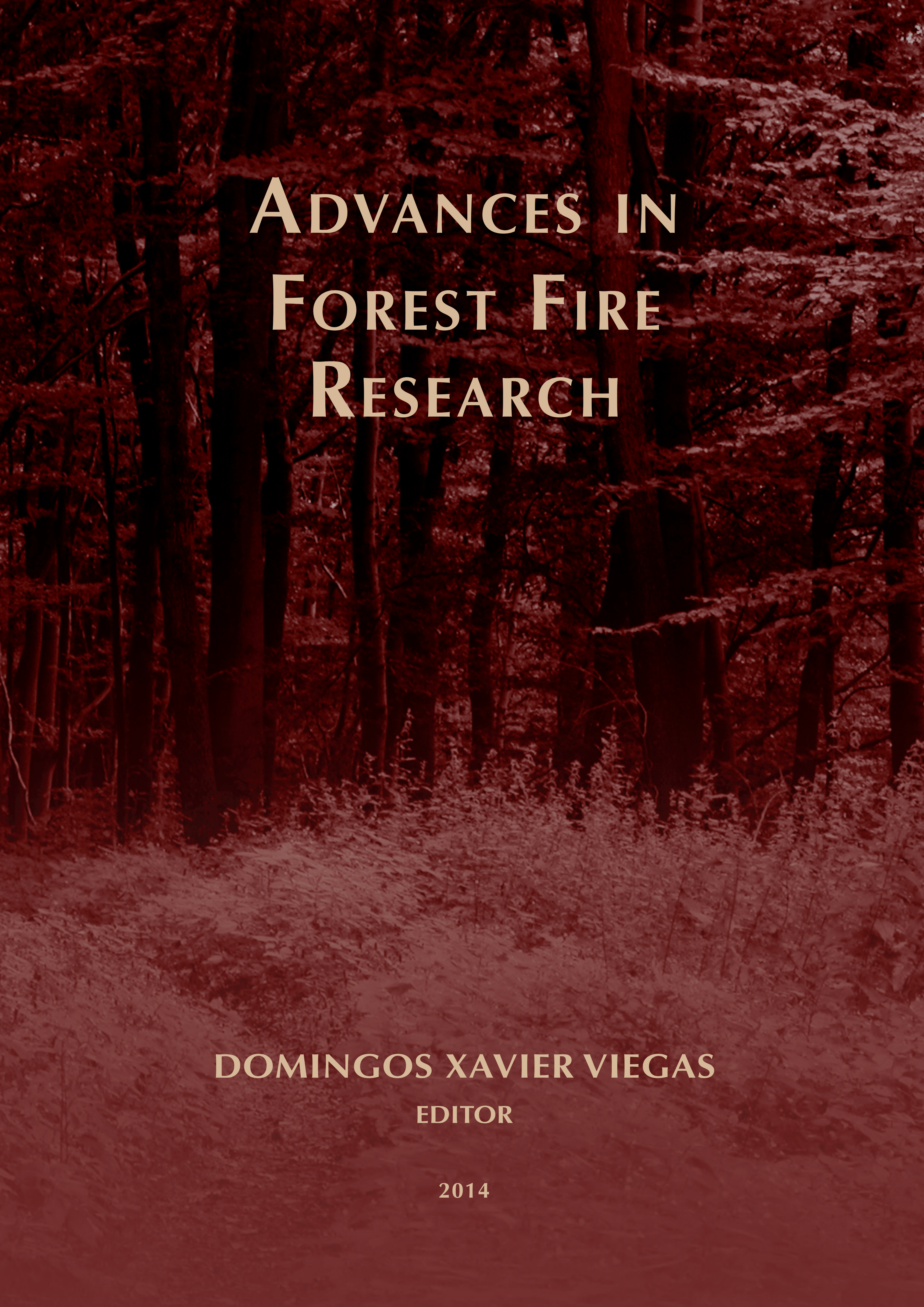

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Monitoring forest fires and burnings with weather radar

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Abstract
The efficiency on forest fire control is directly related to the quickness on detection and localization, which significantly can minimize the potential of damages. The current technology used in the manufacture of weather radars has opened new opportunities for research, making it possible to detect small signals, not necessarily used in the daily rain observations. The objective of this research is to use the capacity of weather radar, configured to execute tasks of high sensitivity, to monitor and detect “non meteorological targets”, i.e., the smoke produced by sugar cane burnings and, by similarity, forest fires. An experimental model was developed and applied to the S-band weather radar operated by the Meteorological Research Institute – IPMet/UNESP, located in the central region of the State of São Paulo, Brazil. In the first experiment, all the monitored sugar cane burnings were efficiently detected by the radar with a delay of 2 to 9 minutes, with an average of 4.67 minutes, a significant reduction in the response time of 15 minutes, considered optimal for conventional detection systems. In the second experiment, the weather radar monitored forest area when the fire danger rating index was medium or high and the same events observed by the observation towers were detected by the weather radar. The methodology used in this study can add significant value to the information in the forest fire suppression decision-making. The results showed the efficiency of weather radar to detect smoke. Therefore, weather radars systems could be used, in the absence of rain echoes, for monitoring agriculture burnings and detecting forest fires.

