęcie and Moscow Sheremetyevo. These cities represent the various types of climate: warm temperate marine, transitional and continental. Thunderstorms mostly occurred in Warsaw – 207 (Moscow – 174, London – 71). The maximum of thunderstorms frequency, in the yearly course, in all towns occurred in July (Warsaw – 11,8; Moscow – 13,4; London – 5,0). Thunderstorms predominantly started at 13:30 in London, 17:00 in Warsaw, 18:00 in Moscow (13:30 means period 13:01-13:30, 17:00 means period 16:31-17:00 etc.). Thunderstorms most often ended at 13:30 in London, 17:00 in Warsaw, 20:30 in Moscow. There were dominated, at all stations, brief thunderstorms, which lasted for 30 minutes. The longest thunderstorm remained 9 hours (Warsaw), 5,5 (Moscow), 4,5 (London).

Key words: thunderstorms, annual course, diurnal course, temperate climate, London, Warsaw, Moscow

INTRODUCTION

Extreme weather phenomena, and among them thunderstorms, may pose a threat to human life and activities. For that very reason climate experts devote more and more attention to thunderstorms. Economic activity of men, as well as the spread of urban areas (the growth of ever bigger agglomerations, where artificial heat emission and the concrete surfaces of the buildings and streets which cumulate heat foster the development of convections, and the polluted air delivers high numbers of condensation nuclei) have definitely led to the growing number of these phenomena in Europe and

worldwide. However one should underline the parallel nature of the influence of geographic and climatic factors, such as the landscape, the distance from the ocean, heat supply connected with geographic latitude or the atmospheric circulation.

Thunderstorms are connected with the development of cumulonimbus clouds. It has been observed (on the example of Poland) that in mountain areas and uplands the development of thunderstorms is influenced by the land surface and the landscape to a much greater extent than in the lowlands where it is the atmospheric circulation and the movement of air masses that play a bigger role.

In Polish climatic literature there is a growing number of publications devoted to thunderstorms. They focus on the changing annual and long term thunderstorm activity, the influence of atmospheric circulation and the chosen meteorological phenomena on thunderstorms and they very often conclude by pointing thunderstorm regions in Poland (Stopa 1962, Koźmiński 1963, Kolendowicz 1996 and 2005, Bielec-Bąkowska 2002), as well as by drafting long term forecasts of thunderstorm phenomena (Grabowska 2002).

There are far fewer publications which touch on the daily cycle of this dangerous phenomenon. Stopa (1962, 1964) has observed a significant time and area differentiation of the daily thunderstorm cycle in Poland. Thunderstorms most often begin early in the afternoon, around 1 p.m. – 3 p.m., and they reach their peak at 2 p.m. – 4 p.m. These phenomena last from 5 minutes to 10 hours, but short thunderstorms dominate (from 11 to 20 minutes). Bielec (2000) studies daily thunderstorm cycle in Cracow (1896-1995). Basing on her research it can be concluded that most thunderstorms begin at 1 p.m. – 2 p.m. and they reach the maximum of their activity at 4 p.m. – 5 p.m. Short thunderstorms, lasting up to 10 minutes, were the ones most frequently observed.

The aim of this paper is to present the differentiation of annual and daily thunderstorm cycle in the chosen European cities, London, Warsaw and Moscow, in the years 2005-2009. These cities have similar latitude and they represent the following climates accordingly: temperate maritime, temperate transitional and temperate continental.

REFERENCE MATERIALS

A thunderstorm day has been defined as a day with at least one thunderstorm. A number of thunderstorm instances has been used in order to characterise the daily thunderstorm cycle, as there were days with more than one thunderstorm.

