The Canadian Smoke Newsletter

Spring 2008

A newsletter dealing with smoke-related issues across Canada

Welcome to the inaugural issue of ***The Canadian Smoke Newsletter***. This publication is intended to reach and inform an audience interested in issues to do with smoke emitted from wildfires, prescribed burns and agricultural fires. It is a direct follow-on from the Smoke Forecasting Workshop held in Edmonton, Alberta in February of 2007, and is a response to the consensus at the conference which called for the establishment of a Canadian smoke forecasting system. It is my opinion that the strength of the consensus and the depth of support indicates a significant appetite for cooperation among a wide variety of agencies and organizations.

This issue contains a number of informative articles written by people working in academia, wildfire prediction and agricultural burning. I encourage you to emulate their example and submit articles, comments and suggestions. This newsletter will be a success if you choose to contribute. To be clear, this is not a publication by any specific government department or organization; it belongs to the community.

Those of you attending CMOS 2008 in Kelowna this spring may be interested in a special session about the current state of smoke forecasting in Canada. It is tentatively scheduled for Monday evening, May 26, 2008. Please check the conference agenda for final details and times.

Thank you to the all the contributors and colleagues who made this issue possible. A special thanks to Liz Pankratz for the photos in the masthead.

Al Pankratz

Smoke from a prescribed burn, June 7, 2003, Banff National Park. The Banff automatic weather station is in the foreground. (Banff prescribed burn photos throughout this newsletter courtesy Brian Wiens, Environment Canada)

In this issue:

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A Smoke Forecasting System for British Columbia and Alberta: The BlueSky Western Canada Extension Pilot Project

Steve Sakiyama, Sr. Air Quality Science Specialist, BC Ministry of the Environment

The national workshop on smoke forecasting held in Edmonton in February of 2007 identified a need for an operational smoke forecasting system (SFS). Such a system would be an extremely useful tool for weather forecasters, health authorities, researchers, regulatory agencies, all levels of government and the public. It would provide weather forecasters with a way to respond to public and media interest about smoke (related to nuisance, tourism, immediate safety, etc.) It would inform health authorities about present and forecast exposure to smoke in order to warn the public about risks from poor air quality, especially individuals who need to take action to minimize exposure. It would provide health researchers with information on smoke-exposed populations. As well, burn managers and regulatory approval agencies for prescribed burns would have a tool to support decision-making on the smoke implications of burns.

The most promising idea coming out of the workshop was to expand upon an existing SFS operated by the U.S. Forest Service that covers the northwestern U.S. The U.S. domain would be extended northward to include all of British Columbia and Alberta. This Canadian addition to the BlueSky project was informally dubbed "Brewsky".

The BlueSkyRAINS SFS

BlueSkyRAINS is a framework developed by the United States Forest Service (USFS) AirFire Team (Seattle, Washington) that links user-selected computer models of fuel consumption and emissions, fire, weather, and smoke dispersion into one system for predicting the cumulative impacts of smoke from prescribed fires, wildland fires and agricultural fires (using information from the ClearSky agricultural burn simulation system operated by Washington State University).

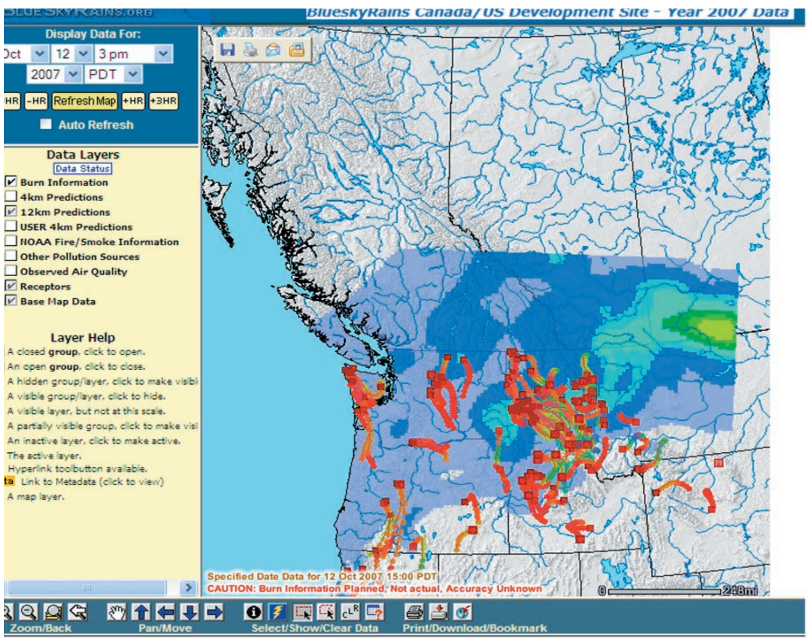

Figure 1. BlueSkyRAINS showing the extended domain

The current spatial domain covers the U.S. Pacific Northwest (all of Washington, Oregon, Idaho and the Western portions of Montana and Wyoming). The system has two compenents: BlueSky and RAINS. BlueSky obtains meteorological forecast fields and burn information every night. The merging of these data with models of fuel consumption and emission along with dispersion and trajectory models, results in a regional forecast of smoke concentrations for a two day period. RAINS is the display portion of the system (Rapid Access INformation System) and is based on Geographical Information System (GIS) display technology. It provides a web-based window where users can overlay data of interest (topography, census data, parks, etc.), zoom and pan, and query a database for additional data regarding the various layers.

In the sample output page shown here, fires are indicated by red squares and the resulting smoke plume forecast trajectories are shown by red/orange lines. Note that the ground level particulate matter (PM2.5) concentration output (indicated by the shaded blue colours) is cut off at the northern edge of the current U.S. domain. The goal of the pilot project is to produce and display similar fire and smoke output for all of

BC and Alberta using Canadian supplied data.

The merging of BlueSky with RAINS provides the latest available science in smoke dispersion in the form of an interactive web-based regional forecast of smoke plume trajectories and concentrations overlaid on a variety of map displays. In this way, any users including members of the public, regulators, the medical community, forecasters or burn response managers can view the potential smoke impacts from regional burning activities. Further details regarding BlueSky, its operation and components, can be found at **http://www.fs.fed.us/bluesky**.

BlueSkyRAINS for British Columbia and Alberta – A Pilot Project

Extending the BlueskyRAINS system into BC and Alberta so that wildfire smoke can be forecast in this domain will require a coordinated effort to develop the required information (geophysical, fire emissions, meteorology) in formats required by BlueSky. In addition, the USFS AirFire Team must be willing to incorporate this extra information in their existing system.

