Forest Fires and Climate in Alaska and Sakha

Forest Fires Near Yakutsk

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ABSTRACT

This paper describes forest fires and weather in Alaska, North America and Sakha, Eastern part or Far East Siberia. Number of forest fires in Sakha is three times greater than that of Alaska. On the other hand, the mean annual burnt area in both places is almost the same and is about 2,400 km^{-2}. Mean air temperature rise from 1830 in Yakutsk, Sakha was about 3^{o}C. In Yakutsk, remarkable temperature rise begun from 1970's. On the contrary, precipitation trend from 1890 shows gradual decreasing trend begun from 1970's. Forest fire histories from the middle of 1950's in Alaska and Sakha show that average burnt area become larger and larger from 1990's. These climate trends push boreal forest very flammable. Under climate condition of higher air temperature and lower precipitation, large forest fires occurred near Yakustk, Sakha, in 2002. The cause of large forest fires is discussed from the climate point of view.

Key words: Forest Fires, Hot Spot, Global Warming, Climate, Precipitation

1. INTRODUCTION

The boreal forest or so-called Taiga is one of the largest contiguous forest areas in the world. Taiga becomes very flammable from spring to fall because total precipitation amount is only less than about 300mm. In addition, temperature rise due to global warming will make good conditions for forest fire. Fire incidence in high latitude may become to increase due to ongoing global warming because precipitation is low. To protect taiga from unnecessary forest fires, it is important to investigate the trends and characteristics of not only forest fire occurrences but also weather conditions in Taiga.

There are not a few papers describing forest fire trends in Alaska. E. S. Kasischke, D. Williams and D. Barry (2002) analyzed the patterns of large fires in the boreal forest region of Alaska. M. D. Flannigan and et al. (2000) reported about climate change and forest fires. B. J. Stocks and et al. (2000) described climate change and forest fire activity in North America boreal forest.

There are several papers describing forest fire trends in Russia and Sakha. Fire statistical studies were carried out by G. N. Korovin (1996) and E. N. Valendik (1996). G. N. Korovin reported an analysis of the forest fire distribution in Russia using data from 1947 to 1992. E. N. Valendik described the temporal and spatial distribution of forest fires in Siberia 1970 to 1983. From the viewpoint of carbon

dynamics, A. Z. Shvidenko and S. Nilsson (2000) estimated carbon emissions from fires in Russian boreal foresst. G. A. Ivanova (1996) reported the extreme fire season in the central Taiga forests of Sakha. These four papers did not provide much detail of the relationship between fires and climate for this region except Ivanova's paper.

This paper describes forest fire and weather trends in Alaska and Sakha, Eastern part or Far East of the Russian Federation. Mean air temperature change from 1830 in Yakutsk, Sakha clearly showed that there is a temperature rise due to global warming. Especially, temperature rise from 1980's is remarkable in Yakutsk. On the other hand, precipitation trend from 1890 shows that precipitation is gradually decreasing from 1980's. Both tendencies will make forest fires active in recent years.

Forest fire histories from 1956 in Alaska and Sakha show that average burnt area become larger and larger from 1990's. This is because taiga is now very flammable due to higher air temperature and lower precipitation conditions.

In 2002, a large number of forest fires occurred in taiga near Yakutsk, Sakha, This paper also describes a few causes of the unprecedented occurrence of forest fires near Yakutsk in 2002. Weather conditions in Yakutsk such as temperature, rainfall, humidity, wind direction, and wind speed were analyzed in detail, and a correlation between fire occurrence and weather conditions was found.

2. Alaska and Sakha (Yakutia), Siberia (Russia)

2.1 Outline of Alaska

Schematic map of Alaska is shown in Figure 1. Area of Alaska is 1,518,800km^2 surrounded by the Arctic Ocean to the north, the North Pacific Ocean to the south, Canada to the east, and the Bering and Chukchi Sea to the west. The forested area is said about 460,000 km^2 and located mainly in the middle of Alaska or so-called Interior Alaska Region.

