The Canadian Smoke Newsletter

2013

"Connecting diverse terrestrial, emissions, air quality and modelling communities."

Welcome to the 2013 issue of the Canadian Smoke Newsletter, our biggest issue yet. It has been an exciting year for smoke forecasting thanks to some big news involving the Western Canada BlueSky project (see article on page 27). This has the potential to significantly advance smoke forecasting and smoke science in Canada.

INTERNATIONAL SMOKE SYMPOSIUM

INTERNATIONAL ASSOCIATION of WILDLAND FIRE
THE MARRIOTT & CONFERENCE CENTER,
UNIVERSITY OF MARYLAND, ADELPHI, MD
OCTOBER 21-24,2013

Please consider attending a most interesting symposium due to take place at the University of Maryland this fall from October 21-24. According to the conference website (http://www.iawfonline.org/2013SmokeSymposium/), the objectives are to:

- create an international forum to discuss complex smoke issues surrounding both wildland and agricultural fire
- identify research gaps and priorities for smoke science and air quality communities to address and meet contemporary challenges regarding public health, transportation safety, fire personnel exposure and changes in climate
- increase awareness of ongoing smoke science research for professionals engaged in fire activities, air quality management, resource stewardship, military land-use activities, and emergency services
- provide innovative training opportunities for managers and operational professionals through a virtual platform
- showcase contemporary science and technologies to promote pioneering management and policy strategies, and
- raise awareness of the global diversity of approaches, issues, ideas and mitigation strategies in fire behavior and smoke management as they pertain to ecological concerns, social perceptions, and economic issues.

For those interested parties who cannot attend the conference in person, organizers have provided the option of attending online for approximately one quarter of the in-person rate. Attendees will be able to watch sessions live, or later on their own time.

The next issue of the CSN comes out in the summer of 2014. Until then,

Best regards,
Al Pankratz

Disclaimer: This informal newsletter is produced on behalf of the wildfire smoke community and has no affiliation with the government of Canada or any other agency. Articles from government, industry and academia, whether Canadian or international, are welcome. Please contact the CSN at csn@uniserve.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 Smoke Newsletter.

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Synoptic Atmospheric Transport of Wildfire Smoke Plumes to Greenland

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Introduction

Most of Greenland is covered by an extensive and thick central ice sheet. If all of this ice melted, global sea levels would rise by 7 meters [Intergovernmental Panel on Climate Change, 2007]. GRACE satellites measuring Earth's gravitational field indicate that Greenland has lost ice at an average rate of 250 km^3 per year since 2002 [Velicogna and Wahr, 2006]. Remote sensing also shows pools of liquid water on the top of melting ice. The concern is that both reflect much less incoming sunlight than does fresh snow; more heat is absorbed, thereby enhancing the melting.

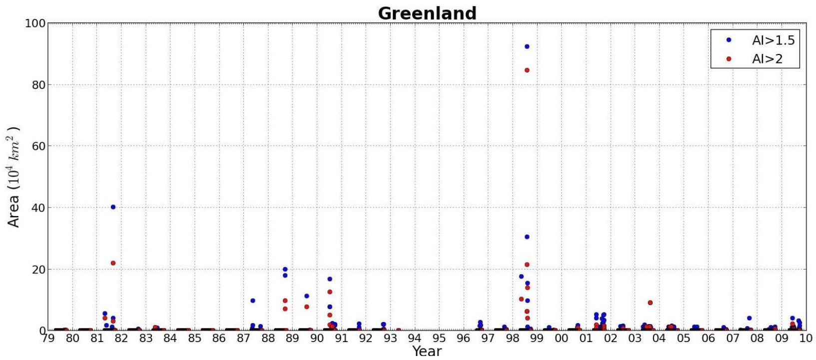

Figure 1: Daily smoke plume areas (in 10^4 km^2) over Greenland derived from Aerosol Index (AI) greater than 1.5 (blue dots) and 2 (red dots) for the months May to September from 1979 through 2009.

Modelling studies suggest that black carbon particles emitted by combustion processes are the second largest cause of global climate change. When black carbon aerosol is deposited onto ice and snow, it causes surfaces to absorb more solar radiation and thus accelerates warming [Hansen and Nazarenko, 2004]. Wildland fires represent a large source of atmospheric black carbon at boreal and temperate latitudes (e.g., Dentener et al. [2006]). A recent study suggests that in 2012, black carbon emitted by boreal forest fires and deposited on the Greenland ice sheet may have contributed to the record melting of the ice sheet (http://www.climatecentral.org/news/arctic-wildfires-pose-growing-threat-to-greenland-ice-15334, verified 29 May 2013).

Many measurement campaigns and modelling exercises have demonstrated that boreal smoke plumes can significantly contribute to atmospheric aerosol loading in the Arctic atmosphere, and over Greenland more specifically. Synoptic meteorological conditions affect not only smoke emission sources, such as fire ignition, fire growth, and plume heights, but also long-range transport pathways of smoke plumes to Greenland. The following presents different approaches used to examine the climatological transport of wildland fire smoke plume to Greenland as well as year-to-year variability in smoke intensity.

Smoke Cover over Greenland from Remote Sensing

Satellite imagery offers a unique perspective of the long-range transport of wildland fire smoke plumes to the Arctic region. For over 30 years, remote sensing instruments, such as Total Ozone Mapping Spectrometer (TOMS) have recorded the atmospheric transport of smoke plumes to the far north and more specifically to Greenland. TOMS has been deployed on four satellites since 1978: Nimbus-7 (11/1978 - 05/1993), Meteor-3 (08/1991 - 12/1994), Earth Probe (07/1996 - 12/2005), and OMI (01/2006 - present). Measurements from this instrument allow the calculation of geographical areas covered by smoke on a daily basis. Hsu et al. [1999] used the Aerosol Index (AI), derived from TOMS observations, as a proxy to calculate smoke plume areas over Greenland. Gridded daily AI values are available for a global scale from http://ozoneaq.gsfc.nasa.gov/index.md (verified 8 July 2013). Figure 1 shows the daily variability of smoke areas for AI>1.5 and AI>2.0 (heavy smoke) for the months of May to September between 1979 and 2009. No AI data was available on this website from mid-1993 through mid-1996, when TOMS was deployed on Meteor-3.

Years with noticeable smoke areas over Greenland are 1981, 1987, 1988, 1989, 1990, 1998, 2001, and 2003. Source regions of smoke plumes conveyed to

Greenland by prevailing winds can be determined from fire statistics databases and animations made of daily AI mapping.

Canada. 1981, 1989, and 1998 are the years with the fourth, first, and fifth largest areas burned in Canada, respectively, since 1960. In 1998, large smoke plumes released by Northwest Territories wildfires were carried over Greenland by prevailing southwesterly winds for several days (see the animation at http://youtu.be/yEep0znkuvU, verified 29 July 2013). Hsu et al. [1999] pointed out that smoke from 1994 Canadian forest fires impacted Greenland as well.

United States. In 1988 and 1990, Canadian fire activity was below average, but boreal wildfires swept across considerable areas of forest in Alaska. In 1988, wildfires also burned large forested areas in Yellowstone National Park and surrounding National Forests in the northwestern US from July through September. About half a million hectares had gone up in smoke by early fall. Large plumes reached Greenland, particularly in September.

Asia. In 1987, the fire season was relatively quiet in boreal North America, but quite the opposite in boreal Asia. The forest fire situation was extreme as early as May along the Amur River, the boundary between eastern Siberia and Chinese Manchuria. By the end of the summer, 15 to 20 million hectares of forest and steppes were burned. The great distances separating boreal Asian fires and Greenland usually limit the smoke impact on Greenland's atmosphere. However, the 1987 fire season was so intense that the smoke pall reached Greenland.

Climatological Air Mass Trajectories to Central Greenland

Over the past 20 years, numerous atmospheric measurement campaigns were conducted at Summit (72.5°N, 38°W, 3210 meters above sea level), a scientific observation site located in the middle of the Greenland plateau. Published [Jaffrezo et al., 1998; Kehrwald et al., 2012] and unpublished [Pertuisot, 1997; Lavoué, 2000] atmospheric measurement datasets at Summit include surface concentrations for various fire chemical tracers (e.g., oxalate, ammonium, black carbon) exhibiting episodic transport of fire smoke to Summit. Legrand et al. [1992], Cachier et al. [1998], and McConnell et al. [2007] inferred the influence of boreal and temperate fires on the Greenland atmosphere during the 19th and 20th centuries from fire tracer records in ice cores drilled at Summit.

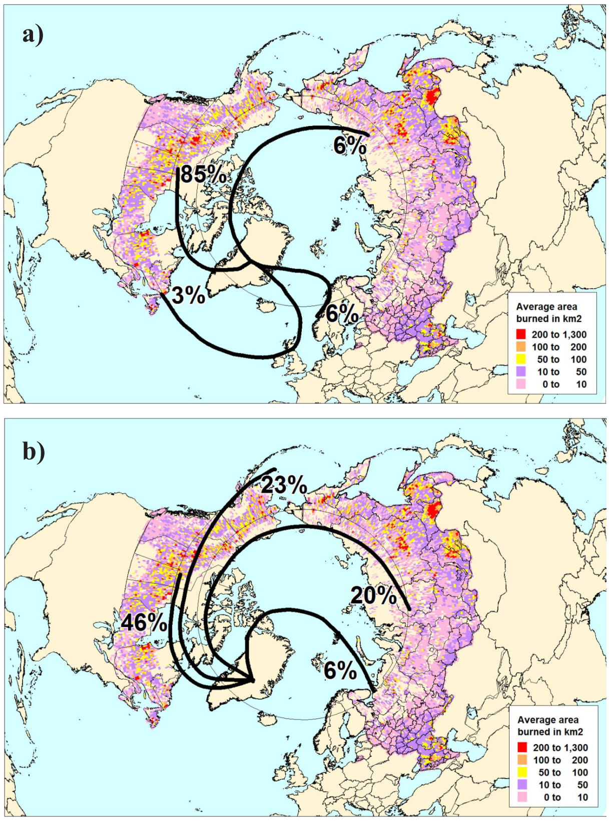

Figure 2: Average air mass back-trajectories to Summit at (a) 700 hPa (1962-1989) and (b) 500 hPa (1946-1989) during summer (June, July and August). Historical fire regions for Canada (1959-1999), Alaska (1950-2004), and Russia (1997-2011) are shown in a regular 0.5° grid with a Lambert Azimuthal Equal-Area projection.

Kahl et al. [1997] applied an air mass trajectory model to assess climatological transport patterns to Summit and to determine potential source regions of fire smoke detected in central Greenland. They calculated 10-day isobaric back-trajectories at 500 hPa (mid-troposphere) and 700 hPa (Summit altitude) based on daily global meteorological fields for 1946-89 (i.e., 44 years of data) and 1962-89 (i.e., 28 years of data), respectively.

Figures 2a and 2b show the summertime back-trajectories (from June through August) averaged over the study periods for 700 and 500 hPa, respectively. Historical fire regions shown in Figure 2 were extracted from the 1959-1999 Canadian Large

Fire Database [Stocks et al. 2003], 1950-2004 Alaskan burn scars (http://agdc.usgs.gov/data/projects/fhm/, verified 8 July 2013), and 1997-2011 Russian GFED v3.1 burned areas [Giglio et al., 2010]. Annual fire data were gridded at 0.5 degree resolution and superimposed on the air mass trajectory map. Summertime represents about three quarters of the annual area burned in the boreal region.

Most of the air parcel transport, with 85% and 70% of the back-trajectories at 700 and 500 hPa respectively, occurred over central and northwestern Canada, which are historically the two most active fire regions in the country. 20% of the 500 hPa back-trajectories originated north of East Siberia/Far East. The 500 hPa altitude corresponds approximately to the plume heights of large crown forest fires in the North American boreal forest. However, since Russian fires’ plume heights are usually much lower than the mid-troposphere, Russian contributions are believed to be limited compared to the Canadian ones. In addition, potential summer transport from Siberian regions frequently takes place over the Arctic Ocean where numerous stratus-type clouds increase in-cloud scavenging.

Episode of Labrador Smoke Plume to Greenland in 2012

Fire Regions. The Canadian Wildland Fire Information System (CWFIS) website (http://cwfis.cfs.nrcan.gc.ca/, verified 8 July 2013) indicates that nearly 140,000 hectares burned in the Province of Newfoundland and Labrador during the 2012 fire season; this