Data regarding thunderstorm days and thunderstorms originates from METAR (*Meteorological Aerodrome Report*) messages from three airport weather stations: London Gatwick, Warsaw Okęcie and Moscow Sheremetyevo (2005-2009). Air and weather METAR reports are coded and sent every 30

minutes. They are a valuable data source on the daily changing nature of many meteorological phenomena which are measured at airport weather stations. The frequency of sending messages influences the time span scheduled for a thunderstorm, which cannot be shorter than 30 minutes. This is the reason why shorter thunderstorms cannot be recognised (there is such a possibility in the case of climate data from synoptic stations, where exact time of the beginning and the end of a thunderstorm is registered). Despite these inconveniences, METAR reports enable to define the time of the day which can be characterised by the biggest thunderstorm activity. In order to make the data easily readable, when determining the beginning and the end of a thunderstorm only the METAR report sending time according to official time has been used (London: UTC, UTC + 1h; Warsaw: UTC + 1h, UTC + 2h; Moscow: UTC + 3h, UTC + 4h). In fact this value stands for the 30 minute time span preceding the report, e.g. a thunderstorm from 5:30 p.m. stands for a thunderstorm which occurred in the timeframe 17:01 p.m. – 17:30 p.m.

VARAIBILITY OF THE NUMBER OF THUNDERSTORM DAYS AND THUNDERSTORMS

From the research on thunderstorm variability in Europe it can be concluded that temperate warm transitional climate (according to the classification by Okołowicz, 1991) is characterised by their strong activity in the upper latitudes. Fewer thunderstorms occur in temperate warm continental climate, a the fewest in the temperate warm maritime climate (Grabowska, 2008).

In the years 2005-2009 thunderstorms were most frequent in Warsaw, with as many as 207 occurrences (in 153 thunderstorm days), a bit less frequent in Moscow – 174 occurrences (in 121 thunderstorm days) and least frequent in London – with only 71 occurrences (in 51 thunderstorm days). The average annual number of thunderstorms in Warsaw amounted to 41,1 (on average 30,6 thunderstorm days a year), in Moscow – 34,8 (24,2 days) and in London – 14,2 (10,2 days) (Fig. 1).

Thunderstorms occurred most frequently during the warm months and it was most visible in Warsaw and Moscow. A significant rise of thunderstorm activity began in May and finished in September. In both cities the most thunderstorms occurred in July and reached an average of 11,8 thunderstorms (8,8 thunderstorm days) and 11,4 thunderstorms (9 days) accordingly. The maximum for July in London was twice lower and reached an average of 5,0 thunderstorms (2,6 thunderstorm days). In Warsaw the fewest thunderstorms were observed in December, as then there were no thunderstorms. In Moscow the “thunderstorm-free” period was longer and lasted 7 months – from October to April. In London, on the other hand, the minimum amounted to 0,2 thunderstorms (the same average for thunder-

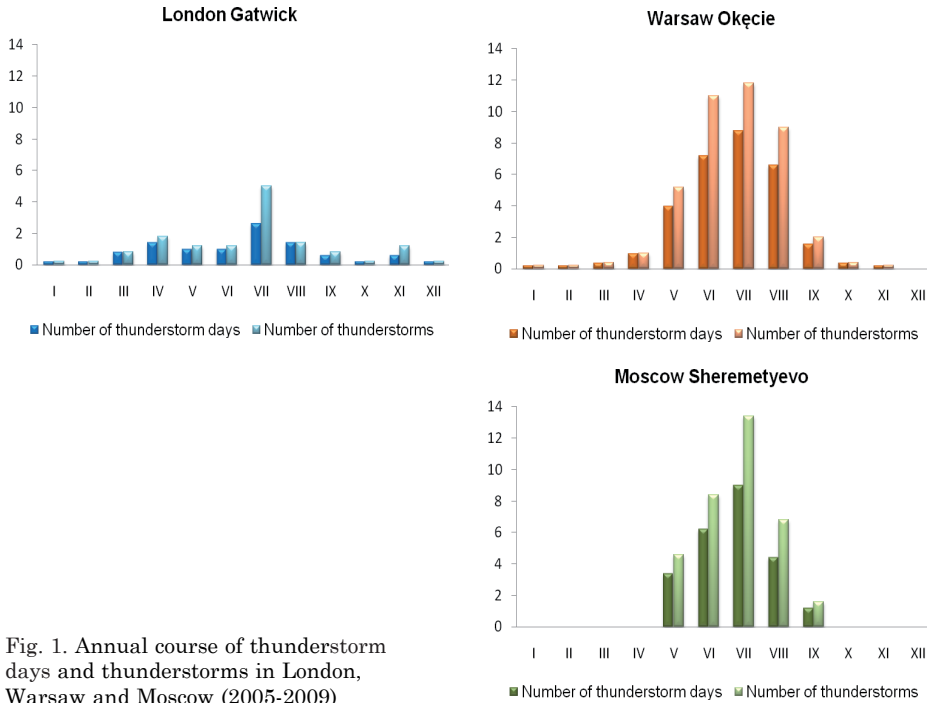


Fig. 1. Annual course of thunderstorm days and thunderstorms in London, Warsaw and Moscow (2005-2009)

storm days) and occurred during the 4 months: from December to February and in October.

