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NOAA Satellite Based Real Time Forest Fire Monitoring System for Russia and North Asian Region

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Abstract

Forest fires cause severe damages to natural resources and human lives all over the world. Though a lot of forest fires occur in Russia and North Asia every year, there is no system available that monitors forest fire in real time processing. However the MODIS Land Rapid Response System provides near-real time fire observations globally, currently forest fire monitoring techniques are not efficient enough to optimally monitor this disaster. For a real-time forest fire monitor system an efficient fire detection method is crucial. Existing fire detection methods are insufficient. Here we reported an improved algorithm for forest fire detection using NOAA AVHRR data. Using the data from AVHRR radiometer of NOAA-16, a real time fire detection method is developed to identify actively burning forest fire and applied to provide daily satellite based fire monitoring for Russia and Northeast Asian region. This paper describes the design and functionality of the system which integrates three components into a data acquisition/processing system and accompanying web browser. The three components are: satellite data reception, image processing for detection of fire and burned area calculation and Web publishing. Our system has been operated since May 2004 and fire information is available on the Internet.

1 Introduction

Recently, a large-scale forest fire happens frequently in all parts of the world. Those forest fires cause severe damages to valuable natural resources and human lives, and exhaust a large amount of carbon dioxide that thought to be a cause of global warming [FRA 2000]. Forest fire and their impact continue to be one of the major factors in the Northeast Asia impacting the condition of nature resources and quality of human life [Kondrashov L. G. and Lyubyakin A. 2005]. Forest fires rise ecological problems and put forest sustainable management, economic development and public health at risk, specially in the region relying upon forest resources as a driving force in their progress. UNDP documents show that up to half a percent of natural forest could burn annually in accord with its natural succession pattern, and only fires exceeding this threshold would create a problem [Kondrashov L. G. and Lyubyakin A. 2005].

Russia is a broad area where forest fire happens every year. The number of forest fires and area burned differs from year to year depending primarily on human behavior and climatic conditions. According to the Russian Federal Forestry Service (FSS), the number varies from 12,000 to

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30,000 fires per annum burning annually from 500,000 to about 2 million hectares (ha) [Kondrashov L. G. and Lyubyakin A. 2005]. The fire situation in Japan is also severe as the number of forest fires is about 3,000 per year [Kohyu Satoh 2005]. Though a large number of forest fires happen in Russia and North Asia there is no real time forest fire monitoring system which is necessary for early warning and early detection for fire fighting. Moreover, forest fire monitoring techniques are not efficient enough to optimally monitor this natural disaster.

At present specialist examines the damage situation after a large-scale forest fire occurs. However, watch from the ground is difficult, laborious and time consuming. Wide-ranging monitor by the satellite remote sensing may be better alternative and has many advantages. Satellite can repeatedly observe the wide area at once and continuously acquired the information about the ground features and environmental changes. The spectral reflectivity of the ground features detected by satellite sensor can show the characteristics phenomena about current damage and post fire damages. It is more useful to use satellite images to investigate the ecological damage affected by forest fire and to monitor the recovering process. A real time monitoring system based on satellite data that can detect the forest fire occurrence might play a great role to reduce the damages by forest fires. The real time archive system of satellite data with forest fire information can also play one of the important roles of a disaster information system.

Various researchers developed methods to detect forest fire using satellite images and some fire monitoring systems are constructed and fire information are spread out all over the world through GFMC (Global Fire Monitoring Center) [The Global Fire Monitoring Center (GFMC)], but those are not real time processes. A real time fire monitor is still insufficient as the reliability of fire detection algorithm is low in the satellite image being used where false fire detection happens significantly.

