2.4 OPERATIONAL FOREST FIRE-GROWTH PREDICTIONS FOR CANADA

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1. INTRODUCTION

Fire growth modelling has been topic of research and development since the 1970s (Kourtz *et al*. 1977). This has lead to the development of models such as Prometheus and Farsite (Richards 1994, 1999; Finney 1998), which currently are being used by forest protection agencies in Canada and the US. These models predict the locations of future fire perimeters and the fire behaviour likely to be associated with such growth, proving their value as fire management tools.

The current challenge for these models is the timely collection of data required to conduct such predictions and the presentation of the results. Fire growth models need data from a variety of sources - forest inventory, meteorological forecasts, current fire perimeter maps - that have made the timely production of fire-growth predictions a difficult, labour intensive endeavour. Often, days are spent collecting the relevant background information while the crucial fire runs are occurring.

This paper presents an operational model that predicts fire growth for wildland fires in Canada. Gridded maps of fuel types and elevation, forecasted weather, and fires detected by remote sensing are entered into a fire-growth model. Predicted fire perimeters are mapped and presented over the Internet through the Canadian Wildland Fire Information System (CWFIS) (http://cwfis.cfs.nrcan.gc.ca/).

2. METHODOLOGY

2.1 Canadian Wildland Fire Information System

The Canadian Wildland Fire Information System (CWFIS) provides most of the data required to conduct operational fire-growth modelling. The CWFIS is a computer-based fire management information system that monitors fire activity and fire danger conditions across Canada. Daily weather observations are collected and used to produce fire-weather and fire-behavior maps based on the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks *et al*. 1989).

2.2 *Detection*

Current wildland fires are detected nationally using MODIS and NOAA/AVHRR satellite imagery (Quayle *et al*. 2003; Englefield *et al*. 2004). Image pixels containing actively burning areas (also referred to as hotspots) are mapped with each satellite pass (approximately every 6 hours). Because the resolution of the imagery used is 1 km² at nadir, precise mapping of hotspot locations is impossible with this method. However, detection is a function of fire intensity and size, such that fires much smaller than 1 km^2 are still detectable. Fire monitoring using hotspots has various drawbacks, the most significant being the inability of the sensors to penetrate cloud. Fires burning under cloud or smoke are not detected.

2.3 *Modelling*

For each selected region, a fire growth simulation environment is assembled. This includes fuels and topography maps, an ignition zone and forecasted weather.

The best fuel type and elevation data available for the fire location is selected. In Canada, the forest protection agencies of the provinces, territories, and national parks are responsible for fire management and fuel type mapping. Fuels are mapped from various sources, typically forest inventory, Landsat imagery, or a combination of the two. Where agency maps are not available, the national fuel type map (Nadeau *et al*. 2005) is used. The national map is based on forest inventory and SPOT VGT land cover (Latifovic *et al*. 2004), and has a coarser resolution (1 km²) than the agency maps.

A daily ignition grid is built by buffering around the previous day's hotspot locations (out 2 km, then in 1.3 km). The areas around hotspots detected prior to the previous day are considered burned area and thus excluded from potential fire growth.

Hourly forecasted weather is provided by the Canadian Meteorological Centre (CMC) of Environment Canada from their Global Environmental Multiscale (GEM) model (Côté *et al*. 1998). Forecasted surface wind, temperature and dew point values are interpolated to estimate the fire weather conditions at the fire location. The Fine Fuel Moisture Code (FFMC) is set in equilibrium with the environment to capture diurnal variation of the fuel moisture (Van Wagner 1987).

A 16-point deterministic fire growth model is used to predict the extent and direction of fire spread over the next 24 hours (Anderson *et al*. 2007). Simulation periods for the model runs were from midnight to midnight, using the ignition grid as determined from the

