"Connecting diverse wildland fire, emissions, air quality and modelling communities."

Welcome to the first edition of the new and improved Canadian Wildland Fire and Smoke Newsletter! We have undergone some exciting changes with a new name, home and editor. As the new name implies, the scope of the newsletter has expanded from smoke related issues to include a suite of wildland fire topics. Mike Flannigan, Professor of Wildland Fire at the University of Alberta and Director of the Western Partnership for Wildland Fire Science, is stepping in as the new editor. Al Pankratz will stay on board to help us out during the transition and will continue to submit quality articles. Al and Mike have each contributed a letter talking about the new and exciting changes (Page 2).

The expansion of the newsletter's scope is quite timely given the early and intense wildfire season we have experienced this spring in western Canada. Al Pankratz nailed it with his opening letter in the 2015 edition of Canadian Smoke Newsletter. Al wrote:

> *"According to NOAA, there is a greater 90% chance that current El Niño conditions in the Pacific will continue through the 2015-16 Northern Hemisphere winter, and around an 80% chance it will last through early spring 2016. If that forecast succeeds, the potential is there for another round of significant fire and smoke at the start of the next fire season."*

The 2016 wildfires to date have already resulted in over one hundred thousand people, an unprecedented number, being forced to flee their homes and places of work due to risks from fire and smoke. Wildfire management personnel, air quality forecasters, first responders, utility companies, local industry, as well as countless municipal, provincial and federal employees have also placed their lives on hold and put in extra hours to respond to these incidents, mitigate further risks, and plan and coordinate the re-entry and recovery of the affected communities and work places. Hundreds of international firefighters and incident management team members have also come to assist when called upon. In addition to the areas evacuated, many other communities experienced days with heavy smoke and poor air quality. While these incidents are a stark reminder of the negative impacts wildfires can have, it is important to remember that wildfires are a natural and necessary part of many ecosystems.

We are looking forward to providing you with interesting articles about the fascinating topics of smoke and wildfire. These articles come from you, our readers. While we may have "Canadian" in our name, we are interested in articles from around the globe. If you would like to submit an article, please go to our website for more information.

Karen Blouin
Assistant Director, Western Partnership for Wildland Fire Science

Disclaimer: This informal newsletter is produced on behalf of the wildland fire and smoke communities. Articles from government, industry and academia, whether Canadian or international, are welcome. Please visit our website or send an email to cwfsn@ualberta.com for author guidelines. Views and comments in these articles are those of the authors or the organizations they represent, and do not necessarily reflect the views of the Canadian Wildland Fire and Smoke Newsletter.

In this issue:

“Connecting diverse wildland fire, emissions, air quality and modelling communities.”

Letters From the Editors

by Al Pankratz[1] and Mike Flannigan[2]

[1] Environment and Climate Change Canada, Edmonton, Alberta

[2] Western Partnership for Wildland Fire Science, University of Alberta, Edmonton, Alberta

It’s not every day that you get a chance to co-write an editorial with someone, but this is one such time. The reason? The Canadian Smoke Newsletter is expanding and coming under new editorship. To reflect its new areas of coverage, we have chosen to call it the Canadian Wildland Fire and Smoke Newsletter. While not exactly short and snappy, the name nevertheless communicates an expanded interest in wildland fire, which is becoming more and more prominent in an era of climate change. It is the goal of the newsletter to serve both the fire and smoke communities and to allow us to keep an eye on changes in fire regimes and their impacts in Canada and around the world. In addition to smoke-related articles, we hope to add articles on fire growth, fire weather, fuels, historical trends, social issues related to fire and smoke, health and fire prevention, to name a few.

The person who will helm the new and improved newsletter should be familiar to people acquainted with fire research in Canada. He is Mike Flannigan, currently the head of the Western Partnership for Wildland Fire Science, headquartered at the University of Alberta (U of A). Mike has a wealth of experience in environment and fire science, having worked as a meteorologist for Environment Canada and then as a fire scientist for the Canadian Forest Service with Natural Resources Canada. Mike has been a professor with the Department of Renewable Resources at the U of A since 2012 and was editor-in-chief of the International Journal of Wildland Fire from 2002-2008. He has authored or co-authored many papers on climate change, lightning-ignited forest fires, landscape fire modelling and interactions between vegetation, fire and weather. He has taken on leadership roles with the US National Assessment on Global Change, IPCC, IGBP Fire Fast Track Initiative and Global Change Terrestrial Ecosystems (GCTE) efforts on the global impacts of fire. He and his team at the U of A are perfectly placed to take the Canadian Wildland Fire and Smoke Newsletter to the next level, and to position it as a prime communications tool for anyone concerned with wildland fire and smoke.

I will continue to be involved with the newsletter over the next several issues and I am extremely pleased to pass the editorship to someone of Mike’s qualifications and stature.

Best regards,
Al Pankratz

I want to thank Al Pankratz for the yeoman’s service he has provided in establishing the original Smoke Newsletter. Thanks also go to the Lung Association of Saskatchewan and in particular Brian Graham for hosting the Canadian Smoke Newsletter for the past eight years. The success of the Newsletter depends on contributors who send in timely and interesting articles. If you have an idea for an article on wildland fire and/or smoke do contact us at cwfsn@ualberta.ca. I will be relying heavily on Al for his guidance as well as Karen Blouin (Assistant Director of the Western Partnership for Wildland Fire Science) and Wankui Zhou for getting the Newsletter out. We plan to have two issues a year to start, with the first issue in May/June and the second issue in November/December. The Newsletter has a new home on the internet, and the current and back issues of the Newsletter can be found at https://www.ualberta.ca/~wcwfs/CWFSN/.

Cheers,
Mike Flannigan

"Connecting diverse wildland fire, emissions, air quality and modelling communities."

Living with fire: Prevention helps, but large wildfires are inevitable

by Mike Flannigan[1] and Mike Wotton[2]

[1] *Western Partnership for Wildland Fire Science, University of Alberta, Edmonton, Alberta*

[2] *Canadian Forest Service, Natural Resources Canada, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario*

Living with fire

The fire in Fort McMurray is over half a million hectares and growing—larger than Prince Edward Island. The organized return of people to the city has begun. As is human nature, many questions continue to be asked to make sense of it all: How did this happen? Could it have been prevented? Why can't this fire be put out? Is this climate change? All are reasonable questions. The most deserving of broader public discourse, however, is: What do we do next? Or, as we who study fire phrase it: How do we live in a fire-prone environment?

Fire happens in Canada's boreal forest. Every year, thousands of small fires and dozens of large ones occur somewhere in Canada's vast forest landscape. It has been the story for centuries and will continue. This is not in itself a problem. Now more than ever people work, build, live and play in the boreal forest; nowhere is this more clearly evident than in Alberta. This in itself is not a problem either. But disaster can occur when people and fire intersect—like in Fort McMurray (Figures 1 and 2). These are problems we must avoid.

There are three ingredients for a fire to occur:

- Fuel (the vegetation that burns)
- Ignition (Sources can be human, either accidental or arson, or from lightning)
- Weather (hot, dry, windy weather is what makes fires grow and also really hard to put out)

How can we alter this recipe for fire?

We have no control over the weather. Hot, dry, windy days happen, sometimes repeatedly, as we have seen over the last several weeks in Fort McMurray.

Figure 1. Aerial view of Fort McMurray on May 27, 2016. Photo taken by Brian Wiens, NRCan.

Figure 2. When people and fire intersect, disaster can occur. Aftermath of the Fort McMurray wildfire. Photo taken May 27, 2016 by Brian Wiens, NRCan.

We have no control over lightning. Fire management agencies do a good job of prevention and education with fire bans and restrictions to limit human-caused ignition. But fires from human activity still occur each year, and what's worse, they tend to occur in the forests and grasslands around communities—where people are. Should we have more fire bans, forest closures, or spend more public money on prevention? This is something for public debate, pitting the restriction of personal freedoms against the reduction in fire risk; there are no easy answers that satisfy all.

This leaves us with fuel. Many provinces have fuel management or FireSmart programs; Alberta has allocated over $20 million for fuel treatment. The idea behind such programs is simple: reduce the amount of fuel, particularly highly flammable conifers. Black spruce was viewed as public enemy number one after the devastating Slave Lake fire in 2011; the problem is, lots of people really like coniferous trees. Fuel management, if carried out over large areas and actively maintained, can reduce the risk of a high-intensity fire close to a community. Can it eliminate the risk? No. But it can change a fire's intensity (the size of its flames) and give fire managers a greater chance of success.

Herein lies one of the misperceptions of wildfire and suppression. We have developed amazing tools and techniques for fighting fire, from hand tools to aircraft dropping thousands of gallons of water or specially designed retardant, and amazing science-based technology to monitor and predict fire growth. These tools and technology are one important reason so many fires (more than 90% of them) stay small and out of the news. But when the weather gets hot, dry and windy, even the biggest and most powerful of tools have little influence on where a fire wants to go and what its wants to burn. During these periods of extreme fire intensity, direct management options become extremely limited—until the weather changes.

Asking if this fire was caused by climate change is the wrong question. We know the things that influence fire, including weather and climate. Day-to-day operational fire management relies on this knowledge and has for decades. We know that, as the climate changes over the next century, fuels will be drier and weather will be more conducive to fire ignition and spread. Was this fire the result of climate change? It doesn't matter. Alberta's, and Canada's, future environment will be shaped by climate change. The important question is, how do we continue to live with fire?

- A version of this article was published in the Opinion section of the Edmonton Journal on May 31, 2016.

Hot spots and regrowth in Fort McMurray on May 27, 2016. Photo by Brian Wiens, NRCan.