Though the resolution of MODIS images are better than NOAA AVHRR images and are viewing the entire Earth's surface twice a day, use of huge MODIS data in the real time fire monitoring system is difficult. On the other hand, precise geometry correction of the AVHRR images is

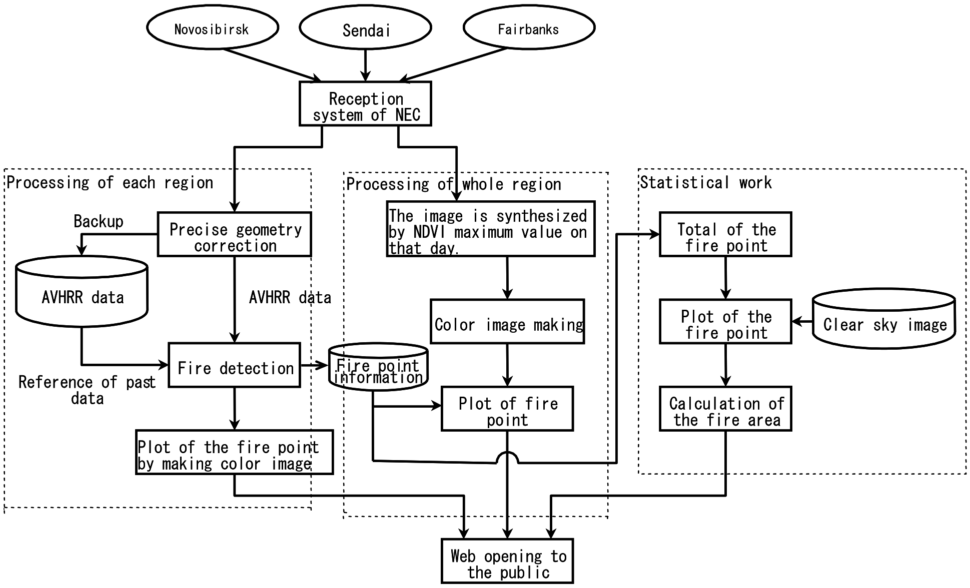

Fig.1: Flow chart of our real time forest fire monitoring system.

a concern for real time forest fire monitoring system.

We developed a new algorithm for forest fire detection with accuracy that reduced false fire detection significantly [Kalpoma K. A. et al. 2005] [Kalpoma K. A. and Kudoh J. 2006]. Using this new algorithm and precise geometry correction of the AVHRR images by M. Nakano et al. [Nakano M. et al. 2004] [Nakano M. et al. 2005] we have constructed a NOAA satellite based operational real time fire monitoring system for Russia and Northeast Asian region.

2 Real time fire monitoring system

Fig.1 shows the outline of our real time forest fire monitoring system. The system mainly composed of satellite data acquisition, image processing, burned area calculation and Web publishing.

A. Satellite data acquisition

This work used the NOAA-16 AVHRR data that was received in Sendai (Japan), Novosibirsk (Russia), and Fairbanks (USA) and transferred to Tohoku University. Tohoku University started to receive directly the NOAA data of Far East region from 20 years ago and also have a satellite station in Siberia to receive NOAA data in Novosibirsk (Russia), and simultaneously transfer the data through the satellite network to Tohoku University. A detailed fire can be monitored by using these data in a vast area of Russia and North Asian region including Tohoku.

First, NOAA-16 AVHRR data is processed geometric and radiometric correction by a program which is provided by NEC [NEC CORPORATION 1996]. But this program cannot process geometric correction with sufficient accuracy. So accuracy of a fire traced is not enough. Therefore, further a precise geometry correction is performed by using the method proposed by M. Nakano [Nakano M. et al. 2004][Nakano M. et al. 2005]. Fig.2 shows the flow diagram of geometric correction method. In this method Ground Control Point (GCP) is created automatically and perspective

