P1.9 A CLIMATOLOGY AND THE INTRA-SEASONAL VARIATION OF SUMMERTIME CLOUD-TO-GROUND LIGHTNING IN MAINLAND ALASKA

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1. INTRODUCTION

Despite most of mainland Alaska being near or above the Arctic Circle, numerous thunderstorms are observed there every summer. Studies have been attempted in the past, but only broad conclusions were put forward, mainly owing to a dearth in reliable lightning data. With the recent expansion of the Bureau of Land Management (BLM) Lightning Detection Network (LDN), a detailed climatology can be produced from the eight years of Cloud-to-Ground (CG) lightning data from 2000 to 2007. The benefits of the climatology are two-fold. First, areas prone to high amounts of CG-lightning can be monitored more closely for thunderstorm development. Secondly, climatology is a useful benchmark from which to measure the accuracy of CG flash forecasts which have recently started to be routinely produced. While not directly affecting many people on the ground in this remote area, the abundance of pine forests puts the state at an increased risk of lightning started fires, which can reach enormous sizes given the vastness of the landscape.

The purpose of this paper is to present a summary of lightning climatology in Alaska from data gathered during 2000-2007. "Typical" season results, absolute and relative maximum and minimum areas will be discussed. Furthermore, a detailed analysis of the magnitude and spatial variations and trends over the course of the lightning season will be discussed.

2. BACKGROUND

The first work to identify areas prone to lightning was done in the 1970's by William Trigg, a Weather Bureau forecaster at the time. In his work, he divided mainland Alaska into several zones based on average temperature and moisture patterns during the summer, with the goal of identifying climatologically favored zones for fire development. While using an indirect method of working toward a lightning climatology, since lightning is a leading cause of natural fires, his microclimate work pinpointed areas where relatively warm and moist conditions needed for thunderstorm development are predominant.

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Later, Gary Grice, from of the WSFO Fairbanks office at the time, began detailing the thunderstorm climatology of Alaska. At the time, the most reliable data sources were various forms of airplane patrols, fire and NWS observing stations, and for the last couple years of the study, early radar and satellite data (Grice and Comisky 1976). Using two week periods, Grice showed that thunderstorms started to occur during the latter half of May in east-central Alaska, and slowly expanded in coverage and magnitude until peaking during the beginning of July. From mid-July onwards, thunderstorm coverage decreased rapidly through the middle of August. Afterword, thunderstorm activity is isolated at best.

In the early 1990s, Ron Reap's work with the 1986 and 1987 lightning seasons using the first LDN in Alaska showed a strong diurnal variation in the lightning magnitude and expanded on Grice's earlier work. Lightning activity peaked from 21UTC until 03 UTC while being an order of magnitude lower during the overnight and early morning hours (Reap, 1991). In Alaskan time, (UTC-8 hours during the summer) 00UTC-03UTC corresponds to 4-7 PM and is at and slightly past the hottest time of the day on average. While peak local time is similar to the continental US, the result is not trivial, given the latitude of mainland Alaska and its smaller diurnal variation in solar insolation during the course of the day.

3. DATA

Data for this study were obtained from the Alaska BLM LDN of eleven lightning direction sensors located throughout Alaska and from six sensors located in the Yukon Territory operated by the Canadian Lightning Detection Network. For proprietary reasons, only strikes west of 141° West longitude, the Alaska/Canadian border, were included in this study. The BLM network was upgraded at the end of the previous decade, increasing detection efficiency across the state which should lead to a better understanding of the lightning patterns across the state. The sensors are concentrated in the middle of the mainland, between the high altitude Alaska Range to the south and the Brooks Range in the north. A lack of sensors north of the Brooks Range reduces detection efficiency in the North Slope area, while five sensors divided between southwest Alaska and the area south of the Alaska Range provide coverage in these regions. The six sensors located in the middle of the state lead to very good detection efficiency in this traditionally favorable area for lightning.