"Connecting diverse wildland fire, emissions, air quality and modelling communities."

The Edmonton PM10 event – July 16, 2014

by Blair Morrow, Brian Luzny and Al Pankratz

Environment and Climate Change Canada, Edmonton, Alberta

Introduction

The Edmonton Prairie and Arctic Storm Prediction Centre (PASPC) of Environment and Climate Change Canada (ECCC) has been responsible for forecasting the Air Quality Health Index (AQHI) for Alberta and the Northwest Territories since 2009. The AQHI is based on a formula which uses 3-hour running averages of three pollutants: O_3 (ozone), NO_2 (nitrogen dioxide) and $PM_{2.5}$ (particulate matter with a diameter less than 2.5 microns) or PM_{10} (particulate matter with a diameter less than 10 microns). The number generated by the formula is presented on a sliding scale of health risk ranging from 1 (low health risk) to 10+ (very high health risk). Historically, wildfire smoke has been responsible for some of the worst AQHI values recorded, and so widespread wildfire smoke plumes in BC and Alberta in mid-July of 2014 were being closely monitored by PASPC meteorologists. The plumes nevertheless managed to create some difficult conditions for forecasters as well as the public.

The episode

Smoke began rolling into the city of Edmonton on the morning of July 16, 2014. Forecasters were monitoring the observed PM2.5 and AQHI values using the local Air Quality Monitoring (AQM) network. By early afternoon the observations began to show some puzzling features. AQHI values were in the 3 to 5 or moderate health risk range but visibilities were dropping to two statute miles or less. Complaints were made by the Edmonton public to Environment Canada's National Inquiry Response Team (NIRT) asking why forecast and observed AQHI values on Environment Canada's Weatheroffice website were only in the moderate range health risk range while at the same time dense smoke appeared to have inundated the city.

Forecasters decided to amend the AQHI forecast for Edmonton to 7 (high health risk) near 12:00 noon LST even though many of observed AQHI values continued to be only in the moderate health risk range. At 4:24 pm LST, after consultation with Alberta Health and Alberta Environment and Parks about poor visibility and poor air quality, a Special Air Quality Statement was issued.

PM_{10} observations vs. $PM_{2.5}$ observations

After the event, forecasters felt this wildfire event was unique and interesting, so an analysis of observed data was done. The Edmonton South AQM site observes both PM10 values as well as PM2.5 hourly values, enabling a comparison of those two measurements (see Figure 1 below).

It is clear from Figure 1 that hourly PM_{10} spiked much higher than $PM_{2.5}$ during the onset of smoke, especially during the early morning hours of July 16, with values exceeding 100 µg/m³ (the 1700 LST observation for $PM_{2.5}$ was missing). Note that because PM_{10} is made up of particles less than 10 microns in size, it also includes those

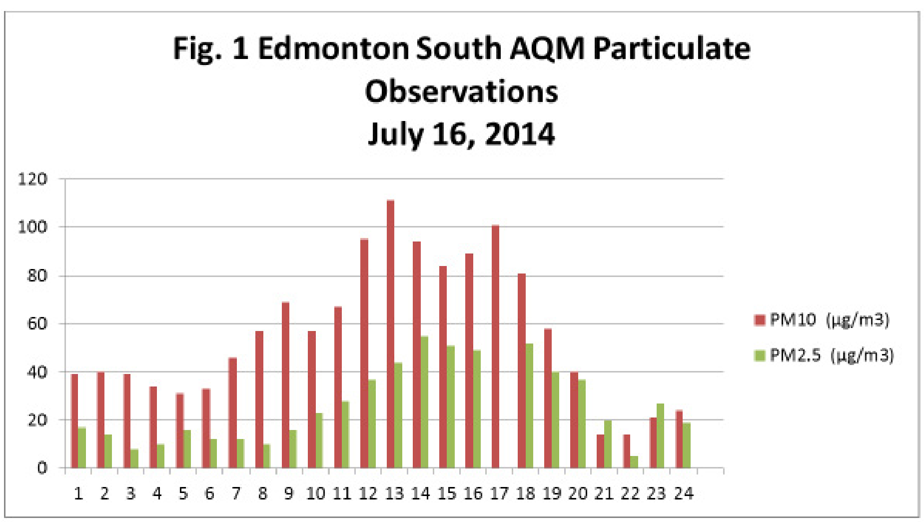

Figure 1. PM_{10} and $PM_{2.5}$ observations versus local time (LST) , July 16, 2014.

particles less than 2.5 microns in size ($PM_{2.5}$). In a few observations, $PM_{2.5}$ appears to be greater than PM_{10}. This is likely due to different methods of drying PM in the instruments prior to measurement. From Figure 1 the $PM_{2.5}$ appears to make up only about 50 percent or less of the PM_{10} concentrations prior to 1300 LST. Weather observations for July 16 indicate that the winds were light and no blowing dust was reported which allowed forecasters to rule out wind-borne dust as a contributor to PM_{10} values.

In order to satisfy our curiosity, we investigated another significant smoke event that occurred on August 19, 2010 in Edmonton to see if PM_{10} dominated the initial stages of that event as well. A comparison of PM_{10} and $PM_{2.5}$ observations for August 19th at the Edmonton South AQM site is shown in Figure 2. In this case, the overall concentration levels were much higher but with the exception of one hour (1200 LST) the observed PM_{10} was made up mostly of $PM_{2.5}$ particles.

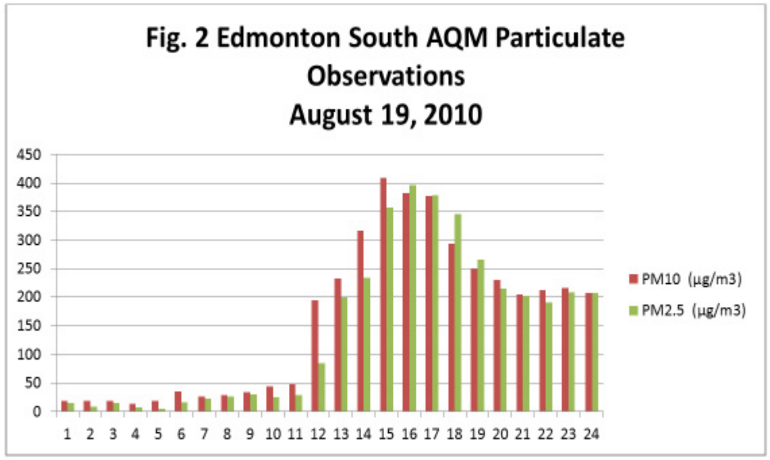

Figure 2. PM_{10} and $PM_{2.5}$ observations versus LST, August 19, 2010.

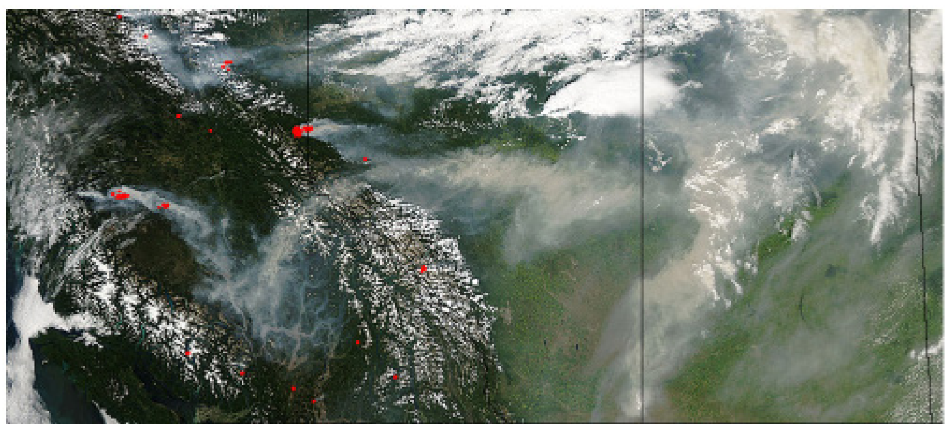

Figure 3. Wildfires and smoke in Western Canada on July 16, 2014. (Image courtesy of U.S. Smog Blog Archives: http://cimss.ssec.wisc.edu/goes/blog/archives/8711)

Wildfire situation and meteorological pattern

The summer of 2014 saw periods of significant wildfire activity. The MODIS imagery for July 16, 2014 is shown in Figure 3 and indicates a west-to east plume over central Alberta. This plume appears to originate from fires in British Columbia as well as the Grande Cache region in Alberta. This is confirmed by HYSPLIT modelled backward trajectories from Edmonton for July 16, 2014 (see Figure 4), which pass over the apparent source hotspots

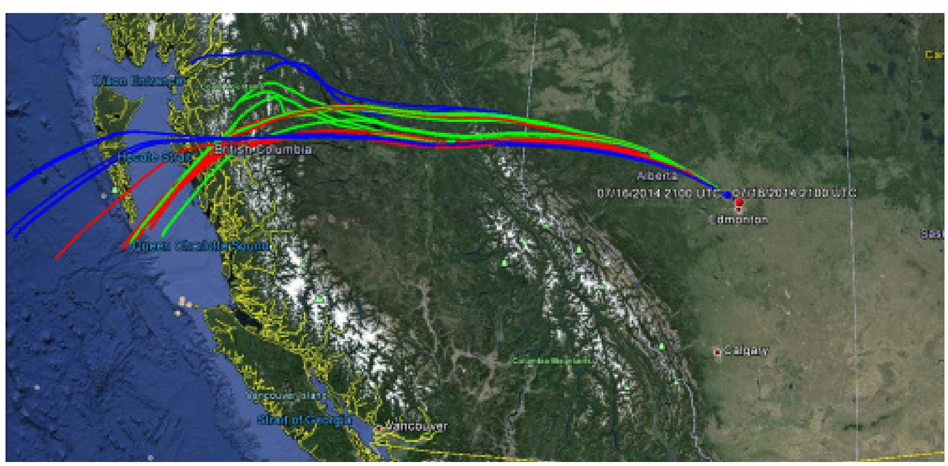

Figure 4. Backward HYSPLIT trajectory ensemble for air parcels terminating in Edmonton on 2100 UTC (3 pm LST), July 16, 2014.