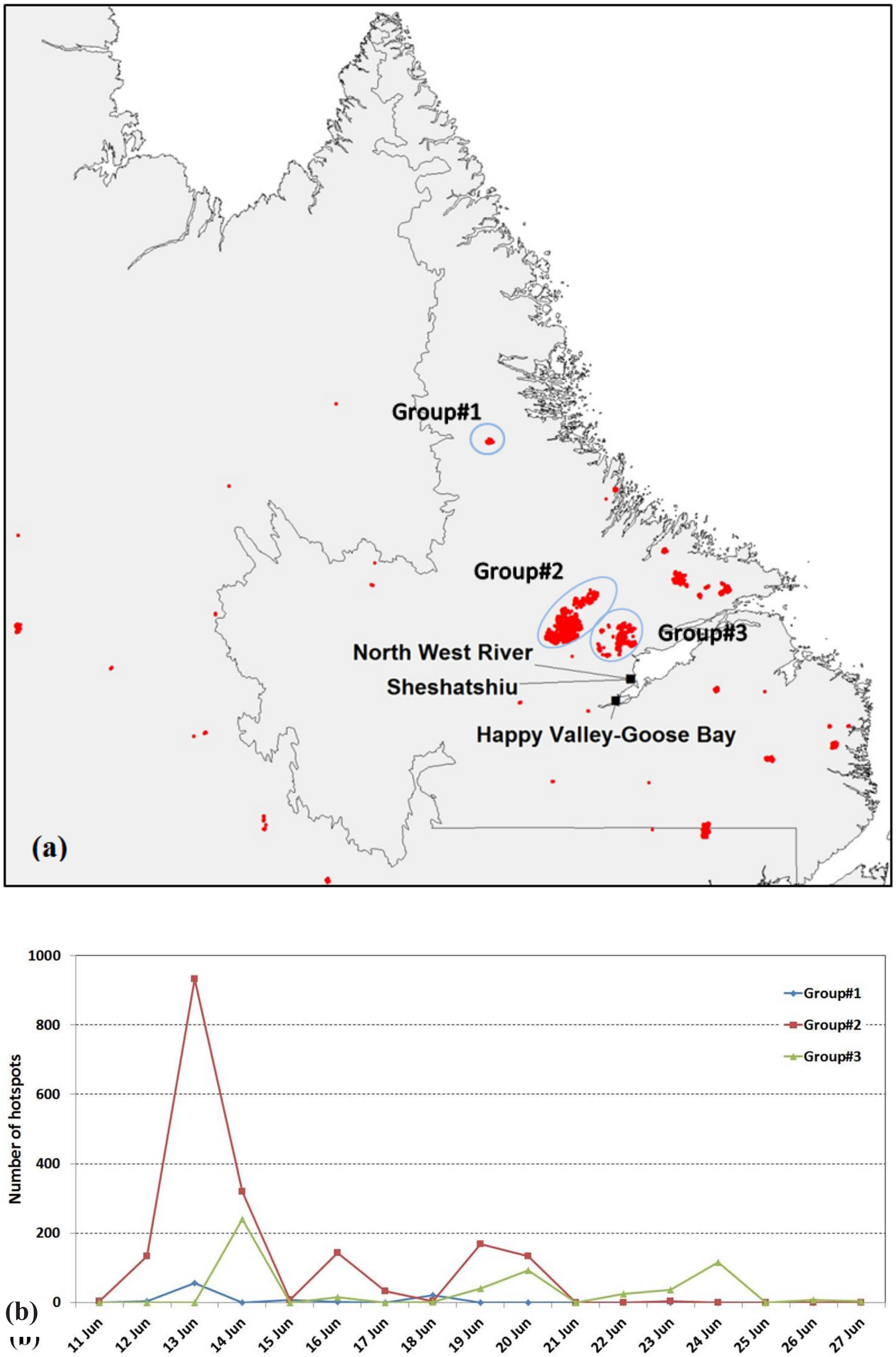

Figure 3: (a) Location of MODIS and AVHRR fire hotspots in Labrador during June-August 2012; (b) Daily number of fire hotspots for the three main fire locations (Groups# 1-3) between June 11th and 27th.

represents eight times the average area burned during 2002-2011. During the summer, a dozen large fires were burning out of control in Labrador. In June, a few fast moving fires threatened the communities of North West River and Sheshatshiu (Figure 3a) and made headlines on national television (http://www.cbc.ca/news/canada/newfoundland-labrador/story/2012/06/23/nl-fire-evacuations.html, verified 8 July 2013). It is likely that these fires also led to poor air quality in both settlements; however there are no ambient air monitoring stations in central or eastern Labrador to confirm this.

AVHRR and MODIS fire hotspots (http://activefiremaps.fs.fed.us/, verified 29 July 2013) show that forest fires were burning in three clusters or groups in June (Figure 3a). The daily number of fire hotspots by group shows that the activity of hotspot group#2 was the most active and peaked on June 13th (Figure 3b). In the following discussion, group#2 is assumed to be a single active fire, referred to as fire#2.

Fire Weather, Behaviour & Emissions. The Canadian Fire Weather Index (FWI) was calculated daily from surface meteorological observations at Environment Canada weather station 'Goose A' (60^{o}25'W, 53^{o}19'N) located in Happy Valley-Goose Bay (Figure 3a). Weather records show that there was limited precipitation at the end of May and no rainfall during the first half of June in central Labrador. Rising temperatures and drought conditions led to extreme fire danger conditions from June 11th to 13th (Figure 4a). Head Fire Rate of Spread (HROS), Fuel Consumption (HFC), and Intensity (HFI) components were calculated hourly with the Canadian Fire Behaviour Prediction (FBP) System; the fire region was assumed to be mostly covered by a mix of boreal spruce and spruce-lichen woodland for the purposes of these calculations. On June 13th, afternoon HROS and HFC reached 50 m/min (or 3 km/hour) and 2.7 kg/m^2 respectively, producing a continuous crown fire with a HFI of 42,000 kW/m (Figure 4b).

CWFIS determined that fire#2 grew by 40,000 ha on June 13th and that fire growth greatly slowed down the following days. Assuming an average fuel consumption of 2.5 kg/m^2 and using CO2, CH4, and N2O emission factors from Lavoué et al. [2007], fire#2 released about 1.5 Mt CO2eq (i.e., CO2 equivalent) on June 13th. This GHG emission from fire#2 over a single day represents 15% of the 9.4 Mt CO2eq released annually by all anthropogenic activities combined in Newfoundland and Labrador, as reported by Environment Canada for 2011 (http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=BFB1B398-1#ghg4, verified 12 July 2013).

Smoke Plume Transport to Greenland. On June 13th, TOMS captured the heavy smoke plume (maximum AI of 6.4) generated by fire#2 located in

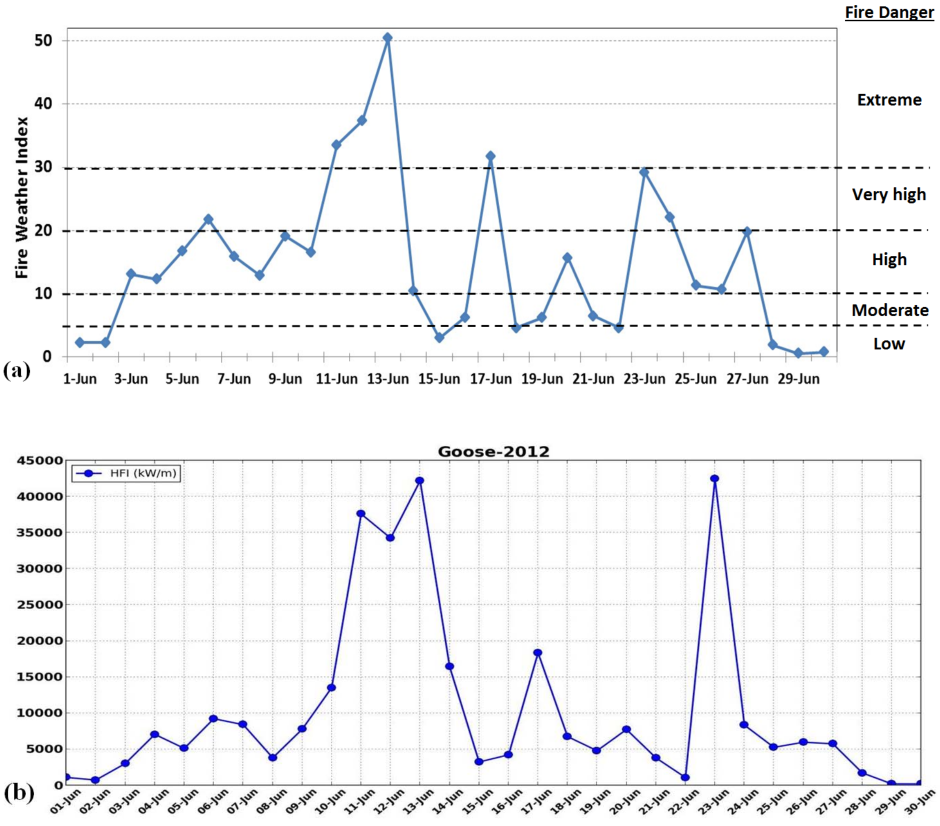

Figure 4: (a) Daily Fire Weather Index (FWI) and (b) maximum hourly Head Fire Intensity (HFI) for each day of June 2012.

eastern Labrador (Figure 5). The next day, a very large smoke plume (maximum AI of 6.4) extended from the fire region to the southern coast of Greenland over the Labrador Sea.

The height of the convection column generated by fire#2 on June 13th was estimated with a force-balance plume model developed by Harrison and Hardy [2002]. The plume model is based on a semi-empirical, two-dimensional Lagrangian algorithm, which incorporates information on atmospheric lapse rate and fire power as model inputs. Lapse rate was calculated from atmospheric temperature soundings over Goose Bay. Fire power was computed from area burned and fuel consumption estimates as shown in the previous section. Plume rise calculations suggest that the large fire front line intensity on June 13th resulted in a plume that reached ~4000 meters above ground level (AGL).

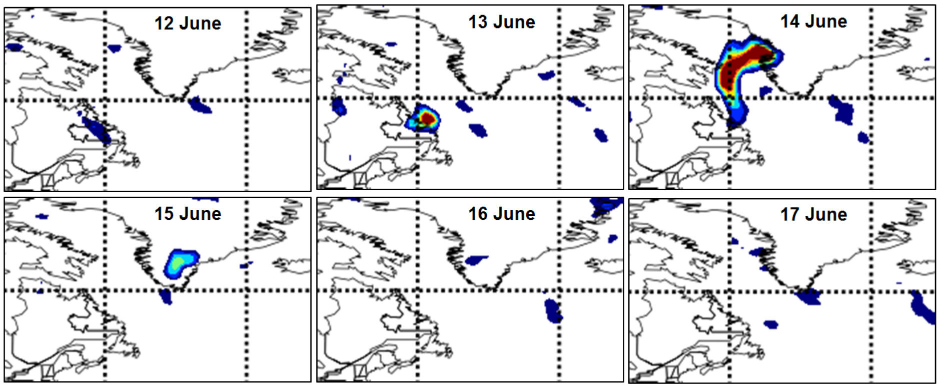

Figure 5: Daily Aerosol Index (AI) from OMI TOMS over Eastern Canada and Greenland between June 12th and 17th, 2012. Red color indicates AI over 4.

The transport pathway of the smoke plume was computed with NOAA air mass trajectory model HYSPLIT (version 4, http://ready.arl.noaa.gov/HYSPLIT.php, verified 8 July 2013). Four-day isentropic forward trajectories originate from fire#2's location and start on June 13th at 14, 16, 18, and 20 UTC (Figure 6). These times correspond to the afternoon peak fire activity in Labrador. Isentropic trajectories provide three-dimensional transport pathways (including the vertical component) of air masses leaving the fire region. The starting height of all trajectories was assumed to be the initial plume height of 4000 meters AGL.

The four trajectories match the northward direction of the smoke plume detected by MODIS on June 13th over

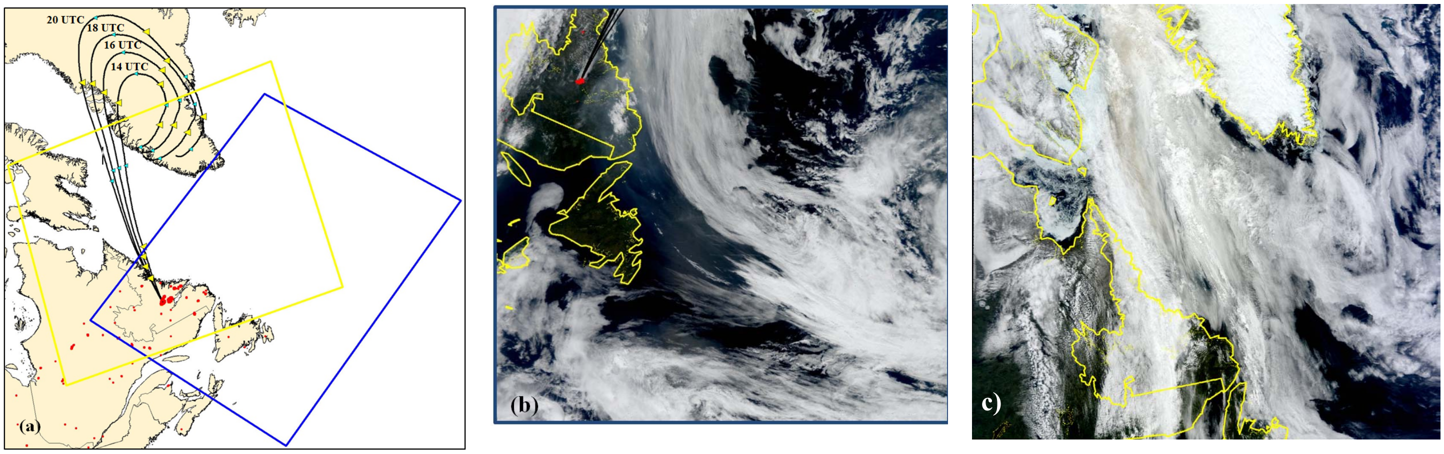

Figure 6: (a) Four day (i.e., 96 hours) forward trajectories of air masses crossing the central Labrador fire region and transporting smoke north to southern Greenland; red dots indicate all fires active during June 2012; the four trajectories start from fire #2 on June 13th at 14, 16, 18, and 20 UTC; yellow (resp. cyan) triangles indicate 00 (resp. 12) UTC of each following day; the last yellow triangles on each forward trajectory correspond to 00 UTC on June 17th. (b) MODIS Aqua imagery (1605 UTC) and active fire hotpots on June 13th; trajectories match the grey smoke plume transport to Labrador Sea. (c) MODIS Terra 14 June 2012 at 15 UTC shows heavy cloud cover over the Labrador Sea. Images courtesy of the MODIS Rapid Response Team, NASA Goddard Space Flight Center.

eastern Labrador (Figure 6b) and by TOMS over the Labrador Sea on June 14th. However, the smoke plume is not discernible in the MODIS visible band on the 14th due to heavy cloud cover (Figure 6c). Finally, trajectories modelled with HYSPLIT suggest that the plume height remained around 4000 meters above mean sea level (AMSL altitude) while being transported to and over Greenland by prevailing mid-tropospheric winds (Figure 7).

Smoke Plume over Greenland. Four days (i.e., 96 hours) after crossing the Labrador Sea and wafting over southern Greenland, the smoke plume returned to the west Greenland coast on June 17th (Figure 6a). This feature is confirmed by measurements made with CALIPSO, a recent NASA space-based instrument, which provides valuable information on shape and vertical profile of smoke plumes directly beneath the satellite (Figure 8). CALIPSO (http://www.nasa.gov/mission_pages/calipso, verified 8 July 2013) shows the Labrador fire plume over the southern coast of Greenland early on June 17th. The mid-tropospheric altitude of the plume detected with CALIPSO corresponds to the initial plume height estimated over Labrador and the heights calculated with HYSPLIT during transport.