The distribution of lightning-caused forest fires (including wild and tundra fires) is also shown in Figure 1 using black dot. Figure 1 shows that forest fires are concentrated in the middle of Alaska between the Alaska and Brooks ranges. The river Yukon runs in the center of this area and vegetation type is mainly "forest" (D. Dissing and D. Verbyla, 1999). In Alaska, evergreen needle-leaved trees such as a black spruce are dominant.

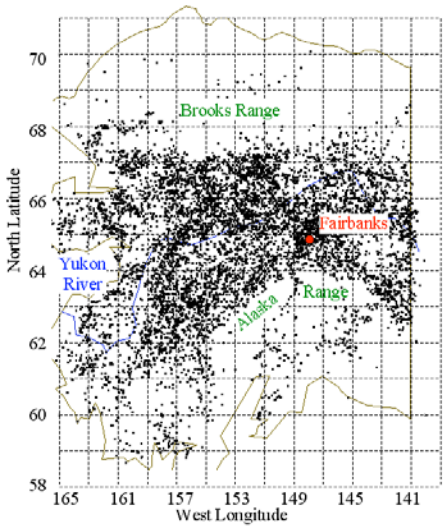

Figure 1. Map of Alaska and lightning-caused forest fire distribution.

2.2 Outline of Siberia and Sakha

The central and eastern parts of Russia are shown in Figure 2. Siberia is vast area of 13,800,000km^2 surrounded by the Arctic Ocean to the north, Kazakhstan, Mongolia, and China to the south, the Pacific Ocean to the east, and the Ural mountains to the west. The forest in Siberia is called the Siberia Taiga and is the largest coniferous forest zone on earth. The forested area is about 7 million km^2 and divided in two areas by the river Yenisey. In the west of Siberia, evergreen needle-leaved trees such as a spruce are dominant, while larch are mainly growing in the east of Siberia.

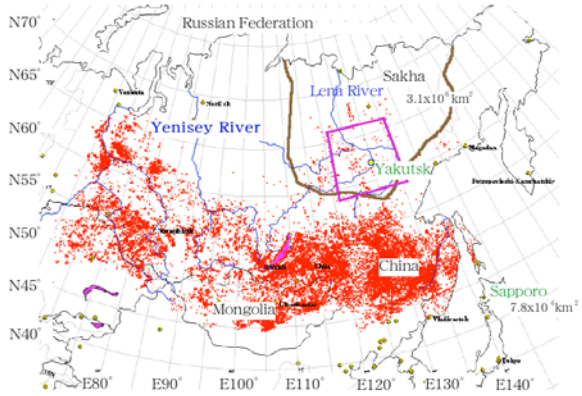

Figure 2. Map of Siberia, Sakha and Hot spots in 2000.

Yakutsk is a capital city of the Sakha republic (Yakutia). Sakha has an area of 3,100,000 km^2. The Taiga zone of Sakha covers about 80% of the area. Yakutsk is located on the river Lena at around 62º N latitude. There are forests of deciduous needle leafed trees such as larch and grass land with the Alas lake on the permafrost spreading around Yakutsk.

3. General Trends of Forest Fires in Alaska and Sakha

.3.1 Forest Fire History

The number of fires and burnt area in Alaska and Sakha are show in Figure 3.

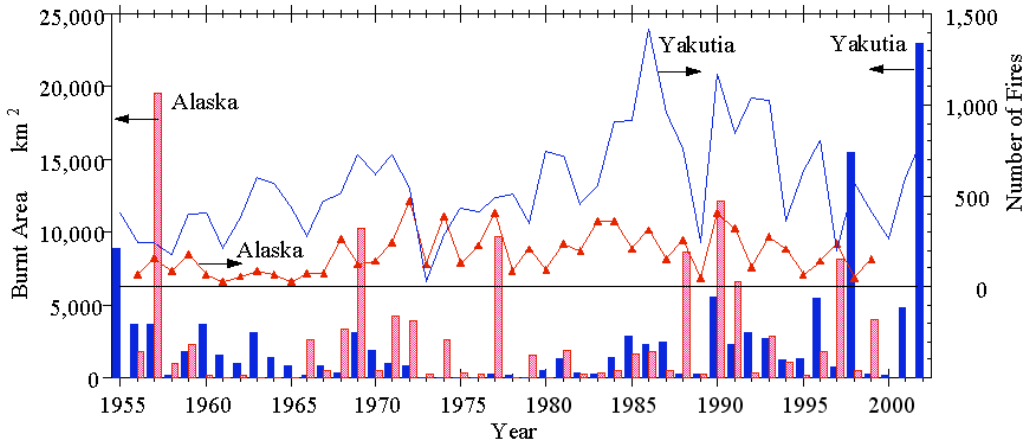

Figure 3. Forest fire history of Alaska and Sakha.

