1.5 ALASKA'S EXCEPTIONAL 2004 FIRE SEASON

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1. INTRODUCTION

Forest fires are a common occurrence during the summer in Interior Alaska, which is vegetated mostly with boreal forest. On average, nearly 4,000 km^2 (980,000 acres) burn annually in Alaska, up to ten times more area than in any other state (Court and Griffiths, 1992). Factors such as the low population density and fire management schemes contribute to this statistic. While most of the fires are started by human activity, 93% of the area burned in Alaska is from fires started by lightning, or wildfires. The development of thunderstorms is due mostly to convection from surface heating, rather than 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. Dissing (2003) and Dissing and Verbyla (2003) studied the spatial patterns of lightning strikes in interior Alaska and found an affinity to elevated and south-facing sloped areas due to preferential surface heating and increased convection. Further, 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 wildfire starts, and McGuiney et al. (2004) investigated the relationship between lightning strikes, temperature, precipitation and wildfires.

The summer (June through August) of 2004 was unusually hot in Alaska. Fairbanks experienced the warmest summer on record in which the mean summer temperature was 18.0°C, a deviation of +2.8°C from the mean. Other regions were also much warmer than normal around the state with Nome, King Salmon, Anchorage, Valdez and Juneau all experiencing new record high summer temperatures. These above normal temperatures were caused by a semi-permanent anticyclone over eastern interior Alaska/Western Yukon Territories, Canada, which also suppressed widespread cloud cover and precipitation. The summer was also quite dry as, for example, Fairbanks recorded only 38% of normal precipitation for the summer, the third lowest on record. These factors led to the record fire season experienced during 2004 with over 6.5 million acres burned.

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2. BACKGROUND

The Bureau of Land Management (BLM) and Alaska Fire Service operate an automatic detection network for observing lightning strikes. The network has been in operation since 1986 with a system upgrade in 2000. It consists of 9 stations in Alaska and 3 in Yukon Territory, Canada (Krider et al. 1976, 1980). The strike location is found by triangulation with an accuracy between 2 and 4 km. Most of the lightning strikes occur in Interior Alaska, where on average there are over 32,000 lightning strikes annually in the state, with large variations from year to year. In addition, the intra-annual variability is also large and the total strike count for the season can be strongly influenced by a few days with a large number of lightning strikes. The majority of all lightning strikes (99%) occur from May to August.

There is a strong diurnal variation to the lightning strikes with a maximum 3 hours after solar noon and low values at night and early morning, which is a strong indication that thunderstorms associated with fronts are relatively seldom, as one would expect lightning to occur fairly evenly over the day. With increasing maximum temperature, the frequency of lightning strikes increases, and at a temperature above 21°C, more than 2000 strikes occur daily on average.

Both positive and negative strikes are observed by the Alaska lightning detection network and positive strikes are found to occur less frequently and are mostly observed under dry thunderstorm conditions, but are more likely to start a fire than negative strikes. The antecedent moisture, soil, and vegetative conditions are also of importance in addition to the weather conditions at the time of the lightning strike. Wildfires occur mostly in June and July, the time during which the most lightning strikes are observed. There is large variability from day to day as well as from year to year in the number of fires started.

It is interesting to note that while the majority of the fires are caused by human action, less that 10% of the area burned is from human-caused fires. These fires are normally started in more populated areas, and hence fought more than fires in remote areas, which are frequently in a limited suppression zone.

3. RESULTS

3.1 *Weather*

Predictions made during the spring of 2004 for the upcoming fire season called for above normal fire danger only for a portion of the Yukon-Kuskokwim Delta region in southwest Alaska. This was due to below normal springtime snowpack conditions in this region, along with above normal temperature predictions for the time period after snowmelt and before green-up, a critical time in the fire season. In addition, climate predictions gave little or no guidance as to the abnormally warm and dry summer weather experienced in 2004, which led to the extreme fire season.