Black Carbon Modeling at High Latitudes

The influence of black carbon aerosol on the Arctic has been extensively studied using different numerical transport and trajectory models, which are useful in the investigation of transport pathways, atmospheric loadings, removal processes and amounts deposited. In one example, Sharma et al. [2013] conducted a 16 year history (1997-2005) of black carbon impacts on the Arctic using the Japanese National Institute for Environmental Studies (NIES) transport model. Their results suggest that Russian and North American fires might contribute 65% and 27%, respec-

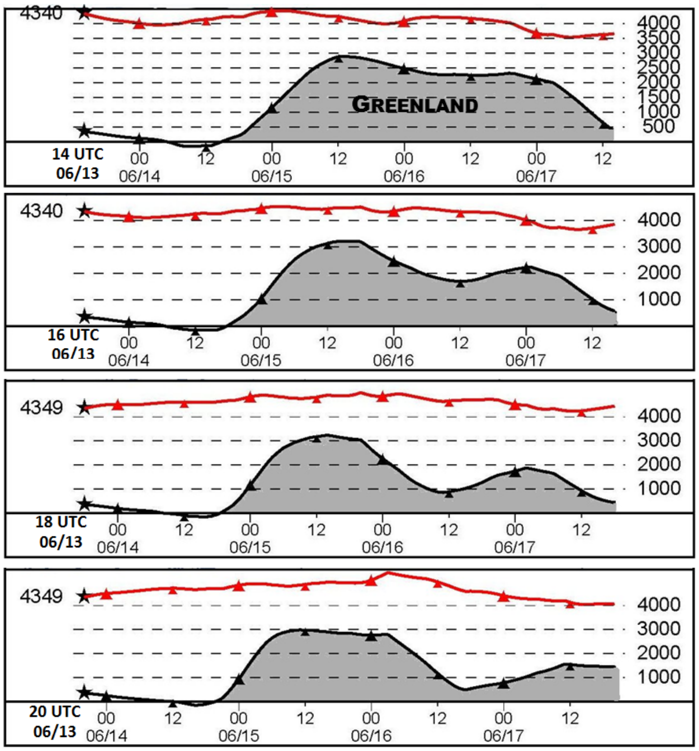

Figure 7: Heights of the four forward trajectories starting on June 13th at 14, 16, 18, and 20 UTC (red curve), and terrain height (black curve) in meters above mean sea level (AMSL). Air mass trajectories start at mid-troposphere over the fire region in Labrador (★).

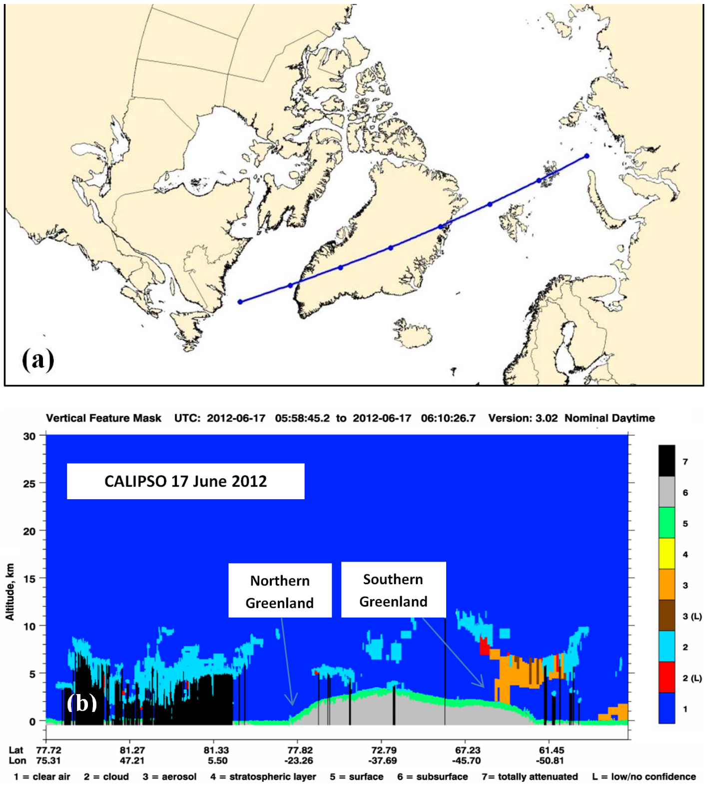

Figure 8: (a) orbit track of CALIPSO on June 17th at about 06 UTC; (b) CALIPSO profile showing aerosols emitted by from eastern Labrador forest fires over southern Greenland at mid-troposphere.

tively, to deposition of black carbon emitted by fires across the entire Arctic.

Similarly, Gong et al. [2012] and Zhao et al. [2012] simulated 10 years (1995-2004) of carbonaceous aerosol atmospheric transport with Environment Canada's aerosol model GEM-AQ/EC. Aerosol processes in GEM-AQ/EC are simulated by the Canadian Aerosol Module, which is a size-segregated multicomponent aerosol module that includes aerosol microphysics, chemical transformation, aerosol-cloud interaction, and dry/wet deposition. The averaged spatial variability of black carbon deposition on Greenland calculated with GEM-AQ/EC indicates the strong influence of Canadian forest fires on the western portion of the island (Figure 9) [Lavoué et al., 2009]. §

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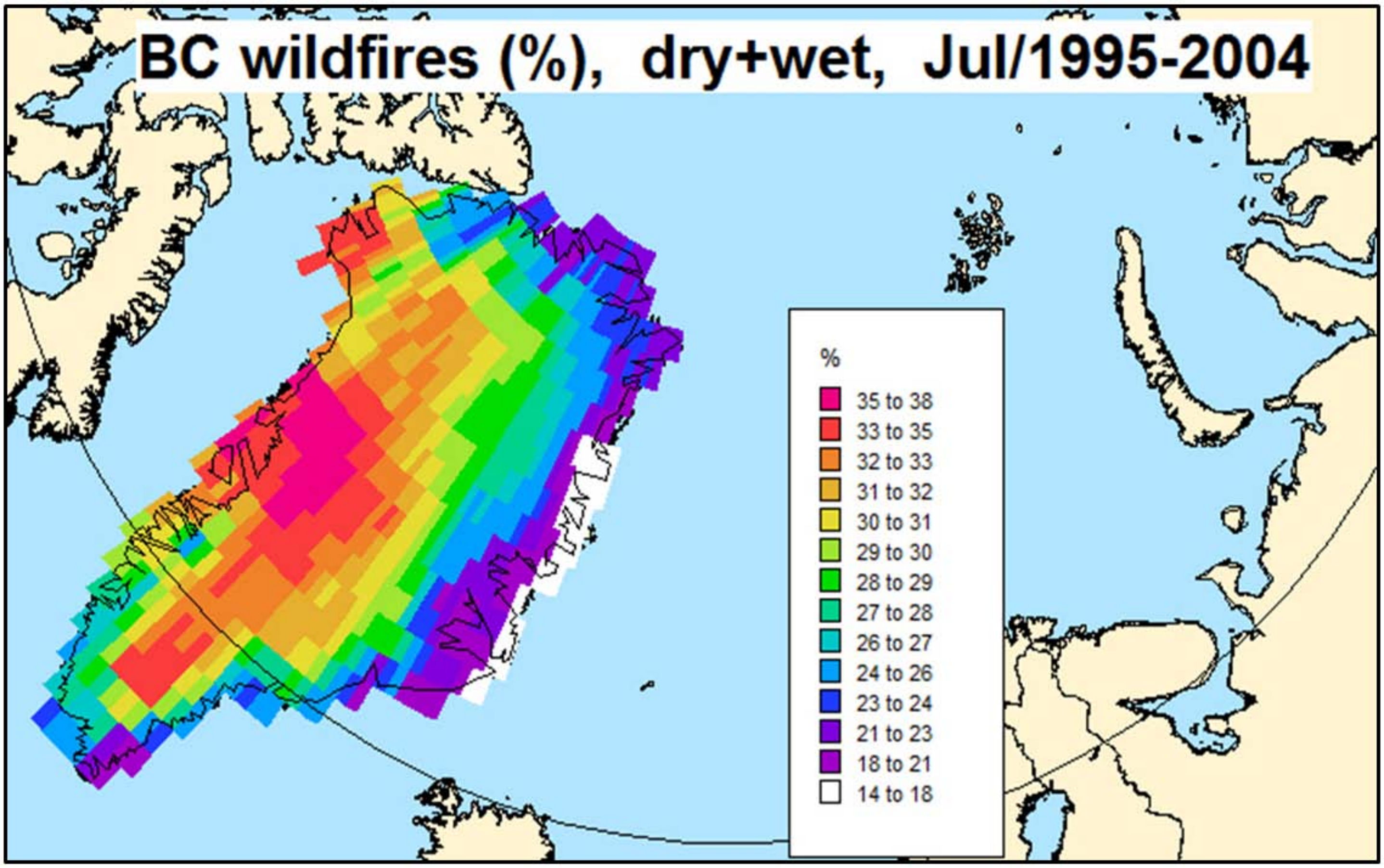

Figure 9: Averaged contribution of wildfires to total black carbon (BC) deposition on Greenland ice sheet from dry and wet atmospheric deposition processes for the month of July between 1995 and 2004.

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2013

"Connecting diverse terrestrial, emissions, air quality and modelling communities."

2006 Jackpine Wildfire
Willmore Wilderness Park

Wildland Fire Canada Conference 2012: Part 1

by Al Pankratz
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The second Canadian Wildland Fire Conference took place in the Canadian Rockies at Kananaskis, Alberta from October 1-4 of 2012. The conference venue was the beautiful Delta Lodge Kananaskis, notable among other things for hosting a G8 meeting in 2002. Conference organizers welcomed approximately 375 attendees, and provided an excellent cross-section of presentations, plenaries and working sessions for people from as far away as Australia and New Zealand. Such was the demand for registration spots that many potential attendees had to be turned away due to restrictions on available space at the Lodge.

Conferences such as this pull together an interesting mixture of operational fire fighters, provincial fire managers as well as fire and smoke researchers. Sessions reflected this diversity by including many aspects of wildfire around the globe, from technology involved in fighting fire, to software for coordination of teams, to overall management and funding, and last but not least, historical aspects of wildland fire.

History of Fire and Research

The conference began with a banquet that highlighted outstanding contributions to fire science by Charles Van Wagner. Mr Van Wagner, aged 87, was present to receive the Ember Award for Excellence in Wildland Fire Science from the International Association of Wildland Fire, and the Wright Award for "excellence in wildland fire research and its contribution to the advancement of wildfire management in Canada". The Wright award was presented by the Wildland Canada Conference organizers. A few well chosen reminiscences by Mr. Van Wagner then led to the featured presentation by Peter Murphy of the University of Alberta on the early history of fire science in Canada, with a focus on Western Canada. The history of fire is far from a dry recitation of facts of the sort many people experienced during their early years of education. The history of fire is not only interesting in its own right, but is especially relevant today because of its ability to inform current debates, such as the one about how often prescribed burns need to be applied to the landscape in order to maintain a semi-natural fire regime. Historic fire regimes in the Kananaskis Valley were studied by scientists during the 1980s, producing evidence of fires that had burned up to 1000 years previous. This data trove allowed scientists to investigate fire return periods, both natural and affected by human development. Photos of the Kananaskis valley and the Banff valley taken 100 years ago show significantly less tree extent than at present. This was a reflection of the fact that First Nations' use of fire was widespread across the prairies and foothills as a means of renewing vegetation, clearing it for travel, and concentrating herds of bison as food sources. This fire management was abruptly terminated in the early

1900s as Europeans spread westward in increasing numbers.

Smoke

While smoke and smoke management were not major themes at the conference, they were mentioned. Two sessions in particular dealt with smoke prediction. The first, by Steve Sakiyama, outlined the progress made by the Western Canada BlueSky Smoke Forecasting System. A number of plans for expanding and improving BlueSky were discussed (see articles beginning on page 25 of this issue for more information).

A new aspect of operational smoke management in which Parks Canada has taken a significant interest is the addition of the BlueSky Playground to Western Canada BlueSky (see page 33 for full details). Playground is a web-based interface which allows fire managers to utilize meteorological forecasts produced by the University of British Columbia by placing virtual fires on a virtual landscape and allowing them to develop and disperse smoke. The goal is to see where the smoke will go and what communities might be affected. As one can imagine, this is of considerable interest to managers who are considering starting prescribed burns potentially upwind of

Figure 1. Scenery behind the Delta Kananaskis Lodge.

major population centers. At the time of writing, Playground is in fact being tested for use in the 2013 fire season. One interesting question raised by the existence of Playground is: What happens when validation studies and experience show that BlueSky smoke predictions are accurate enough often enough to allow significant confidence to be placed in them? Will it be enough to simply notify a community that smoke is coming its way and then proceed with the burn? Or will external authorities go so far as to shut down the prescribed burn before it starts, on the basis of potential threats to health?

Development vs. fire, and the need to get fire back on the land

The next day's passionate presentation award went to Johnny Stowe of the South Carolina Department of Natural Resources. Mr. Stowe spoke on the need to keep fire on the landscape and to keep people aware of the natural environment in which they live. He showed some particularly striking contrasts between urban sprawl and development on the one hand, and shrinking natural habitats on the other. He also showed time lapse images of the growth of the metropolitan Atlanta area, one of the largest urbanized/built-up areas in the world. The effects of this type of growth on the diversity and extent of native vegetation, and the constraints it puts on prescribed burning are not hard to imagine. His

Figure 2. Presentations in the main hall.

final quote came from Jim Posewitz, a conservationist from Montana: "A society is ultimately measured not by what it develops or consumes, but by what it has nurtured and preserved."

Mr. Stowe's sentiments were echoed by different speakers in different ways. Brian Simpson of the British Columbia Wildfire Management Branch mentioned that only 4000 hectares of prescribed burns took place in BC in 2012. Mark Heathcott noted that dendrochronologies show time between fires has lengthened dramatically since Europeans showed up in North America. Other speakers raised the following ideas and questions:

- fear, ignorance, and apathy are among the reasons why prescribed burns are used far less than they should be – we need far more prescribed burns
- there is a reluctance by the citizenry to take action to protect communities in the wildland urban interface if they themselves have not been directly affected
- we may need advice from social psychologists on how to get the public motivated to be fire smart and take action before disaster occurs
- fire management should become local. We should try to devolve more power and responsibility to the community/municipality. People could feel they have a stake in the health of the forest by giving them ownership of the local resource. For example, cleaned up fuels can be sold or used as biomass to generate energy
- there could be legal requirements/inspections to determine that FireSmart funds were used properly
- consideration should be given to re-establishing old fire corridors in the boreal forest to limit large fires and allow some prescribed burns
- British Columbia is instituting the FireSmart program in over 300 communities. What is the rest of the country doing?
- recovery costs can be many times the immediate suppression costs. Pinning down the actual costs over and above immediate suppression is very difficult for researchers because the costs occur across departments (health, environment, resources, heritage, finance) and can go on for, in some cases, generations after the fire is done
- where are economic studies supporting arguments to mitigate and strategically prepare wildlands for fire rather than doing nothing and then spending large amounts after fires occur?

