

Welcome to the 2010 Fall/Winter issue of the Canadian Smoke Newsletter. As usual in the Fall/Winter issue, we bring you some of the major fire and smoke-related conferences confirmed for the upcoming year:

- National Air Quality Conferences, Manchester Grand Hyatt Hotel, San Diego, CA, March 7-10, 2011
- European Geosciences Union General Assembly, Vienna, Austria, April 3-8, 2011
- 5th International Wildland Fire Conference, Sun City, South Africa, May 9-13, 2011
- The 19th International Conference on Modelling, Monitoring and Management of Air Pollution, Malta, September 19-21, 2011
- 1st Forest Ecology and Management Conference on Exploring the Mega-fire Reality, Florida State University Conference Center, FL, November 14-17, 2011
- American Geophysical Union Fall Meeting, San Francisco, CA, December 5-9, 2011

The American Meteorological Society is also planning the 9th Fire and Forest Meteorology Symposium for the fall of 2011, but final announcements as to time and location have not been made at the time of writing.

Best wishes for a happy and uneventful 2011!

Cheers,

Al Pankratz

Disclaimer: This informal newsletter is produced by Prairie and Northern region of Environment Canada on behalf of the smoke community. It does not represent the policies of Environment Canada.



A collage of scenes from the BORTAS-A study, an international effort to study boreal smoke plumes over the Atlantic Ocean.

In this issue:

- 2 Canadian Wildland Fire Conference 2010 Report
- 4 International Conference on Open Burning and the Arctic: Summary and Conclusions

David McCabe, Elena Kobets and conference participants

7 Forecast Support to BORTAS-A (2010): Predicting Forest Fire Smoke Plumes over Nova Scotia

David Waugh et al.

12 The Western Canada BlueSky Wildfire Smoke Forecasting System Pilot: A Successful Launch

Steve Sakiyama

- 15 Quebec Wildfires Spread Smoke to Eastern Canada and New England David Lavoué
- **18** Papers of Interest



Canadian Wildland Fire Conference 2010 Report

wildland fire canada 2010

Wildland Fire Canada 2010 took place in Kitchener-Waterloo, Ontario on October 5-7, 2010. Almost 250 people enjoyed an excellent conference which provided attendees with a wide spectrum of information and conversation on topics related to wildland fire.

The opening plenary session was devoted to a one hour presentation by Thomas Homer-Dixon, professor of global systems at the Balsillie School of International Affairs in Waterloo. His talk dealt with increasingly complex global pressures, focused in this case on natural resource management.

Humans frequently attempt to manage increasing complexity by setting up correspondingly complex organizations and management structures. Unfortunately, the chaotic and non-linear nature of the interactions between fire, weather, environment and people defies the ability of any organization or operational structure to keep up. When humans insist on building homes and commercial structures that encroach on or even leapfrog deep into forests, the job of fire management agencies becomes exponentially more difficult. Simply keeping track of where individuals and resources are within a fire management

area is an onerous undertaking, let alone setting up and maintaining systems to protect them all. Throw in an increasingly litigious society and ever diminishing resources, and one has the ideal inducement for wildfire managers to retire early.

The management programs that enable society to cope with wildland fire issues have become increasingly tightly linked and dependent on each other. These characteristics make the programs brittle and prone to breakdown. According to Prof. Homer-Dixon, systems that are resilient do not depend on one critical path of action, can continue to function if other nodes in the operational network of support break down, and are less dependent on the correct sequence of actions. For example, a car manufacturer could buck the prevailing wisdom of just-in-time production and increase resilience by storing more inventory on site. The resulting reserve would ensure that a shipment of parts failing to arrive exactly on schedule did not idle the factory. Another way to increase resilence would be to decentralize by increasing the number of potential support hubs through which resources flow, reducing the ability of any one to cripple the

entire system if it fails. For example, spreading airline traffic out by cutting back on the use of hub airports such as Toronto or Heathrow would prevent outages at either from affecting flights all over Canada and Europe.

Such ideas seem to fly in the face of current paradigms which emphasize sharing equipment and resources so as to maximize efficiency. These paradigms do not invalidate the ideas. but simply indicate that they would be politically and economically difficult to put into practice. Would fire management agencies realistically be able to adopt practices such as widespread stockpiling of quasiredundant equipment so as to be less dependent on other agencies? This is unlikely. As a result, the only other practical alternative would appear to be that of simplifying the requirements - namely reducing goals and requirements to realistic levels. Should the public and industry be discouraged from placing assets in remote forested areas? Should agencies refuse to fight fires within areas declared to be remote, even though they could negatively affect these assets? Should governments pass legislation to insulate fire agencies against lawsuits arising from smoke impacts? Should insurance agencies require homeowners in

Fall/Winter 2010

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

wildland-urban interface areas to adopt fuel-reduction practices around their communities on pain of losing house insurance?

It seems unlikely that fire agencies will be able to continue layering complex management systems atop each other in perpetuity and have them all continue to perform to everyone's satisfaction. Common sense would suggest that a managed and guided simplification of the problem would be better than unmanaged and unanticipated breakdown to a simpler state.