In Alaska, over 90% of the burnt area by forest fires is lightning-caused, and measure to reduce lightning-caused fires becomes an important issue. The total number of lightning-caused forest fires during the past 44 years is 7,949 and the total burnt area is 101,348 km^2. The mean annual number of fires is 181with mean annual burnt area of 2,303 km^2. Figure 3 shows that the maximum annual burnt are was about 20,000 km^2 in 1957. Burnt areas of around 10,000 km^2 happens in 8-12 year cycles. In the 1990s, the number of fires has tended to decrease to 100-150 per year, however the burnt area has not decreased.

In Sakha, there are 200 - 1400 wildland fires occurred annually. Most fires are caused by humans while lightning causes 15- 30% of fires. The total number of forest fires during the past 47 years is 26,802 and the total burnt area is 115,389 km^2. The mean annual number of fires is 558 with mean annual burnt area of 2,455 km^2. Figure 3 shows that the maximum annual burnt are was about 16,000 km^2 in 1998 except 2002. Fire in 2002 will be discussed in the below. According to statistics since 1955, the annual burnt area is almost always less than 4,000km^2, and the burnt areas show a tendency to increase after 1989. The type of forest fires around Yakutsk is mainly surface fires and crown fires do not easily occur, possibly mainly due to the characteristics of larch tree forests.

3.2 Yakutsk Forest Fire in 2002

In 2002, a large number of wildland fires occurred near Yakutsk. The wildland fires started from early May and continued into September, with a burnt area now estimated at more than 23,000 km^2, this burnt area is the largest since 1955 (G. Takao, 2003). In 2001, the burnt area was 4,805 km^2.

The forest fires were observed both from the ground and the sky using a helicopter and a satellite. Observation results from a helicopter and a satellite are shown in Figures 4 and 5. The picture in Figure 4 clearly shows that forest fires near Yakutsk occurred in various places at the same time. This picture was taken in the right bank of the Lena River at noon of August 4th, 2002.

The satellite image in Figure 5 shows hot spots (fires) and long-tail smokes from fire around Yakutsk. From Figure 5, large areas were burning at the same time, especially in the left bank of the Lena River. Wind direction was mainly southeast except northeast area of Yakutsk.

Figure 4. Forest fires near Ykutsk, Sakha (August 4th, 2002)

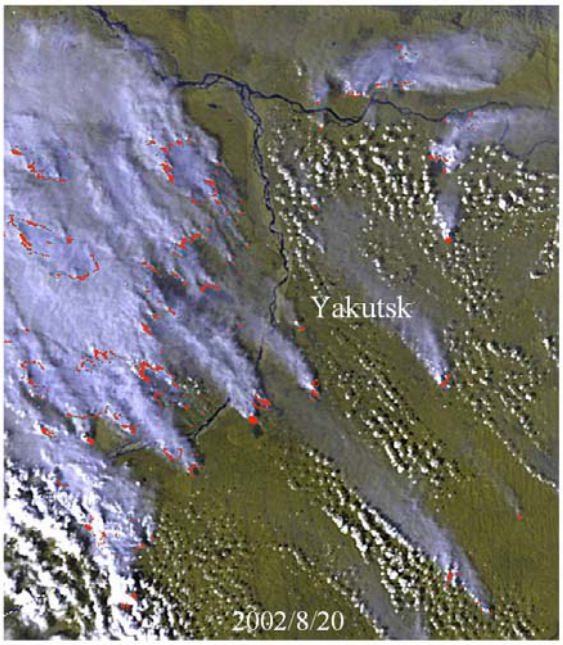

Figure 5. Satellite image & hot spots near Ykutsk, Sakha (August 20th, 2002)

4. Global Warming Trend in Yakutsk, Sakha

4.1 Long term trend of mean air temperature and precipitation

Mean air temperature change in Yakutsk from 1830 is shown in Figure 6. Mean air temperature in 1830 was around -11^{O}C. In the present, air temperature become around -8^{O}C. There is nearly 3^{O}C temperature rise. This temperature rise may be due to the effect of global warming.