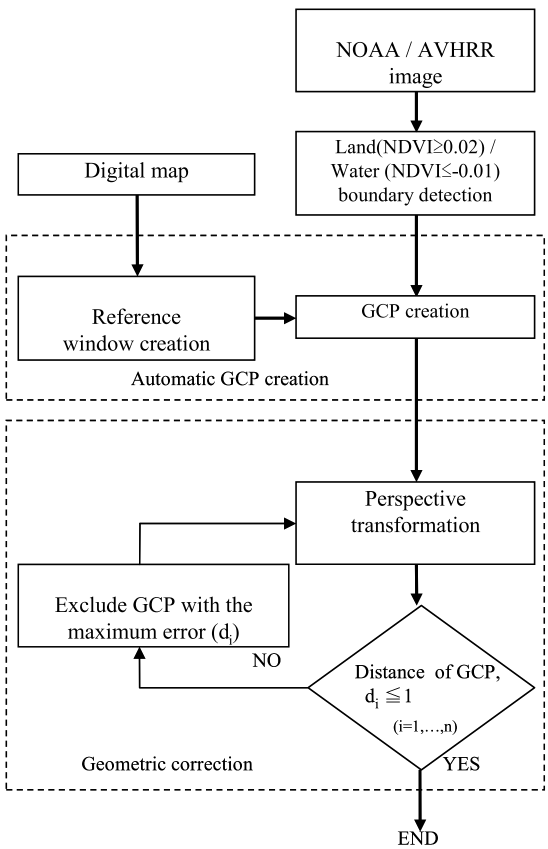

Fig.2: Flow diagram of geometric correction method proposed by M. Nakano et al. [Nakano M. et al. 2005]. Here, NDVI means normalized differentiate vegetation index, GCP for ground control point and di is the distance of the coordinates of GCP after perspective transformation.

transformation is used as the geometric correction algorithm. No manual process is required. Therefore, the processing time has become very short. This GCP creation method is very effective in the cases where a lot of images have to be processed. It allowed fire tracing by our system with high accuracy geometric correction in real time.

B. Image Processing

Image processing function analyzes the received data after geometric and radiometric correction and detects forest fires. Here, the fire detection has done by dividing the whole analysis area into 17 regions because the range of the observation is wide (latitude 24° N~70° N and longitude 27° E~179° E). The entire AVHRR image monitored by the resolution of 11km/pixel and the image in each region of 1.1km/pixel are generated from the received data. This image function is divided in three main parts: 1) processing of each region, 2) processing of whole image and 3) statistical data processing for burned area calculation. Hereafter, each part is explained separately.

1) Processing of Each Region

Precise geometry corrected AVHRR data are backed up for one month to use as reference during fire detection as shown in the left part of Fig.1. Then the fire detection was performed by using our previously developed method [Kalpoma K. A. and Kudoh J. 2006]. To improve the accuracy of traced fire, a process to remove the false detection by a temporal analysis was done. All the information of detected fire is stored into the system for future use. Fire detection and temporal analysis are described below.

a) Fire Detection

Fig.3 shows the flowchart of fire detection method that used in this system. First, the false detection on the non-vegetated surfaces such as seas, are eliminated by considering the MVC (Maximum Value Composite). MVC is calculated from the highest value of NDVI (Normalized Difference Vegetation Index) from past one month of backed up images. When the value of MVC for a pixel becomes higher than 0.3 (MVC > 0.3) it is considered as a target pixel for fire detection.

Next Kudoh method is applied on the target pixels to detect the fire points [Kudoh J. and Hosoi K. 2003] Kudoh et al. made fire category model from Three Dimensional Histogram data of 14 years forest fires information using

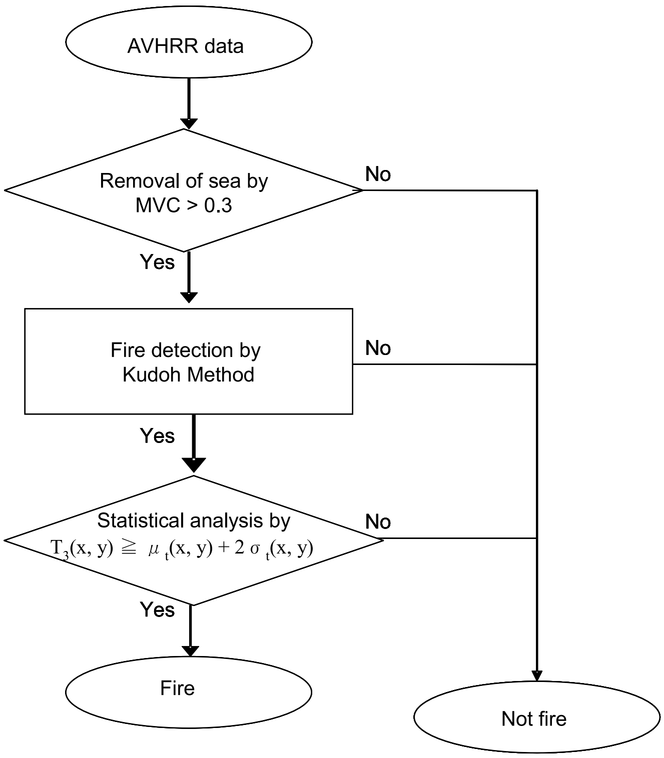

Fig.3: Flowchart of fire detection method.