A working group to shepherd the pilot project along was initiated with representatives from Alberta Environment, Alberta Sustainable Resource Develpopement, BC Ministry of Environment, BC Ministry of Forests, Environment Canada (Prairie and Northern Region, and Pacific and Yukon Region), Natural Resources Canada, University of British Columbia (Occupational Health, Atmosphere and Ocean Sciences) and the United States Forest Service (AirFire Group). All agreed that building on the current BlueSkyRAINS system would offer a number of advantages including working with a system that had already been tested in actual use, commonality with the U.S. (long term plans for BlueskyRAINS include its use across the U.S.), the ability to extend the system elsewhere in Canada without inventing a new system from scratch, and the application of a common system to determine the impacts of smoke from fires outside North America.

Forest Fire Emissions

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In order to determine trajectories and concentrations, BlueSky requires fire location and corresponding daily fuel consumption. The latter parameter requires both an estimate of the daily area burned, and fuel loading (or the fuel consumed should a fire occur) for that area.

The daily burn area can be obtained by ground or flight observations taken at the fire or through remote sensing. Daily ground or flight observations of area burned are rare – obtaining burn area via remote sensing is more typical. The Northern Forestry Centre of Natural Resources Canada in collaboration with the Canadian Space Agency has over the years developed Fire M3 – a MODIS Satellite based system that uses “hotspot” detects with perimeter polygons and other algorithms to estimate fire size. Testing of this approach involving actual measured burn areas using infrared imaging and daily ground observations for select BC fires that occurred during for the 2003 fire season is currently underway. In addition to this, a simpler MODIS-based approach developed at UBC is also available for testing.

Fuel load estimates for BC are already calculated by the Spatial Fire Management System (SFMS). The SFMS uses a spatial inventory of forest fuel types and fire weather index values to continuously estimate the fuel loading at a 2 km grid resolution across BC. This figure, combined with an estimate of the daily area burned will link the location of each wildfire with a corresponding daily fuel consumption. This information will be transferred to the Seattle BlueSky RAINS center for further processing to obtain emission rates and heat released (for plume rise estimates).

Meteorology

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BlueSky currently uses forecast meteorology generated by the MM5 model produced by the University of Washington. After some exploration, the Canadian workgroup settled on MM5 model output that was already being produced at the University of British Columbia (Atmospheric and Ocean Sciences). However, the original UBC 4 km domain covered only a portion of that province. Through support from the BC Ministry of the Environment and Alberta Environment, an expansion of this domain to cover all of BC and Alberta was undertaken. The domain expansion and corresponding MM5 output for the complete domain at 4 km grid resolution was successfully completed at the end of 2007. An example of the output is shown in Figure 2 on the following page.

Once the MM5 domain expansion became a reality, it was evident that the initial plan of transferring the MM5 files to the BlueSkyRAINS system located on the AirFire Team servers in Seattle was impractical due to long data transfer times. This bottleneck threatened to introduce long delays in generating forecast smoke trajectories and concentrations. The solution was to eliminate the data transfer to Seattle by using a using a machine already loaded with BlueSky located at UBC. At the time of writing, the USFS has completed hardware and software configuration of a computer loaded with BlueSky and is ready to send it on loan to UBC. Testing with the UBC generated MM5 output is expected in March.

Trajectory, Concentration Calculations and Output Display (RAINS) for BC and Alberta

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BlueSky uses the emissions and forecast meteorological model output as input to CALPUFF or HYSPLIT to produce forecast trajectories of the smoke plumes and the respective PM2.5 concentrations. The output is displayed through the RAINS system.

With support from UBC (Occupational Hygiene) and Alberta Environment, RAINS for BC and Alberta was established on the existing USFS AirFire Team servers in Seattle by expanding the current RAINS mapping application to include the new domain. The new development website has the same look and features as the original BlueSkyRAINS display. Further work was completed on separating the new

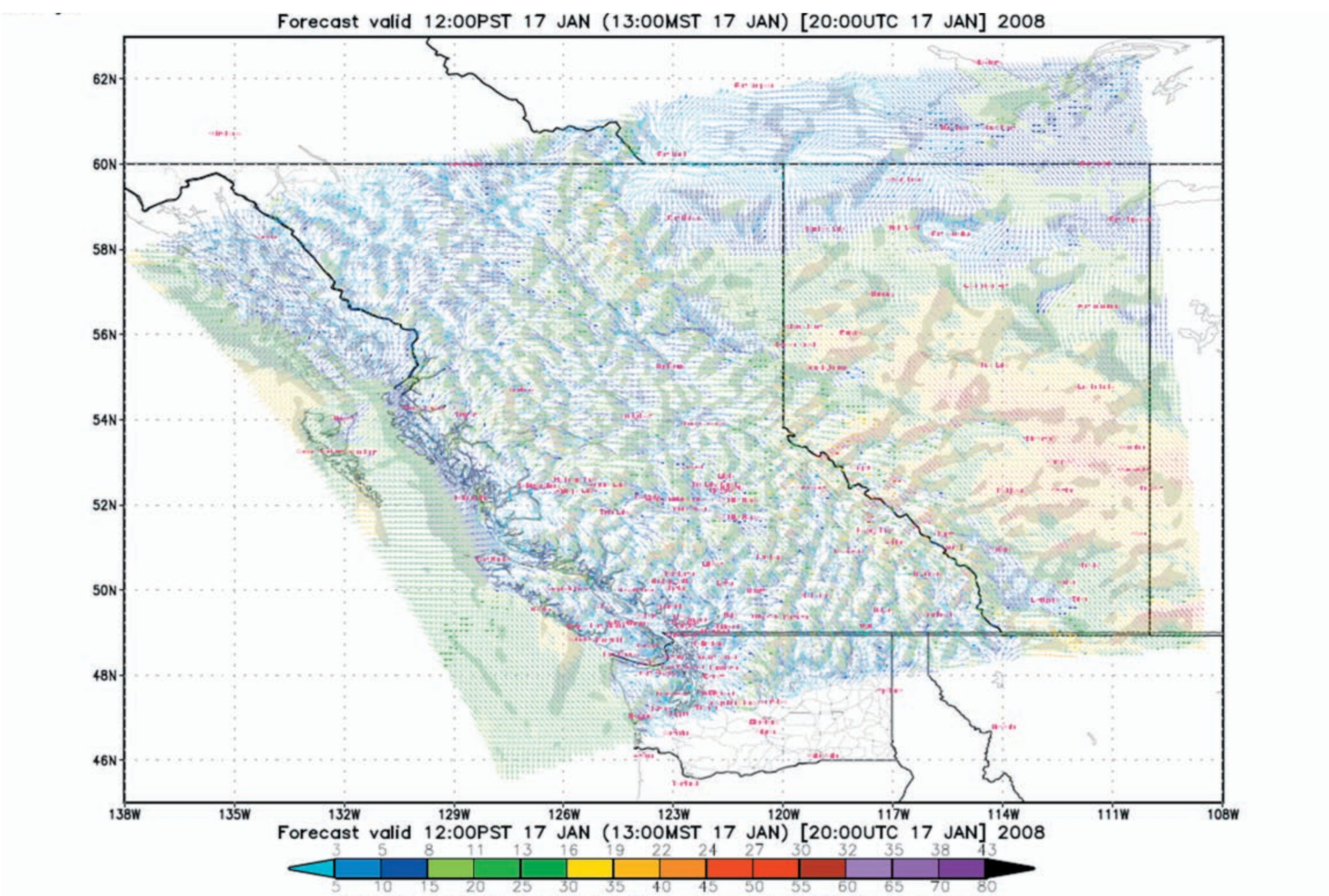

FIGURE 2. BlueSky Western Canada domain - image courtesy UBC Geophysical Disaster Computational Fluid Dynamics Centre

