An Introduction to the International Crown Fire Modelling Experiment[1]

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Abstract

The International Crown Fire Modelling Experiment (ICFME) constitutes a major, cooperative, global undertaking involving coordination by the Canadian Forest Service Fire Research Network and the Government of the Northwest Territories' Forest Management Division combined with participation of collaborating scientists and operational fire personnel, principally from Canada and the USA, but with representation from several other countries as well. The initial impetus for the ICFME was oriented towards the testing and calibration of a newly developed physical model for predicting the spread rate and flame front intensity of crown fires. However, the ICFME has also provided the opportunity to examine other aspects or implications of crown fire behavior, without comprising this primary objective, including linkages to firefighter safety/personal protective equipment (PPE) and wildland-urban interface or intermix issues as well as certain ecological and environmental impacts or effects, including concerns about atmospheric chemistry from biomass burning. The 18 experimental crown fires that have taken place in the last four years (1997-2000) are providing valuable new data and insights into the nature and characteristics of crowning forest fires needed for dealing with the fire management problems and opportunities that will be affecting both people and ecosystems in the coming century.

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[1] Based on a presentation made at the International Crown Fire Modelling Experiment Session, chaired by the senior author, of the 2000 International Wildfire Safety Summit sponsored by the International Association of Wildland Fire held in Edmonton, Alberta, October 10-12, 2000. The above abstract appears as page 7 in: Butler, B.W. and K. Shannon (editors.). Proceedings of 2000 International . Wildfire Safety Summit. International Association Wildland Fire, Montana City, Montana.

This broad overview of the ICFME project will set the stage for the other presentations being made at the 2000 International Wildfire Safety Summit dealing with specific ICFME studies. Some preliminary findings regarding community fire protection in the northern boreal forest, based on observations of the ICFME experimental crown fires, especially as they pertain to both public and firefighter safety, are also addressed.

Keywords:

Canada; community fire protection; fire behavior; firefighter safety; fuel treatments; Northwest Territories; personal protective equipment; protective fire shelter; safety zones; wildland fire research; wildland-urban interface.

I have been privileged to collaborate with forest fire research personnel of the Canadian Forest Service in an effort to create, calibrate, and test a predictive physical model for the rate of spread and intensity of a crown fire. In June and July, 1997, I took part in the first phase of the International Crown Fire Modelling Experiment as part of this research. The experiments were meticulously planned. Site preparation and prefire fuel inventories were the best I have ever seen in terms of thoroughness and professionalism of execution. These experiments must be thoroughly documented for they will become the standard against which all models will be tested. **F.A. Albini**[2]

Introduction

Despite the fact that high-intensity, crowning forest fires presently account for an exceedingly large proportion of the annual area burned by wildfires in Canada (Weber and Stocks 1998) and in other regions of the world, a complete understanding of all aspects of crown fire phenomena has been standing research need within the wildland fire management and wildland fire research communities (Dickerman et al. 1962; Sando and Wick 1972; Taylor et al. 1975; Anon. 1980; Rothermel 1991; Taylor et al. 1998; Dam 2000).

The Canadian Forest Service (CFS) fire behavior researchers have been international leaders in conducting experimental crown fires in coniferous forest fuel types (Alexander and Quintilio 1990, Alexander et al. 1991; Stocks and Hartley 1995), and in formulating, simplistic, empirical models (Van Wagner 1977; Alexander 1998) and systems for quantitatively predicting crown fire initiation and spread for practical operational use by Canadian fire management

[2] From Alexander, Stocks, Wotton and Lanoville (1998), which should be consulted for comments from other ICFME participants.

agencies (Forestry Canada Fire Danger Group 1992; Taylor et al. 1997; Lee et al. 2000) and others (Finney 1998; Scott 1998, 1999).