Related ideas echoed throughout the plenary talks. Fire directors from several provinces spoke of lengthening fire seasons, of challenges posed by the reduced numbers and increasing ages of fire fighters, of widespread death of trees due to insect infestations, of diminishing budgets, of proliferating lawsuits and of the loss of the majority of experienced fire managers within the next five to ten years due to retirement. Subsequent comments by the audience reflected a frustration at the inability of fire managers and scientists to convey the gravity of these situations to politicians.

Not the least of the concern had to do with the sense that Canada had narrowly escaped disaster in some of the areas affected by fire in 2010. According to one speaker, a community in central British Columbia came within 3 miles of being completely devastated by fire. It is increasingly reasonable to imagine incidents where remote communities are assailed by fires on all sides, where the only road in or out is blocked, and where the local airport is closed due to smoke. Are support agencies and the public ready for such events? It would be inaccurate to say that these important questions weighed down the overall conference atmosphere. The conference had a delightful mix of operational fire managers, fire researchers and developers of fire and smoke management tools. Discussions were animated and presentations insightful. The end of the conference coincided with Kitchener-Waterloo's Oktoberfest, with attendees treated to a beer and bratwurst evening supervised by local Oktoberfest party organizers.

Presentations and recordings are available on the conference website at http://www.wildlandfirecanada.ca/ Presentations.html. The next Wildland Fire Conference will be held in Alberta, Canada in 2012. Judging by the Kitchener conference, it should be well worth attending. §

report by Al Pankratz

Thinking of contributing to the Canadian Smoke Newsletter?

We are interested in articles from across the globe, not just in Canada. To contribute, or to be added to/removed from the email list for the CSN, send a note to al.pankratzATec.gc.ca.

- Please submit any articles as a .txt, Word or OpenOffice file. Format text as 11 point Times New Roman, linespacing single.
- The article can be short (minimum 400 words) or long (up to 5000 words).
- · Please include images and diagrams if possible. These serve to illustrate your article and allow flexibility in layout.
- · Ensure that you have permission to use any graphics you include and credit the artist/photographer if necessary.
- · Images/diagrams embedded in your documents should have sufficiently high resolution to allow reasonable resizing without degradation.
- Include captions for any photos, figures or tables.
- Include your name, title and institutional affiliation. If you are open to being contacted by readers, please add your mailing address and/or email address.
- You may submit your article in English or French. Please note that we are not able to have documents translated from French to English at this time.
- Your submissions may be edited for space, spelling, grammar, etc.
- Where possible, you will be provided with a final draft before the newsletter is published in order to ensure that accuracy and the sense of the article has been maintained.
- · Depending on space constraints, we may retain some articles for publication in succeeding issues.
- · Please ensure that acronyms and potentially obscure references are adequately explained on first use.
- The target audience is composed of professionals in government, industry and academia, all of whom are involved with smoke and smoke issues. Both descriptive and technical articles are welcome.
- The Canadian Smoke Newsletter will be published via email and on the Internet. Contents of all articles will be freely shared with anyone who is interested.



International Conference on Open Burning and the Arctic: Summary and Conclusions

by David McCabe¹, Elena Kobets² and conference participants
1. Clean Air Task Force, Boston, MA, USA
2. Environmental Rights Center Bellona, St. Petersburg, Russia

In early November 2010, over seventy policymakers, scientists, activists, and academics from Russia, Europe and North America met in St. Petersburg, Russia, for a twoday conference to discuss the causes and impacts of set fires in forests, peatlands, croplands, and steppe in Northern Eurasia and North America.

Open burning in Northern Eurasia is a particularly important source of soot or black carbon (BC) in the Arctic, which is warming at nearly twice the rate of the rest of the planet. BC from these fires is likely an important warmer of the Arctic climate, particularly in spring when ice and snow are melting. These fires, often set intentionally on croplands, rangelands, steppe, and woodlands, can also have negative health, safety, and economic effects. Laws on burning vary widely from place to place, with gaps between laws, enforcement, and practice.

The conference explored both the emissions from these fires and their impacts on the Arctic, and uses of these fires, their impacts on health and safety, and approaches to reducing fires and fire impacts. Participants included representatives of a very diverse set of organizations, such as agencies of the governments of Russia, Canada, and the United States (US), the United Nations Economic Commission for Europe (UNECE), and officials from US State governments; scientists from a wide variety of disciplines and institutions; representatives from Russian and US non-governmental organizations; and farmers and firefighters.

The meeting agenda, presentations, and other materials are available at the meeting website: http://www.firesand-the-arctic.org. This document summarizes the conclusions of the meeting.

Emissions from Fires and Impacts on the Arctic

Scientists studying fires, Earth's atmosphere, forests, and geography met in one track of the meeting to consider what we currently understand about:

- sources of BC in the Arctic
- contribution from open fires
- location, timing, and fuel of those fires.

