THUNDERSTORM ACTIVITY AND ITS RELATIONSHIPS WITH SOUTHERN CYCLONES IN ESTONIA, 1950-2004

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I. INTRODUCTION

Thunderstorms are among the most damaging weather events. Thus, it is important to study their spatial and temporal characteristics. It is also useful to know the possible relationships between thunderstorms and atmospheric circulation. Such relationships are determined in many countries. Finland and Poland are geographically closest examples to Estonia. In Finland it was found that thunderstorms that formed during the eastern airflow were the most active ones and produced one third of all flashes registered during 1998-2007 (Tuomi and Mäkelä, 2008). The most intense and severe thunderstorms in Poland tend to develop in case of advection of warm and humid tropical air from southerly directions before a front (Kolendowicz, 2006). This kind of relationships between atmospheric circulation and thunderstorms will be valuable and helpful for more accurate thunderstorm forecasts in the future.

Thunderstorm activity in Estonia based on thunder detector data set from the NORDLIS network was analysed during 2005-2009 (Enno, 2011). Relationships between thunderstorms and atmospheric circulation in Estonia have not been analysed so far.

Estonia is located in a transition zone between the maritime and continental climates characterised by very high cyclonic activity. Many thunderstorms in Estonia are associated with cyclonic activity, especially with cold fronts. About 10-13% of all cyclones that affect Estonia are southern cyclones. Southern cyclones form over the Mediterranean, Black and Caspian Seas, move northwards and transport warm and humid tropical air to the higher latitudes. Thus, during the warm season they have high potential to cause wide and severe thunderstorms in the northern part of Europe. Climatological studies of southern cyclones are of great importance because they cause the most unfavourable and dangerous weather conditions during summer (Merilain and Tooming, 2003). For example, the most severe extreme precipitation events in Estonia have concurred with the incidence of southern cyclones (Mätlik and Post 2008).

The aim of this paper is to study the activity of thunderstorms over Estonia during 1950-2004 and to analyse possible relationships between southern cyclones and thunderstorms.

II. PRESENTATION OF RESEARCH

Visual observations form five Estonian meteorological stations are used to study the thunderstorms activity during 1950-2004. One of them is maritime, two are coastal and two inland stations. The maritime station Vilsandi is located on a small island near the westernmost point of Estonia. Thus, it is directly affected by the open waters of the Baltic Sea. Two coastal stations Pärnu and Tallinn are located near the coastlines of smaller gulfs about 100 km east of open sea. Sea and inland areas both can affect their climate. Two inland stations Tartu and Võru are located 200 km east from the nearest gulfs and thus represent more continental climate.

Visual data records contain the beginning and end times of registered thunderstorms. The beginning of a thunderstorm is registered when the sound of thunder is first time heard by observer. The end of a thunderstorm is recorded 15 minutes after the last sound of thunder was heard by observer. The quality of visual thunderstorm observations is discussed by Reap and Orville (1990).

We summed the durations of individual thunderstorm events to find annual sums. Five-station average durations of thunderstorm events were also calculated. Seven-year moving average of storms duration was calculated for better visualisation of long-term fluctuations. A Fourier analysis was performed to study the period of fluctuations.

For the information about southern cyclones, we used the database of cyclones described by Gulev *et al.* (2001). All southern cyclones in the cyclone database that might have had an effect on weather conditions in Estonia during the years 1948-2004 were determined. We defined southern cyclones as lows, determined by Gulev *et al.* (2001), which had formed south of 47°N and east of the 0° meridian, and entered a circle of radius 1000 km centred in Estonia (Fig. 1).

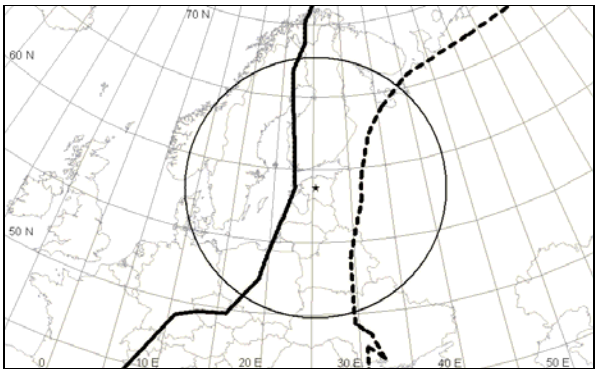

FIG. 1: Map of Europe showing the circle of 1000 km radius with its centre in Estonia at 58.75ºN and 25.5ºE, and example trajectories of two southern cyclones.

List of the dates when there was a southern cyclone in the 1000 km circle was compared with thunderstorm data. Southern cyclones that were associated with thunderstorms in Estonia were determined. We found the fraction of southern cyclones that caused thunderstorms. In addition, we calculated the fraction of thunderstorms that were associated with southern cyclones.

III. RESULTS AND CONCLUSIONS

Annual average duration of all recorded thunderstorms varied from 26 to 41 hours in the studied stations during 1950-2004. Similar values of annual thunderstorm hours are found in other studies for the Northern and Western parts of United States (Huffines, Orville, 1999) and in Kyrgyzstan (Podrezova, 2009).

The highest thunderstorm activity was observed in the most continental station Võru, the lowest activity appeared in coastal station Tallinn. Other three stations Tartu, Pärnu and Vilsandi had 34-36 thunderstorm hours per year in the average. As Tartu is a continental, Pärnu is a coastal and Vilsandi is a maritime station, it can not be said that annual duration of thunderstorms depends on the distance of the sea. These results differ from the conclusions of the earlier study that based on annual numbers of thunderstorm days in 23 Estonian stations during 1991-2003 and showed clear rise in the annual number of thunderstorm days from west to east (Enno, 2010).