While much has been accomplished with respect to studying crown fires in the past four decades, much still remains to be explored and developed (Alexander 1998, Cruz 1999). Towards this end, the CFS, in cooperation with the Northwest Territories' Department of Resources, Wildlife and Economic Development, with significant participation by the USDA Forest Service, initiated a new research thrust in the mid 90s.

The International Crown Fire Modelling Experiment (ICFME) represents a major field activity of the International Boreal Forest Research Association's Fire Working Group (Stocks et al. 1997) and the International Geosphere-Biosphere Programme's project on global atmospheric chemistry associated with biomass burning (Stocks, Goldammer, Cahoon and Cofer 1998; Goldammer 2000). ICFME is one of recent experimental burning projects being carried out to investigate the behavior, ecological impacts and atmospheric chemical effects of high-intensity crown fires in northern circumpolar boreal forests. The other two efforts – the Bor Island Fire Experiment and the FROSTFIRE Project -- having taken place in central Siberia in July 1993 (FIRESCAN Science Team 1996) and interior Alaska in July 1999 (*http://www.fsl.orst.edu/fera/frostfire.html)*, respectively.

The principal focus of ICFME was directed towards the testing and calibration of a new physically-based model for predicting the rate of spread and intensity of crown fires. The model was developed by Dr. Frank Albini of Montana State University, a world renowned theoretical wildland fire modeller, and supported by both the CFS and U.S. Forest Service (Albini 1997,1999, 2000).

Experimental Design and Research Methodology

In June of 1994, an ideal outdoor laboratory for carrying out experimental crown fires during the early summer was located approximately 50 kilometres northeast of the town of Fort Providence, Northwest Territories (NWT). The forest type is a dense, 70-year-old jack pine stand averaging 13 metres in height with an equally dense black spruce understory – a fuel complex deemed perfect for generating crown fires. The bulk of the plot establishment, fireguard construction and pre-burn sampling of ground, surface and crown fuel characteristics was undertaken during the summers of 1995 and 1996.

The “burning window” for the ICFME project was judged to be roughly a three-week period from about mid June to early July in advance of the lightning fire season in the NWT. In preparation for burning, a fully automated fire weather station was set-up on site each season. Daily observations from this station were used to calculate the Canadian Forest Fire Weather Index System

components (Canadian Forestry Service 1984, Van Wagner 1987). This information coupled with the formulated burning prescription (i.e., Duff Moisture Code > 40, Fine Fuel Moisture Code > 89, and 10-m open wind speed > 15 km/h), the daily fire weather forecasts issued by a CFS meteorologist (Alexander, Stocks, Wotton, Flannigan, Todd, Butler and Lanoville 1998), and the results from small-scale test fires, were the principal considerations in deciding which plot if any should be burned on a given day.

In order to quantify the characteristics associated with the complex and dynamic nature of crown fires as possible, a network of ground-, tower-, and aircraft-based instrumentation was deployed at various locations inside, around and above each burning plot (e.g., Ackerman and Dakin 2000, Butler and Cohen 2000). This included a vast array of thermocouples and continuous video, and involved measurements, etc. prior to, during and following each fire. This permitted the measurement, monitoring and recording of, among other things, thermal radiation, vertical profiles of temperature within and above the advancing flame front, fire spread pattern, spotting distances and densities, flame front residence times, flame size and geometry, fuel moisture and consumption, trace gases/aerosol emissions from smoke (Cofer et al. 1998), entrainment winds and other fire dynamics (Clark et al. 1998, Latham 1998, Radke et al. 2000).

Accomplishments to Date: 1997 to 2000

The actual burning of plots commenced auspiciously enough on July 1, Canada Day, in 1997 and the last fire in 2000 took place on June 28. In total, 18 experimental crown fires were successfully carried out at the ICFME study area between 1997 and 2000; this involved three fires in 1997 (Alexander, Stocks, Wotton, Flannigan, Todd, Butler and Lanoville 1998), two fires in 1998 (Alexander, Stocks, Wotton and Lanoville 1998, Stocks, Alexander, Wotton and Lanoville 1999), six fires in 1999 (Stocks, Alexander and Lanoville 1999) and seven fires in 2000 (Alexander, Stocks, Wotton and Lanoville 2000); an attempt will be made in June 2001 to burn the single remaining plot (I1). This constitutes the most thoroughly documented set of experimental crown fires undertaken anywhere in the world to date.