This group concluded:

- the most important climatewarming pollutant, even in the Arctic, is carbon dioxide
- global climate impacts of BC remain quite uncertain, particularly when considering co-emitted pollutants and the interactions between these pollutants and clouds / precipitation. However, atmospheric BC, when deposited to snow in the Arctic during late

winter and spring, adds a definite positive forcing (warming) to that of carbon dioxide, because it darkens snow, so that it absorbs more incoming radiation

- vegetation fire emissions (VFE) in Eurasia make a significant contribution of BC to the Arctic lower-atmosphere and snow surface
- transport of aerosols to the Arctic is more efficient from Eurasia than from North America, especially in winter and spring when Arctic BC concentrations are highest. As a result of this and the greater extent of snow and ice cover in the springtime, BC from spring fires in Eurasia affects Arctic climate more than BC from summer fires, despite the larger extent of the summertime fires
- Eurasian VFE plumes reach the North American side of the Arctic, but it is not clear what fraction of these plumes remains aloft and what fraction reaches the lower atmosphere where BC can be deposited to snow
- fires produce other light-absorbing particles (i.e., "brown" organic carbon) as well as BC, which also darken surface snow. Mitigation of open burning would reduce both types of light-absorbing particles
- BC from spring VFE may also impact climate forcing by reducing albedo of seasonal snow at midlatitudes (40°-60° N). The resulting

Fall/Winter 2010

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

mid-latitude warming may in turn contribute to Arctic warming, as well as reducing snow cover at mid- to high-latitudes. These effects need more examination in model investigations; studies which quantify the climate effects (including effects on snow and ice cover) of realistic BC mitigation measures would be particularly useful.

Research likely to significantly improve understanding of open burning as a source of BC in the Arctic over the next one to two years should address:

- improved monitoring across northern Eurasia of the amount and seasonality of biomass and fossil fuel aerosols in the lower atmosphere
- land cover and use, such as cropland, rangeland, abandoned land, etc. Current maps lack accuracy and specificity
- the height to which plumes from springtime fires rise in the atmosphere
- fuel loads, burning efficiency, and emission factors for BC and other species, as functions of location, time, fuel type, and type of fire
- assessments of area burned for croplands and wildlands after fires
- seasonality of fires
- model estimates of impacts of BC from set fires on snow and ice cover in the Arctic and mid- to high-latitudes using climate models of different complexity.

Other, more long-term research needs for better quantification of the impacts

of open burning on the Arctic, in order of importance, are:

- aerosol-cloud-precipitation (indirect) effects of biomass burning emissions on climate
- albedo change of mid-to-high latitude temperate zone seasonal snow, including non-pristine and vegetated areas, due to BC deposition
- testing models' ability to predict climate response to snow darkening
- quantification of open burning vs. biofuels as sources of BC in and near the Arctic
- factors controlling rates of wet and dry deposition of BC
- black carbon / organic carbon (BC/OC) ratio in fire emissions, and other co-emitted species
- vertical profiles of BC and OC in the atmosphere in the Arctic and along primary transport routes from sources
- emissions from flaming vs. smoldering fires, and techniques to distinguish them with data from satellites
- effects of weather conditions before and during fires on emissions
- the height of smoke plumes from fires in the winter and summer.

Uses of Fires, Impacts on Health and Safety, and Approaches to Reducing Set Fires

Fire, agricultural, and forestry scientists, environmental advocates,

firefighters, and government officials from state / provincial and national governments met in a second track of the meeting to consider:

- why fires are set
- impacts of fires on health and safety
- effective ways to reduce fire frequency and impacts on human health, safety and climate.

Presentations and discussions covered practices and reasons for burning in various areas; regulations, laws, and management practices which affect the volume of burning; impacts of fire and smoke locally and regionally; alternatives to burning and best practices; and approaches to mitigation.

The group identified several critical land-management and fire prevention issues in the Russian Federation, Ukraine, and other nations in the Commonwealth of Independent States:

- responsibility for land and land management is ill-defined, especially at the interface of forest and agricultural lands and on lands abandoned in the past 20 - 30 years
- fire management should concentrate on preventing accidental wildfires and avoiding unnecessary application of fire in land management
- fires often spread from agricultural lands into adjoining lands, where they become wildfires; mitigation programs should address this behavior.

The following steps and approaches were identified as essential to effective

Fall/Winter 2010

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

efforts to reduce the amount of land burned in Northern Eurasia:

- develop infrastructure, markets, incentives, and awareness for alternative uses of residues, e.g., biofuel
- promote and educate farmers on crop rotation, conservation agriculture practices, organic farming, and other alternatives, and their advantages to crop yields and soil health
- educate farmers and the wider public on the negative impacts of burning, particularly local effects, building upon the attention generated by the fires in 2010
- focus on unnecessary fires, including on abandoned land, during all seasons
- assess impacts of fire on abandoned lands, especially those fires that spread to forests and peatlands
- review national legislation hampering effective fire management; e.g. in agricultural areas and at the interface between agricultural lands and forests and rural settlements
- expand resources for fire monitoring, fire management decision support, and fire response
- promote and support communitybased fire management, including participation by civil society, with a balance between local control and enforcement of laws, such as with a fire warden system
- test alternatives through regional pilot or demonstration projects.

