ALASKA LARGE FOREST FIRES IN 2004 AND WEATHER
- Discussion based on satellite and weather data

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1. INTRODUCTION

The boreal forest or Taiga occupies one third of forest area in the world. From spring to fall, the risk of fire is high in this region due to low precipitation regime which amounts to less than 300mm. Due to ongoing global climate change, fire incidence in high latitude may increase because of the observed decreasing trend of summer precipitation.

In 2002, many large-scale forest fires occurred near Yakutsk, the capital city of the Sakha Republic in Siberia. The total burnt area was estimated at more than 23,000 km^2, this burnt area is the largest reported in Sakha since 1955 and about ten times larger than mean burnt area (about 2,400 km^2).

In 2003, forests near the Baykal lake in Siberia burned severely. The total burnt area in Russia (whole Siberia) was estimated at more than 234,000 km^2.

In 2004, many large-scale forest fires occurred in Alaska. The main cause was lightning. Many of them grew into large-scale fires due to severe drought conditions and the presence of Chinook or Foehn phenomenon. As a result, the total burnt area in 2004 was about 26,000 km^2, the largest historical record since 1956.

To protect the Taiga from severe forest fires due to global climate change, it is important to investigate the trends and characteristics of not only forest fire occurrences but also weather

2. FOREST FIRES IN ALASKA

2.1 History of Forest Fire and 2004 Fire

Alaska Forest fire history data from 1956 was obtained at the University of Alaska, Fairbanks (UAF) and at the Alaska Fire Service (AFS).

In Fig.1, bar graph indicates burnt area and line graph shows number of fires. Smaller bar and line indicate lightning caused forest fires. There is a big difference between the two lines but difference between the two bars is very small. This indicates that forest fires In Alaska are mainly caused by lightning and they account for much of the burnt area and for about 40% in the number of fires.

In 2004, many fires occurred despite remarkable high precipitation in May for most of Alaska. Rainfall was observed in mid May through mid June due to strong convection. But a long drought period (about one month) in June-July and strong Foehn winds increase the activity of fires ignited by lightning. Thus, the total burnt area in 2004 became the largest since 1956.

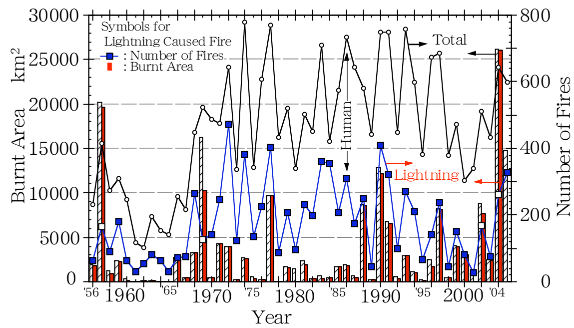

Fig. 1 Forest Fire History in Alaska (1956～2004)

2.2 Recent Tendency of Forest Fire and Lightning

Forest fire data from 1986 to 1999 and lightning data from 1989 to 1999 were processed to characterize average occurrence tendency of forest fire and lightning in Alaska (Hayasaka, H., 2003). Fig. 2 was drawn to show general trend of forest fire and lightning in Alaska. As explained below:

1. Almost all forest fires start or are ignited in June and July.
2. Forest fire occurrence peak appears in early July.
3. Occurrence date of the ten largest fires is shown in Fig.2 using numbers from 1 to ten. These numbers are next to the X-axis of Fig.2. Large fires mainly occur in June.
4. Lightning has two occurrence peaks, namely in early and mid July.
5. First lightning peak in early July corresponds with the forest fire occurrence peak.
6. Second lightning peak in mid July could not ignite forest as first peak did. This may be due to increasing rainfall.
7. Half of lightning occurs until the end of June while 80% occurs until mid July.

3. VARIOUS ASPECTS OF FOREST FIRES IN 2004

3.1 Forest Fire Activity Trend using Hot Spot

Number of daily hot spots detected by NASA using MODIS images was plotted in Fig.3. Hot spot (HS for short hereafter) is detected by infrared radiation sensor. Spatial resolution of HS is about 1.1x1.1 km. HS does not always mean fire but it is a useful tool to understand fire activities in a large area such as Alaska.

