Aerial Fire Suppression Evaluation Gains Effectiveness

New technology based on thermal imaging allows quantitative assessment of aerial suppression chemicals.

By Prof. Elsa Pastor, Dr. Matt Plucinski and Prof. Eulàlia Planas

Are aerially delivered fire suppression chemicals effective in firefighting? Recent experiments conducted in South Australia shed light on this very question.

As part of the study, fires were set in the Ngarkat Conservation Park during a period of hot, dry weather in 2008, with fire danger ratings in the "very high" category (McArthur Forest Fire Danger Index). The investigative team evaluated foam and gel suppressants in addition to a retardant.

What's more, the team employed a research-grade infrared (IR) camera and standard visual video camera to capture footage of the fire. The footage was used to determine the outcome of the aerial suppression drops and processed to provide quantification of fire conditions before, during and after suppression.

FIELDS OF FIRE PLOTS

The fires were conducted in large plots, greater than 40 hectares (ha) each, of mallee-heath (shrubland) vegetation. Each plot was ignited using a long ignition line (greater than 200 m) perpendicular to the wind direction in order to quickly establish well-developed fires.

Left: An Airtractor 802 delivering a gel suppressant on the head of an experimental fire at Ngarkat Conservation Park. Suppressant drops are usually delivered directly onto the fire edge (direct attack) or immediately adjacent to it (parallel attack). Photo by Ian Tanner, South Australian Department of Environment and Heritage.

The fires burned through a series of monitoring equipment including a thermologger grid, in-fire cameras and a radiometer flux tower before being suppressed. During this time, the fires achieved average forward rates of spread above 40 m/h with average flame heights between 2.5 m and 4 m.

The experiments were organized by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the South Australian Department of Environment and Heritage[1]. Aerial suppression was contracted to and supported by the South Australian Country Fire Service (CFS).

