PROVIDING SATELLITE-BASED EARLY WARNINGS OF FIRES TO REDUCE FIRE FLASHOVERS ON SOUTH AFRICA'S TRANSMISSION LINES

Philip Frost
CSIR Meraka Institute
Pretoria, South Africa
pfrost@csir.co.za

Prof Harold Annegarn
University of Johannesburg, Dept of Geography
Johannesburg, South Africa
han@na.rau.ac.za

Abstract— **The Advanced Fire Information System (AFIS) is the first near real time operational satellite-based fire monitoring system of its kind in Africa. The main aim of AFIS is to provide information regarding the prediction, detection and assessment of fires using detections made by satellite sensors. The main funding for the development and implementation of AFIS came from South Africa's biggest power company – Eskom. Wild land fires underneath power lines can cause flashovers which severely affect industries electricity supply. Eskom and the CSIR commenced research to investigate the affectivity of the MODIS and MSG satellite sensors to detect fires that could cause flashovers on the 28 000 km of transmission lines of South Africa. During the 2004 fire season, Eskom began using the fire information in the form of SMS text messages that were distributed to line managers as soon as fire was detected close to any transmission line. This information enabled managers to reduce fire flashovers due to early fire detection. Lines could be shut down or fires exctiquised before it caused flashovers to occur. The comparisons between fires detected and flashovers recorded showed some very interesting results that confirmed AFIS as a valuable management tool for Eskom.**

Keywords-component; Fire detection, MODIS, MSG

I. INTRODUCTION

During the 2004 fire season, South Africa's largest power company Eskom, implemented a satellite based fire information for the first time to help combat line faults caused by fires underneath transmission lines. The quality of electricity supply through transmission lines are severely affected (in the form of line faults) by natural phenomena such as, bird streamers, lightning, fires and pollution. Line faults cause very short interruptions in the supply of power and these in turn have major financial implication to customers with continuous process factories.

Eskom operates 28 000 km of high voltage Transmission lines (132kV and above) and about 250 000 km of Distribution Lines (132kV and below). Eskom is South Africa's national electricity utility and operates a transmission system that operates at voltages between 132kV to 765kV. Electricity is generated predominantly by means of coal-fired power stations and one nuclear station with three hydro peaking stations. This constitutes 95% of the electricity of Africa (Anon 2004). The rights-of-way (ROW or servitudes) of these power lines cover large areas and traverse a number of biomes, ranging from arid vegetation through grasslands and savanna, to tropical vegetation.

The Council for Scientific and Industrial Research (CSIR) - Satellite Application Centre (SAC) in collaboration with Eskom developed the Advanced Fire Information System (AFIS) with the main focus on the prediction, detection and assessment of fires in South Africa. The system combines fire detection information from the TERRA and AQUA MODIS (Moderate Resolution Imaging Spectro Radiometer) polar orbiting satellite sensors with the Meteosat Second Generation (MSG) geostationary satellite sensor from Eumetsat.

Because of its dielectric properties, air acts as an isolation medium between live conductors and the ground below it. During a fire, the properties of the air change as smoke particles fill the space between the ground and transmission line which could result in an electrical discharge or flashover to occur. This is normally referred to as a line fault or flashover. The mechanism active during a fire-induced flashover of a power line is highly dynamic and complex and authors explain the phenomenon in different terms (Sukhnandan and Hoch 2002). In order to prevent the spread of fires underneath transmission lines early fire detection information is required to pinpoint the location and possibly provide additional info on the temperature and size. In the past Eskom line managers were dependant on information from local residents about fire occurrences and locations

The source of ignition of fires is an important factor to consider in the determination of fire risk. Although 20% of fires in Fynbos (Cape shrubs) and about 10% of vegetation in the Kruger National Park are ignited by natural causes such as lightning, humans are the major origin of fires (Bond 1997). Fire awareness and appropriate prevention and suppression must be included in fire management programme. The National Veld and Forest Fire Act (Act 101of 1998) places a high

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importance on communal involvement in successful fire prevention and suppression strategies. Many of the fires burning in South Africa are caused by activities such as harvesting of crops (sugar cane), preparing fire breaks, burning refuse and arson. Cultural reasons such as the belief that good grass fires cause good rains are especially evident in the rural areas.