4. METHODOLOGY

The initial format for the lightning strike data was ASCII text. The data were formatted with strike location in latitude and longitude listed to one-thousandth of a degree, time listed to the nearest second. The data were then plotted in three hour long bins using FORTRAN and GEMPAK on a 45 km x 45 km grid with North Pole stereographic projection (AWIPS 216 grid). Next, for each grid box, all three hour bins in each day were summed together to get daily totals. Furthermore, all the in each month were summed together to get monthly totals. Lastly, all the strikes for each day individually over the eight year period were added and averaged in order to create a time-series of lightning strikes for the entire season.

In addition, grids were created containing the percentage of days a box received lightning as the season progressed. For smoothing purposes, this was done in five day periods in which the day in question and two days immediately before/after were grouped together. For this study, a successful event is defined as one flash.

5. RESULTS

a) Overall Spatial Distribution

There were approximately 725,000 lightning strikes in Alaska from 2000 to 2007, of which 2007 accounts for a remarkable 200,000 strikes, or 27% of the total strikes. Figure 2 depicts the total number of flashes per 45 km grid box from 2000 to 2007. The highest flash counts are located in the east central portion of the state near 65° 146° W with a peak of 4450 strikes per grid box. The climate of this region is continental in nature characterized by short warm summers where mean maximum temperatures can range from 68 to 72 degrees F (Grice and Comisky 1976). Noticeable local minima of lightning activity occur over the tall mountains of the Alaska Range in south central portion of the state and in a 1500 flash area near 64° N 147° W that is nearly surrounded by areas receiving anywhere from 2500 to 4500 strikes. South of the Alaska Range is a maritime influenced region where Anchorage is located. In this region, flash counts steadily increase over the foothills of the Alaska Range heading inland. Elsewhere, lightning is fairly uncommon on the Seward Peninsula, of which the northern part receives little precipitation over the year (Trigg 1971) and on the North Slope located north of the Brooks Range. For the North Slope, flash counts steadily decrease to the north in part due to detection efficiency diminishing but also in part due to the increasing influence of the Arctic Ocean, particularly north of 69° N latitude. Lastly, extreme southeast mainland Alaska receives few if any lightning strikes owing to the extremely mountainous terrain of the area.

While thunderstorms occur almost every day in central Alaska during the summer, the area of peak activity from Fig. 2 receives lightning from 30% to 40% of days at the peak of the season in the first week of July (not shown). Looking at the season as a whole for nearly all time periods, there is small area near 63° N 142° W that leads the state in percentage of days with lightning (Fig. 3) but only receives roughly half the lightning strikes of the maximum peak region of CG lightning activity, This suggests that while thunderstorms occur on more days in this particular area, they tend to be less electrically active when they do occur.

b) Intra-Seasonal Trends by Month

The Alaskan lightning season is relatively short and marked by sharp increases and decreases in flash rates on either side of the first half of July, consistent with previous work (Reap 1991). However, Figure 4 illustrates new insights to the conventional wisdom. When plotted, a time series of the eight year aggregate strike counts averaged over five days shows a bi-modal distribution. The two peaks are located around June 14 and July 10, with a noticeable local minimum centered on June 22 that lasts for about a week. This is not an artifact of a couple of big lightning days in one or two years, rather most years between 2000 and 2007 demonstrate this pattern (not shown).

The preferred areas for lightning development shift over the course of the season. During the month of May, the eight year total for flashes has a peak of nearly 400 flashes per grid box in east central Alaska (not shown), nearly twice has much as anywhere else. Furthermore, lightning is almost exclusively confined in an east-west belt between the two mountain ranges. For the month of June (Fig. 5), lightning activity expands to encompass nearly the entire mainland with the notable exception of the mountainous areas of extreme southeast Alaska. The highest flash densities are still located in the east central part of the state, between 64° and 66° N, and east of 154° W where toward the end of the month, the mean amount of flashes experienced per day approaches ten (not shown).