A quick, uniform ignition was desired on each experimental crown fire. All of the ICFME plots were ignited as a “line of fire” using a truck-mounted pressurized flame thrower device called a “terra torch” (Tveidt 1989).

The ensuing fire behavior characteristics were typical for fully-development crown fires in the boreal forest, advancing at about 1-5 kilometres per hour, consuming significant quantities of fuel and in turn releasing vast amounts of thermal heat energy; an experimental crown fire rate of spread “record” was established on Plot 9 in 1999 (90 m/min). The resulting flames were commonly two to three times the tree height. In spite of the small size of the areas being

burned, well-defined convection columns did become established, albeit, temporarily, and prolific, short-range spotting immediately downwind was commonly observed for distances up to 300 metres from the plot.

The control, mop-up and patrol of all experimental fires was the responsibility of the territorial fire management staff and their contract fire suppression crews. No problems were experienced in containing and extinguishing the fires.

Wildland Fire Research: Lessons for the Future

While the initial impetus for ICFME was physical modelling of crown fire behavior, it also afforded the opportunity to examine other aspects and implications of crown fires, including linkages to certain fire impacts and effects (Cofer et al. 1998, Amiro 2000, Despain 2000), firefighter safety (Anderson 2000), and the wildland-urban interface (Cohen 1999). As evident by the comments made by the participates (Alexander, Stocks, Wotton and Lanoville 1998), ICFME enabled both researchers and managers alike to test and examine models, theories, operational guidelines and equipment. Such diversity illustrates that multi-disciplinary undertakings of this magnitude can accommodate both applied or practical as well as more basic or fundamental studies, including client-driven and long-term research and development, as well as involving the interests of local community members and schools (Alexander et al. 1999, Lanoville 2000; Vandell and Johnson 2000).

International endeavors like ICFME, involving global partnerships, are considered by many as how much of the world's wildland fire research will get done in the future (Stocks and Conrad 2000). The right unobtrusive atmosphere must be created in which participants can work in as relatively unfettered a manner as possible. In this regard, the success that ICFME has achieved to date can be attributed to a number of factors, including thoughtful planning based on experiences with similar experimental burning projects, an enlightened fire management perspective, good working relationships within and amongst the local community, operational personnel and researchers (Alexander et al. 1999, Lanoville 2000), and the support of senior management, coupled with a healthy dose of patience and perseverance on the part of the participants.

Further Information Forthcoming

ICFME has provided valuable new data sets and insights into the nature and characteristics of crown fires needed by both researchers and managers for addressing the challenges facing forest fire management in the future such as devising strategies to protect communities from wildfire (Anon. 2000a, Beck et al. 2000, Cohen 2000a, 2000b, 2000, n.d.) and ensuring the safety of wildland firefighters (USDA Forest Service 1999, Ackerman and Dakin 2000, Butler and

Cohen 2000). Improvements in the science of fire behavior prediction can be expected (Clark et al 1999; Radke et al. 2000). The knowledge and experience acquired during ICFME with be critical to developing the next generation of fire behavior models.

The photographic documentation acquired over the course of ICFME is proving valuable in fire management training and public education (e.g., Simon 1999) – for example, ICFME footage has been used in the ***Interface Fires*** video released by the British Columbia Ministry of Forests in May 1999 and the ***INFERNO*** video dealing with the August 1999 Salmon Arm Fire in British Columbia. ICFME has been featured in three wildland fire documentaries produced by film and television production companies:

- ***Fire of Life*** (50 minutes) -- produced by Cosmos Factory Film Production, Vienna, Austraia.
- ***Into the Flames: Fire in the Hills*** (52 minutes) – produced by for The Learning Channel by Wall to Wall Television Limited, UK.
- ***Vernieuwend Vuur*** [translation: Recreating Fire] (24 minutes) – an episode produced for their Northern Lights program by VPRO Television, Hilversum, The Netherlands.