Keywords*: Fire detection, Weather radar, Forest fire*

1. Introduction

The efficiency on forest fire control is directly related to the rapidness on the occurrences detection and localization, what significantly minimizes the potential of damages. There are several difficulties and limitations in the most widely method used for monitoring and detection of forest fires, the observation towers. The high cost of installation and operation is one of the handicaps of the system. When the number of towers is not sufficient, some fires are detected when the intensity is already high and the suppression more difficult.

Trying to improve monitoring and detection of forest fires, this research used the remote sensing technology to detect events related to fire. The biomass combustion process produces large amounts of smoke, an excellent target which can be detected by deploying various electromagnetic wavelengths. The particles and water vapor that constitute the smoke is an excellent electromagnetic spreader.

Due to the absence of rain, during the dry season, the degree of fire hazard increases. Therefore an experimental model of fire detection was developed, and initially tested on the frequent and programmed sugar cane harvesting burnings in the central region of São Paulo State, which is monitored by a weather radar equipment “S-band Doppler”, operated by the Meteorological Research Institute, UNESP, located in Bauru. County. In the same region covered by the radar system, there are large plantations of pine and eucalyptus owned by Duratex, that in the second phase of the experiment were monitored during high fire danger indices

2. **Methods**

2.1. **Weather Radar**

The Radar (***Ra****dio* ***D****etection* ***A****nd* ***R****anging)* is considered an active element, considering that it illuminates the target with a microwave beam and identifies this target through the detection of the energy portion reflected back. The choice of the operation wavelength (λ) is primarily defined according to the type and size distribution of the targets to be investigated or detected. (Doviak 1992; Lhermitte 2002).

2.2. **Detection Capability**

Operacional and research weather radars have already been deployed in the past to observe “non-meteorological targets” such as: wind speed profiles, gust fronts, particles in suspension, flocks of birds, clusters of insects as well as smoke plumes (Banta and Olivier 1992; Calheiros and Gomes 1999; Erkelens and Venema 2000; Gary *et al*. 1998; Held *et al*. 2011). This became even more feasible with the continuous technological advances of data acquisition and signal processing, sensitivity and improved detection capability as well as mitigating the associated measurements errors.

2.3. **Fire Detection**

The detection of a fire occurs indirectly, since it is detects not the fire flame or the heat, but the smoke produced by the biomass burning. Initially, a high sensitivity parameter task is programmed (low PRF, pulse length of 2 microseconds). Unlike its conventional Unlike its conventional operation mode, while the radar monitors rain from up to the soil surface, in the forest fire detection the monitoring occurs from the soil surface to up in the sky.

When forest fuel or biomass burns, the released smoke rises and crosses the microwave beam of the radar, backscattering incident energy, resulting in the event detection (figure 1). An important detail is the effect of the curvature of the earth in determining the height of the center beam, because the height relative to the ground increases with distance from the radar site. The purpose of this study was the detection of smoke originated from biomass burning as close to the ground as possible.