July (Fig. 6), the peak calendar month for lightning activity, is very similar to June, but with slightly higher flash volumes. However, there is one key difference. During July, significant activity expands toward the southwest part of the state. In grid boxes that contained around 250 flashes over the eight year period during June, 1000 to 1250 flashes were experienced during the month of July over the same period. August (Fig. 7) confirms this trend toward the southwest. The earlier peak in the east central part of the state has waned substantially except for a small area near the Canadian border, while the highest grid box counts are now located in the southwestern part of the mainland. The shift is dramatic, as the June and July maximum areas in eastern Alaska of roughly 2000 strikes is a relative minimum of only 25 to 50 strikes in August while totals in the southwest part of the state change little. However, the August strike totals statewide pale in comparison to the totals of either June or July. By September, lightning activity is limited to very isolated strikes as insolation rapidly declines, and for the most part confined in a north-south belt along 156° W between 62° N and 67° N (not shown).

c) Diurnal Trends

Earlier work demonstrated the main source of lightning in Alaska is the convection spawned by peak solar insolation in the afternoon (Reap 1991). Analysis of the 2000-2007 lightning seasons (Fig. 8) confirms this conclusion, as lightning activity for the nine hours between 21UTC and 06UTC (1-10 PM local time), accounts for 80% of all the lightning observed in Alaska. While not surprising, the nature of the high-latitude summer with its 20 hour or greater long days called for an investigation to determine if those longer days altered the typical timeframes for thunderstorm development. It should be noted though, that nocturnal lightning is not impossible in Alaska. During the peak of the season in early July, it is not uncommon to have a few consecutive days where flashes occur at all hours of the day or night, particularly on high flash count days. Although lightning activity is still sharply diminished during the overnight hours, the presence of nocturnal lightning suggests that other factors besides solar insolation play a role in thunderstorm development. It should also be noted, that outside of a couple isolated flashes, nocturnal lightning outside of mid-June to mid-July is a rare event.

6. SUMMARY AND CONCLUSIONS

Located near and above Arctic Circle, mainland Alaska experiences a brief, but noteworthy lightning season that peaks in early July. Most of the activity occurs in the central and southwest part of the state where maximum daily temperatures routinely top 70 degrees F during the summer. The central part of the state is the overwhelming preferred area for lightning during the early and middle of the season, but starting in July, lightning activity begins to shift southwestward. By August, east central Alaska is nearly dormant leaving the majority of activity in the southwest part of the state, but at sharply reduced levels to those seen in June or July.

Lightning in Alaska is for the most part driven by the heating of the day, as evidenced by the maximum activity in the early afternoon hours, and 90% of the activity takes place in the 12 hour period from 21UTC-09UTC. The ramping up of lightning activity during the afternoon hours is also faster than the decrease of activity during the late evening hours which suggests thunderstorms initiate quickly, but once started, the storms take longer to wind down.

7. ONGOING AND FUTURE WORK

Developing a lightning climatology of Alaska was the first step toward developing a perfect-prognosis forecast system that produces probabilistic three hour lightning forecasts. In the perfect-prognosis system, training data from archived model output is compared to observed lightning during the same time period in order to find correlations between atmospheric conditions at the time and the observed lightning (Bothwell and Buckey 2009). In short, parameters that correlate well enough are used to produce a regression equation that inputs data from the model and outputs a percentage chance of lightning occurring in that grid box for each three hour forecast period. Climatology will be used as a baseline to determine the significance of the forecast. Forecasts below climatology should be a predictor of less than normal lightning activity, while forecasts above climatology could be a sign of an active day.

8. REFERENCES

Bothwell, P. and D. Buckey, 2009: Using the Perfect Prognosis Technique for Predicting Cloud-to-Ground Lightning in Mainland Alaska, *Fourth Conference on the Meteorological Applications of Lightning Data,* Phoenix, AZ. Amer. Meteor. Soc..

Grice, G. K. and A.L. Comisky, 1976: Thunderstorm Climatology of Alaska. NOAA Technical Memo. NWS AR-14, 36 pp. [Available from Alaska Region Headquarters, 222 West 7th Ave. No. 23, Anchorage, AK 99513-7575.]

