Diurnal variation of storms and meteorological conditions observed during the longest storms in Northern and Central Europe

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I. INTRODUCTION

In Europe, the highest storm activeness appears in its southern part – in the basin of the Mediterranean Sea and in the mountains (e.g. in the Alps, the Pyrenees and the Carpathians) (Grabowska 2010). The least storms appear in the northwest part of Europe, particularly in the seacoast. However, these regions can also be affected by dangerous weather conditions, including storms, posing threat to human life and activities.

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 storm cycle in Poland.

Storms most often begin early in the afternoon, around 1:00 PM – 3:00 PM, and they rich their pick at 2:00 PM – 4:00 PM. These phenomena last from 5 minutes to 10 hours, but short storms dominate (from 11 to 20 minutes). Bielec (2000) studiem daily storm cycle in Cracow (1896-1995). Basing on her research it can be concluded that most storms begin at 1:00 PM – 2:00 PM and they reach the maximum of their activity at 4:00 PM – 5:00 PM. Short storms, lasting up to 10 minutes, were the ones most frequently observed.

The objective of the study is to present the diversity of the annual and daily course of storms in selected cities of northern and central Europe during the years 2005-2012. These cities are located in the area of moderate cool and warm climate. Brest (France) and Trondheim (Norway) represent maritime climate, Warsaw (Poland) and Tampere (Finland) – temporary, while Orenburg and Syktyvkar (Russia) – continental.

II. PRESENTATION OF RESEARCH

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

Data on storms and meteorological conditions comes from the METAR airport reports (http://www.ogimet.com/metars.phtml.en). Air and weather METAR (*Meteorological Aerodrome Report*) are coded messages sent every 30 minutes. The frequency of reporting determines storm duration which cannot be shorter than 30 minutes. Despite these inconveniences, METAR reports enable to define the time of the day which can be characterised by the biggest storm activity.

In the period under study the longest storm (lasting several hours) for each city was chosen and then examined to see what weather conditions generated the storm. The changes in temperature, air humidity, wind direction and atmospheric pressure before, during and after the storm were analysed. The atmospheric pressure field and synoptic conditions also traced over northern and central Europe.

The analysis of weather conditions during the longest storms in the selected cities was carried out based on synoptic maps (http://www.pogodynka.pl/polska/mapa_synoptyczna/ oraz http://www.wetterzentrale.de/topkarten/ tkfaxbraar.htm), visible and infrared satellite images (http://www.sat24.com/history.aspx) as well as vertical aerological sounding (http://weather.uwyo.edu/upperair/sounding.html).

III. RESULTS AND CONCLUSIONS

From the research on storm variability in Europe it can be concluded that temperate warm transitional climate (according to theclassification by Okołowicz 1991) is characterised by their strong activity inthe upper latitudes. Fewer storms occur in temperate warm continental climate, a the fewest in the temperate warm maritime climate (Grabowska 2008, 2011). It is somewhat different in moderate cool climate: the most storms appear in the continental climate, less in temporary and the least in maritime climate.

During the years 2005-2012, the most storm days appeared in Warsaw (average of 31.1 days), slightly less in Orenburg (27,8 days), and the least in Trondheim (only 4,8 days).

The average annual number of storms in Warsaw was 41.1, in Orenburg – 38.1 and in Brest – 9.5, as well as in Trondheim – 5.5 (TABLE 1).

2005-2012	**Trondheim**	**Tampere**	**Syktyvkar**
Average annual number of storm days	**4.8**	**10.9**	**16.1**
Average annual number of storms	**5.5**	**13.7**	**24.4**
2005-2012	**Brest**	**Warsaw**	**Orenburg**
Average annual number of storm days	**7.5**	**31.1**	**27.8**
Average annual number of storms	**9.5**	**40.1**	**38.1**

TABLE 1. The average annual number of storm days and storms in selected European cities (2005-2012)

Most storms occurred during warm months and this was seen best in Warsaw, Orenburg, Syktyvkar and Tampere. The most storm days and storms in these cities fell to July. The visible growth of storm activeness began in May and ended in September.

In both coastal cities, the annual course of storms looked differently. In Brest there were two maximums of storm activity – in May and in November, and in Trondheim – in June.

In the maritime (Brest and Trondheim) and temporary climate (Warsaw and Tampere), the storms occurred throughout the entire year, while in the continental climate (Orenburg and Syktyvkar) only from April or May until September (FIG. 1 i 2).

