Applying geographic information systems and remote sensing to forest fire monitoring, mapping and modelling in Canada

B. Lee[1], Z. Li[2], T. Lynham[3], R. Fraser[2], P. Engelfield[1], R. Hall[1], Z. Jin[2], R. Landry[2], W. McColl[2], R. Suddaby[1], D. Klita[1], F. Ahern[2], J. Cihlar[2]
[1]Canadian Forest Service, Natural Resources Canada, 5320 – 122 St., Edmonton, AB, Canada, T6H-3S5
[2]Canada Centre for Remote Sensing, Natural Resources Canada, 588 Booth St., Ottawa, ON, Canada, K1A-0Y7
[3]Canadian Forest Service, Natural Resources Canada, 1219 Queen Street East, P.O. Box 490, Sault Ste. Marie, ON, Canada, P6A 5M7

1. Introduction

Canada contains approximately 10% of the world's forests. The 4 million km^2 of forest covers 40 % of the country and is dominated by boreal and sub-boreal forest types. Each year wildfires have a significant impact on the environment and economy of the Canadian forest estate. On average, 10,000 fires burn 2.5 million ha per year in Canada. Approximately 3 % of these wildfires grow larger than 200 ha in size, however, they account for 97 % of the annual area burned (Stocks 1991, Stocks et al. 1996). Recognising the potential economic and scientific benefits of satellite technology, Natural Resources Canada has developed the Fire Monitoring, Mapping and Modeling System (Fire M3). The goals of Fire M3 are to monitor actively burning large fires in near real-time; to estimate annual area burned; and to model fire behavior, biomass consumption and carbon and greenhouse gas emissions using large to medium scale remote sensing platforms. Products from Fire M3 have been used in fire management planning and operations, national reporting, monitoring criteria and indicators for sustainable forest management, and fire and global change research. Fire M3 uses a fire detection algorithm recently developed by the Canada Centre for Remote Sensing (CCRS) (Li et al. 1997, Li et al. 2000). This algorithm recognises active fires using AVHRR satellite data. Monitoring with AVHRR data also makes it possible to track daily fire development and to map fire boundaries. Using the algorithm, the Canadian Forest Service and the Canada Centre for Remote Sensing developed a demonstration fire monitoring, fire mapping and fire behavior modeling system for Canada. The system was first tested in 1998 to automatically detect, monitor and map large forest fires on a daily basis. Detailed post-fire burn boundary mapping was used in combination with high and low-resolution satellite data to validate the detection and mapping procedures.

2. Daily Data Flow and System Architecture

For the identification of actively burning fires, the Fire M3 System acquires NOAA/AVHRR data from four afternoon passes per day across Canada. These data are received from two satellite receiving stations located at Prince Albert, Saskatchewan and Gatineau, Quebec (Figure 1). These data are processed daily using the GEOCOMP-N system to produce precision geocoded, Canada-wide composite images which are corrected for time varying sensor and atmospheric effects. The system achieves sub-pixel geometric accuracy using adaptive spacecraft modeling techniques and a Landsat MSS image chip library for accurate automated control point marking. The fire detection algorithm, which is incorporated into the GEOCOMP-N system, is then applied to the single day AVHRR image to automatically identify active wildland fires. Smoke and cloud detection algorithms are also part of the daily processing stream. Automated processes convert the daily fire activity maps into geographic information system compatible formats and products. These products are transmitted by FTP to the Northern Forestry Centre in Edmonton, Alberta for further processing by the Canadian Wildland Fire Information System (Lee 1995). The CWFIS receives hourly and synoptic meteorological data via the ANIK satellite from approximately 650 weather stations located across Canada. The Spatial Fire Management System (sFMS) (Englefield, et al. 1999) is the spatial modeling engine used by CWFIS to produce daily fire danger and fire behavior potential maps and reports. This engine has been incorporated into Fire M3 to attach fire weather and fire behavior attributes to each fire pixel on the hotspot mask received from the GEOCOMP-N system.

Fire M3 products are shared through a distributed world wide web site which includes text, daily maps, regional images and summary reports. Reports include daily and cumulative fire hotspots by terrestrial ecozone. An internet map server application allows panning and zooming of daily satellite composites, fire hot spots and smoke (Figure 2).

3. Annual Area Burned and Carbon Emission Products

Fire M3 also incorporates a national fire mapping component. Coarse resolution estimates of annual area burned are produced using a technique called hotspot and NDVI differencing synergy (HANDS) (Fraser et al. 2000). Spatial estimates of area burned are combined with spatial and temporal CWFIS modeled fire behavior products to estimate carbon and greenhouse gas emissions. Data assimilation techniques are used to fill in remote sensing data gaps when portions of fires are obscured due to dense smoke and cloud cover.

4. References

Englefield, P.; Lee, B.; Suddaby, R. 2000. Spatial Fire Management System. In Proc. ESRI User Conf., June 26-30, 2000, San Diego, California.

Fraser, R.H., Li, Z., and Cihlar, J., 2000. Hotspot and NDVI Differencing Synergy (HANDS): a new technique for burned area mapping over boreal forest. *Remote Sens. Environ.* 74:362-376.