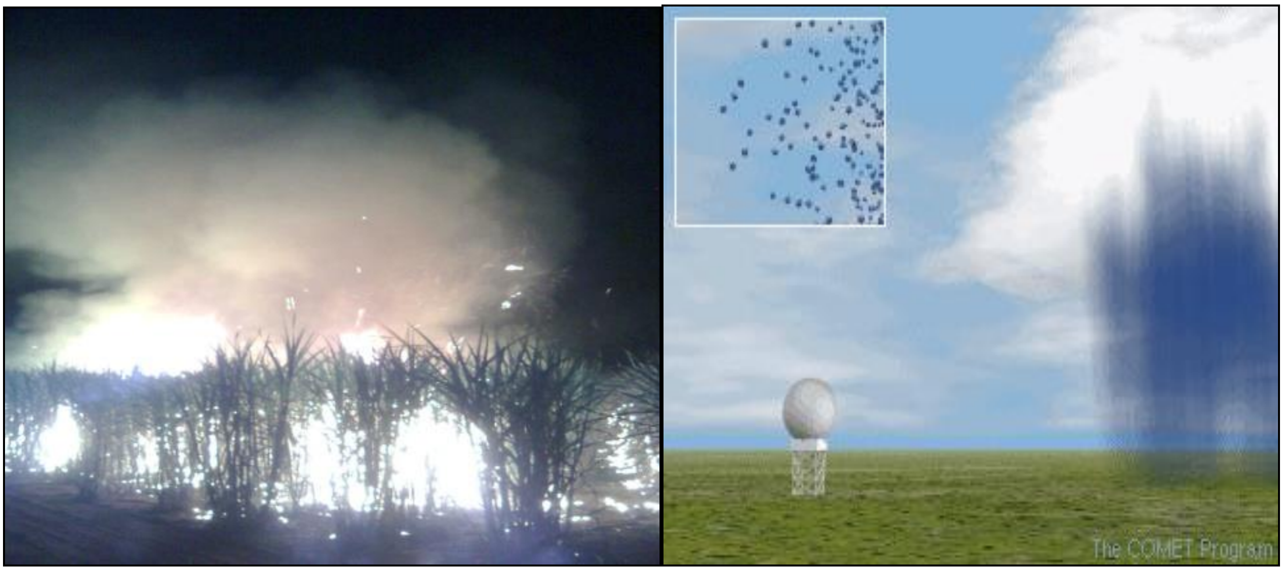

Figure 1. Vegetation fires release smoke and intercept the radar beam.

As the fire starts in the soil surface and the quicker it is detected easier is its control. Idealy the radar beam should be as low as possible on height above the monitoring area, but not too low as reflect ground echoes and contaminate the image with noises**.**
The study area should not be too close to the radar in order to avoid the effects of side lobes of antenna radiation that impair detection efficiency. With the distance of around 50 km from the radar, and antenna elevation between 0.3 and 2 degrees, the beam intercept smoke up to 2000 meters above ground level.

3. **Results**

Data from the burned plots, including time of ignition and detection, duration of fire, and response time between ignition and detection are showed in Table 1.

Table 1. Summary of monitored and detected events

Sample	Area (ha)	Schedule of Burnings (GMT)			Radar Detection	Response Time (min)
		Start (hh:mm)	End hh:mm)	Duration (min)	Start (hh:mm)	
1	6,42	22:28	22:48	20	22:30	2
2	15,11	22:17	22:31	14	22:20	4
3	10,29	22:56	23:20	24	23:00	4
4	4,86	22:20	22:36	16	22:29	9
5	8,73	22:07	22:19	12	22:13	6
6	8,35	22:07	22:24	17	22:11	4
7	8,68	21:48	22:13	25	21:52	4
8	5,56	21:02	21:18	16	21:07	5
9	**8,23**	**22:02**	**22:32**	**30**	**22:07**	**5**
10	5,81	22:25	23:02	37	22:30	5
11	10,85	21:18	21:32	14	21:22	4
12	3,99	21:26	21:42	16	21:31	5

Running task with high sensitivity and temporal sampling of 7.5 minutes, the S-band Doppler weather radar monitored the 12 burning events in the sugar cane plots. All the burnings were accompanied *in situ*, and with the time synchronized to the radar time system; the exact ignition time and the events duration were recorded.
The radar data have been treated with the TITAN software, developed at NCAR (National Center for Atmospheric Research), for applications in nowcasting the displacement of storms based on the methodology of centroids (Dixon and Wiener 1993). The images used are Cartesian products called CAPPIs (Constant Altitude Plan Position Indicator) with the viewing plane at constant average height of 1.5 km amsl (above mean sea level). Figure 2 shows the area of study and distance of radar site.
The response time ranged from 2 to 9 minutes with an average of 4.67 minutes (table 1), reducing in 68.9% the response time considered ideal in the conventional detection systems (Soares and Batista 2007).
Figure 3 shows the sample n° 9 (table 1), before ignition of burning and without radar echoes (22:00 GMT), while figure 4 (22:07 GMT) depicts it 5 5 minutes after ignition (22:02 GMT) and with the first radar echoes. The figures 5 and 6, show the area of sample n° 9 with the radar echoes during burning (22:15 and 22:22 GMT).