Lessons from Kananaskis

There is a fundamental conflict between the need to get fire on the landscape once again, and the philosophy of continual growth as manifested by widespread development of natural resources in remote areas. Planning of disturbances in the form of towers, pipelines, sheds, homes, roads and cutblocks needs to take fire into account at the start, rather than after the fact.

Paradoxically it seems that too much efficiency can set society up for disaster. One of the lessons of the talks given by the Slave Lake, Alberta mayor, reeve and fire chief was that in order for a community to be resilient against fire, it has to have redundancy. One fire station, one water line, one water pumping station or one road into the community may be efficient, but when a fire burns the station, cuts the line, damages the water pump or closes the road, there is nothing left with which to fight fire and nowhere to go. The Province of Alberta has provided large sums of money for Slave Lake to recover and to put in place the required redundancy, but what of other currently unburned communities and their need for similar redundancy?

As with other health-related issues such as diet and exercise, society can save itself a lot of money and grief if it takes preventative action, in this case with respect to wildfires. And yet it doesn't. So the perennial question arises: How can long-term public good be made to pay off in the present for decision makers? Perhaps one way would be to create short-term benefits that many in society want, that in addition have the desired long-term effects. In this way, by recognizing and working around our own shortcomings, we can find practical approaches that take into account our obligations to future generations.

The next Wildland Fire Canada conference is in Halifax in fall, 2014. Plan to attend, and book early! §

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Wildland Fire Canada Conference 2012: Part 2
"Aren't we there yet?" – Reflections on the Fire Management Journey

by Peter Murphy
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Forest and prairie fires began to occur naturally in Alberta about 10,000 years ago as the glaciers retreated and plants returned. Fires have been part of the ecosystem process ever since. Aboriginal people suffered as a result of wildfires and their effects, but learned to live with fire and use it to 'manage' parts of the ecosystem to their advantage. Early explorers and fur traders remarked on the evidence of fire and deplored the evident destruction. With the arrival of European settlers and settlement, fires had greater consequences and various organized efforts to prevent and control fires began.

When Canada was created in 1867, forests became provincial rights and responsibilities, so the focus on fire fighting varied among the provinces. However, fires were also seen as having national implications, so a number of separate agencies, organizations and associations evolved. Since fire did not respect human boundaries, the concept of cooperation and collaboration became a recurring theme, in some cases transcending agency mandates. The spirit of collaboration is clearly reflected in the Canadian Interagency Forest Fire Centre (CIFFC) model, and in the broader audience of this Wildland Fire Canada Conference itself. Many events have led us to this place. The Kananaskis area and Alberta are microcosms of the national Canadian scene, and serve to emphasize the fact that effective working collaboration remains essential to address the many moving targets of fire management.

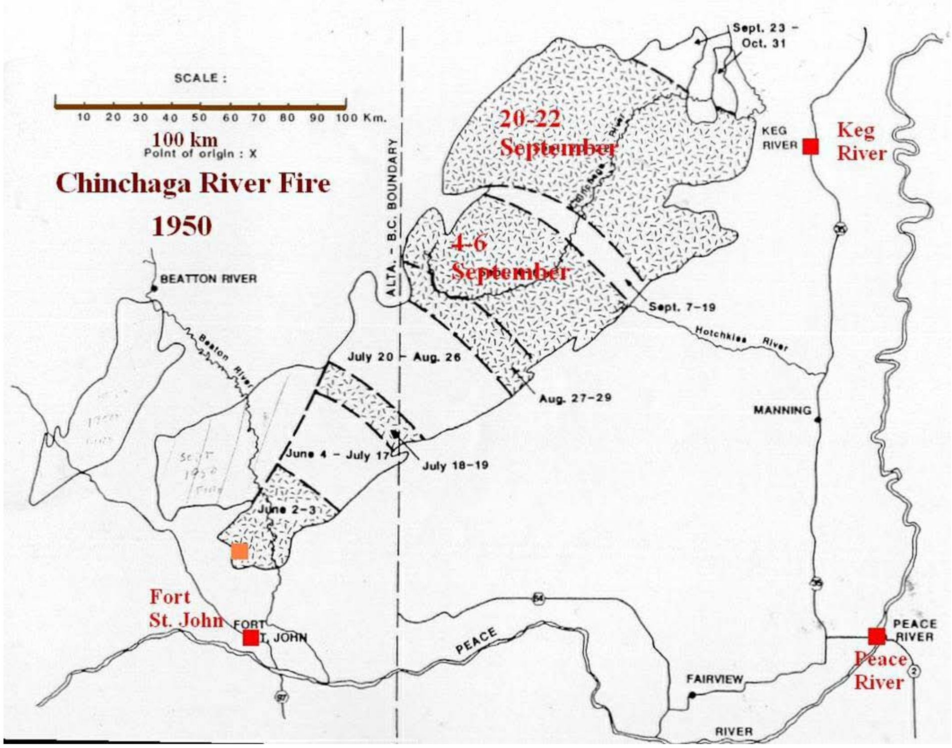

Figure 1. Path of the Chinchaga River Fire, 1950.

One example that illustrates the abiding effect of fire and smoke in Canada and the challenges faced by fire managers is the 1950 Chinchaga River fire. This blaze began on June 1st about 30 kilometres northwest of Fort St. John, B.C., burning in logging slash, with an area estimated at 40 hectares. It was one of many fires burning at the time, but this one was located in a zone where fire permits were not needed and where it was believed that clearing for agriculture would soon be allowed. As a result, a triage-type decision was made to take no action on the fire. The fire flared up periodically over the following months as it headed northeast into the Chinchaga River valley in Alberta. The ranger at Keg River became concerned and requested permission to attack it during its quiet spells, but it also lay outside the 'protected area' in Alberta so it was essentially a free-burning fire. It made its final and most significant spread during a two-day 'blow-up' on September 20 and 21, spreading about 40 km on a 60 km wide front and burning about 2,400 km^2. Smoke from this fire and others in the region drifted over Ontario, the northeastern United States, Atlantic provinces, England and Holland before dispersing over Germany, as described in weather journals. When the Chinchaga River fire was finally stopped by rain and snow at the end of October it had spread 245 kilometres and burned 1.4 million hectares.

Our continuity of forest extent combined with changing climate and weather presents us with the potential for large fires. In pre-European settlement times, this was just part of the ecosystem process. However, values at risk, potential loss of harvestable forest and concerns about the effects of smoke have made fires mostly undesirable. Consequently, detection, rapid initial attack and control have become society's responses. Left largely unspoken is the question of how to substitute disturbance by fire with other forest-rejuvenating and fuels-reducing treatments. Early thinking, based on European models, was that systematic forest harvesting would fulfil that role -- but harvesting has not kept pace with the 'natural' rate of burning - and harvested areas are not necessarily fire-resistant either - so ongoing fire management strategies are still important. Banff and Jasper national park staff have developed programs to reintroduce fire to the ecosystem through a combination of mechanical treatments, such as logging, along with prescribed fire. Fire Smart programs are also addressing the problem of fuel management around communities and other at-risk sites. And yet the threat remains, as the Arizona tragedy in June, 2013 illustrates. §

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Wildland Fire Canada Conference 2012: Part 3

Federal Forest Fire Research in Canada: An Impressive Past and an Uncertain Future

by Brian J. Stocks

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[This article is an adaptation of my keynote address given at the Kananaskis Conference. - BJS]

Overview of Issue

Forest fire impacts, and public awareness of these impacts, have been increasing dramatically in Canada in recent years. The Kelowna/Barriere Fire of 2003 in British Columbia, and the Slave Lake Fire of 2011 in Alberta, resulted in the destruction of numerous homes and businesses in these communities, with a collective cost of more than $1 billion in insurable losses. The scale of these impacts was unprecedented after an era that saw the development of sophisticated, world-class fire management programs aimed at mitigating unwanted fire impacts. Today fire management agencies are facing near-term escalating fire risks, driven by the expansion of communities into flammable wildlands, along with climate change-driven increases in extreme fire weather/danger and fuel conditions. Fire management program costs are escalating, with overall expenditures in Canada approaching $1 billion in years with significant fire activity.

For almost a century, the Canadian Forest Service (CFS) has conducted forest fire research in support of, and in cooperation with, provincial/territorial fire management agencies across Canada. This has resulted in the development of many research products that have, through their use by operational fire agencies, contributed directly to fire suppression effectiveness and the health and safety of the Canadian public. Most prominent among these is the Canadian Forest Fire Danger Rating System (CFFDRS), a fundamental component in short-term tactical as well as long-term strategic decision-making, that is in use throughout Canada and in many other countries. However, over the past four decades, federal government support for in-house fire science has declined steadily. As a result, CFS research capacity, including forest fire research, has eroded to the point where critical mass and program delivery are major issues. At a time when fire impacts are forecast to increase significantly, the CFS fire research program is greatly under-resourced, and unable to adequately assist fire management agencies in addressing emerging and future threats.

This article briefly traces the history of federal fire science in Canada, and explains how inextricably the CFS fire research program has been tied to the rising and falling fortunes of the CFS in general, which have in turn been linked to both federal/provincial issues and, more recently, declining federal government support for in-house basic scientific research.

The Historical Role of Federal Involvement in Forestry

The role of the federal and provincial governments in managing forest resources has been complex and confusing since Confederation, when provinces were given control of forest resources. Cooperation between both levels of government has been inconsistent at best, with provinces often critical of the lack of federal participation in forestry programs, which has been sporadic, while at the same time resisting federal encroachment in their jurisdictions. Provincial control of forest resources has thus had consequences both for the federal government's role in Canadian forestry, and the quest for a national forest policy. As we will see, this almost constant inability to come together politically and forge a lasting national forest policy, has created the tenuous environment in which federal forestry research has laboured over the past century.

The federal forestry agency now known as the Canadian Forest Service (CFS) was created in 1899, and since that time has resided in over a dozen different departments in the federal government, a strong indication of the uncertainty over the federal role in forestry during this period. This forestry agency (for simplicity, referred to in this article as the CFS) did not seem to be a good "fit" within the federal government structure, rising to full departmental status at one point, but more often existing as a small agency in many different government departments, with fluctuating resource levels.

In the period leading up to 1930, the CFS was the most prominent forest agency in Canada, due to its management responsibilities on Dominion lands in the west, and an expanding involvement in forestry research. However, the transfer of natural resources to Manitoba, Saskatchewan, Alberta and British Columbia in 1930 crippled the CFS, which barely survived through the Great Depression and World War II with a greatly restricted research mandate.

The 1949 Canada Forestry Act ushered in a new era in federal forestry, and the CFS prospered during the 1950s and 1960s as federal-provincial cooperation in forestry was expanding, with federal forest science gaining strong support. The CFS became a full government department in 1960, and new federal forest science laboratories were established across Canada (NL, NB, QC, ON, MB, AB and BC). During this period, budgets were increased and large numbers of research staff hired. The CFS had a vigorous national identity. This period of dynamic growth came to an abrupt end in the late 1960s/early 1970s, with repeated government restraint programs resulting in chronic budget cuts, downsizing, and merging of laboratories. The CFS lost departmental status in 1966. A brief respite due to short-lived federal/provincial cooperative forest development agreements in the 1980s and early 1990s ended in 1995 with Program Review. The CFS budget was massively cut from $221 million to $96 million, resulting in the closure of the Petawawa National Forestry Institute (PNFI - formerly PFES), closure of the NL regional centre, and the cutting or relocation of staff. Since that time budgets have steadily declined through attrition to the point that A-base (ongoing operations) budgets are virtually non-existent, with scientists forced to seek outside funding. This often means aligning with the agenda of the funding agency. Overall CFS staff numbers have dropped from a high of 2400 employees in 1970 to a current level of 700.

A closer look reveals that this CFS-level decline is the result of a much larger federal government policy initiative over the past 40 years aimed at transferring funding away from government laboratories towards academia and business corporations, with the nebulous and to-date unfulfilled argument that this would promote Canadian innovation and benefit the country economically. In 1970, when this trend began, government science, academia, and business each accounted for roughly 1/3 of Canadian scientific output. Government science now accounts for only 9% of the total output. This has occurred despite the fact that government in-house science is viewed as a strategic national asset and a major contributor to a knowledge-based society in most developed countries around the world. The current Canadian government continues to cut crucial scientific programs in many science-based federal departments despite growing public awareness and concern.

A Brief History of Federal Forest Fire Research in Canada

Canadian forest fire research began in the mid-1920s with the pioneering fuel moisture/flammability work of James G. Wright and Herbert W. Beall. They initiated fieldwork at the Petawawa Forest Experiment Station (PFES) in Ontario in 1928 and, over the next two decades, conducted numerous experimental fires and monitored selected wildfires in Quebec, British Columbia, New Brunswick and the Prairie Provinces (Figure 1). They developed relationships between various weather factors (e.g., wind, relative humidity, temperature and precipitation) and the moisture content of fuels critical to fire initiation and spread. This research led to the Wright/Beall system of fire danger rating, which is the foundation of the current CFFDRS. In recognition of his distinguished accomplishments, Herb Beall was posthumously recognized as an Officer of the Order of Canada in 2000.

The 1950s became a decade of optimism, as research efforts were expanded, new laboratories were constructed, and more staff were hired. On the fire research front, the CFS, through the Protection Division in Ottawa, conducted research on fire season severity, fuel type classification, and fire suppression techniques. Regional versions of the Wright/Beall fire danger rating system were developed during this period.

During the 1960s, with increased resources and recognition, the trajectory of the CFS reached its zenith. Regional fire research programs were underway at newly-established research centres, in close cooperation with provincial fire management agencies. This research was closely linked with strong fire research programs at the newly established Forest Fire Research Institute (FFRI) in Ottawa and the PFES. Strong and productive research programs on fire danger rating, fire meteorology, fire behavior, fire ecology, and fire management systems were all well established during this period. The Canadian Forest Fire Weather Index (FWI) System was released in 1972, and regional experimental burning programs continued toward the development of the Canadian Forest Fire Behavior Prediction (FBP) System. During this period the CFS fire research program staffing peaked, with 50 full-time staff (29 researchers) located at the FFRI, PFES, and the regional research laboratories.