The summer was unusually warm and dry in Interior Alaska. After the snowmelt, which occurred in late April, May was warmer and wetter than normal, in fact, Fairbanks had the wettest May on record. However, the situation changed in June and the rest of the summer was under the influence of a semi-permanent high-pressure ridge located in western Yukon Territory and eastern Alaska, bringing above normal temperatures and below normal precipitation. A detailed description of the weather of 2004 is given by Richmond and Shy (2005).

The temperature in Fairbanks was unusually high during the summer of 2004 with a positive deviation of 2.8°C. The deviations were especially pronounced for most of June and 4 to 22 August, while September 2004 had below normal temperatures. An isopleth map of temperature departure for Alaska for the summer of 2004 shows that the high temperatures were widespread over the state (Fig. 1). Only the extreme southern parts of Alaska, while still warmer than normal, showed this to a lesser extent. This is likely caused by the maritime influences, which normally reduces temperature deviations. A time series of the mean summer temperatures for Fairbanks since 1955 shows summer 2004 was the warmest of the 50-year time period. The best linear fit shows that the average summer temperature has increased about 1°C over the last 50 years. This is less than winter or spring temperature change, but more than observed in autumn (Stafford et al. 2000).

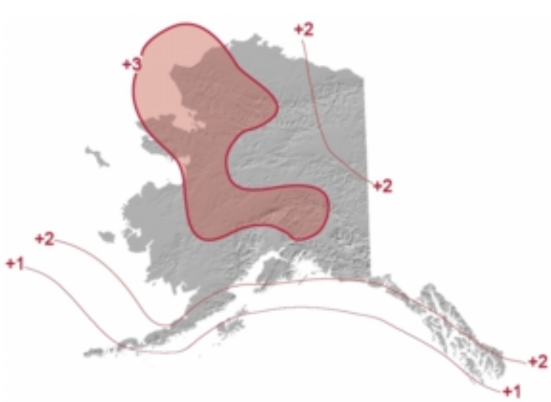

Figure 1: Summer temperature departure from normal (°C) for 2004 (Normal taken as 1971 – 2000 mean).

There was a precipitation deficit of 78 mm for the three summer months for Fairbanks. This might not appear to be a large amount, however, precipitation is light in Interior Alaska (123 mm on average for summer), and the amount received represents a deficit of 63% from normal. It is furthermore the third lowest value of summer rainfall ever observed in Fairbanks. The precipitation departure map demonstrates that the eastern part of interior Alaska had less than half of the expected precipitation for summer, which is normally the season with highest precipitation (Fig. 2).

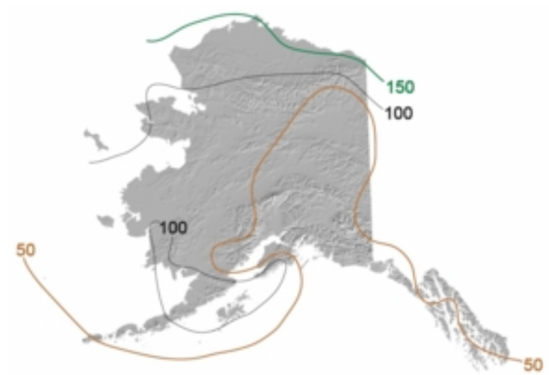

Figure 2: Summer precipitation 2004 percent of normal (taken as 1971 – 2000 mean).

Lightning activity was high in Alaska during the summer of 2004 with a record number of lightning strikes observed. The total of 147,642 was almost 5 times average (Fig. 3). Extensive lightning outbreaks occurred several times during the season with 8,589 on 14 June, 9,022 strikes on 15 July, and almost 8,000 strikes on the 18th and 20th of August.

Table 1: Total annual lightning strike count in Alaska. Data are missing for 1987 and 1989.

Year	Lightning Strike Count
1986	25807
1987	
1988	30326
1989	
1990	33572
1991	26311
1992	25888
1993	38216
1994	41434
1995	26022
1996	16071
1997	28590
1998	25200
1999	33779
2000	52457
2001	29881
2002	52750
2003	48989
2004	147642

3.2 *Wildfires*

The total area burned in Alaska during the 2004 fire season set a new record dating back to 1955 with 26,669 km^2 (6.59 x 10^6 acres) (Fig. 3). Incidentally, the year with the next highest area burned was in 1957, also a very warm and dry summer in Alaska. Though the area burned set a new record, the number of fires was not exceptionally high at just under 700 (Fig. 4).