From Fig. 3, first HS or fire was found at day number 162 (DN for short hereafter). Fire started just

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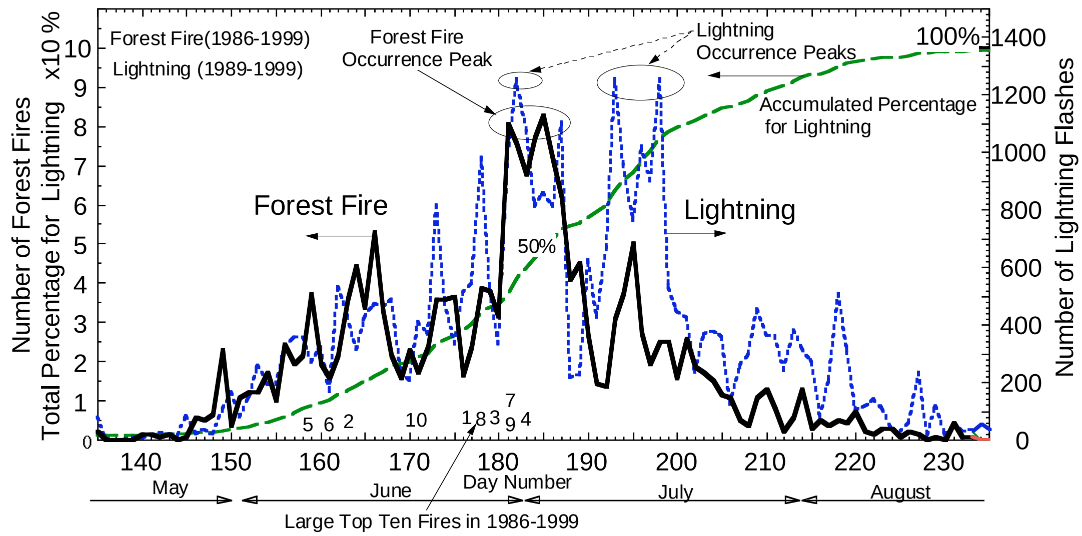


Fig.2 Forest Fire and Lightning Tendencies in Alaska

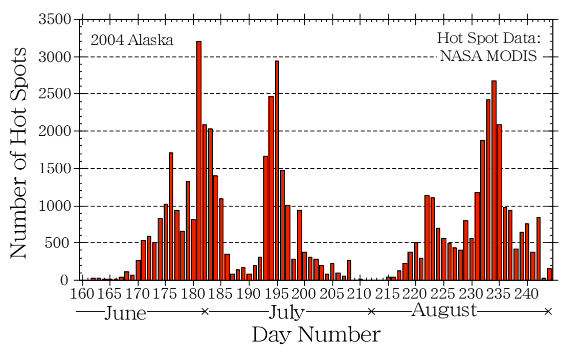


Fig.3 Fire Occurrence Tendency Using Hot Spot

after rainfall in early June. Three HS peaks exceeding 2500 are found in Fig.3. These fire peaks occurred on DN=181(6/29), 195(7/13) and 234(8/21).

3.2 Forest Fires Observed By Satellite

A Terra satellite image for DN=181(6/29) or most fire active day is shown in Fig.4. From this image, a few characteristics of 2004 fires are derived.

1. Many fires occurred at small limited area of Interior Alaska shown by a triangle with white line in Fig.4. This area is mostly surrounded by the Alaska and Dalton Highway and the Canadian border (vertical straight line in Fig.4). We may say that this area is the so-called large-scale fire free area found in the Alaska Fire History Map provided by AFS.
2. Many fires had straight long smoke tails. This means fire became active due to strong wind from east and northeast.
3. Massive smoke from fires was formed in the central of Yukon basin or in the west of Fairbanks. Smoke headed westward.

