2.14 ALASKA LIGHTNING CLIMATOLOGY AND APPLICATION TO WILDFIRE SCIENCE

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1. INTRODUCTION

Forest fires are a common occurrence during the summer in the boreal forest of Alaska, but they can have deleterious effects on human health and infrastructure. Up to ten times more area is burned annually in Alaska than in any other state (Court and Griffiths, 1992). Factors such as the low population density and fire management schemes contribute to this statistic. In the summer of 2004, a total area of 27,200 km^2 (6.72 million acres) was burned, setting a new record dating back to 1955. Smoke blanketed the state for much of the summer. Most of the acreage burned in Alaska is from fires started by lightning, or wildfires, rather than human-caused.

The development of thunderstorms are either airmass-related, such as convection from surface heating, or are from large-scale synoptic forcing (Sullivan 1963, Biswas and Jayaweera 1976, Reap 1991). Previous work by Reap (1986) has shown a diurnal variability in the lightning strike count in which the maximum was observed from three to six hours after solar noon. Reap (1991) also found that the peak positive count was one hour behind the maximum negative count. Spatial patterns of lightning strikes in interior Alaska and their relation to elevation and vegetation were studied by Dissing and Verbyla (2003). Rorig and Furgeson (1999, 2002) found that atmospheric sounding data could be used to help predict occurrences of 'dry' versus 'wet' lightning conditions, a significant factor related to widlfire starts.

This paper investigates the relationships between lightning strikes, precipitation, temperature, and wildfires to produce statewide lightning and fire statistics and examine the interactions between factors responsible for wildfires.

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2. DATA and METHODS

Lightning data were obtained from the Bureau of Land Management Alaska Fire Service for the period 1986 to 2002 with missing data for 1987 and 1989. For each lightning strike, the coordinates, date, time, signal strength, and polarity were given. There are nine detectors in Alaska and three in Canada's Yukon Territory and individual strikes are observed by triangulation requiring two to three detectors for an observation (Krider et al. 1976, 1980). Strike position accuracy is estimated at 2 to 4 km. In 2000 the lightning detection system was upgraded. Daily, monthly, and annual lightning strike count statistics were generated. The data were then divided into positive and negative strikes and the lightning polarity was studied to test for any significant differences in seasonal and diurnal variability.

The Alaska Fire Service also provided fire data for the years 1986 to 2003. The data included information regarding the location, date started, size, and cause of the fire (human or lightning). The data were divided into human-caused and lightning-caused fires and the number of fires per season by lightning and humans as well as the area burned per season were determined.

Daily temperature and precipitation data were obtained from the Summary Of the Day dataset (SOD, National Climate Data Center) and the Remote Automated Weather Station (RAWS) network (Western Regional Climate Center). The number of stations that recorded precipitation for each day was totaled and compared to the number of fires started and the total acreage burned. The number of fires started by lightning was then compared to the daily stroke count.

3. RESULTS and DISCUSSION

3.1 *Lightning*

Each year, there are an average of over 32,400 lightning strikes in Alaska and around 90 days with lightning, where June and July account for 25 and 28 lightning days, respectively. Seasons with exceptionally high lightning totals were 1993, 1994, 2000, and 2002 while exceptionally low lightning totals include 1986, 1991, 1992, 1995, 1996, and 1998 (Fig. 1). More than 99% of all lightning strikes occur during May through August. Furthermore, 91% of all lightning strikes occur in June and July with a mean daily maximum stroke count of 1,370 in mid-July and a mean monthly maximum stroke count of more than 17,300 for the month of July (Fig. 2). The highest daily stroke count occurred on July 18, 2002 with 7681 strikes. For individual years, there is a large amount of variance and sometimes a high percentage of the yearly total is observed during a relatively short period. For example, lightning strikes during the four day period July 17 through July 20, 2002, accounted for 46% (24,449 strikes) of the total for that year (Fig. 3).

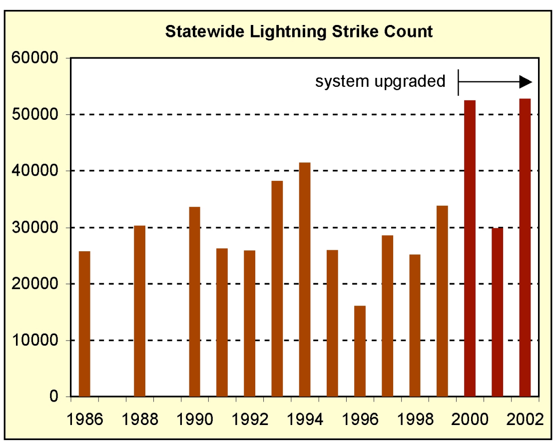

Figure 1: Total annual lightning strike count (1986 – 2002).