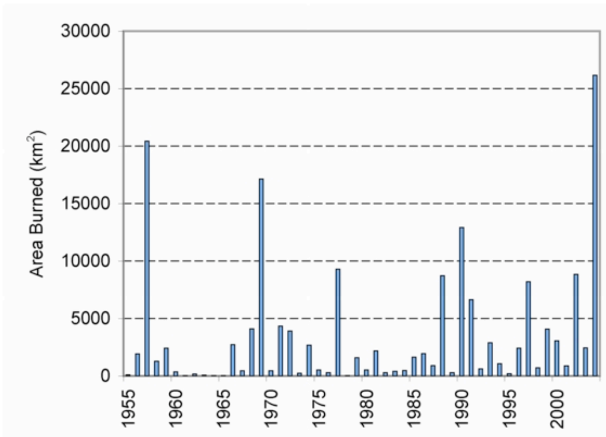

Figure 3: Total area burned in Alaska each year (km^2), 1955 to 2004.

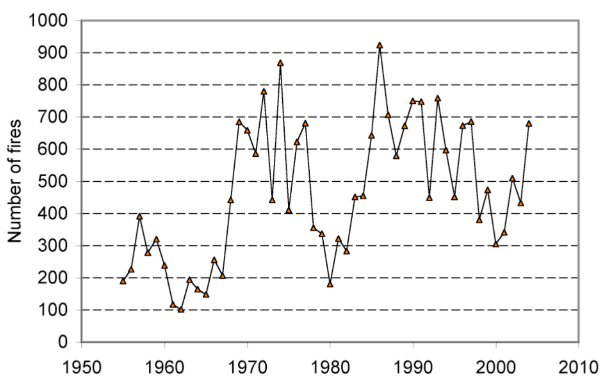

Figure 4: Number of fires in Alaska per year (1955 to 2004).

A time series of the number of wildfires started is presented in Figure 5. It should be pointed out that the number of wildfires represents a relative minimum, as the cause of a fair number of fires is “unknown” and only confirmed wildfires were counted. The two most pronounced maxima occur around the middle of June and the middle of July. The number of active fires was low with 16 or below until 10 June 2004, then a sharp increase occurred, and by 15 June, 58 fires were active throughout the state. Until the middle of July the number of fires increased only slightly, but thereafter a second strong increase was observed and by 21 July, 114 fires were burning. Throughout August the number of active fires stayed high with values around 100, and for most of September the number was around 80.

Fires were spreading fast after the middle of June and about 4 million acres burned over the following 4 weeks (some 600 km^2 daily). Toward the end of July there was widespread rain, the first substantial precipitation in Interior Alaska since the beginning of June. The fires started to flare up again on 10 August 2004 and over the next month 2 million additional acres burned (Fig. 6). Note that the rate is only half of the value earlier in the summer. While quite a number of fires were still smoldering in September, little additional area was consumed by the fires.

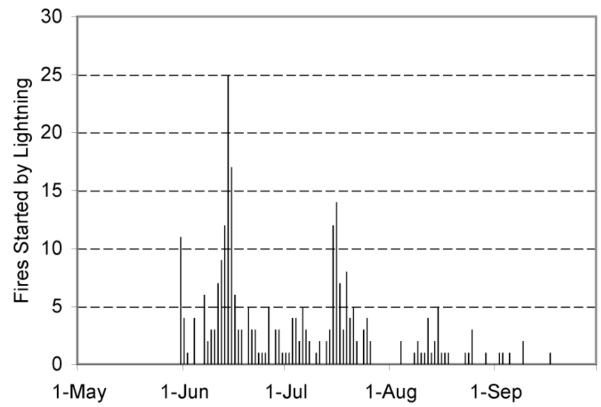

Figure 5: Daily number of fires started by lightning, 2004.