Grass fires exceed the number of bush and forest fires, although the latter are more spectacular and reported more extensively in the media. From reports received of fires affecting both electrical utilities and the commercial forest industry, grass fire frequencies appear to be higher in South Africa than countries such as Australia, South America and the United States. In a forest of approximately 90 000 ha in South Africa, 600 fires were reported in a year, in comparison with the Australian forest of similar size, where 36 fires were recorded for the same period (Oosthuizen pers. comm. 2003). This fact was further confirmed by a report received from the Australian power utility, TransGrid. With the exception of outages caused by bushfires, very few of their line outages are due to grass fires. Lightning is the typical cause of power outages. The numbers of bushfire outages are comparable to lightning but the severe bushfires only occur about once every five years. (Turner, pers. comm. 2003). The fire frequency of low intensity grass fires in South Africa is much higher than the case quoted above.

This aim of this paper is to provide a first look at the effectiveness of a satellite based fire information system for a power utility such as Eskom.

II. Methodology

A. Advanced Fire Information System

The Advanced Fire Information System (AFIS) has been developed as a service module of the Wide Area Monitoring Information System (WAMIS), which aims to deliver fire information products to researchers, Fire Protection Agencies and Disaster managers all over Southern Africa in support of effective decision-making in the monitoring of natural and manmade fires. AFIS is the first near real time operational satellite fire monitoring system in Southern Africa. The system architecture was originally based on the MODIS Rapid Response Web Fire Mapper system developed at the University of Maryland. The CSIR have now developed AFIS II which is running on a fully operational OGC compliant architecture.

B. Utilization of multiple satellites

The perfect fire detection satellite capable of identifying very small fires over large areas regularly does not exist yet. The only option is to make use of current satellites that have near and mid infra red spectral bands in order to detect fires. Polar orbiting satellites have the advantage of detecting small fires, but with a very low overpass frequency, while geostationary satellites have the advantage of frequent views over large areas (every 15 minutes with MSG), but with a very low resolution, i.e. can only detect big fires. In order to make use of the advantage of higher resolution imagery (MODIS) and frequent views from MSG the two satellite sensors have been combined within AFIS.

C. Polar Orbiters (MODIS)

The two MODIS satellites are polar orbiting, moving around the North and South Poles every 98 minutes while the earth is turning from west to east. Terra scans the Southern African region between 10 – 11:30 am while Aqua scans in the afternoons between 14:00 – 15:30 pm. Each satellite also scans the region at night (Terra at 22:00 pm and Aqua at 03:00 am). Validation results indicate that in many biomes the minimum flaming (~800-1000K) fire size typically detectable at 50% probability with MODIS is on the order of $100m^2$ (Giglio, L. et al. 2000).

D. Geostationary (MSG)

MSG is a geostationary satellite that scans the African continent every 15 minutes in a south to north direction. The biggest limitation is its coarse resolution which limits the detection of small fires. Validation of the minimum detectable fire size for MSG in Southern Africa is currently being researched. Validation in the USA on similar satellites have shown detectable sizes in the region of $500m^2$, but scan angles, biome, sun position, land surface temperature, cloud cover, amount of smoke and wind direction will be the final determining factor **(**Prins et al. 2001).

E. System Description

1) MODIS ingest and processing

The CSIR SAC's MODIS direct broadcast system is responsible for processing all incoming MODIS data to a standard level 1b format. The processing is done using the Goddard Space Flight Centre (GSFC) code but can also make use of the IMAPP code if needed (Justice et al. 2002)

2) MSG ingest and processing

The MSG HRIT data are received and processed every 15 minutes making use of David Taylor's Data Manager software to generate raw 10 bit calibrated radiance counts. These raw radiance counts are then converted to brightness temperature values for the thermal bands and to surface reflectance values for the visible bands

3) MODIS fire detection

Collaboration between the CSIR SAC and NASA enabled the installation of the MODIS Rapid Response software within the SAC MODIS direct broadcast processing system. The main component of the MODIS Rapid Response code from the University of Maryland and Goddard Space Flight Centre (GSFC) is the enhanced contextual fire detection algorithm for MODIS (Giglio 2003). The new algorithm can detect fires roughly half the minimum size that could be detected with the original algorithm while having an overall false alarm rate 10–100 times smaller. The system generates an ASCII text file containing information regarding the Latitude, Longitude, Brightness Temp, Along scan pixel size, Along track pixel size, Date , Time of acquisition, Satellite (A=Aqua and T=Terra)

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and Confidence. This text file is automatically sent via to the ArcIMS and ArcSDE server where it will be displayed in real time.