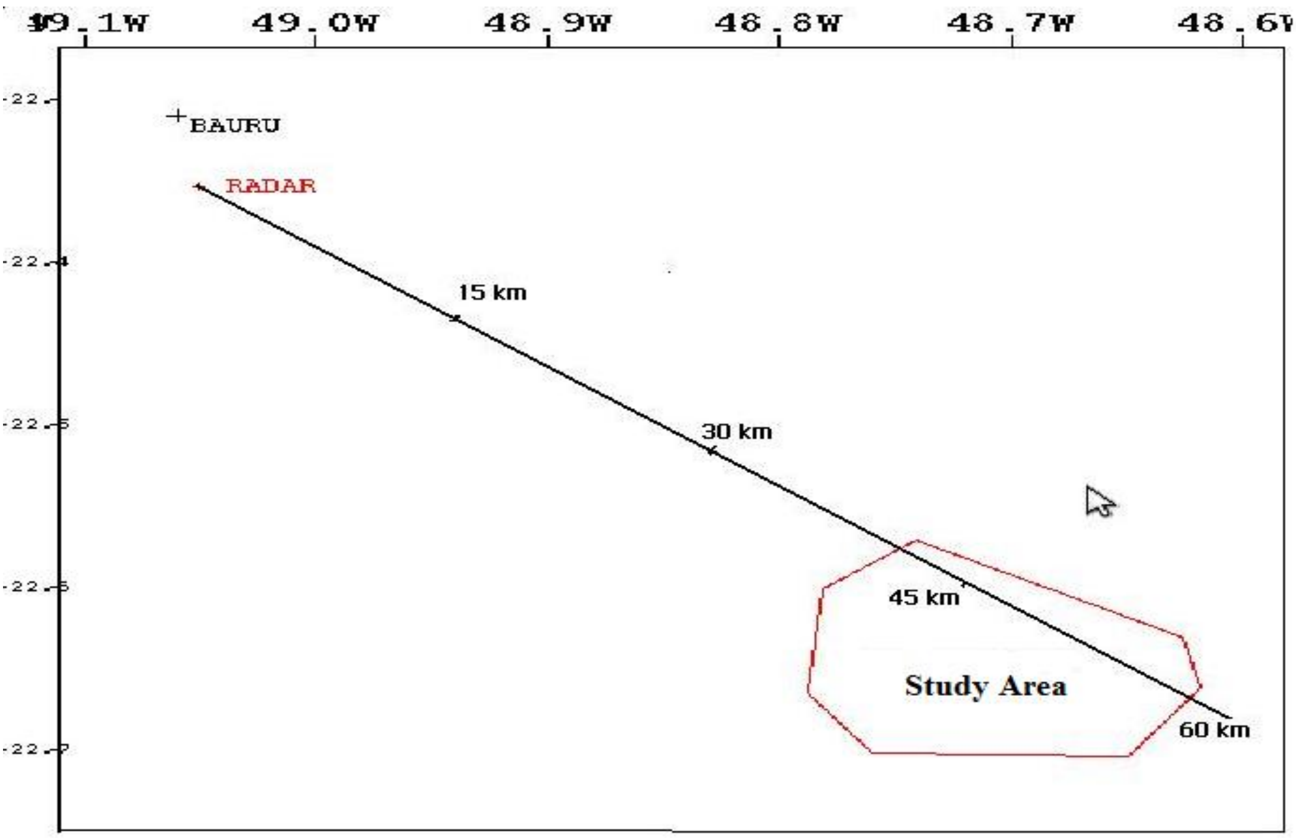

Figure 2. Study area (red polygon) and distance of radar site