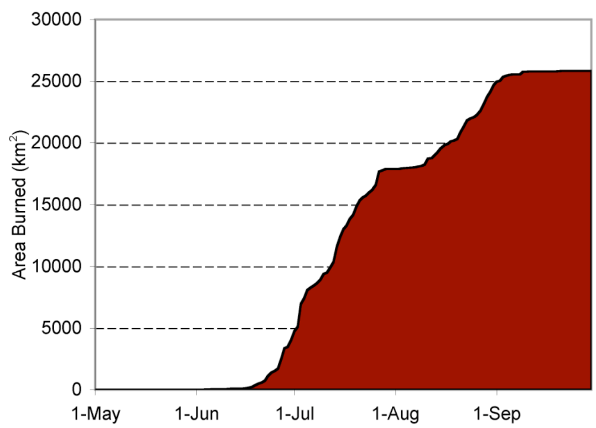

Figure 6: Cumulative total burned area in Alaska, 2004.

From late June, throughout July, August and into September, most of interior Alaska was under a blanket of smoke, the intensity of the smoke varied with time and place. The visibility, which can be taken as an indication of the smoke intensity in the absence of fog, is presented for Fairbanks. It is measured at the international airport with an automatic device, which is part of the Automatic Surface Observing System (ASOS), and employs a Belfort Model 6220 forward scatter visibility meter from which the Sensor Equivalent Visibility (SEV) is derived. The observation range of the instrument is from <1/4 mile to >10 miles with a restriction that visibilities above 10 miles cannot be distinguished. The hourly visibility observations were averaged and daily mean values are presented (Fig. 7). There were 2 periods of extreme visibility reductions, with values dipping to less than ¼ mile, namely 27 June – 4 July 2004 and 16 – 30 August 2004.

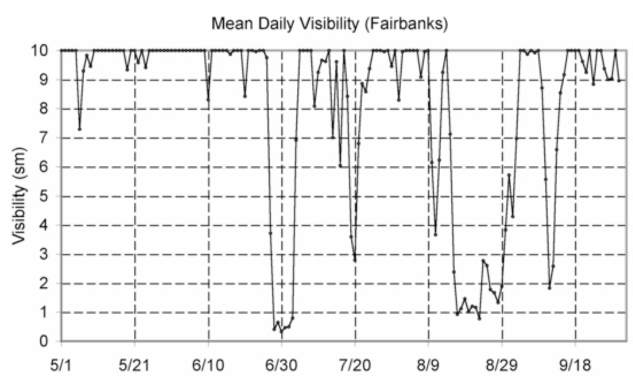

Figure 7: Mean daily visibility as observed at Fairbanks International Airport (May – September, 2004).

3.3 *Radiative Fluxes*

Continuous radiative measurements were carried out on the roof of the Geophysical Institute at the University of Alaska Fairbanks. Observations of direct beam solar radiation, global, diffuse, and ultraviolet A and B radiation were taken. The direct beam radiation on average was reduced by 90% (Table 2) comparing the period before and during the heavy smoke event. Spot measurements with broad spectrum filters were also carried out, which gave in part even higher values. They showed further that the shorter wavelengths (blue) were reduced to a larger extent than the longer wavelengths (red); this is not surprising, as the solar disk has a red/brownish color under smoky conditions. Applying the Bouguer-Lambert law, we can determine the optical depth. From values close to solar noon we calculated the airmass and found a value of 0.34 for clear conditions and 1.82 after the arrival of the smoke.

The global radiation is reduced on average by nearly 60%, however losses in the direct beam radiation are in part compensated by an increase in the diffuse radiation, which nearly doubled. Before the smoke arrived, the diffuse radiation contributed 16% to the global radiation, but after the arrival of the smoke, it contributed 76%. The ultraviolet measurements show an even higher depletion rate than the visible spectrum, which is more pronounced for UV-B than UV-A. Under heavy smoke, hardly any UV radiation reaches the surface. As the smoke particles are relatively large, they absorb a higher percentage of the shorter wavelength's radiation instead of being scattered by it.

