SPATIAL AND TEMPORAL DISTRIBUTION OF CLOUD-TO-GROUND LIGHTNING OVER ESTONIA DURING 2005-2008

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I. INTRODUCTION

Development of national and international lightning detection systems during the last decades has made it possible to study thunder climate by using flash density as the main measure. It is more accurate than the classical average annual number of thunder days as it not only reflects the presence of thunder but also gives an overview of the number and spatial distribution of lightning strikes.

Many authors have published regional studies about spatial and temporal distribution of lightning. In Europe, for example, Finland (Tuomi and Mäkelä, 2008a), Sweden (Sonnadara et al., 2006), Iberian Peninsula (Rivas Soriano et al., 2005), Austria (Schulz et al., 2005) and Southern Germany (Finke and Hauf, 1996) are analysed for flash density. In North America, a continental scale lightning detectors network covers most of Canada (Burrows et al., 2002), the United States (Orville and Huffines, 2001; Orville et al., 2002) and the surrounding sea areas.

Estonian Meteorological and Hydrological Institute has been using one lightning detector since the end of 2004. It is located in the Tartu Meteorological Station in south-eastern Estonia. The detector cooperates with NORDLIS (*NORDic Lightning Information System*) detectors in Finland and Sweden (Tuomi and Mäkelä, 2008a) and registers cloud-to-ground lightning on the whole territory of Estonia.

This study gives the first results of spatial and temporal distribution of cloud-to-ground lightning over Estonian territory and the adjacent sea. Data from 2005 to 2008 are used.

II. PRESENTATION OF RESEARCH

Lightning data were obtained from the Finnish Meteorological Institute where the central unit of NORDLIS network is operating. All cloud flashes were removed from the raw data as the detection efficiency for such flashes is estimated to be poor (Tuomi and Mäkelä, 2008a).

In this research, a 10×10 km spatial grid was used to calculate flash densities. The same grid size was used for NORDLIS data analysis in Finland (Tuomi and Mäkelä, 2008a). The grid bases on the Estonian coordinate system. It covers 102 500 km^2 between 57.5-59.8° N and 21.0-28.5° E. Total 122 753 cloud-to-ground flashes were registered in the study area during 2005-2008.

The number of lightning strikes per square kilometre was used as the main characteristic of flash density. Flash density was analysed for the whole four-year period but also year by year and month by month. No corrections for detection efficiency were made in this analysis. The detection efficiency of NORDLIS network in Finland is estimated to be as high as 88.0-99.4 per cent for cloud-to-ground lightning (Tuomi and Mäkelä, 2008b).

In addition to the spatial distribution, a temporal distribution of lightning was studied month by month and day by day. Diurnal variations in lightning occurrence were analysed for the whole study area and also separately for the land and the sea. All strikes over the islands were added to the sea data and all strikes over inland lakes were used as the land data. It was previously checked that diurnal lightning distribution over the biggest island, Saaremaa (area 2700 km^2), was similar to the sea areas, and over the biggest lake, Lake Peipsi (area 3500 km^2), resembled that of the land areas.

III. RESULTS AND CONCLUSIONS

In this study, the annual average flash density map for Estonia during 2005-2008 was compiled (Fig. 1). The annual average flash density for the whole study area was found to be 0.30 flashes km^{-2} y^{-1}, which is a low value in the global scale. However, many other land areas like Finland (Tuomi and Mäkelä, 2008a), Sweden (Sonnadara et al., 2006), Northern and Western Canada (Burrows et al., 2002) and western parts of the United States (Orville and Huffines, 2001) experience similar or even lower values.

The lowest values, less than 0.1 flashes km^{-2} y^{-1} were found over the Baltic Sea in the north-western corner of the study area. The highest values up to 0.8 flashes km^{-2} y^{-1} were found in the south-western part of Estonian land area, west from the Sakala upland. Enhanced lightning activity west from the uplands was also found in north-eastern and south-eastern parts of the country. Although all the uplands are only about 100-200 m above the surrounding areas, it is obvious that the prevailing airflow from the west is forced to rise when crossing such landforms. Development of convective clouds and lightning is advanced on the western i.e. windward sides of uplands. A higher number of lightning flashes over the sea near the north-western and north-eastern coast was occasionally caused by single very intense frontal storms in 2005 and 2007.

