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Thunderstorm Climate of Finland 1998–2007

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Abstract

The ten-year period 1998–2007 of relatively even-quality lightning location data in Finland is summarized into diagrams of spatial and temporal variations. The mean flash density of 0.34 per square kilometre and year is lower than the estimated longest-term, 48-year average of 0.39 available so far, but no clear trends can be drawn. The spatial flash-density distribution varies widely from year to year, but on the average it is concentrated in the central part. Pre-analyzed synoptic weather maps have been used to classify thunderstorms into four frontal and three air mass types, as well as into western (maritime) and eastern (continental) types. Eastern air-mass thunderstorms are the dominant type, both by frequency and intensity, in the most active month July and partly already in June. Otherwise the most frequent type is western frontal, with lower intensity.

Key words: weather, thunderstorm, Finland, lightning location, climate, air mass

1. Introduction

Thunderstorms are an important part of weather, but in climatic studies and summaries they have long had a subsidiary role. For decades, the annual thunder-day number was the only climatic variable representing thunderstorms (e.g. WMO 1956, see *Israel*, 1970). Later, flash counters and more recently lightning location systems have provided more detailed data, not only about thunder days but also flashes. This allows the term "thunderstorm climate" to be defined in more accurate and versatile ways than just thunder days. The most important climatic lightning variable is flash density, calculated for a representative spatial grid. While more or less comprehensive descriptions on lightning location results are published in local reports and bulletins, some ten-year summaries of relatively even-quality lightning location data have also been published in journals (e.g. *Orville and Huffines*, 2001; *Schulz et al.*, 2005). A comparison between thunder days and forest growth has also been made (*Solantie and Tuomi*, 2000). A yearbook of lightning observations (location data) in Finland has been published since 1984, and the latest ones (e.g. *Tuomi and Mäkelä,* 2007, 2008a) are available electronically.

In addition to the primary parameter flash density, lightning location reports may have emphasis on technical matters such as accuracy and detection efficiency, lightning-physical quantities like return-stroke peak current, flash polarity and flash multiplicity, all of which may be considered secondary parameters from the thunderstorm-climatic point of view. The effect of the detection efficiency on the flash-density statistics is a straightforward concept even though the corresponding correction may not be easy. On the other hand, while spatial variations of the secondary parameters may also reflect climatic or topographic effects, their dependence on the inhomogeneities in the performance of the lightning location network is less clear (*Orville and Huffines*, 2001).

The grid size used by *Orville and Huffines* (2001) for flash density (and other parameters) is 0.2 degrees latitude and longitude over the continental United States, so the unit area is close to a square with 20 km side. Interestingly, this size well represents the area covered by a classical thunder-day observer, as well as the area of an actual thunderstorm cell. *Schulz et al.* (2005) use a grid of 1-km squares, which is compatible with the typical accuracy of present-day lightning location systems, but the spatial distribution tends to be noisy because relatively few flashes hit such small areas even during longer periods. Whenever minute topographic details (e.g. masts) need not be considered, a coarser grid would be more suitable for thunderstorm climatology.

The most useful temporal analyses in thunderstorm statistics are diurnal (hour-to-hour), seasonal (day-to-day or month-to-month) and annual (year-to-year) variations. In addition, thunder days equivalent to those recorded by a human observer can be computed from lightning location data using 20 km squares. In a similar way, thunderstorm duration can be estimated statistically by computing thunderstorm hours (flash hours) for these squares (*Huffines and Orville*, 1999).

The lightning location system used in our study is described in Section 2 and the flash statistics are presented in Section 3.

Thunderstorm climatology can be brought closer to the traditional (meteorological) climatology if thunderstorm occurrences are somehow related to the weather conditions. Of course, numerous case studies have been made in this respect, sometimes for more extended periods (e.g. *Livingston et al.*, 1996). A question arises, what are the meteorological/climatological parameters best suited for comparison with thunderstorms. One major criterion is whether meteorological information is used to forecast thunderstorms, or how a thunderstorm, once formed, is associated with the type of weather. In the former case, certain stability indices (e.g. *Huntrieser et al.,* 1997) can be used for forecasting. In the latter case, indices are not the best means for classifying the weather type. For long-term statistics (climatology), the parameters should describe regional or synoptic rather than local weather, and should be simple enough for illustrative classification and tabulation. *Tuomi and Mäkelä* (2003) have chosen the surface polar-frontal activity and the nature of the associated air masses as a basis for synoptic characterization of weather, well suited for the northern European climate. The study covered the years 1998–2002, and Section 4 of the present work extends the period to the ten years 1998–2007.