Approximately 80% of all strikes occurr in Interior Alaska (63°N to 68°N latitude), an area roughly half the size of all of Alaska bounded by the Alaska Range to the South and the Brooks Range to the North. All lightning strikes during the months of October through March took place in Southern Alaska, below 64 degrees latitude, with more than 75% of those strikes below 61 degrees latitude, where the temperature is warmer. Lightning activity in northern Alaska near the trans-Alaska oil pipeline was also investigated to examine lightning activity in an Arctic climate. The first/last lightning strike in the northern quadrant (68°N – 71°N and 148°W – 150°W) occurs on average about two weeks after/before the first/last strike in the southern quadrant (66°N – 68°N and 149°W – 151°W). The strike count in the southern quadrant (1030) is also about ten times the amount in the northern quadrant (105).

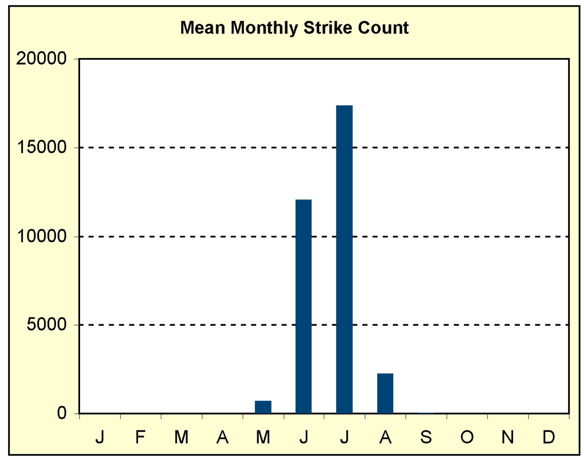

Figure 2: Mean monthly lightning strike count (1986 – 2002).

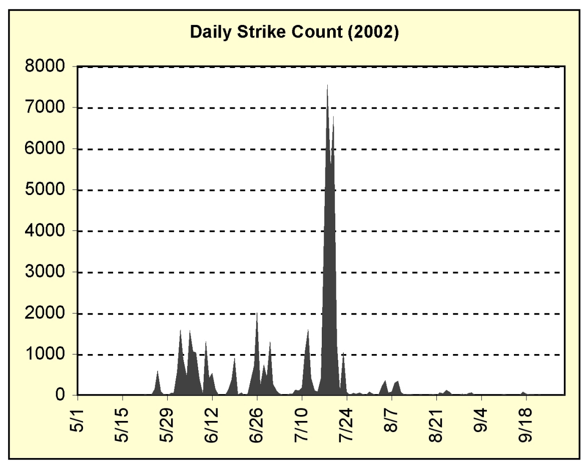

Figure 3: Daily lightning strike count (2002).

The diurnal variability shows a bell-shaped curve for all months with the lightning activity increasing around 11:00 AST, a maximum at 17:00, and then decreasing and remaining quite level from 3:00 until 11:00 (Fig. 4). This signifies that most thunderstorms are forming due to convection from surface heating and not frontal passages. If the latter were true, one would expect the curve to be more uniform, since frontal thunderstorms can pass through at any time. The actual curves, however, display an increase around 11:00 AST when solar heating becomes more pronounced. The maximum stroke count is near 17:00, three hours after solar noon, which is 14:00 AST.

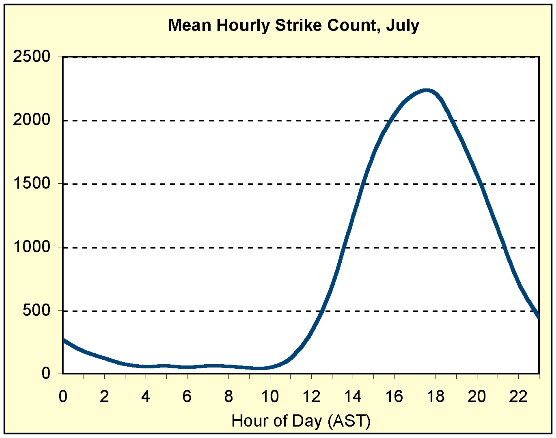

Figure 4: Mean hourly lightning strike count (1986 – 2002).

Lightning strike polarity was investigated to test for any differences in seasonality and diurnal variability. Although negative strikes are much more common than positive strikes during June and July in Alaska (Fig. 5), they peaked at the same time diurnally and seasonally and followed the same curve. There was no apparent difference in the temperature at which they occur and since negative and positive strikes alike followed the same diurnal variability, there was no difference in formation (frontal vs. convective). There was no difference in location with respect to polarity. Positive and negative strikes occurred throughout Alaska and did not prefer certain locations based on polarity. They also occurred both in large clusters and individually.

