P2.11

LARGE CURRENT FLASHES IN CANADA

B. Kochtubajda*, W. R. Burrows , B.E. Power

Environment Canada, Edmonton, Alberta, CANADA

1 INTRODUCTION

The range of lightning flash discharges associated with thunderstorms in the atmosphere varies from low current intra-cloud occurrences to large cloud-to-ground events with peak currents of several hundred kA. Large current lightning flashes (LCLFs) are of particular interest because of the potential impact they have on such sectors as the forestry and the electric power sectors. Furthermore, large peak current cloud-to-ground lightning flashes from MCCs have been shown to be associated with sprites and elves in the High Plains-upper Midwest region of the United States (Lyons et al. 1998). In this study LCLFs were defined as flashes with peak currents > ±100 kA. Evidence has also been presented for the probable chance of observing sprites above winter storms occurring over the Gulf Stream southeast of Nova Scotia (Price et al. 2002). Therefore, an LCLF climatology would help identify areas where there is an increased likelihood of elves and sprites occurring over the Canadian landmass and the potential for enhanced ground damage.

Although, Canadian studies of lightning climatology have been published (Burrows et al. 2002), none have examined the climatology of LCLFs. The objective of this study is to advance our understanding of the nature of LCLFs over Canada through an examination of their spatial and temporal distributions with the aid of GIS technology.

2 DATA

The Canadian Lightning Detection Network (CLDN), established in 1998 as the first ever national lightning network in Canada, is a hybrid configuration of 26 IMPACT-ES and 2 IMPACT-ESP sensors and 55 LPATS-IV sensors. The IMPACT sensors integrate the Time-Of-Arrival (TOA) and Magnetic Direction Finding (MDF) lightning detection methodologies, while the LPATS are strictly based on TOA lightning detection methodology. Detection efficiency of CG flashes is 85-90% or better within the CLDN to approximately 200km of the periphery, decreasing to 80% at the periphery. Beyond the periphery detection efficiency decreases to approximately 10-30% at 300km, where high peak current events are detected but low peak current events are missed. Median stroke location accuracy is 500m or better (Burrows et al. 2002). Further information on detection methodologies can be found in Cummins et al (1998).

Six years (1999-2004) of CLDN data were examined for flashes with peak currents > ±100 kA. The flash characteristics used in this study include time of occurrence, location, polarity, and multiplicity (number of strokes). The Canadian landscape is diverse and spans many eco-climatic regimes including the Cordilleran zone of the Pacific, the Grasslands zone of the prairies, the Boreal, the Sub-Arctic, Arctic and Temperate zone of eastern Canada (Figure1). CLDN data were retrieved from the Environment Canada archives and LCLFs were extracted for latitudes between 41N and 75N and longitudes between 55W and 141W. Using GIS software, only those flashes which fell within the borders of Canada's landmass were selected. The data was then sorted based on their location with respect to the Canadian eco-zones for further analyses. All flashes that occurred over the Great Lakes and ocean bodies were excluded from the analyses.

3 CHARACTERISTICS OF LARGE CURRENT LIGHTNING FLASHES

Analysis of over 12 million cloud-to-ground flashes during the 6-year study period

---

* Corresponding Authors Email: bob.kochtubajda@ec.gc.ca

indicates that LCLFs are rare occurrences, comprising 0.6% of the annual cloud to ground flashes detected over the Canadian landmass. Table 1 summarizes the annual cloud to ground flashes during the study period. It was found that the polarity characteristics of LCLFs differ markedly from that of the lightning population. An examination of the polarity of LCLFs reveals that about 51% are positive compared to the total cloud to ground flashes where 17.5% are positive.

Although LCLF occurrences in all eco-zones behave as expected (maximum in summer and minimum in winter), the peak positive flashes frequency does not necessarily follow this same pattern. Figures 2a and 2b illustrate the seasonal distribution of positive and negative LCLFs respectively in flashes 400km^{-2}. Though large current flashes are observed throughout the year, distinct seasonal and geographical differences in their distribution are observed (Table 2).

