FOREST FIRE MONITORING USING REMOTE SENSING

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ABSTRACT

For the last two decades the forest fire monitoring using remote sensing has been developed. The purposes of this paper are to present the fire detection by airborne and polar–orbiting satellite (NOAA), and discuss the ability of remote sensing for fire monitoring. Though the subpixel–sized fires as small as 1 ha can be detected by the 3.8 channel, only 10–15% fires are identified, the accuracy is very low. Therefore satellite observations of forest fires can not replace the manned tower and aircraft reconnaisance especially the airborne thermal IR sensor's important application.

INTRODUCTION

A forest fire is a major disaster which destroies many forest resources and ecological enviroment. In China the yearly number of fires was from thousands to tens thousands and up to one million ha forest area may be burned. In the world, the average number yearly was about two hundred thousand fires and burned forest area exceed five million ha. The control costs may be up to several billion dollars every year[1]. In order to effectively prevent and control fires, the early fire detection and timely monitoring is an imperative necessity. Monitoring forest fires using remote sensing technique began at early 1960s. Ever since, the researche on airborne IR forest fire mapping was carried out. Wilson (1971) had finished the report of "Airborne IR Forest Fire Detection System"[2]. Since 1987 BIFC approach to develop a method of fire mapping using a small FLIR with a Loran–C navigation unit, the fire perimeter and any fire spots are plotted diretly and scaled on a map with a few minutes[3].

From 1974 to 1980, the systematic study and test of airborne and ground IR forest fire detection were made in China. And a great success had been achieved[4,5]. But due to economic and operating condition limitation these works couldn't go on. Entering into 1980s the remote sensing technique has gotten a great development. In the course of 1987 Chinese huge fire fighting owing to the satellite (NOAA 3 channel) fire picture's aid, the forest fire remote sensing using meteorological satillite has been interested by Ministry of Forestry and enters firmly into the fire management. Satellite fire observation is of value in providing rapid inexpensive adventage, but it is not accurate enoughto detect small fires. This paper will present some researches based on author's and other's works.

FIRE MONITORING SYSTEM

The fire monitoring system, being applied or researched, is either airborne or satellite system. For airborne system the best one is a linescanner bispectral thermal IR sensor. It has two opectral channel, one is 3–5 for fire detection and other is 8–14 for forest background. So the same picture provides two kinds of information to identify easy the fire target and its precision position. Besides this, the small view field thermograph and foregoing small FLIR fire perimeter plotting system are importante to monitor fires. Now only a few satellites are appropriate for fire detection. Known Landsat, with a resolution of 30m, would be of the 16–day gap between passes over the same area. So its data can be used to estimate burned area after a fire. GOES is excellent in frequency of observations (every 30′) but its main drawbacks are its low resolution (7 km at nadir) and in 60N limited. However it is possible to detect fire′s smoke plumes by using visble channel. The best observational system is that carried by polar–orbiting meteorological satellite (NOAA series). On board satellite is of the AVHRR which provides two or three IR channels (resolution 1.1km (IFVO 1.4 mrad)). Now there are two satellites in operation over the same area four times a day. Therefore the satellite monitoring of forest fires especially in remote forest area is valuable supplement to aircraft and ground tower′s survey.

ESTIMATE OF MONITORING ABILITY

How much the ability of remote sensing system to monitor small fires is is hihly important. The theoy and test on that has been more concerned. using the AVHRR 3 and 4 IR channel temperatur from NoAA,Dozier (1981) developed an algorithm to estimate the area and temperature of the hot source .

$$L_3(T_3) = PL_3(T_f) + (1-P)L_3(T_b)$$
$$L_4(T_4) = PL_4(T_f) + (1-P)L_4(T_b)$$

where P is portion of the pixel oceupied by a fire; T_f and T_b are temperatures of fire and background respectively; $L_3(T_3)$ and $L_4(L_4)$ represent NOAA 3 and 4 channel radiance that can be culated by Planck′s function. If $T_b$is known by nearly pixel, the $L_3(T_b)$ and $L_4(T_b)$ will be calculated, then P and T_f can be found. Using mutispectral remote sensing system to identify the target is decided by the brightness temperature differences betweent 3 and 4 channels. Figure 1 shows a typical plot without cloud cover.

