

Characterising Bush Fires in Australia's Top End using MODIS Active Fire Observations.

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Abstract – This study used MODIS active fire detections and associated fire radiative power estimates to characterise bush fires in the savanna region of Australia's Northern Territory. In contrast to other sensors MODIS has dedicated fire channels that rarely saturate over fires, enabling fire detections during the day and estimates of fire radiative power. Using number of day- and night-time fire detections it was possible to distinguish two phases of fire activity. The first phase, occurring in the early dry season, is dominated by low intensity management fires that are lit during the day and extinguish in the evening. In the late dry season, the second phase shows many high intensity fires which are burning through the night.

Keywords: fire detection, fire intensity, MODIS, savannas, seasonality.

1. INTRODUCTION

In Australia between 300 000 km² and over 700 000 km² are affected by fire annually (Craig et al. 2002, Russell-Smith et al. 2007). Apart from threatening lives and destroying assets fires have significant effects on biodiversity (Bradstock et al. 2002) and erosional processes (Ellis et al. 2004) and are a significant source of greenhouse gas emissions (e.g. Hao and Liu 1994, Meyer 2004, Carmona-Moreno et al. 2005). The majority of fires occur in northern Australia's tropical savannas with some areas experiencing a fire every year (Craig et al. 2002). The wet/dry season climate creates a distinct fire season with a seasonal variability in fire activity.

Earth observation satellites have been used to monitor fire for more than two decades, using computer algorithms that detect the location of active fires at the time of satellite overpass (Matson & Holben 1987). Active fire detection utilises the thermal bands of remote sensing instruments. The detection algorithm compares the temperature of the investigated pixel with an absolute threshold and/or a threshold relative to the temperature of surrounding pixels. Pixels with a temperature above these thresholds are marked as containing a fire.

One instrument used for active fire detection is the MODerate resolution Imaging Spectroradiometers (MODIS) (Justice et al. 1998, Salomonson et al. 2006). It is carried on board two satellite platforms, Terra and Aqua. Significant advantages of MODIS over other sensor systems are the high sensor saturation level (500 K; Justice et al. 2006) and the high radiometric and geometric data quality. This makes it possible to use MODIS for active fire detection not only during the night but during day time as well. Another advantage of the MODIS sensor is that its platforms are in stable orbits that don't drift over time as atmospheric drag is compensated for with orbit corrections manoeuvres. This leads to stable observation times and makes comparisons between seasons and between years easier.

The National Aeronautics and Space Administration (NASA) is processing global MODIS data to derive active fire detections, including fire radiative power estimates on an operational basis

(Giglio et al. 2003, Justice et al. 2006). The data are made available for free through the internet.

2. DATA AND METHODS

2.1 Study Areas

The study areas are located in the tropical savannas of the Northern Territory, Australia (Figure 1). The areas lie between 15°S-10.5°S and 129°E-137°E.

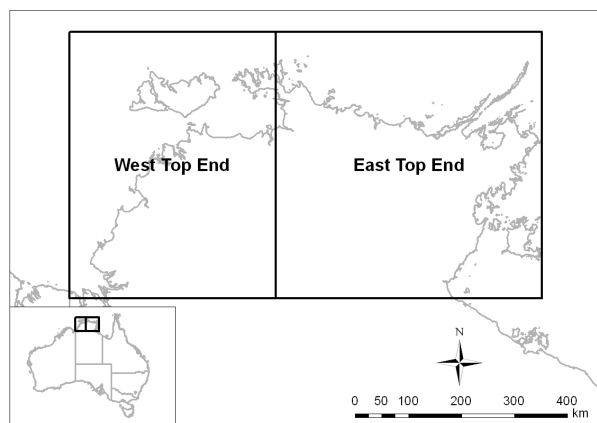


Figure 1. Location of the study areas (West Top End and East Top End) in the tropical savannas of the Northern Territory, Australia.

The climate in the study areas is defined by a wet and dry season with 90% of the annual rainfall occurring in the wet season months November to April. Average annual rainfall varies between 2000mm and 500mm along a North-South gradient (WWW1). This climate leads to a pronounced fire season during the dry months. Land cover of the area is dominated by open forest, woodland and open woodland referred to as savanna throughout this paper (Fox et al. 2001).

2.2 Data

For this study the global MODIS Collection 5 Active Fire product MCD14ML for years 2003 to 2009 was downloaded from the ftp server at the University of Maryland (<ftp://fuoco.geog.umd.edu/>). The MODIS fire detection algorithm detects fires by applying thresholds to the brightness temperatures observed in the middle and thermal infrared. In addition, the brightness temperature of a potential fire pixel is compared with the brightness temperatures of surrounding pixels (Giglio et al. 2003, Justice et al. 2006). Apart from the location of fires (including quality information) the algorithm also provides an estimate of the instantaneous fire radiative power (FRP; Justice et al. 2002). MCD14ML contains one line of ASCII text for every fire detection, providing date, time, satellite name, latitude, longitude, temperature in channel 21, temperature in channel 32, sensor sample number, fire radiative

power (FRP) and confidence level. Fire detections located in the study areas (Fig. 1) were extracted from the global dataset.

2.3 Methodology

Fire detections were separated by study area, year, month and local solar time class. Four local solar time classes were defined: *night AM* (0:00-6:00 local solar time), *day AM* (6:00-12:00 local solar time), *day PM* (12:00-18:00 local solar time) and *night PM* (18:00-0:00 local solar time).