BC/Alberta RAINS domain package from the current RAINS display in order to facilitate eventual transfer of the system to a permanent home on a Canadian server.

Summary: A Series of Technical and Partner Linkages

The complete system is illustrated in the following flowchart. Over the next few months, development of each of the components in the flowchart will continue, and linkages will be established and tested. New challenges will arise, but the workgroup is optimistic that the momentum and progress achieved through the coordinated efforts of our many partners will result in an opportunity to test the system during the 2008 fire season.

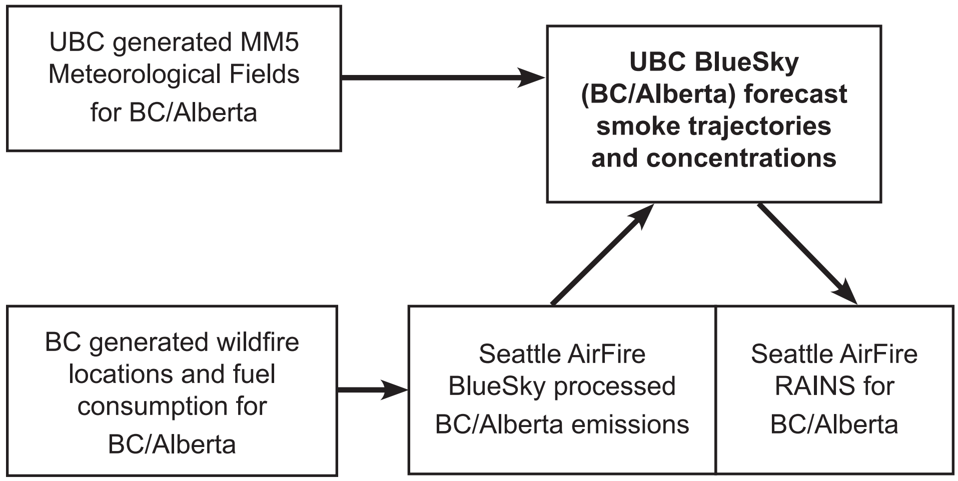

Figure 3. BlueSky Western Canada Extension Pilot: Conceptual Approach

The progress achieved during the evolution of this pilot project could not have occurred without the contribution and flexibility of the partners involved. This multi-faceted effort has required the background and insights of a variety of disciplines and the financial support of different groups to carry the pilot through to reality. The future of the system and smoke forecasting in general will depend on long term support from Canadian agencies. §

Another prescribed burn lit in Banff National Park on 6 June, 2003. The burn was carried out by Parks Canada staff. Fires were lit at several locations along the Lake Minnewanka valley that day. More photos appear on pages 10, 13 and 14.

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Fire Smoke and Human Health

by Sarah Henderson and Michael Brauer, School of Environmental Health, University of British Columbia

Smoke from vegetation fires can elevate ambient concentrations of gases and aerosols at local, regional and global scales. Relative to other potentially-harmful pollutants in fire smoke, increases in fine particulate matter are the most pronounced and persistent. The majority of particles are less than 2.5 micrometers in diameter, which means they remain suspended for a long time (days – weeks), easily penetrate into indoor environments, and can be inhaled deep into the human lung. Extensive epidemiologic literature implicates particles of this size in a wide range of cardiovascular, respiratory and reproductive health effects. Such studies have found no evidence of a "safe" elevation threshold, suggesting that any increase in fine particulate matter is associated with some increased risk to public health.

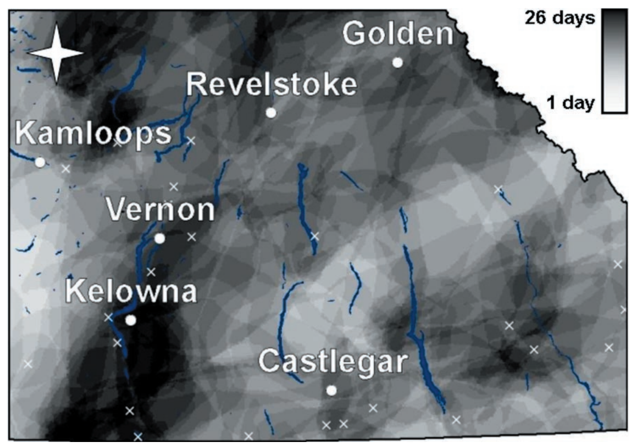

Figure 1. Number of days that forest fire smoke covered southeastern British Columbia between July 1st and September 30th, 2003. Plumes were hand-traced from satellite images by researchers at the US National Oceanic and Atmospheric Administration.[2] Continuous particulate matter samplers were located in Kamloops, Vernon, Kelowna, Golden, Revelstoke and Castlegar (white dots), but other populated areas (white crosses) were obviously impacted.

During the summer of 2003 large fires in southeastern British Columbia resulted in multiple episodes of reduced air quality at all locations where particulate matter is monitored. Figure 1 uses tracings from satellite images to show the number of days the whole region spent under smoke plumes between July 1st and September 30th, 2003. Moore and colleagues[1] assessed the impact of elevated particulate matter concentrations during this period on outpatient physician visits around the cities of Kelowna and Kamloops. Figure 2 shows that weekly visits for respiratory disease increased 45–80% (relative to the 10 year average) in Kelowna, where the highest particulate concentrations were measured.