Reap, R. M., 1991: Climatological Characteristics and Objective Prediction of Thunderstorms over Alaska. *Wea. and For.,* 6, 309-319.

Trigg, W. M., 1971: Fire Season Climatic Zones of Mainland Alaska. USDA Forest Service Research Paper PNW-126, 22 pp. [Available from Pacific Northwest Research Station 333 SW First Ave. Portland, OR 97204.]

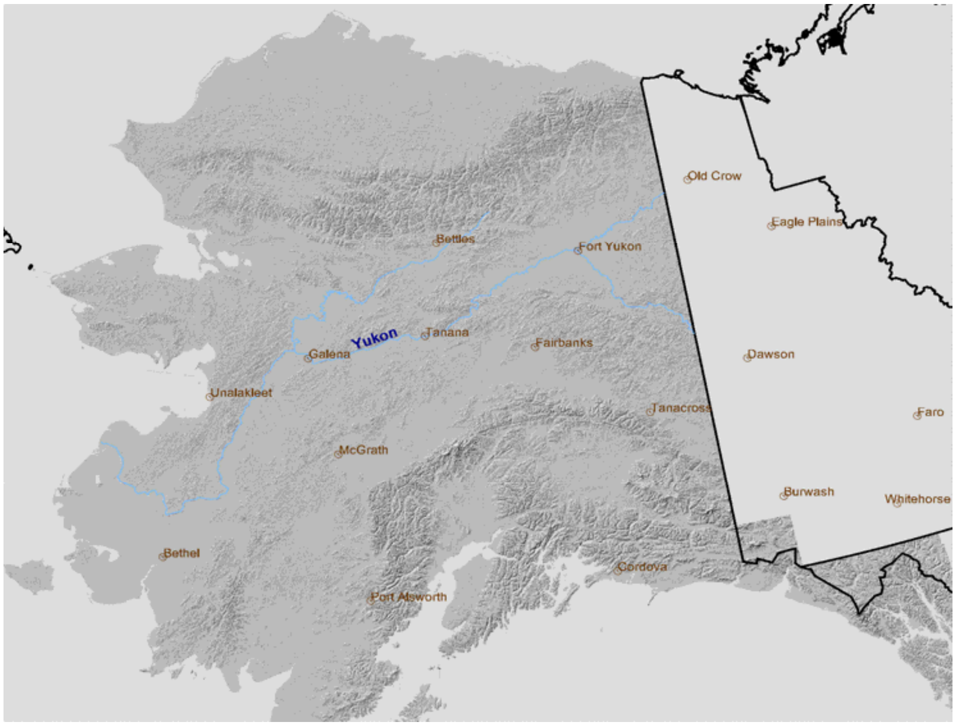

Figure 1. Map of the detection finders used for locating lightning in Alaska.