An important characteristic of fires is whether they are small, controllable and have little long term impact on vegetation or are large, uncontrollable and have large long term impact on vegetation. For fires to become large, uncontrollable and destructive in Australia's savannas they usually have to burn through the night. Therefore number of night time fire detections is a good measure for number of big fires. But fire activity varies over the fire season depending on the number of ignition sources. To compensate for this the ratio of number of night time (classes *night AM* and *night PM*) and number of day time (classes *day AM* and *day PM*) fire detections has been calculated assuming every day time fire is a potential ignition source for a night time fire.

To investigate seasonal and diurnal variations in fire intensity monthly mean fire radiative power for each time class has been calculated. Months with less than 20 fire detections were excluded from analysis to reduce bias by individual events.

3. RESULTS

Figure 2 shows the ratio of number of night-time and day time fire detections for months April to November of years 2003 to 2009 in the two study regions.

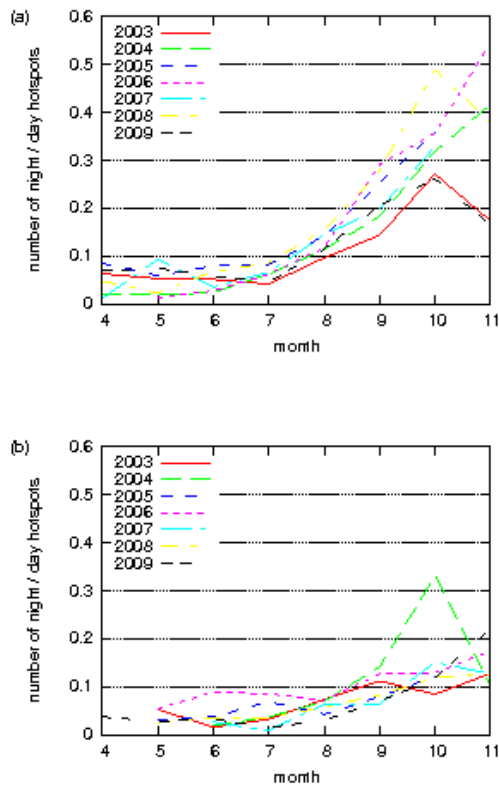


Figure 2. Ratio of number of fire detections (hotspots) at night and number of hotspots during the day for West Top End (a) and East Top End (b) for years 2003-2009.

For West Top End the ratio stays below 0.1 until July. From August the ratio strongly rises at least until October with only some years showing a slight drop in November. For East Top End the ratio stays below 0.1 until August or September. While the ratio also increases towards the end of the year it doesn't reach values as high as for the West Top End.

Figure 3 illustrates monthly mean fire radiative power of fire detections in 2004 within West Top End (a) and East Top End (b) for the four time classes. The two study areas exhibit very similar monthly mean FRP values. Both show an increase in FRP as the season progresses with a slight drop-off in November. Highest values in a given month are usually observed for the early afternoon detections (time class *day PM*), followed by the late morning detections (time class *day AM*). Night time detections (time classes *night PM* and *night AM*) almost always show the lowest values. Other years (data not shown) show a similar behaviour.

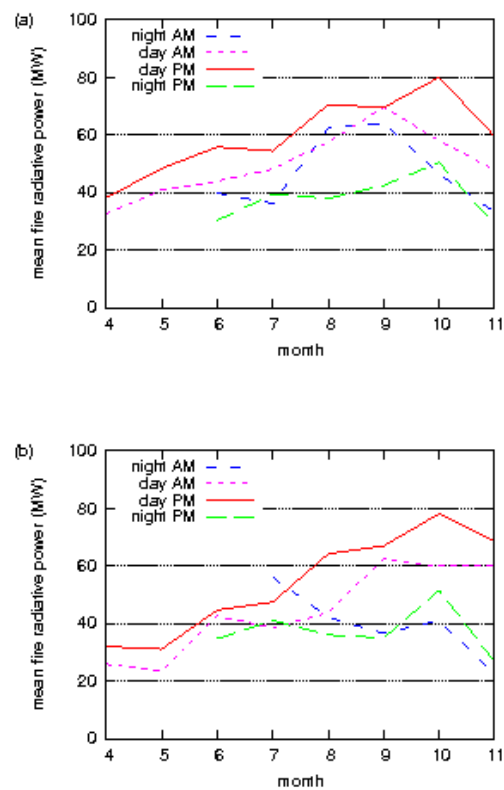


Figure 3. Mean fire radiative power for West Top End (a) and East Top End (b) for four time classes in 2004.

4. DISCUSSION

Figure 2 clearly shows there are two phases of fire activity in both study areas. The first phase, up until around July/August shows a low number of fire detections during the night. This phase mainly consists of management fires of low intensity (see Figure 3). These fires are lit during times when temperatures drop and relative humidity rises at night. Under these conditions fires usually extinguish at night.

After July/August night time temperatures increase and relative humidity level decrease as the season progresses. This leads to more and more fires burning through the night, reflected by the increasing ratio of numbers of night time and day time fire detections (Figure 2).

In addition to that fires are getting more intense during the day (see Figure 3) as day time temperatures increase and winds are getting stronger. Most of these fires are difficult to control. These findings are in agreement with anecdotal evidence from fire managers and researchers.

5. CONCLUSION

Dedicated fire channels and stable sun-synchronous orbits of its satellite platforms make MODIS a sensor system suitable for investigation of seasonal and diurnal changes in fire characteristics. This study has shown two distinct phases of fire activity can be observed in the tropical savannas of Australia's Northern Territory. The first phase, early in the dry season, is characterised by low intensity fires that usually extinguish at night. The second phase, later in the dry season, is dominated by high intensity fires burning through the night.

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ACKNOWLEDGEMENTS

The authors thank NASA and the University of Maryland for providing MODIS active fire information free of charge.