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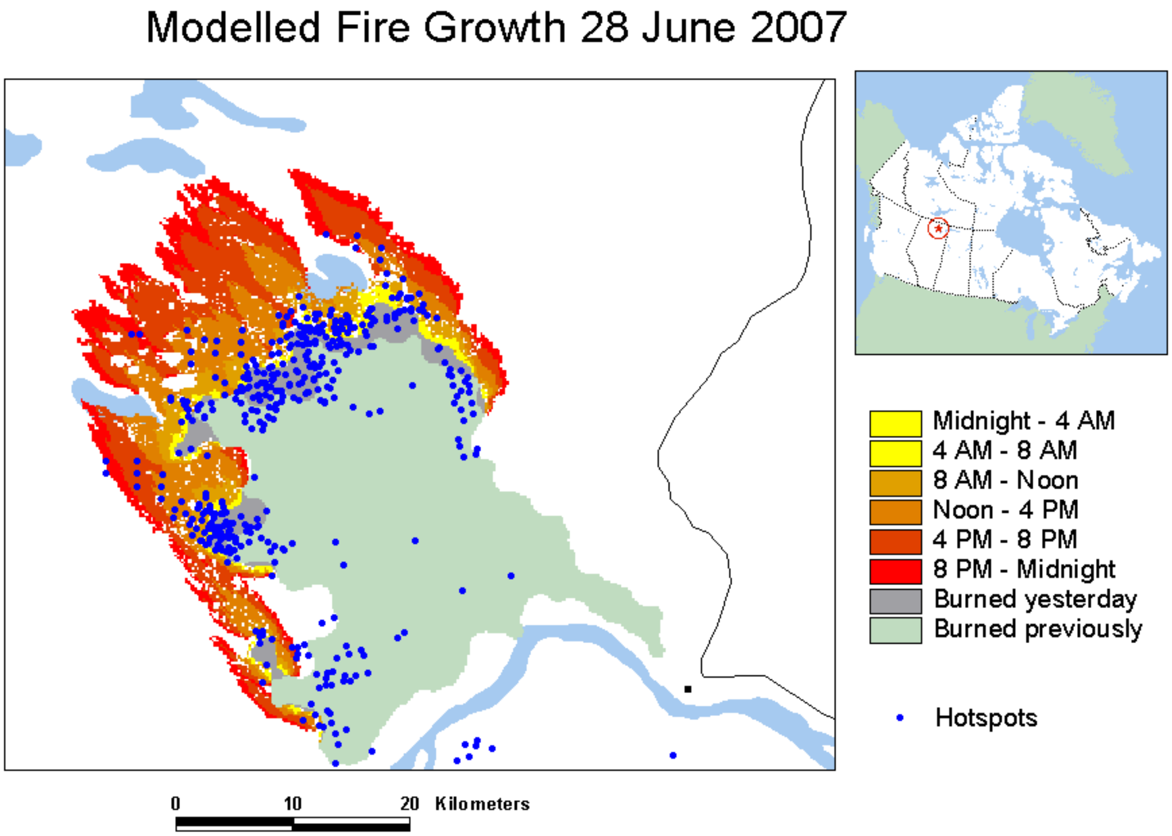

Figure 1. Fire-growth prediction for 07WB002 on June 28, 2007. Predicted growth is shown in shades from yellow to red. The ignition zone, shown in dark grey as yesterday's burned area (as determined from the June 27 hotspots), while previously burned area (hotspots prior to June 27) is shown in light grey. Observed hotspots for June 28 (the period of predicted fire growth) shown as blue dots.

previous day's hotspots as the point of initiation of fire spread.

Spread rates in the fire growth model are calculated using the Canadian Forest Fire Behaviour Prediction (FBP) System (Forestry Canada Fire Danger Group 1992), which is part of the CFFDRS.

2.4 *Presentation*

Predicted fire perimeters are mapped and presented on the CWFIS web site. Supplemental information is presented as well to aid users in interpreting the model results. This includes the forecasted weather conditions, recent satellite images and past model predictions.

3. CASE STUDY

The described modelling approach was used for two large fires that occurred in Wood Buffalo National Park (WBNP) in 2007. Fires 07WB001 and 07WB002 both started on May 27, 2007 as a result of lightning occurring along a stalled cold front. These fires, referred to as the Boyer Rapids Complex, burned on opposite sides of the Peace River. Suppression activities were limited to the southeast and southwest corners of the fires where communities were threatened; the remainder of the fires were left to grow naturally. By August 6, fire 07WB001 on the southern side of the river reached its final size of 89 204 ha, while 07WB002 reached 125 208 ha (a combined size of 214 412 ha).

Fuel type and elevation grids for the park were obtained from WBNP. The fuels map was based on Landsat imagery, and had a resolution of 28.5 m; the elevation map had a resolution of 50 m. Because the fires were very large, the fire growth model was run at a coarser resolution (100 m).

Fire-growth predictions were produced for the two fires each morning and presented through the CWFIS, generally by 9:30 LDT each morning.