Lee, B.S. 1995. The Canadian Wildland Fire Information System. Pages 639-646 *in* Proc. 9th Annual Symposium on Geographic Information Systems in Forestry, Environment and Natural Resource

Management, Mar. 27-30, 1995, Vancouver, B.C. GIS World, Inc., Fort Collins, Colorado.

Li, Z.; Cihlar, J.; Moreau, L.; Huang, F.; Lee, B. 1997. Monitoring fire activities in the boreal ecosystem. *Journal of Geophysical Research*, Vol. 102 , No. D24, Pages 29,611 - 29,624.

Li, Z., S. Nadon, J. Cihlar, 2000. Satellite detection of Canadian boreal forest fires: Development and application of an algorithm, *Int. J. Rem. Sens.*, 21, 3057-3069.

Stocks, B.J. 1991. The entent and impact of forest fires in northern circumpolar countries. In *Global Biomass Burning: Atmospheric, Climatic, and Biospheric Implications*, edited by J.S. Levine (Cambridge, MA: MIT Press), pp.197-202.

Stocks, B.J.; Lee, B.S.; Martell, D.L. 1996. Some potential carbon budget implications of fire management in the boreal forest. p. 89-96 *in* Forest Ecosystems, Forest Management, and the Global Carbon Cycle (eds. M.J. Apps and D.T. Price), NATO ASI Series, Subseries 1 Vol. 40 "Global Environmental Change", Springer-Verlag, Berlin, Germany.

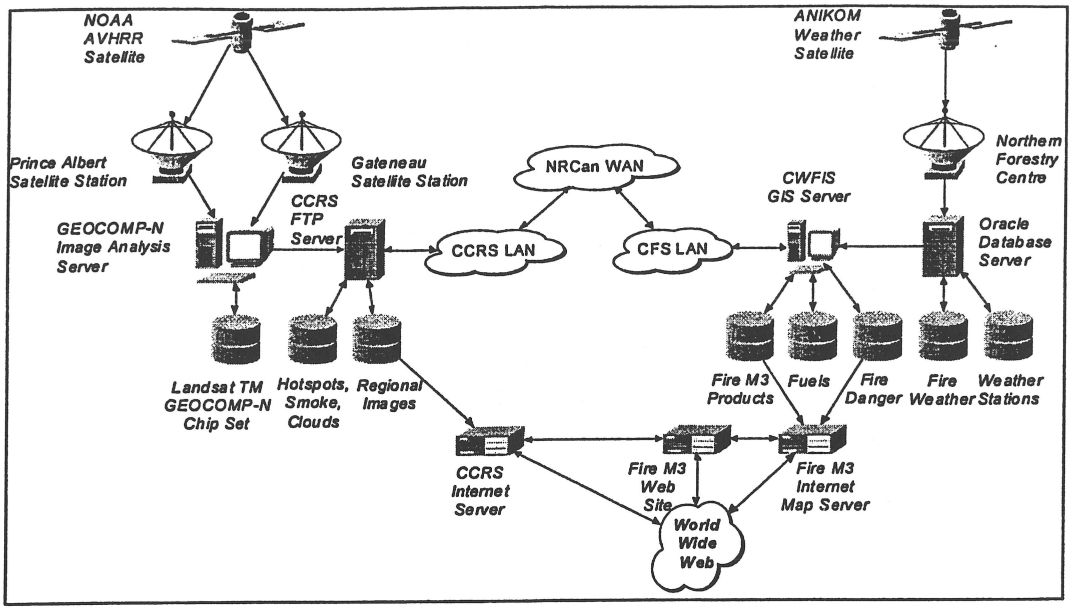


Figure 1: Fire M3 system architecture showing the data flow for daily monitoring and modeling of large fires in Canada for publication and distribution on the world wide web.

