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RECENT ACTIVE FOREST FIRES AND FIRE WEATHER IN ALASKA

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1. INTRODUCTION

Recent weather conditions under rapid climate change will greatly affect each process in forest fire, such as ignition by lightning, extinction, smoldering, rate of fire spread, crown fire, spotting, and other process. Forest fire behaviors are usually not so simple and most of them are strongly related to weather and climate conditions. In this paper, forest fire processes in Alaska are carefully examined to explain background of recent active forest fires in Alaska. Forest fire behavior in 2004 was carefully analyzed because total burn area in 2004 was the largest since 1956 and number of lightning flashes was the second largest since 2000. 2004 wildfires burned 26,700km² in Alaska and nine individual fires exceeded 1,000km² in size. From these large fires, the author tried to extract critical fire expansion processes under so-called fire weather conditions in Alaska by analyzing various data. Analysis results showed: most of fires with large burnt area were ignited during second lightning period of several days in mid June under lightning weather condition. After ignition by lightning, first remarkable fire activity or fire propagation started in rate June and highest peak of fire activity was observed in early July. In 2004, weather conditions during fire and lightning active periods were clearly divided by air temperature. Thus, fire and lightning weather conditions were identified from around three high fire peaks using weather data measured at Fairbanks and its vicinity.

2. Data and Methods

2.1 Fire Data (AFS data and MODIS hotspot data)

Fire data from 1956 to 2012 provided by Alaska Fire Service (AFS) were analyzed. Yearly fire data included various fire information about fire location, detection date, out date, size (final burnt area), cause, and so on. Data for lightning-caused fire could be extracted easily. The Moderate Resolution Imaging Spectroradiometer (MODIS) hotspot data were obtained by using NASA ATBD-MOD 14 algorithm (Giglio et al., 2003) where MODIS WGS-84 geographic projection (the "latitude/longitude projection") data were used as input. Each MODIS data set represents active fire data (NASA, 2002) of the area of interest i.e. Alaska. The recent daily hotspot data in 2004 were mainly processed and analyzed to determine fire occurrence tendencies.

2.2 Weather and Lightning Data

Weather data measured at Fairbanks (Fort Wainwright) and Caribou Peak were chosen as representative of interior Alaskan weather because both locate in the middle of eastern part of interior Alaskan. Weather data was obtained from the Alaska Climate Research Center and Alaska Fire Service (AFS). Weather station in Fort Wainwright located at 64.8367ºN, 147.6150ºW, and 138m above sea level. Caribou Peak Weather station located about 40km north of Fairbanks in 65.1928ºN, 147.4992ºW, and 773m above sea level. The weather components considered were minimum, average, and maximum air temperatures, wind speed and direction, precipitation, relative humidity. In this paper, the daily and hourly weather data in 2004 for both stations was mainly used.
Lightning data in 2004 provided by the Alaska Interagency Coordination Center (AICC), Bureau of Land Management was used in this paper. Nine lightning detection sensors are now working in Alaska and cover the region from the Bering Strait to the Canadian mountainous areas (135ºW to 179ºW Longitude), and from the tundra in the Arctic region to the forest areas on the southeast coast (70ºN to 50ºN Latitude). Each lightning flash data contains coordinates, dates, times, signal strength, polarity, and strokes. A positional accuracy of lightning detection system is 0.5~2 km and detection efficiency is 80~90% from 2000. (Dissing and Verbyla, 2003).

3. Fire Trend in Alaska

Yearly burnt area due to lightning-caused forest fires from 1956 to 2013 in descending order was shown in Fig. 1. In Alaska, lightning-caused forest fires were responsible for more than 90% of the annual burnt area and the burnt area due to human-caused fire was not very large except in 1969, 1980 and 2013. In 2004, nine lightning-caused large fires(> 1,000 km^2) occurred and 99.7% of burnt area due to lightning-caused fires.
In the last 58 years, the average burnt area by lighting-caused fires was 3,475 km^2. Recently, large forest fires occurred consecutively in 2004 and 2005, their burnt areas were 26,591 km^2 (largest since 1956) and 18,822 km^2 (3rd largest) respectively. The total burnt area of these two years was 10% of Alaska's total boreal forest area. On the contrary, burnt area for 2007 (3rd severe lightning year) was only 2,389 km^2. The standard deviations on burnt areas (σ_{ba}) for these three years were 4.1σ_{ba} for 2004, 2.8σ_{ba} for 2005, and

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-0.20σ_{ba} for 2007. Large factors of σ_{ba} in 2004 and 2005 may correspond to recent trends of boreal forest fires (Wallenius et al., 2011; Flannigan et al., 2005).