2. Lightning location system

The Finnish Meteorological Institute (FMI) is a member of the so-called NORDLIS co-operation (NORDic Lightning Information System), where lightning sensor data from Finland, Norway, Sweden and Estonia are shared between the members (Fig. 1). The sensor type is mainly IMPACT (*Cummins et al.*, 1998) or its later successors, presently manufactured by Vaisala, Inc. Only ground flashes are used in this study, and the region considered is the land area of Finland unless stated otherwise. The detection of ground flashes is based on low-frequency (LF) electromagnetic radiation. The system is also capable of detecting cloud lightning, but with poorer detection efficiency and larger regional inhomogeneities, because a large part of cloud-lightning radiation occurs at very high frequencies (VHF) while the LF part is weaker. Efficient detection of cloud flashes would require a dense network with highly sensitive sensors. In the FMI/NORDLIS network, only the three SAFIR sensors (open circles in Fig. 1) are meant for the detection of cloud lightning using VHF measurements, but their small coverage area (SW corner of Finland) restricts the use of the data in this study. The rest of the NORDLIS sensors use low frequencies and apply a relatively simple pulse-width criterion to discriminate between the LF signals of cloud flashes and ground flashes. Preliminary studies of *Tuomi* (2008) and *Mäkelä* (2008) suggest that the cloud flash – ground flash ratio in SW Finland is between 1 and 2.

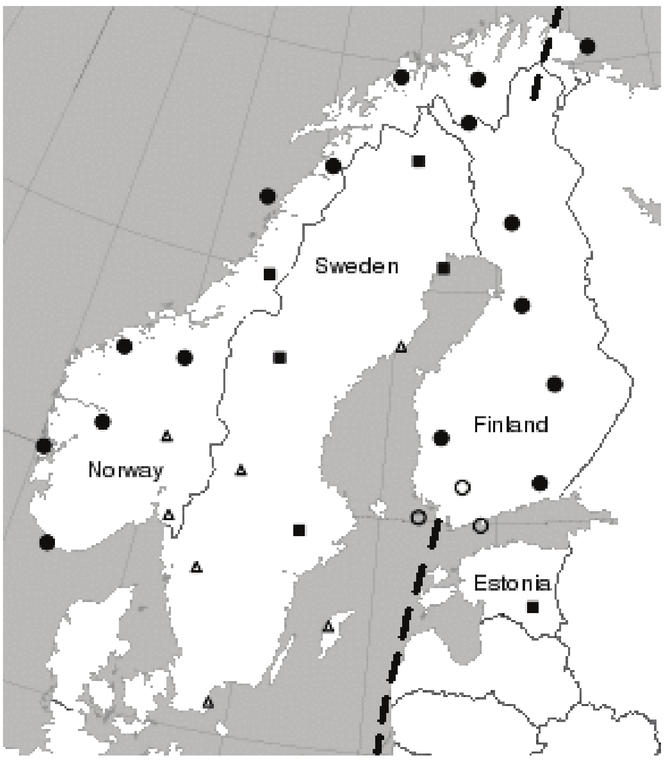

Fig. 1. NORDLIS sensors in 2007: IMPACT ES (black circle), IMPACT ESP (triangle), LS7000 (square), SAFIR 3000 (open circle). The SAFIR sensors and the Estonian sensor were not part of NORDLIS. The thick dashed lines indicate the division into western and eastern sectors as seen from Finland (Sec. 3).

The NORDLIS network has grown gradually since mid-2001 so that the number of sensors available to FMI has increased from five to about 30. The five sensors in 1998–2001 covered most of Finland, excluding a large part of Lapland (apparent in Fig. 3 below). In addition, an increase of sensor gain was made before the year 2000 season, increasing the number of flashes by a factor of 1.35 with respect to years 1998 and 1999. This factor has been taken into account in our statistics. Hence, the detection efficiency has improved, increasing not only the useful area but especially the fraction of weak flashes. It may be mentioned that the identity of weak flashes (roughly speaking, negative flashes weaker than -5 kA, positive flashes weaker than +10 kA) is uncertain: a significant fraction of them may originate from cloud lightning or may be other processes misinterpreted as ground strokes (*Cummins et al.,* 1998; *Biagi et al.,* 2007). We have not selected the data in this sense; while improvements in the network quality may have increased the fraction of weak flashes, changes in the sensor settings have limited their occurrence to some degree in the latest years.

We try to account for the changes in the detection efficiency in the following way. Accurate analyses are difficult to make, and often very rough corrections are applied; e.g. *Huffines and Orville* (1999) have assumed a constant detection efficiency of 70 % in the U.S. The 2007 level of the detection efficiency of the NORDLIS network over the area of Finland is assumed 96 %, based on the results described in *Tuomi and Mäkelä* (2008a, b). In 2000 and 2001 the average ground-flash detection efficiency (excluding Lapland) was around 80 %, but at that time the ground-flash data contained also some unidentified cloud flashes, improving the apparent detection efficiency. In addition, because the area-averaged flash density estimate of Finland for the earlier period 1998–2001 excludes Lapland, where the flash density is generally lower, the average is biased towards a higher value. This bias compensates for the lower level of the detection efficiency of that period. We believe the compensation is effective enough to provide reasonably even statistics, without further refinements between years. A similar conclusion is assumed for thunder days, which generally show smaller variations than flash density.