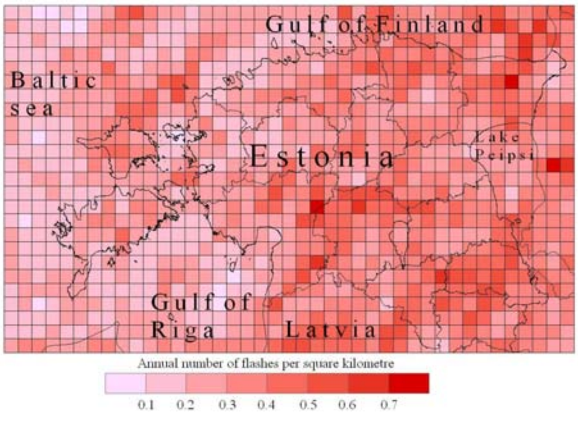

FIG. 1: Annual average flash density in the study area during 2005-2008.

Inter-annual variations in lightning activity are remarkable. The mean flash density over the study area was only 0.17 flashes km^{-2} in 2006, 0.23 in 2008, 0.24 in 2005 and 0.56 in 2007.

Seasonal variations typical for high latitudes were found for Estonia, with the main thunderstorm season occurring from April to October while only few flashes were detected during the cold season form December to March. 99.7 per cent of all flashes occurred during April–October and 94 per cent of the flashes were registered from May to September. Spatial distribution of lightning also differs from month to month. During spring and early summer (from April to July), flash densities are higher over the inland areas which are warmer. From August to November, a number of storms occur over the Baltic Sea as the sea-surface temperature is higher in autumn causing convective airflows. Most of the few lightning events during the wintertime (from December to March) were also registered over the sea.

Daily variations in lightning activity were found to be significant. Few days gave a half or even more of the total number of annual flashes. During 2005-2008, 48-58 per cent of all annual flashes were registered during five most active days. The most active days were 26 and 28 May 2007 with 6300-6500 cloud-to-ground strikes (more than 0.06 flashes km^{-2}) over the whole study area. More than 5000 strikes (over 0.05 flashes km^{-2}) were registered on 22 and 23 August 2007 and 1 October 2006. Such a high activity is always associated with extensive and intense frontal storms. In a typical high-activity situation, warm and humid tropical air lies over Western Russia and reaches to Eastern Estonia. At the same time, Western Estonia is encompassed by much cooler polar air. During the afternoon hours, temperature differences between these air masses can exceed 10 degrees and the development of intense thunderstorms covers large areas.

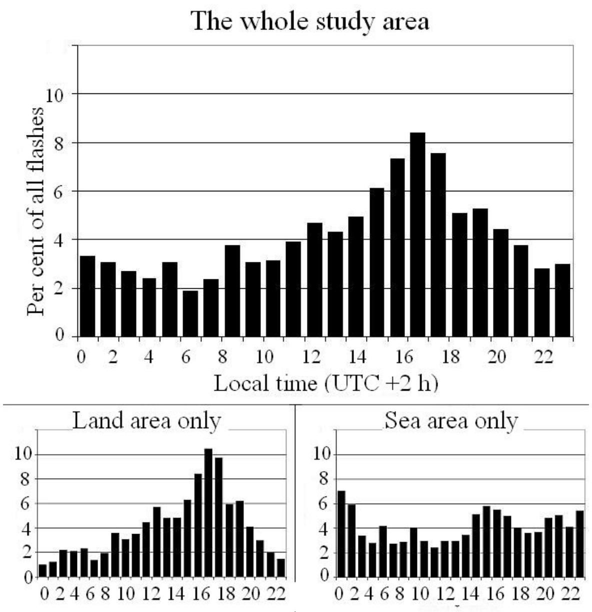

FIG. 2: Diurnal distribution of flashes over the whole study area (up), over land (down left) and over sea (down right).

The diurnal distribution of flashes (Fig. 2) indicates an evident peak during afternoon, between 15 and 17 p.m. local time. A minimum occurs early in the morning, between 3 and 6 hours a.m. It is revealed that large diurnal variations in lightning activity are much larger over the land areas where diurnal temperature fluctuations are remarkable. The night time lightning minimum can easily be explained with the temperature minimum and the afternoon lightning peak coincides with the temperature maximum on the land area. Sea areas as well as islands show a more even diurnal distribution of lightning flashes. However, small maxima appear during afternoon hours, possibly caused by land-generated storms effect near the coastline, and after midnight when the sea surface is comparatively warmer.

IV. AKNOWLEDGMENTS

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