Figure 1: Herb Beall documenting two-minute test fire, Val Cartier QC, 1937.

1978 brought restraint and budget cuts that, among other impacts, forced the consolidation of the FFRI with PFES, resulting in major personnel disruptions. During this period the CFS fire research program struggled, but continued regional experimental burning programs, releasing the FBP System in 1989, completing the CFFDRS, which immediately gained acceptance across Canada. At the same time, CFS fire researchers were assuming a leadership role in the development of computerized fire management systems (FMS), working closely with agencies to develop decision support programs to greatly improve operational fire management decision-making across the country. Together the CFFDRS and FMS revolutionized Canadian forest fire management.

The next massive cuts came in 1995, with 40% of the fire research staff from PNFI and the NL laboratory relocated to AB and ON regional centres, while the remaining positions were lost. At that time the federal government shifted research priorities, dictating that federal scientific research should serve the national/international policy needs of the federal government. The CFS was transformed from a science organization to a science-based policy and program organization. The CFS fire research program, while continuing to address Canadian fire priorities such as the next generation CFFDRS, national decision-support system, and hazard mitigation, became increasingly involved in international/interdisciplinary global-scale fire issues. This involvement has been beneficial for Canada, bringing a broader range of scientific expertise to bear on Canadian fire issues. With dwindling funding, CFS fire researchers have also developed self-organized groups with national and international colleagues from governments and academia to address emerging issues such as climate change and fire, carbon budget modelling etc. The International Crown Fire Modelling Experiment (ICFME), conducted in the Northwest Territories between 1995 and 2001, was an example of an interdisciplinary, international experiment organized by CFS fire researchers. ICFME attracted over 100 collaborators from 30 different organizations in 14 countries (Figure 2).

At present, the CFS has approximately 24 person-years devoted to fire research. This includes 14 fire researchers, roughly half the number employed by the CFS in 1970. Forest fire science is no longer a separate research program within the CFS, but fire researchers, seeking collaboration as always, have worked with forest, weather and remote sensing communities to maximize relevance and productivity as much as possible. The current fire research budget is in the range of $2-3 million, with 80-90% of this represented by salaries, leaving very little A-Base funding. As a result, fire scientists have been forced to compete for funding elsewhere, which means collaborating on research with other agencies, whose research agenda may differ from Canadian priorities.

Figure 2. Experimental crown fire, International Crown Fire Modelling Experiment, Northwest Territories, June 30, 1999.

A comparison of current fire research funding levels between Canada and the United States yields some interesting results. The United States Forest Service (USFS), with fire management costs of approximately $2 billion annually, has an annual fire research budget of ~$53 million. Regular USFS A-Base funding has been augmented substantially over the past 10-15 years by funding from the Joint Fire Sciences Program (JFSP) and the National Fire Plan - both initiatives resulting from a recognition that alternate sources of research funding needed to be developed in order to adequately address rising fire impacts.

In the early 1970s, when wildfire management in Canada was costing an average of $200 million annually, the CFS fire research program was at its zenith, addressing a variety of fire research issues with adequate resources. Currently, with fire impacts increasing significantly, fire management costs are approaching $1 billion, CFS fire research program staff levels are at 50% of those in 1970, with research budgets that are effectively non-existent.

Final Thoughts

Given this brief history, it is obvious that the decline in federal fire research capacity over the past four decades can be attributed to a series of concentrated and deliberate choices by successive federal governments to reduce the role of government science across the Canadian physical landscape. The short-sighted approach of reducing in-house governement applied science has been accompanied by a shift toward the promotion of science based on its economic value. It does not appear that this policy will change anytime soon. Even in the unlikely event of a belated recognition that government science is a vital national resource, followed by a commitment to funding this research adequately, it would be impossible to recoup the losses of the past 40 years.

With fire impacts rising, as recognized in the Canadian Wildland Fire Strategy released in 2005 (and largely unfunded to-date), there is an urgent need to consider alternative approaches to funding the crucial fire research necessary to mitigate future Canadian fire impacts. This problem has already been recognized and addressed in both the United States and Australia, where stakeholder government agencies have begun to contribute to national fire research programs. Given the success of these approaches to date, it seems that asking provincial and territorial fire management agencies to contribute funding to ensure that their future fire research needs are addressed is a logical step at this time in Canada. The establishment of a Canadian national fire research institute with funding from stakeholder groups, which fire researchers from government and academia could use to address recognized Canadian fire priorities, is one possibility.

Finally, mention must be made of those that have been working to promote federal forest fire science, including government fire researchers and their managers, over all these years. Their task has been to deal with the politics of keeping CFS forest science research viable in constantly changing times. This examination of the decline of federal fire research is not an indictment of their efforts, but rather an appreciation of those efforts under an increasing weight of political factors, none of which they could influence, let alone control. This is addressed in the following quote:

"*.....forest fire research in this country has followed a winding and uncertain path. The fact that these research efforts and the products evolving from this program are not only critical to Canada today, but are increasingly important internationally, is a tribute to all of Canada's forest fire scientists, past and present*".

...from the Foreword to Feds, Forests, and Fire: a Century of Canadian Forestry Innovation by Richard A. Rajala, 2005. §

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Manitoba Health-Office of Disaster Management's Emerging Work on the Wildland Fire Smoke Portfolio

by Barbara Crumb[1] and Darlene Oshanski[2]
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2. Special Project Coordinator, Office of Disaster Management, Government of Manitoba

Background

Climate change models indicate that conditions will likely become drier and warmer throughout much of Canada. Wildland fires can therefore be expected to increase in Canadian forests on the whole, with the area burned possibly doubling over the next century.

Within the burning boreal forests however there is another hazard, and one which has a much wider impact: dense smoke. Smoke from wildland fires can travel hundreds of kilometers, affecting air quality far from the flames. Smoke rises from a fire in a plume consisting of liquids, gases, and particles of different sizes. The small particles in smoke, and ozone produced by the reaction of sunlight with gases in the plume, can easily move into our lungs and cause health problems in children, the elderly, and people with heart or lung conditions. Wildland fire smoke from as far west as British Columbia travels to Manitoba annually, with significant impact to communities.

Figure 1. Dense smoke from the Cranberry-Portage wildland fire, June 23rd, 2010 (photo source: Manitoba Conservation and Water Stewardship)

The study of wildland fire smoke and its relationship to air quality and human health is a relatively novel and emerging field. Thus, with concern about climate change and climate variability mounting, especially in relation to wildland fire smoke and air quality, new demands are being created for scientific, economic and social information to reduce the remaining uncertainties in these fields. The need is growing exponentially for better understanding around the prediction of the various properties of the atmosphere, smoke plume composition and tracks, together with health impacts and their interactions with socio-economic factors.

Opportunity for Manitoba Health to Pilot Smoke Monitoring Project

As smoke caused by wildland fire events is an important public health issue, involving major risks to the health of people and the environment, Manitoba Health's Office of Disaster Management (ODM) decided to undertake the critical work of improving our understanding of some of the aspects of these scientific and social issues.

Wildland fires occur regularly throughout much of Manitoba during the May to October months, and are primarily caused by human activity (accidental or intentional) or by lightning strikes. Climate change and severe weather events may increase the frequency of wildland fires or increase risk associated with more lightning strikes, dry weather or drought. New research indicates that large areas of Canada are approaching a threshold value where they may experience a rapid increase in the number and size of wildland fires.

Wildland fire smoke composition depends on many factors, including the types of vegetation burned. Pollutants in smoke can include deadly gases like carbon monoxide and many solid and liquid elements often known as particulates or particles. Many, like acrolein, formaldehyde and benzene, are toxic or carcinogenic for humans.

The health impacts from wildland fire smoke include:

- increased mortality
- increased hospital admissions due to respiratory and cardiovascular diseases, and
- increased emergency room and outpatient visits.

Because the effects of wildland fire events can often be nation-wide and/or province-wide, a "natural" disaster such as a wildland fire can quickly evolve into a more complex emergency, by causing voluntary or planned population movement (evacuations), and through effects on health, the economy and overall community wellbeing.

The decision to evacuate residents of a community because of smoke from a wildland fire is complex. Before evacuating, it is important to

Figure 2. View from across the lake, Cranberry-Portage wildland fire, June 23rd, 2010. (photo source: Manitoba Conservation and Water Stewardship)

assess health risks. Evacuations can be disruptive and costly. They should happen only when health benefits outweigh all risks, and scientific evidence about the effects of wildland fire smoke on human health is limited.

Chronology of the Work to Date by Manitoba Health-Office of Disaster Management

In response to the potential evacuation of several northern communities due to the presence of significant wildland fire smoke in the summer of 2010, Manitoba Health identified the need for a guideline that outlined priority groups and air quality triggers for evacuation based on risk to human health. The intent of the guideline was to assist the health sector, communities and other relevant stakeholders in communicating health risks and recommending actions or precautions to protect people from wildland fire smoke exposure.

In the spring of 2012, ODM provided the BlueSky Canada team with the funding that was required to include Saskatchewan, Manitoba and Northern Ontario in the wildland fire smoke plume modelling for the 2012 fire season. ODM worked with the team throughout the 2012 fire season to refine Manitoba's requirements from such a tool. ODM also promoted the importance of having a predictive modelling tool to allow decision makers to begin the message planning

Figure 3. Water Bomber flying over Northern Manitoba (photo source: Manitoba Conservation and Water Stewardship)

process in a proactive manner. ODM was able to do some ground truthing of the tool in July 2012 when the models linked together by BlueSky predicted a large smoke plume would affect a community in Northern Manitoba.

On July 13, 2012, BlueSky models forecast a smoke event with elevated PM2.5 levels in Flin Flon, Manitoba. Manitoba Health issued a Wildland Fire Smoke Advisory suggesting that residents of Flin Flon and surrounding areas take appropriate measures to protect themselves from the smoke. Using the local Manitoba Conservation air quality station, ODM was able to verify that the BlueSky forecast was very accurate in its prediction of elevated levels of PM 2.5. The result of Manitoba Health's advisory was very positive: despite verified increases in PM 2.5, there were no reported increases in hospital admissions for the period of July 14-16. This exercise also demonstrated the need for the development of consistent messaging throughout the province. Therefore, in September of 2012, ODM and Health Canada partnered with Environment Canada (Regional and Ottawa), and Health Canada (Regional) to purchase four TSI Dust Trak II (Desktop) smoke monitors in order to assist with the validation process of smoke forecasts emanating from BlueSky.

In November 2012, ODM was approached by Environment Canada's Prairie and Arctic Storm Prediction Center who were looking into how they could add value to the warning and advisories that they issue. Traditionally most Environment Canada advisories and warnings only focus on weather conditions and do not include other safety messaging, especially from external sources. However, after further consultations, it was decided that the addition of a public health message to the warning or advisory would be well received by the public.

In December 2012, a Geographic Information Student from Red River College was tasked through a co-op program to determine how data collected from the DustTrak monitors can be viewed remotely in "real-time" by decision makers. ODM requires a means to not only visualize and analyze data from these sensors but also to leverage predictive plume modelling to aid in the deployment of these monitors to the field.

Data collected by the DustTrak II monitors will be spatially displayed in MB Health-ODM's Common Operating Picture (COP). COP is an advanced technology integration tool for emergency response management. It facilitates collaborative planning and improves situational awareness. MB-Health-ODM's COP consists of geospatial displays and a common repository of information for decision makers.

MB Health-ODM's plan for the 2013 wildland fire season is as follows:

- MB Health-ODM will monitor BlueSky to identify areas where smoke may be an issue and pose a risk to human health.
- Given the 48 hour lead time, MB Health-ODM will deploy multiple DustTrak's to the identified area.
- With RAELink III software, MB Health-ODM will have a designated individual set up the monitors. Satellite compatible software will allow decision makers to have remote "real-time" access to the particulate (smoke concentration) levels in the field where the monitors have been deployed.
- The particulate levels will then be displayed in MB Health-ODM's Common Operating Picture (COP).

By amalgamating these various tools, ODM hopes to ground truth the smoke forecasts and resulting air quality data, to enhance our capabilities for effective risk management and decision making.

Conclusion

Wildland fires can cause significant health effects for people in the immediate vicinity of the fires, and also to populations farther away (predominantly from the effects of air pollution). With an increasing risk of wildland fire in Manitoba, health care workers such as general practitioners, respiratory and emergency physicians need to understand more about the health risks of wildland fires. Prediction of these events, and increased understanding of the hazards will allow officials to better respond to them. The better prepared Manitoba is for wildland fire smoke events, the more can be done to mitigate against their adverse health effects. §

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BlueSky Canada Part 1 - A Historical Perspective

by Steve Sakiyama

Air Science Specialist, British Columbia Ministry of the Environment

A coffee break is where it all started.

The idea for a Canadian wildfire smoke forecasting system was hatched during a coffee break at the 2007 Workshop on Wildfire Smoke Forecasting in Edmonton. Fortunately those that converged around the snack table happened to have the right combination of expertise, so after some caffeine-fuelled chatting and some scribbles on a napkin - a system concept was created. The idea was to use an existing wildfire smoke forecasting framework developed by the US Forest Service called "BlueSky", and populate it with Canadian models and data. Various names for the Canadian implementation of the BlueSky framework were suggested, among them "BlueSky Eh?" and "BrewSky". For some reason, these were, in the end, not officially adopted.

The coffee break participants formed a steering group that had the right combination of expertise, personalities and resources to bring the idea to reality. These informal partnerships provided financial and in-kind contributions, and were critical in the early development and operation of the system. This informal affiliation remains in place to this day and includes the BC Ministry of Environment, Alberta Environment and Sustainable Resource Management, Natural Resources Canada, the University of British Columbia, US Forest Service, Parks Canada, Environment Canada, Manitoba Health, and the BC Ministry of Forests, Lands and Sustainable Resource Operations.

System development occurred over a period of two years and involved the linking of Canadian wildfire data (hotspot location via satellite detection and fuel estimates provided by the Canadian Wildland Fire Information System) with output from a meteorological forecast model (MM5) produced by the University of British Columbia (UBC). The BlueSky framework, operating on a dedicated server at UBC, combined this information with a dispersion model (HYSPLIT) to produce hourly smoke forecasts up to 48 hours into the future. The results were displayed as animations of the spread and progression of surface smoke concentrations.