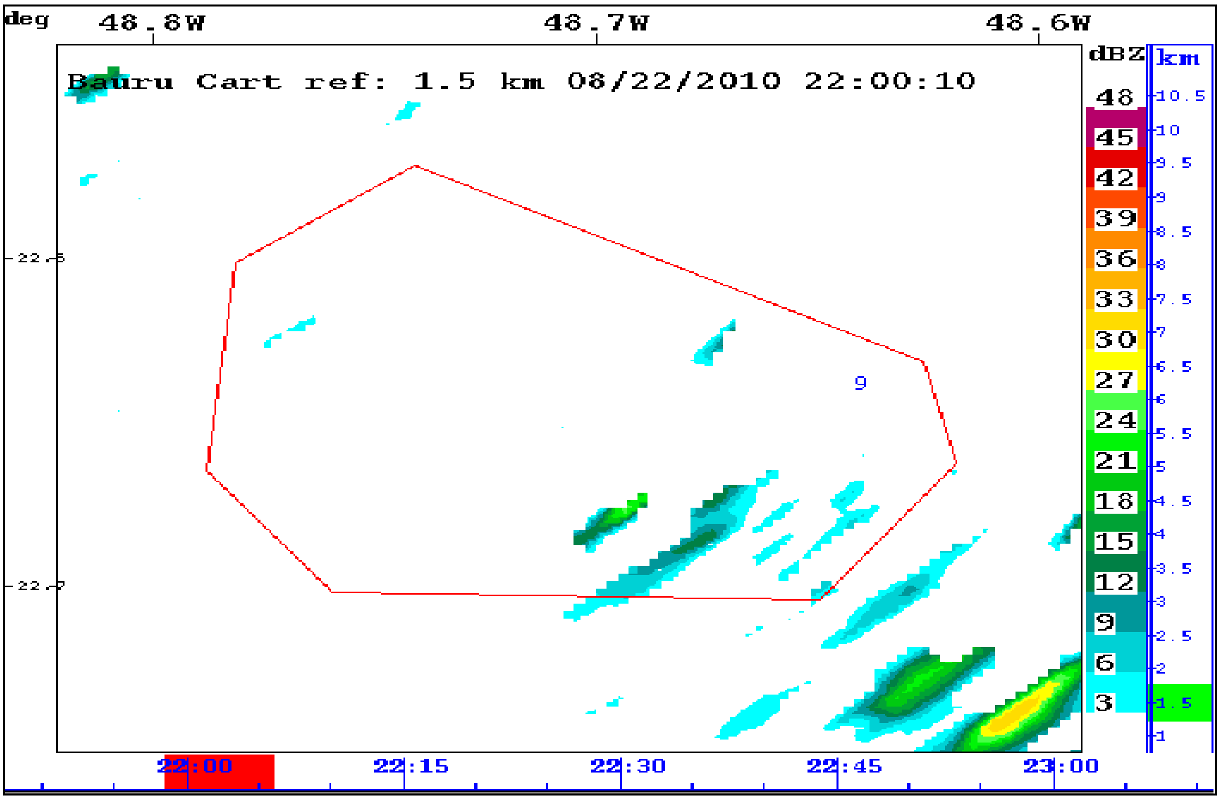

Figure 3. Image of the location of sample n° 9 (indicated by the number 9)