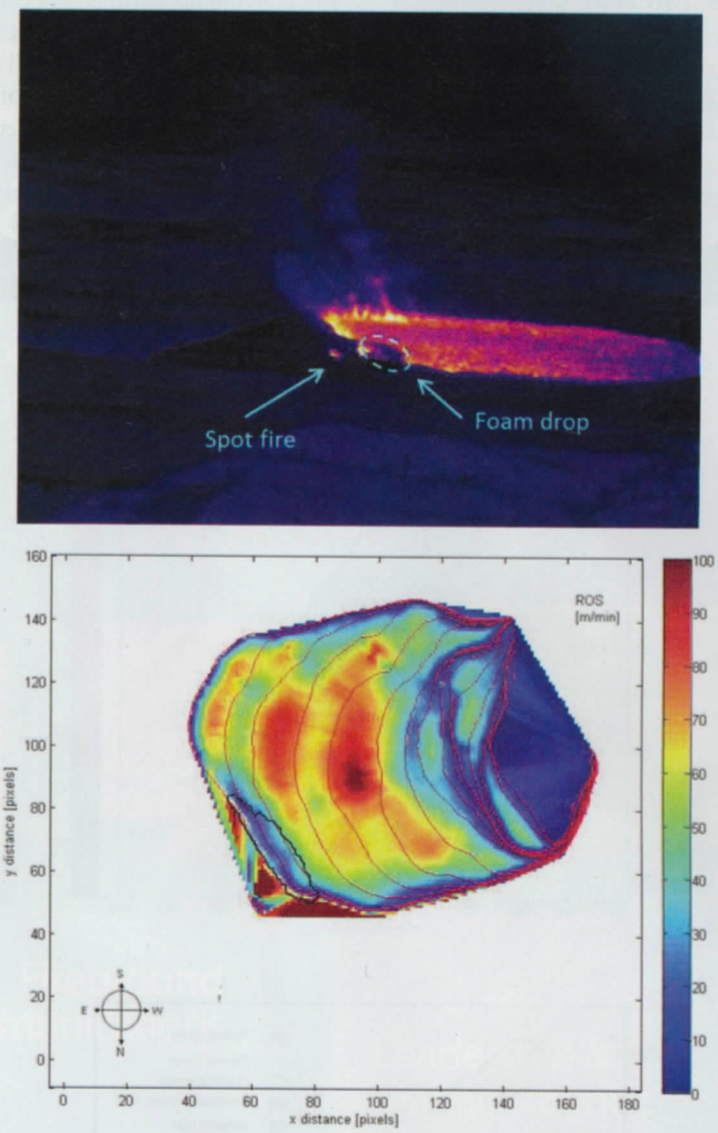
SUPPRESSION RESOURCES

The suppression resources were two single-engine, fixed-wing aircraft (Air-tractor AT-802) delivering different suppression chemicals in each plot. These included foam and gel suppressants, which were applied directly onto the perimeters of active fires, and a retardant, which was applied across the path of one fire prior to ignition. Details of the experiments can be found in the project report.[2]

The fire and suppression actions were monitored from the air and ground. Drop sites were surveyed after the plots had been fully burned out. Aerial monitoring took place from a helicopter and used a research-grade IR camera and standard visual video camera.

The captured footage featured a side view of the whole fire, including four reference points employed as geo-references for image processing. The footage was used to determine the outcomes of aerial suppression drops and processed to provide quantification of fire conditions before, during and after suppression.

Figure 1



The IR footage was analyzed to determine the time the fire was held by each drop. Because of the absence of ground suppression, all drops in the experiments were eventually breached by the fire (via spotting, burn-around or burn-through).

Examples of all three breaching mechanisms were evident in the raw IR footage *(an example can be seen in Figure 1)*. Drop hold times were determined using the time difference between breaches and suppressant drops landing on fire edge, or fires reaching retardant drops.

Figure 1. Top: Raw infrared image of a foam drop on an experimental fire. This image shows an area cooled by the drop and a spot fire that could not be seen by the pilots.

Bottom: Plot map developed from processed infrared imagery showing fire spread contours and the drop perimeter (black line). The pixel size is 3 m x 3 m.

DROP IMPACT ON FIRE BEHAVIOR

The quantitative assessment of fire conditions required substantial processing of the IR imagery. Image processing encompassed first geo-referencing every frame, then locating and outlying the perimeter of the drops based on IR temperature changes before and after drops — as well as finally identifying the location of the fire perimeter at regular time steps to produce a rate of spread map. This processed IR data was then used to study the characteristics of each drop and its effect on fire behavior.

The analysis of the drop area provided the dimensions of the footprint including the distance to the fire edge, other drops and anchor points *(see Figures 1 and 2)*. This allowed for a detailed assessment of drop accuracy and the determination of the effective drop length, which is the length of fire edge suppressed by the drop. It also enabled the burning state of fuels within the drop area (unburnt, flaming or smoldering) to be calculated at the time of the drop and afterwards.

