BIRS/MITACS Front propagation in heterogeneous media: mathematical, numerical, and statistical issues in modelling a forest fire front
October 17-22, 2010

MEALS

*Breakfast (Buffet): 7:00–9:30 am, Sally Borden Building, Monday–Friday
*Lunch (Buffet): 11:30 am–1:30 pm, Sally Borden Building, Monday–Friday
*Dinner (Buffet): 5:30–7:30 pm, Sally Borden Building, Sunday–Thursday
Coffee Breaks: As per daily schedule, 2nd floor lounge, Corbett Hall
***Please remember to scan your meal card at the host/hostess station in the dining room for each meal.**

MEETING ROOMS

All lectures will be held in Max Bell 159 (Max Bell Building accessible by walkway on 2nd floor of Corbett Hall). LCD projector, overhead projectors and blackboards are available for presentations. Note that the meeting space designated for BIRS is the lower level of Max Bell, Rooms 155–159. Please respect that all other space has been contracted to other Banff Centre guests, including any Food and Beverage in those areas.

SCHEDULE

Sunday

16:00	Check-in begins (Front Desk - Professional Development Centre - open 24 hours)
	Lecture rooms available after 16:00 (if desired)
17:30–19:30	Buffet Dinner, Sally Borden Building
20:00	Informal gathering in 2nd floor lounge, Corbett Hall (if desired)
	Beverages and a small assortment of snacks are available on a cash honor system.

Monday

7:00–8:45	Breakfast
8:45–9:00	Introduction and Welcome by BIRS Station Manager, Max Bell 159
9:00	Mark Finney
10:00	Coffee Break, 2nd floor lounge, Corbett Hall
10:30	John Braun
11:30–13:00	Lunch
13:30–18:00	Burn Tour. Details available on Sunday 17th during the reception
18:00–19:30	Dinner

Tuesday

7:00–9:00	Breakfast
9:00	David Martell
10:00	Sylvia Esterby
10:30-11:00	Coffee Break, 2nd floor lounge, Corbett Hall
11:00	Robert Bryce
11:30	Chris Bose
12:00–13:30	Lunch
13:30	Kerry Anderson
14:00	Doug Woolford (via Video link)
15:00	Coffee Break, 2nd floor lounge, Corbett Hall
15:30	Reg Kulperger
16:00	TBA
16:30-18:00	Poster Session: 2nd Floor Lounge Corbett Hall
17:30–19:30	Dinner
19:30 –	Posters continued

Wednesday

7:00–9:00	Breakfast
9:00	Rob Deardon
9:30	Han Lengyi
10:00	Hao Yu
10:30 - 11:00	Coffee Break, 2nd floor lounge, Corbett Hall
11:00	Jonathan Lee
11:30	TBA
12:00–13:30	Lunch
13:30	Mary Ann Jenkins
14:30	Alexandre Desfosses-Foucault
15:00 - 15:30	Coffee Break, 2nd floor lounge, Corbett Hall
15:30	Thomas Hillen
16:30	Anne Bourlioux
17:30–19:30	Dinner

Thursday

7:00–8:30	Breakfast
8:30	Ed Johnson
9:30	Petro Babak
10:30-11:00	Coffee Break, 2nd floor lounge, Corbett Hall
11:00	Jonathan Martin
12:00–13:30	Lunch
13:30 - 15:00	Roundtable: A glimpse into the future: new directions for wildfire science and policy in Canada and the rôle of mathematical and statistical researchers
15:00 - 15:30	Coffee Break, 2nd floor lounge, Corbett Hall
15:30 - 17:00	Roundtable continued
17:30–19:30	Dinner

Friday

7:00–9:00	Breakfast
9:00- 12:00	Informal Discussions
Checkout by 12 noon.	

** 5-day workshops are welcome to use BIRS facilities (2nd Floor Lounge, Max Bell Meeting Rooms, Reading Room) until 3 pm on Friday, although participants are still required to checkout of the guest rooms by 12 noon. **

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ABSTRACTS
(in alphabetic order by speaker surname)