Next steps

A number of projects to address items of concern raised at the conference are underway or beginning. For example:

- planning is underway for six pilot projects in Russia, including some funded by a US government program, to be undertaken in spring of 2011 to test efforts to reduce burning in a variety of locations
- preliminary work is underway on a number of collaborations involving scientists and other meeting participants from the US, Russia, Ukraine, and other nations
- one such effort provides better fire emissions data from active crop waste fires. The participants in this project are developing a second project to distinguish between abandoned lands and croplands in satellite-based land use classifications
- planning is also underway for exchange programs between Russian and US organizations working to reduce agricultural burning
- the Global Fire Monitoring Center (GFMC), working under the umbrella of the United Nations International Strategy for Disaster Reduction (UNISDR) and the UNECE, will continue to work with Russia and the EECCA countries (East Europe-Caucasus-Central Asia) in developing regional and international agreements on transboundary cooperation in fire management, to reduce the negative impacts

of wildfires and land management fires on the environment and society.

We anticipate a variety of collaborations initiated by discussions at the conference will occur. For further information about the meeting, please contact David McCabe (dmccabe@catf.us) or Elena Kobets (ekobets@bellona.ru). **§**

The meeting was organized by the Environmental Rights Center Bellona (Russia) and Clean Air Task Force (United States) with support from the Oak Foundation. The organizers gratefully acknowledge the invaluable assistance of the advisory committee in developing the meeting agenda. The advisory committee included representatives of the following organizations:

Russian SRI Atmosphere

Sveshnikov Institute of Agrochemistry, Russian Academy of Agricultural Sciences

Voeikova Main Geophysical Observatory

Institute of Global Climate and Ecology, RosGidroMet, Russian Academy of Sciences

B.J. Stocks Wildfire Investigations Ltd. (Canada)

Global Fire Monitoring Center (GFMC), Germany

International Cryosphere Climate Initiative

Clean Air-Cool Planet

U.S. Department of Agriculture and Forest Service

University of Louisville, Kentucky

NASA/National Institute of Aerospace

State of Washington Department of Ecology.



Forecast Support to BORTAS-A (2010): Predicting Forest Fire Smoke Plumes over Nova Scotia

David Waugh¹, Doug E. Steeves¹, Thomas J. Duck², Lisa Langley¹, Steve Beauchamp¹, Mark Gibson³, Matt Seaboyer³, Mark Parrington⁴, Paul Palmer⁴, Stephan Mathiesen⁴, David Tarasick⁵, Mike Earle⁵, Steven Pawson⁶, Chris Fogarty¹

Environment Canada – Dartmouth, NS, Canada
 Dalhousie University – Aerosol Optics Laboratory – Halifax, NS, Canada
 Dalhousie University – Atlantic Aerosol Research Network – Halifax, NS, Canada

 University of Edinburgh – Edinburgh – Scotland, UK
 Environment Canada – Downsview, Toronto, Canada

 Global Modeling and Assimilation Office, NASA GSFC – Greenbelt, Maryland, USA Contact: david.waugh@ec.gc.ca

The Meteorological Service I of Canada – Atlantic Region participated in the BORTAS-A measurement campaign during the summer of 2010. The term BORTAS¹ is derived from "Ouantifying the impact of BOReal forest fires on Tropospheric oxidants over the Atlantic using Aircraft and Satellites". BORTAS-A was a pilot for BORTAS-B which will be based out of Halifax, NS during the summer of 2011. Plans for BORTAS-B call for the United Kingdom BAe146 research aircraft to fly sample missions within 500 nautical miles of Halifax, intercepting plumes of trace gases and aerosols originating from North American forest fires while avoiding anthropogenic pollution plumes.

The prime objective of BORTAS is to examine the connection between the composition and distribution of biomass burning outflow as well as the associated ozone production and loss, and the resulting perturbation of oxidant chemistry in the troposphere. Projects of this nature support the development of Global Climate Models and Chemical Transport Models and assist with discerning the separate influences of natural and anthropogenic forcing in climate change predictions. This initiative is being directed by the School of

GeoSciences at the University of Edinburgh. The Department of Physics and Atmospheric Science at Dalhousie University, Halifax, hosts the Dalhousie Ground Station (DGS) (44.638N, 63.593W). Weather and air quality forecasts, provided by the Meteorological Service of Canada (Dartmouth, NS) focused on the DGS location, and were provided from July to early September, 2010 during BORTAS-A. These forecasts assisted with lidar personnel scheduling and facilitated the most efficient use of filter-based sampling, especially during periods when anthropogenic and/or biomass episodes were expected.

Methods

BORTAS-A forecast preparation involved identification of sources of boreal biomass burning in the US² and Canada³, viewing past, current and predicted tropospheric flow maps (e.g., 500 hPa contour charts), creating forward trajectories using the Hybrid Single Particle Lagrangian Integrated Trajectory model (HYSPLIT⁴) when required, examining regional meteorology for vertical mixing, precipitation (washout), low cloud and fog (which blocks lidar retrievals) and boundary layer flow patterns considered favourable for long-range transport of anthropogenic and biomass burning aerosols. Local air quality data were considered along with information on other sources of particulate matter which might complicate the interpretation of data.