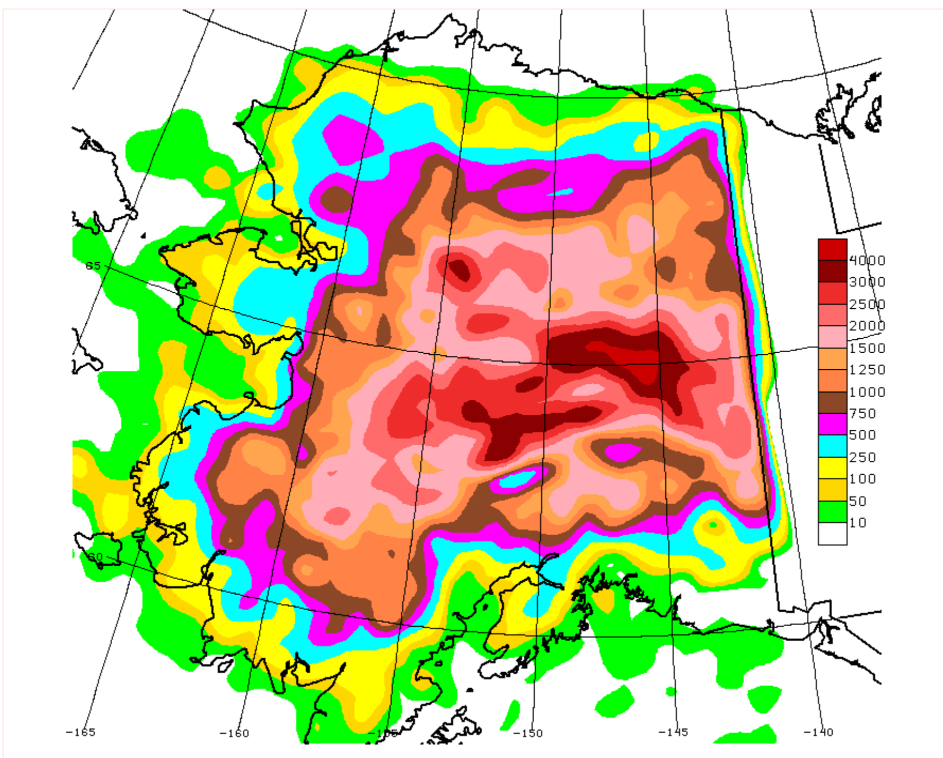

Figure 2. Total CG strikes per 45 km grid box for all months. Color values range from 0-4000+. Note: All data for locations east of 141° W (Canada) was excluded from this study.

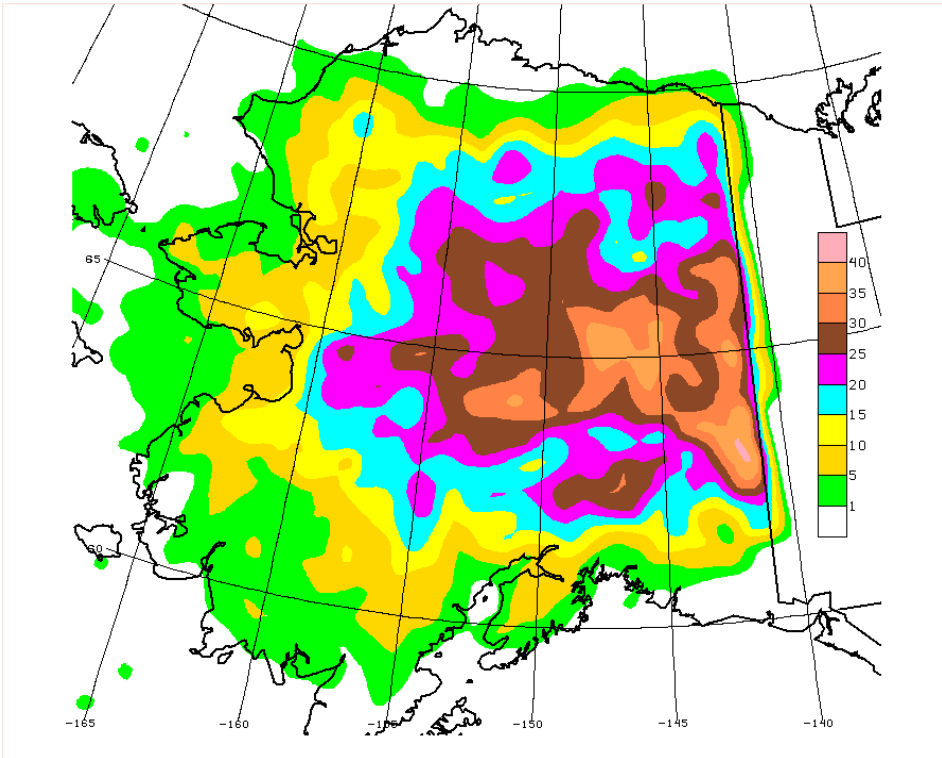

Figure 3. Percentage of days between July 4th and July 8th that a grid box received CG lightning from 2000 to 2007. Color values range from 0-40 in units of 5.