4) MSG fire detection

The CSIR SAC in collaboration with David Taylor developed the MSG Fire Tracker software package. The software code is based on a contextual fire detection algorithm, originally developed for AVHRR data (Flasse and Ceccato 1996). The MSG Fire Tracker software is activated every 15 minuets using the Windows XP scheduler. An ASCII text file is generated every 15 minutes containing the following information: Latitude, Longitude, Brightness Temp, Date, Time of acquisition, and Satellite (M = MSG). This text file is then automatically ftp'ed to the ArcIMS and ArcSDE server where it will be archived and displayed.

5) Email and SMS messaging service

An email and cell phone text message (SMS) system have been developed to provide rapid alert to fires without having to first view the web server. With the use of C++, software routines were developed to enable the identification of fires close to pre defined points, lines or polygons. As soon as a fire is detected within a pre defined zone an alert is triggered through these C++ routines. An email message is automatically generated which is in turn converted to an SMS message.

AFIS scans a 2.5 km buffer a long side all transmission lines searching for fires every 15 minutes. As soon as a fire is detected by either of the MODIS or MSG satellites an SMS message is generated indicating fire location and distance to the power line. This information is send to the regional ESKOM manager responsible for that portion of the line.

Researchers more interested in the frequency and distribution of fires in specific areas can register to receive a daily email. The email will contain a referenced image and a list of all fires detected within the defined area. Information such as date, time, location (lat/long), detected temperature and confidence of each fire will be included in the list. Researchers in Angola, Mozambique, Lesotho, Swaziland, Botswana and Zimbabwe have been monitoring fire prone areas since beginning of July 2004.

III. Results and Discussion

The success of AFIS as a management tool within Eskom is measured in its ability to provide early detection of fires close to transmission lines before fire flashovers occur. All satellite-based fire detections from AFIS (2003 – 2005) within a 5 km buffer of any transmission line was identified and compared to fire flashover faults for the same period. The fire flashover point data for 2003 – 2005 describing the position and time of each line fault was also recorded. All AFIS fires within a 5 km radius of a fire flashover point that occurred on the same day as the line fault were assumed to be the fire that caused the flashover. The statistics were calculated for both the MODIS and MSG fire detections during the period of 2003 – 2005.

Figure 1. The percentage flashover fires detected by MODIS, MSG and combined MODIS/MSG

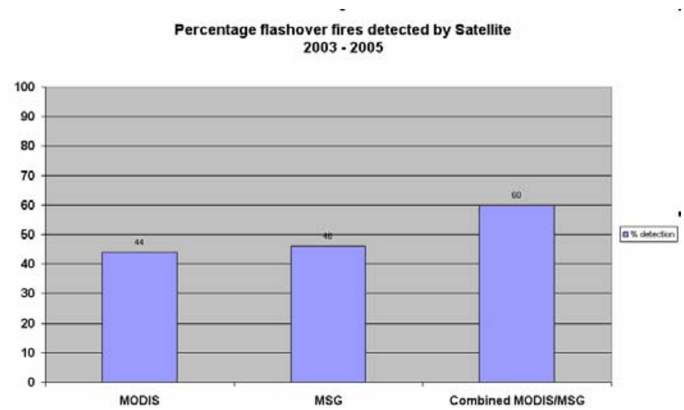

Figure 1 shows the percentage of flashover fires detected by the MODIS sensor, MSG sensor as well as the joint detection accuracy. MODIS was able to detect an average of 44% of all flashover fires during 2003 – 2005 while MSG detected 46% of all flashover fires during the same period. By combining the detection accuracy of MODIS and MSG within one system (AFIS) the detection accuracy rose to 60% detection of all flashover fires.

The statistics of the MODIS and MSG detections demonstrate the limitations of these current sensors as a detection tool on its own. The MODIS sensor was able to detect many of the smaller fires, but due to its infrequent revisit time was unable to detect more than 40% of the fires. The MSG sensor on the other hand struggled to detect smaller fires due to its coarse resolution, but due to the fact that it provided 15 minute updates, could track fires until they were big enough to be seen by the current algorithm. The 2% higher detection accuracy calculated for MSG with its lower resolution and less advanced detection algorithm shows the importance of frequent observations. A significantly increased detection accuracy of 60% was calculated through the combining of the polar orbiting and geostationary satellite sensors. The combination of accurate detection from MODIS with the frequent detection from MSG increased the detection rate by more than 15%.