In the Cordilleran eco-zone, we found that highest percentage of positive LCLFs per season occurred in the winter. This peak is due largely to an area on the west coast of British Columbia (Figure 2a). An analysis of the annual peak current strengths reveal that a maximum peak positive strength of +540.0kA in central BC and a maximum peak negative strength of -537.1kA in the region of Lethbridge, Alberta were recorded in the spring.

In the Boreal eco-zone, spring marks the peak in positive LCLF occurrence reflected by an area of increased activity in the south-eastern portion of Manitoba (Figure 2a). The lowest fraction of positive LCLFs occurs in the summer (Table 2). Areas in north-eastern Alberta and in northern Ontario exhibit an increase in summertime negative LCLF activity. Summer peak current strengths of +574.1KA and -529.1kA were detected in north-western Alberta and west central Manitoba, respectively.

Positive strength LCLFs are dominant in all seasons, except winter over the Grasslands eco-zone (Table 2). A region in the south western portion of Manitoba shows a relatively high concentration of positive LCLFs in the spring (Figure 2a). It should be noted that the strongest negative flash of the study period was recorded in mid-spring in area of Swift Current Saskatchewan, with a peak current of -598.0kA. The peak positive LCLF current of +574.0kA was measured near Swift Current, Saskatchewan in the spring.

An area of LCLF activity along the southern coast of Hudson Bay characterizes the Arctic and Sub-Arctic eco-zones. On an annual basis, LCLFs exhibit an overall tendency toward negative polarity; a reversal of the trends detected in the southern eco-zones. Positive LCLFs are dominant in the spring and fall (Table 2). The strongest positive flash of the study period was recorded in the summer near Churchill, Manitoba, with a peak current of +596.0kA, while the highest negative peak current flash was detected in spring in northern Québec with a value of -411.5kA. It should be noted that the detection efficiency of the CLDN over much of the Arctic eco-zone is <50%, therefore the LCLF occurrence in this eco-zone is likely to be underestimated.

Finally, in the Temperate eco-zone, the highest percentage of positive LCLFs occurs in the winter. The maximum positive peak current of +378.9kA was recorded in the summer, near the south coast of Georgian Bay. However, a peak negative current of -376.2kA was measured in the vicinity of Lake Ontario in the fall.

The temporal distribution across the Canadian landmass is largely affected by the timing of the snowmelt on the land cover. Initially, more flashes are detected over the Grasslands and Boreal eco-zones in the early spring months and over the Sub-Arctic in the late spring. In the summer months, LCLFs have been detected as far north as Southampton Island in the northern Hudson Bay. With the southward passage of the Arctic front in the early fall, comes a decrease in LCLF occurrence in the Arctic and Sub-Arctic eco-zones followed by the rest of the eco-zones.

Analyses of the average stroke multiplicity also reveal seasonal and geographic differences. Most of the LCLFs with multiplicity of ≥ 10 are associated with negative cloud to ground flashes and detected in all seasons except winter over several areas of the country (Table 3). Positive flashes with multiplicities ≥ 10 are rare and have only been detected in the summer primarily over the Boreal eco-zone of central Alberta and Saskatchewan.

Analyses of the diurnal distributions reveal two peaks of activity occurring in the early mornings (9-12 UTC) and late afternoons (20-01 UTC) during all seasons except winter (Figure 3). The secondary peak is evident in both the spring and fall seasons. Burrows et al.(2002) demonstrated that there exists a secondary peak in the diurnal cycle of overall lightning activity in the Great Lakes region. Therefore, it could be this signature being seen as the secondary peak in the LCLF diurnal cycle.

SUMMARY AND CONCLUSIONS

This study examined the characteristics of large current cloud-to-ground lightning flashes (LCLF) recorded by the Canadian Lightning Detection Network (CLDN) across Canada's landmass. We have defined LCLFs as flashes with peak currents ≥ ±100kA.The occurrence of LCLFs in Canada comprise 0.6% of the total annual lightning activity. The spatial, temporal and polarity characteristics of LCLFs across Canada's landscape reveal distinct seasonal and geographic differences.