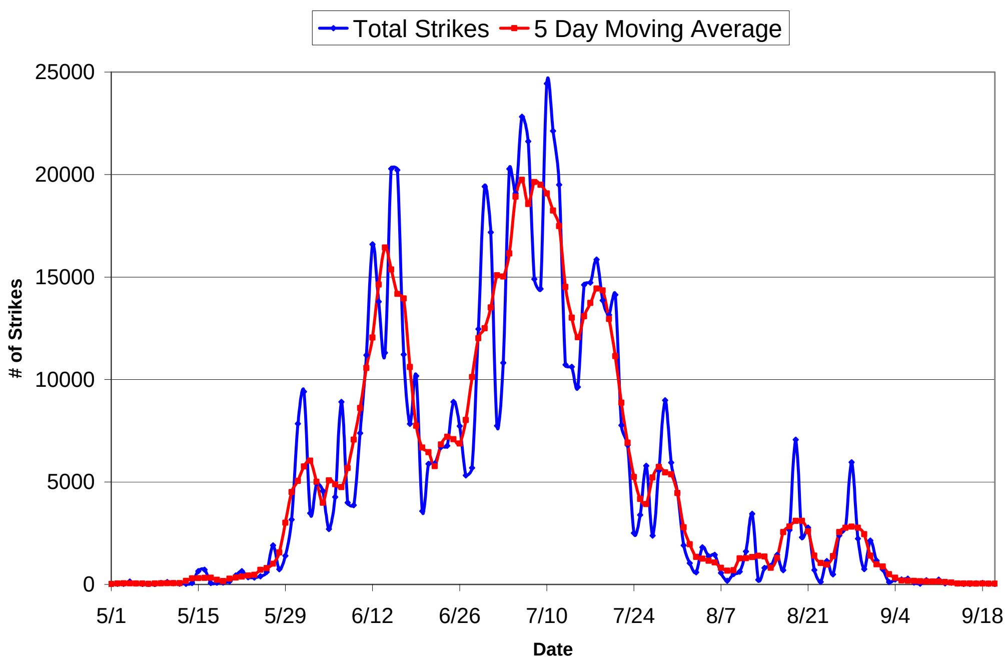

Figure 4. Time series of total strikes per day and a 5 day moving average of the sum of all CG strikes occurring on each day from 2000 to 2007.