In the warmer part of the year, from April to October, there some discrepancies between the number of thunderstorm days and thunderstorms. During that period it is possible that several thunderstorms might occur in one day. Despite the fact that among all three stations there were fewest thunderstorms in London, the ratio of the number of thunderstorm days and thunderstorms in July was the highest here and amounted to 1,9 (almost twice as many thunderstorms than thunderstorm days). In Moscow in July there were 1,5 times more thunderstorms than thunderstorm days, whereas in Warsaw only 1,3 times more (Fig. 1).

In temperate warm maritime climate thunderstorms occur equally often throughout the year (in London except for July). In the same climate zone, but in the temperate transitional climate, thunderstorms may also occur during all months and only in the temperate continental climate they do not occur during the colder part of the year (in Moscow there were no thunderstorms from October to April) (Fig. 1). Most often during these months in London and Warsaw there was only one thunderstorms on the particular day.

During the five year period (2005-2009) the years 2007 and 2008 can be singled out as the ones with the highest thunderstorm activity in London,

2007 in Warsaw and 2008 in Moscow. The fewest thunderstorms in London and Warsaw occurred in 2005, whereas in Moscow in 2009.

THUNDERSTORM START TIMES

Thunderstorms may occur throughout the whole day. However the phenomenon is most frequently observed in the afternoon hours.

In London it is most often that thunderstorms start early in the afternoon or in the evening. Most thunderstorms occurred at 1 p.m. and then at 5:30 p.m. The rarest occurrences were observed during the night, between 0:00 a.m. and 3:00 a.m. In Warsaw and Moscow the thunderstorm start times were shifted to later afternoon and evening hours, with the maximum frequency at 5:00 p.m. and 6 p.m. accordingly. The time of the lowest activity in Warsaw was observed in the early morning hours, from 5:30 a.m. to 9:00 a.m., and in Moscow a bit later, namely during the early and late morning hours, from 8:00 a.m. to 12:00 p.m. (Fig. 2).