Precipitation trend in Yakutsk from 1890 is also shown in Figure 6. There is a strange trend found in Figure 6. Precipitation trend changes suddenly into the decrease from the increase. It occurred at around 1970.

A remarkable temperature rise and decreasing trend of precipitation from around 1970-1980 may affect occurrence of forest fire around Yakutsk.

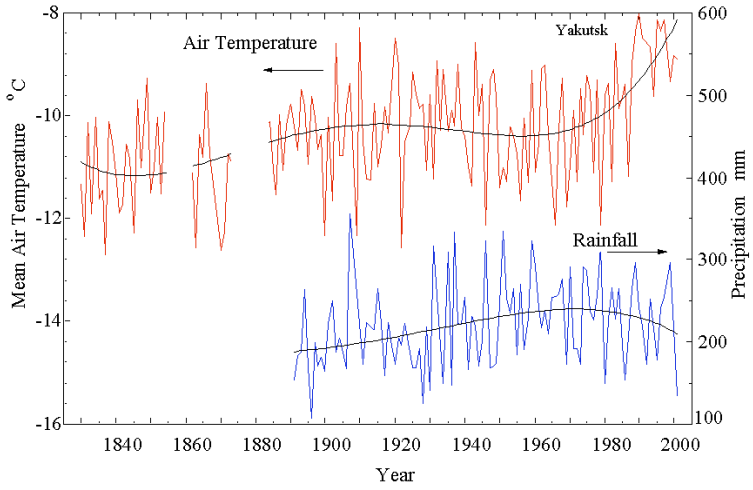

Figure 6. Global Warming and Rainfall Trend in Ykutsk, Sakha

4.2 Recent trend of seasonal precipitation

Recent precipitation trend in Yakutsk from 1994 is shown in Figure 7. Total and fire season (May to September) precipitation amounts are shown by thin and thick solid lines in Figure 7. Thick broken line shows daily mean precipitation amount in fire season. There are a few remarkable trends in Figure 7. Total precipitation increased suddenly from 1999 although there is a decreasing trend in fire season precipitation from 1994. Daily mean precipitation shows the same decreasing trend.

These above-mentioned trends suggest that forest fire near Yakutsk will increase as long as decreasing trends of fire season precipitation and daily mean precipitation last. In other words, precipitation will be one of the important factors to control forest fire because rain is only one natural extinguisher in the boreal forest.

The cause of total precipitation increase from 1999 is mainly due to the increase of winter (October to April) precipitation. Winter precipitation amount increased very rapidly from about 50 mm in 1994-95 to 200 mm in 1999. This winter precipitation increase may be mainly due to the ongoing global warming.