Meteorological forecasts were based on guidance provided by the Canadian Meteorological Centre's (CMC) operational Global Environmental Multiscale (GEM⁵) model. Air quality forecasts of anthropogenic pollutants were based on the operational air quality model Modelling Air quality and CHemistry (GEM-MACH⁶). Forecast guidance for forest fire plumes was based on the NASA Goddard Earth Observing System Model Version 5.2.0, (GEOS-5)⁷, a global atmospheric general circulation model. GEOS-5, in addition to meteorological forecasts, predicts a number of aerosol and chemical tracers including CO associated with boreal biomass burning sources. Biomass burning sources are initialized in the GEOS-5 forecasts using near real-time MODIS hot spot data to produce emissions estimates which are calibrated against the Global Fire Emissions Database v2 [Arlindo da Silva, personal communication]. Analysed meteorological fields from GEOS-5 were also available in near



real-time and were used to drive global atmospheric chemistry simulations with the GEOS-Chem chemical transport model, results of which are not presented here. Site specific products were developed by the University of Edinburgh for the DGS at Halifax and included time cross-sections of CO from fossil fuel sources, non-boreal biomass burning sources and boreal biomass burning sources. These GEOS-5 products were available to the DGS team via the Internet.

Data used in developing forecasts included local and upstream surface air quality information, Dalhousie Raman Lidar imagery⁸ (Figure 1), satellite imagery, University of Maryland Smog Blog⁹ discussions on biomass and anthropogenic pollutant transport, CoralNet¹⁰ Lidar imagery and nearreal-time reports from the DGS.

Daily forecasts covered two days, with an outlook for the third day, and discussed the following:

- upstream fire hotspot locations
- tropospheric flow patterns impacting smoke plume movement
- predictions from GEM and GEM-MACH
- predictions from GEOS-5
- probability of lightning over the Atlantic provinces (added in the latter part of the study)
- Halifax-specific weather, air quality and CO predictions divided into separate periods for today, tonight, tomorrow and the following day.

Lightning probability forecasts, based on a technique developed by Burrows¹¹ were available on an internal Environment Canada website¹². Lightning produced NO_x is an important factor in separating natural precursor sources to ozone formation. The DGS was instrumented with the Aerosol Optics Laboratory Raman

Lidar⁸ (532 nm), continuous PM_{2.5} mass (PDR 1500) nephelometer,



Figure 1. Dalhousie University Raman Lidar beam. Courtesy Peter Klages.



Reference Method (PM_{25}) , Thermo Partisol 2025-dicotomous PM_{2.5} (fine fraction) and PM_{2.5}-PM₁₀ (coarse fraction), Thermo Partisol 2300 12channel Chemical Speciation Sampler (PM_{2,5}), TSI 3321Aerodynamic Particle Sizer (APS), TSI 3031 Ultrafine Particle Monitor (UFP), MOUDI 12-stage impactor, AEROCan sunphotometer, Portable Atmospheric Research Interferometric Spectrometer for the Infrared (PARIS-IR), Bomem **DA8** Fourier Transform Spectrometer (FTS), Thermo 49i hourly ozone and Davis weather instrumentation. This suite of instruments provided aerosol mass, size distribution, chemical composition including tracers for biomass burning, and vertical profile of the backscatter ratio. Data from the Ferguson's Cove wind profiler (44.587N, 63.550W) located 6.5 km south-southeast of DGS at the entrance to Halifax harbour was available retrospectively. Ozonesondes¹³ (data available retrospectively) were launched daily from Yarmouth and Sable Island, NS and Goose Bay, NL, from July 12 to August 4 with some launches scheduled to correspond with GEOS-5 predicted biomass burning CO maxima.

Thermo Partisol 2025 Federal

Results

A number of cases of elevated aerosol concentration were observed during the study. Fair skies during August 6-11, 2010, allowed continuous operation of the DGS Lidar. The lidar profiles from this period are presented in Figure 2, along with PM_{2.5} and aerodynamic particle sizer number concentrations. The yellow and red arrows indicate event periods commencing at approximately the same time.

532 nm Backscatter Cross-section (/Mm/sr) [Klett] 2 00 06 12 18 00 Time (UTC) on 06-08 August 2010 00 06 12 18 Time (UTC) on 08-10 August 2010 22 00 02 04 Time (UTC) on 10-11 August 2010 Nephelometer PM_{2.5} Mass Concentration 30.0 b) 25.00 20.00 PM_{2.5}[µgm⁻³] 5.00 08-07-2010 UTC Date and Time (mm-dd-yy hh:mm) Aerodynamic Particle Sizer (APS) Total Number Concentration (linear plot, right-hand axis) Number Distribution through particle size range (3-D image plot) 2.2 2.0 1.8 1.6 1.4 1.2 00:00 00:00 08/08/10 UTC I 00:00 00:00 00:00 08/10/10 00:00 00:00

Figure 2. Data display for August 05-11, 2010; a) Dalhousie University Raman Lidar image; b) PDR 1500 nephelometer time series; and c) number concentrations and size distributions from the TSI 3321 APS. Yellow and red arrows indicate the beginning of events on August 6 and August 10, respectively. The Lidar shows aerosol in several layers throughout the time period. The nephelometer data indicates higher concentrations of PM2.5 during the two events, which correspond to increases in number concentrations on the APS.