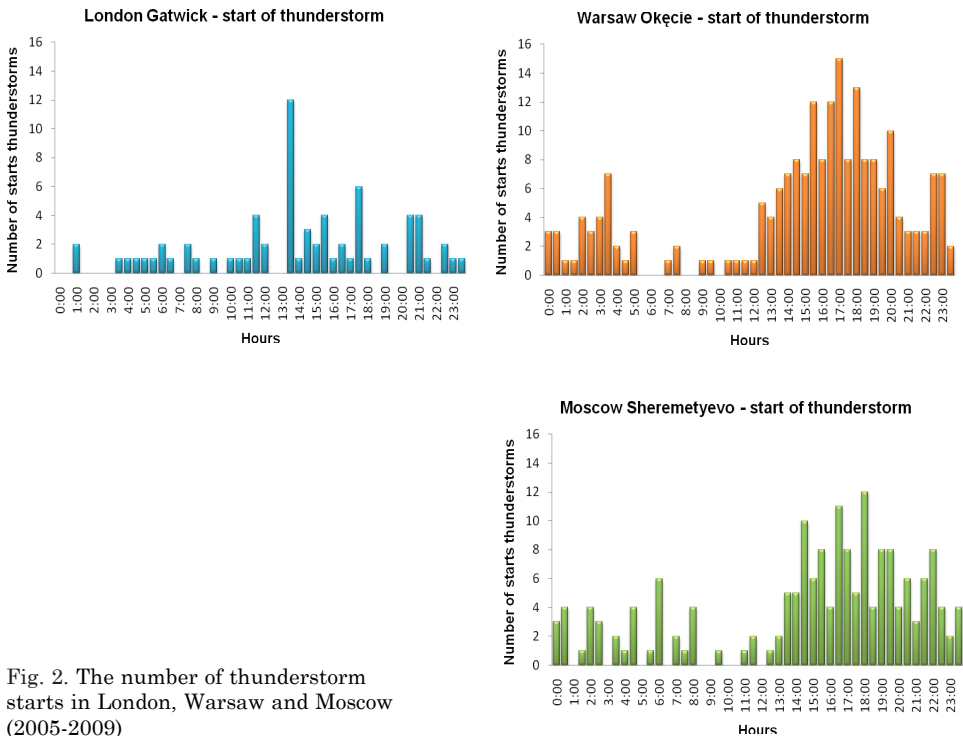


Fig. 2. The number of thunderstorm starts in London, Warsaw and Moscow (2005-2009)

THUNDERSTORM END TIMES

In London thunderstorms ended at 1:30 p.m. or at 3:30 p.m. most often. In Warsaw the end time in comparison to the start time shifted from late morning hours to early evening and early night hours (most end times were recorded accordingly: 5:00 p.m. and 4:00 p.m., 6:30 p.m. and 7:00 p.m.). In Moscow it was most often that thunderstorms ended in the evening or early during the night. The maximum number of end times occurred at 8:30 p.m. However, there were also many instances at 4:30 p.m., 6:00 p.m. and 10:30 p.m. The rarest occurrences in Moscow were observed between 9:00 a.m. and 12:00 p.m. (Fig. 3).

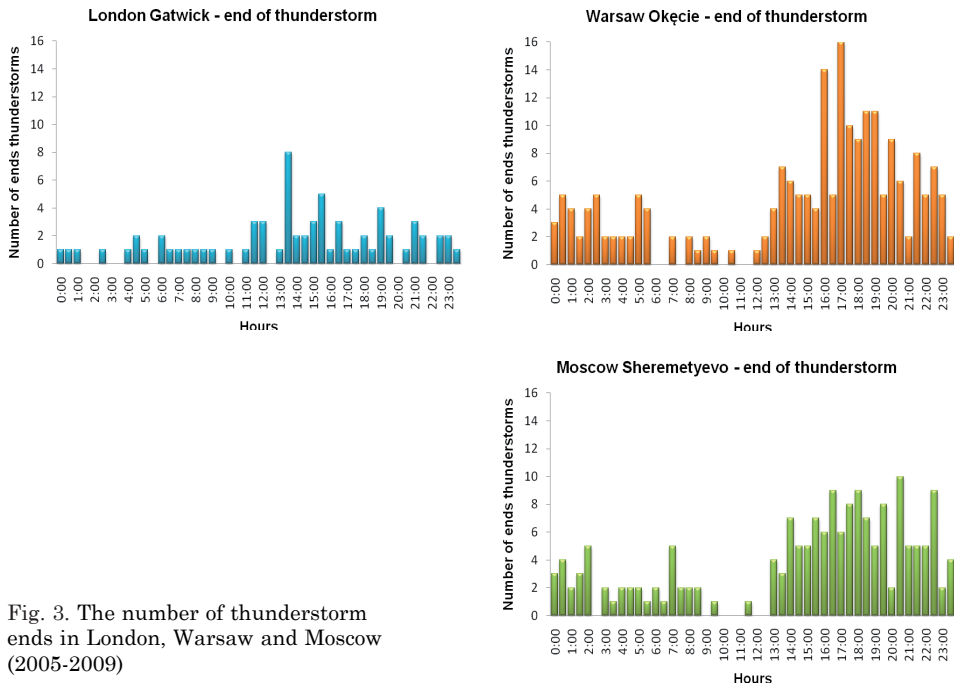


Fig. 3. The number of thunderstorm ends in London, Warsaw and Moscow (2005-2009)

THUNDERSTORM DURATION

In London the majority of thunderstorms were short, lasting up to 30 minutes. There were twice fewer one hour long thunderstorms. There was, however, an occurrence of a thunderstorm which lasted 4 hours and 30 minutes. In Warsaw it was also the short, 30 minute long, thunderstorms that dominated. However there were more one hour long thunderstorms (30% fewer than the ones 30 minute long) than in London and Moscow.