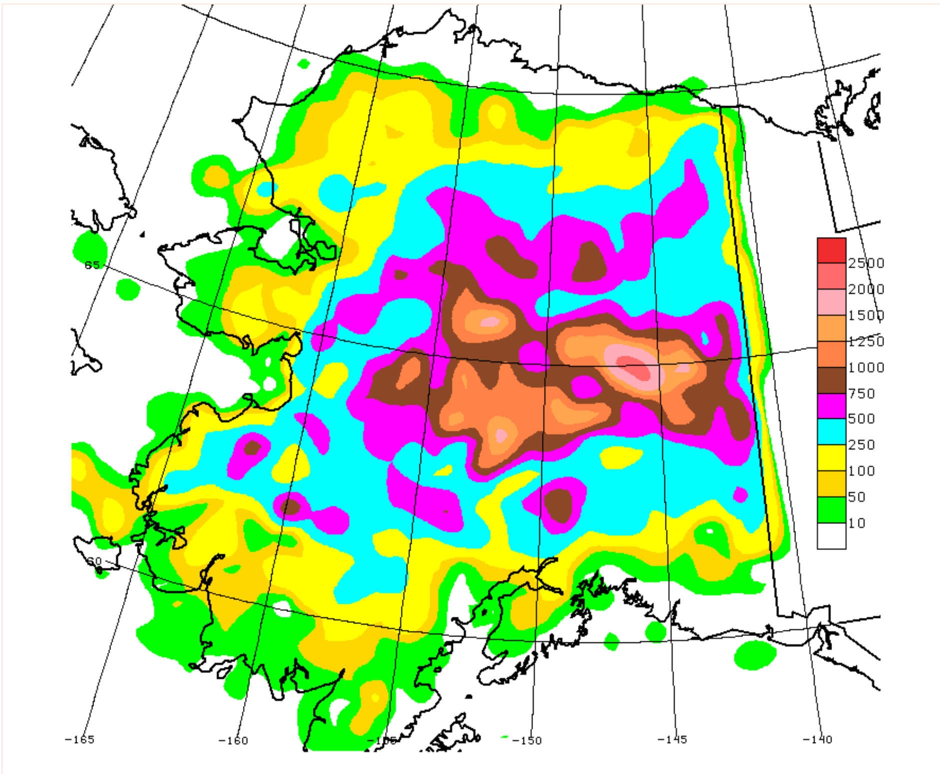

Figure 5. Total CG strikes per 45 km grid box during 2000-2007 for June only. Values range from 0-2000+.

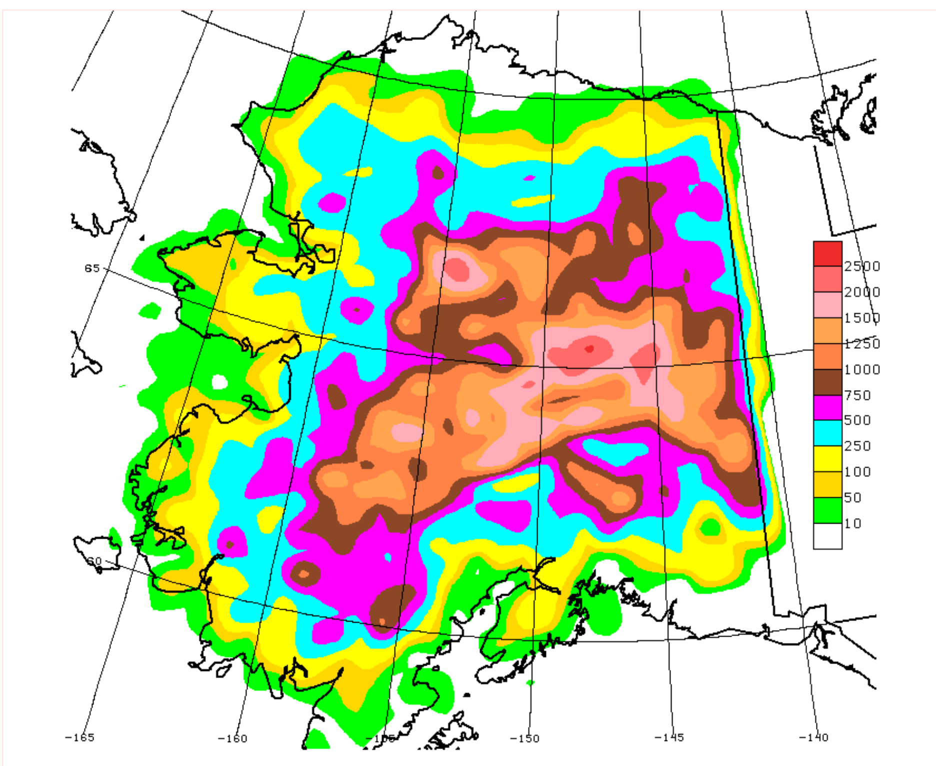

Figure 6. Total CG strikes per 45 km grid box during 2000-2007 for July only. Color values range from 0-2500+.

