FOREST FIRES IDENTIFICATION USING AATSR AND MODIS DATA

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ABSTRACT

Forest fire is a kind of worldwide natural calamity. It is extensively distributed with high occurrence frequency and destroys forest resources thus disturbing normal living order of people and leading to environmental deterioration. The appearance and development of modernistic new high technologies, such as Remote Sensing (RS), Geographic Information System (GIS) and Internet, have given more convenience for preventing and decreasing disaster than before. In this study, basing on analyzing the information of related bands of Advanced Along Track Scanning Radiometer (AATSR) and integration of background GIS data, a forest fire identification methodology has been developed. At the same times, the accuracy of the results by using AATSR and Moderate Resolution Image Spectroradiometer (MODIS) data has been tested in northeast of China.

1. INTRODUCTION

Forest fires are a prominent global phenomenon, which not only destroy natural vegetation, but also pose enormous danger to wildlife as well as to human life and property. In addition, biomass burning by fires has been identified as a significant source of aerosols, carbon fluxes, and trace gases, which pollute the atmosphere and contribute to radiative forcing responsible for global climate change[1]. Forest fire in Northeast of China region is especially severe and has aroused extensive attention by Chinese government.

Timely and accurate detection of fires has become an issue of considerable importance. Various international organizations, such as the International Geosphere and Biosphere Program (IGBP), have recognized the need for fire detection and monitoring [2]. Space-borne fire detection has been a topic of intensive research since the early 1980s [3, 4]. Much of the work has concentrated on fire monitoring methodology or estimation of atmospheric emissions from fires [5]. Until now, most fire detection activities have been based on the use of data from the Advanced Very High Resolution Radiometer (AVHRR) onboard the National Oceanic and Atmospheric Administration’s (NOAA) polar orbiting satellites. The AVHRR series of sensors offer a spatial resolution of 1km and cover most of the Earth’s surface every day, once in the daytime and once at night. AVHRR data have been widely used for fire detection because they have some unique radiometric advantages relative to other satellite data, and provide a good balance in spatial and temporal resolutions [6]. There are many algorithms by using AVHRR data to detect fires [3, 4, 7, 8, 9]. The Moderate Resolution Imaging Spectroradiometer (MODIS) which carried on both the Terra and Aqua satellites makes possible monitoring earth four times everyday. MODIS has the ability to observe fires, smoke, and burn scars globally. Its main fire detection channels saturate at high brightness temperatures: 500 k at 4 µm and 400 k at 11 µm which can only be obtained in rare circumstances at the 1 km fire detection spatial resolution [10]. Thus, MODIS is different from other polar orbiting satellite sensors with similar thermal and spatial resolutions (such as Advanced Very High Resolution Radiometer). In recently years, MODIS data has been broadly used for fire detection [11, 12, 13, 14, 15, 16, 17]. The Advanced Along Track Scanning Radiometer (AATSR) is the third in a series of instruments, continuing from ATSR-1 launched on ERS-1 in July 1991 and ATSR-2 launched on ERS-2 in April 1995. The instruments have a common heritage, although certain aspects of instrument design have evolved and improved. Data from the AATSR sensor have also been used for fire detection [18]. However, since the 3.7 band of ATSR-2 saturates at about 312 k, night-time data have been used in fire detection for global fire map [19, 20, 21, 22]. The ‘Dragon Project’ gives the opportunity to study the potential fire detection by using AATSR sensors in northeast of China.
2. STUDY AREA AND DATASET

2.1. Study Area

The northeast of China is the first of five important forest region of China. Its’ climate belongs to temperate zone. The main vegetation is needleleaf forests in cold-temperate, needleleaf and broadleaf mixed forests in temperate zone and deciduous broadleaf forests in warm-temperate zone. At the same time, the northeast forest region is a region with high occurrence of large forest fires. Many large forest fires have been taken place in this region, such as the famous large forest fire which has taken place in 1987. The study site is located between 127°E to 136°E and 48.0°N to 56.0°N (Figure 1).

2.2. Dataset

The AATSR_TOA images have been used for the analysis of forest fires in the northeast of China. The selected data with a total of 40 scenes have been supplied by our European partners. The analysis was carried out during the months of April, May, June and July corresponding to the year 2002, 2003 and 2004. At the same time, the fire points getting from Moderate Resolution Image Spectroradiometer (MODIS) and the large forest fire information, such as location, vegetation type and fire duration, have been collected.