Forecasts by GEOS-5 and GEM-MACH are shown in Figures 3 and 4, respectively. Both models successfully predicted increasing concentrations of aerosols on the evening of August 10. Back-trajectory analysis suggests that near-surface aerosols were of anthropogenic origin on August 10, mixing with biomass burning aerosols on August 11 during the passage of a cold front. GEOS-5 predicted a strong biomass burning signal in the lower troposphere commencing early on August 11 while GEM-MACH forecasted increasing anthropogenic PM mass at the same time with a peak in concentrations predicted for 1200 UTC August 11. A poster presentation on forecast support for BORTAS, similar to that described above, was delivered at the International Air Quality Forecasting Workshop in Quebec City, Canada in November, 201014.

GEOS-5 forecast output at 63.4 W, 44.5 N; 20100810_00z

CO from boreal biomass burning

Figure 3. GEOS-5 forecast of boreal biomass CO for the 70 hour period commencing 0000UTC August 10 2010. The red arrow indicates the model prediction of increased CO below 4 km at 0000UTC August 11 2010

Recommendations

The following recommendations were developed to improve forecast support for BORTAS-B:

- improved 3-D visualization (horizontal and cross-sectional slices) of forecast products and air quality data using the Meteorological Service of Canada (MSC) NinJo display platform, currently under development by MSC
- improved collection and standardization of US and Canadian surface air quality data. This is being explored by MSC
- near real-time data display from Dalhousie Ground Station (DGS) wind profiler and continuous monitors



Figure 4. GEM-MACH predicted PM10 surface concentrations at Halifax. The red arrow indicates an increase in concentrations around 0000UTC August 11 2010.



Fall/Winter 2010

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

- ready access to 48 hour backtrajectories for the DGS as well as forward-trajectory and dispersion model output from major Canadian forest fires. This was proposed to CMC in October 2010
- expanded access to air quality forecast products from the US as per the Smog Blog. This is being investigated as part of MSC's Air Quality Forecasting Program
- addition of an Aerosol Chemical Speciation Monitor (ACSM) to provide real-time chemical speciation including identification of biomass burning organics. An ACSM instrument is projected to be available for BORTAS-B
- redesign of the forecast based on the expanded area of focus for aircraft flights in summer 2011. The redesign is being developed by MSC
- use of 3-D measured data for model validation. This requires access to a 3-D array of data points from model runs and is being explored by MSC
- signal-to-noise ratio plots of the wind profiler data to better understand boundary layer development and break-down. This product is being explored by MSC.

Future Work

Conclusive evidence of boreal biomass burning plumes impacting surface monitors at the DGS site will not be available until filter sample analysis is complete, likely in early 2011.

DGS observations and model

predictions (back trajectories and GEOS-Chem data) are being used in a detailed analysis of boreal biomass burning plumes over the DGS, building on a BORTAS-A data analysis and paper-writing workshop which took place in December 2010. Further results from this study will be presented in a future issue of the Smoke Newsletter.

Acknowledgements

The authors wish to acknowledge the support provided by Jason Hopper, Kim Sakamoto, Loren Bailey, Kaja Rotermund and Stephen Doyle of the Summer 2010 Lidar Team at Dalhousie University; James Kuchta, Gavin King, Adrian MacDonald and Dr. Neil Brewster of the Atlantic Aerosol Research Network, Dalhousie University, and Fran DiCesare of Nova Scotia Environment. §

References

1. http://www.geos.ed.ac.uk/research/ eochem/bortas/

2. http://www.geomac.gov/viewer/viewer. htm

3. http://cwfis.cfs.nrcan.gc.ca/en_CA/fm3maps/tri

4. http://www.arl.noaa.gov/HYSPLIT_ info.php

5. http://www.weatheroffice.gc.ca/ model_forecast/index_e.html

6. Anselmo, D., Moran, M. D., Menard, S., Bouchet, V., Makar, P., Gong, W., Kallaur, A., Beaulieu, P-A., Landry, H., Stroud, C., Huang, P., Gong, S., Talbot, D. 2010. A new Canadian air quality forecast model: GEM-MACH15. 16th Joint Conference on the Applications of Air Pollution Meteorology with the A&WMA, Atlantic, GA, American Meteor. Soc.