3. *Flash statistics*

The surface area of Finland, excluding the open waters of the Baltic sea, is about 377,000 square kilometres. Although we consider here the thunderstorm climate of the ten-year period 1998–2007, Fig. 2 shows the year-to-year variation of flash density for the 48-year period 1960–2007. It is based on a combination of a flash-counter network period 1960–1986, the first FMI lightning location system in 1987–1997, and the present FMI/NORDLIS network since 1998. The matching of the three different systems is not easy, and a degree of uncertainty remains in addition to the problem of the changing detection efficiency discussed above. The long-term (1960–2007) average annual flash density is 0.39 flashes/km^2, which corresponds to about 150,000 ground flashes. The two most active years were 1972 (flash density 1.1) and 1988 (1.0). The average of the recent ten-year period is only 0.34 because in the last three years the number of flashes has been only about half the average. Fig. 2 shows also the 48-year variation of the annual thunder-day number, whose 48-year average is about 12, being close to 15 in the central part of Finland and below 10 in the north. For the last ten years, it is based on flash occurrence on 20 km squares. Of the two highly variable curves in Fig. 2, flash density appears to have a slightly decreasing trend and thunder-day number grows slowly, but considering the uncertainties discussed above, the reality of the trends is difficult to assess, especially as they are opposite; therefore we have not drawn them.

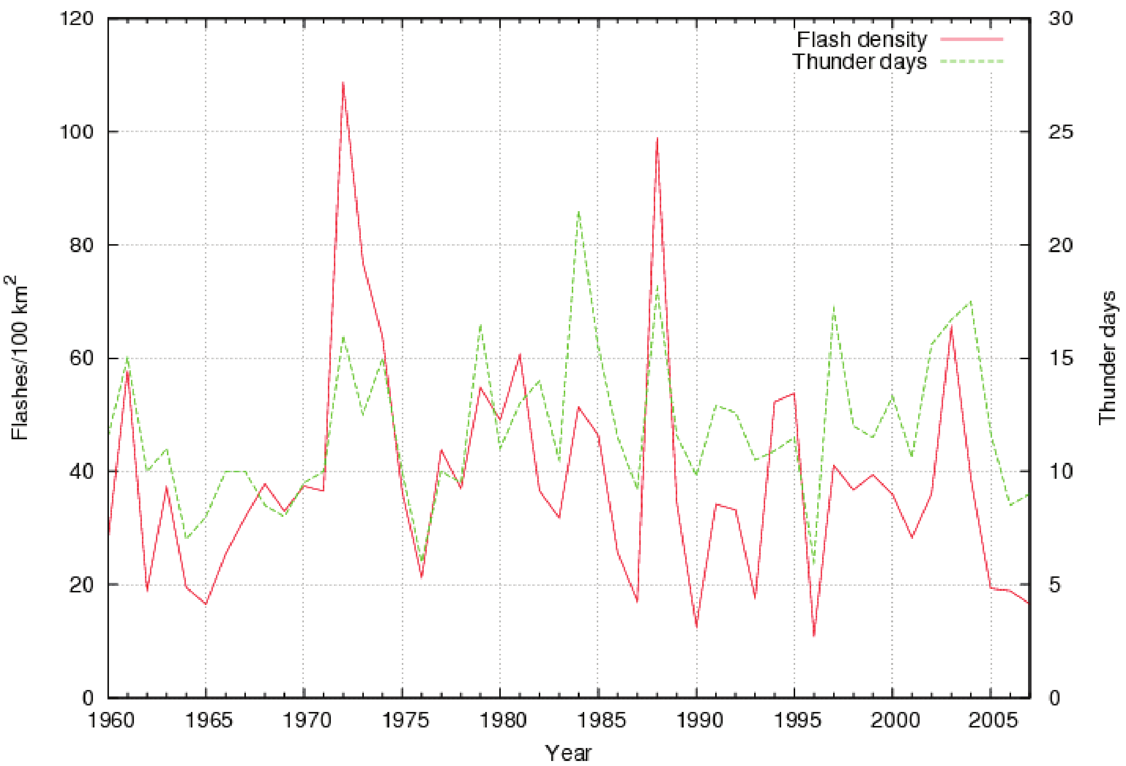

Fig. 2. Estimated year-to-year flash density (red, solid) and thunder-day number (green, dashed) in Finland, based on flash counters and two generations of lightning location systems.

In addition to thunder days, flash hours can be computed by recording every starting hour when a flash occurs within an observing area. The result, computed for the latest ten-year period for the 20-km squares, is that the number of flash hours is about twice the number of thunder days, i.e. on the average, a thunderstorm observed on a fixed site is over within 2 hours. *Huffines and Orville* (1999) compute a flash hour by recording every starting 15-min period when a flash occurs and dividing the number by 4; for our data, this would lead to slightly less than one flash hour per thunder day. We prefer our method because it is perfectly analogous with the thunder day.

The spatial variation of the annual mean flash density, separately for each year 1998–2007, is presented in Fig. 3. Instead of the 20 km size mentioned above, these maps have 10 km squares, which give a slightly more detailed but not too noisy variation. The limits for different colours have been chosen so that the contrast would be optimal (i.e. roughly equal areas of each colour normally), but the unusually low activity of the last three years is reflected in the relatively low area covered by the violet colour. Northern Lapland is adequately covered only since 2002. The average of these ten maps is given in Fig. 4 (the colour scale differs from that of the individual years in Fig. 3, because density peaks tend to smooth out in the average). The reference grid is based on a Finnish map system, the indicated coordinates being in units of kilometres. The mean flash density in Lapland, north of 7400, is based on the six latest years 2002–2007. The average spatial pattern shows that the middle region has the highest lightning activity. However, its north-western part includes a large contribution from year 2003, which had an unusual occurrence of stagnant air-mass thunderstorms in that region. The south-eastern part, on the other hand, has a significant contribution from all years. This is due to an eastern weather type, further discussed below with the synoptic classification.