The U.S. Forest Service's Missoula Technology Development Center in Missoula, Montana, also released a short feature video tape entitled ***International Crown Fire Modelling Experiment, Northwest Territories, 1997*** in early 1998 produced by J. Kautz (Alexander et al. 2000).

While some preliminary findings and particular studies carried out during ICFME have already been published, results of a more detailed and scientific nature will begin to appear in the next year or so. Readers are encouraged to visit the ICFME website[3] for a comprehensive listing of existing information, including extensive photo coverage of all the ICFME fires, and in order to keep abreast for the latest updates (see: http://www.nofc.cfs.nrcan.gc.ca/fire/frn/nwt/).

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[3] Note that the ICFME website was profiled in the May/June 1998 issue of *Wildfire* (Hogenbirk 1998), the May 1999 issue of *Wildland Firefighter* (Ballou 1999) and the Winter 2000 issue of *Fire Management Today* (Anon. 2000b).

Dennis Dube, Boyd Case, Steve Taylor, George Dalrymple, John Mason, Gary Hartley, Tom Blake, Brian Mottus, Mike Flannigan, Murray Maffey and Chris Stefner of the CFS, and Bret Butler and Don Latham of the U.S. Forest Service.

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ANNEX I:

INTERNATIONAL CROWN FIRE MODELLING EXPERIMENT PARTICIPANTS[4]

1999 Experimental Burning Phase III

CFS: M. Alexander, T. Blake, G. Dalrymple, B. de Groot, M. Flannigan, G. Hartley (retired), K. Hirsch, V. Kafka, D. McRae, M. Maffey (retired), J. Mason, B. Mottus, N. Payne, A. Robinson, C. Stefner, B. Stocks, S. Taylor, M. Wotton; USFS-IFSL: R. Babbit, B. Butler, J. Cohen, M. Davies, D. Jimenez, D. Latham, J. Reardon, B. Schuette, K. Shannon, P. Sopko, R. Susott; DRWED: D. Allaire, E. Campbell, R. Currie (contractor), R. Lanoville, F. Lepine; UA: M. Ackerman, N. Lavoie; ALFS: G. Dakin; USFS-MTDC: L. Anderson, J. Davies, J. Kautz, D. Mangan, W. Throop; USFS-NFS: T. Knauth, G. Lemon, T. Petrelli, M. Vanderpas; USGS: D. Despain; BCFS: J. Beck, M. Dittaro; UM: M. Cruz; Agricultural University Wagemimgen (Holland): J. Dam; New Brunswick Dept. of Natural Resources & Energy: P. Gilmore; Underwriters Laboratories: M. Pabich; Hokkaido University (Tokyo, Japan): T. Chikahisa.

2000 Experimental Burning Phase IV

CFS: M. Alexander, P. Bothwell, G. Dalrymple, B. de Groot, M. Flannigan, G. Hartley (retired), M. Maffey (retired), J. Mason, N. Payne, A. Robinson, C. Stefner, B. Stocks, S. Taylor, M. Wotton; USFS-IFSL: J. Cohen, D. Jimenez, J. Jones, B. Schuette, K. Shannon, P. Sopko; DRWED: D. Allaire, B. Croft; R. Currie (contractor); C. Hval, F. Johnson; R. Lanoville, F. Lepine, P. Rivard; UA: M. Ackerman, M. Gunning, M. Kolla, N. Lavoie, N. Watson; ALFS: G. Dakin; Alberta Environmental Training Centre: P. St. John; University of New Brunswick: G. Strickland; USFS-NFS: B. Snodgrass; USGS: J. Harden, E. Langenburg, K. Maines, B. Neff, K. Wickland; BCFS: J. Beck, C. Duffy; UM: M. Cruz; National Institute of Technology (Gaithersburg, Maryland): J. Conny, G. Klouda: Max Planck Institute of Chemistry (Germany); J. Trentmann, T. Zorn; Universitat Politec nica de Catalunya (Spain): X. Navalon.