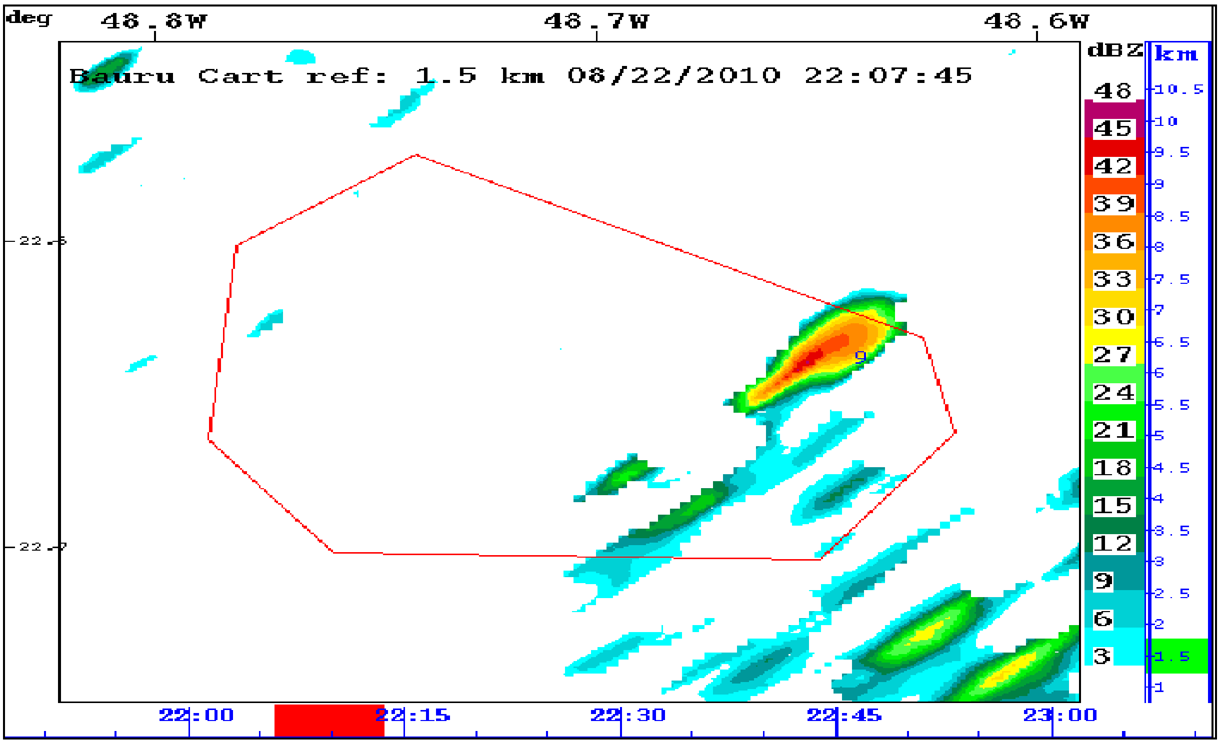

Figure 4. Location of sample n° 9 with the first radar echo after ignition

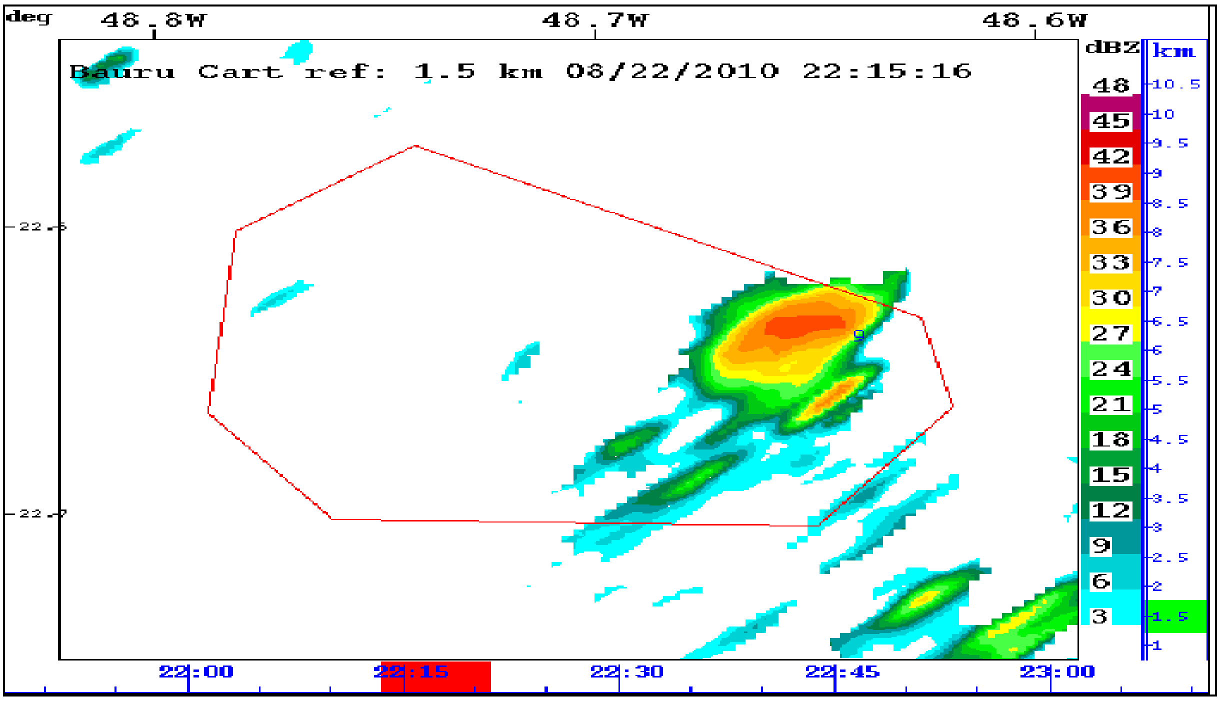

Figure 5. Location of sample n° 9 with radar echoes during the fire (22:15)