SPEAKER: **Kerry Anderson** (Canadian Forest Service, Northern Forestry Centre, Edmonton; kanderso@nrcan.gc.ca)
TITLE: *A multi-scale approach to fire growth modelling*
ABSTRACT: This research investigates the role of meteorological data and the possible methods in which such data can be used in predicting fire growth. Multiple time scales are defined to correspond with the confidence levels that can be placed on forecasted weather products. Fire growth is modelled through the various stages, changing from deterministic to probabilistic as the range of the weather forecasts increases. Predicted fire perimeters are provided as probability maps of potential fire extents as meteorological uncertainties are introduced. The short-range model predicts fire growth on an hourly scale using a deterministic, sixteen- point fire-growth model. This model is used to demonstrate an operational approach to predicting fire growth for wildland fires in Canada. The approach addresses data assimilation to provide predictions in a timely and efficient manner. Fuels and elevation grids, forecasted weather, and active fire locations are entered into a fire-growth model; then predicted fire perimeters are mapped and presented on the web. MODIS and NOAA/AVHRR satellite-based detection systems are used to detect current wildland fires (referred to as hotspots). Fuel type data from several fire management agencies is available in grid format at a resolution of 100 m or less; in areas where such data is not available, a national fuels map based on SPOT VGT land cover and forest inventory is used. Similarly, terrain data is available from a variety of sources. Current hotspots are used as ignition points while past hotspots are used to delineate area burned. Weather forecasts from Environment Canada are incorporated for surrounding weather stations using their SCRIBE matrices, which are based on model-output statistics. Surface wind, temperature, and dew-point values are then interpolated to the fire location to determine the fire behaviour conditions for fire growth modelling. The medium-range model predicts fire growth over several days. This model uses the same deterministic fire-growth engine run multiple times in an ensemble-like fashion, with each model run using a perturbed weather forecast. Observed variations of temperature, humidity, wind speed, and wind direction are applied as perturbations to hourly values within a weather time series to produce a number of possible forecasts. In turn, these are used to produce an ensemble of possible final fire perimeters. A sensitivity analysis based on the observed variations showed that wind speed accounted for a 44% difference in area burned, while temperature accounted for only a 16% difference. The long-range model predicts fire growth on a scale of weeks. The model combines the probabilities of fire spread and of survival to produce a probable fire extent map. Probability of spread is determined from exponential distributions of potential rates of spread for various fuel types and eight compass directions, based upon thirty years of fire weather data and elliptical fire growth. Probability of survival is determined from the probable evolution of the duff moisture code over the fire season predicted with Markov chains and a duff moisture code of extinction.
Validation studies were conducted to assess the skill of each of the models. Wood Buffalo National Park was chosen as the study site for its natural fire regime. The short-range model was tested on a large fire in the park, which burned nearly 200,000 ha in June 2007. Results showed the model had skill but that there were significant issues with using remotely-sensed hotspots to map the fire. For the medium-range model, case studies were conducted showing that daily fire-growth predictions using maximum-minimum value weather forecasts over- predicted fire growth based on actual hourly weather observations (hindscasted) by

27%. Systematic-perturbation model runs best compensated for this with most fire growth falling with the predicted range of the models (52 out of 63 days). The long-range model predictions were compared with distributions of fire perimeters predicted by repeated simulations using the hourly-based, deterministic fire growth model. The study was conducted in stages, starting with a homogeneous fuel type and weather from one station. Later, fuels and weather were introduced to determine their effects on the model. The study showed a close agreement between the long-range model and the deterministic model, confirming the probabilistic approach used by the long-range model.

SPEAKER: **Petro Babak** (Mathematics and Statistical Sciences, University of Alberta; petro@math.ualberta.ca)
TITLE: *A probabilistic model for forest fire spread*
ABSTRACT: The aim of this presentation is to propose a novel methodology for incorporation of various uncertainties in forest fire spread simulations. In this talk we will derive a probabilistic model for forest fire propagation. This model contains coupled parabolic differential equation with an ordinary differential equation. The parabolic differential equation describes the probability density of fire, and contains diffusion, advection and reaction components. The diffusion component corresponds to different sorts of uncertainties. The advection component represents, for example, the effects of wind and slope. And the reaction component describes the dynamics of change in the probability of fire without taking into account spatial interactions. The ordinary differential equation defines the cumulative probability of fire which is calculated as an integral of the probability density. Implementing the probabilistic model for forest fire spread allows estimation of fire propagation with any confidence level in a much more efficient way than simulation approaches for existing deterministic and stochastic models. Finally, numerical simulations of the probabilistic model for homogeneous and heterogeneous environments will be shown.
This is joint work with Thomas Hillen, Alberta.

SPEAKER: **Chris Bose,** (Mathematics and Statistics, University of Victoria; cbose@uvic.ca)
TITLE: *Tangling with Prometheus*
ABSTRACT: The Lagrangian description of fire front evolution is both simple and natural, but numerical schemes based on such models all suffer from troublesome numerical instabilities. One such problem is the appearance of non-physical tangles in the evolving front. Every version of Prometheus, based on the Lagrangian description proposed by Gwyn Richards in 1993, requires that some sort of untangler routine be applied in order to remove these numerical artifacts. Early untanglers were based on winding number calculations. We proposed a simplified untangler, based on the so-called two-colour theorem, which works much faster, but which also seems to give more realistic results for most of the tangles seen by Prometheus developers. We review the history and outline the idea behind the modified untangler.
This talk is based on a joint paper with Rob Bryce and Gerald Dueck.