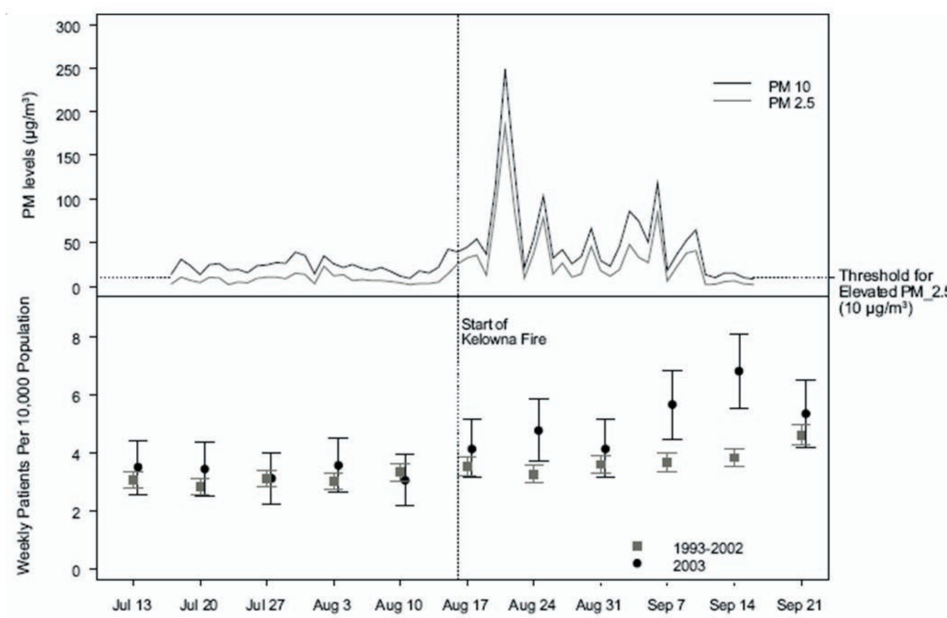

Figure 2. Daily time-weighted averages for ambient particulate matter (top panel) and weekly rates of physician visits (and 95% confidence interval) for respiratory diseases (bottom panel) for Kelowna. (Reprinted with permission of the Canadian Public Health Association. Originally published in Moore et al, 2006.[1])

No increase in respiratory visits was observed in Kamloops, and no association between smoke-related particulate matter and cardiovascular diseases was found in either city.

Other studies report similar results. Southern California also experienced a record-setting fire season in 2003, and particulate matter concentrations were 10 to 20 times higher than normal for several consecutive days. Künzli and colleagues[3] found that children who could detect the smell of fire smoke indoors on six or more days had increased risk of eye irritation, respiratory symptoms, use of respiratory medication, physician visits and school absences. The "smoke smell" indicator was used because many air quality monitors were overloaded with particulate matter during the episode. A 2002 fire near Denver resulted in moderate elevation of particulate matter concentrations for two days. Sutherland and colleagues[4] reported that 21 patients with Chronic Obstructive Pulmonary Disease (COPD) experienced a significant increase in respiratory symptoms during this period. Further analysis on the same smoke episode did not detect any relationship with increased mortality in the Denver metropolitan area. The 2001 fire near Chisholm, Alberta was used as a case study to assess the economic impacts of smoke-related health effects. Rittmaster and colleagues[5] used monitoring data and a simple dispersion model to simulate how fire smoke affected air quality in Edmonton and Red Deer. Using Health Canada's and Environment Canada's Air Quality Valuation Model, the economic impacts of resulting health effects were estimated at $10-12 million over two days. Over 90% of this estimate was attributed to increased mortality. While there is strong evidence of a relationship between urban particulate matter and mortality, this has yet to be demonstrated in the fire smoke literature.

A recent review of 17 fire smoke studies[6] concludes there is a generally-consistent relationship between smoke exposure and increased risk of respiratory symptoms, hospital admissions, emergency room visits, decreased lung function, and other measures of compromised health. Furthermore, the review concludes that we have little evidence to suggest that particulate matter from vegetation fire smoke elicits different impacts than particulate matter from other sources. Unlike most other sources, however, we cannot predict when and where wildfires will burn and who the resulting pollution will impact. Smoke forecasting tools like BlueSky RAINS[7] and the Fire Hazard Mapping System[2] can be used in combination with news reports and the local air quality index to help individuals and public health professionals prepare for smoke episodes. The health risks associated with fire smoke can be reduced by limiting exposure to smoke-related particulate matter. Children, older adults, and people with preexisting heart and lung conditions may be affected by small elevations and they need special consideration. The US Environmental Protection Agency[8] advises that vigorous outdoor activity should be avoided, and indoor environments should be protected from smoke penetration by closing doors and windows (if not too hot) and using air conditioners. Studies have shown that properly-sized HEPA air cleaners can effectively remove fine particulate matter from indoor air, but ionic cleaners that generate ozone are not recommended. In situations where indoor smoke is unavoidable, relocation to a more protected environment should be considered. Use of personal dust masks is not recommended because they are not practical for long term protection from smoke particles and they can complicate breathing.

Over the past year a team of people from Alberta, British Columbia and the US Forest Service has been collaborating to launch a pilot of the BlueSky RAINS smoke forecasting system for western Canada.[9] Although we expect a national framework to be operational in the future, we believe that this interim step can help to protect the health of western Canadians during upcoming fire seasons. For more information on forest fires, smoke forecasting and public health please refer to **www.firesmoke.ubc.ca**. §

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1. Moore D, et al., Population Health Effects of air quality changes due to Forest Fires in British Columbia in 2003: Estimates from Physician-Visit Billing Data. Canadian Journal of Public Health, 2006. 97(2): p. 105-108.

2. http://www.firedetect.noaa.gov/viewer.htm.

3. Künzli N, et al., Health effects of the 2003 Southern California wildfires on children. American Journal of Respiratory and Critical Care Medicine, 2006. 174: p. 1221-1228.

4. Sutherland ER, et al., Wildfire smoke and respiratory symptoms in patients with chronic obstructive pulmonary disease. Journal of Allergy and Clinical Immunology, 2005. 115: p. 420-422.

5. Rittmaster R, et al., Economic analysis of health effects from forest fires. Canadian Journal of Forest Research, 2006. 36: p. 868-877.

6. Naeher LP, et al., Woodsmoke health effects: A review. Inhalation Toxicology, 2007. 19: p. 67-106.

7. http://www.blueskyrains.org/.

8. http://www.epa.gov/airnow//smoke/Smoke2003final.pdf.

9. http://marlin.airfire.org/website/bluecvs/viewer.htm.

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Agricultural Burning in Manitoba

by Andrew Nadler, Agricultural Meteorologist, Manitoba Agriculture, Food and Rural Initiatives

Manitoba's Red River Valley has some of the richest farmland in the world, enabling many agricultural crops, traditionally cereals, to flourish. With high grain yield comes abundant production of straw, a byproduct that farmers must contend with. The preferred method to manage excess straw is to incorporate the material back into the soil to restore valuable organic matter and nutrients which promote overall soil health. However, when residue production is excessive, straw can clog tillage and seeding equipment and slow the rate of soil warming in spring, which may then delay seeding and emergence, thus lowering yields. This problem is particularly pronounced in heavier soils with high clay content that tend to remain cooler in the spring, slowing the rate of decomposition. In such cases, farmers must find a way to minimize the problems that may be caused by excess straw.