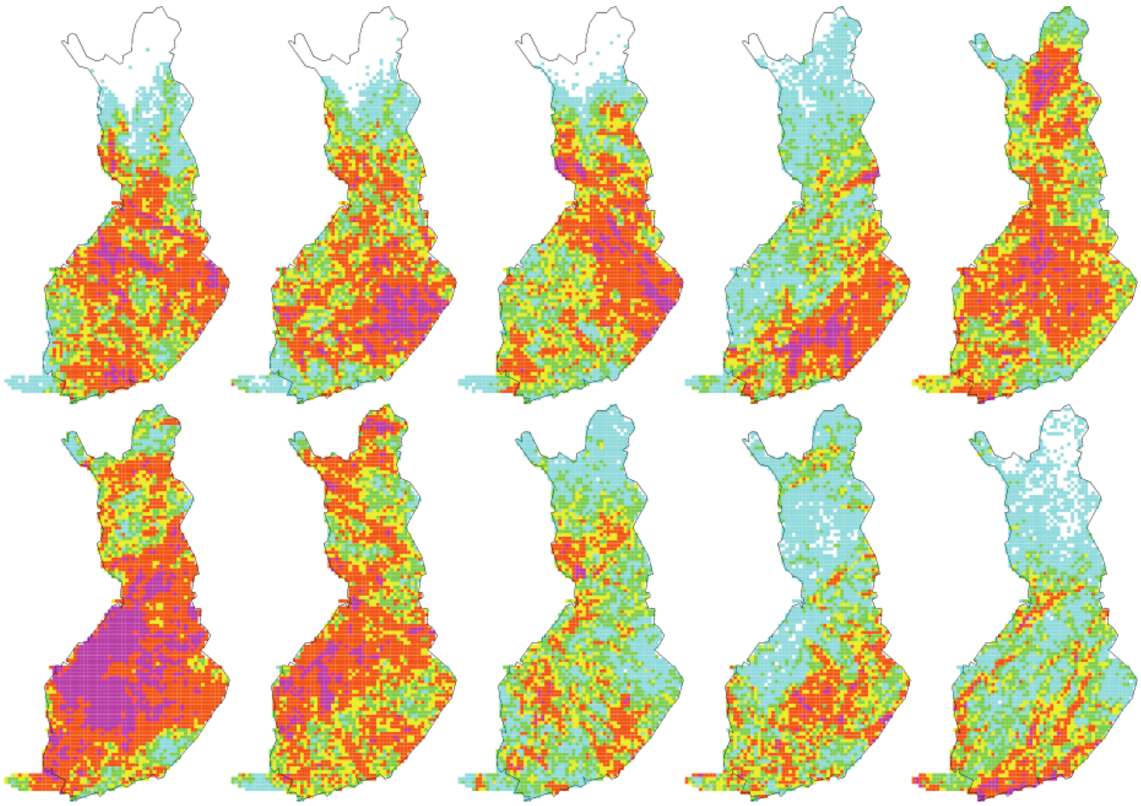

Fig. 3. Annual flash density. Upper from left: 1998–2002; lower: 2003–2007. The colour scale is: blue 1–10, green 11–20, yellow 21–30, red 31–80, violet 80– flashes per 100 km^2. Square size is 10 km. Northern Lapland was not covered by the system in 1998–2000 and partly in 2001.

The southern and south-western coastal areas have relatively low flash density. The reason for this is most probably the vicinity of the sea which remains relatively cool until late June or early July and therefore weakens the conditions for deep convection. Violent and spectacular thunderstorms do occur also there, but their rare occurrence suppresses their weight in the ten-year average. Also, apart from the sea coastal zones, the general spatial variation of flash density (even in a map with 1-km resolution, not shown) does not have an obvious correlation with the topography, which contains numerous small lakes and low hills. Possible topographic influences would require a detailed and perhaps case-oriented study or a time series of more than ten years (the spatial accuracy before 1998 was too poor for this).