3.3 Forest Fires Distribution and Fire Expansion

Two fire maps near Fairbanks are shown in Fig. 5 to display fire location and size clearly. Left-hand and right-hand maps in Fig. 5 are for DN=180 (6/28) and DN=234 (8/21) respectively. Relatively large forest fires will be called by name such as “Boundary Fire” in Fig.5. In this paper, numbers from 1 to 24 were used to identify a fire like the one shown in Fig.5. For example,

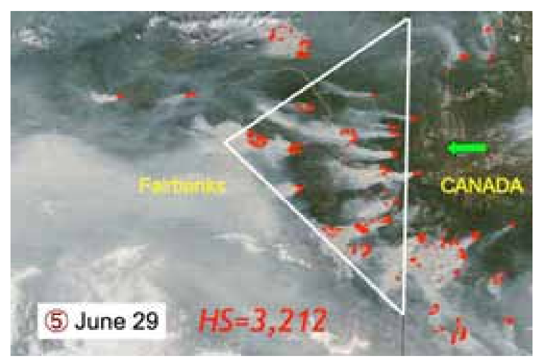
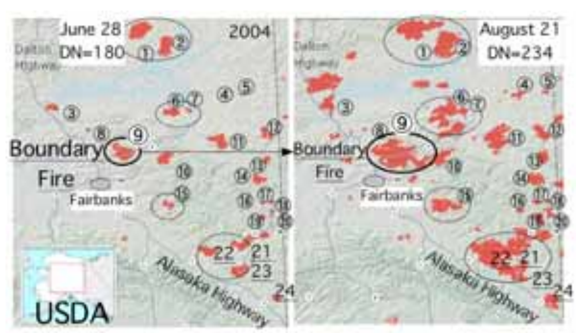


Fig.4 Large-scale Forest Fires observed on June 29.



DN=180 (6/28) DN=234 (8/21)

Fig.5 Forest Fire Maps : Fire Location and Size

there is a big difference between shapes of fire affected area near figure 1. Thus, fire expansion will be easily grasped by comparison of two maps in Fig.5. “Boundary Fire” (figure 9) finally became one of the largest fires of Alaska in 2004.

3.4 Precipitation and Drought

Precipitation measured at Fairbanks is plotted in Fig.6. Integrated precipitation from DN=122 (5/1) is shown by a line. A drought period will be easily found on the line graph.

The 39-days (DN=164~202) drought period started just after record precipitation in May. During this long drought period, two fire peaks appeared at DN=181 and 195 as shown in Fig.3. The second drought in August is responsible for the third fire peak at DN=234 shown in Fig.3.

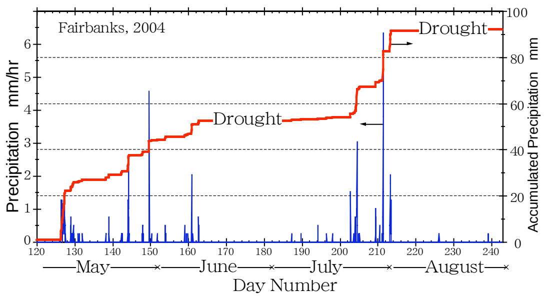


Fig. 6 Precipitation and Drought

4. THE BOUNDARY FIRE AND WEATHER

4.1 Outline of The Fire

The Boundary Fire, located about 32 km Northeast of Fairbanks, was ignited by lightning and detected on June 13 (DN=165). Rapid expansion of fire occurred due to Northeast wind and severe drought. Final burnt area reached 2,174 km^2. This value accounts for 8.4% of total burnt area in Alaska. Thus, the Boundary Fire was the second largest fire in 2004.

Two fire peaks were found on DN=181(6/29) and 199(7/17) in the fire trend of the Boundary Fire (Fig.7). These two peaks correspond closely to the first two peaks in June and July in Fig.3. In Fig.7, there were two fire active periods from DN=179(6/28) to 184(7/2) and from DN=194(7/12) to 199(7/17). The Boundary Fire did not show a third peak in August. One of the reasons may be due to complete fire suppression done by the type I incident management team.