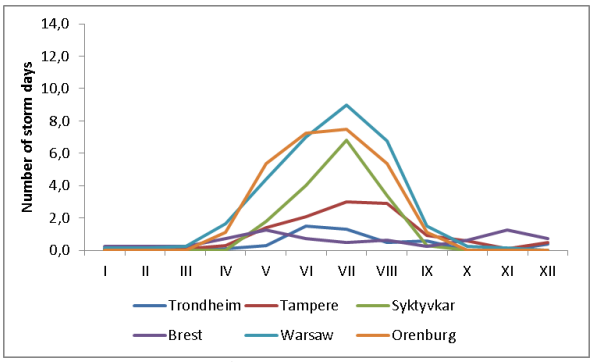

FIG. 1. Annual course of storm days in selected European cities (2005-2012)

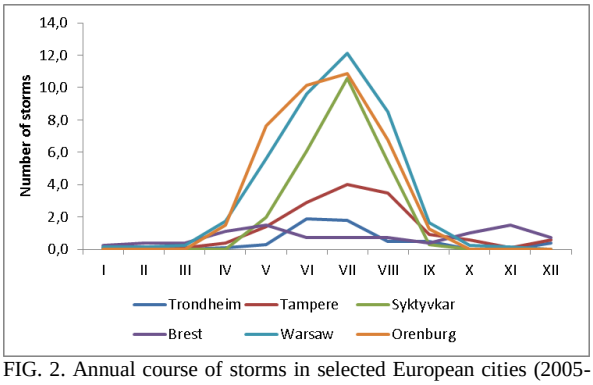

FIG. 2. Annual course of storms in selected European cities (2005-2012)

Storms may appear throughout the day, however, this phenomenon is most often observed during the afternoon hours.

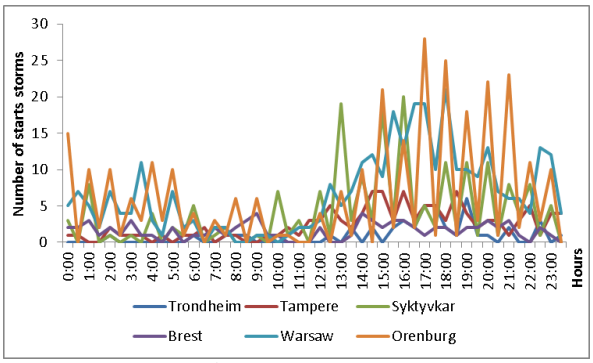

FIG. 3. The number of storm starts in selected European cities (2005-2012)

In Brest the storms usually began in the early afternoon and the evening, they also occurred at night and died down early in the afternoon. The most storms formed at 2:00 PM, which was followed by 9:00 AM. Their rarest time was during the middle of the day, between 10:30 AM and 1:30 PM. In Trondheim the storms began in the afternoon and evening, no later than at 7:00 PM. In Warsaw and Orenburg the storms started in the late afternoon and evening, no later than adequately 6:00 and 7:00 PM. The time of the weakest storm activeness in Warsaw fell to the morning hours, between 6:00 and 10:30 AM, and was slightly later in Orenburg, the morning and forenoon hours between 9:30 and 11:30 AM. In Tampere and Syktyvkar, despite the fact that the storms occurred throughout the entire day, they were most frequent in the afternoon and evening with maximums at the first station at 2:30, 3:00, 4:00 and 6:30 PM and 4:00 PM at the second station (FIG. 3).

Short storms, up to 30 minutes, dominated at all stations. The most frequently occurring storms in the maritime climate (Brest and Trondheim) last up to 1h, in moderate cool temporary and continental climate (Tampere and Syktyvkar) up to 1.5h, while in moderate warm temporary and continental climate (Warsaw and Orenburg) up to 2.5h.

The longest storm lasted 9 hours (one storm) and occurred in Warsaw. The longest storms in Orenburg lasted 6.5h (two storms), in Syktyvkar – 5.5h (two storms), in Tampere – 4h (two storms), in Brest – 3.5h (one storm). In Trondheim the longest storms had the shortest duration – only 2h (three storms) (FIG. 4). Together at all stations, there were 11 such record-setting storms.