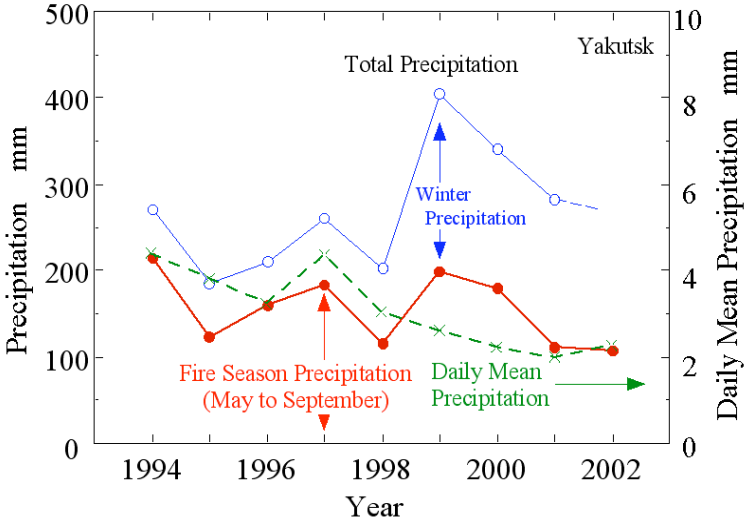

Figure 7. Recent precipitation trend in Ykutsk, Sakha

5. Catastrophic Fire Occurrence around Yakutsk and Background

5.1 Fire Progress

Fire occurrence was determined by processing satellite images. Daily satellite images for the area around Yakutsk were processed to show how catastrophic fires in August occurred around Yakutsk and shown in Figure 8. Fire occurrence of each fire month from May to September is distinguished by six different colors. These color dots are so-called hot spots. Hot spots data in Figure 8 is obtained by analyzing NOAA images (S. Tashchilin, 2002). Different colors in Figure 8 will help to understand the progress of fires in 2002.

Fires in May of yellow color dots in Figure 8 were distributed relatively near the Lena River and Yakutsk. This may mean fires occurred in May mainly caused by human. Then, flying sparks or embers from human caused fires may spread fire deep in the forest. This type of fire is called spotting fire.

May fires are very important because once Taiga forests near Yakutsk had fires, some fires will be able to survive even if it rains. Because small amount of rain shown in Figure 8 could not extinguish forest fires completely. In addition to this, fires have a way to be alive in the state of smoldering in the forest floor. If the forest floor was usual thick litter layer, the forest floor can keep smoldering for long time. In this meaning, May fires will be called "seeds for next fire".

June and July fires of bluish color dots in Figure 8 were distributed circumference of the May fires. There was 15 mm precipitation in the middle of July. But fires began to become active again after the rain in the middle of July.

Finally, a large number of fires occurred in August at once. They are shown with reddish color dots in Figure 8. We may say that catastrophic fires occurred in August burn up the left bank of the Lena river. Lightning or meteorites may ignite these areas because they are so far from towns and main rivers. They also form a straight line.