Figure 2

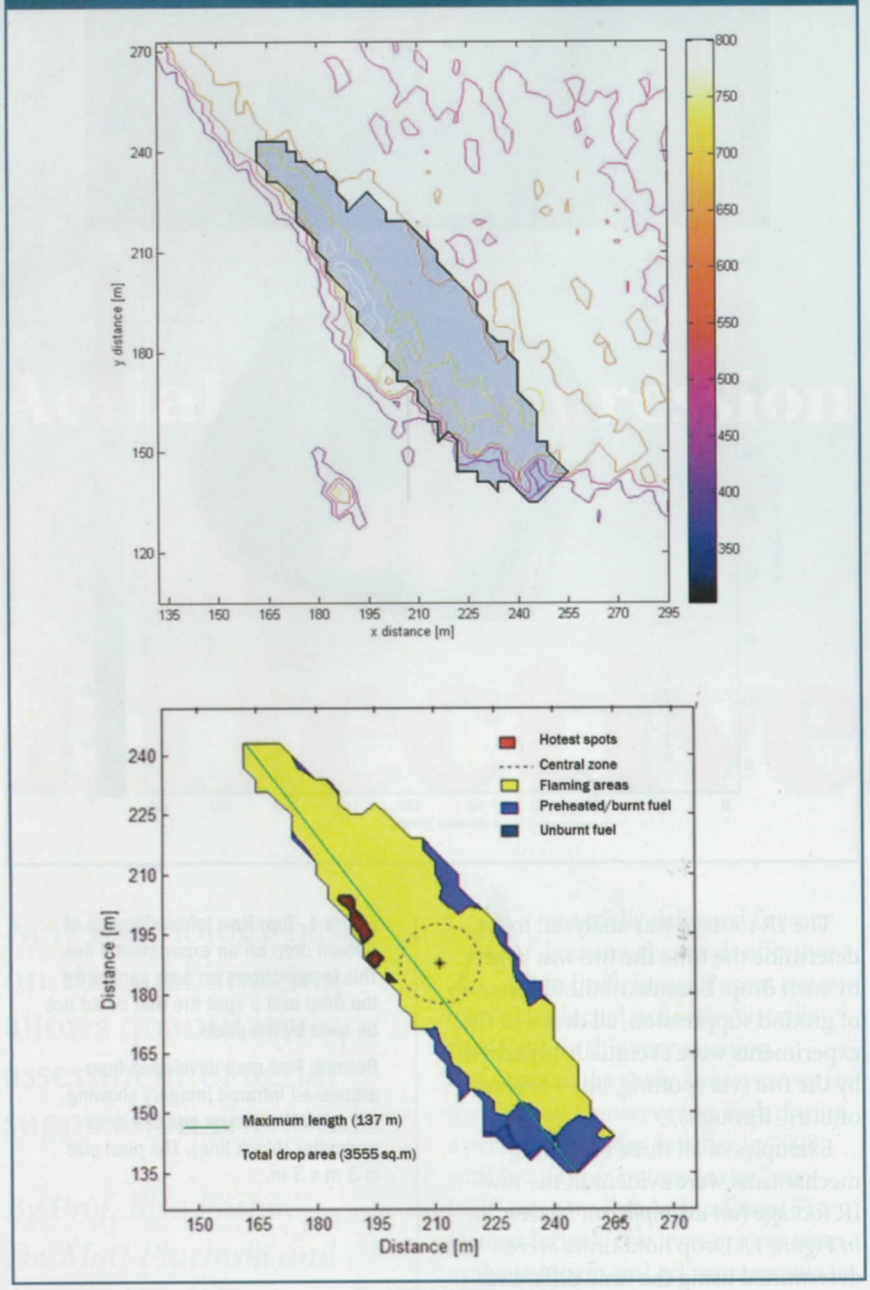


Figure 2. Top: Processed infrared image showing the drop location (blue area) superimposed over a temperature contour map (in °C) of the surrounding area at the time the drop was delivered.

Bottom: Outcome of the image analysis showing the different fire activity within the drop perimeter: flaming areas, fuel preheated or already burnt and unburnt fuel.

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The analysis of fire behavior provided quantification of the drop effects on fire activity in terms of rate-of-spread reduction. A detailed description of the airborne imagery analysis methods is available in Pastor et al[3] and Perez et al.[4]

A complete evaluation of suppression chemicals would require direct comparison of drops to resist burn-through and reduce fire behavior as a function of the fire size, fuel type, weather conditions and drop characteristics. But this could not be achieved in these experiments because the other breaching mechanisms could not be prevented. In addition, the fire conditions between the different suppressant-type drops were different.

The Ngarkat aerial suppression experiments enabled the development of sound drop assessment methodologies using aerial IR imagery. The analysis of the raw IR footage provided accurate data on drop hold times, breaching mechanisms and fire spread.

A STEP FORWARD

Aerial suppression is expensive and requires significant logistical support. Assessing the effectiveness of aerial suppression drops provides valuable data for determining if the cost and effort are justified. It also can be useful for reviewing and improving firefighting tactics and procedures and can provide training material for wildfire aviation specialists.

IR monitoring has not been comprehensively used to investigate the effectiveness of aerial suppression drops on wildland fires. The Ngarkat experiments have demonstrated its potential.

In principle, IR footage can be captured during any wildfire event, provided there is a suitable IR camera and a viewing platform. Some new airborne IR monitoring instruments are able to geo-reference imagery in real time. These technologies could be further developed to analyze drop assessments during wildfire conditions. In an operational environment, raw IR footage could be used to detect drop breaches and monitor general fire behavior and suppression effectiveness.

Processing the raw IR data would provide accurate quantification of drop placement, coverage and effects on fire behavior. However, data processing is computationally intensive. An eventual real-time assessment apparatus to be used during wildfire operations would require significant computational resources, as well. W

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