Figure 1 shows the prediction for 07WB002 for June 28, 2007, as displayed on the CWFIS web site. Predicted growth (from midnight to midnight) is shown

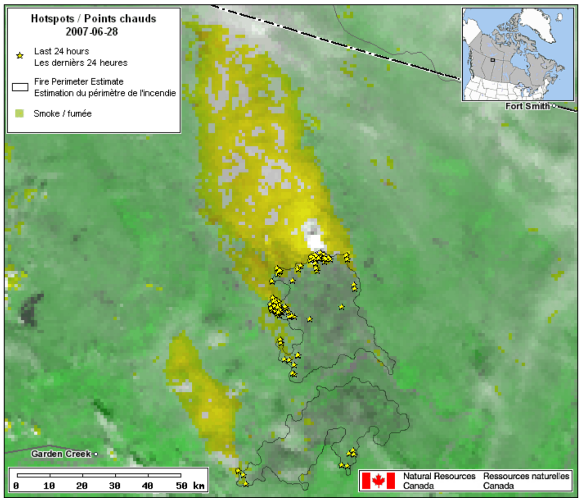

Figure 2. NOAA/AVHRR satelitte image of fires 07WB001 and 07WB002 for June 28, 2007. Smoke plumes from the fires are enhanced in yellow. Previous day's hotspots (June 27) are shown as yellow stars.

in shades from yellow to red. The dark grey area labelled "Burned yesterday" was determined from the June 27 hotspots. It is used as the ignition zone. Area burned prior to yesterday's hotspots is shown in light grey. Both burned regions are considered burned out and are excluded from possible fire spread.

Observed hotspots for June 28 (the period of predicted fire growth), shown as blue dots, are plotted as a way to validate the prediction. This serves to highlight some of the strengths and the weaknesses of this approach.

First, the figure shows that the model predicted the spread rate and direction with reasonable accuracy. Hotspots show the fire wrapping around lakes on the northern and western edges. On the other hand, the model over-predicted the flank spread on the northeast and southwest edges of the fire. This may be due to inaccuracies in the weather forecast or diurnal variation of the fuel moisture, as most of this spread occurs from 8:00 PM to midnight.

Fire growth at the head of the fire in the northwest corner appears to have been overestimated, though hotspot detection may have been prevented by the smoke plume. Satellite imagery from June 28 (Figure 2) shows thick smoke from the fire heading northwest and obscuring the fire front. This was an issue with fire predictions on other days as well. In the same sense, the smoke plume could have prevented the detection of the previous day's hotspots, thus affecting the current ignition zone. A worthwhile product to help with the smoke plume issue could be a remote sensing routine to detect burned area. Such a routine would help in mapping fire perimeters, accounting for past burned areas that were hidden under smoke plumes.

Another issue is the large number of hotspots within the burned areas, both for yesterday and for the days prior. There are many unburned or partially burned islands within the mapped fire perimeter. While the buffering approach is an efficient way to estimate fire perimeters, it is approximate and is limited by the coarse resolution of the hotspot imagery.

Higher-resolution burned area maps can be produced by other means. Routines for mapping burned area using LANDSAT imagery have been developed but the long return interval and delay in acquiring images makes it unsuited for operational use. Infrared mapping by aircraft such as Airborne Wildfire Intelligence System (AWIS) (http://www.awis.ca/) can provide high resolution, high frequency burned area maps regardless of smoke or cloud conditions, but flight costs and aircraft availability limit their use as well.

Finally, these predictions are all based on intermediate products, which introduce their own sources of error. For example, a simple error in the predicted wind direction will lead to fire growth in the wrong direction, or a misinterpreted fuel type could lead to erroneous spread rates. Such an error was experienced when it was noted that 07WB002 was consistently burning towards the west, yet this was not observed from detected hotspots. Closer examination revealed that there was an old burn to the west of 07WB002 that was not properly classified in the fuels data. A correction of this eliminated much of this erroneous spread.

4. CONCLUSIONS

This paper presents an operational approach to fire-growth modelling in Canada. The Canadian Wildland Fire Information System (CWFIS) provides the necessary framework to handle the data requirements and run the model. This system detects hotspots and estimates fire perimeters; it handles the forecasted weather used by the fire-growth model; and it provides some of the necessary static background data, including national fuels and topography when required. Through the CWFIS, the processing of all this information is conducted in the morning and is available to forest protection agencies for their suppression planning.

A case study was presented showing predictions of two fires in Wood Buffalo National Park. In turn, this information helped to support suppression operations within the park.

There are several issues regarding this approach. Specifically, smoke and cloud prevent the detection of some hotspots, which in turn prevents accurate mapping of the fire; hotspot buffering as a method to map fire perimeters fails to capture many unburned islands and smoldering zones, which can turn into active fires in the future; possible errors introduced by intermediate models and information such as fuels classification or weather forecasts. While these are issues that need to be addressed, the operational approach shown in this paper serves as an example of how fire-growth models can be used in an operational setting.

5. ACKNOWLEDGEMENTS

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