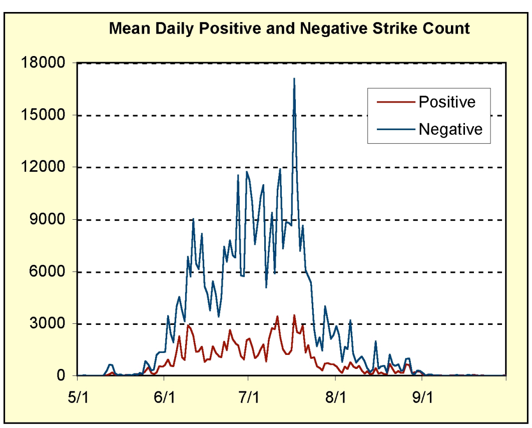

Figure 5: Mean daily lightning strike count, positive and negative (1986 – 2002).

There was a correlation found between daily maximum temperature and stroke count. For any thunderstorm activity to occur, the temperature must be greater than 10°C, and for intense lightning activity (> 2000 strikes), the temperature must be higher than 21°C.

3.2 *Fires*

Each year there are an average of 550 fires that burn 3,965 km^2 (980,000 acres). Humans have been the cause of more than two-thirds of forest fires, sometimes causing up to five times as many fires as lightning (Fig. 6). Lightning-caused fires, however, burn almost 93% of the total area each year on average (Fig. 7). One factor responsible for this is wildfires tend to occur in remote areas and human-caused fires generally occur closer to homes, buildings, and populated areas. The latter are more likely to be suppressed whereas fires that start in remote areas are generally not fought extensively.

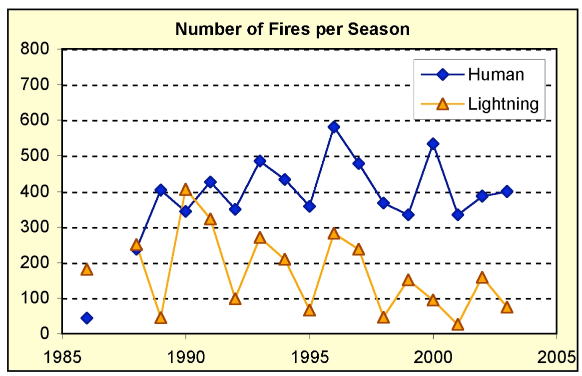

Figure 6: Number of fires per season, human and lightning-caused (1986 – 2002).

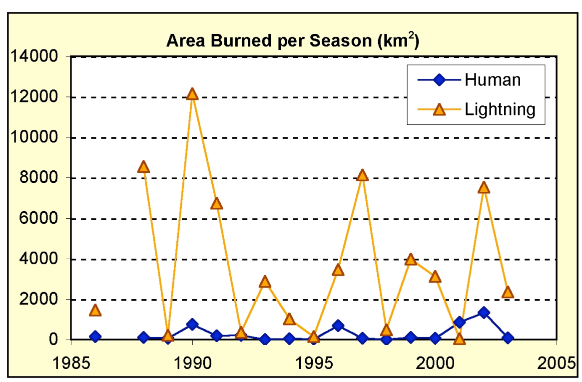

Figure 7: Total area burned per season, human and lightning-caused (1986 – 2002).

3.3 *Fires and Lightning*

At first glance there appears to be a cycle to the total annual lightning strike count with a peak about every three years. Also, there seems to be large burns about every three to five years that might be related to the natural cycle of revegetation and burning. A Fourier series analysis was conducted on both datasets, however, no significant results were found regarding cyclic behavior.

As expected, a positive correlation was found between lightning strikes and wildfires. As the strike count increases, the chance of a fire being started increases as well (Fig. 8). It is important to note, however, that it only takes one strike to cause a fire if forest conditions are suitable. Obviously when there are no lightning strikes, no fires start by lightning. In many cases, high strike counts produce many forest fires, however this is not always true. For example, on June 26, 2002 there was a high strike count (2108), but due to high precipitation, very few fires started (Fig. 9). The opposite may also be true. One strike when dry conditions are present may be more likely to produce a fire than many strikes on a day when conditions are wet.

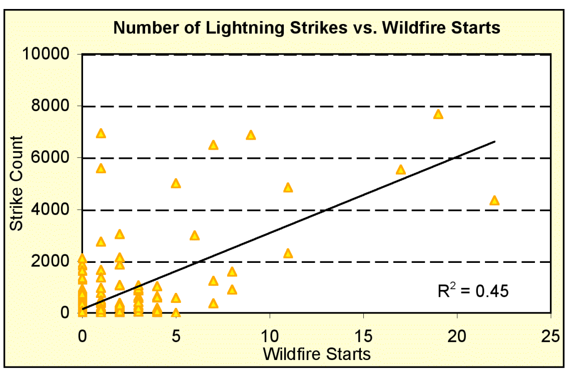

Figure 8: Number of wildfires vs. positive and negative lightning strike count (2000 – 2002).