NOAA AVHRR images of Far East Russian region. The combinations of channels were 1 (Ch1), 3 (Ch3) and 5 (Ch5). Fire category model was made from this Three Dimensional Histogram [Kudoh J. and Noguchi S. 1991]. However, as all the Ch3 values were saturated, a Two Dimensional Histogram composed of Ch1 and Ch5 is obtained which provided this reliable fire detection category model. From an unknown image those pixels enter into this category are considered as fire points. In this category the accuracy of the fire detection goes up by using the number of frequency four or more in the histogram. During accumulation of fire data in Three Dimensional Histogram, false fire detection points due to the cloud region were removed manually by human vision.

However, some false detection might be appeared. To remove this possibility a statistical analysis was done over those fire points. First of all, from the backed up images value of mean and standard deviation of pixels for past 20 days from the target day was calculated for Ch3. When the value of Ch3 of a pixel (of obtained fire points) was higher than the threshold of (1), it was considered as a fire point.

$$T_3(x, y) \geqq \mu_t(x, y) + 2\sigma_t(x, y) \qquad (1)$$

Here, $T_3(x, y)$ is the value of Ch3 of target image on (x, y) coordinates, $\mu_t(x, y)$ is the mean value of Ch3 for past 20 days from target day and $\sigma_t(x, y)$ is the standard deviation on (x, y) coordinates. Still some false detection appeared. To reduce this false detection, this system has a temporal analysis to trace the detected fire.

b) Temporal Analysis

The temporal analysis is done by using the total information of detected fires stored into the system. The flowchart of this temporal analysis is shown in Fig.4.

Here system judges each and every detected fire pixel whether it is actual fire or false by checking some conditions. First it checks whether a fire is detected in the same place for consecutive 2 or more days. If a fire is detected in the same place for 2 days, possibility of a fire continuing is high and it is considered as a fire. In the case that a fire was not detected back and forth, the presence of smoke in neighborhood of fire pixel is checked. If there is smoke, a fire is considered. If there is no smoke, NDVI of detected fire is compared with NDVI of neighborhood. If NDVI shows no difference, the fire point is a false detection. If

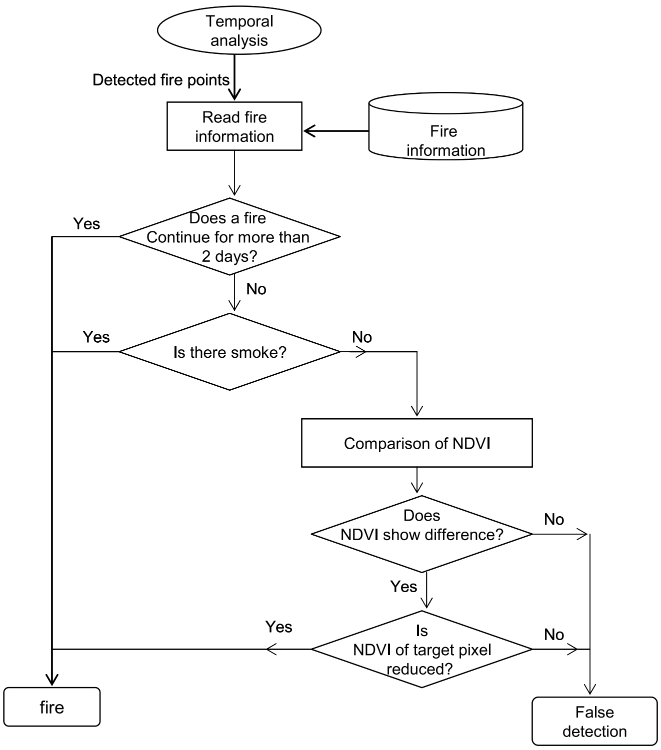

Fig.4: Flowchart of the false detection removal by a temporal analysis.