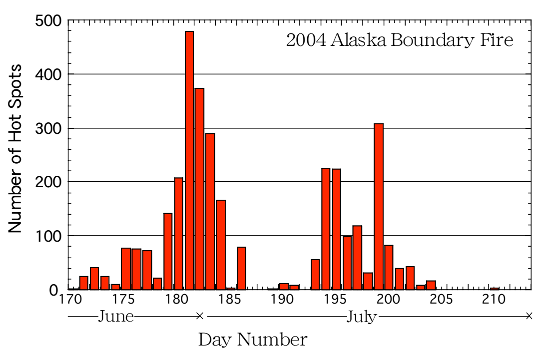


Fig.7 Fire Occurrence Tendency of the Boundary Fire Using Hot Spot Data

4.2 Fire Expansion Analysis Using Hot Spot Data

Hot spot data released from NASA contains information about location, acquisition date and time and so on. Hot spot distribution plotted above a map of the Boundary Fire is shown in Fig.8. Number of hot

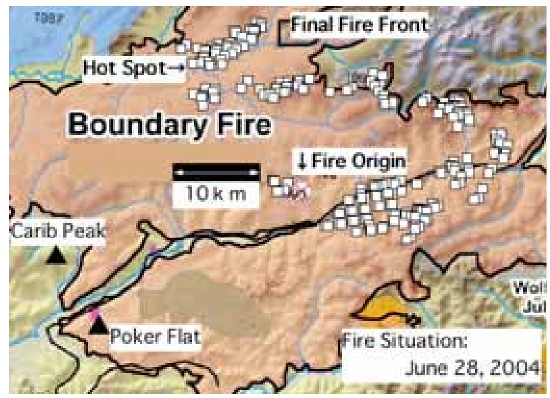


Fig.8 Map of the Boundary Fire and Hot Spot Distribution

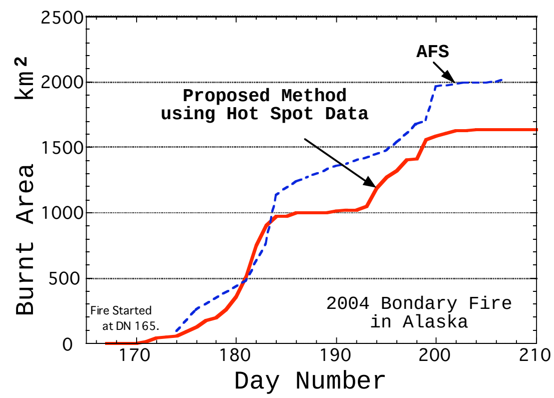


Fig.9 Comparison of Burnt Area Values

spots on June 28 was 208 and is shown by square symbols. Plot of hot spot was done with the help of CAD software.

As many overlapping squares of hot spot are found in Fig.8, it is difficult to get clear information regarding burnt area. One of the authors is now developing a new and simple method with the help of CAD function to obtain burnt area from hot spot data. Obtained burnt area is expected to contain certain error originated mainly from the capability of infrared sensor in MODIS. But burnt area from hot spot data closely matches the value announced by the Alaska Fire Service. Final error was about 20%. This difference may arise from undetectable small fires and the simplified method still being under developed.

4.3 Weather During The Boundary Fire

Weather data was measured from DN=153 (6/1) to DN=213 (7/31) at the top of Carib Peak (peak height 773m) as shown in Fig.8. The Carib Peak is located at the west end of the Boundary Fire. As fire came near the Carib Peak, a long and wide fire line developed on the ridge-way.

4.3.1 Relative Humidity and Air Temperature

Relative humidity and air temperature are shown in Fig. 10. Two rectangles show fire active days when number of hot spots exceeds 100. Two straight lines show the first hot spot detecting day and first hot spot free day except DN=210.

The Boundary Fire was ignited by lightning on DN=165(6/13) and the first hot spot was detected on DN=170(6/18). Just after this day (DN=170), temperature increased to nearly 28 degree C. On the other hand, relative humidity dropped to 20%. After that, temperature gradually decreased and humidity went up slowly. But temperature rose to 26 degree C and humidity dropped to around 30% again on DN=179 (6/27). From this day, fire became very active. Number hot spots exceeded 100 (Fig. 7).