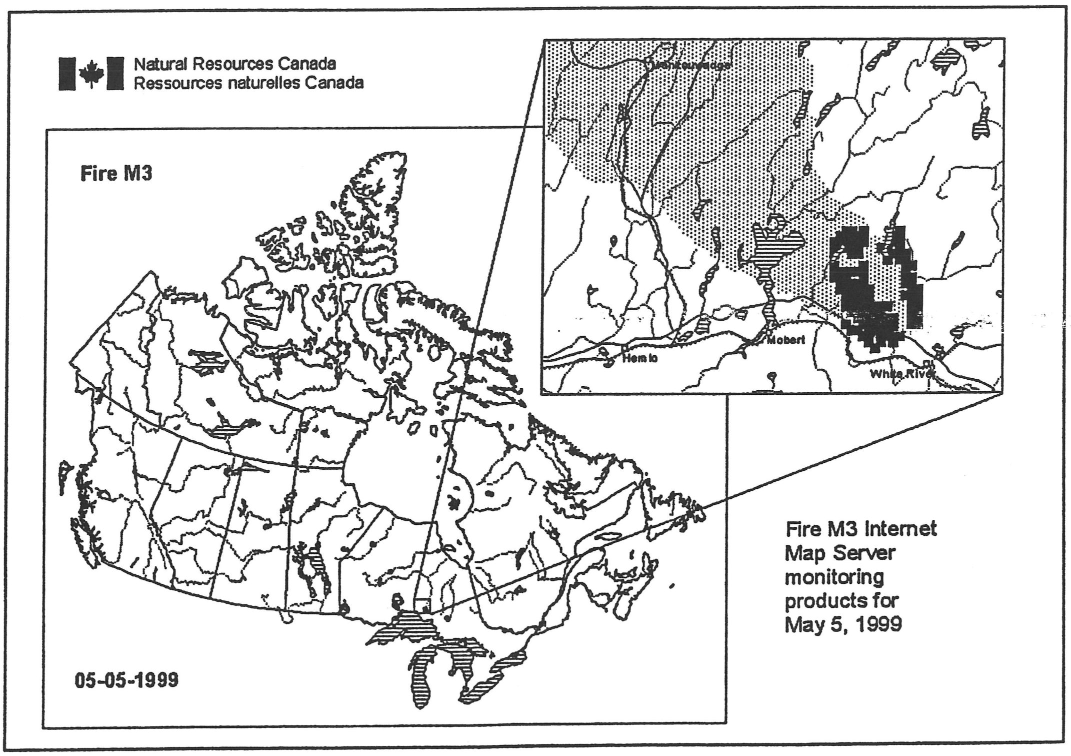
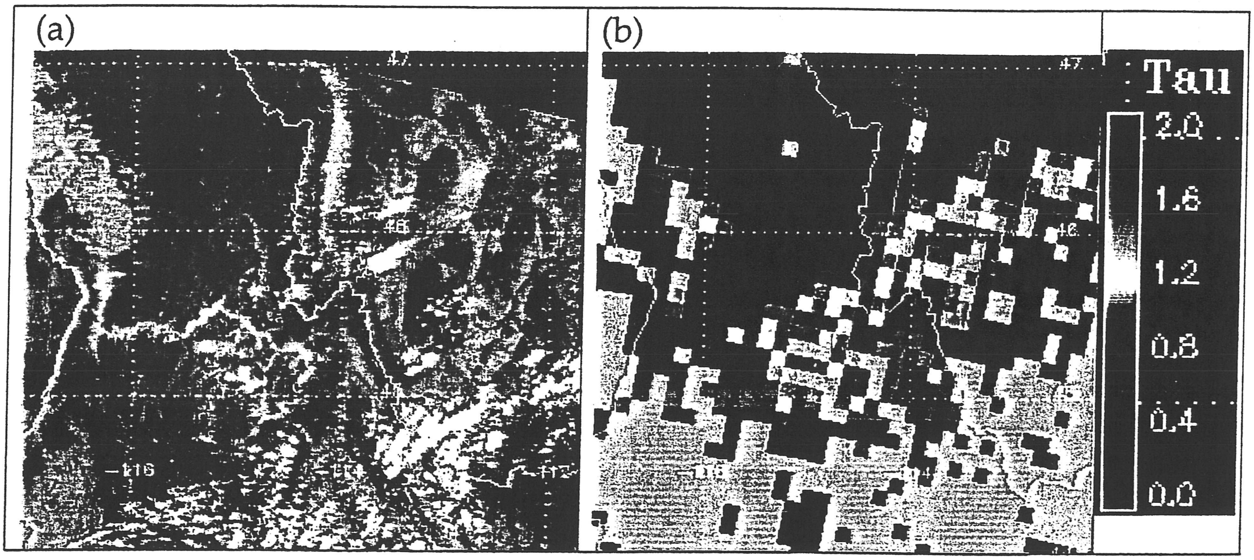


Figure 2: Fire M3 Internet map server screen snapshot of Canada-wide hotspots for May 5, 1999. The inset shows the zoom capability of the Internet map server for fires in Ontario on the same day. The elliptical shape of an actively burning fire (black) can be seen clearly along with its associated smoke plume (grey).

European Association of Remote Sensing Laboratories
Special Interest Group on Forest Fires

3rd International Workshop on Remote sensing and GIS applications to Forest Fire Management



New methods and sensors

Emilio Chuvieco and Pilar Martín (Editors)

Paris, 17 and 18 May, 2001

Emilio Chuvieco and Pilar Martín (Editors) (2001): *Proceedings of the 3rd International Workshop on Remote Sensing and GIS applications to Forest Fire Management: New methods and sensors*, Paris, European Association of Remote Sensing Laboratories, 169 pages. ISBN: 2-908885-24-7

Front cover: MODIS image of Wildfires in Montana and Idaho, Aug. 26, 2000: (a) color composite of the smoke and fires, red dots are fires detected by the MODIS 3.9 μm channel and the smoke is the observed as a composite of the MODIS blue, green and red channels. Burn scars are dark. (b) The smoke optical thickness derived from the MODIS data. The optical thickness is derived on resolution of 10 km, giving it the discontinued look. The color bar of the optical thickness is given on the right. (From Kaufman et al., this volume).