NDVI decreases then it considered as a fire. Otherwise it is false.

Obtained fire detection points are collected as fire point information database. To display the fire result on Web, false color image is made from AVHRR images that are allocated on Ch1, Ch2 and Ch1 respectively. Fire points are plotted as red dots. The burned area is calculated from the number of detected fire points. Finally this information is uploaded to the Web server as HTML format. All these processes are done for each of 17 regions.

2) Processing of Whole Image

The information of fire in a whole image is made, which cover the entire 17 regions. The middle part of Fig.1 shows the outline of this process. The received data from reception system of NEC obtained within a day is synthesized to make this whole image. To synthesize the data, maximum NDVI value on that day is used. The false color image is made from synthesized data that allocates Ch1, Ch2 and Ch1 respectively. In addition, detected fire points from fire point information database are plotted in this image and open it to the public on Web.

3) Statistical Data Processing for Burned Area Calculation

Clear sky image database was constructed in advance. Fire detection is executed for a month and total detected fire points are plotted on clear sky image. Geometric correction was executed

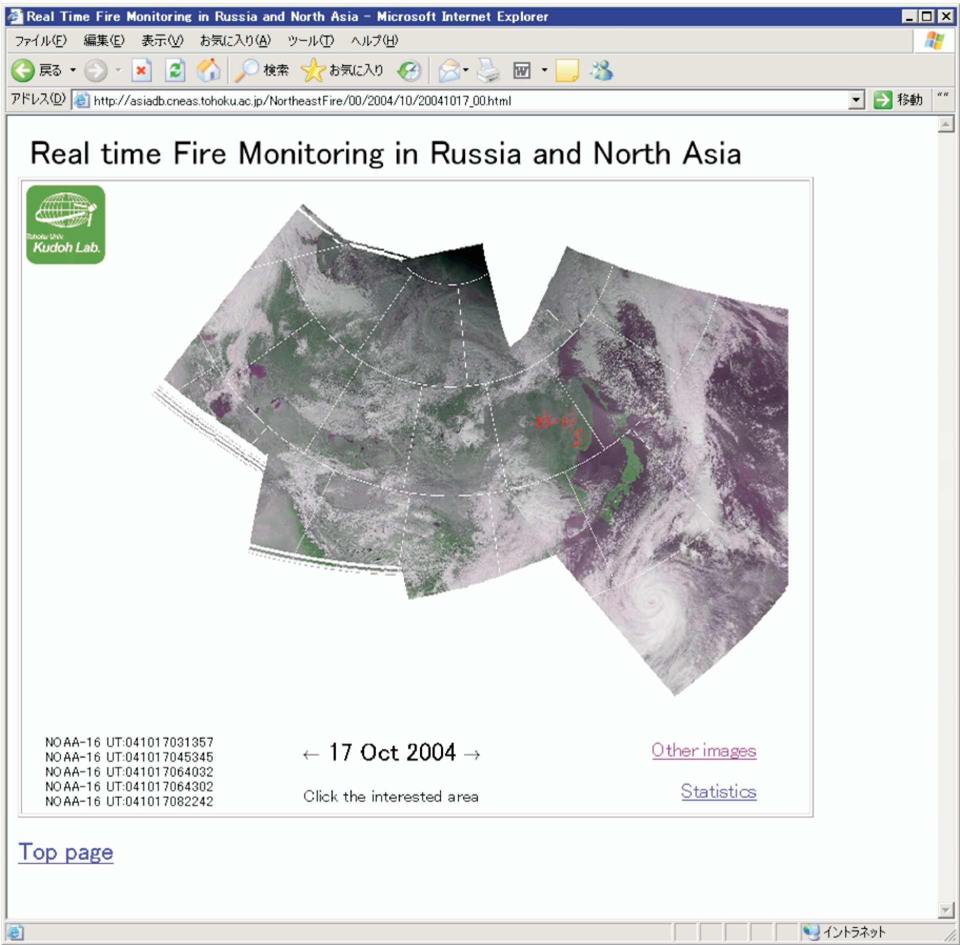

Fig.5: Top page view of our real time fire monitoring system on Web.

on NOAA AVHRR image to 1.1 km per pixel. Therefore, a plotted fire is 1.21 ㎢ per pixel. Burned area is calculated from the number of detected fire points based on accumulated results of every 10 days and totaled in 1 month for entire 17 regions. The out line of this process is shown in the right part of Fig.1. Finally this information is uploaded to the web server as HTML format.