The decreased global radiation had an effect on the temperature for the period, 23-27 June, before the arrival of smoke, and the smoky period, 28 June – 3 July 2004. The mean maximum as well as the mean daily temperatures dropped from 27.9°C to 23.8°C and from 22.0°C to 19.0°C, respectively. Furthermore, the mean diurnal temperature range was reduced from 12.1°C to 10.2°C for the second period. These changes in the temperature are consistent with the expectations deduced from the changes in the radiative fluxes.

The transmissivity was calculated as the percentage of the solar radiation outside of the atmosphere, which reaches the surface as direct radiation, and were calculated as the mean of the 7 hourly values around solar noon. While about ½ of the direct solar beam reached the surface as direct radiation before the major smoke event, less than 10% did so when the smoke arrived.

Table 2: Mean radiative fluxes before (23 – 27 June, 2004) and during (28 June – 3 July, 2004) the smoke pall was over Fairbanks. Radiative units are W/m^2.

Component	Before	After
Direct beam	683	71
Global	531	225
Diffuse	86	170
UV-A	10	1
UV-B	0.45	0.01

3.4 Air Quality

The particle matter with aerodynamic sizes smaller than 2.5 μm (PM 2.5) was measured on top of the Fairbanks Regional Office Building in downtown Fairbanks. Hourly data have been collected with a MetOne BAM 1020 sampler (Beta Attenuation Monitor) since midsummer 2003. A beta attenuation process is applied to determine the mass collected on a filter tape as calibrated airflow passes through the tape. The beta radiation attenuation is compared before and after collection within the instrument with an accuracy of ± 7 μg. Carbon Monoxide (CO) measurements in summer were carried out at a single location in downtown Fairbanks approximately ½ mile from the particle samplers. The instrument is an Environmental Corporation Dasibi Model 3008 CO Analyzer and is based on the Gas Filter Correlation technique with an accuracy of ± 0.5 ppm.

As with visibility restrictions, two strong maxima are evident in the PM2.5 and CO concentration, arriving on 28 June and 24 August 2004, respectively (Fig. 8). On 27 June, strong northerly winds accelerated the Boundary Fire, located north of Fairbanks, and advected heavy smoke into town. The inversion during the night hindered vertical mixing, and at 02:00 h on 28 June 2004, a CO concentration of 10.3ppm was recorded, resulting in an 8-hour average concentration of 9.2 ppm. By 10:00 h the 8-hourly averaged CO concentration had dropped to 8.6 ppm, and did not approach the violation level again. This is quite a rare event, as previously never such a high value was observed in Fairbanks during summer. For example, the maximum for summer 2003, including smoke events from forest fires in the area, was 3.5 ppm. The high value observed in 2004 was more typical for winter when, due to a strong and semi-permanent inversion, the boundary layer is separated from the air aloft.

Fine particle matter (PM2.5) exceeded 1000 $\mu g/m^3$ generally at the same time as the CO reached a maximum. In the early morning hours of the 28 June 2004, the sensor became saturated, and measurements remained offscale for the next 8 hours. The steep decrease from the peak in particle matter is somewhat delayed when comparing it to the CO. The maximum observed PM2.5 exceeded the most dangerous EPA standard (hazardous) by nearly a factor of two. As with CO concentration, no previous observations have recorded such high values in Fairbanks during summer, and the normal summer average for PM2.5, including short-lived wildfire smoke, is 7 $\mu g/m^3$.