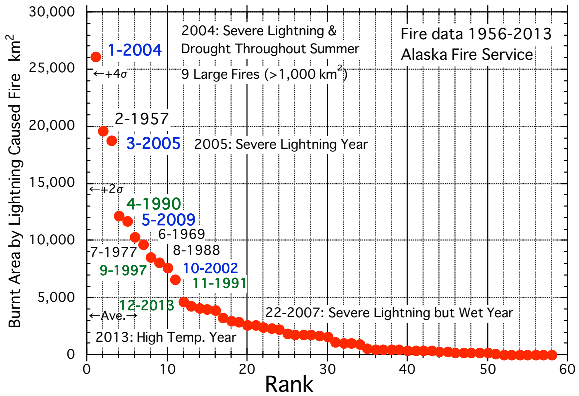

Fig.1 Fire trend in Alaska from 1956 to 2013

4. Forest Fire Occurrence and Weather conditions in 2004

4.1 Fire Occurrence and Daily Weather Conditions

In Fig. 2, five different graphs for (a) maximum, average, and minimum temperature, (b) lightning flash, (c) precipitation, (d) burnt area, and (e) hotspot were combined from top to bottom to explain fire occurrence in 2004, fire and lightning weather, and other fire weather conditions. X-axis for five graphs in Fig. 2 was common or day number from 120 to 270 (May to September).

Daily burnt area was calculated by summing up the final burnt area (FBA) of individual fire at the same fire discovery date. Although accumulated curve for final burnt area in second graph from the bottom in Fig. 2 could not show daily change like the other four graphs in Fig. 2, we could easily grasp when large fire occurred from steep gradient of accumulated curve. The daily accumulated burnt area was calculated by the following equation:

$$(\textit{Daily Burnt Area})_{DN} = \sum_{i=1}^{n} FBA_{DN,i} \qquad (1)$$

where *DN* is the 'specified day number', *FBA* is the 'final burnt area' of each fire, and *n* is the number of fires with the same discovery date *(DN)*.

From steep and flat gradients in four accumulated curves in Fig. 2 (b)~(e) clearly showed four lightning peak, two drought periods, three fire occurrence periods, and three fire expansion periods from four corresponding graphs in Fig. 2.

In 2004, nine very large fires (FBA>1,000 km^2) occurred and their total burnt area was responsible for about 53.6 % of total burnt area of 26,591 km^2. Largest fire in 2004 was called "Boundary fire" with FBA=2,716 km^2. From Fig. 2 (b) and (c), second peak of lightning in mid June ignited fires including six out of nine very large fires (FBA>1,000 km^2). These fires were responsible for about 60% of FBA in 2004. From late June, large fires increased continuously until early July. Total final burnt area in this period was about 5,000 km^2 responsible for about 19% of FBA in 2004. Then, third lightning peak in early July in Fig. 2 (b) ignited other large fires including 2nd largest fire (FBA=1,956 km^2). Total FBA of fires in June and July exceeded 25,000 km^2 in mid July and these fires were responsible for about 94% of FBA in 2004. Thus, most fires ignited by lightning before mid July could wait for favorable weather conditions for fire. Second and third hotspot peaks in mid July and late August in Fig. 2 (e) supported this idea. Fire expansion period from mid to late August occurred mostly by the above-mentioned fires ignited before mid July. Because only small fires newly ignited in August like in Fig.2 (d). Most of hotspots observed in August were from expansion of old fires started in June and July.

Time lag between ignition and fire expansion found in Fig.2 (d) and (e) is suggesting there are fire and lightning weather conditions. From comparison among three figs in Fig.2 (a), (b) and (e), three lightning peaks before mid July in Fig.2 (b) were corresponding to relatively cool temperature period and three fire expansions in Fig.2 (e) occurred under relatively high temperature period. In other words, lightning tended to occur under intrusion of cold air flow and fires under high temperature condition could become active.

To clear fire weather conditions regarding wind and humidity, Fig.3 was made by using hourly data measured at Caribou Peak. Hourly data was needed especially for evaluation of wind data such as frequent wind direction change, constant wind direction, occurrence of wind gust, and so on. In Fig. 3, five different graphs for (a) temperature, (b) hotspot, (c) wind direction, (d) wind speed, and (e) relative humidity were combined from top to bottom. X-axis for five graphs in Fig. 3 was same of Fig.2 or day number from 120 to 270 (May to September).

Weather conditions for three hotspot peaks in Fig.3 (b) were: wind directions were east-northeast (≒60°) for first and third hotspot peak and west-southwest (≒240°) for second peak like found in Fig.3 (c). Relatively strong wind more than 6m/s was observed for three hotspot peaks easily found from Fig.3 (d). Relatively low humidity less than 40 % and temperature higher than 20℃ (≒24℃ at sea level) could be found in Fig.3 (e) and (a).