Figure 2 describes the percentage of fires that was detected before the fire flashovers had occurred. Both the MODIS and MSG sensors were able to detect a high percentage of fires in advance. MODIS was able to detect 70% of fires while MSG one again archived a higher percentage of 81% of fires detected before the line fault had occurred. These statistics highlights the fact that the biggest limitation currently is the inability of current satellite sensors to detect fires that cause flashovers and not as much the late detection of existing fires.

Figure 2. The percentage of fires detected by AFIS before the fire flashover had occurred

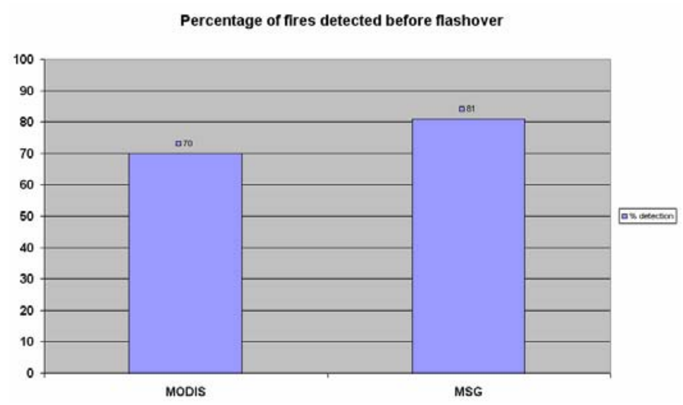

Figure 3. The percentage flashover fires detected by MODIS, MSG and combined MODIS/MSG

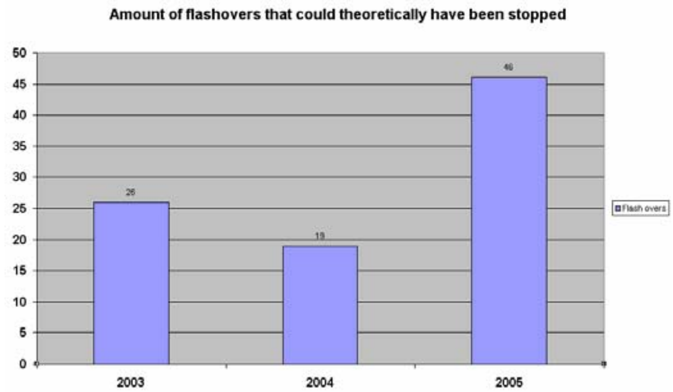

Figure 3 demonstrated the theoretical amount of flashovers that could have been avoided during 2003 – 2005 because of early detection by AFIS. These amounts are highly dependant on the actual amount of fires during a season close to transmission lines. The 2005 fire season had significantly more fires (6147) within the 5 km buffer alongside transmission lines compared with the 2003 season (3987) and 2004 season (3905). The difference in the amount of fires can be attributed to the good rains recorded over the north eastern parts of South Africa during the 2005 rain season.

IV. CONCLUSION

The AFIS project has shown great potential and has demonstrated the ability of technologies such as satellite remote sensing to aid industries in the public and private sector. The combination of research, public and private organisational partnership have shown to work very well, and will provide a strong link for further work in this domain.

The statistics have shown that AFIS can provide information that could be used in the reduction of fire line faults by early identification of fires close to transmission lines. The ability to stop even 1 flashover from occurring could save Eskom hundreds of thousands or rands. It is extremely difficult to put a price tag on a line fault. In some cases there might be very little impact of a line fault but cases have been reported where companies lost huge amounts of money due to the malfunctioning of machinery as a result of a fire flashover.

On of the biggest challenges now to Eskom is to build AFIS in to the current line management systems in such a way that reaction to fire events becomes as efficient as the detection itself. Knowing about a fire and not reacting to it in time, is just as bad as not having the system at all.

Many challenges still lie ahead but the system has already proved its value not only in the early detection of fires, but also in the raising of awareness around fire, and the importance of proper management

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