Cheng B.Y and Jin X.Z (1990) considered the fire target signal and background noise from bispectral system. A resarch for the question had been proposed [7]. By assuming that fire target and forest background are Lambertian radiators. The radiance received from the sensor can be written.

$$P_{\lambda_1\lambda_2} = (A_B/\pi)\int_{\lambda_1}^{\lambda_2} \varepsilon_{\lambda T} W_{\lambda T} \frac{A_0}{H^2} \tau_0 \tau_a \, d\lambda \tag{1}$$

where A_B: area of radiator
A_0: efective optical aperture of system
H: distance from sensor to radiator
τ_0, τ_a: optical and atmosphere transmitance
$\varepsilon_{\lambda,T}$: emissivity
$W_{\lambda,T}$: radiant flux of unit area)

If fire target is supposed to be blackbody and forest background to be greybody (ie $\varepsilon_f = 1, \varepsilon_b = 0.9$)

,τ_0,$\tau_a$and sensors responsibility are taken the mean betwenn $\lambda_1$and λ_2. The sensor's signal voltage can be shown

$$V_s = \frac{A_B}{\pi}\varepsilon\frac{A_0}{H^2}\tau_0\tau_a RF(T)$$

where R sensor's responsibility

$$F(T) = \int_{\lambda_1}^{\lambda_2} W_{\lambda T} d\lambda$$

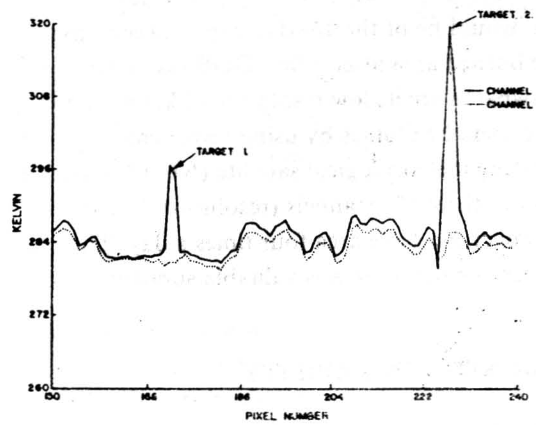

Fig.1 Channels 3 and 4 brightness temperature plot of hot targets 1 and 2 (From Stephens etal.1989)

Considering two adjacent IFOV one has a fire target and other does not have it (Fig.2). The resulting signal voltage to former marks $V_a(b+f)$ and other marks $V_a(b)$ which can be regerded as noise. After transformation the signal to noise ratio given

$$\eta = \frac{\varepsilon_f A_f F(T_f) + \varepsilon_b (A_b - A_f) F(T_{b1})}{\varepsilon_b A_b F(T_{b2})}$$

where f is a parameter related to fire target and b is a parameter with background, $b_1$and $b_2$are respectively containning and not containning fire's IFVO parameters. To airborne remote sensing system a small fire is tested (A_f=0.3m × 0.3m). If T_f= 575 ° k, T_{b2}=312 ° k, $\lambda_1 = 3\mu$,$\lambda_2 = 4\mu$,A_b=3m × 3m,H=3000m (IFOV=1 mard). From (3) the value η is 4.6. According to tests and image decision experiences, as $\eta = 3$, the fire target smaller than 0.3m × 0.3m should be clearly detected.