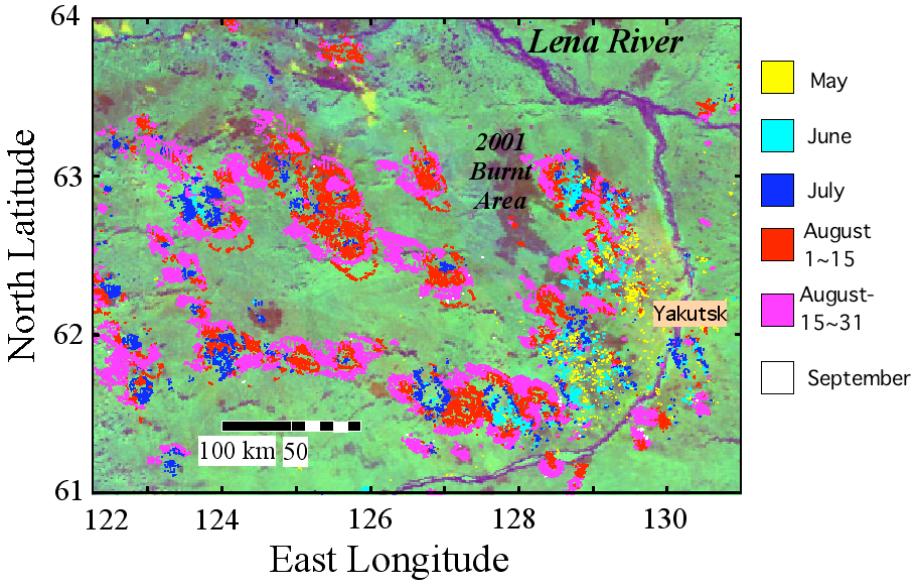

Figure 8. 2002 catastrophic fire progress near Ykutsk, Sakha

5.2 Background of Catastrophic Fire

5.2.1 Hot spot (fire) and precipitation

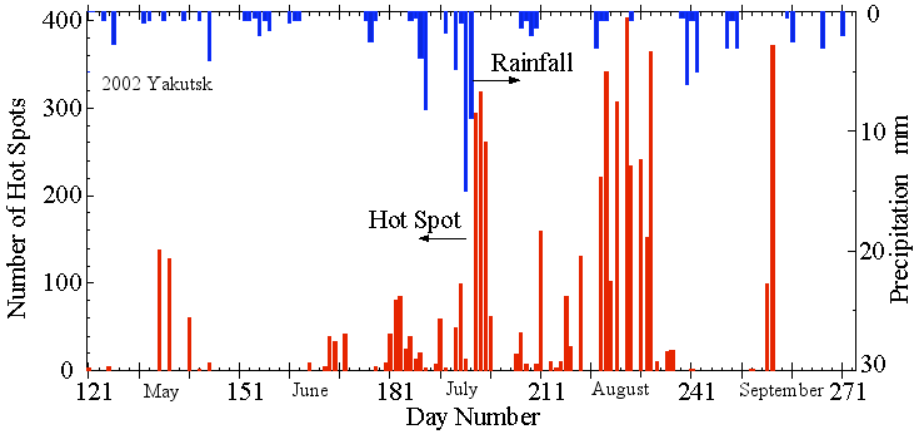

Figure 9. Hot spots (fires) and precipitation in 2002

The tendency of hot spot (fire occurrence) and precipitation in Yakutsk in from May to August of 2002 are shown in Figure 9. Hot spots data in Figure 9 is obtained by analyzing NOAA images (J. Kudo, 2002). Precipitation is expressed using inverse axes. Namely, precipitation is zero at the top. Maximum precipitation in 2002 or longest bar in Figure 9 was observed in the middle of July and it was about 15 mm.

Figure 9 shows that every month except June has large number of hot spots (fires). Just after heaviest rainfall of 2002, fires become very active in the middle of July. There was no precipitation larger than 5 mm from the middle of July until the end of August. This drought period may be one of the triggers of catastrophic fires occurred in the middle of August.

5.2.2 Atmospheric pressure and precipitation

Tendencies of atmospheric pressure and precipitation were shown in Figure 10. Tendency of 2002 atmospheric pressure is show along with a last nine years average curve and its fitting curve. Mean precipitation tendency and its fitting curve are shown in the bottom of Figure 10.

There is a negative correlation between atmospheric pressure and precipitation. Atmospheric pressure is gradually decreasing from the beginning of May and has minimum value at day number 180 or end of June. From top of July, atmospheric pressure is gradually increasing. On the contrary, precipitation is gradually increasing from the beginning of May and has maximum value at the day number 200 or middle of July. From end of July, atmospheric pressure is gradually decreasing. There is about 20 days offset between atmospheric pressure and precipitation.

Low air pressures are usually made when low pressure air masses or cyclones pass near Yakutsk. Cyclones tend to bring some moisture and make a weak rainy season in summer. Figure 10 shows that there are several peaks of precipitation of around 10 mm on the last nine years average curve of precipitation. Several valleys of precipitation are also found using the fitting curve for last nine years average of precipitation. These valleys correspond with almost all hot spots (fires) in 2002.

Finally, several peaks of atmospheric pressure of 2002 which exceed 1015 hPa are easily found in

Figure 10. They also correspond with almost all hot spots (fires) in Figure 9. The above relationship among fire, precipitation and atmospheric pressure may imply that fire starts under low pressure condition or cyclone and grows under high pressure condition or anticyclone. If anticyclone does not move like in the middle of August 2002, fire will become large one.