Canadian Wildland Fire & Smoke Newsletter
Spring 2016
"Connecting diverse wildland fire, emissions, air quality and modelling communities."

north of the Alberta "elbow" (a kink in the province's western border).

The meteorological conditions occurring in the Edmonton area can be illustrated by the progression of two vertical Aircraft Meteorological Data Relay (AMDAR) temperature and wind profiles taken by aircraft landing or taking off from Edmonton International Airport. Shortly before noon LST, the sounding shows a westerly flow aloft (wind barbs at right, Figure 5). A strong surface inversion exists up to about 4000' above sea level (ASL) with a well-mixed, unstable layer above that. On that day, Edmonton experienced above normal temperatures with afternoon highs reaching 28 °C. Figure 6 shows that as the near ground temperatures increase, the vertical profile becomes more unstable near the surface, with a weak stable layer forming about 6000 ft ASL. Surface observations at Edmonton International Airport showed generally light winds during the morning increasing slightly during the afternoon and peaking at 20 gusting 31 km/h in the early evening. Thundershowers early the next morning appear to have completely dispersed the smoke.

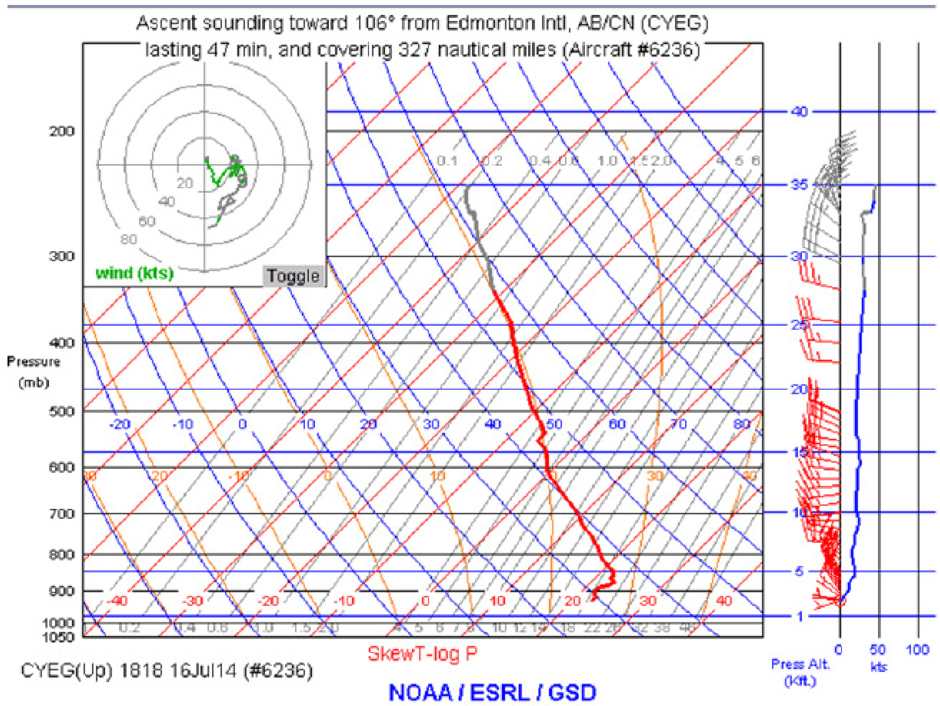

Figure 5. AMDAR profile for 11:18 AM LST, July 16, 2014.

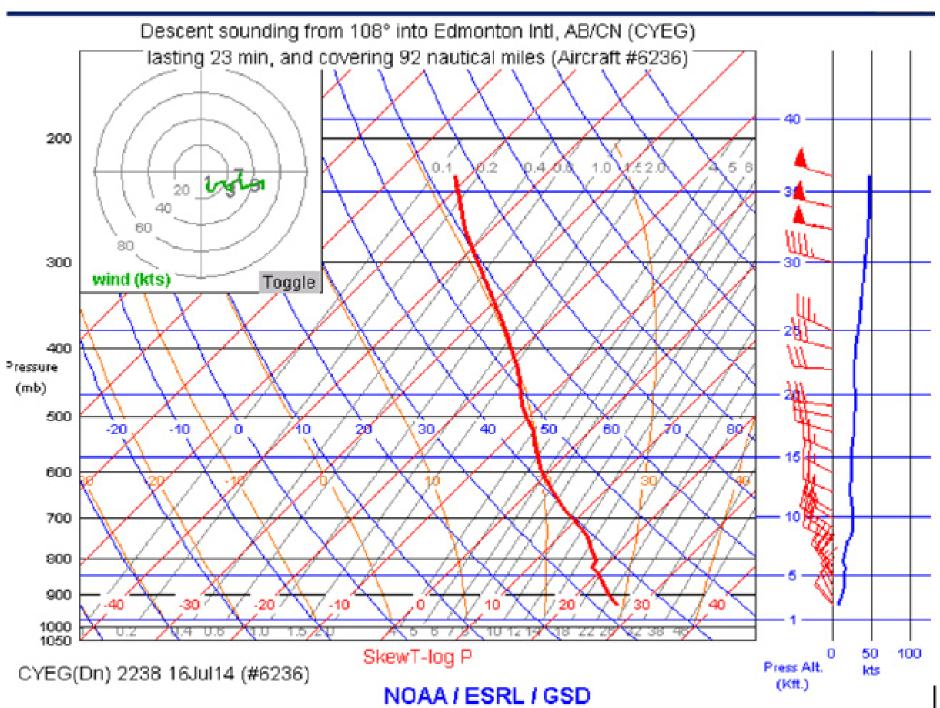

Figure 6. AMDAR profile for 3:38 PM LST, July 16, 2014.

Discussion

Forecasting the AQHI during the wildfire season has taught forecasters to look for two main conditions when dealing with long range transport of smoke:

- rapid transport of a concentrated plume aloft, and
- a mechanism such as a cold front or mixing due to daytime heating

to bring the smoke plume down to the ground.

In general, significant buoyancy is needed to lift parcels of air into the free atmosphere above the boundary layer. This requirement is easily met by larger fires, as occurred in this case. Once aloft, both coarse and fine particles from the various smoke plumes were rapidly transported eastward into the Edmonton area early in the day on July 16th. The question remains as to what caused the early predominance of PM_{10} particles. Did it have to do with the fuel source characteristics - in other words, the type of fuel that burned first? Did fire-induced winds whip up particles from the ground? Did the temperatures in the fire during the initial phase of the burn favour incomplete combustion and larger particles? Did settling times of variously sized particles have anything to do with it? This latter idea seems unlikely, given the short time available for settling to sort the sizes to any noticeable degree. Compounding the uncertainty, there were also unofficial reports of ash falling over parts of Edmonton indicating the presence of even larger particulates. In any case, the spike in concentrations in the afternoon and the associated drop in visibility almost certainly occurred as smoke particles became incorporated into boundary layer convective mixing and were transported down to the ground.

For forecasters, a significant aspect of this discussion has to do with public reaction to the event and whether the forecasting of it may have been hampered by the emphasis on $PM_{2.5}$ and the $PM_{2.5}$-based AQHI formula. $PM_{2.5}$ has been shown to have a more significant effect on the respiratory system than PM_{10} but coarse particulates can still pose a health problem [Lin, et. al. 2002]. Edmonton residents were monitoring forecast and observed AQHI values and comparing it with what they saw outside. They felt that they were not being provided the health risk information that they required and lodged complaints.

As mentioned before, a PM_{10} version of the AQHI formula exists, and as a result of this incident, procedures have been updated to encourage forecasters to monitor both $PM_{2.5}$ and PM_{10} values, and to apply discretion as to which to emphasize. Interestingly, the province of British Columbia is considering the issuance of a Smoky Sky Advisory in situations where $PM_{2.5}$ is present but does not exceed threshold criteria.

Summary

July 16, 2014 may have been an unusual event but more data analysis of past smoke events in Alberta is needed to determine just how unusual PM_{10}-dominant wildfire smoke events are. When a PM_{10} wildfire smoke event does occur, standard operating procedures should be in place for forecasters and local health authorities to properly communicate appropriate health information to the public.

References

Lin M, Chen Y, Burnett RT, Villeneuve PJ, Krewski D. The influence of ambient coarse particulate matter on asthma hospitalization in children: case-crossover and time-series analyses. *Environmental Health Perspectives*. 2002; 110 (6): 575-581.

"Connecting diverse wildland fire, emissions, air quality and modelling communities."

Ventilation forecasting

by Al Pankratz

Environment and Climate Change Canada, Edmonton, Alberta

Ventilation is a term used to describe the ability of the atmosphere to disperse pollutants. For example, smoke from a burning pile of wood (see Figure 1) or a field of crop residue may collect near the ground on a day with poor ventilation or may be lofted and disperse with no impact at the surface on a day with good ventilation.

Why a ventilation index?