In the winter months, the majority of LCLFs are detected along the Pacific coast of the cordilleran zone and temperate zone of eastern Canada. The timing of snowmelt on the land cover influences the distribution during spring as more flashes are initially detected over the grasslands and boreal zones in the early spring months and over the sub-arctic in the late spring. The greater part of annual LCLFs occurs during the summer. Some flashes have been detected as far north as Southampton Island in northern Hudson Bay. The southward passage of the Arctic front in early fall diminishes LCLF occurrence over the arctic and boreal zones.

Analyses of the diurnal distributions reveal two peaks of activity occurring in the early mornings (9-12 UTC) and late afternoons (20-01 UTC) during all seasons except winter. Most LCLFs with multiplicity ≥ 10 are associated with negative CG flashes which were detected in all seasons except winter over several areas of the country. Positive flashes with multiplicity ≥ 10 have only been detected in the summer principally over the Boreal zone of central Alberta and Saskatchewan.

ACKKNOWLEGEMENTS

The authors thank Monique Lapalme for her help with processing the CLDN data.

REFERENCES

Burrows, W.R., P. King, P.J. Lewis, B. Kochtubajda, B. Snyder, and V. Turcotte, **2002**: Lightning occurrence patterns over Canada and adjacent United States from lightning detection network observation *Atmosphere-Ocean,* **40 (1),** 59-81.

Cummins, K.L., M.J. Murphy, E.A. Bardo, W.L. Hiscox, R.B. Pyle, and A.E. Pifer, **1998**: A combined TOA/MDF technology upgrade of the U.S. National Lightning Detection Network. *J. Geophys. Res*. **103**, 9035-9044

Lyons, W.A., M. Uliasz and T.E. Nelson, **1998**: Large peak current cloud-to-ground lightning flashes during the summer months in the contiguous United States. Mon. Wea. Rev. 126, 2217-2233.

Price, C., W. Burrows and P. King, **2002**: The likelihood of winter sprites over the Gulf Stream. Geophys. Res. Lett, 29(22), 2070, doi:10.1029/2002GL015571.

Table 1: Annual summary of CG lightning data and polarity characteristics

Year	Total	%Pos	LCLF	%Pos
1999	2219334	16.2	14110	47.9
2000	2217016	19.8	14681	44.4
2001	2163621	19.9	13447	52.8
2002	2015998	16.6	9950	57.1
2003	1831983	16.5	9110	57.7
2004	1819391	15.6	14838	51.5
Total	12267343	17.5	76136	51.1

Table 2: Annual and Seasonal LCLF Characteristics Stratified by eco-zone

	Annual		Spring		Summer		Fall		Winter	
	Total	% Pos	Total	% Pos	Total	% Pos	Total	% Pos	Total	% Pos
Cordillera	13251	55.4	1033	46.5	11462	56.0	671	57.4	85	64.7
Boreal	38882	48.4	3216	76.6	31750	44.3	3873	58.6	43	72.1
Grassland	9990	64.2	896	78.9	8463	62.1	631	71.0	-	-
Sub-Arctic	8717	42.6	418	67.5	7685	39.8	612	59.6	2	50.0
Arctic	246	24.4	6	33.3	228	24.1	12	25.0	-	-
Temperate	5050	51.3	1295	72.6	2809	37.1	887	63.7	59	74.6
Total	76136	51.1	6864	71.0	62397	47.9	6686	60.4	189	69.3

Table 3: LCLFs with multiplicity ≥ 10 stratified by eco-zone

	Spring		Summer		Fall	
	Positive	Negative	Positive	Negative	Positive	Negative
Arctic	-	-	-	-	-	-
Sub-Arctic	-	-	-	15	-	1
Cordilleran	-	-	1	33	-	1
Boreal	-	2	4	155	-	8
Grassland	-	4	-	82	-	6
Temperate	-	2	-	23	-	2