SPEAKER: **Anne Bourlioux** (Mathematics and Statistics, University of Montreal; anne.bourlioux@umontreal.ca)
TITLE: *TBA*
ABSTRACT: TBA

SPEAKER: **John Braun** (Statistics and Actuarial Sciences, University of Western Ontario; braun@stats.uwo.ca)
TITLE: *Prometheus for mathematicians and statisticians*
ABSTRACT: TBA

SPEAKER: **Robert Bryce** (Heartland Software Solutions; rbryce@heartlandsoftware.ca)
TITLE: *TBA*
ABSTRACT: TBA

SPEAKER: **Robert Deardon** (Mathematics and Statistics, University of Guelph; rdeardon@uoguelph.ca)
TITLE: *Modelling the dynamics of combustions via ILMs*
ABSTRACT: Deardon et al (2010) introduced a class of model, individual-level models (ILMs), for modelling the spread of infectious disease. ILMs can also be considered as a tool for modelling the spatio-temporal dynamics of fire. Initially, we consider the simplified problem of modelling the combustion dynamics of a piece of wax paper under relatively controlled conditions. The models are fitted in a Bayesian framework using Markov chain Monte Carlo (MCMC) methods. The focus here is on choosing a model that best fits the combustion pattern.
This work is joint with Irene Vrbik, Zeny Feng, (both UoGuelph) and John Braun (UWO).

Deardon, Brooks, Grenfell, Keeling, Tildesley, Savill, Shaw & Woolhouse (2010) *Inference for individual level models of infectious diseases in large populations* in Statistica Sinica, 20(1), 239 - 261

SPEAKER: **Sylvia Esterby** (Mathematics, Statistics and Physics, UBC Okanagan; sylvia.esterby@ubc.ca)
TITLE: *Historical records of the Fire Weather Index*
ABSTRACT: The Canadian Forest Fire Danger Rating System includes the Forest Fire Weather Index (FWI) which gives a numeric rating of fire intensity. Automated electronic fire weather stations have been operating in British Columbia since the 1980s and there are now about 200 stations with records of daily fire weather for as long as 25 years. We investigate the nature of the temporal change in the FWI and spatial groups in two ways. First, we use several methods of cluster analysis to cluster stations on the basis of the FWI time series for each station. We use measures of similarity that account for the ordering of the measurements in time as well as measures which do not. In addition to using the complete record, we have investigated changes in the annual station maximum, 90% quantile, and the number of days within a fixed fire danger class. Comparisons are made with existing fire zones and some atypical years are identified.

SPEAKER: **Alexandre Desfosses Foucault** (Mathematics and Statistics, University of Montreal; foucault@DMS.UMontreal.CA)
TITLE: *A numerical scheme for the simulation of anisotropic propagation using the level-set method*
ABSTRACT: A numerical method to solve the instationary Hamilton-Jacobi PDE representing the anisotropic propagation of forest fires will be introduced. Some examples showing the convergence of the numerical scheme will be presented, along with a test case showing the method can be used with realistic data.

SPEAKER: **Mark Finney** (Rocky Mountain Research Station, Fire Sciences Lab; mfinney@fs.fed.us)
TITLE: *The growth of fire growth modelling*
ABSTRACT: Techniques used for fire growth modeling have greatly improved since the first computer applications of early 1970s. Interest in using fire growth models for a variety of practical purposes has grown along with these advances. Now, with the increasing accessibility of computing and needed spatial input data, wildland fire management agencies in the U.S. have become aware of the potential for using fire growth for strategic assessments and quantitative wildfire risk analysis. Because risk assessment requires intersection of probabilities with impacts, they entail running fire growth models many times to generate spatial probability fields of fire behavior. This talk will be an overview of the components of ongoing fire risk assessment research that has been applied to active wildland fires for decision support and for general fire risk at multiple spatial scales (project to continental). Comparisons of simulation results with observations will also be discussed.