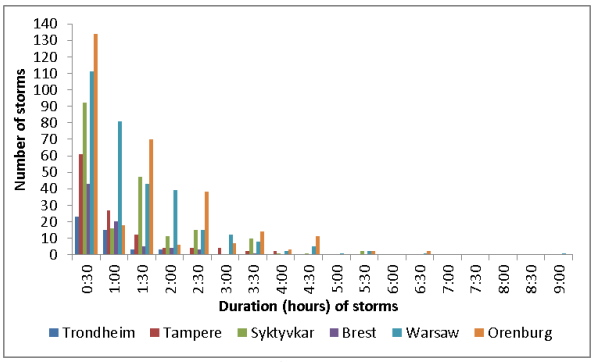

FIG. 4. The duration (hours) of storms in selected European cities (2005-2012)

The further analysis selected one storm from each location from among these 11 longest storms observed at six stations. If more than one storm was up for selection (two or three storms with the same duration), the selected storm was the one with the later date, due to the better access to data.

Table 2 below presents the basic data describing the selected storms: date of occurrence, hour of start and end of the storm, duration of the storm. The longest storms appeared in various months, which mostly fell to spring, summer and early fall. This was spring and early summer in western and northern Europe (Brest, Trondheim, Tampere and Syktyvkar), but late summer and early fall in central and eastern Europe (Warsaw and Orenburg).

	The longest storms			
	Date of occurrence	**Hour of start**	**Hour of end**	**Duration of the storm**
Trondheim	2011-06-11	7:00 PM	8:30 PM	2:00 h
Tampere	2012-04-02	2:30 PM	6:00 PM	4:00 h
Syktyvkar	2008-06-24	3:00 PM	8:00 PM	5:30 h
Brest	2006-03-20	5:30 PM	8:30 PM	3:30 h
Warsaw	2009-08-02/03	10:30 PM	7:00 AM	9:00 h
Orenburg	2011-09-17/18	6:00 PM	12:00 AM	6:30 h

TABLE 2. The data describing the longest storms: date of occurrence, hour of start and end of the storm, duration of the storm in selected European cities (2005-2012)

		Trondheim	Tampere	Syktyvkar	Brest	Warsaw	Orenburg
	Data	2011-06-11	2012-04-02	2008-06-24	2006-03-20	2009-08-02/03	2011-09-17/18
	Duration	2:00 h	4:00 h	5:30 h	3:30 h	9:00 h	6:30 h
Air temperature (^oC)	Before	19.0	-3.0	29.0	15.0	22.0	23.0
	During	18.0	-3.0	21.0	9.0	20.0	18.0
	After	16.0	-3	18.0	8.0	19.0	15.0
Air humidity (%)	Before	78	100	48	63	64	57
	During	83	100	81	90	75	82
	After	88	93	94	93	94	94
Wind direction	Before	SW	NE	SE	SE	E	SW
	During	NW	N	E	NE	NE	NE
	After	SW	N	SE	NE	E	NE
Wind speed (ms^{-1})	Before	14.8	14.8	10.8	9.3	18.5	10.8
	During	29.6	20.4	21.6	13.0	24.1	21.6
	After	9.3	18.5	7.2	5.6	18.5	7.2
Atmospheric pressure (hPa)	Before	1009	987	1005	1003	1011	1011
	During	1010	990	1004	1003.5	1010	1009.5
	After	1011	991	1005	1004	1009	1008
Circulation (pressure system)		cyclone (low)	cyclone (low)	cyclone (low)	cyclone (low)	cyclone (low)	anticyclone (high)
Airmass		PMw	AM	PC	PM	PMw/AM	PMo
Front		warm/cold	occlusion	warm	occlusion	cold	
Type of storm		frontal storm/advection storm in warm sector	frontal storm	frontal storm	frontal storm	frontal storm/advection storm in cold sector	termic storm

Airmasses	
PM	Polar Maritime airmass
PMw	Polar Maritime warm airmass
PMo	Polar Maritime old airmass
AM	Arctic Maritime airmass
PC	Polar Continental airmass

TABLE 3. The weather conditions describing the longest storms in selected European cities (2005-2012)

Table 3 contains the values of meteorological elements and profile of the weather during the days on which the examined storms occurred.

The longest storms formed in lows, on the fronts: warm, cold and occluded, in Polar Maritime, Arctic Maritime and Polar Continental airmasses. Only in Orenburg longest storm was in high due to warm the surface of the ground by solar radiation and inflow of more humid Polar Maritime old airmass (TABLE 3).

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