7. Rienecker, M., Suarez, M., Todling, R., Macmeister, J., Takacs, L., Liu, H.-C., Gu, W., Sienkiewicz, M., Koster, R.D., Gelaro, R., Stajner, I., Neilsen, J. 2008. The GEOS-5 Data Assimilation System – Documentation of Version 5.0.1, 5.1.0, and 5.2.0. NASA/TM-2008-104606, Vol. 27. PDF version available at http://gmao.gsfc. nasa.gov/systems/geos5/

8. http://aolab.phys.dal.ca/

9. http://alg.umbc.edu/usaq/

10. http://www.coralnet.ca/

11. Burrows, W.R., 2008. Dynamical-Statistical Models for Lightning Prediction to 48-hr over Canada and the United States. Third AMS Conference on Meteorological Applications of Lightning Data in Meteorology, New Orleans.

12. http://ronlx.edm.ab.ec.gc.ca/lightning. html

13. http://exp-studies.tor.ec.gc.ca/~bortas/

14. Waugh, D., Steeves, D.E., Duck,
T.J., Langley, L., Beauchamp, S.,
Gibson, M., Seaboyer, M., Matthiesen,
S., Parrington, M., Palmer, P., Tarasick,
D., Earle, M., Pawson, S., Fogarty, C.,
2010. Forecast Support to BORTAS-A
(2010) Boreal Forecast Fire Smoke
Observations: Successes and Challenges.
2nd International Workshop on Air Quality
Forecasting Research, poster session.
Quebec City, QC. PDF version available
at: http://aolab.phys.dal.ca/bortas-dgs/
BORTAS Forecasting Poster.pdf



The Western Canada BlueSky Wildfire Smoke Forecasting System Pilot: A Successful Launch

by Steve Sakiyama, Air Quality Science Specialist British Columbia Ministry of the Environment

Previous Canadian Smoke Newsletters have detailed the development progress of a wildfire smoke forecasting system for British Columbia and Alberta that is based on the US Forest Service BlueSky framework. With the help of partner agencies, steady progress has been made in overcoming many technical and funding challenges to achieve the goal of a working system.

In the summer of 2010, a milestone was reached when the system began producing publicly available daily wildfire smoke forecasts for British Columbia and Alberta. This article will provide background on the system, the initial testing and public release process, and outline further steps in the development of the system.

BlueSky System Description

At the core of the smoke forecasting system is the BlueSky Framework



Wildfire locations (through satellite hotspot detection) and fuel consumption estimates are provided by the Canadian Wildland Fire Information System (http://cwfis. cfs.nrcan.gc.ca/en_CA/index). This information is downloaded daily from Natural Resources Canada's Northern Forestry Research Centre in Edmonton, Alberta.

Forecast meteorology is generated by the MM5 model which is run at the University of British Columbia Department of Earth and Ocean Sciences' numerical computing lab in Vancouver, BC. The model is



Figure 1. The Western Canada BlueSky Smoke Forecasting System.

initialized once per day, and produces hourly meteorology for 60 hours into the future at a 4 km grid resolution, over a domain encompassing all of British Columbia and Alberta.

The wildfire source and meteorological model output is processed by the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) transport and dispersion model that is part of the BlueSky framework. HYSPLIT calculates the path and ground level $PM_{2.5}$ concentration of each wildfire smoke plume over the domain area. The framework and components (Figure 1) are described in more detail at http://www.bcairquality. ca/bluesky/BlueSky-Western-Canada-description.pdf.

Testing and Forecast Availability

Once the system was up and running, a stress test with real data was conducted using the wildfire season of 2009 – a particularly intense wildfire period with hundreds of fires burning simultaneously throughout the domain. Although processing times were long, the system survived and produced smoke location predictions that were not unreasonable, i.e., the fires were located correctly, smoke went in the right direction with the expected timing, indicating that the components were working together in proper sequence. A qualitative evaluation of the performance was conducted using satellite photos and aerosol optical

The Canadian Smoke Ne<u>wsletter</u>

Fall/Winter 2010

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

depth data for selected case days. This evaluation confirmed again that the system was working, and although not perfect, was producing reasonable output.

Based on these encouraging results, the system was run continuously beginning in August 2010. Output was posted and updated every morning on a British Columbia government website (http://www.bcairquality.ca), along with a qualifier that forecasts were to be considered "experimental".

Output on the website consisted of :

- a) a map showing the model domain with an animation of hourly smoke concentrations in colours that corresponded to different ranges of predicted PM_{2.5} concentrations at the surface (see screen shot in Figure 2), and
- b) a KMZ file for viewing in Google Earth, which provided the most flexible (and visually rich) format, including layers for cities, towns or roads, and which allowed users to zoom in on specific areas (see screen shot in Figure 3 next page).

Coincidentally, the debut of the BlueSky system occurred during an extreme wildfire period in British Columbia. Interest in the smoke forecast was high from both government agencies (notably health-related) and the public. On one day in August the website received over 40,000 hits, thus confirming the overwhelming interest and need for such a tool.