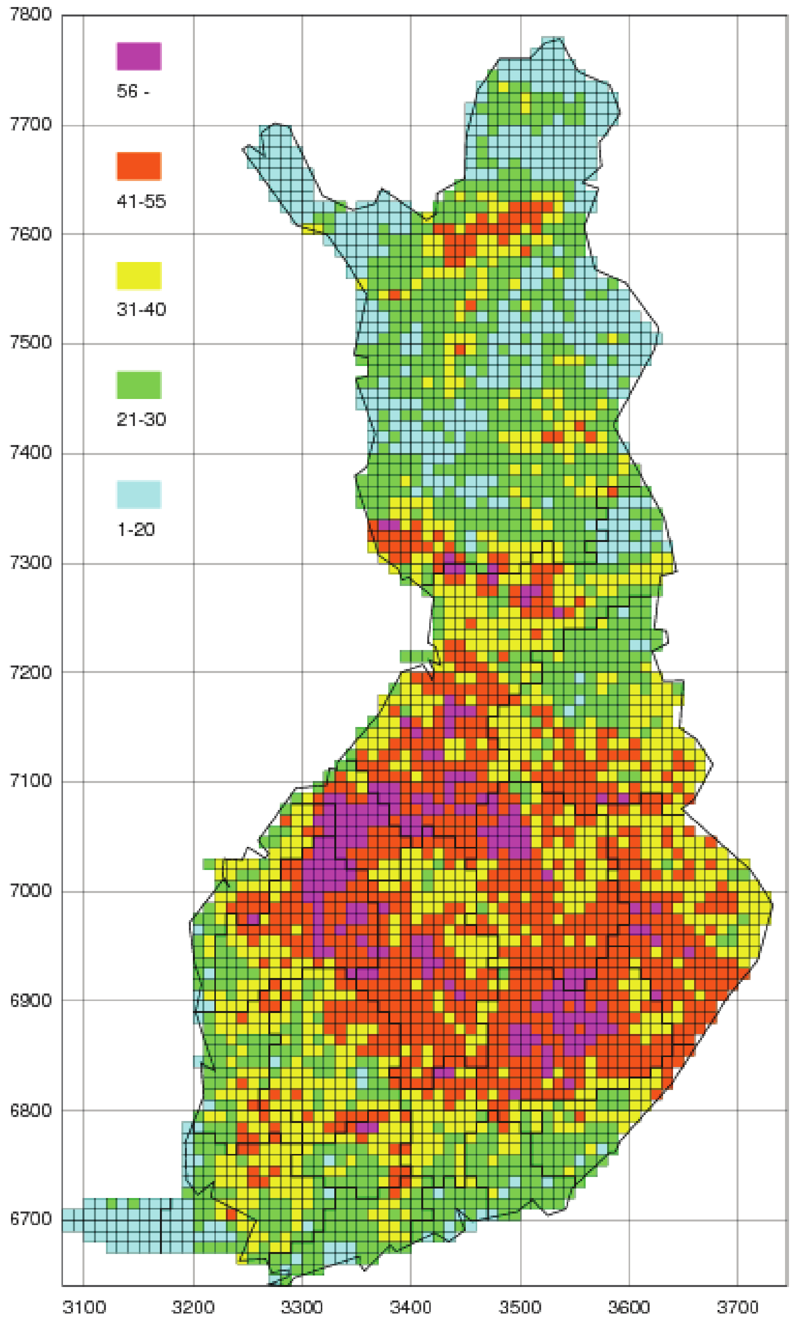

Fig. 4. Ten-year mean 1998–2007 of the spatial variation of flash density on 10 km squares shown in Fig. 3. Grid numbers (km) refer to a Finnish coordinate system. Lapland (north of 7400) contains only the last six years 2002–2007 for better representativeness.

The average day-to-day variation of the flash density is shown in Fig. 5. The season in the figure is limited to May–September. Very low activity may occur in April and October, sometimes even in November. For each day, the number is a ten-year average. The season may be said to start in May, usually with a couple of more active days rather than gradually. The season intensifies after mid-June, reaches its peak at mid-July and fades out by the beginning of September. We will see in the next section that the most active month, July, also signifies a change in the synoptic conditions.

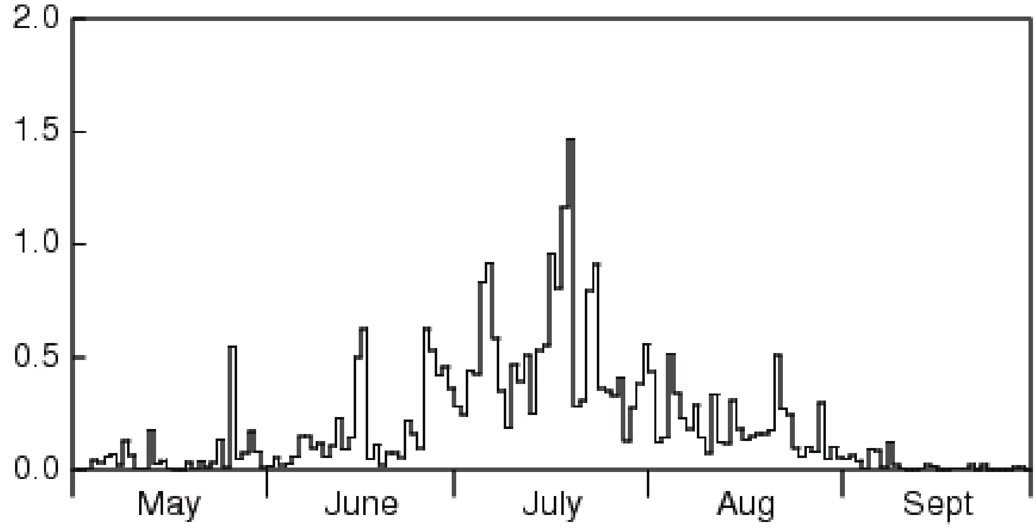

Fig. 5. Ten-year mean 1998–2007 of the day-to-day variation of flash density, averaged over the country. The y-axis unit is flashes/100 km^2. The highest daily peaks for individual years are about 5.5 flashes/100 km^2, corresponding to about 20,000 flashes within the country.