Figure 1. Stubble burning near Bratts Lake, SK. (courtesy Pat Kyle, Environment Canada)

One method of managing excess straw is to remove it. Straw may be baled and used for livestock bedding if there are livestock operations nearby. Since straw is bulky, expensive to transport, and widely available, demand is limited and therefore baling may not be an option. Until 2004, prior to the closing of Manitoba's strawboard plant, approximately 100,000 tons of straw per year were used to produce engineered composite panels. When the plant closed, a large straw market was eliminated. With a limited demand for straw, many farmers are compelled to employ a traditional method of reducing the amount of excess residues – they burn it.

Smoke from the combustion of organic materials consists mainly of small suspended particulate matter (2.5 microns) that has a relatively long residence time in the atmosphere and the ability to penetrate into the deepest part of the lungs when inhaled. The effects of burning can be problematic for sufferers of chronic lung conditions such as asthma, emphysema, or chronic obstructive pulmonary disease (COPD) who know that the fall harvest season may bring about severe breathing difficulties and possibly visits to the emergency room. Even for those with healthy lungs, the fine particles which are the main constituents of smoke can irritate the eyes, nose, and throat, resulting in coughing, wheezing, shortness of breath, nausea, and overall physical discomfort. Children and the elderly are particularly vulnerable. Unfortunately, smoke does not respect property or neighborhood boundaries and the effects of smoke may be felt great distances from the source. Closing doors and windows does little to block the smell since smoke can enter a home through the smallest cracks and holes or through ventilation systems. The social and economic impacts can also be significant due to increased doctor visits and increased absenteeism from school and work. In severe cases, thick smoke can be a safety hazard on roads and highways due to reduced visibility.

Prior to 1993, farmers in Manitoba were able to burn crop residue without restrictions. Following a damp and late harvest season in 1992, burning was excessive resulting in the persistence of heavy smoke throughout southern Manitoba and the declaration of a state-of-emergency. Based on the recommendations from the newly appointed Manitoba Crop Residue Burning Advisory Committee, a Controlled Burning Program was implemented. The Committee is made up of stakeholders who provide guidance to the government in the management of agricultural burning. The board consists of several government departments, farmers, and concerned citizens. Starting in 1993, a regulation was introduced to minimize the negative effects of smoke from crop residue burning while still allowing farmers to do some burning when necessary.

The first component of the new regulation was to prohibit nighttime burning year-round. During the night, the mixing height is at its shallowest, often less than 100 meters, and temperature inversions can develop whereby the air aloft is warmer than the air near the ground. These stable atmospheric conditions limit the rise of smoke thus causing it to be trapped near the ground rather than dispersing vertically. Calm winds during the night can result in heavy accumulations of smoke in an area. The mixing height is normally highest during the early to mid-afternoon. Daytime burning of dry residues therefore can result in smoke that can rise well over 1000 meters. As the sun begins to set, dispersion normally degrades rapidly.

A second component to the regulation applies to the typical fall harvest season. From August 1 through November 15, the burning of crop residue is prohibited unless an authorization to burn has been issued for that day by the province. Throughout this period, personnel from Manitoba Agriculture, Food and Rural Initiatives assess current and forecast parameters such as the height of the planetary boundary layer, the speed and direction of surface and upper-level winds and the ventilation coefficient to determine when and where burning will be allowed on that day. In addition to observing overall dispersion characteristics, personnel can also restrict burning in regions upwind of major population centres such as Winnipeg to minimize the risk of smoke entering the city. Good weather data and accurate forecasts are the key to providing safe authorizations.

Another consideration is the cumulative effect of multiple fires burning at the same time. In this case, decision makers must take into account the volume of smoke being generated. Even during conditions with good atmospheric dispersion, too much smoke may still saturate a region.

Since the program began, it has been reasonably successful at controlling smoke from crop residue burning and reducing the number of smoke-related problems. Farmers have had the flexibility to burn during periods when smoke is least likely to have negative effects downwind. However, there have been some challenges. As with any regulation, compliance is perhaps the most important aspect, particularly when a very small amount of non-compliance can have huge consequences. The vast majority of farmers have accepted these restrictions and realize their purpose of ensuring that crop residue burning is not completely banned due to public pressure. Still, whether due to ignorance, convenience, or necessity, some illegal burning occurs despite the risk of significant fines. This burning, which takes place at night or on days when unfavorable atmospheric conditions have prompted the province to prohibit burning, tends to cause the most serious impacts.

The consequences of illegal burning were particularly evident in the fall of 2007 when the high-yielding crop resulted in above average production of straw. While harvest occurred early in the season leaving ample time for fall field work, the abundance of straw resulted in many farmers deciding to burn. As result of the sheer magnitude of burning that took place, combined with some illegal burning during times of poor atmospheric dispersion, stubble burning was the cause of numerous complaints related to air quality and highway safety. During the month of September, several motor vehicle accidents and road closures were attributed to stubble burning and on one occasion a large part of Winnipeg was engulfed in smoke for an entire night. These events led to severe restrictions on burning for the remainder of the season. The restrictions on burning are likely to continue.

When urban populations are in close proximity to agricultural activities, friction may occur. Livestock operations can emit unpleasant odours. Pesticide drift into non-target areas can result in damage to vegetation. Southern Manitoba is in a unique situation whereby very fertile and high-yielding lands with heavy soils are located to the south and to the west of Winnipeg, Manitoba's largest centre with a population of about 650,000 – over half that of the entire province. While urban zoning bylaws may prevent heavy industrial development near residential zones, in largely agricultural areas such as the prairies where crops make up the majority of the land base, a distinct separation between agriculture and residential areas is neither feasible nor desirable. For this reason, activities that can adversely affect populations over large areas must be carefully managed. As long as any agricultural burning occurs, safeguards must be in place to minimize the risk to society. The crop residue burning program was designed with the intent of enabling both agriculture and the rest of society to coexist and to minimize adverse interaction. §

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Where There's Fire, There's Smoke

by Kerry Anderson, Fire Research Officer, Canadian Forest Service, Natural Resources Canada

Last summer saw a successful test of operational fire growth prediction by the Canadian Forest Service (CFS) and Parks Canada. Using remotely-sensed fire information (hotspots) and forecast weather from Environment Canada, the Wildland Fire Information Systems Group at the CFS was able to regularly produce fire-growth predictions. These predictions were then used by Parks Canada to make decisions on fire suppression tactics.