Many agencies use ventilation indices (VIs) to regulate when crop or pile burning takes place or to advise the public to voluntarily modify behavior, in an attempt to prevent adverse effects on populated centers and transportation. Several instances of such effects have occurred in recent years when smoke from pile or crop burning has moved into populated areas and triggered respiratory problems among the public, or where a dense layer of smoke has covered a highway, reducing visibilities to near zero and causing serious accidents or deaths [http://globalnews.ca/news/1709862/poor-visibility-leads-to-17-vehicle-crash-west-of-edmonton/, accessed 23 March 2016].

The extent to which VIs are used vary considerably from province to province. British Columbia (or BC) for example, enforces the Open Burning Smoke Control Regulation (OBSCR). The regulation permits burning to take place if the VI for the current afternoon is "GOOD" and for the following afternoon is "GOOD" or "FAIR". The VI in question is supplied to BC by Environment Canada. Meanwhile, next door in Alberta there is no requirement to incorporate information from a VI into decisions to burn piles. Rather, anyone planning to light a fire (other than a campfire) in a Forest Protection Area must contact their local Agriculture and Forestry office for a burn permit. Environment Canada does issue an automated VI for several major cities in the Prairies and the North, but nothing for rural areas.

Figure 1. Burning piles of woody debris near Smithers, BC. Photo courtesy of Ben Weinstein, BC Ministry of the Environment.

Types of Ventilation Indices

There are many ways of calculating ventilation indices. In this article we will mention three general types.

1. The VI in widest use is described in fairly general terms in a paper by Tennekes [1974] . It has a simple formulation:

$$VI = \text{wind speed} \times \text{mixing height} \quad (1)$$

The assumption behind this formula is that the boundary layer (the layer within which surface features of the earth influence the atmosphere) consists of air that is fully mixed by various processes such as convection and turbulence, so that emissions into the layer will be quickly diffused throughout its depth (see Figure 2).

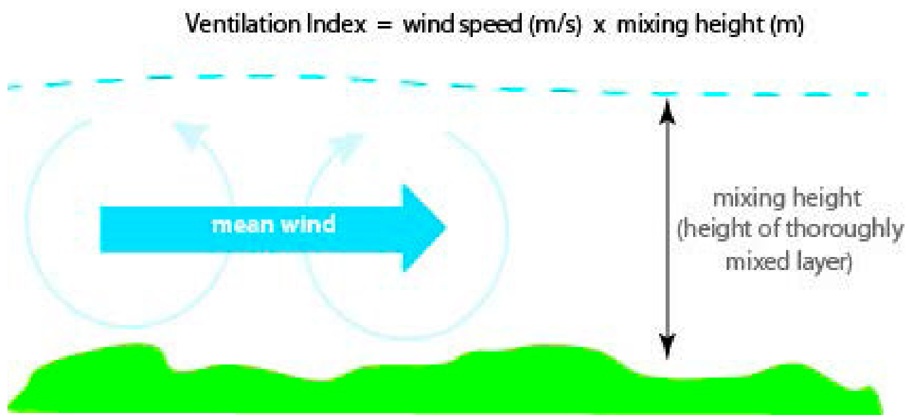

Figure 2. Conceptual diagram of a common method of calculating ventilation.

The mixing height term has been determined in different ways over the years, for example:

- by assessing stability based on a vertical temperature sounding, or
- by determining at what height the Richardson number or turbulent kinetic energy (TKE) values cross various thresholds [Fearon 2015].

The wind speed term can take a number of forms depending on the agency calculating it. It may be an average of the wind speeds across the entire mixing layer, it may be the mean surface wind speed (measured or forecast at 2 meters or 10 meters above ground) or it may be the mean wind speed near the top of the mixing layer.

2. Another way of calculating a VI is to simulate a smoke plume in a pre-defined volume of air. This is the method used by the Atmospheric Dispersion Index or ADI. The Gaussian plume is given a normal distribution of pollutant concentration, the smoke is released at the rear edge of a rectangular control volume and the concentration assessed at the downwind face. Then, an equal weighting of an atmospheric ventilation factor (similar to the VI discussed above) and a processed value derived from the downwind concentration yields the dispersion index value.

3. A third way is the experimental Brunt-Väisälä Ventilation Index (BVVI) which calculates the Brunt-Väisälä frequency in the lowest 500 meters and multiplies it by the wind speed at 20 m above ground. The Brunt-Väisälä frequency is the frequency at which a displaced parcel of air will oscillate in a statically stable atmosphere. This method may therefore not be valid in statically neutral or unstable environments.

There are a number of other methods designed to support specific smoke dispersion issues (such as smoke accumulation from wood fires used to heat homes). Whatever the method used, the numbers that result from the calculation of the chosen VI are typically separated into categories for purposes of regulation. Those separations are termed breakpoints. For example, the VI used in the 2001 Smoke Management Guide published by the US National Wildfire Coordination Group has five categories defined as follows:

Poor:	VI < 2350 m^2/s
Marginal:	VI between 2350-4699 m^2/s
Fair:	VI between 4700-7049 m^2/s
Good:	VI between 7050-24999 m^2/s
Very High:	VI >= 25000 m^2/s

whereas the VI used in BC has tweaked the equation to yield numbers that range between 9 and 100 as follows:

Poor:	VI between 9-32
Fair:	VI between 33-54
Good:	VI between 55-100

Issues with VIs

There are a number of problems with ventilation indices.

1. One of the issues that should be obvious by now is the lack of consistency between agencies and regions. For example, even if Agency A uses the same general formula as Agency B (e.g., Equation 1), they may decide that the wind speed is to be assessed at the 10 m level above ground, whereas Agency B may decide that the wind speed should be the average speed across the entire mixing layer. Because windspeeds almost always increase with height, that choice will result in a significant difference in the final VI number. Some of the different

choices that agencies make in how to calculate the VI reflect local or regional meteorology and user needs. For this reason, the VI may not be appropriate for use in a different region or for a different need.

2. Ventilation indices are a simplification of a complex process and as a result may run into problems when they are not adequately representing what is really going on. At present, some level of human intervention is still needed to overrule the VI number when appropriate.

3. The VI forecast does not take into account the actions of individuals and groups who light the fires. It may be that one group lights their fire at the bottom of a mountain valley, while another lights theirs a few kilometers away on a plateau which is 3000 feet higher. One group may light a small fire composed of stubble, while the other is lighting over one hundred separate piles (Figure 3) composed of remnants from logging operations, each of which may have hundreds of kilograms of fuel mixed with soil and other debris. One fire may be out in 1-2 hours, while the other fire burns for several hours and then smoulders for days. All of these choices affect what the smoke will do, but are not taken into account by current VIs.

4. The underlying assumption that emissions will be dispersed throughout the entire volume of the originally calculated mixing layer fails once the layer changes significantly. This can occur when the height of a mixing layer is based on convective mixing in a thermally unstable atmosphere (as assessed from a morning sounding), but the expected sunny skies change to conditions where the ground is shaded by cloud or smoke. In this case, eddies generated by mechanical turbulence may become the dominant process (rather than buoyancy), and over a different range of heights than originally expected.

   Another problematic change occurs when the sun sets and the relatively deep mixing layer of the afternoon is replaced by an inversion close to the ground as heat from the earth's surface radiates into space and the ground cools the air in contact with it. If the formulation of the mixing height does not take this into account, or incorrectly times it, the VI calculation will be wrong.

5. Smoke dispersion from small scale fires is subject to mesoscale atmospheric processes (scales on the order of kilometers or 10s of kilometers) occurring at or near the ground. Current operational weather models operate in the neighbourhood of resolutions like these, but nevertheless experience the most difficulty in the complex boundary layer where the atmosphere and surface of the earth interact. In the years ahead more and more small scale circulations will be explicitly modelled, but for the time being, things like katabatic flows (cool air spilling down hills and through valleys, usually at night) can create dense rivers of smoke from smouldering piles which can trip up a simple ventilation forecast based on a coarse resolution model.

Figure 3. Multiple piles burning near Burns Lake, BC. Photo courtesy of Ben Weinstein, BC Ministry of the Environment.

6. As mentioned earlier, the output from VI calculations is continuous, but decisions are made based on categories such as "Poor", "Fair" and "Good". This raises the question of what numbers are used for the breakpoints which separate the categories. If health criteria are used, then it may be reasonable to choose breakpoints that take into account the criteria laid out in the Canadian Ambient Air Quality Standards. On the other hand, visibility in smoke is also a safety issue. What density of particulate matter (PM) corresponds to dangerous visibility on a highway, for example? Should that value be defined as poor? Or should a hybrid health/visibility value be used? And once the categories have been agreed upon, can the ventilation forecasts accurately and consistently discriminate one category from another? So far, results have not been encouraging.

7. In any attempt to establish a firm scientific foundation for a ventilation forecast, it would appear obvious that one needs to compare a forecast VI with actual smoke dispersion to see if it was close to the mark. A major drawback in ventilation forecasting is that systematic dispersion observations over multiple regions and across multiple seasons do not exist, so for the simpler VIs, we struggle to find values to verify them against. Some studies have verified the components of a VI (e.g. wind, mixing height), but this is not the same as verifying how well a plume actually dispersed.

One way to sum up the problems facing VI prediction is to say that modellers are faced with a situation where the phenomena we are attempting to predict are small scale in nature, where the inputs are controlled by individuals or groups and where there are no datasets to verify good dispersion. A challenging task indeed.

Potential Solutions

There are a number of approaches we can take to address the problems listed in the previous section.

1. Use dispersion models (which release virtual particles from a predefined location into a simulated atmosphere) rather than simple VIs. This would provide a somewhat firmer scientific grounding because of studies which have confirmed the reliability of dispersion models.