SPEAKER: **Thomas Hillen** (Mathematics and Statistical Sciences, University of Alberta; thillen@ualberta.ca)
TITLE: *Mathematical Models for Wind Driven Fires*
ABSTRACT: TBA

SPEAKER: **Mary Ann Jenkins** (Earth and Space Sciences and Engineering, York University; maj@yorku.ca)
TITLE: *Testing the current wildfire models for simulating topographical flow and the implications for prediction of up-hill fire spread rates*
ABSTRACT: We will describe the capabilities of several fluid dynamical prognostics fire-atmosphere coupled models — the WRF-fire, UU-LES, WFDS and WindNinja — when simulating flow over the Askervein Hill.
Variable winds in complex terrain together with a high dependence of wildfire-spread rate on the slope inclination make prediction of the fire behavior in sloped terrain very difficult. The results from each model will be compared to the Askervein Hill wind observations and the results discussed in the context of the importance of accurate wind forecast in complex terrain for prediction of up-hill fire spread.
This is joint work with Adam Kochanski and Steven Krueger, University of Utah, William Mell, National Institute of Standards and Technology.

SPEAKER: **Ed Johnson** (Bioscience Institute, University of Calgary; Johnsone@ucalgary.ca)
TITLE: *Landscape scale patterns of smoldering combustion; Duff water budgets and post-fire soil erosion*
ABSTRACT: TBA

SPEAKER: **Reg Kulperger** (Statistical and Actuarial Sciences, University of Western Ontario; kulperger@uwo.ca)
TITLE: *TBA*
ABSTRACT: TBA

SPEAKER: **Jon Lee** (Statistical and Actuarial Sciences, University of Western Ontario; jlee253@uwo.ca)
TITLE: *Assessing Wildfire Risk with Burn-P3 and Prometheus*
ABSTRACT: Ignition risk and burn risk due to wildfire have been studied in a region of Ontario, Canada. Our goal is to establish a methodology which could be used across the boreal forest region of Canada. The Burn-P3 implementation of the Prometheus fire growth simulation model was used with the goal of obtaining an accurate burn probability map, in the absence of data on the actual regions burned by particular fires. This approach takes into account fuel types and weather to construct realistic fire shapes. The map of the vegetation in the region was veried and corrected, based on a eld study. Burn-P3 simulations were run under the settings recommended in the software documentation and were found to be fairly robust to errors in the fuel map, but simulated fire sizes appear to be substantially larger than what is indicated in the historic record. By using a generalized additive model to obtain ignition risk probabilities of the area and adjusting the input parameters in ways that might reect suppression effects, we conclude with a model which gives more appropriate fire sizes.

SPEAKER: **Han Lengyi** (Statistical and Actuarial Sciences, University of Western Ontario; lhan3@uwo.ca)
TITLE: *TBA*
ABSTRACT: TBA

SPEAKER: **David Martell** (Faculty of Forestry, University of Toronto; david.martell@utoronto.ca)
TITLE: *Using forest fire ignition and spread models to produce spatially explicit burn probability estimates*
ABSTRACT: Burn probability maps that indicate the probability that specific forest stands will burn during designated future time intervals can be used to help evaluate fuel management strategies (e.g., when and where to establish fuel breaks and other fuel treatments) and how best to schedule harvesting activities (e.g., when and where to establish roads and cut blocks). We describe how we coupled climatological and historical forest fire ignition data with a contagion fire spread model to predict burn probabilities for an area in northeastern Ontario. Our primary objective is to stimulate discussion of best practices for using such data and fire ignition and spread models to produce reliable burn probability predictions.

This is joint work with Thomas Jones and Neil Isaac, University of Toronto.

SPEAKER: **Jonathan Martin** (Mathematics and Statistical Sciences, University of Alberta; jmartin@math.ualberta.ca)
TITLE: *TBA*
ABSTRACT: TBA

SPEAKER: **Douglas Woolford** (Mathematics and Statistics, Wilfrid Laurier; dwoolford@wlu.ca)
TITLE: *Testing for Possible Climate Change-Caused Shifts in Forest Fire Ignitions*
ABSTRACT: We propose a mixture model framework to investigate climate change signals in historical records on forest fire ignitions for Ontario, Canada. A three component mixture of logistic generalized additive models is employed, with components reflecting the zero-heavy, seasonal and extreme nature present in the data. Models with fixed and non-linear mixing weights are compared. The modelling framework, a discussion of model selection, and a test statistic for increasing extremes in ignitions are presented. Seasonal and annual changes in ignition risk are observed and discussed. Potential confounding factors are noted and examined.
This is joint work with Charmaine Dean and Jiguo Cao, SFU and David Martell, University of Toronto.

SPEAKER: **Hao Yu** (Statistical and Actuarial Sciences, University of Western Ontario; hyu@fisher.stats.uwo.ca)
TITLE: *TBA*
ABSTRACT: TBA