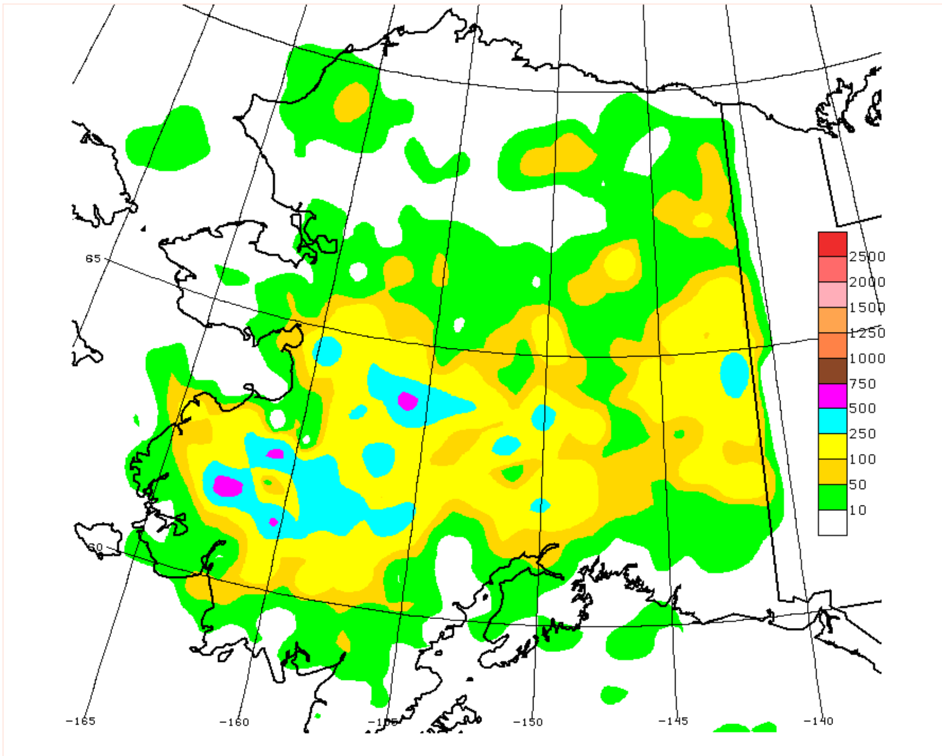

Figure 7. Total strikes per 45 km grid box during 2000-2007 for August only. Color values from 0-500+.

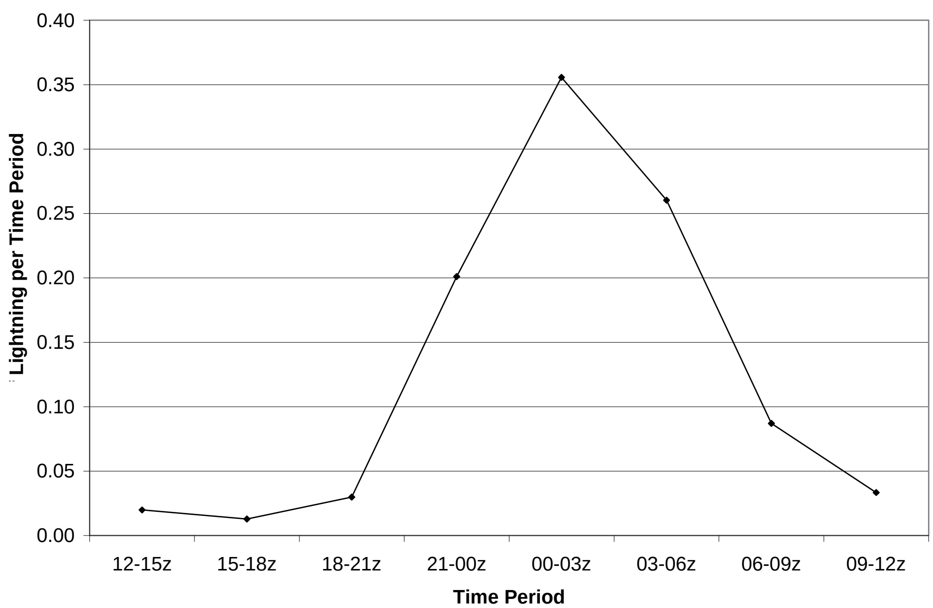

Figure 8. Fraction of Total Flashes for the 2000-2007 seasons by 3 hour bins.