2. Use a range of inputs. If the nature of the fuel being burned nor the mass nor the number of piles are known, we can attempt to cope by:

   a) simply ignoring the fuel inputs and plume heights (as we do with the current ventilation indices), or

   b) carrying out particle dispersion runs using the same value for fuel mass and plume height everywhere, or by

   c) carrying out individual particle dispersion runs for each of many possible inputs. Those inputs would represent the most common categories of fuel mass, fuel type and plume heights.

3. The outputs from 2.a) and 2.b) would be single, deterministic forecasts. However, c) would allow us to create an ensemble which would contain the entire range of reasonable inputs, and hopefully produce a realistic range of forecast outcomes. Such an ensemble would allow the risk of fumigating an area to be quantified in a probabilistic way, and users could burn or not burn based on the amount of risk they were willing or allowed to assume.

Practical concerns

As mentioned previously, the province of British Columbia regulates debris burning in a significant way. Other provinces take a more hands-off approach, typically requiring people who want to burn to consult with a local forestry agency if they wish to do so during the wildfire season in the portions of the province designated as forestry zones. In some cases this leads to people waiting until the official end of the fire season before lighting their fires, so as to avoid bureaucracy. Whatever the time of year, regulations also typically require that people burning debris do so with due care and attention, that they take into account the effects of the smoke and that they have enough resources on hand to put out the fire. In other words, they could still be held liable in the event of damage or injury resulting from the smoke they generate. Despite these stipulations, burns taking place during fall, winter and spring still create problems from time to time due to the increasing ability of the air to trap smoke beneath inversions during those

Figure 4. Smoke aloft over Summerland, BC. This image highlights one of the challenges of ventilation forecasting - getting the height of the plume right. If the plume were contacting the ground, it would be a problem. Aloft, it presents few significant issues. Photo courtesy BC Ministry of the Environment.

seasons. This implies that a ventilation product would need to be available throughout the year.

Another requirement for a ventilation product would be ease of use. Any system that requires users to work through a series of complicated steps (such as running an online plume model themselves) is almost certainly doomed to failure. In the US Northwest, some states have officials who process requests to burn crop residue (these requests can be made online), and approve or deny the requests as the situation warrants. Conceivably, those employees could be trained to a level which would allow them to use more sophisticated tools to assess user requests.

Summary

Dispersion of smoke from large fires that are lit by individuals and groups have the potential to adversely affect members of the public (Figure 4) and to degrade our natural resources should they get out of control. A number of tools that assess the atmosphere's ability to disperse smoke have been developed over the years, as it is in everyone's interest to have these activities done in a safe and controlled manner. These tools suffer from a number of problems. Consultations are beginning within Canada on how to address those problems and on how to simultaneously meet the needs of people who need to carry out burns and the public who may be affected by the smoke.

References

Fearon, M. G., T. J. Brown, and G. M. Curcio (2015): Establishing a national standard method for operational mixing height determination. *J. Operational Meteor*., 3 (15): 172-189, doi: http://dx.doi.org/10.15191/nwajom.2015.0315.

Tennekes, H. (1974): The Atmospheric Boundary Layer. *Phys. Today*, 27 (1): 52–63.

"Connecting diverse wildland fire, emissions, air quality and modelling communities."

Increasing wildfire growth modelling decision support using ensemble weather forecasts over the province of Alberta, Canada

by Brett Moore[1,2]

[1] Western Partnership for Wildland Fire Science, University of Alberta, Edmonton, Alberta

[2] Current Affiliation: Alberta Agriculture and Forestry, Government of Alberta, Edmonton, Alberta

Introduction

Wildfires in Alberta have recently posed a considerable challenge to industry, the public and wildfire managers. The fire environment continues to change and weather is beginning to trend into the unknown as a result of climate change. Wildfire managers are therefore tasked with managing a great deal of uncertainty (Flannigan et al. 2009). The 2015 wildfire situation in Alberta yielded more than 60 fires that consumed over 200 hectares each. These fires are currently under analysis using a probabilistic methodology. This methodology uses each wildfire growth simulation output from 20 ensemble member weather forecasts to create a probability map.

When a wildfire escapes initial action, defined as not under control by 10:00 AM the following day, a Wildfire Analysis and Strategy (WAS) is required. A fire growth projection must be included within the WAS. Fire growth projections to date have been based on a single weather forecast yielding a single projected perimeter; this is a major shortfall. Weather and wildfires are dynamic and often influence each other; therefore, a single perimeter may not suffice.

When a wildfire is extinguished and the final perimeter is compared to the modelled wildfire growth projections, growth is rarely equal. This occurs because the model does not simulate suppression, and the stochastic nature of fire spread is not fully understood. Using ensemble weather, fire growth modelling has the potential to describe a wide variety of outcomes.

While analysing the fires with the probabilistic methodology, success was defined using the contingency table from Stanski et al. (1989). The index chosen for this work is the Critical Success Index (CSI) as it best captures the accuracy of the modelled outputs. The CSI, a combination of the correctly predicted growth, missed growth and incorrectly predicted growth, ranges from 0 to 1 (perfect prediction). Using the 2014 fire season as test data, we saw a small difference between ensemble and deterministic weather based fire growth projections based on the average CSI (0.17 and 0.16 respectively); however, the difference was not statistically significant. It should be noted that 2014 had a small sample size with only 10 fires acceptable for this study.

The difference noted within individual simulations is much greater than that seen in the overall average, with the maximum CSI being 0.75 at the 95th percentile (5% of the observations are higher than this value while 94% are lower). This same process is being applied to the 2015 Alberta wildfire data wherein 92 fires greater than 100 hectares will be modelled, a much better sample size than 2014.

The objective of this work was to create a methodology for using decomposed ensemble weather forecasts on wildfires to increase the decision support capacity of fire growth models. The 2011 Flat Top Complex Wildfire Review provided recommendations to the Wildfire Management Branch of Alberta Agriculture and Forestry. Recommendation #7 is to improve information for fire behaviour specialists, which can be partially fulfilled through probabilistic fire growth modelling.

Data for the Machine

This work used the Prometheus Wildfire Growth Simulation Model to generate probabilistic outputs from ensemble weather inputs. Prometheus (available at www.firegrowthmodel.ca) is an elliptical fire growth model that follows Hyugen's wave theorem. Prometheus operates on the Canadian Forest Fire Danger Rating Systems' (CFFDRS) Fire Weather Index (FWI) and Fire Behavior Prediction (FBP) Systems.

Gridded binary (GRIB) data from the Regional Ensemble Prediction System (REPS) provided by the Canadian Meteorological Centre (CMC) were used

"Connecting diverse wildland fire, emissions, air quality and modelling communities."

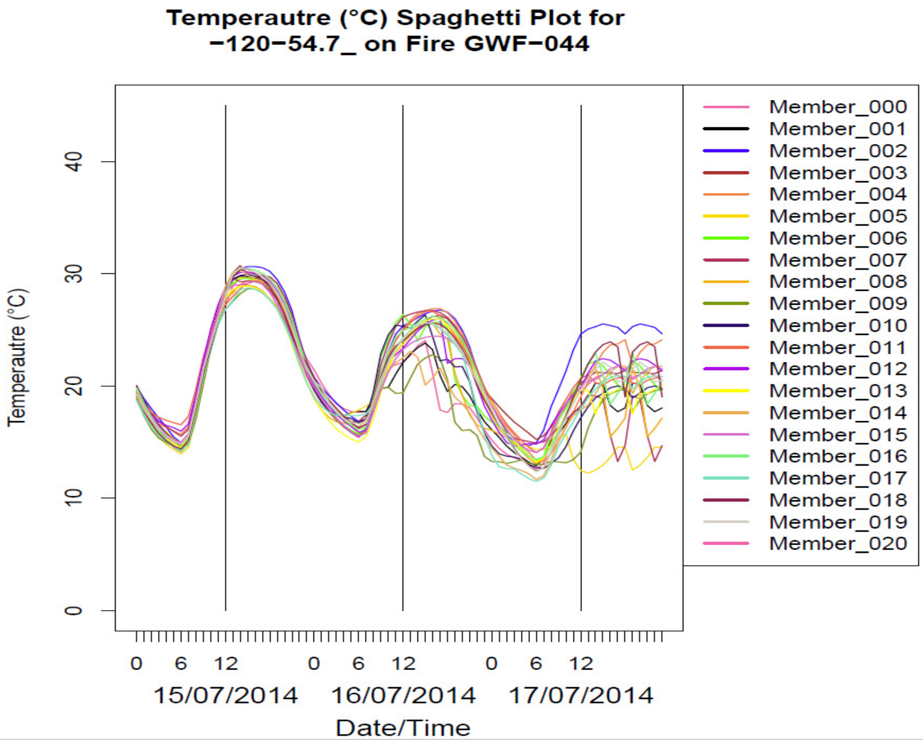

Figure 1. Spaghetti plot depicting temperature for Edson Wildfire 54 in 2104

as weather inputs. This data was decomposed into its individual ensemble members and processed within the R software. The REPS has 20 ensemble members and one control, which is the deterministic output (Figure 1, deterministic not shown).

Decomposition was done to ensure that resolution loss, through the process of Kalman filtering, did not confound fire spread within Prometheus (Kalman filtering is a statistical process used when creating an ensemble forecast from many individual forecasts). Each of the members was used to model fire spread and the resulting grids were summed and divided by the number of members to calculate a probability surface. The probability surface indicates the likelihood a fire will achieve varying extents over the course of a 3-day forecast. Wildfire information required for this study included: location, start date and final size (Table 1) in addition to a georeferenced perimeter. This information was obtained through the Wildfire Management Branch of Alberta Agriculture and Forestry. As this study was retrospective, the final perimeter was at a stable state. During a real-time wildfire incident, perimeter data has a high potential to be inaccurate due to the inability to collect data in such a hostile environment. This can create issues when implementing this work operationally.