Fires 07WB001 and 07WB002 both started on May 27, 2007 as a result of lightning along a stalled cold front. These fires, referred to as the Boyer Rapids complex, burned on opposite sides of the Peace River in Wood Buffalo National Park. Suppression activities were limited to the southeast and southwest corners of the fires where communities were threatened; the remainder of the fires were left to grow naturally.

In early June, Parks Canada enlisted the help of the Wildland Fire Information Systems Group at the CFS. The group makes use of remotely-sensed fire information from MODIS and NOAA/AVHRR, and this information, generally referred to as hotspot data, was used to define the currently active zone of the fire. A simple 16-point growth model (referred to as the Bigfoot Fire Growth Model) was used together with numerical weather model data to predict the spread of the complex. Results were compiled and displayed on a web page (Figure 1). Updated information was made available to the Park fire command team by 9:30 am each morning. By August 6th, fire 07WB001 on the south side of the river reached its final size of 89,204 ha, while 07WB002 reached 125,208 ha, for a combined size of 214,412 ha.

Much has been learned from this operational modelling endeavour. One challenge was posed by cloud cover which intermittently prevented accurate fire mapping. Additionally, fuels data provided by the Park did not account for recent burns over the last two years. CFS researchers are working on ways to minimize such impacts in the future.

What relevance does this test have for smoke forecasting? It is our contention that similar fire growth modelling efforts can be applied to smoke emissions from large fires. In addition to rate of spread (ROS) which is routinely used by fire-growth models, the Canadian Forest Fire Behaviour Prediction (FBP) system predicts fuel consumption and fire intensity. Fuel consumption directly relates to the amount of smoke emitted from the fire while fire intensity relates to buoyancy and therefore plume height. The Canadian Forest Service plans to embark on cooperative projects with Environment Canada within which it will apply lessons learned during the 2007 fire season. §

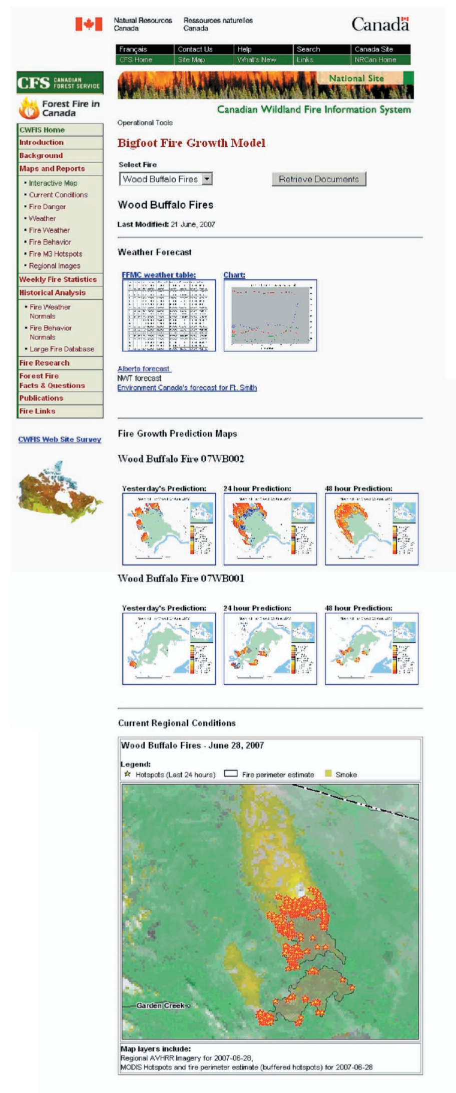
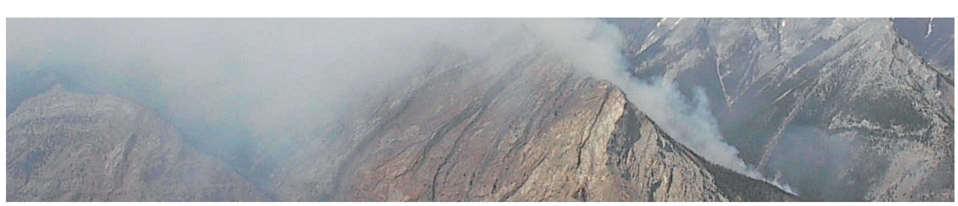


Figure 1. Bigfoot web-page showing fire growth predictions and additional relevant information such as forecast weather and satellite imagery



Smoke creeps over a ridge at Lake Minnewanka.

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Biomass burning plumes observed with the Dalhousie Raman Lidar

by Thomas J. Duck[1], Lucy Crawford[1], Jonathan Doyle[1], Steve Beauchamp[2], and Ray Hoff[3]

1. Department of Physics and Atmospheric Science, Dalhousie University, Halifax

2. Air Quality Science, Meteorological Service of Canada, Halifax

3. University of Maryland Baltimore County

The Dalhousie Raman Lidar has obtained profiles of aerosols above Halifax, Nova Scotia, during each summer since 2004. The instrument, also known as a laser radar, transmits pulses of intense green laser light (532 nm wavelength) into the sky and detects backscattered photons from aerosols and molecules using a telescope and sensitive photomultiplier detectors. An example measurement from the lidar that was obtained during the summer of 2007 is shown in Figure 1.

The measurements are being collected as part of a CFCAS*-sponsored study between Dalhousie University and the Meteorological Service of Canada (MSC), with collaboration from Nova Scotia Environment and Labour. The lidar is operated in fair sky conditions (no heavy cloud), and is run intensively during July and August - key months for observing smoke plumes transported from distant sources. The lidar measurements are complemented by a co-located aerosol sun photometer which contributes to the AERONET and AEROCAN networks. Because Halifax is on the East Coast of North America, biomass burning emissions from fires to the west are frequently observed. During the summer of 2007, smoke plumes from Quebec, Northwest Territories, Montana, Utah, and Mongolia were all in evidence.

The key information provided uniquely by a lidar system is how plume altitudes vary with time. In contrast, most other instruments (e.g. sun photometers) provide column measurements such as optical depth. The Dalhousie Raman Lidar profiles aerosols from the ground up to about 15 km altitude in the lower stratosphere. Understanding the vertical distribution of aerosols from pyroconvection is essential for identifying their ultimate impact on clouds and climate. The height of aerosol injection into the atmosphere has consequences for their transport and mixing, and is essential knowledge for understanding ground-level impacts.