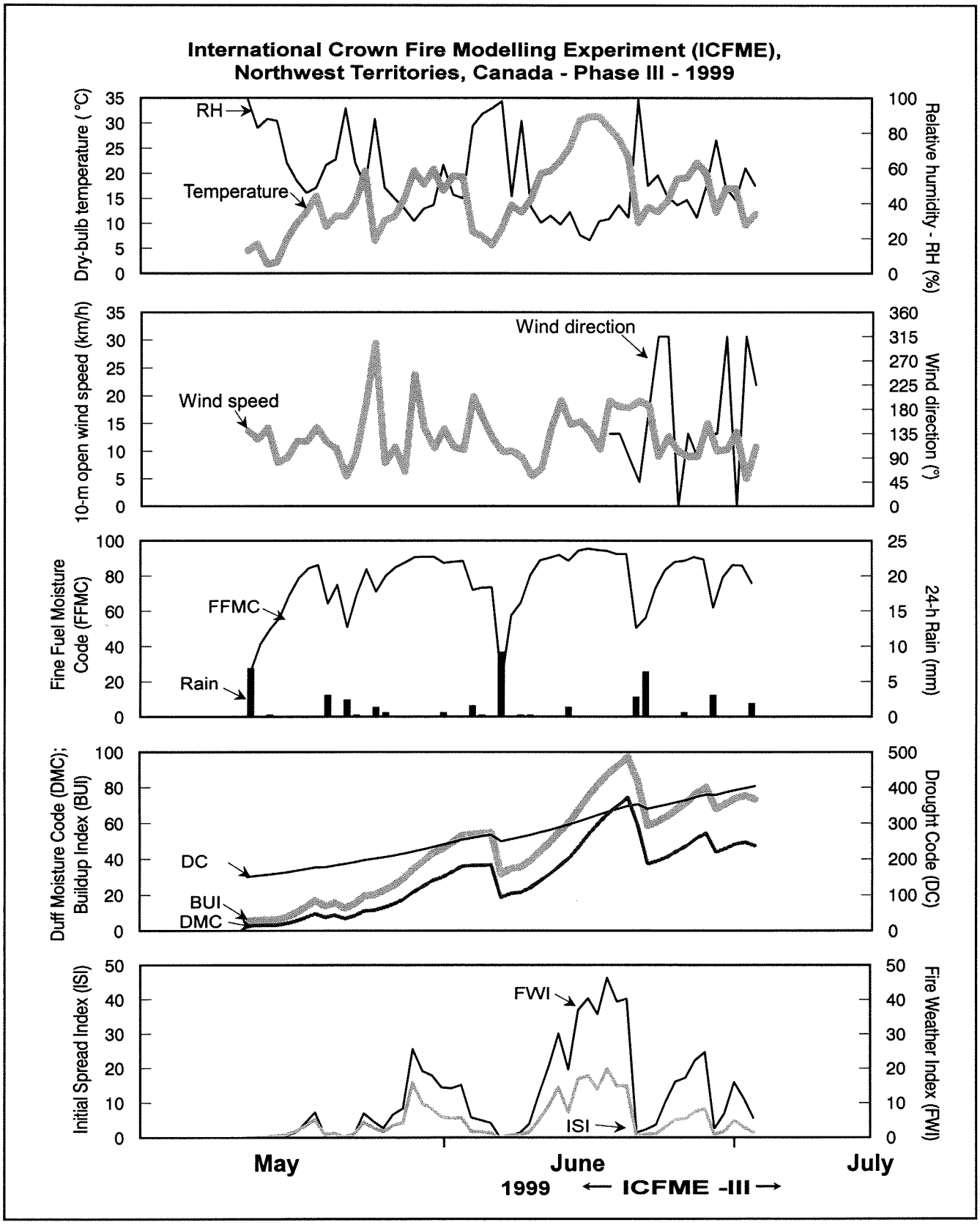
[4] The participants in the 1995 and 1996 preburn sampling phases and the first two burning phases in (I – 1997) and (II – 1998) of ICFME are listed in Alexander, Stocks, Wotton and Lanoville (1998). Abbreviations: CFS = Canadian Forest Service; USFS-IFSL = U.S. Forest Service – Intermountain Fire Sciences Laboratory; DRWED = Department of Resources, Wildlife and Economic Development; UA = University of Alberta; ALFS = Alberta Land and Forest Service; USFS-MTDC = U.S. Forest Service – Missoula Technology Development Center; USFS-NFS = U.S. Forest Service – National Forest Systems; USGS = U.S. Geological Survey; BCFS = British Columbia Forest Service.