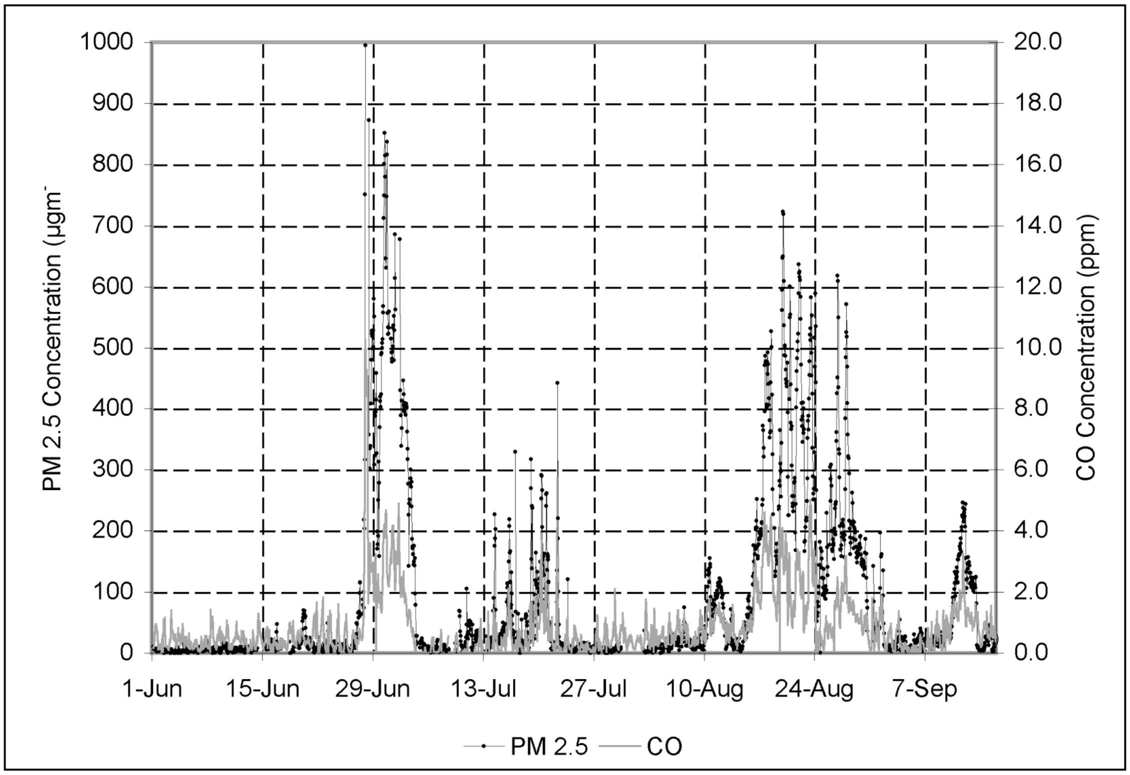

Figure 8: Concentration of PM2.5 and CO in Fairbanks (1 June to 30 September, 2004).

4. CONCLUSION

Current fire management schemes in Alaska have critical areas defined in which fires are to be fought, which is generally in the vicinity of towns, villages, and developed areas. However, a limited fire suppression scheme accounts for the largest area in the state and if a fire starts in this area it is allowed to burn. In the case of the Boundary fire, northeast of Fairbanks, it originated in a limited suppression zone, however it grew toward town with the help of northeast winds threatening infrastructure and causing homes to be evacuated. This represents a case in which a forest fire was not fought in the beginning stages because of where it was started, however as the fire grew, it moved into a critical area.

Forest fires frequently occur during in Alaska and over the last half-century, approximately 1 million acres burn annually on average. A large majority of the area burned (93%) is due to lightning-caused fires. Lightning strikes are most common in June and July, predominantly in Interior Alaska, when localized areas of convection occur with solar heating. The number of lightning strikes is related to the instability of the surface layer, for which the daily maximum temperature is an indicator. In summer 2004, a new record high in summer temperatures was observed for Interior Alaska and close to 7 million acres burned. This is nearly 5 times the area that burned in the all of the 48 contiguous states combined. While fire fighting efforts in Alaska are substantial, less than 10% is spent for every acre burned when compared to the contiguous U.S.

Air quality in the area of the fires was shown to be significantly hindered, with the CO concentration staying just under the violation level, while the particle count exceeded it, representing health hazards. The smoke had not only an effect on the climate of Alaska in regard to incoming solar radiation and surface temperatures, but smoke particles from the season's wildfires were detected by lidar as far away as Wisconsin (Damoah et al. 2005).

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