Historical weather data was also required in order to generate FWI system values. The historical weather from the day prior to the start of a wildfire was used to initiate the calculation of hourly FWI system values. The GRIB forecast began at 0000 UTC or 1800 LST and the FWI values recorded are the 1600 LST values as calculated from the 1200 LST measurement. The 1600 LST FWI Indexes were used as hourly starting codes for the GRIB forecast starting at 1800 LST.

Weather streams that comply with the data structure required by Prometheus were generated for each ensemble member and the control (21 streams in total). These weather streams contain hourly values for temperature, relative humidity, wind speed and direction, precipitation and hourly FWI system values. The hourly FWI system values include the fine fuel moisture code (FFMC), initial spread index (ISI), and fire weather index (FWI); while duff moisture code (DMC), drought code (DC) and build-up index (BUI) are considered constant throughout the day (changing at the time of daily calcula-

Table 1. 2014 Information for fires included in this study.

Fire Number	Start Time	Start Date	End Date	Final Size	Date Final Size Reached	Latitude	Longitude
EWF-054	1705	15-Jul-14	9-Aug-14	419	17-Jul-14	54.07	-118.29
GWF-044	2135	15-Jul-14	29-Aug-14	4173	16-Jul-14	54.66	-119.96
HWF-058	1243	1-Jun-14	9-Jun-14	702	02-Jun-14	59.97	-118.07
HWF-059	1308	1-Jun-14	9-Jun-14	198	03-Jun-14	59.97	-119.00
HWF-133	1520	3-Jul-14	11-Jul-14	130	03-Jul-14	59.83	-116.94
HWF-219	1912	17-Aug-14	7-Nov-14	182	18-Aug-14	59.10	-114.47
MWF-051	1501	30-Jul-14	14-Sep-14	2092	15-Aug-14	58.58	-110.05
PWF-116	1455	19-Sep-14	25-Sep-14	353	22-Sep-14	55.91	-116.98
RWF-034	2226	3-Jul-14	11-Sep-14	8972	7-Aug-14	51.99	-116.66
SWF-113	1411	8-Jul-14	22-Jul-14	4211	15-Jul-14	57.26	-115.76

tion, 1700 LST).

Modelling Wildfire Probabilistically

The modelling process was inspired by previous dynamic wildfire models such as Burn P3 and the Probabilistic Fire Analysis System (PFAS). Prior to assessing fire growth projection accuracy, the variation and accuracy of the weather was a critical component of this study. Weather was assessed using the root mean square error (RMSE). The RMSE gives the user an impression of the amount of variation between the forecast and the actual weather that day (Figure 2).

Probability is calculated by summing burn grids (a binary raster output from Prometheus) from each of the 20 ensemble weather streams and dividing by the number of scenarios. These probability grids are used to create

Table 2. Contingency matrix for calculating model accuracy

		Observed	
		Yes	No
Forecast	Yes	A (Hit)	B (False Alarm
	No	C (Miss)	D (Correct Non-Event)

50th, 75th and 95th percentile agreement perimeters. These perimeters are then compared to the actual final fire perimeter. The overlapping areas correspond with the contingency matrix in Table 2 and Equations 1 through 4.

$$Bias = \frac{A+B}{A+C} \quad [1]$$

$$Hit-Rate = \frac{A}{A+C} \quad [2]$$

$$False\ Alarm\ Ratio = 1 - \frac{A}{A+B} \quad [3]$$

$$Critical\ Success\ Index = \frac{A}{A+B+C} \quad [4]$$

The CSI (Equation 4) describes a combination of hits, false alarms and bias, yielding the best description of a successful prediction for this study.

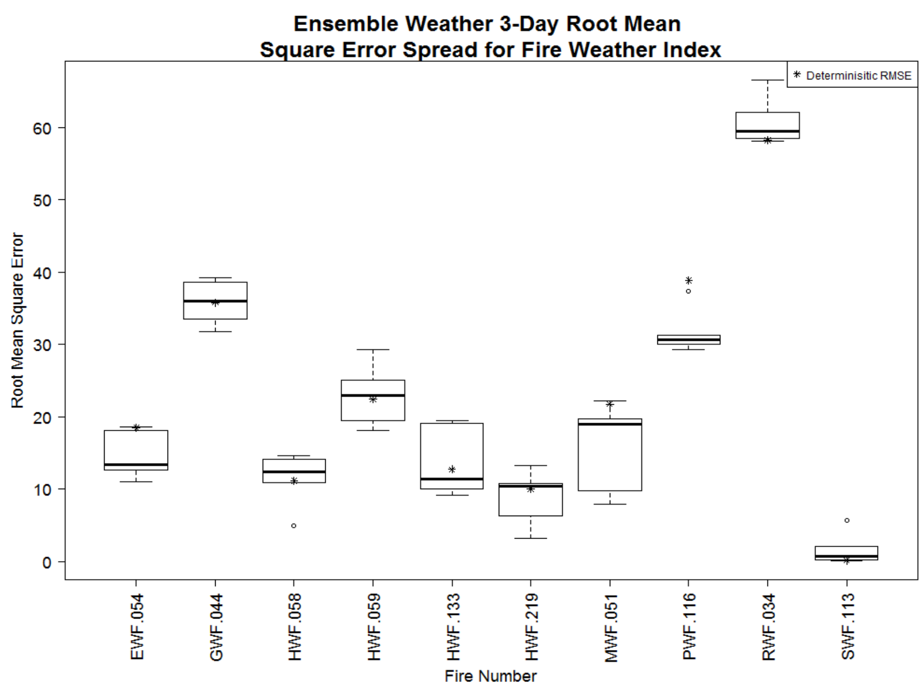

Figure 2. Ensemble weather 3-day Root Mean Square Error spread for Fire Weather Index from fires in study

Probabilistic Outputs

The intent of this process is to create probabilistic fire growth projection maps. These maps are intended to serve as a decision support tool at the incident management team, duty room, and provincial levels. The raw probability outputs can be challenging to interpret rapidly therefore agreement perimeters were created. Agreement perimeters are intended to give fire managers a tool that would allow for rapid decision making with a documented, repeatable process. This should increase confidence in decisions due to an increased amount of rigor behind the products supporting decisions. Most importantly, this information is not meant to prescribe the way fire management is to occur based on the outputs. This information is a tool to increase situational awareness and allow a fire management organization to make decisions on the best available information (example provided in Figure 3).

The average CSI value was considered rather low at 0.17; however, individual ensemble member CSI values had a maximum of 0.31 while the corresponding deterministic model in that situation had a CSI of 0.19. Average values for 50 to 95% agreement for Hit-Rate, False Alarm Ratio and Critical Success index can be seen in Figure 4. Overall, 85% agreement appears to perform best with respect to CSI.

Future development on this project will lead towards determining how agreement between ensemble members influences fire growth projections. Additionally, it will be important to understand how the probabilities' outputs fare over time. A projection under this process extends for a 3 day period. Understanding the accuracy during the entire growth period of the incident will continue to strengthen fire growth projection models. Prometheus has the capacity to produce many more outputs than simple perimeters, such as fire intensity, rate of spread and each of the other FBP system outputs. As techniques to measure elements of fire develop and improve, probabilistic head fire intensity modelling becomes possible and may provide further information about firefighter safety during operations.

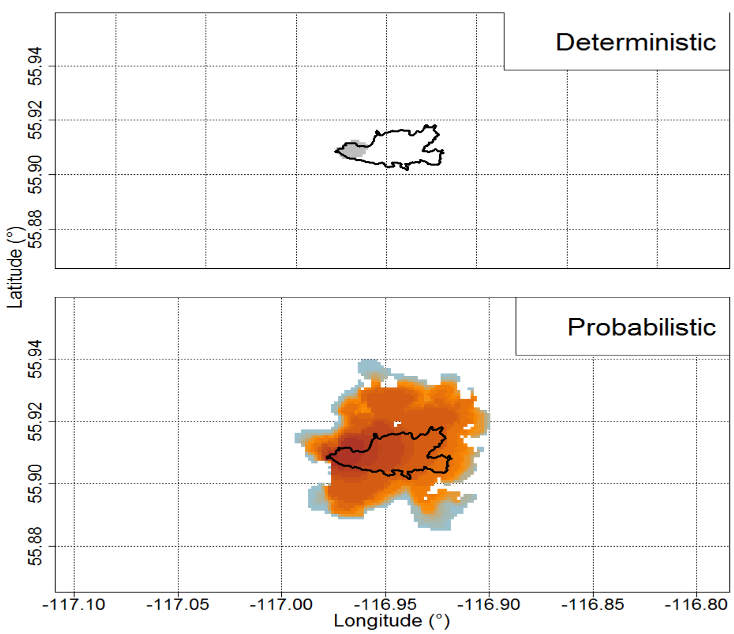

Figure 3. Outputs for Peace River Wildfire 116 in 2014

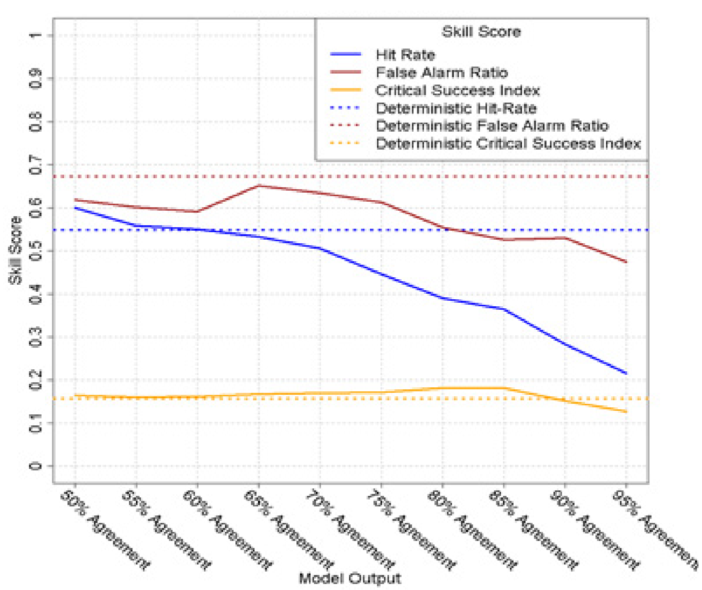

Figure 4. Average skill scores from fires in this study

Summary

As wildfires become more complex and prevalent on the landscape, longer term (3 to 5 day) wildfire growth projections will become desirable. Additionally, fire load may require the triage of wildfires, which will require probabilistic growth if decisions are to be made about fires that will be monitored rather than actively managed.