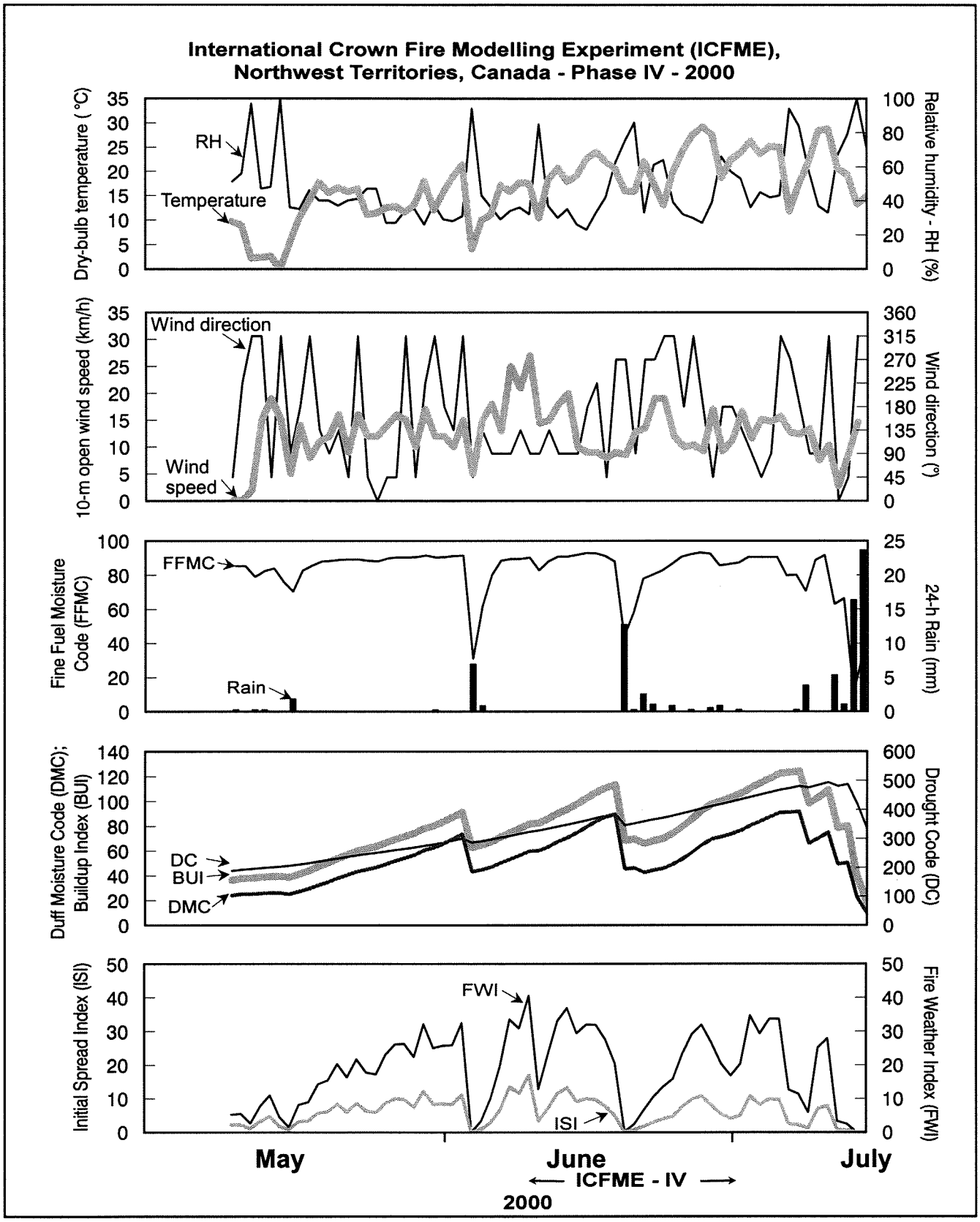
Fire Suppression Crews

The three Evergreen Forestry Ltd. fire suppression crews based at Fort Providence have provided much needed support to the ICFME, ranging from fuel treatments on selected plots to mop-up after the experimental fires to construction of the simulated houses in Plots I1 and I2. The senior crew supervisor is T. Matto. In 1999 and 2000, Crew "India" was comprised of J. Canadien, J. Matto (crew boss), W. Naldli, G. Sabourin and H. Sabourin. Crew "Juliette" consisted of W. Bonnetrouge (crew boss), A. Minoza Jr., K. Minoza, M. Nadli and Steven Nadli. Crew "Kilo" was composed of M. Canadien, X. Canadien (crew boss), L. Elleze, P. Farcy and Stewart Nadli.

ANNEX II:

DAILY TRENDS IN 1300 HOUR MDT FIRE WEATHER OBSERVATIONS PRIOR TO AND DURING THE III (1999) AND IV (2000) PHASES OF THE INTERNATIONAL CROWN FIRE MODELLING EXPERIMENT (ICFME)


International Crown Fire Modelling Experiment (ICFME),
Northwest Territories, Canada - Phase III - 1999
Dry-bulb temperature (°C)
Relative humidity - RH (%)
RH
Temperature
10-m open wind speed (km/h)
Wind direction (°)
Wind direction
Wind speed
Fine Fuel Moisture Code (FFMC)
24-h Rain (mm)
FFMC
Rain