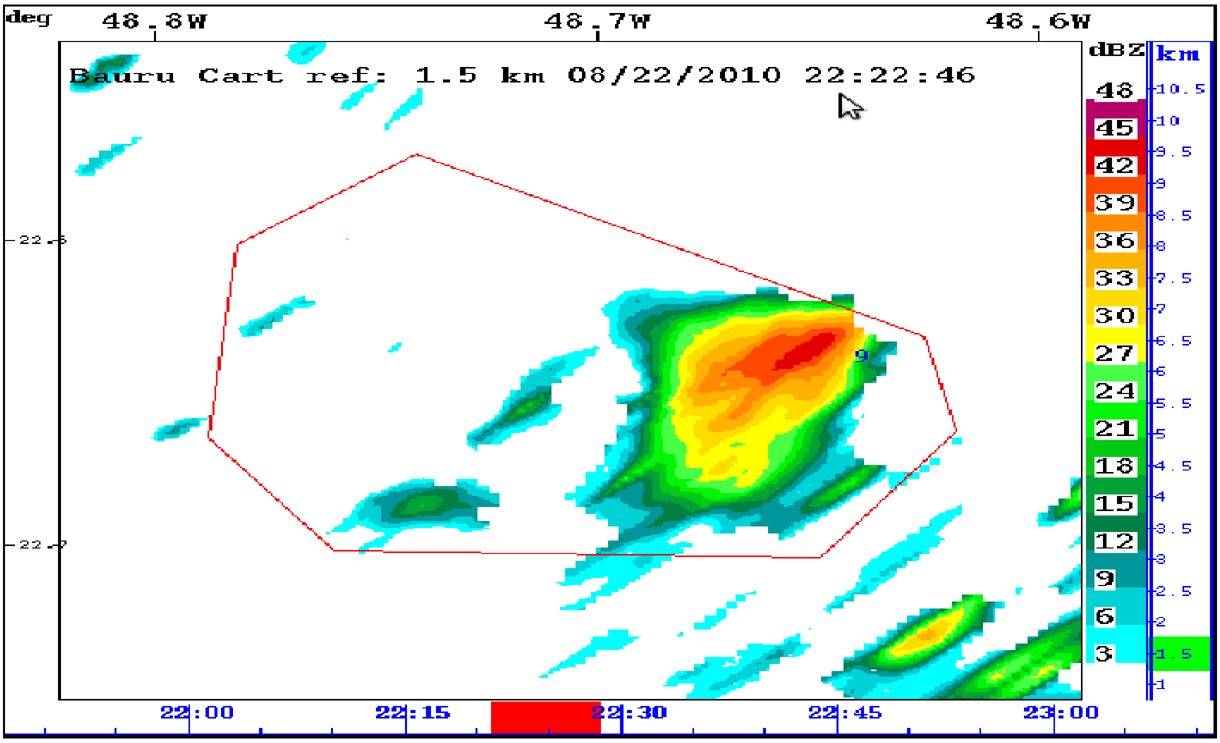

Figure 6. Location of sample n° 9 with radar echoes during the fire (22:22)

The figures 7 and 8 shows the sample n° 9 at 22:37 and 22:45 GMT, 5 and 13 minutes, respectively, after the end of burning and already without radar echoes within the monitoring area.

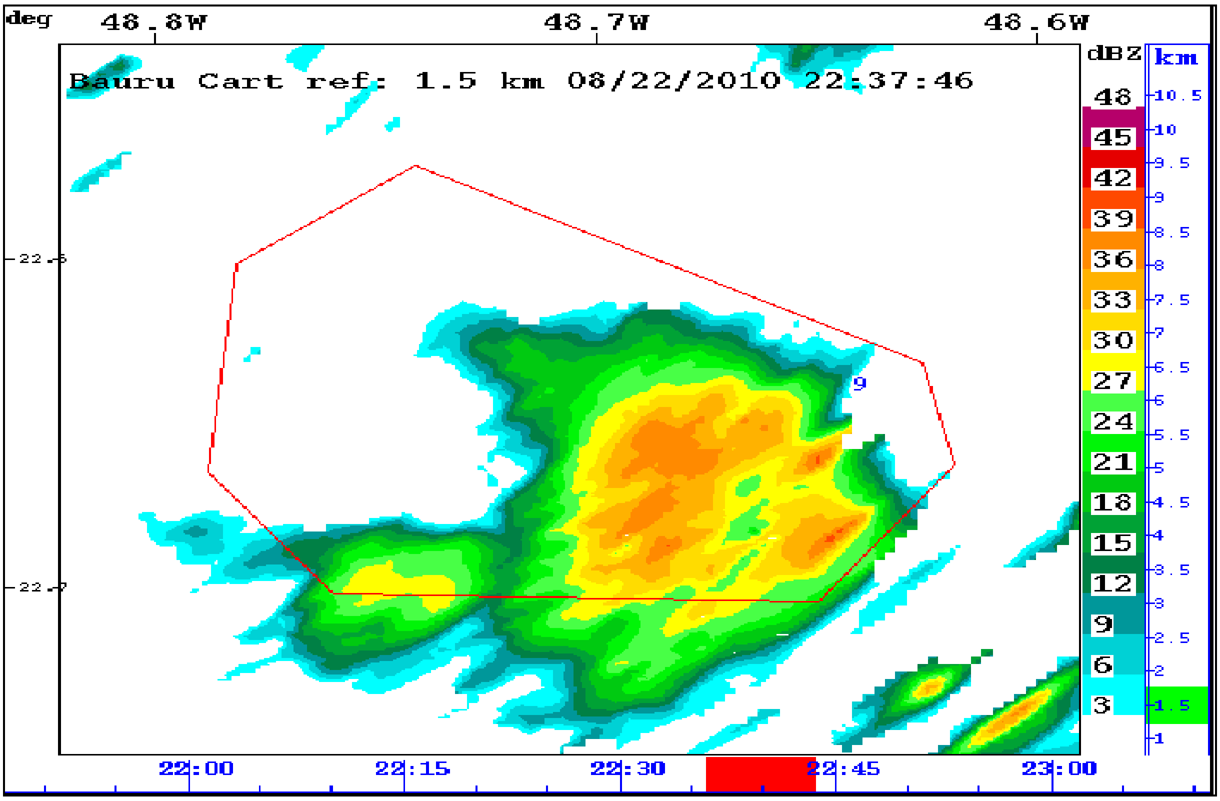

Figure 7. Sample n°9 after burning and without radar echoes (22:37)