This approach is relatively new to fire management agencies and will continue to evolve as it is implemented. The 2015 Alberta fire season has allowed the opportunity for a more extensive analysis of the utility of products like this. Until these improvements are implemented, we can see the 75th to 85th percent agreement perimeters are the strongest estimates of fire growth potential.

References

Flannigan MD, Krawchuk MA, de Groot WJ, Wotton BM, Gowman LM (2009) Implications of changing climate for global wildland fire. *International Journal of Wildland Fire* 18 (5), 483–507.

Stanski HR, Wilson LJ, Burrows WR (1989) Survey of common verification methods in meteorology. Second: World Meteorological Organization Geneva, 9-42.

Canadian Wildland Fire & Smoke Newsletter
Spring 2016
"Connecting diverse wildland fire, emissions, air quality and modelling communities."

Ensemble lightning prediction models for Alberta, Canada

by Karen Blouin
Western Partnership for Wildland Fire Science, University of Alberta, Edmonton, Alberta

During an average year in Alberta, 330 000 cloud-to-ground lightning strikes occur. These strikes act as nature's ignition agent, starting ~45% of reported wildfires which result in ~71% of area burned (Alberta Government, 2015). Lightning-caused wildfires in remote areas of the province have a greater chance of escaping initial attack and becoming large campaign fires when compared to human-caused fires. This can result in large costs associated with fire suppression.

Accurate fire occurrence prediction models can greatly aid in the responsible management of forests and firefighting resources. While Canada has national systems in place to provide information and guidelines about fuel moisture (Fire Weather Index System; Van Wagner 1987) and potential fire behaviour (Fire Behaviour Prediction System; Forestry Canada Fire Danger Group 1992), an accurate medium-range lightning prediction system is currently not available. While methods and models exist to predict the probability of a known lightning strike resulting in a new start or hold-over fire, the lack of a spatial lightning prediction model that forecasts 3-7 days in advance leaves a gap in fire occurrence prediction where new lightning-caused starts cannot be forecast in the future.

Long term climatic trends and recent weather are critical components influencing fuel moisture and thus wildfire ignition, spread potential and behaviour. The day-to-day weather can also result in atmospheric conditions conducive to lightning, a major ignition source of wildfires. In addition to atmospheric conditions, the probability of lightning-caused ignitions depends on many factors including individual strike characteristics of the lightning, fuel moisture at the time of the strike(s), and the weather and fuel moisture in the days following lightning activity (in the case of hold-over fires).

In an attempt to fill the "lightning gap" in fire occurrence prediction, we used a random forest modelling approach to predict cloud-to-ground lightning occurrence in Alberta for 50km by

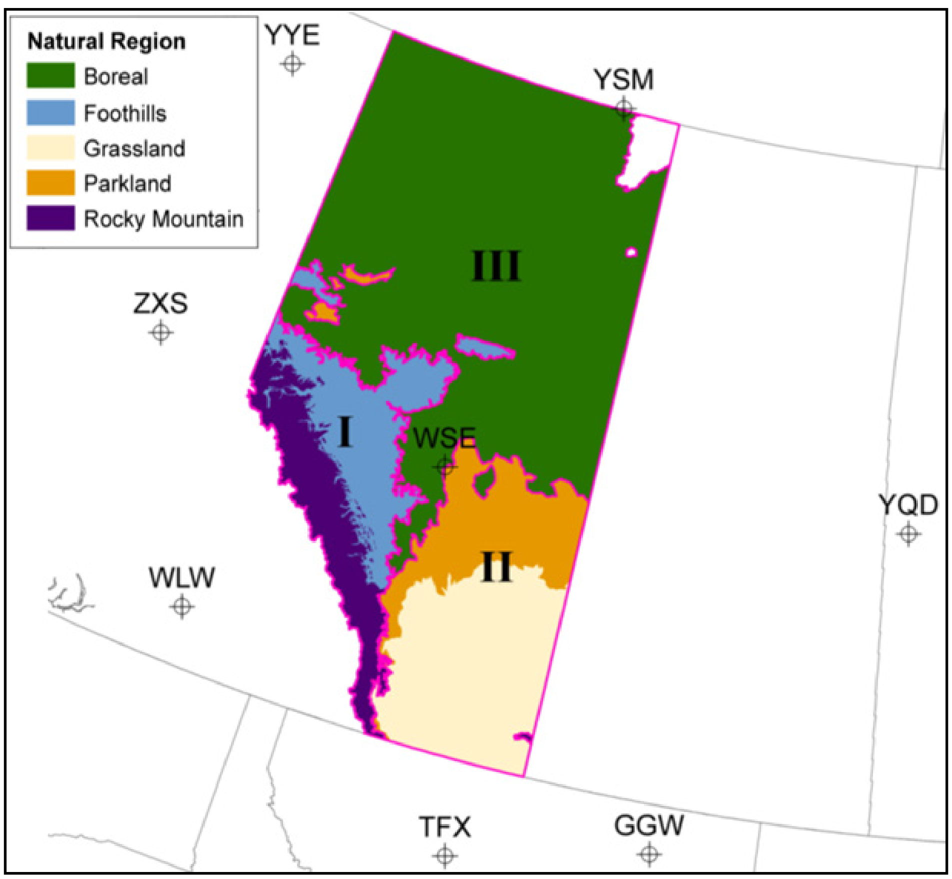

Figure 1: Modelling zones (I = Foothills; II = Grassland and Parkland; III = Boreal) based on the Natural Regions of Alberta. Radiosonde observation stations are identified by crosshair symbols (YYE = Fort Nelson; YSM = Fort Smith; ZXS = Prince George; WSE = Stony Plain; YQD = The Pas; WLW = Kelowna; TFX = Great Falls; GGW = Glasgow). Figure adapted from Blouin et al., 2016.

50km grid cells. Random forest is a supervised machine learning method of classification and regression that utilizes numerous decision trees, allowing it to effectively model complex interactions.

Overview of data and methods

This study was run on lightning data from the years 1999 to 2011 acquired from the Canadian Lightning Detection Network. Predictor variables included weather data as well as temporal and geographic data including Julian day, time of day, latitude, longitude, and elevation. Weather records were obtained, or calculated, from three sources: Reanalysis I (Kalnay et al. 1996); Reanalysis II (Kanamitsu et al. 2002), and radiosonde upper air sounding data. A thin-plate spline regression was used to interpolate the weather data to a 50km by 50km grid.

Using weather, geographic, and temporal predictors, we were able to predict, with reasonable accuracy, whether or not cloud-to-ground lightning would be detected by the Canadian Lightning Detection Network during a given time frame (6-hour or 24-hour intervals) in each 50 by 50 km grid cell. In order to do this we split the province into three distinct modelling zones (Figure 1; Foothills (I), Grassland and Parkland (II), and Boreal (III)) based on the Natural Regions and Subregions of Alberta (Natural Regions Committee 2006). Modelling zones I and II were of primary interest for this study as they overlap with the forest protection area.

We used seven randomly selected years as training data to generate a series of random forest models. Since lightning events are rare and episodic in nature, the lightning data set is imbalanced (many more observations of non-occurrence than observations of actual cloud-to-ground lightning events). A balanced random forest approach with down sampling (Table 1) was used to help mitigate the data imbalance. The remaining six years were used to validate the model. A detailed look at random forest and the methodology used to generate the models is available in Blouin (2014) and Blouin et al. (2016).

Results

The models were compared using four forecast skill criteria (Tables 2 and 3). The ensemble lightning prediction models generated had an overall forecast skill, or proportion correct, of ~80%. Overall, the 0.6 : 1 sampling method generated the most-skilled ensemble forecasts when measured by hit rate while also generating the least-skilled forecasts for non-events. Probability of predicting lightning-events was maximized for all modelling zones by using a prediction threshold of ≥0.5 (50% or more of the ensemble forecasts must predict lightning).

Table 1: The sampling method controls the number of observations sampled, with replacement, from the majority (non-events) and minority (lightning-events) classes. *n* = number of observations in the minority class. Table adapted from Blouin et al., 2016.

Sampling Method	# of non-events sampled	# of lightning events sampled
Balance (1)	n	n
0.8 : 1	$0.8n$	n
0.6 : 1	$0.6n$	n
Control	Proportion approx. equal to original class imbalance	

Table 2: Contingency matrix showing inputs for forecast skill criteria shown in Table 3.

		Event Observed	
		Yes	No
Event Forecast	Yes	*A* (hit)	*B* (false alarm)
	No	*C* (miss)	*D* (correct non-event)

Table 3: Forecast skill criteria. Formula inputs provided in Table 2.