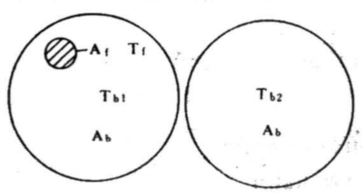

Fig.2 two adjecent FIOV with different temperature T_{b1}, T_{b2}(T_{b1}, T_{b2}: the lowest and the highest backgroud temperature respictively; A_f: fire size; T_f: fire temperature)

For meteorological statellite at nadir, a pixel is about 121ha. If there is a small fire which does not fully occypy the IFOV and considering $\varepsilon_f F(T_f) >> \varepsilon_b F)T_b)$ form (3) the fire's area can be estimated.

$$A_f = \frac{\varepsilon_b A_b (\eta F(T_{b2}) - F(T_{b1}))}{\varepsilon_f F(T_f)} \tag{4}$$

Take the $\eta=3, \varepsilon_b=0.9, \varepsilon_f=1, A_b=1.21\times10^6 m^2, T_{b1}=286°K, T_{b2}=312°K, T_f=575°K, \lambda_1=3.55\mu$, $\lambda_2=3.93\mu$, from(4) the calculated fire area will be about 1 ha. If fire area's average temperature comes up to 800 ° K, fire area as small as 40m × 40m should be identified.

From (4) we can know that using satellite thermal IR chanel with other parameters do not change the background temperature difference of adjoined pixel will be an improtant influence factor on fire monitoring. Table 1 shows a comparison with several representative forest background temperature differences.

Table 1

T_{b1}(k)	286	286	312	312
T_{b2}(k)	286	312	286	312
A_f(ha)	0.5	1.0	Flase	0.8

It is very unfavorable to monitor fires when fire targets locate at lower tempture pixel. In order to check the abitlity of satellite fire monitoring, we had made use of field prescribed buring to contrast with satellite image (3 channel). Fire intensity then was not more than 3000kw / m. Fire area was break–off in middle and its size about 0.64ha. Fig3 shows that the field experiment agree with the estimate

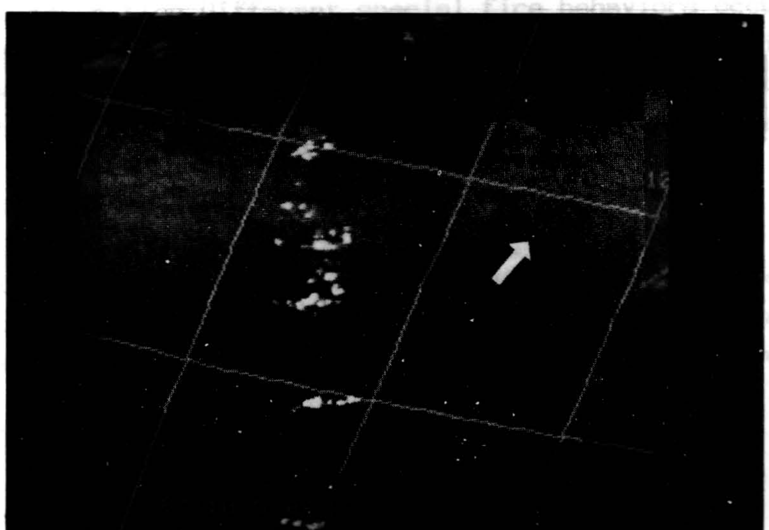

Fig.3 channel 3 satellite of prescribed burning (0.64ha) (Dct. 5.1987)

CONCLUSION

According to Experiment and algorithm it has been proved that using satellite remote sensing can complement ground tower and aircraft each other for forest fire reconnissance as soon as posible. The airborne IR system is able to detect fires as small as 0.1m × 0.1m. Satellite can monitor not only large fires but also subpixel sized fires less than 1 ha. Howere, the meteorological satellite fire reconnisance would suffer some influence such as cloud and tempreature difference.

For small fires only 10–15% can be detected. About 80% mistakes are fail to report or flase alarm. For this reason the satellite forest fires surveillance cann't replace the existing conventional methods.

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