3 Web opening

Our system named "Real time Fire Monitoring in Russia and North Asia" (Fig.5) has been operated since May 2004. The result has been published in Web and available in the Internet; http://asiadb.cneas.tohoku.ac.jp/NortheastFire/.

Web opening function converts AVHRR image to image data (png) with indication of 17 different regions by dotted lines. The fire point is plotted with red dot in the image and all the information and results (fire points and burned area) are also uploaded to Web server. As the system is real time, fire information of the day is always displayed and arbitrary fire information can be retrieved from the part of old images.

Fig.5 shows a top page view of our real time fire monitoring system on Web. It displays latest fire information of Russia and North Asian region on October 17, 2004. Displayed whole image was made by the process mentioned previously on chapter 2. The reception time when the AVHRR received data which were used for generating the image is displayed on the left of this screen at the GMT time. On the right two other options is displayed; "Other images" and "Statistics".

When any part of the image in this web page is clicked, it moves to display the regional screen and displays the regional image with the burned Area (㎢). Fig.6 shows a regional screen where a large scale forest fire

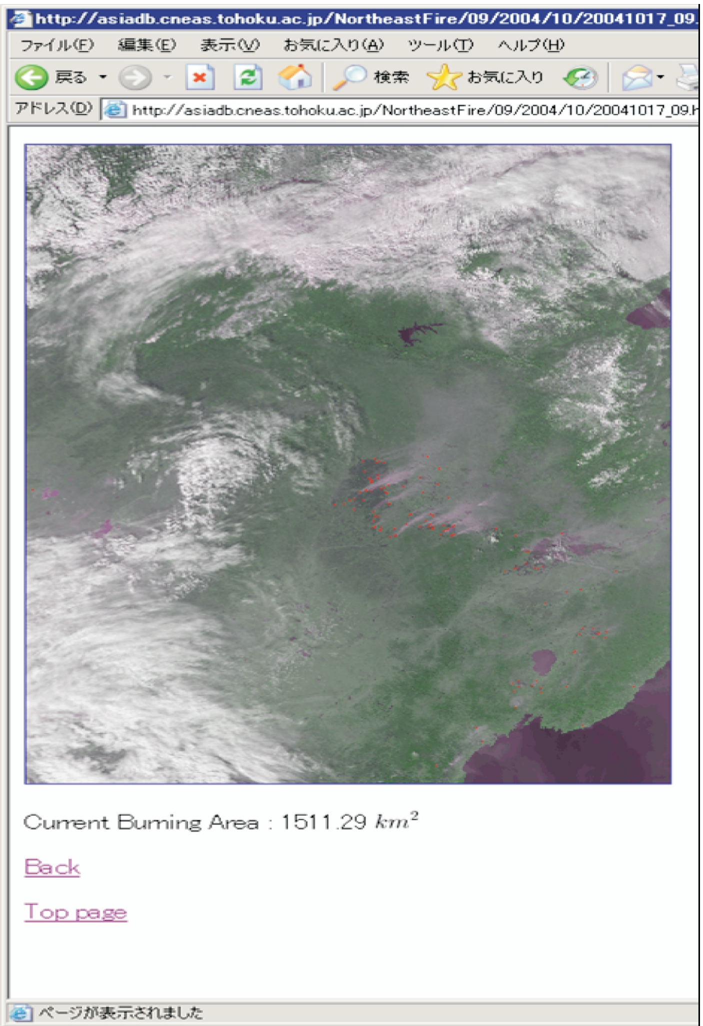

Fig.6: View of detail image for regional screen with burned area (㎢).