From Fig.10, a certain level of daily maximum temperature and minimum relative humidity were found in two fire active periods. They are about 25 degree C (30 degree C at sea level) and roughly under 50 % (30-40% was found during the first fire active period) respectively. Fire will be active provided that both conditions are met.

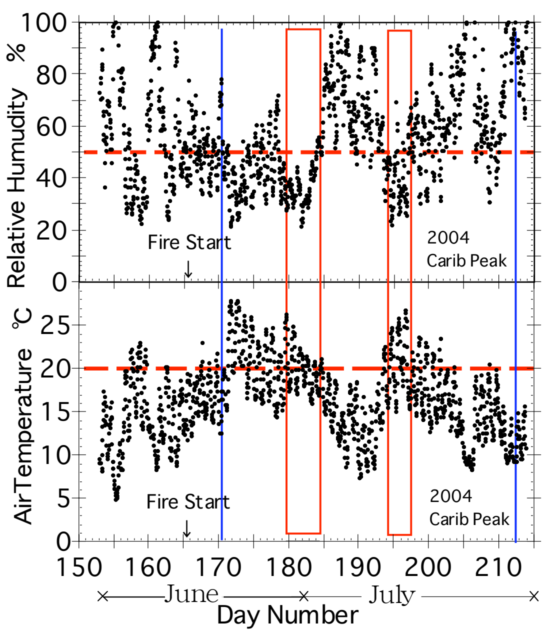


Fig.10 Relative Humidity and Air Temperature

4.3.2 Wind Speed and Direction

Wind speed and direction are shown in Fig.11. Foehn winds called Chinook are easterly winds in summer according to the Alaska Fire Service. First Chinook wind blew on DN=157(6/5) and continued for a few days. On DN=157, 2004 first hot spots or fire were detected (Fig.3).

In the Boundary Fire, Chinook played an important role in the first fire active period from DN=179(6/28) to 184(7/2). Almost constant wind direction (east-northeast) and strong wind (about 6.5 m/s on DN=180 to 184) were detected during the first fire active period (Fig.11). Crown fire could occur if wind speed exceeds 4.47 m/s (10 mph) according to AFS. Crown fire occurred and it explains the rapid fire expansion detected (Fig.9) and thick smoke accumulation found in the satellite images (Fig.4). About half size of the Boundary Fire burned during the first fire active period.

By the end of the first fire active period, wind began to blow from an opposite direction, namely west. Westerly wind with relatively high speed (6 m/s) continued to blow for about one week from DN=186 to 193. But fires did not become active because relative humidity was high (from 50 to 100%) and temperature was low (from 7 to 18 degree C, see Fig.10). Under these conditions, crown fire may hardly occur.

In the second fire active period from DN=194(7/12) to 199(7/17), wind direction was not stable but wind blew mainly from west and south with relatively low wind speed of about 3 m/s. Nevertheless fire become active because relative humidity was below 50 % and temperature became high (from 15 to 27 degree C, see Fig.10).