Figure 1

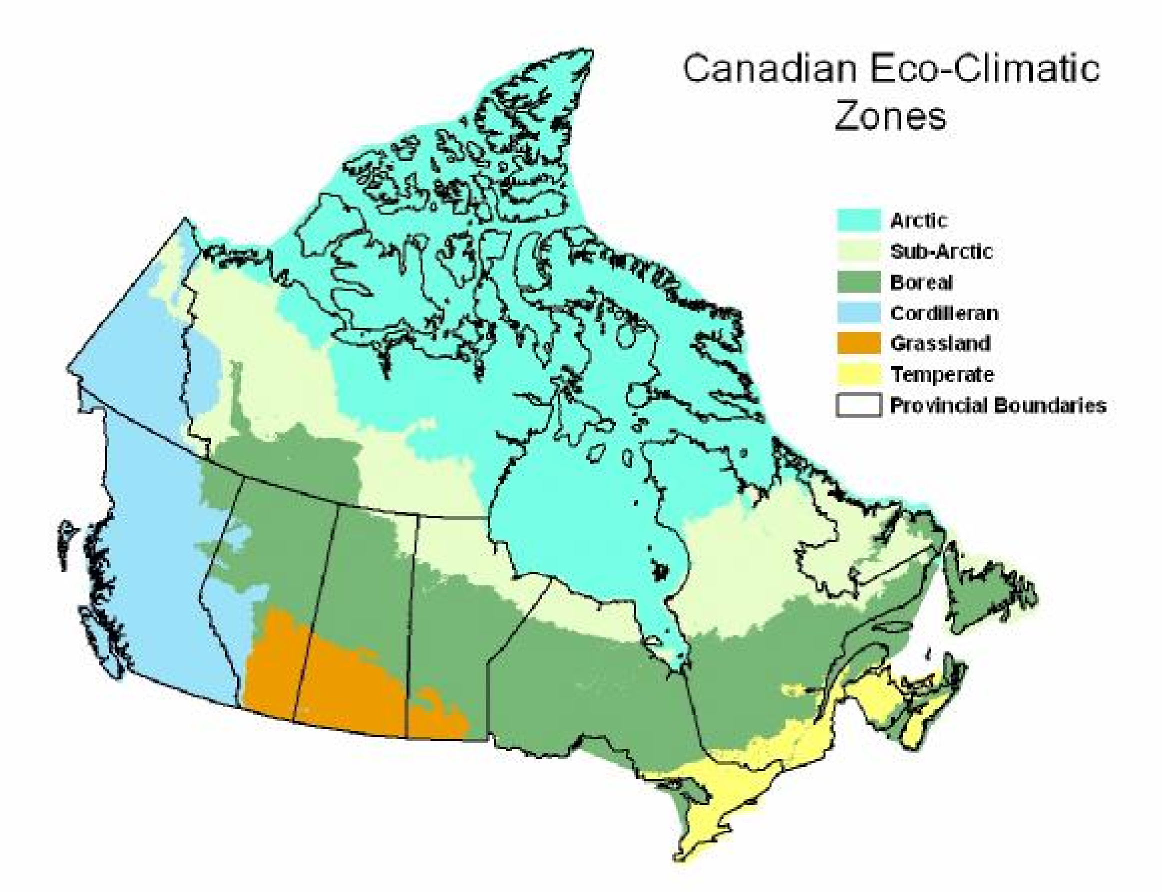

Canadian Eco-Climatic Zones
Arctic
Sub-Arctic
Boreal
Cordilleran
Grassland
Temperate
Provincial Boundaries