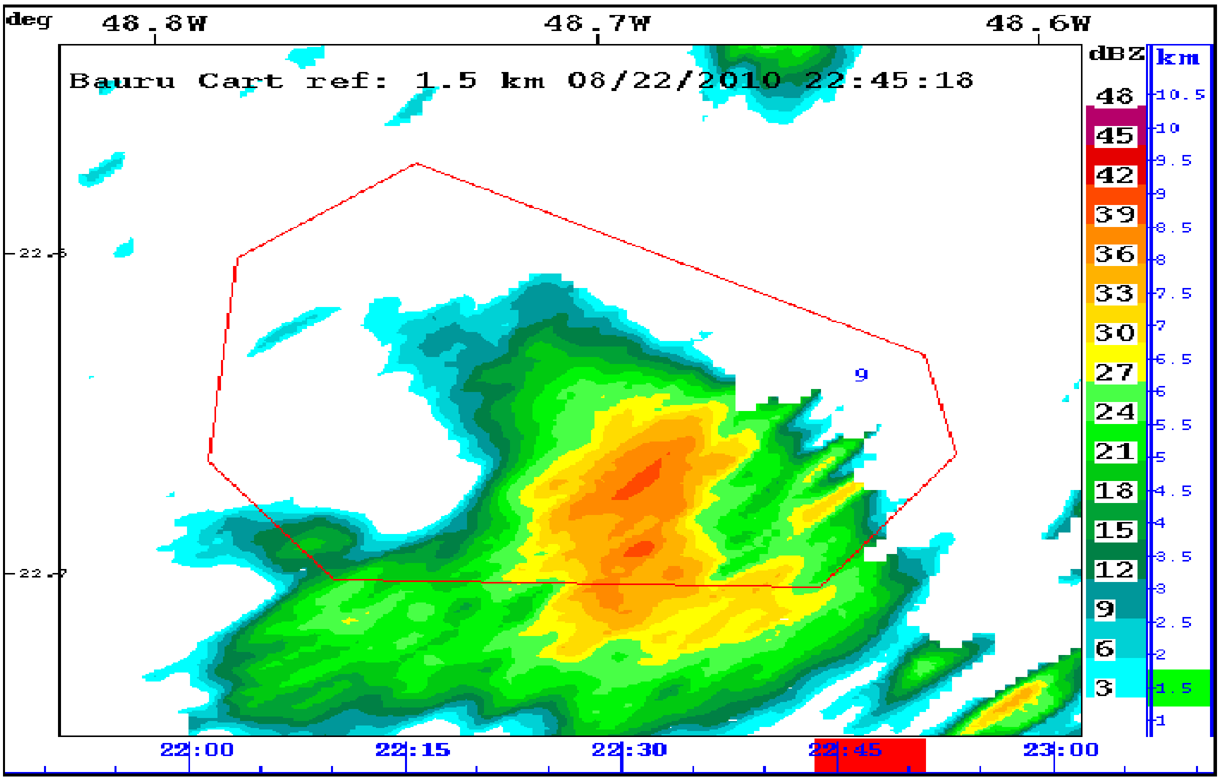

Figure 8. Sample n°9 after burning and without radar echoes (22:45)

Durant August 2013, which was a period of high index of fire danger in the region, the radar was operated again with high sensitivity and the temporal resolution shortened to 5 minutes, monitoring the reforestation areas owned by Duratex Company. The only two small fire spots detected by the company's observation towers were also detected by the radar system. Synchronizing the time from the radar and the observation tower, the radar detected the fires 6 an 8 minutes in advance, respectively.

4. Conclusions

The Bauru S-band Doppler weather radar had successfully detected of burning of 12 plots of sugar cane. The two events identified by the observation towers in the reforestation area during the second experiment were also monitored and detected by the radar.
Based on the results, weather radar can be considerate an important auxiliary tool for detecting unauthorized burning and forest fires, adding significant value to the information for decision-making in monitoring, detecting and suppressing wildfires.
The X-band radar, for example, with its own technical characteristics combined with increased temporal resolution, would be more suitable for smaller targets and smoke, could be an even better alternative to fire detection, and shorter response time.

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