Name	Formula	Description
False Alarm Rate (F)	$F = \frac{B}{B+D}$	Fraction of observed non-events that were forecasted as false alarms.
False Alarm Ratio (FAR)	$FAR = \frac{B}{A+B}$	Fraction of forecasted false alarms.
Hit Rate (H)	$H = \frac{A}{A+C}$	Also known as the probability of detection, this measure of skill is sensitive only to misses and does not take false alarms into account.
Proportion Correct (PC)	$PC = \frac{A+D}{A+B+C+D}$	Overall skill of the model but is not a fair measure of skill for forecasting rare events.

The 24-hour Foothills model was selected as the best model for overall performance, ranking first for hit rate (>85%) and false alarm ratio (53%), and second for proportion correct (~80%) and false alarm rate (19%). The 24-hour Boreal model placed second overall, ranking second for false alarm ratio and third for hit rate, proportion correct and false alarm rate. The 00 UTC Showalter index was found to be the highest ranking predictor for all models. Top predictors for the Boreal zone also included latitude, 00 UTC mean sea-level pressure, 00 UTC convective available potential energy (CAPE), and Julian day. Daily lightning prediction in the Foothills also showed latitude, elevation, longitude, Julian day and 00 UTC CAPE to be important predictors. Finally, the 6-hour Foothills ensemble found time of day, Julian day, latitude, 00 UTC CAPE, and elevation to be important predictors, in addition to 00 UTC Showalter index. A sample output for the 24-hour boreal forest model is provided in Figure 2.

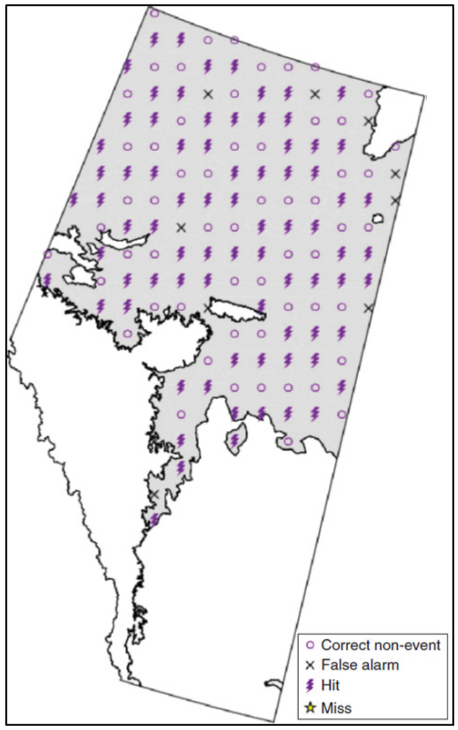

Figure 2: 24-hour Boreal ensemble for a randomly selected day (13 July 2005). Figure modified from Blouin et al., 2016.

Discussion

Rather than predicting all detectable lightning, our study focused on cloud-to-ground strikes which are capable of igniting wildfires. By employing a spatial resolution of 50km by 50km, and splitting the province into three geographic modelling zones, this study accounted for variations in local geography and weather patterns.

Random forest classification is well suited for lightning-prediction modelling due to its ability to model complex interactions, efficiency with large datasets and high classification accuracy when compared to other classification and regression models. Individual decision trees are often biased or have high levels of variance. Random forests mitigate this by producing numerous decision trees whose output votes are averaged, theoretically producing some level of balance. Conversely, random forest can over-fit and show poor skill when a large number of irrelevant predictor variables are included. We believe this did not affect our models as overfitting occurs in extreme scenarios when the sample size is very small or a large number of highly noisy variables exist. The sample size for this study was adequate, variable selection was informed by previous studies on lightning prediction, and correlated variables were removed further preventing the likelihood of irrelevant features being included in the predictive models.

Where should we go?

The models we generated in this study predict lightning occurrence strictly as a yes or no output. A model that predicts a continuous spectrum of the number of lightning strikes could prove very useful as lightning density could also be quantified. Ideally, lightning forecast models for wildfire occurrence prediction would also be able to predict polarity and long continuous current as these are important strike characteristics contributing to the probability of ignition. As technology improves, the prediction of these characteristics may become feasible.

Conclusion

The primary objective of this study was to generate robust lightning prediction models for Alberta. Random forest classifications were used to generate 6-hour and 24-hour lightning prediction models for the months of April through October. Ensemble forecasts generated with the 0.6 : 1 sampling method and an ensemble threshold of ≥0.5 resulted in optimized hit rates. The Showalter index (00 UTC), latitude, Julian day, mean sea-level pressure and convective available potential energy (00 UTC) were commonly identified top predictors province wide. In addition to these variables, longitude and elevation were key predictors in the Foothills zone.

The 24-hour lightning prediction model for the Foothills zone had the best overall performance achieving a hit rate of over 85%. The addition of lightning prediction models to the fields of wildland fire science and management will increase knowledge of lightning ignitions, improve fire occurrence prediction models, allow for better pre-planning and allocation of suppression resources and help increase the preparedness of wildfire management agencies.

The study was published in the International Journal of Wildland Fire (Blouin et al., 2016) and was funded by the Western Partnership for Wildland Fire Science.

References:

Alberta Government (2015) Historical wildfire database (1961–2014). Available at http://wildfire.alberta.ca/wildfire-maps/historical-wildfireinformation/historical-wildfire-database.aspx [Verified 11 September 2015]

Blouin KD (2014) Lightning prediction models for the province of Alberta, Canada. MSc thesis, University of Alberta, Canada.

Blouin KD., Flannigan MD., Wang X, Kochtubajda B (2016) Ensemble lightning prediction models for the province of Alberta, Canada. International Journal of Wildland Fire 25, 421–432.

Forestry Canada Fire Danger Group (1992) Development and structure of the Canadian Forest Fire Behavior Prediction System. Fire Danger Group and Science and Sustainable Development Directorate, Information Report ST-X-3. (Ottawa, ON)

Kalnay E, Kanamitsu M, Kistler R, Collins W, Deaven D, Gandin L, Iredell M, Saha S, White G, Woollen J, Zhu Y, Chelliah M, Ebisuzaki W, Higgins W, Janowiak J, Mo KC, Ropelewski C, Wang J, Leetmaa A, Reynolds R, Jenne R, Joseph D (1996) The NCEP/NCAR 40-year reanalysis project. Bulletin of the American Meteorological Society 77, 437–471. doi:10.1175/1520-0477(1996)077,0437:TNYRP.2.0.CO;2

Kanamitsu M, Ebisuzaki W, Woollen J, Yang S, Hnilo JJ, Fiorino M, Potter GL (2002) NCEP–DOE AMIP-II Reanalysis (R-2). Bulletin of the American Meteorological Society 83, 1631–1643. doi:10.1175/BAMS-83-11-1631

Natural Regions Committee (2006) 'Natural regions and subregions of Alberta.' Available at http://www.environment.gov.ab.ca/info/library/8031.pdf [Verified 19 January 2015]

Van Wagner CE (1987) Development and structure of the Canadian Forest Fire Weather Index System. Canadian Forest Service, Technical Report 35. (Ottawa, ON)

Wildland Fire Canada 2016
Building Resilience

October 24-28, 2016

Delta Okanagan Grand Resort

Kelowna, British Columbia, Canada

Themes:

Anticipating change

Designing resilient fire management systems

Defining and managing resilient landscapes

Planning smarter, safer, resilient communities

Held in conjunction with the

National Smoke Forum 2016

For more information,

http://www.wildlandfire2016.ca/

@WildlandFireCan

Assistant Professor in Wildland Fire

UNIVERSITY OF ALBERTA

Faculty of Agricultural, Life and Environmental Sciences - Department of Renewable Resources

Competition No. - A108229470
Closing Date - Will remain open until filled.

The Department of Renewable Resources seeks an Assistant Professor (tenure track) for a teaching/research position focused on wildland fire ecology, management, behaviour or operations research. The Faculty of Agricultural, Life & Environmental Sciences emphasizes excellence in teaching and encourages innovative pedagogical approaches, including distance delivery and blended learning. Teaching responsibilities may include courses in fire management, forest ecology, or related fields. The successful applicant is expected to develop a nationally competitive, externally funded research program that creates and sustains collaborative relationships with fire scientists and managers at the provincial and federal governments through the Western Partnership for Wildland Fire Science, https://www.ualberta.ca/~wcwfs/. The candidate's research should complement the existing research strengths of the Department in forest ecology, forest protection and sustainable forest management.

Applicants require a PhD and a strong record of practically oriented work in forest fire ecology, behaviour, modeling or management. Preference will be given to those with at least one forestry degree, postdoctoral experience and experience in fire management, planning of forest landscapes and/or forest ecology related to fire and disturbances. The Selection Committee will begin consideration of applicants on 9 August 2016 and will continue until the position is filled. Only short-listed candidates will be contacted.

Please submit the following complete package online as one document by clicking the **Apply Online** button below:

- letter of application, outlining your research and teaching interests
- names of three referees
- curriculum vitae
- teaching dossier

For information about the Department of Renewable Resources and our Faculty please visit http://www.ales.ualberta.ca/rr/. Information about fire science and management programs of the Alberta provincial government may be found at http://wildfire.alberta.ca/ and of the Canadian Forest Service at http://www.nrcan.gc.ca/forests/fire-insects-disturbances/fire/13143.

To assist the University in complying with mandatory reporting requirements of the Immigration and Refugee Protection Act (R203(3) (e)), please include the first digit of your Canadian Social Insurance Number in your application. If you do not have a Canadian Social Insurance Number, please indicate this in your application.

Apply Online