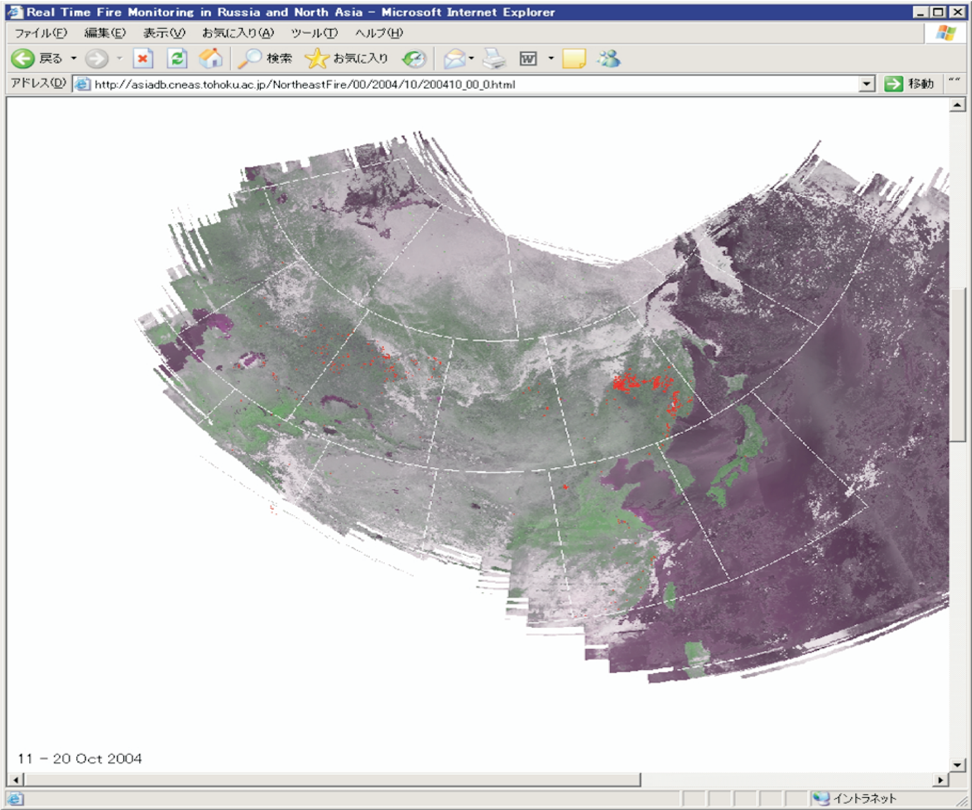

Fig.7: View of the page of statistical data.

broke out around Khabarovsk of Russia on October 17, 2004. Here, smoke is generated at the central part on the screen where fires have been detected. This regional page also contains two options; "Top page" and "Back". Clicking on "Top page" enables to reach the top page on current date and "Back" enables to reach the top page on the same date as it is (October 17, 2004).

It is possible to move to a statistical data page by clicking "Statistics" of a top screen (Fig.5). It displays accumulated results of every 10 days and accumulated results in 1 month for entire 17 regions. Fig.7 shows a partial view of the page of statistical data (October 11^{th} to 20th, 2004). By clicking any part of this image, it is possible to display the enlarge image of the corresponding region. The period of fire accumulation is written under the left of the image on this screen. Arbitrary fire information on the date can be retrieved by clicking "Other images" on a top screen of our fire system as shown in Fig.8. It sows the retrieval steps for the data of October 18, 2004.

Global Fire Monitoring Center (GFMC) and FAO (Food and Agricultural Organization) display fire information of our system (Fig.9). Fire information are spread out all over the world through GFMC and our results also available at http://www.fire.uni-freiburg.de/current/globalfire.htm/.

4 Conclusion

In this work a real-time fire monitor system was constructed by using the NOAA/AVHRR image for Russia and North Asian region including Tohoku, Japan. We have a plan to improve fire detection method, burned area calculation and to mix different kind of satellite images such