Figure 1 shows a particularly thick plume measured by the Dalhousie Raman Lidar in the mid-troposphere during 15 August 2007. Aerosols

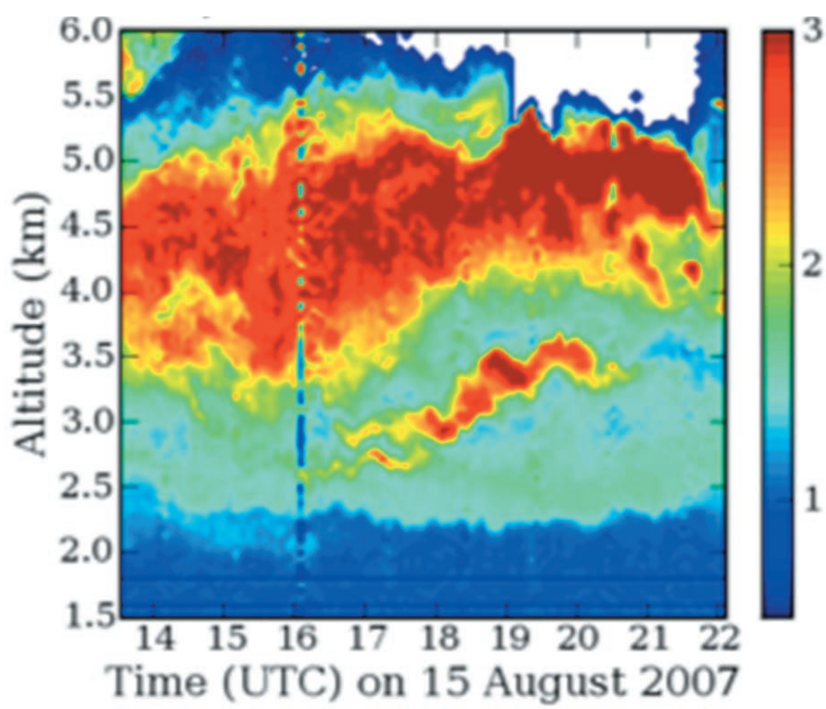

Figure 1. Measurement of the aerosol backscatter ratio on 15 August 2007. Scattering ratios of 1 indicate clear air, whereas higher values are due to scattering from aerosols. The measurements show an intense aerosol plume above 3.5 km altitude (yellows and reds) embedded in a diffuse aerosol haze (greens and light blues) that extended down to 2.3 km altitude. Data can be obtained nearly to ground level, but the lowest altitudes are not shown in this plot for clarity.

** Canadian Foundation for Climate and Atmospheric Studies* were evident between 3.5 and 6.5 km altitude throughout the measurement interval (1330 - 2200 UTC). The air below 2.5 km altitude was mostly clear, and so in this case the aerosols did not likely mix down to ground level in the vicinity of Halifax during the lidar measurements.

The horizontal extent of the plume can be visualized with the aid of carbon monoxide column measurements using the MOPITT satellite instrument. Figure 2 reveals a plume originating from wildfires in Idaho that covers most of the US eastern seaboard and Atlantic provinces of Canada. The plume continues over the Atlantic Ocean and at that time dominated the net aerosol export from North America. Examination of meteorological charts confirms that aerosols injected into the mid-troposphere were swept across North America by a persistent westerly jet.

Measurements from the lidar at University of Maryland Baltimore County (UMBC) on the same day are shown in Figure 3. The measurements show a variable aerosol plume between 3.5 and 6 km altitude, similar to what was observed above Halifax. Aerosols seen close to the ground at UMBC are most likely the result of local emissions.

The Dalhousie University and UMBC lidars are part of a network called REALM: The Regional East Atmospheric Lidar Mesonet. More information on the REALM lidars and network can be found at **http://alg.umbc.edu/REALM/**. Measurements from REALM can be used to construct 3-dimensional visualizations of an aerosol field, and are complemented by

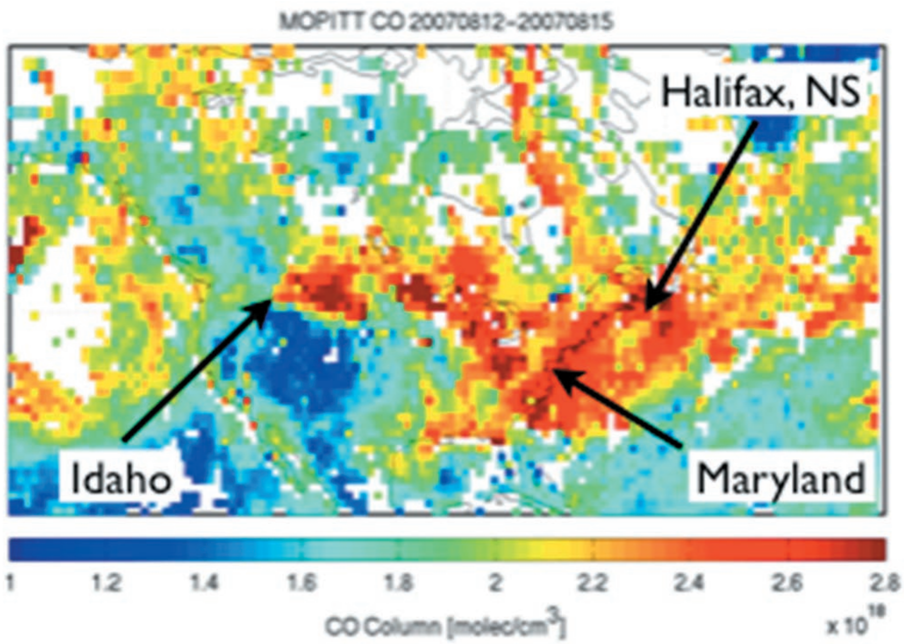

Figure 2. Measurements of the average carbon monoxide column for August 12-15 from the MOPITT instrument aboard the TERRA satellite. The image shows a plume of smoke originating from forest fires in the US State of Montana.

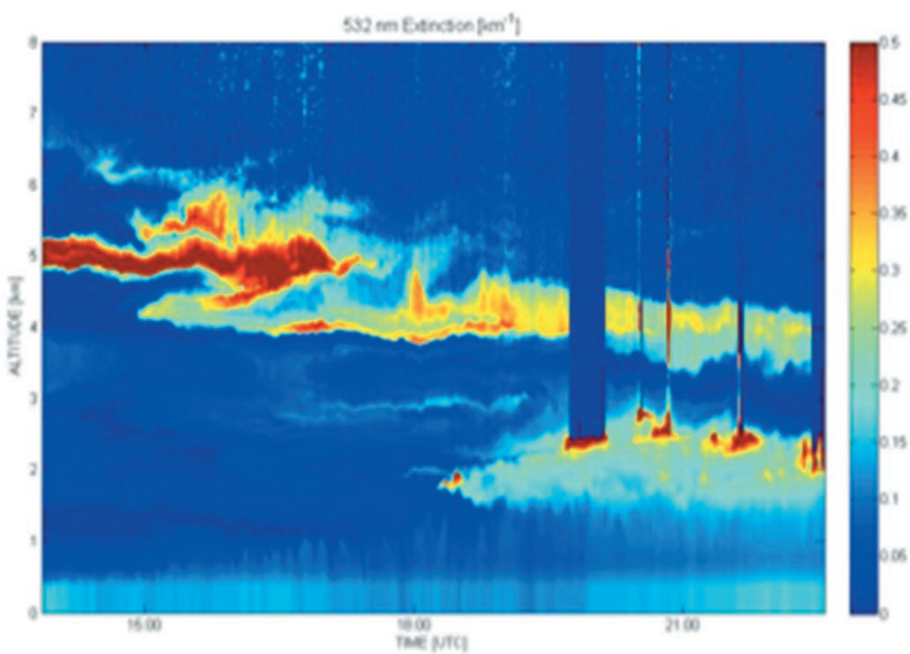

Figure 3. Measurements of aerosol extinction from the lidar at UMBC on 15 August 2007.