3. METHODOLOGY

3.1 Samples Test

The AATSR-TOA production has seven bands at centre wavelength 0.55, 0.65, 0.87, 1.60, 3.7, 11 and 12μm. In order to get the fire detection model of northeast of China with AATSR data, the parameters of fire, vegetation, land, cloud, water and burnt scar have been sampled from the AATSR-TOA production image. We have sampled more than 100 pixels every classes. Here, The bright temperature of 3.7, 11, 12μm and the difference between 3.7μm and 11μm at the nadir direction has defined as T4, T11, T12 and DT14. The bright temperature of 3.7, 11, 12μm and the difference between 3.7μm and 11μm at the fward direction has defined as TF4, TF11, TF12 and DT2. The reflectance of 0.55, 0.65, 0.87 and 1.60μm at the nadir direction has defined as R1, R2, R3 and R4. The reflectance of 0.55, 0.65, 0.87 and 1.60μm at the fward direction has defined as RF1, RF2, RF3 and RF4.

![Fig. 1. National Forest Resources Map of China and the study area](image-url)
The statistic analysis includes their average, maximum, minimum and standard deviation. The statistics of the thermal values were analyzed according to the bright temperature in the central wavelength bands 3.7, 11, 12μm and the difference between 3.7μm and 11μm, distinguishing between night images and diurnal images, always on non-saturated pixels. Besides, for diurnal images, the reflectance in bands 0.55, 0.67, 0.87 and 1.60μm were also analyzed with a view to using them for the filtering of false alarms. Part of analysis results have been listed in Fig. 2 and Fig. 3.

3.2 Algorithm Description

According to the AATSR product Handbook [18, 22], the data just in nadir direction has been used for fire detection in this time.

3.2.1 Cloud Masking

Cloud detection was performed using a technique based on that used in the production of the International Geosphere Biosphere Program (IGBP) AVHRR derived Global Fire Product [23]. But we found sometimes the land’s bright temperature in band 12 μm is lower than 265 k. So, heritage algorithms are developed in our cloud detection. We changed the bright temperature of band 12 μm from 265 k to 262 k. The Daytime pixels are considered to be cloud if one of Eqs.1-3 condition is satisfied.

\[
R_2 + R_3 > 0.9 \\
T_{12} < 262 \text{ K} \\
\begin{cases} 
R_2 + R_3 > 0.8 \\
T_{12} < 285 \text{k}
\end{cases}
\]

Nighttime pixels are classed as cloud if the single condition Eq. 2 is satisfied.

These simple criteria were found to be adequate for identifying larger, cooler clouds but consistently missed out small clouds and cloud edges.

3.2.2 Water masking

Water pixels were identified if a pixel satisfied the condition of Eq. 4.

\[
\begin{cases} 
R_4 < 0.03 \\
R_5 < 0.02 \\
NDVI < 0.0
\end{cases}
\]
where: $R_2$ is the reflectance of band at 0.65 $\mu$m;  
$R_3$ is the reflectance of band at 0.87 $\mu$m;  
$R_4$ is the reflectance of band at 1.6 $\mu$m;  
NDVI is the normal vegetation Index;

3.2.3 Potential Fire Pixels Identification

A preliminary classification is used to eliminate obvious non-fire pixels. Those pixels that remain are considered in subsequent tests (described in the next sections) to determine if they do in fact contain an active fire.

A daytime pixel is identified as a potential fire pixel if its’ value satisfied Eq. 5.

$$
\begin{align*}
T_4 &> 308K \\
DT_4 &> 20K \\
5\% < R_4 < 15\%
\end{align*}
$$

For nighttime image, the reflective test is omitted and the $T_4$ threshold reduced to 300 K. A Pixel will be identified as a potential fire pixel if its’ value satisfied Eq. 6.

$$
\begin{align*}
T_4 &> 300K \\
DT_4 &> 20K
\end{align*}
$$

3.2.4 Background Characterization

In the next phase of the algorithm, an attempt is made to use the neighboring pixels to estimate the radiometric signal of the potential fire pixel in the absence of fire. Valid neighboring pixels in a window centered on the potential fire pixel are identified and are used to estimate a background value. Within this window, valid pixels are defined as those that (1) contain usable observations, (2) are located on land, (3) are not cloud-contaminated, and (4) are not potential fire pixels.

3.2.5 Fire Identification

A neighbour ‘split windows’ criterion identical method has been used for fire identification. The neighbour ‘split windows’ criterion identical method is widely used in fire detection of satellite image (e. g. NOAA-AVHRR). Here, a $(5 \times 5$ pixels) ‘split window’ has been used to identify fire and a series of tests are used to perform fire detection. These look for the characteristic signature of an active fire in which both the 3.7 $\mu$m brightness temperature ($T_4$) and the 3.7 $\mu$m and 11 $\mu$m brightness temperature difference ($DT_1$) depart substantially from that of the non-fire background. Relative thresholds are adjusted based on the natural variability of the background. The conditional tests formula are listed from Eqs.7-11.