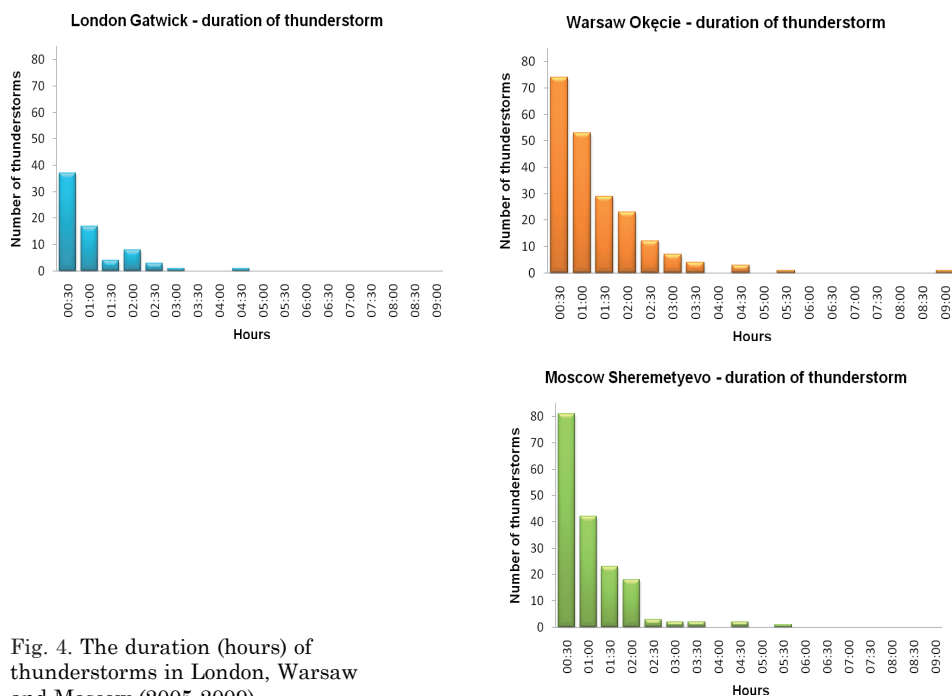


Fig. 4. The duration (hours) of thunderstorms in London, Warsaw and Moscow (2005-2009)

Longer thunderstorms were also more often here, with the longest one reaching 9 hours. In Moscow, similarly as in London, short 30 minute long thunderstorms were most frequent and there were 50% fewer thunderstorms lasting one hour. Thunderstorms longer than 2 hours occurred very rarely, with longest one lasting 5 hours and 30 minutes (Fig. 4).

CONCLUSIONS

Research confirms the rules known from other sources that thunderstorms are more frequent in continental climate than in maritime climate. It is an interesting fact that most thunderstorms occur in the transitional climate zone where oceanic and continental influences collide. It is here that atmospheric front related thunderstorms occur. During the warm part of the year strong heating up of the surface by the sun favours the development of thermal (air mass) thunderstorms.

The most thunderstorms occurred in the temperate transitional climate (Warsaw), fewer in temperate continental (Moscow) and the fewest in temperate maritime (London). In Warsaw and Moscow they occurred mostly during the warm months, from May to September, whereas in London the period of slightly greater activity lasted from March to September, as well as in

November. In the cities included in this research the maximum of thunderstorm days and thunderstorms has been observed in July.

In London thunderstorms occur all year round and the differences in their number between the warm and the cold season are little. In Moscow thunderstorms occur only from May to September and they do not occur at all during other months. In Warsaw, where oceanic climate features along with continental ones are noticeable, thunderstorms occur throughout the whole year. However, they are most frequent during the summer months.

Thunderstorms occur at all times during a day in all the studied cities. In London, in maritime climate, it was most frequent that thunderstorms started and ended in a 30 minute time frame, at 1:01 p.m. – 1:30 p.m. In Moscow, in continental climate, thunderstorms started most frequently in the evening (5:31 p.m. – 6:00 p.m.) and ended no sooner than early in the night (8:01 p.m. – 8:30 p.m.).

At all stations short, 30 minute long thunderstorms were the ones which dominated. The longest thunderstorm lasted 9 hours in Warsaw, 5 hours and 30 minutes in Moscow, and 4 hours and 30 minutes in London.

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