measurements from an orbiting aerosol lidar system aboard the CALIPSO satellite (**http://www-calipso.larc.nasa.gov/**) which has been in operation since April 2006. CALIPSO is part of the so-called A-Train constellation of satellites for atmospheric observations (**http://www-calipso.larc.nasa.gov/about/atrain.php**). The constellation completes 14.55 orbits per day with a separation of 24.7 degrees longitude between each successive orbit at the equator. The ground-based network, with regular and continuous coverage of the Eastern seaboard, is complemented by the global but distributed coverage of the satellite system.

Comparison of the lidar measurements in Figures 1 and 3 show important differences. For example, the aerosol layer above Halifax was physically deeper than that seen above Maryland, and the time evolution between the two cases was different, with the aerosols above Halifax and Maryland rising and subsiding, respectively.

By simulating the initial injection of aerosols from pyroconvection and the subsequent transport and mixing processes in the atmosphere with the use of a numerical model, we hope to recreate the aerosol fields in a manner consistent with both the lidar and MOPITT observations. The model should then be able to help identify if, when and where the emissions reached ground level. Given that this was a particularly intense event, it will be interesting to see and validate whether or not the plume later affected air quality in Europe and/or Asia, or if it was at any time lofted into the upper troposphere / lower stratosphere.

The Atmospheric-Optics Laboratory at Dalhousie University is preparing for another measurement campaign in the summer of 2008, and will be implementing an enhanced high-altitude measurement capability to better visualize the injection of aerosols into the lower stratosphere from pyroconvection. Mixing processes and fumigation to the ground level will continue to be of considerable interest. Significant detections are announced and posted immediately on the pyrocb email list (email **pyrocb@yahoogroups.com** to join). Quicklook images are also posted on our Web site (**http://aolab.phys.dal.ca/archive/index.cgi?id=DRL**), and the measurements are shared on a collaborative basis. Measurements from the sun photometer are made available online through the AERONET network site (**http://tinyurl.com/ys8ryz**).

Acknowledgments. The CO data were made available by Prof. James R. Drummond and the MOPITT team. Figure 2 was prepared by Aaron van Donkelaar. Li Zhu and Ruben Delgado obtained and analyzed the UMBC measurement. Colleen Farrell, David Waugh and Lisa Phinney are thanked for their contributions to the Dalhousie-MSC collaboration. §

Smoke from another burn further down the lake combines with previous plume.

The Canadian Smoke Newsletter

Spring 2008

A newsletter dealing with smoke-related issues across Canada

Research Notes and Recent Papers of Interest

Contribution of Biomass Burning to Global Atmospheric Mercury Emissions

(summary by Atmospheric Science Assessment and Integration, Environment Canada)

Highlights

Using measured ratios of total gaseous mercury (TGM) and carbon monoxide (CO) in biomass smoke and average global emissions of CO from biomass burning during 1996-2000, Ebinghaus et al. estimated that between 3-11% of all mercury emissions to the atmosphere are from biomass burning.

Description

The ratio of TGM to CO was measured in plumes of smoke from biomass burning during flights over South America during the fall of 2005. The measured ratios of TGM to CO fell within the range of (0.67 - 2.4) x 10^{-7} reported for sites as geographically diverse as South Africa, Canada and the U.S.A. Based on average global emissions of CO from biomass burning during 1996-2000, it was estimated that between 210-750 t/yr or 3-11% of all mercury emissions to the atmosphere are from biomass burning. Furthermore, in South America, mercury emissions from biomass burning are likely to exceed anthropogenic emissions during the ‘burning season’ of August to October.

Ebinghaus, R., F. Slemr, C.A.M. Brenninkmeijer, P. van Velthoven, A. Zahn, M. Hermann, D.A. O’Sullivan, and D.E. Oram (April 28, 2007) Emissions of gaseous mercury from biomass burning in South America in 2005 observed during CARIBIC flights. Geophys. Res. Lett., 34, L08813.

Fire and Biofuel Contributions to Annual Mean Aerosol Mass Concentrations in the United States

(summary by Markus Kellerhals, Head, Air Quality Section, Prairie and Northern region, Environment Canada)

Highlights

Using measured aerosol mass data from the IMPROVE network the authors derive estimates for the contribution of biomass burning to total carbonaceous aerosol and to total aerosol in the US. The authors found that biomass burning contributed approximately 30% of mean annual aerosol mass in the west and 20% in the east. Of the biomass burning component about 80% in the west and 50% in the east is accounted for by fires (wildfire, prescribed burning, and agricultural burning).

Description

The authors used aerosol concentration of non-soil potassium (ns-K) as a tracer of biomass burning. Site specific emission ratios for total carbonaceous aerosol (TC) were derived from sites with strong correlation between TC and ns-K. The highest TC/ns-K emission ratios (70-130 $\mu gCm^{-3} / \mu gm^{-3}$) were found in the northern US where forest fires were the main source of biomass burning. The TC emission ratios were multiplied by summertime ns-K concentrations above a derived background to estimate the summer wildfire contribution to TC. The highest wildfire contributions to TC were in the US Pacific states. In 2004 there was a significant wildfire contribution to aerosol concentration in the northwest due to wildfires in Yukon and Alaska. A significant wildfire influence in the US Northeast was attributed by the authors to long range transport from Canadian wildfires.

Park, R. J., Jacob, D. J. and Logan, J. A. (2007). Fire and biofuel contributions to annual mean aerosol mass concentrations in the United States, Atmos. Environ., 41, 7389-7400.

A smoke-filled valley: aftermath of successful burns

This informal newsletter was produced by the Air Quality section of Prairie and Northern region, Environment Canada, on behalf of the smoke forecasting community across Canada.

Layout and editing by Al Pankratz.

If you wish to be on the email list for future issues or if you want to be taken off the list, please send a note to **al.pankratz@ec.gc.ca**. *You can use the same email address if you want to contribute articles, make comments or offer suggestions.*