$$
\begin{align*}
DT_1 > DT_{ib} + 2.0\Delta DT_{ib} \\
T_4 > T_{4b} + 2.0\Delta T_{4b} \\
T_{11} > T_{11b} + \Delta T_{11b} - 2k \\
R_4 < 10\% \\
R_4 < 15\%
\end{align*}
$$

where: $DT_1$ is bright temperature difference of 3.7 $\mu$m and 11 $\mu$m;  
$\Delta DT_{ib}$ is the standard deviation of background pixels of $DT_1$;  
$\bar{T}_{4b}$ is the mean of background pixels at 3.7 $\mu$m band;  
$\Delta T_{4b}$ is the standard deviation of background pixels at 3.7 $\mu$m band;  
$\bar{T}_{11b}$ is the mean of background pixels in 11 $\mu$m band;
$\sigma_{\text{b}}$ is the standard deviation of background pixels at 11 $\mu$m band;

A pixel in daytime will be flagged as fire point if it satisfies Eqs. 7-11. However, a pixel in nighttime just need satisfy Eqs. 7-9 and Eq. 12.

$$R_1 < 10\%$$  \hspace{1cm} (12)

3.2.6 False Alarm Rejection

To the diurnal image, false fire alarm can be caused by strong solar, desert boundary and coastal. The 1:1,000,000 scale map of vegetation has been used to identify the type of landcover in this experiment. So, we just consider the false fire caused by strong solar in this time. A pixel in daytime will be eliminated as sun false fire point from fire point if its’ sun glint satisfies Eq. 13.

$$\begin{align*}
R_1 &> 20\% \\
R_1 &> 5\% \\
\theta &< 40^\circ
\end{align*}$$  \hspace{1cm} (13)

Here, $\theta$ is the sun glint. It is calculated by using Eq. 14 [10, 13].

$$\cos \theta = \cos \theta_v \cos \theta_s - \sin \theta_v \sin \theta_s \cos \Phi$$  \hspace{1cm} (14)

Here, $\theta_v$ and $\theta_s$ are the view and solar zenith angles, respectively, and $\Phi$ is the relative azimuth angle.

4. Fire detection results

Six large forest fires have been selected to test the fire detection methodology in this time. Here, we use the hitting precision and missing precision to test the method. The hitting precision is calculated by using Eq. 15. The missing precision is calculated by using Eq. 16. At the same times, the fire results gotten from MODIS image have also been used. Part of results has been listed in Tab. 1 and Fig. 4.

\begin{align*}
\text{Hitting Precision} &= \frac{\text{Hitting pixels numbers}}{\text{Fire pixels numbers}} \times 100\% \\
\text{Missing Precision} &= 100\% - \text{Hitting precision}
\end{align*}  \hspace{1cm} (15, 16)

Tab. 1. The fire detection results of AATSR-TOA and MODIS data

<table>
<thead>
<tr>
<th>Date</th>
<th>Fire pixels' number</th>
<th>AATSR-TOA</th>
<th>MODIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hitting pixels' number</td>
<td>Missing Pixels' number</td>
<td>Hitting Precision (Unit: %)</td>
</tr>
<tr>
<td>July 28, 2002</td>
<td>8</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Apr. 25, 2003</td>
<td>34</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>May 3, 2003</td>
<td>25</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>Oct. 2, 2005</td>
<td>16</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Oct. 3, 2005</td>
<td>22</td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>
5. Discussion and Conclusions

The relative threshold fire identification by using the bright temperature and reflectance of AATSR-TOA nadir image for the experiment area has been developed and validated in this time. From tab. 1, we can see all of the hitting precisions are more than 65%. It shows the methodology is viable. However, there are still missing some fire pixels in the experiment area. At the same time, this study just has been validated by using part of AATSR-TOA image. So, further study is needed to verify the algorithm of AATSR whether it can satisfy the condition of national of China. In the future, there might be some parameters that needed to be considered in the model, adjustment and modification.

By combining the hitting precision of AATSR and MODIS data from Tab.1, we can see the fire hitting precision by using MODIS data is relative higher than by using AATSR-TOA data. There are two reasons. One reason is the instrument. There are two satellite which carries MODIS sensor. So, the same place can be covered four times everyday. At the same time, its’ main fire detection channels saturate at high brightness temperatures: 500k at 4 µm and 400 k at 11 µm [13]. However, there are just one ENVISAT which carries AATSR. It just can pass over the same place two times everyday and their bright temperature saturation is lower than 320k at 3.7 µm [22]. This will lose some fire information. The other is the methodology. The saturated pixels have been eliminated in the fire identification method. This will also miss some fire information. In fact, the forest fires often take place during 10:00 am to 15:00 pm in northeast of China. We can see there are spatial differences among the fire points by using AATSR and MODIS data from Fig. 4. It shows the fires’ change with time. So, combining both AATSR and MODIS data, the Fire monitoring result will be more reliable.

6. References