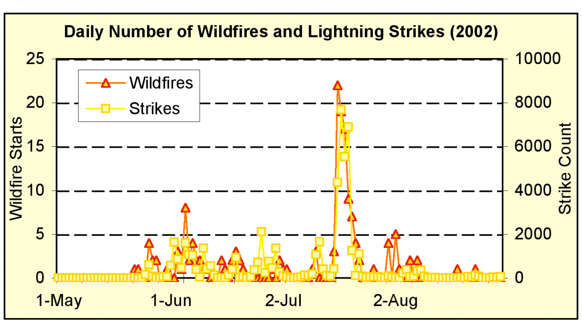

Figure 9: Daily number of wildfires lightning strikes (2002).

Lightning polarity is also relevant in starting a wildfire (Fig 11). Positive strikes are more than three times more likely to produce a wild fire than negative strikes. Previous work has stated that the reason for this is because dry lightning tends to produce positive strikes while negative strikes usually accompany thunderstorms with heavy rainfall. In this study, the correlation between precipitation and polarity was weak and statistically significant conclusions could not be made.

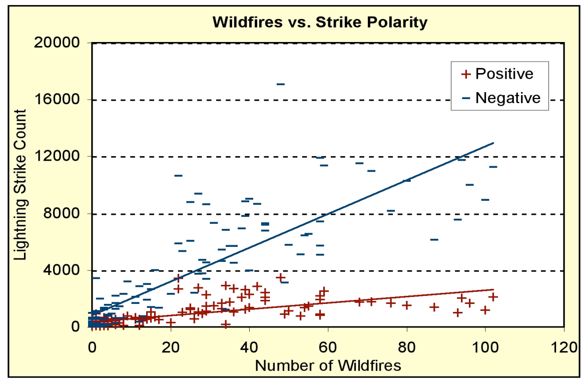

Figure 11: Number of wildfires vs. positive and negative lightning strike count (1986 – 2002).

There is a negative correlation between precipitation and wildfires (Figs. 12, 13). If the atmosphere and soil contain a large amount of moisture, the chance of a fire starting decreases. Large burns usually occur when dry conditions are present. They are also more common when there are many fires taking place at one time. Large burns are more likely during times when little precipitation is received.

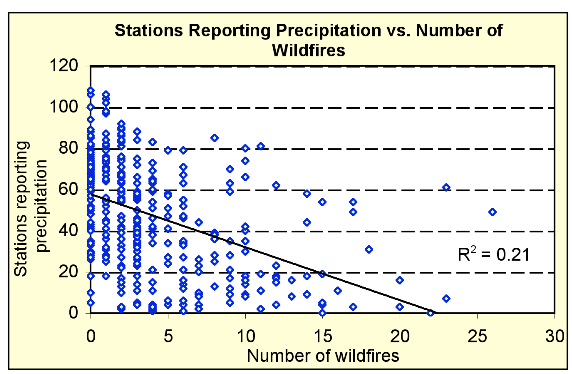

Figure 12: Number of wildfires vs. positive and negative lightning strike count (2000 – 2002).

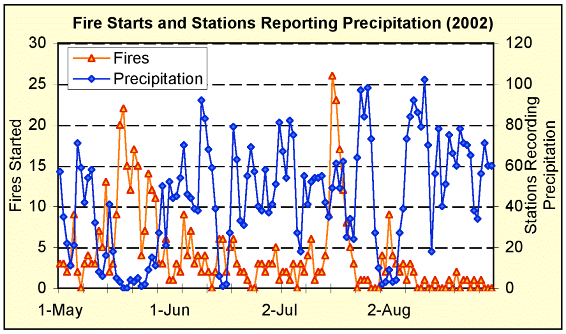

Figure 13: Number of fire starts and stations reporting precipitation (2002).

4. CONCLUSIONS

Almost all lightning strikes occur from May through August in Interior Alaska. The majority of lighting activity in Alaska is due to convection by solar heating and the polarity of strikes does not show a seasonal or diurnal variation. For intense lightning activity to take place, temperatures should be greater than 21°C.

Each year an average of 550 fires burn almost one million acres. Although humans are responsible for starting a majority of the fires, lightning-caused fires, or wildfires, burn over ninety percent of the total area. Positive strikes, although they occur less frequently than negative strikes, are 3 times more likely to cause a fire.

Acknowledgments
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