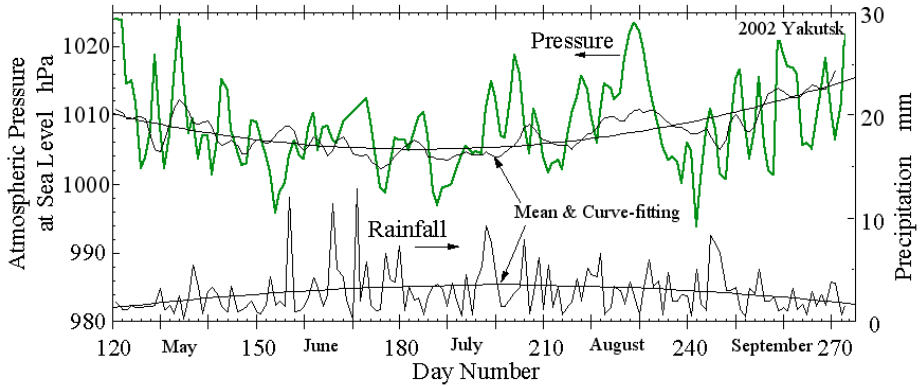

Figure 10. Recent trend of atmospheric pressure and precipitation

5.2.3 Maximum air temperature and dew point

Tendencies of maximum air temperature and dew point were shown in Figure 11. Maximum air temperature has a peak at the day number of 195 or in the middle of July. Temperature difference between maximum air temperature and dew point indicates humidity. Distance between two fitting curves for maximum air temperature and dew point is almost same from the day number of 120 to 200. After the day number of 200, distance of two lines narrows gradually. This trend imply that spring is relatively dry and autumn becomes relatively wet.

Maximum air temperature of 2002 was 1.1ºC higher temperature than the recent average of last nine years. On the contrary, dew point of 2002 was 0.2ºC lower temperature than the recent average. Maximum air temperature may be one of indices of forest fire. A straight line is drawn at the 20ºC in Figure 11. If maximum air temperature exceeds 20ºC, fire tends to occur. This criterion can explain fires (hot spots) in Figure 9. Especially, fires in May and September occurred when temperature exceeded 20ºC. Large fire in August happened after long high temperature period from June.

Sudden temperature drops of dew point found in the day number of around 198 and 208 may due to cool and dry air mass from circumpolar regions. First one came after the cyclone with heavy rain in the day number of around 190 and high pressure lasted several days. During this period, large fire in July occurred. Second cool and dry air mass came after the cyclone with light rain in the day number of around 209 and high pressure lasted about two weeks. During this period, catastrophic fire in August occurred.

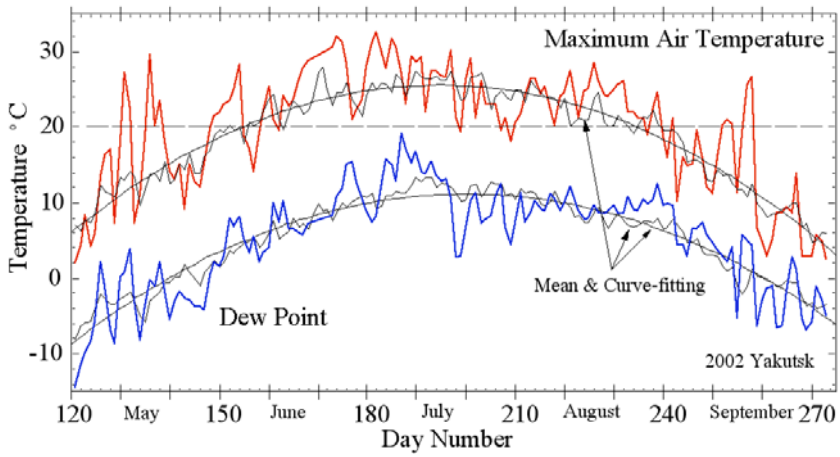

Figure 11. Recent trend of maximum air temperature and dew point

6. Conclusions

From the above discussions about forest fires in Alaska and Sakha may allow the following conclusions.

1. Forest fires in Alaska and Sakha at high latitude become now very active mainly due to global worming.
2. The mean annual number of fires in Sakha is about 560. This number is three times greater than that of Alaska. On the contrary, the mean annual burnt area in both places is about the same and 2,400 km^{-2}.
3. Lightning-caused forest fire in Alaska tends to have greater burnt area.

Detailed climate analysis of Yakutsk may allow the following conclusions.

4. Fire season (from May to September) precipitation amount showed gradual decreasing trends from 1994. Daily mean precipitation amount in fire season became half in the past nine years. Forest fires in Yakutsk would become active under these precipitation trends. On the other hand, winter (from October to April) precipitation amounts increased suddenly from 1999. These anomalous trends may be due to the ongoing global warming.
5. Catastrophic fire may occur if stable weather with high pressure and low dew point was sustained by such as a ridge above forest area or blocking anticyclone.

Finally, the first author would like to point out that catastrophic forest fire due to the ongoing global warming may have already begun in Taiga around Yakutsk. If we could not develop a suitable method to control forest fire occurred in Taiga, boreal forest will be lost soon or later.

Acknowledgments

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