Operational wildfire smoke forecasts for British Columbia and Alberta started during the summer of 2010 - a particularly intense wildfire season for these provinces. These forecasts were made available to the public via a BC Ministry of Environment website (http://www.bcairquality.ca, verified 14 August, 2013). During one very smoky day in August, there were over 40,000 hits on the site – indicative of the need for and interest in the information provided by the system. Since its introduction, the system has undergone several improvements – mainly thanks to the expertise of Sonoma Technology Inc, the technical consultant for the BlueSky framework. Although originally intended as a temporary "pilot" project that was to feed the development of a national system, the BlueSky Canada system has continued to operate and improve each year due to in-kind and financial support from agencies that see the value of these forecasts.

Since its unveiling in 2010, the following key events have occurred.

- In 2011, spatial coverage was expanded to cover all of Western Canada as well as the southern parts of the Yukon, Northwest Territories and Nunavut, and the northern parts of the Canada/US border states.
- In 2012, twice daily forecasts were started in order to include the latest hotspot detections in the forecasts. In addition, algorithms to clump nearby hotspots into a single fire were included. Qualitative and quantitative performance evaluations of the forecasts using satellite

imagery and ground based air quality measurements were undertaken by UBC and Alberta Environment and Sustainable Resource Development. Finally, the Canadian BlueSky Playground (based on the US Playground system) was created. This is a tool that allows fire managers to examine smoke-related consequences of a planned prescribed burn in order to inform burn decisions.

- In 2013, the Weather Research and Forecasting meteorological model (WRF) has become the underlying meteorological forecast model, and daily provincial fire reports have been incorporated into the processing of wildfire source data.
- Further development and operation of Canadian implementations of the BlueSky framework, Playground and the development of a version for Eastern Canada were given a boost through funding from the Canadian Safety and Security Program, a federal program led by Research and Development Canada's Centre for Security Science (see following article in this issue).

From its humble "coffee break" beginnings to an evolving operational research project that will continue to develop and mature, the Canadian implementation of the BlueSky framework is an example of how a common vision can drive a group of dedicated partners to use existing models and data that were waiting to be linked together in order to create something new: national wildfire smoke forecasts that serve the needs of Canadians. §

For further information on BlueSky Canada please contact Steve Sakiyama at steve.sakiyama@gov.bc.ca.

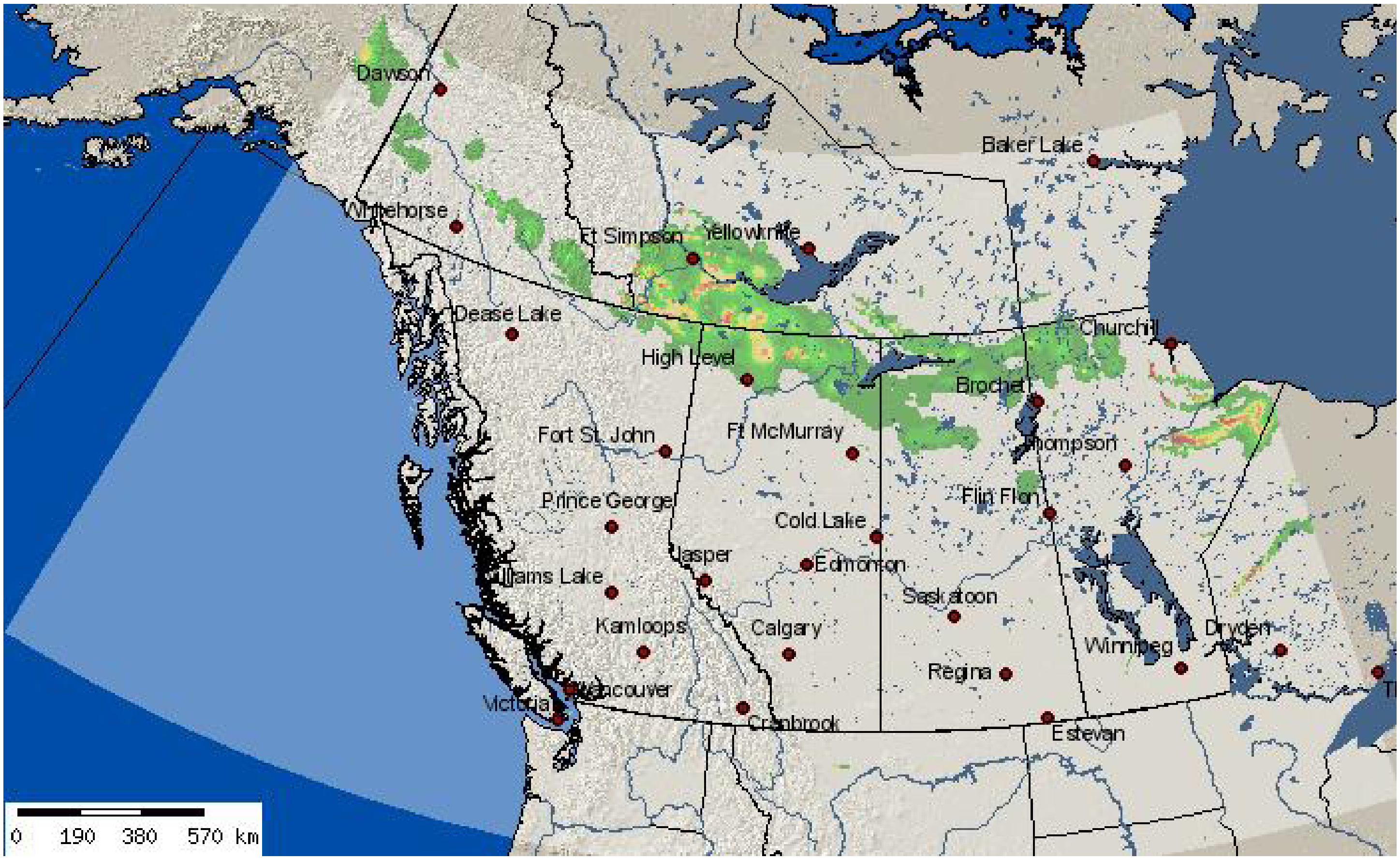

Figure 1. BlueSky Canada Framework – Western Canada domain forecast for 1900 UTC, July 4, 2013.

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BlueSky Canada Part 2 - 2013 CSSP Project

by Kerry Anderson
Northern Forestry Centre, Natural Resources Canada

Centre for Security Science
Centre des sciences pour la sécurité

Canada

Canadian Safety and Security Program

During the Wildland Fire Canada 2012 conference in Kananaskis, the author, a research scientist with the Canadian Forest Service, was approached by management regarding a possible funding opportunity through the Canadian Safety and Security Program (CSSP), a federal program led by Defence Research and Development Canada’s Centre for Security Science. Through discussion, it was decided that the current BlueSky for Western Canada project would be a worthwhile candidate for this funding. Fortunately for the author, many of the team members on the project were also at the conference. An impromptu meeting was held and a synopsis for a potential BlueSky Canada project was hashed out. The synopsis was then submitted to the CSSP.

In December, the synopsis was accepted and a formal proposal was requested. Again, the team deliberated and came up with a full proposal, which was accepted in February of 2013. To say that this was momentous news for the project would be an understatement. Since its original implementation, the BlueSky Canada project had been trickling along with year-to-year funding from provincial agencies. This successful bid had the potential to place the project on a much sounder financial and managerial footing.

CSSP Proposal Summary

[*The following is an adaptation from the project proposal submitted to the CSSP.*]

Output. The intended output of the project will be the creation of national smoke forecast products and tools useful for providing information to the public. These will include:

- BlueSky Canada, a web-based forecast product available to the public
- BlueSky Canada Playground, an interactive smoke forecast tool used by fire management agencies to predict possible smoke emissions and dispersion from prescribed fire operations
- Canadian Forest Fire Emissions Prediction System (CFFEPS), a new module compatible with the Canadian Forest Fire Danger Rating System used to predict smoke plume dynamics and emissions
- webinars and presentations, an outreach program intended to make agencies aware of the BlueSky Canada products and provide an opportunity for their feedback
- a national forum/workshop, providing a forum for scientific exchange with users, possibly leading to a national smoke science group, and
- publications, technical documentation and manuscripts submitted to peer-reviewed journals based on project results.

Project output will better inform the public, health protection agencies and hospitals, fire management agencies and other federal and provincial departments Canada-wide by predicting and assessing the risk of smoke from wildland fires up to 48 hours in advance. The system will provide guidance to health agencies to make informed evacuation decisions and provide public messages in advance on ways to reduce risk due to smoke exposure. The Playground interactive tool will help fire managers plan prescribed burning operations to minimize the public’s exposure to adverse smoke effects.

Scope. The scope of this project is to develop and enhance smoke forecasting systems to better predict smoke occurrence for the protection of health and safety of Canadians. This will affect four main areas of study:

- systems operations, which will focus on improving the existing system to a timely and reliable forecast product
- research and new applications, which will focus on the advancement of knowledge and system versatility, thus improving the science behind the forecast and expanding its uses
- performance and validation, which will focus on assessing the accuracy of the forecasts in terms of spatial extent and concentrations
- outreach and engagement, which will focus on methods of disseminating the product to the public as well as health agencies, emergency measures organizations and fire management agencies. As well, information on user needs and feedback will be obtained.

Linkages. This project is closely linked to the Canadian Wildland Fire Informations System (CWFIS - http://cwfis.cfs.nrcan.gc.ca/, verified 15 August 2013), which supplies much of the related wildland fire location and fire weather information. The project is also tied to the original BlueSky Modelling Framework and the BlueSky Playground System, developed by the USDA’s Forest Service AirFire Team at the Pacific Northwest Research Station in Seattle.

Team. The project team consists of experts from:

- BC Ministry of Environment
- Environment Canada
- Natural Resources Canada
- Parks Canada
- University of British Columbia

Collectively, this team has over 120 years of experience in atmospheric, air quality and fire sciences.

Summary

The BlueSky Canada CSSP project has the potential to significantly advance the science and operational capability of smoke prediction in Canada, thereby enhancing the safety and security of Canadians. Project funding will run from July 2013 to March of 2016. It is hoped that this three year period of stability will allow stakeholders to set the BlueSky Canada project on a firm foundation for the years ahead. §

For more information on BlueSky Canada and the CSSP project, please contact Kerry Anderson at Kerry.Anderson@nrcan-rncan.gc.ca

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BlueSky Canada Part 3 - BlueSky Canada Wildfire Smoke: Status at UBC

by Roland Schigas and Roland Stull
Geophysical Disaster Computational Fluid Dynamics Center
Earth, Ocean & Atmospheric Science Dept.
University of British Columbia

Overview

The University of British Columbia (UBC) began work with the British Columbia Ministry of Environment (BC MoE) on BlueSky wildfire smoke forecasting in 2007, and began the first daily smoke forecasts for BC and Alberta during the 2008 fire season through the support of BC MoE and Alberta Environment. Work has continued and expanded with support from environment and natural-resource ministries in Saskatchewan, Manitoba, and Ontario. The BC MoE hosts forecast graphical output on behalf of participating agencies in the form of animated jpeg sequences and Google Earth kmz files at http://www.bcairquality.ca (verified 14 August 2013) (Fig. 1).

The BlueSky system was originally developed by the US Forest Service and Sonoma Technology Inc. (STI) to utilize meteorological input from the MM5 model (Mesoscale Model version 5) from Penn State University and the US National Center for Atmospheric Research (NCAR). UBC has been running the MM5 model daily in real-time since about 1998, so it was relatively easy to adapt the operational UBC MM5 output for use by the BlueSky system. UBC has been running the BlueSky framework with MM5 input every fire season between 2008 and 2013.

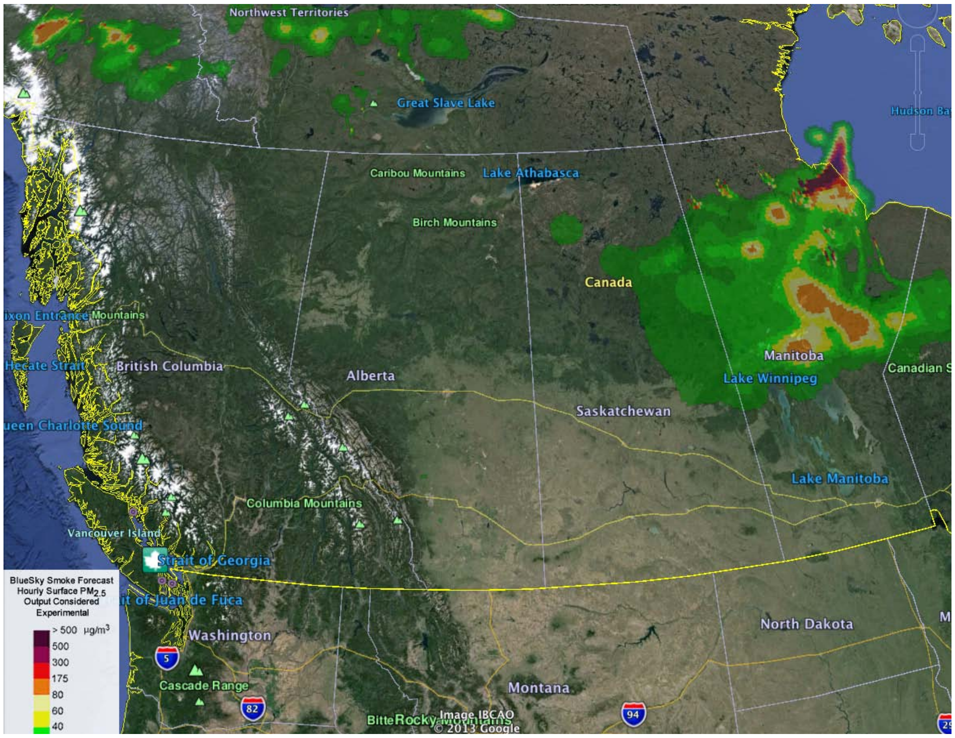

Figure 1. Sample Google Earth depiction of BlueSky framework forecast.

In 2012, the US Forest Service expressed a desire to switch from MM5 to the newer Weather Research and Forecasting (WRF) model, also developed at NCAR. Two important reasons for this change were: (1) the MM5 model has not been supported by NCAR since 2008, and (2) the WRF model takes better advantage of multi-core computers and optimum numerical methods, and is the weather-forecast model that is run by the most users worldwide.