5. Conclusions

Total burnt area in 2004was the largest since record-keeping began in Alaska in 1956. This paper explained why fires in 2004 made largest burnt area by using various data of weather, hotspot, and fire. Most of large fires in 2004 were ignited by second and third lightning peak in mid June and early July. Most fires could expand under favorable weather conditions for fire, high temperature, dry condition made by drought, relatively high wind speed. Long drought condition started from early June lasted until rate August.

References

Dissing, D. and D. L. Verbyla, 2003. “Spatial patterns of lightning strikes in interior Alaska and their relations to elevation and vegetation”, Can. J. For. Res., 33, pp. 770-782.

Flannigan, M. D., Logan, K. A., Amiro, B. D., Skinner, W. R. and B. J. Stocks, 2005. “Future area burned in Canada”, Climatic Change, 72, pp. 1–16.

Giglio, L., Descloitres, J., Justice, C. O. and Y. Kaufman, 2003. “An enhanced contextual fire detection algorithm for MODIS”, Remote Sensing of Environment, 87, pp. 273-282.

Wallenius, T., Larjavaara, M., Heikkinen, J. and O. Shibistova, 2011. “Declining fires in Larix-dominated forests in northern Irkutsk district”, International Journal of Wildland Fire, 20(2), pp 248-254.

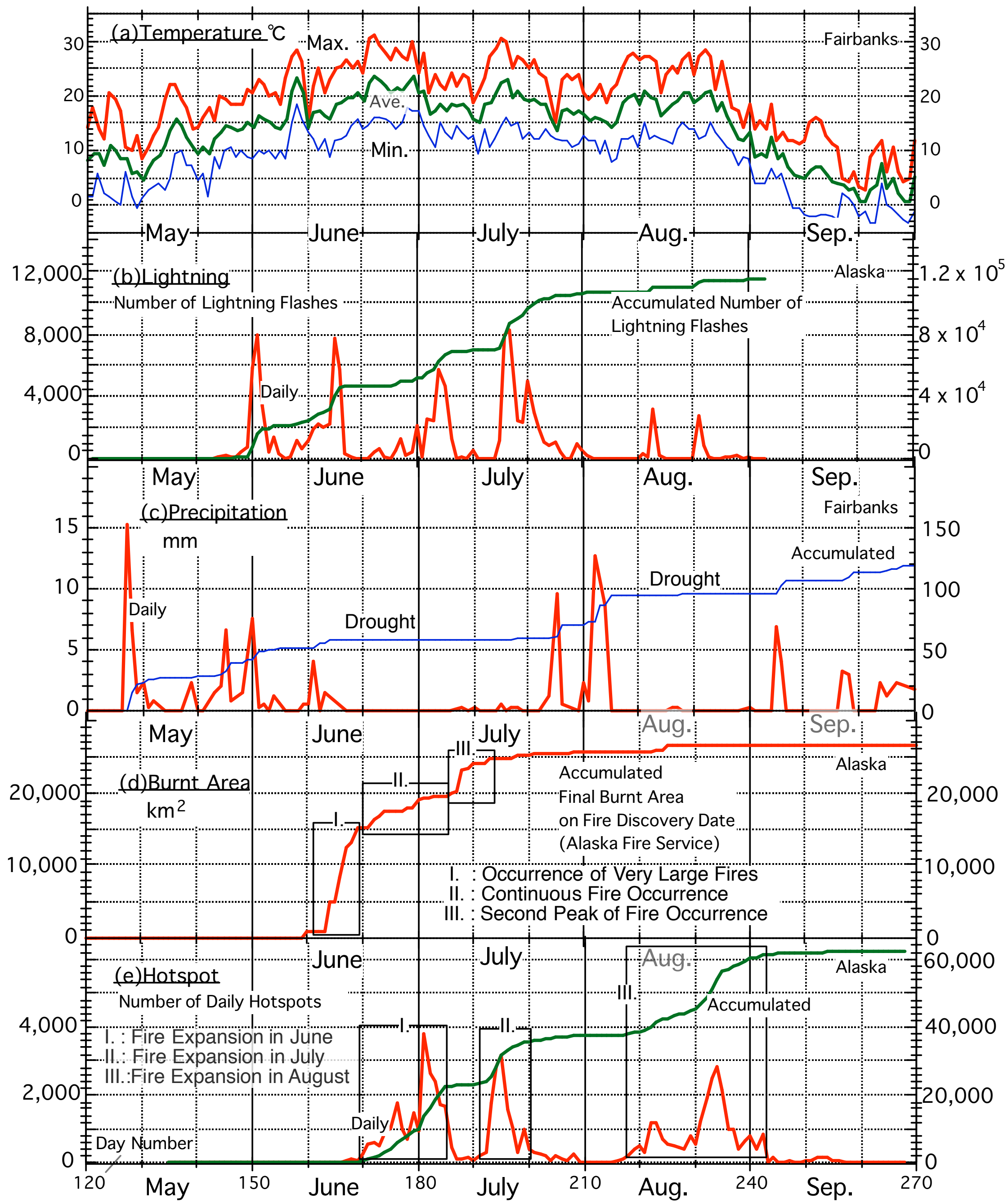

Fig.2 Temperature, Lightning, Precipitation, Burnt Area, and Hotspots in 2004 in Alaska