Fig. 6 shows the diurnal variation of the number of flashes. Land area (left) is approximately that given e.g. in Fig. 4, and the seas (right) are the two arms of the Baltic Sea close to the Finnish coasts (cf. Fig. 1). Over land, the nighttime is rather quiet until about local noon (9 UTC) and reaches the peak at 15–17 local time. Over the seas, the average activity is relatively constant. Because the sea-surface temperature has little diurnal variation, the afternoon intensification occurring over land is absent; thunderstorms developing over the warm water in late summer may occur in any time of the day. Thunderstorms developing either in Sweden (SW) or Baltia – eastern Europe (S) in the afternoon arrive in Finland late in the evening, and it often happens that a thunderstorm, active over the sea, soon dissipates after entering the land. Indeed, the hourly distribution over land is skewed towards the evening, the tail disappearing by midnight. A sea effect is also present in the day-to-day variation: if Fig. 5 is plotted for the sea (not shown), the July peak disappears and the activity is relatively constant from late May to early September.

Although the diurnal variation is very similar from year to year, some differences may occur; e.g. in 2007 (not shown) there is a secondary peak in the night-time (at about 3 am local time) which is due to the large fraction of frontal storms (see Table 1 below). In the ten-year average (Fig. 6) these less frequently occurring features smooth out and the average diurnal variation follows the course of solar heating.

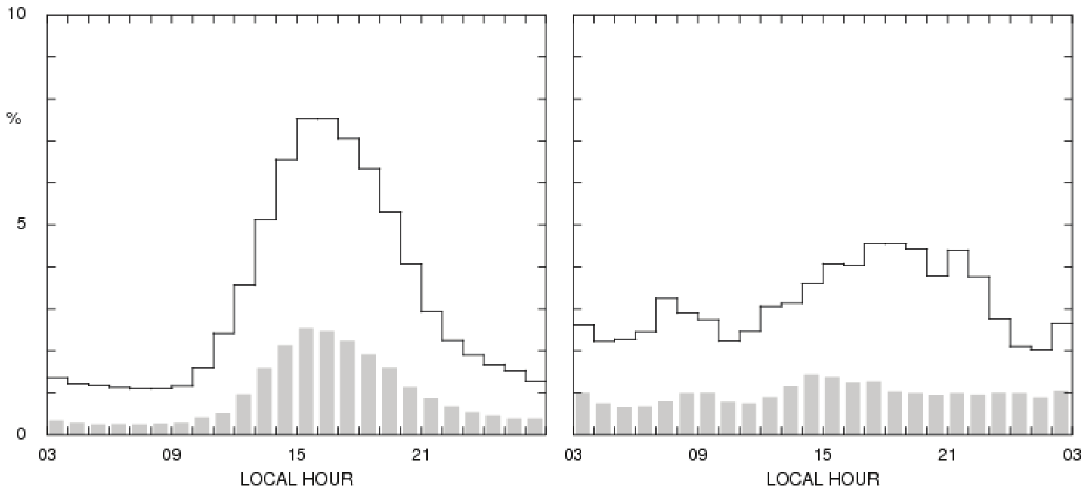

Fig. 6. Diurnal variation of negative (line) and positive (bar) flashes in land area (left) and seas (right). The vertical scale is hourly percentage of the total number of flashes. 15 h local time is 12 UTC.

Table 1. Classification of the annual thunderstorm systems into the four frontal and three air-mass types. See text for explanations.

year		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
cold	cases	3	8	8	4	10	8	10	11	9	6	7.7
front	fl/case	5000	2688	1525	1150	4190	4900	2360	2418	3089	3317	3017
	fl %	15.9	19.6	12.3	6.1	35.2	17.1	17.8	43.3	46.6	39.3	22.6
warm	cases	4	1	0	0	1	3	4	1	1	5	2
front	fl/case	3425	1800	0	0	800	2567	2050	4400	500	2320	2435
	fl %	14.5	1.6	0	0	0.7	3.4	6.2	7.2	0.8	22.9	4.7
occl.	cases	1	4	1	2	3	3	9	5	8	6	4.2
front	fl/case	1500	1775	1500	2300	1667	2600	1033	2020	1200	1217	1519
	fl %	1.6	6.5	1.5	6.1	4.2	3.4	7	16.4	16.1	14.4	6.2
stat.	cases	2	7	4	5	5	5	2	6	0	1	3.7
front	fl/case	2750	5186	5350	1460	1360	4100	1450	1733	0	4500	3124
	fl %	5.8	33.1	21.6	9.7	5.7	9	2.2	16.9	0	8.9	11.2
front	cases	10	20	13	11	19	19	25	23	18	18	17.6
	fl/case	3570	3335	2700	1500	2868	3958	1760	2239	2106	2406	2616
	fl %	37.8	60.9	35.5	22.0	45.8	32.9	33.2	83.7	63.6	85.4	44.7
warm	cases	6	8	10	4	7	17	15	1	3	1	7.2
mass	fl/case	3583	2963	3590	1500	4129	6188	3753	1000	2133	500	3964
	fl %	22.8	21.6	36.3	8	24.3	46	42.5	1.6	10.7	1	27.7
polar	cases	7	6	6	2	12	3	6	4	3	7	5.6
mass	fl/case	2371	1950	1333	1600	1550	3133	2033	825	1433	986	1682
	fl %	17.6	10.7	8.1	4.3	15.6	4.1	9.2	5.4	7.2	13.6	9.1
squall	cases	4	3	4	10	8	7	10	1	5	0	5.2
line	fl/case	5175	2500	5000	4920	2200	5557	1990	5700	2200	0	3650
	fl %	21.9	6.8	20.2	65.7	14.2	17	15	9.3	18.5	0	18.4
air-	cases	17	17	20	16	27	27	31	6	11	8	18
mass	fl/case	3459	2524	3195	3650	2385	5685	2852	1667	1973	925	3163
	fl %	62.2	39.1	64.5	78.0	54.2	67.1	66.8	16.3	36.4	14.6	55.3
total	days	20	29	29	25	39	39	49	29	27	25	31.1
	cases	27	37	33	27	46	46	56	29	29	26	35.6
	fl/case	3500	2962	3000	2774	2585	4972	2364	2121	2055	1950	2893