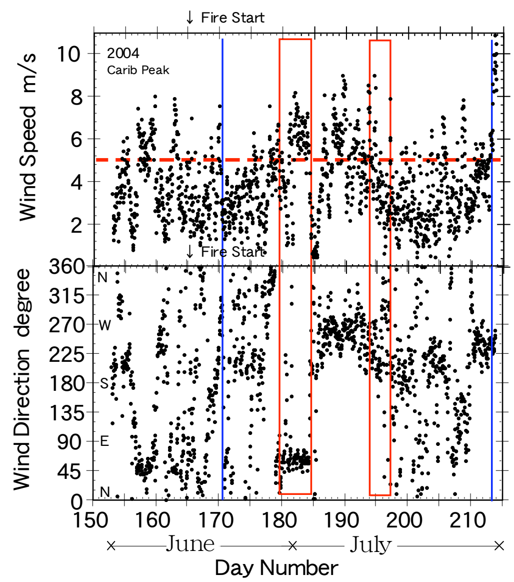


Fig.11 Wind Velocity and Direction

4.3.3 Solar Radiation

In the first fire active period from DN=179(6/28) to 184(7/2), rapid solar radiation decrease of about 60% was observed (Fig.12). It was from about 750 W/m^2 on DN=178(6/27) to 300 W/m^2 on DN=181(6/30). This significant solar radiation reduction was caused by dense fire smoke. Dense fire smoke may shield sunlight to ground considerably. Under dense smoke, maximum temperature was gradually decreased to 15 degree C on DN=192(6/10). After this, temperature gradually recovered to 24 degree C on DN=194(6/12).

This temperature descent due to significant solar radiation reduction by dense fire smoke may affect local weather. Under low temperature and high humidity condition, fire could not be active. In other words, fire break was made by smoke from fire itself. We can conclude that there was a small-scale weather change due to fire smoke and a negative feedback called “self-extinguishment” occurred in the Boundary Fire.

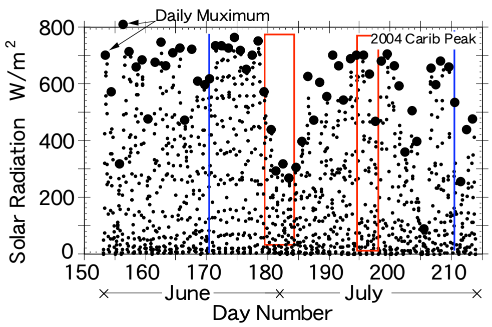


Fig.11 Solar Radiation

5. CONCLUSIONS

First, forest fires in Alaska were discussed using fire history, recent fire and lightning tendencies. Forest fires in 2004 were visualized and analyzed with the help of NASA MODIS data. Hot spot data was used to display daily fire activity.

Second, one of the large-scale fires called “Boundary fire” that occurred near Fairbanks was chosen to investigate the relationship between fire expansion and weather condition in detail.

Conclusions are listed below.

1. In 2004, large fires occurred according to recent lightning and fire occurrence tendency. Namely, many fires ignited by lightning in June as usual but became very active at the end of June due to strong Chinook and long droughts.
2. According to weather data measured at the Carib Peak near the Boundary Fire area, Chinook occurred on DN=179(6/27) and lasted about six days. During Chinook, east-northeast wind speed was about 6 m/s, maximum temperature reached about 31 degree C (at sea level) and low relative humidity decreased to about 35%.
3. Thus, the first peak of hot spot (fire) on DN=181(6/29) occurred and it corresponded to the first lightning peak of normal year.
4. The second fire peak also appeared on about DN=195(7/13) and also followed the recent tendency of lightning.
5. Fire ceased after the first fire peak. Many fires may be self-extinguished or lost strength due to the dense and large massive smoke from severe fires.
6. The third hot spot peak appeared on DN=234(8/21). This late summer or autumn fire may occur due to drought from the beginning of August. Autumn fires are responsible for about one third of total burnt area in 2004.

Autumn fires also occurred in the Taiga forest near Yakutsk (Far East Siberia) in September 2002 (Hayasaka, H., 2004). The cause of autumn fire may be due to climate change.

Forest fires in 2005 were also very active in Alaska. As a result, number of fires is almost the same as in 2004 and the total burnt area will reach about 60% of the previous year. It will be the fourth fire active year in the past 60 years.

Active fire occurrence of two consecutive years has seldom occurred. A four-year interval was reported by Kasischke, E.S., Williams, D. and Barry, D (2002). Relationship with El Nino episode was investigated by Hess, J.C. and et. al. (2001). Recent climate change on boreal forest fire activities in Alaska should be more thoroughly studied (Stevens, E. and Dallison, D, 2005). New strategies facing climate change conditions should be introduced to keep the Taiga saved from being permanently depleted by forest fires. The authors will continue to clear present fire situation in Alaska from various scientific points of view.

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