UBC has been running version 3 of the WRF model operationally since 2009, and was running version 2 before 2009. Motivated by the need to generate smoke forecasts earlier each day, UBC moved the WRF model to run on the fastest cores in the UBC cluster, and moved MM5 to older, slower cores. With support from the provincial ministries, UBC began to work with STI in 2012 to modify the BlueSky framework to accept WRF meteorological input. WRF-based BlueSky smoke forecasts became operational in May 2013. During the first half of the 2013 fire season, UBC produced both MM5-based forecasts and WRF-based forecasts in order to evaluate any differences between the two.

Another enhancement implemented for the 2013 fire season was the input of carryover smoke. Every smoke forecast produces a particle dump file, which is then used as input into the next subsequent BlueSky framework run. This results in more realistic forecasts because it models smoke that remains in the atmosphere from a previous forecast.

A final enhancement implemented for the 2013 fire season was an upgrade to the SmartFire2 (SF2) database, which provides the fire input data to the BlueSky framework. Ground reports collected from provincial and territorial agencies and now available through the CWFIS have been incorporated into SF2 as a new data source. SF2 then provides BlueSky with a fire data stream which merges the ground report data with the MODIS hotspot satellite data for more complete fire input for the framework.

In 2013, with national support from CSSP (see previous article in this issue), UBC further expanded operations to produce forecasts covering all of Canada except the Arctic, and the smoke forecasting system being run by UBC became known as BlueSky Canada. UBC now produces twice-daily smoke forecasts for BlueSky Canada-West (covering the provinces west of Ontario) and BlueSky Canada-East (covering the provinces east of Manitoba). Western forecasts are produced at a grid resolution of 12 km with a nested 4 km grid over BC and Alberta, and eastern forecasts are produced at a grid resolution of 36 km (these resolutions depend on WRF meteorology input, as shown in Figure 2). The forecasts for both BlueSky Canada-West and BlueSky Canada-East incorporating all of the 2013 enhancements - WRF meteorology input, carryover smoke input and fire ground report input - are currently being evaluated prior to releasing them to the public.

Plans for additional improvements in mid-2013 include two new BlueSky framework servers, one as a dedicated compute node for Western Canada forecasts and one dedicated to Eastern Canada forecasts. A new, faster high-performance computer (HPC) cluster with over 130 cores will also

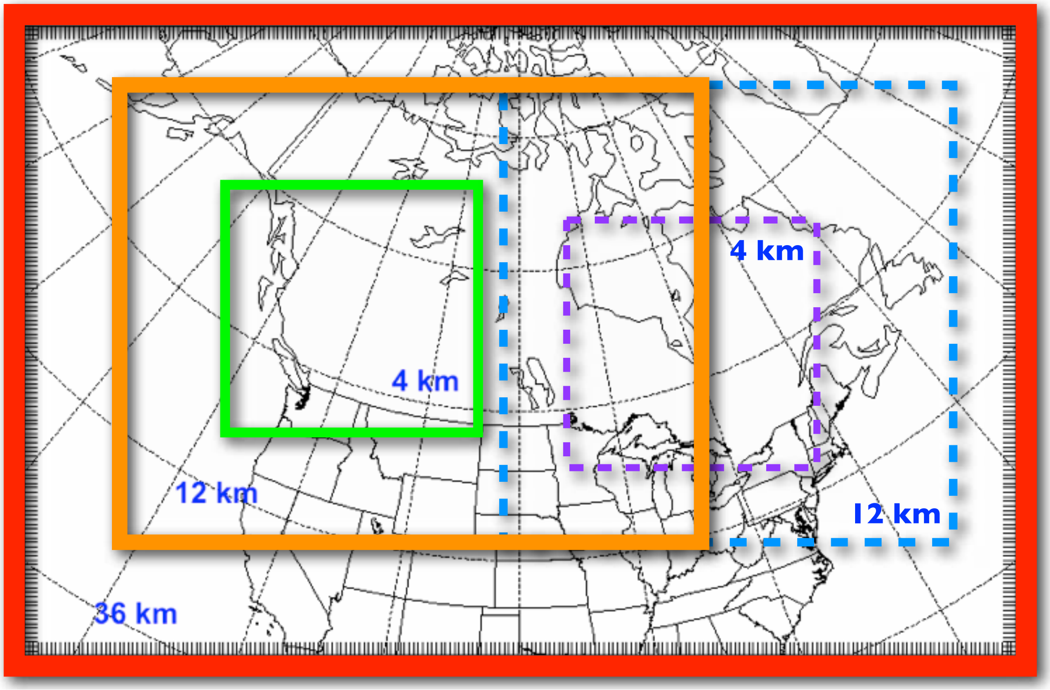

Figure 2. WRF forecast weather domains for the BlueSky Canada framework. Numbers indicate horizontal grid spacings. Dashed lines indicate proposed additional domains. BlueSky domains are slightly smaller than the weather domains, to avoid edge effects.

be purchased in order to meet the goals of further accelerating the delivery of WRF forecasts, producing higher-resolution East forecasts (nested domains with 12 and 4 km grid spacings) and eventually producing meteorology data twice a day as input to the twice-daily BlueSky framework runs. §

For more information on UBC's implementation of BlueSky Canada, contact Roland Stull at rstull@eos.ubc.ca, or Roland Schigas at rschigas@eos.ubc.ca.

Technical summary of the MM5 model settings at UBC

UBC runs MM5 with one overall forecast domain at 108 km resolution and four nested domains (36 km, 12 km, 4 km & 1.3 km), but the highest resolution domain used for BlueSky is 4 km (i.e., the model computes results over a grid of points separated by roughly 4 km). These telescoping domains cover progressively smaller areas with increasing geographic resolution. The domains are also nested so that smaller domains are informed by the previous larger domain (i.e., the 12km domain feeds its data into the 4 km domain). The model is initialized from 00 UTC and 12 UTC North American Mesoscale (NAM) data.

Through the 2012 fire season, UBC ran the MM5 model on a high-performance computer cluster with 96 cores. For runs initialized from the 00 UTC NAM data, MM5 would take 5 hours to run. Its weather output was then automatically fed into the BlueSky framework, yielding BlueSky forecasts between 02:00-06:00 PDT most days. On days with many fires, the BlueSky smoke dispersion module, HYSPLIT, takes longer to run. For the run initialized from 12 UTC, the BlueSky forecast was finished between 14:00-18:00 PDT most days.

1. Grid Set-up and Run Times. The first four domains are run in a two-way nested mode. In this mode, all the domains are run together, and the results at each coarser time step are shared between the domains. Namely, fine-resolution forecast information can feed back to inform the medium and coarser mesh domains. In essence, it is like running all the domains simultaneously. The time steps are the length of time taken in the forecast between calculations. The 108 km domain has a 270 second time step (makes calculations every 4.5 minutes of the forecast). The 36 km has a 90 second time step, the 12 km has a 30 second time step and the 4 km has a 10 second time step. At present, utilizing 100 processors, it takes roughly 7.5 hours to complete a 60-hour forecast, running these first 4 grids simultaneously.

The 108 km domain runs over a 59x77 grid (4,543 points) covering most of North America. The 36 km domain runs over a 121x121 grid (14,641 points) covering the northwest portion of the United States, British Columbia, Alberta, Yukon, and most of Alaska. The 12 km domain runs over a 172x181 grid (31,132 points) covering Washington and parts of the surrounding states, most of British Columbia, and parts of Alberta. The 4 km domain runs over a 154x211 grid (32,494 points) covering Vancouver Island, the southern portion of British Columbia and the northwest portion of Washington. Finally, the 1.3 km domain runs over a 442x442 grid (195,364 points) covering the southern half of Vancouver Island, the Fraser Valley, and parts of northern Washington. The finer grids dominate the total run time, because they have much larger numbers of grid points and take much smaller time steps.

2. Physics Packages. The 108 to 4 km grids run with the following configuration:

- simple ice scheme (Dudhia)
- Grell convective parameterization
- MRF planetary boundary layer scheme
- vertical mixing moist adiabatic in clouds
- ground temperature calculated from surface energy budget
- multi-layer soil thermal diffusion
- single sea-surface temperature calculation
- Carlson-Boland scheme for viscous sub-layer moisture
- snow effects
- Dudhia longwave and shortwave radiation schemes
- horizontal diffusion of perturbation temperature
- linear interpolation of vertical moisture and temperature advection
- potential temperature advection
- 3D Coriolis force
- upper radiative boundary
- relaxation and feedback of boundary conditions
- 30 vertical levels

3. Output. Each of the domains saves forecast data as output. The 108, 36, and 12 km domains generate output for each hour of the forecast (60 output files each for a 60 hour forecast). The 4 km domain generates output every 30 minutes of the forecast (120 files for a 60 hour forecast). These files are put through three stages of post-processing to yield data files that can be used to produce graphics and human-readable text files.

Technical summary of the WRF model settings at UBC as of March 2013

1. Version.

- WRF 3.3.1

2. Mode.

- Eulerian
- non-hydrostatic
- conservative flux form

3. Mapping/projection.
- polar stereographic
- reference latitude = 55.0 (latitude of center-point of the 36 km domain)
- reference longitude = 100.0 (longitude of the center-point of the 36km domain)
- true latitude = 55.0 (the true latitude in the 36 km domain)

4. Dynamics.
- 5th-order advection in the horizontal
- 3rd-order advection in the vertical
- Runge-Kutta 3rd order (RK3) split-explicit time stepping scheme

5. Physics.
- WRF single-moment 5-class microphysics (for clouds & precipitation)
- Kain-Fritsch cumulus (for convection)
- Noah LSM (not the same as Noah-MP) Land Surface Model
- YSU PBL (for boundary layer)
- MM5 surface-layer scheme
- RRTM longwave radiation (previous version of RRTMG)
- Dudhia shortwave radiation

6. Terrain & Land-use.
- USGS 30 arc-second horizontal resolution (roughly 900 m) for digital elevation data
- land use data = 24 USGS categories

7. Nesting.
- 2-way
- coarse-mesh grid = 36 km horiz. grid spacing
- medium-mesh grid = 12 km
- fine-mesh grid = 4 km

8. Domains of each grid.
- see Figure 2, and corner points listed at end of this section

9. Vertical layers.
- No. of vertical layers = 41
- model top at P = 5 kPa (≈ 22 km MSL)

10. Time steps.
- adaptable time steps used, with max of:
    - ◊ del t = 300 s for 36 km grid
    - ◊ del t = 72 s for 12 km grid
    - ◊ del t = 24 s for 4 km grid
- automatically adjusts to smaller timesteps if needed for numerical stability

11. Initialization time.
- 00 UTC every day

12. Forecast duration.
- 60 h (= 2.5 days) from initialization time
- 2.5 day fcst - 0.5 day to produce fcst yields 2 day forecast horizon

13. Output intervals.
- saved to disk every 1 forecast hour

14. Initial and boundary conditions.
- from the 00 UTC NAM 32 km runs (NAM = the operational WRF model run in USA by NCEP)

15. Run schedule.
- note: 00 UTC = 5 pm PDT
- from 5 to 7 pm PDT, wait for obs data to reach NCEP, and for them to run NAM
- from 7 to 8 pm PDT: download NAM data from NCEP via internet
- at 8 pm PDT: start UBC WRF model
- roughly at midnight PDT: finish weather forecast (+/- 0.5 hr, depending on weather)
- note that all grids step forward in time together, because of the 2-way nesting. Hence, all finish at same time

16. Spin up.
- note the first 3 hours for each domain are tossed out, while model is spinning up. Thus, effective initialization times are:
    - ◊ 00 UTC (=5 pm PDT) for 36 km grid
    - ◊ 03 UTC (=8 pm PDT) for 12 km grid
    - ◊ 06 UTC (=11 pm PDT) for 4 km grid.

17. High-performance computing (HPC) cluster at UBC used to make forecasts.
- Old nodes: 128 processors (16 nodes x 8 processors each)
- New nodes: 96 processors (8 nodes x 12 processors each), faster, more memory
- WRF was switched to new nodes June 2013

18. Output produced.
- each BlueSky raw WRF forecast (60h of hourly output) uses ~65 GB of disk space (~50 GB of WRF output and ~15 GB of post-processed initialization data for WRF)

19. Domain location for 36 km WRF runs for BlueSky.
- corner lat/lons (lower-left / upper-left / upper-right / lower-right)
- corner_lats: 25.68863, 51.07824, 51.07825, 25.68863
- corner_lons: -132.5920, -173.4015, -26.59848, -67.40802
- the min/max latitude values are 25.68 degs N and 78.47 degs N.
- the min/max longitude values are -173.40 degs E and -26.598 degs E.