Figure 2a: Seasonal distribution of Positive LCLFs

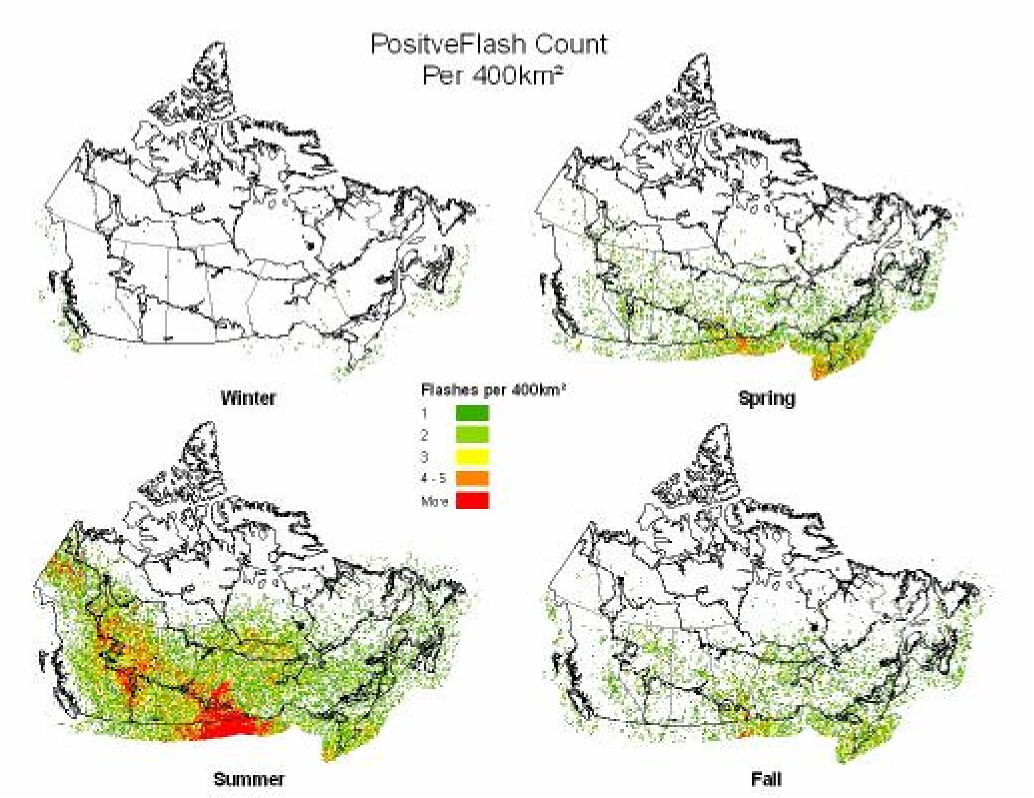


Figure 2b: Seasonal distribution of Negative LCLFs

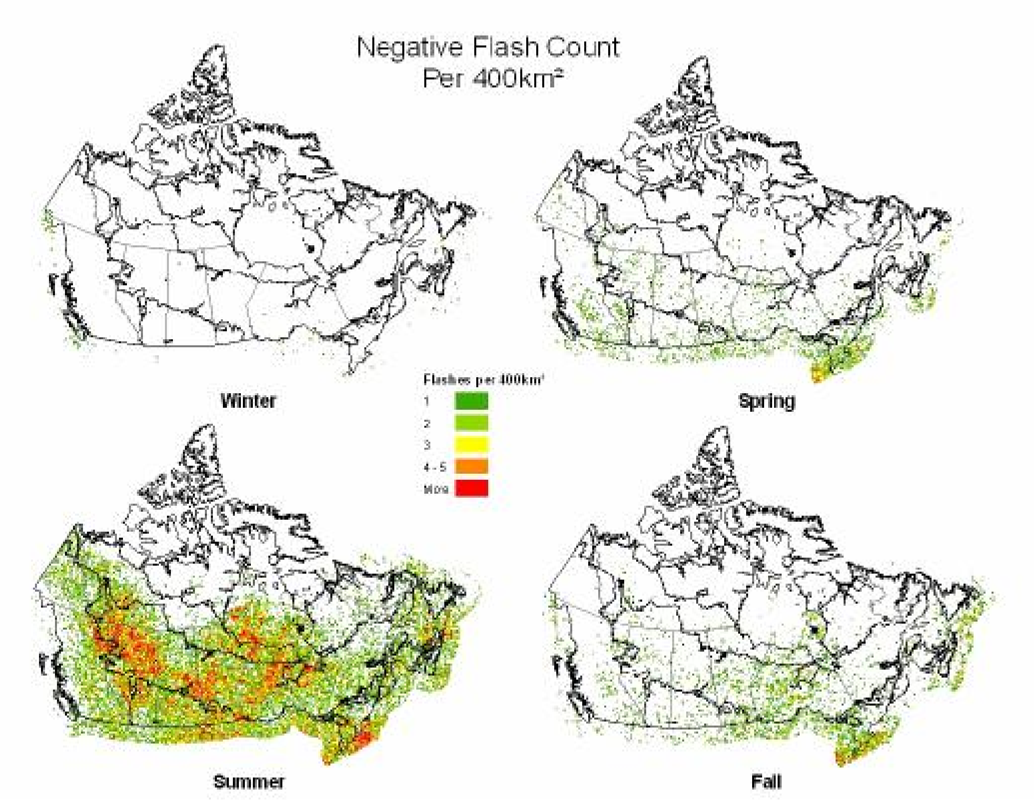
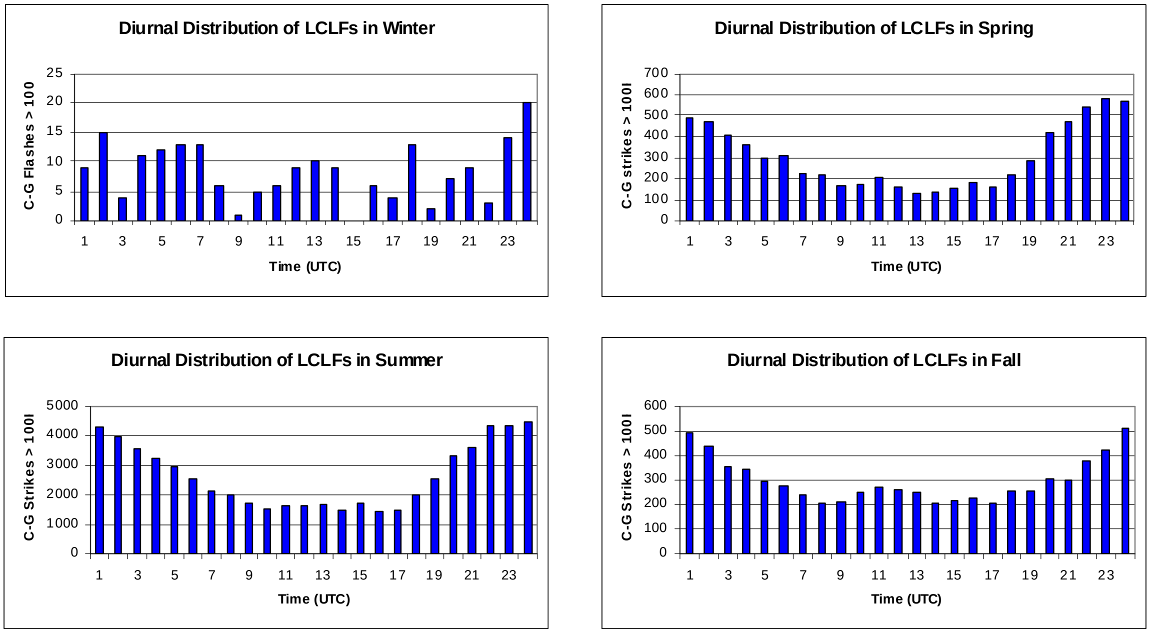


Figure 3: Seasonal Diurnal Distribution of LCLFs



Diurnal Distribution of LCLFs in Winter

Diurnal Distribution of LCLFs in Spring

Diurnal Distribution of LCLFs in Summer

Diurnal Distribution of LCLFs in Fall