There were remarkable variations in annual thunderstorm activity. The highest annual number of thunderstorm hours was 90 (Vilsandi, 1972) and the lowest was only 2 during the study period (Vilsandi, 1952).

The annual thunderstorm duration has a statistically significant decreasing trend at three stations (Pärnu, Tartu and Võru) and insignificant upward trend at two stations (Tallinn and Vilsandi). Obvious fluctuations in thunderstorm activity appeared. These are most clearly visible in the time series of five-station averages (Fig. 2). There were four maximum and four minimum periods in thunderstorm activity in Estonia during 1950-2004. The highest maximum occurred around 1960 and the strongest minimum was at the beginning of 1990s. Periodicity of 12-13 years strongly appeared from the Fourier analysis. We do not know the reasons of this periodicity, but it seems to continue after the end of the study period. Minimum in thunderstorm activity was observed in Estonia during 2004-2008 and a new clear maximum appeared in 2009 and 2010. It is interesting to mention that this kind of periodicity has not occurred in other countries. For example, long-term thunderstorm studies in Poland (Bielec, 2001; Bielec-Bakowska, 2003) and in the United States (Changnon and Changnon, 2001) did not reveal such a periodicity. On the other hand, all studies mentioned above used thunderstorm day as a measure of thunderstorm activity. The fact that we used thunderstorm hours instead of thunderstorm days may explain different results.

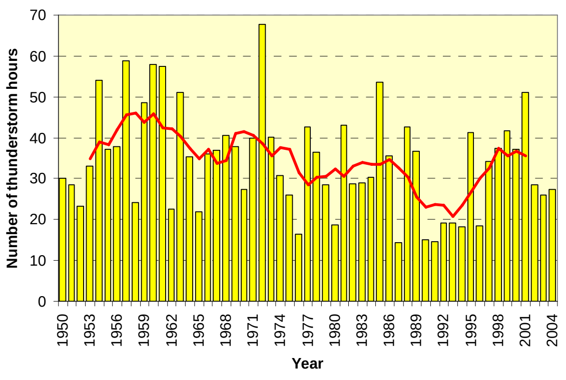

FIG. 2: Annual five-station average thunderstorms duration (columns) and its seven-year moving average (red line) in Estonia, 1950-2004.

In total, 489 southern cyclones were detected within the 1000 km radius circle around Estonia during 1950-2004 Mändla et al., 2011). It was found that 141 or 28.8 per cent of them were related to thunderstorms to Estonia. Our study revealed that 99% of all southern cyclones that caused thunder appeared from April to October. The highest thunder appearance percentages (about 60-80%) in case of southern cyclones found in summer months. In August, even 82.5% of all southern cyclones induced thunder. It is not surprising that most thunderstorms that were associated with southern cyclones occurred during summer months. At this time, air masses that are transported northwards by southern cyclones attain their highest temperatures and water vapour pressures. Thus, their potential to cause thunderstorms is the highest.

Thunderstorms that were associated with southern cyclones constituted only 7.3 per cent of the annual total duration of thunderstorms. This percentage was 8-11 for coastal and inland stations, but only 1 for maritime station Vilsandi. Thus, thunderstorms in association with southern cyclones tended to occur over (or near to) the continental areas and not over the sea.

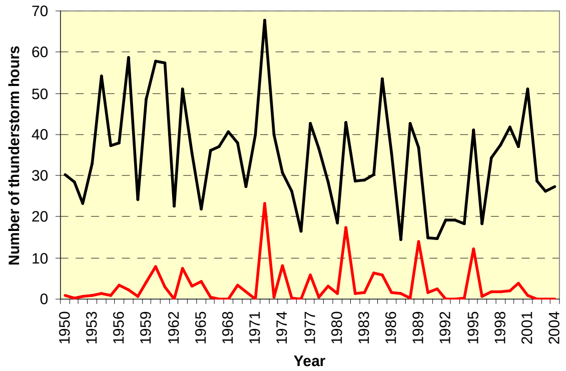

FIG. 3: Annual five-station average total thunderstorms duration (black line) and southern cyclones related thunderstorms duration (red line) in Estonia, 1950-2004.

The percentage of thunderstorms associated with southern cyclones fluctuated remarkably during the 55 study years (Fig. 3). In 1972, 1974, 1981, 1989 and 1995 about 25-41 per cent of annual thunderstorms were associated to southern cyclones. Four of the five years exhibited higher than average thunderstorm activity. It should be noted that, in 1972, there was the highest thunderstorm activity during the study period. Over 34 per cent of thunderstorms recorded in 1972 were associated to southern cyclones. On the other hand, there were many years around 1960, in mid-1980s and around 2000 when the annual number of thunderstorm hours was high but thunderstorms related to southern cyclones were rare. Thus, we can say that high thunderstorm activity in Estonia is usually not caused by the influence of southern cyclones. On the other hand, we should take into account that in some particularly active years southern cyclones can cause more than one third of all thunderstorms.

Although this study revealed that thunderstorms associated with southern cyclones are not very frequent, there are many examples during last two decades when such thunderstorms were remarkably severe in Estonia. Thus, further studies are needed to compare the intensities and damages of thunderstorms associated with southern cyclones with thunderstorms that have developed in different synoptic conditions.

IV. ACKNOWLEDGMENTS

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