4. *Synoptic classification*

The traditional observation that thunderstorms may have different characteristics depending on the direction of arrival or other weather-dependent factors led *Tuomi and Mäkelä* (2003) to seek a means to classify the thunderstorm situations as mentioned in the Introduction. The synoptic factors are those presented on an analysed surface weather map: polar fronts (cold, warm, stationary and occluded) and air masses (polar and mid-latitude). Air-mass thunderstorms may have a number of causes for their development, but we restrict ourselves to three broad classes: polar thunderstorms in polar air mass, usually north of the polar-frontal zone; warm-mass thunderstorms in the warm sector or similar mid-latitude air mass; and the special case of a surface trough, usually within the pre-frontal warm sector. The trough line is not included in ordinary surface maps, but is shown in U.K. MetOffice 00 UTC maps. We call the latter case here squall-line thunderstorms. Thus we do not make meteorological analyses but use pre-analysed, relatively simple information on the synoptic weather.

We define a "case" as follows: a thunderstorm (or a system of simultaneous thunderstorms associated with the same conditions) occurs within Finland, producing at least 500–700 flashes, depending on how scattered the situation is; one, two or even three cases may occur during a day (and in some cases, a "day" may extend over the midnight). The corresponding flash density would depend on what area the thunderstorm covers or traverses, but we are now interested in a more integral measure and use here just the number of flashes as was done in *Tuomi and Mäkelä* (2003). In a strict sense, a thunderstorm (situation) could be characterized by the spatial distribution of the flash density, which could be used to calculate a kind of index for the intensity. For the present purpose, we use just the number of flashes, subjectively choosing on a map those flashes that appear to belong to the case. A thunderstorm with a few flashes is hardly useful here, and the lower limit of 500–700 flashes for an interesting case is also judged subjectively. We may note that a thunderstorm could also be characterized in terms of its cell structure (e.g. *Tuomi and Larjavaara,* 2005; *Tuomi and Mäkelä,* 2008c), in a more or less similar manner as with the flash density.

We look at the weather map to identify the type of front or air mass associated with the thunderstorm as well as the "origin" or history of the air mass, including the front-associated air masses. The geography of Finland suggests a two-part division of arrival directions of thunderstorms, indicated by the two dashed lines in Fig. 1. The western sector extends from SSW, i.e. the Baltic Sea between Sweden and Estonia as seen from Finland, through W up to NNE, and the rest is the eastern sector. The western sector is characterized by maritime air from the North Atlantic, either directly or by a detour via western Europe; the SW direction has a dominant role in the weather of Finland. The eastern sector is more continental in nature, and in the summer season the air mass during "eastern episodes" flows to Finland mainly from S (Estonia) or SE (e.g. Russia), and eventually from Balkan and the Black Sea. The practical line of division between the two sectors in the south is the eastern coast of the Baltic Sea, as also indicated in Fig. 1. The exact NNE opposite has little significance because thunderstorms virtually never come to Finland from N or NE.

Tables 1–3 are ten-year extensions of Tables 1–3 of *Tuomi and Mäkelä* (2003). Table 1 shows the year-to-year synoptic classification of the thunderstorm cases. The rows give the four frontal types and three air-mass types, and their totals. In this table, W-E division is not made. The intensity or activity of the thunderstorms is expressed by the average number of flashes per case (fl/case), and fl %, the fraction of the flashes of the total amount of the column, measures the relative importance of the synoptic type along with its frequency (number of cases). It can be seen, for instance, that cold front is the dominant type for frontal thunderstorms and warm mass is the most usual type for air-mass thunderstorms; in addition, air-mass cases as a whole are equally frequent but slightly more active than fronts in the production of thunderstorms. Stationary fronts are sometimes effective (1999–2000, 2005), but may be difficult to distinguish from cold fronts. Polar thunderstorms are relatively frequent but quiet or scattered, as are also warm and occluded-front storms. From the "total" row it can be seen that during the five-month season, noticeable thunderstorms (with at least 500 ground flashes) occur every five days on the average, producing an average of 3000 flashes. In reality, most of these days are less active while a few have much more flashes.

Table 2 resolves the total frontal and air-mass cases into the western and eastern sectors. All four classes contain 8–10 cases, but the eastern air-mass thunderstorms A(E) are the most effective, producing one third of all flashes; the number 4310 flashes/cases is by far the largest. The second largest is F(E), eastern frontal storms.