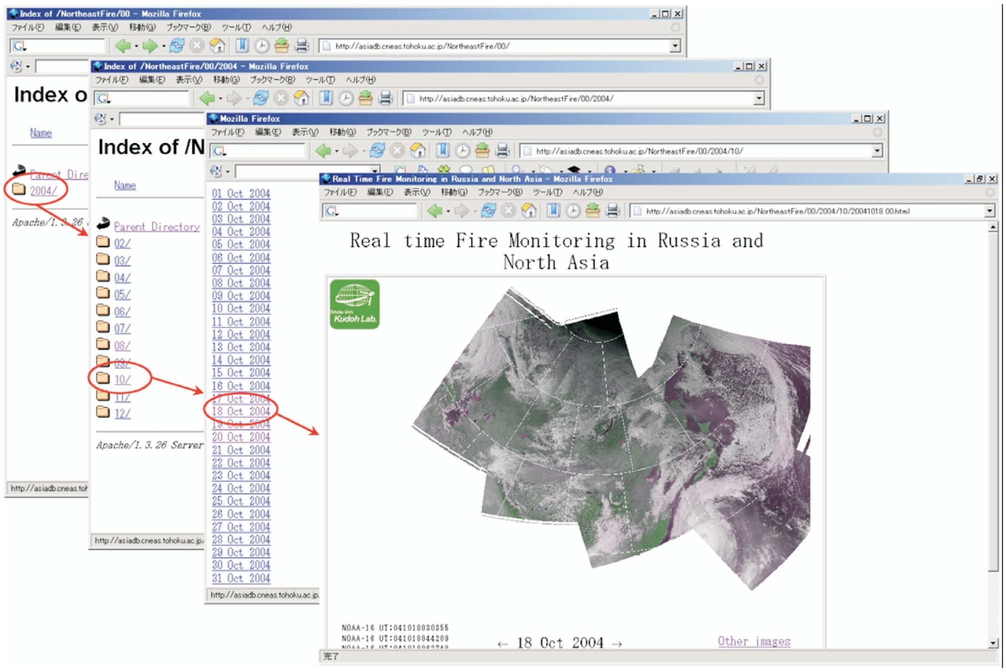

Fig.8: View the page of the fire information retrieval by date (October 18, 2004).

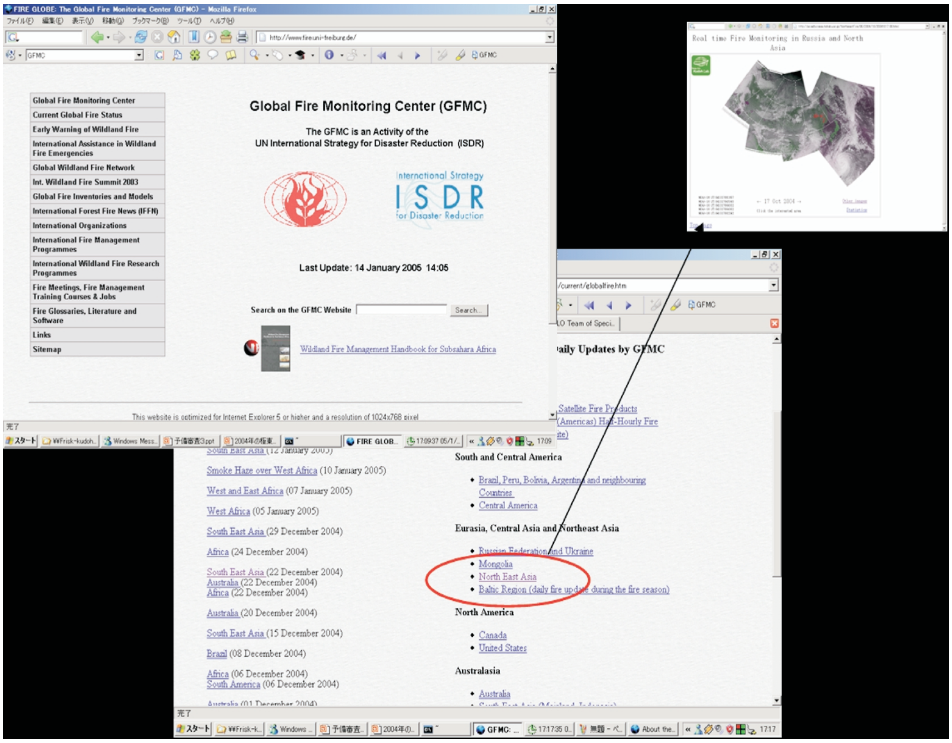

Fig.9: Global Fire Monitoring Center (GFMC) displays our system.

as one meter class resolution images. This system may help to develop the ecology monitoring and early warning for various disasters.

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