Duff Moisture Code (DMC); Buildup Index (BUI)
Drought Code (DC)
DC
BUI
DMC
Initial Spread Index (ISI)
Fire Weather Index (FWI)
FWI
ISI
May
June
July
1999 ← ICFME -III →


International Crown Fire Modelling Experiment (ICFME),
Northwest Territories, Canada - Phase IV - 2000
Dry-bulb temperature (°C)
Relative humidity - RH (%)
RH
Temperature
10-m open wind speed (km/h)
Wind direction (°)
Wind direction
Wind speed
Fine Fuel Moisture Code (FFMC)
24-h Rain (mm)
FFMC
Rain
Duff Moisture Code (DMC); Buildup Index (BUI)
Drought Code (DC)
DC
BUI
DMC
Initial Spread Index (ISI)
Fire Weather Index (FWI)
FWI
ISI
May
June
July
ICFME - IV
2000

CITATION

Alexander, M.E.; Lanoville, R.A.; Wotton, B.M.; Stocks, B.J. 2000. Introduction to the International Crown Fire Modelling Experiment. Paper presented at the International Association of Wildland Fire sponsored 2000 International Wildland Fire Safety Summit held October 10-12, 2000 in Edmonton, Alberta.[1]

[1] The abstract of this paper was published in the CD-ROM conference proceedings. The full paper now appears with the proceedings of the 2000 Wildland Fire Safety Summit on the International Association of Wildland Fire website (http://www.iawfonline.org/proceedings.php).