Table 2. Classification of the annual thunderstorm systems into western (W) and eastern (E) air-mass (A) and frontal (F) types.

year		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	mean
A(W)	cases	5	9	10	11	23	7	20	5	9	2	10.1
	fl/case	1620	2533	1400	1945	1987	3900	3290	860	2022	650	2266
	fl %	8.6	20.8	14.1	28.6	38.4	11.9	49.7	7	30.5	2.6	22.2
A(E)	cases	12	8	10	5	4	20	11	1	2	6	7.9
	fl/case	4225	2513	4990	7400	4675	6310	2055	5700	1750	1017	4310
	fl %	53.7	18.3	50.4	49.4	15.7	55.2	17.1	9.3	5.9	12	33.1
F(W)	cases	5	10	6	8	16	8	11	11	12	9	9.6
	fl/case	2000	2520	1700	1563	2706	3713	1545	1636	2583	1544	2196
	fl %	10.6	23.0	10.3	16.7	36.4	13	12.8	29.3	52	27.4	20.5
F(E)	cases	5	10	7	3	3	11	14	12	6	9	8.0
	fl/case	5140	4150	3557	1333	3733	4136	1929	2792	1150	3267	3120
	fl %	27.2	37.9	25.2	5.3	9.4	19.9	20.4	54.5	11.6	58	24.2
total	cases	27	37	33	27	46	46	56	29	29	26	35.6
	fl/case	3500	2962	3000	2774	2585	4972	2364	2121	2055	1950	2893

The monthly distribution of thunderstorms is shown in Table 3. In June, the total number of flashes is normally close to the average of July and August, but for the last years June has been unusually inactive. Hence the total activities of June and August are similar in this ten-year period (about 75 cases and 2500 flashes/case). However, June has higher stationary-front activity while August is more active with cold fronts; and the most intense thunderstorms of August are associated with warm air mass. Also, June has a more eastern nature than August. The eastern influence is culminated in July: although both sectors have a similar frequency (80 and 88 cases), the number of flashes/case is a factor of 2.2 larger for the eastern cases, and this is mainly due to air-mass thunderstorms. The frontal activity (flashes/case) is relatively even through May–August. Interestingly, one of the very active eastern air-mass cases, 5 July 2002, has been studied in detail by *Punkka et al.* (2006) and interpreted as a *derecho*, a kind of long-lived, fast-moving destructive thunderstorm.

Table 3. Monthly occurrences of the different types of thunderstorm systems. The cases are summed over the ten years.

month	98-07	May	June	July	August	Sept	total
cold fr	cases	5	14	36	17	5	77
	fl/case	4180	1514	3353	3394	2360	3017
warm fr	cases	4	5	6	3	2	20
	fl/case	3050	2820	2283	2400	750	2435
ocl. fr	cases	3	8	15	14	2	42
	fl/case	900	1225	2053	1350	800	1519
stat. fr	cases	3	16	12	5	1	37
	fl/case	800	3919	3408	1720	1000	3124
front	cases	15	43	69	39	10	176
	fl/case	2547	2507	2987	2369	1590	2616
w-mass	cases	5	9	47	11	0	72
	fl/case	1720	1767	4353	5118	0	3964
polar	cases	1	12	24	16	3	56
	fl/case	1300	2075	1583	1663	1133	1682
squall	cases	3	12	28	8	1	52
	fl/case	3267	3300	4154	2838	1400	3650
air-mass	cases	9	33	99	35	4	180
	fl/case	2189	2436	3625	3017	1200	3163
western	cases	13	41	80	49	14	197
	fl/case	3038	1690	2060	2967	1479	2232
eastern	cases	11	35	88	25	0	159
	fl/case	1673	3397	4548	2104	0	3711
total	cases	24	76	168	74	14	356
	fl/case	2413	2476	3363	2676	1479	2893

5. *Conclusions*

This study summarizes the lightning location results in Finland from the ten-year period 1998–2007, during which relatively even-quality lightning data have been available. A time series from a 48-year period, matching data from flash-counters and two generations of lightning location systems, is also presented, although the match is certainly not perfect. A period of ten years, or even 48 years, would in any case be rather short for an evaluation of a possible impact of climate change, but considering that homogeneous lightning measurement periods so far (except those of thunder days only) are generally much shorter than periods of meteorological observations, it may be allowable to speak of "lightning climatology" here. This povides a basic characterization of Finnish thunderstorms against which coming years can be compared.

The treatment is separated into two parts: plotting temporal and areal variations of the flash data as such, and dividing the data into different meteorological categories, called here synoptic classification. The latter has been made as simple as possible, in order to find features that correspond to common experiences with thunderstorms, e.g. the relative occurrence of western and eastern cases and the difference in their violence.

There is a large year-to-year variability in the total thunderstorm activity of Finland (Fig. 2). In 2005–2007 a negative trend is apparent but the behaviour of the whole 48-year period suggests that the quiet phase may be only temporary. Record years like 1972 and 1988 are missing in the later years, hardly being challenged by year 2003. The regional variability is also large (Fig. 3), and it is partly related to the dominance of the western and eastern nature of the weather in summer.

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