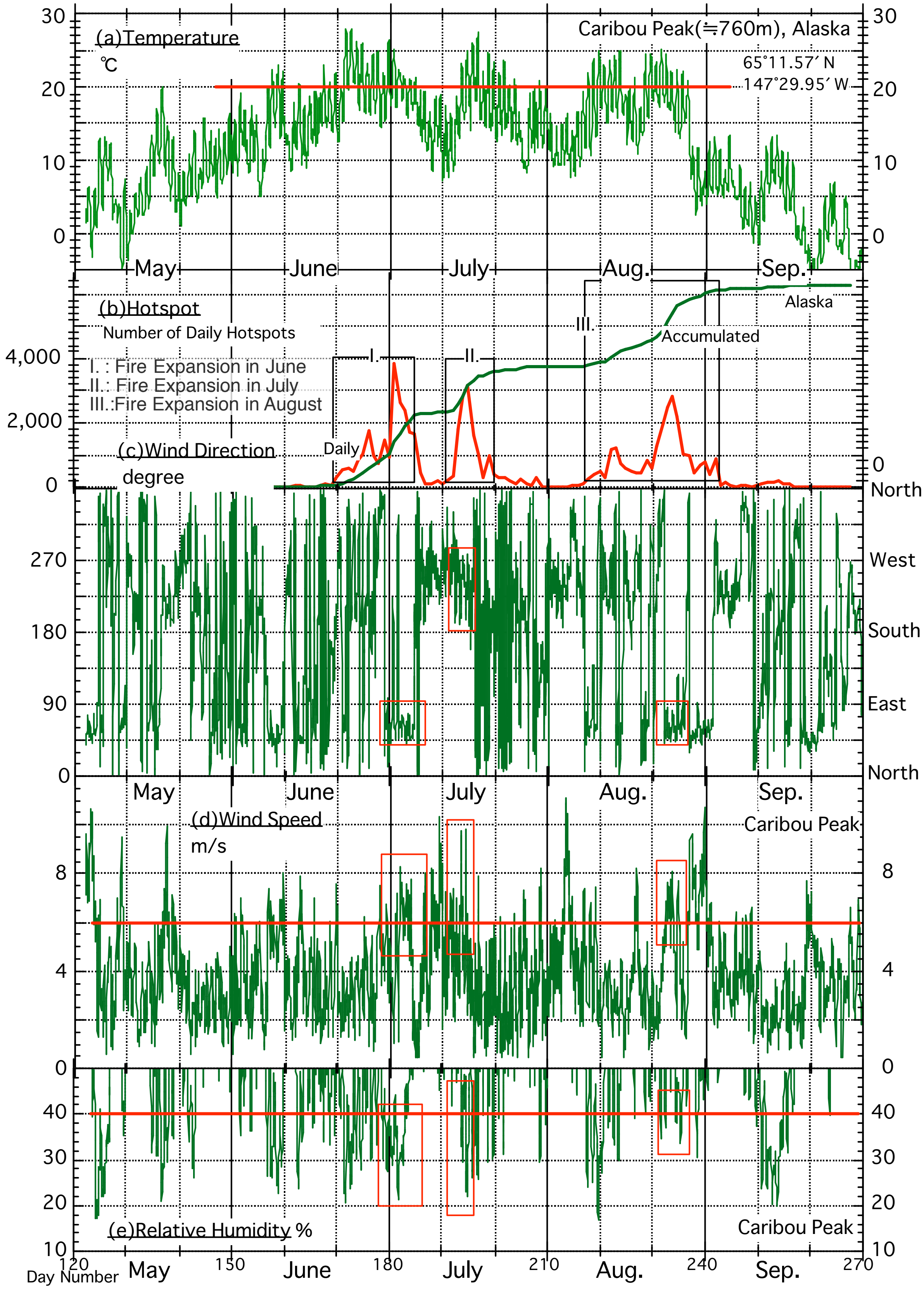

Fig.3 Temperature, Wind Direction, Wind Speed, and Relative Humidity at Caribou Peak, and Hotspot in 2004