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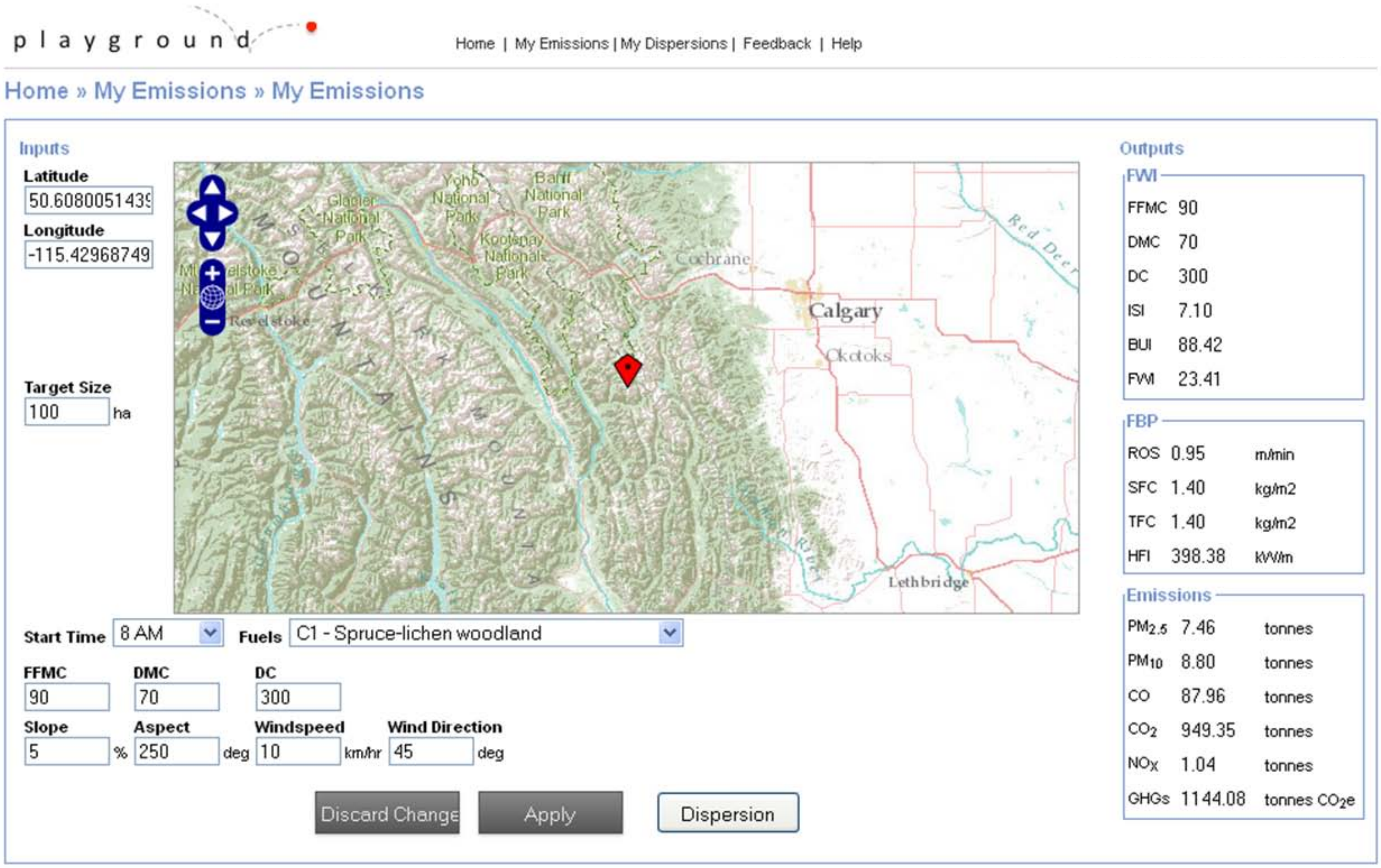
BlueSky Canada Part 4 - Playground: A Tool to Inform Prescribed Burn Decisions (the Canadian Version)

by Jed Cochrane
Fire and Vegetation Specialist,
Parks Canada

In the fall of 2011, a partnership was developed between BC Ministry of Environment, Parks Canada and the Canadian Forest Service to develop a Canadian version of the BlueSky Playground. The key difference between Playground and the Canadian BlueSky Wildfire forecasting system is that Playground allows fire managers to input the details of their planned prescribed fire prior to ignition and to assess the forecast smoke impact areas from the prescribed fire every hour up to two days into the future. Such information helps inform decisions regarding the burn and also provides pre-burn guidance for health agencies regarding public advisories for communities that may be affected by the smoke. The Canadian version of Playground was developed using the American system as a template with modifications to account for differences between the two countries on items such as fuel models, fire behaviour predictions and units of measurement.

BlueSky Playground relies on the input of variables such as fuel type, fire weather indices, forecast weather and planned fire size to generate predictions of fire behaviour prediction, subsequent fire emissions,



Latitude: 50.608005143
Longitude: -115.42968749
Target Size: 100 ha
Start Time: 8 AM
Fuels: C1 - Spruce-lichen woodland
FFMC: 90
DMC: 70
DC: 300
Slope: 5 %
Aspect: 250 deg
Windspeed: 10 km/hr
Wind Direction: 45 deg

FWI
FFMC 90
DMC 70
DC 300
ISI 7.10
BUI 88.42
FWI 23.41

FBP
ROS 0.95 m/min
SFC 1.40 kg/m2
TFC 1.40 kg/m2
HFI 398.38 kW/m

Emissions
$PM_{2.5}$ 7.46 tonnes
PM_{10} 8.80 tonnes
CO 87.96 tonnes
CO_2 949.35 tonnes
NO_x 1.04 tonnes
GHGs 1144.08 tonnes CO_2e

Figure 1. Screenshot of Playground Interface

plume rise and dispersion. Dispersion forecasts are represented as ground concentrations of particulate matter smaller than 2.5 microns in size (PM2.5) and are quantitatively displayed as hourly increments on GoogleEarth maps (Figure 2). Mapping of surface particulate concentrations has proven to be a very powerful tool for communications between fire management agencies and health agencies or interested stakeholders.

The Canadian version of BlueSky Playground became available for the first phase of operational testing during the 2012 prescribed fire season. Improvements were subsequently made to the system and it was tested again in the winter of 2012/2013. For this second phase of testing, representatives from the BC Ministry of Forests, Alberta Environment and Sustainable Resource Development, Saskatchewan Environment, Manitoba Conservation, Ontario Ministry of Natural Resources and Parks Canada were invited to test the system and provide feedback to developers. Given the time of year, this testing was not linked directly to prescribed fire implementation, rather agencies were asked to evaluate usefulness and ease of use. All agencies that responded were of the opinion that the Playground system would be a powerful tool for prescribed fire management and that their agency would be interested in supporting the system in the future.

Thanks to financial assistance from the Canadian Safety and Security Program (CSSP), improvements to the overall BlueSky Canada smoke forecasting system will significantly benefit BlueSky Playground. Planned CSSP projects will provide for improved fuel consumption and plume rise models, as well as dedicated efforts and funds specifically focused on Playground. A key deliverable of this project is operational access to BlueSky Playground for all Canadian agencies. This project will therefore allow full operational testing of the system, including critical feedback on the precision and accuracy of forecasts. §

For further information on BlueSky Canada's version of Playground please contact Jed Cochrane at jed.cochrane@pc.gc.ca, or Steve Sakiyama at steve.sakiyama@gov.bc.ca.

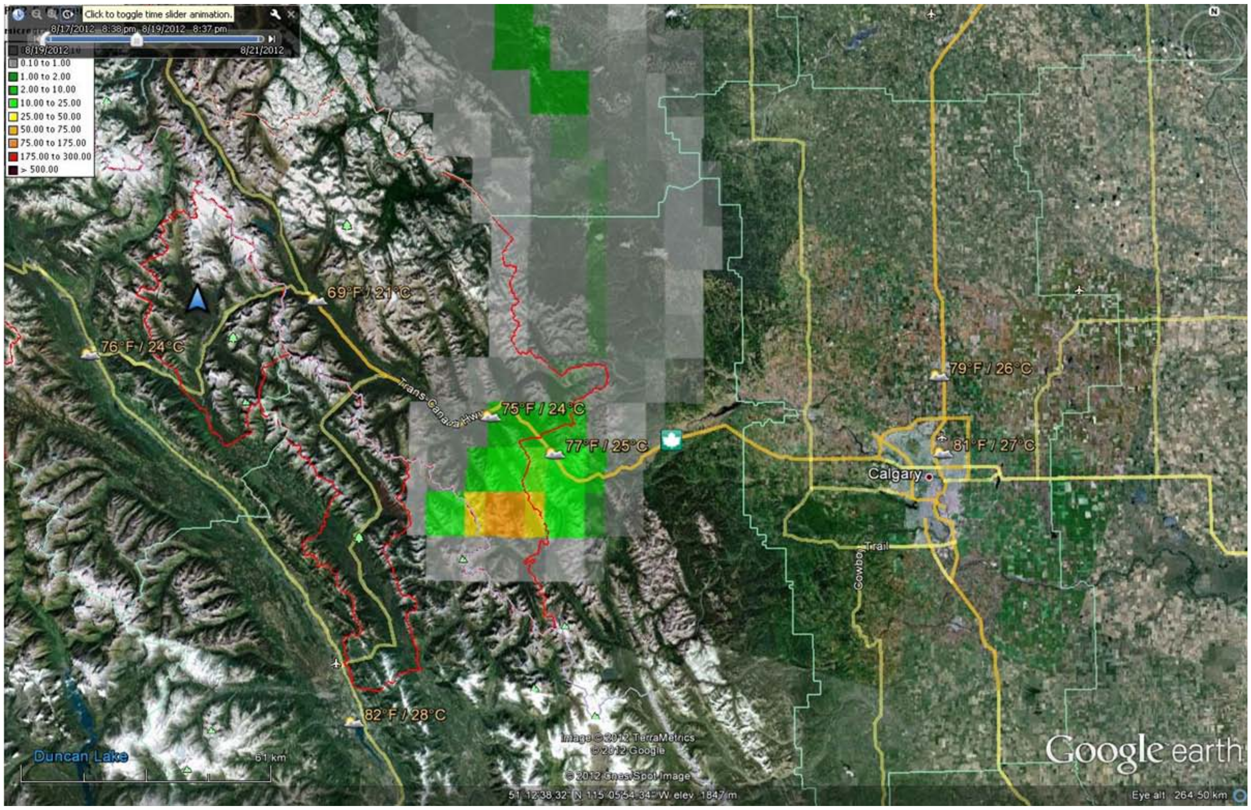


Figure 2. Playground-generated Google Earth depiction of predicted prescribed burn smoke dispersion.

Papers of Interest

Comparison of chemical characteristics of 495 biomass burning plumes intercepted by the NASA DC-8 aircraft during the ARCTAS/CARB-2008 field campaign

Paper published in Atmospheric Chemistry and Physics, 22 December 2011. Authored by A. Hecobian, Z. Liu, C. J. Hennigan, L. G. Huey, J. L. Jimenez, M. J. Cubison, S. Vay, G. S. Diskin, G. W. Sachse, A. Wisthaler, T. Mikoviny, A. J. Weinheimer, J. Liao, D. J. Knapp, P. O. Wennberg, A. Kürten, J. D. Crounse, J. St. Clair, Y. Wang, and R. J. Weber.

The ARCTAS campaign was mounted by NASA in spring and summer of 2008. Based in Fairbanks, Alaska; Cold Lake, Alberta; and Palmdale, California for periods of one to two weeks, the NASA DC-8 aircraft was flown into approximately 500 smoke plumes during the three sub-campaigns, sampling new and aged biomass emissions in environments ranging from pristine boreal forest to areas subject to urban influences. The paper compares measurements made during those campaigns for specific gases and aerosols.

Measuring the composition of smoke plumes is a complicated business, thanks to variations in fuel type, fuel condition and meteorological conditions, fire locations and where along the plume the sampling took place. The authors chose to present their measurements in terms of normalized emission ratios (NEMRs), where a measurement is defined as the ratio of in-plume to outside-plume difference for some species to the in-plume to outside-plume difference of CO. CO is chosen because it is a co-emitted, non-reactive species which experiences the same physical processes as the species in question and can therefore act as a suitable reference point for more reactive species. Primary emission species should tend to decline relative to CO due to deposition and photochemical effects. Secondary gases and aerosols should increase with respect to CO as the plume ages, due to production reactions.

In order to determine if the aircraft was in a smoke plume, the authors defined a plume as an increase in CO or CO_2 concentration twice the size of measurement uncertainty, sustained for 4 seconds or more. The presence of CH_3CN and HCN were then used to indicate whether the source was biomass burning. Wildfire sources were identified using HYSPLIT and FlexPart back-trajectories and forward plume movement estimations using upper air information.

The paper contains results for all three ARCTAS campaigns. The results in Table 1 concentrate on fresh gases and aerosols over boreal regions of Canada and the more aged gases and aerosols over Arctic regions.

Species	Boreal NEMRs (fresh)	Arctic NEMRs (aged)
Gases (ppbv/ppmv except pptv/ppmv for NOx, NOy)		
CH_3CN	0.9	1.1
HCN	2.3	2.3
Benzene	0.4	1.2
Toluene	0.04	
NOx	1477	276
NOy	5805	4473
Ozone	100	300
Aerosols (µg/sm^3 per ppmv)		
NO_3	2	5
SO_4	6	30
NH_4	3	8
Chloride	0.2	0.3
Organics	120	80
WSOC*	22	4
** water soluble organic carbon*		

Table 1. NEMRs for sampled gases and aerosols over Canada's boreal and Arctic regions.

Near-Real-Time global biomass burning emissions product from geostationary satellite constellation (GBBEP-Geo)

Paper published in the Journal of Geophysical Research, July 2012. Authored by Zhang, X., S. Kondragunta, J. Ram, C. Schmidt, and H.-C. Huang.

Fire radiative power (FRP) is proportional to the rate of consumption of biomass by wildfire. FRP data are calculated from information obtained every 15-30 minutes by a constellation of geostationary satellites (NOAA's GOES, Europe's METEOSATs and Japan's MTSAT). Data from these satellites for 2010 was used by the authors to quantify biomass emissions over much of the globe with the exception of significant areas of India, the Middle East and boreal Asia due to lack of geostationary satellite coverage.

WF_ABBA. The algorithm that calculates FRP is the WF_ABBA (wildfire automated biomass burning algorithm) developed by NOAA, the University of Wisconsin and others. Once the FRP value is obtained, emissions can be derived from it using the following formula:

$$Emissions = B \times F \times FRE$$

where B is the biomass burning rate, which is assumed to be .368 kg/MJ for all land surface conditions (Wooster et al., 2005), F is an emission factor for the species of interest (11.07 g/kg for PM2.5 for forests and savannas) which depends on the land cover type and FRE is the Fire Radiative Energy (time integral of instantaneous FRP).

Limitations. Only 41% of fire detections produced by WF_ABBA_V65 are considered to be of high quality, and despite the fact that medium probability detections are also employed, in all only 60%, 27% and 41% of fire detections can successfully be used to generate FRP values from Meteosat, MTSAT and GOES respectively. Observations of fires can be affected by factors such as cloud, forest canopies, heavy smoke and satellite view angle. These limitations result in gaps in the data, which are overcome by the use of smoothed climatological diurnal FRP patterns derived from statistics for each landuse category.

Results from GBBEP-Geo were compared against wildfire emission measurements that used other methodologies, for example, estimates based on burned area and fuel loading. FRP was shown to be a good proxy for those methodologies, with strong correlations. However, magnitudes of emission estimates differed to varying degrees depending on the region being studied and the season, with discrepancies being larger over Africa and smaller over North America. GBBEP-Geo results were also shown to be similar to other FRP-based estimates. In general, the discrepancies between various global satellite-based emissions products can be very significant.

GBBEP-Geo calculations of emissions have a latency of one day, and can therefore be used in near-real-time to assist with operational air quality and atmospheric modelling. The GBBEP-Geo product is expected to be publicly released in May 2014 through NOAA/NESDIS. §