Summary and Next Steps

The operation of the pilot system has demonstrated that a Canadian Wildfire Smoke Forecasting System using the BlueSky framework is possible and is of high interest to the public. This has prompted further efforts to enhance the system and to correct errors that have appeared through comparison of forecasts with actual events from this past summer. Specifically:

- unrealistic bull's eye concentration patterns sometimes randomly appear and disappear at distances far from the fire location
- although twelve hours worth of the previous day's smoke is accounted for in the current day forecast, further enhancements will now increase this "carryover" smoke period to at least 24 hours
- accounting for smoke from American wildfires

Smoke forecast issued on: Mon Aug 2, 2010 for the period of Sun Aug 1, 2010 5:00pm to Wed Aug 4, 2010 4:00am

Play speed: " Currently showing smoke forecast for: Wed Aug 4, 2010 4:00am PST Fort St. John ice George dmonton Illiams Lake Capital amloops Calgary more than 500,000 Vancouver. 100,000-500,000 Victoria 50,000-100,000 less than 50,000 280 420 km National Park 140 0 2 10 25 40 60 80 175 300 500

Hourly total PM_{2.5} (ug/m³)

Figure 2. BlueSky Western Canada wildfire smoke forecast webpage

Fall/Winter 2010

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

- maintaining continuous emissions through the forecast period
- adding the ability to run in nestedgrid mode so that a larger domain can be included without incurring a proportional increase in computer run time, and
- replacing the current computer (on loan from the US Forest Service).

The goal is for the new hardware and system enhancements to be up and running in time to produce smoke forecasts for the 2011 fire season. The development consortium for the Canadian BlueSky Western Canada Extension consists of the following people and agencies:

- Steve Sakiyama: BC Ministry of Environment
- R Gibson, C Jenkins, W Mohns, G. Okrainetz: BC Ministry of Environment
- S Larkin, R Solomon: US Forest Service
- S Raffuse, K Craig: Sonoma Technologies Inc.

- E Meyer: BC Ministry of Forests and Range
- R Stull, G Hicks, M Brauer: University of British Columbia
- L. Cheng, D. Lyder: Alberta Environment
- C. Tymstra: Alberta Sustainable Resource Development
- A. Pankratz, B. Wiens, R. Vingarzan: Environment Canada
- K. Anderson, P. Englefield, S. Taylor: Canadian Forest Service §



Figure 3. One frame from a Google Earth animation depicting ground-level one hour average PM2.5 concentration, Aug 20, 1500 PDT



Quebec Wildfires Spread Smoke to Eastern Canada and New England

by David Lavoué DL Modeling and Research, Brampton, Ontario Consultant for the Air Quality Research Division, Environment Canada, Toronto, Ontario

In 2010, forest fires burned a total of 250,000 hectares in Quebec according to SOPFEU, the fire protection agency for la Belle Province. In May alone, about 200,000 hectares were destroyed. Many wildfires remained out of control for several days. By the end of the month, thick smoke produced by fast spreading and high intensity fires significantly degraded air quality in many urban areas of southeastern Canada and New England. This critical situation prompted daily news coverage from both Canadian and American media.

Fire Activity in late May 2010

In the spring of 2010, unusual dry conditions and increased fire risk prevailed over southern Quebec. On May 25, lightning strikes ignited many wildfires in upper Mauricie, north of Trois-Rivières. Blazes spread quickly

Obedijiwan Roberval Parent Nanawan Quebes Gity Trois Rivieres

Figure 1. Detection of fire hotspots and smoke plumes by Aqua-MODIS on May 30, 2010 at 17:50 UTC (13:50 DST) over Southern Quebec (image courtesy of the MODIS Rapid Response Team, NASA Goddard Space Flight Center).

across the forests of the region until early June amid record temperatures and dry weather (Figure 1). Hundreds of Quebec firefighters were dispatched to fight the raging wildfires. Hundreds more came from other Canadian provinces and nearby American states to assist their Quebec colleagues. On May 30, 54 fires were active in the southern region of the province, eight of which were out of control.

Figure 2 shows the daily variability of the Fire Weather Index (FWI) for the village of Parent, located west of the main fires (Figure 1 - left centre). The FWI trend steadily increased during May, and on the 25th hit critical levels in the upper Mauricie region. Calculations suggest that extreme conditions were reached on May 30, when MODIS detected a peak in fire pixel counts. On May 31, cooler temperatures and rainfall helped firefighters battle fires still raging across southern Quebec. The fire



Figure 2. Daily Fire Weather Index and corresponding Canadian Forest Service fire danger categories calculated from weather records at the village of Parent for May 12-June 5, 2010.

Fall/Winter 2010

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

danger category dropped to "Low".

One of the largest fires burned at the limits of the Wemotaci First Nation reserve located 100 km northwest of La Tuque (Figure 1 - right centre). The 1300 residents of the reserve were forced to leave their homes on May 26. Two days later, the situation became critical in upper Mauricie where numerous fires went out of control, forcing the evacuation of 1000 people from the Manawan reserve. In addition, 300 people of the Obedjiwan reserve were evacuated.

Air Quality Impact in Urban Areas on May 30 and 31

Smoke plumes from these high intensity forest fires degraded air quality over a large portion of southeastern Canada, including the St. Lawrence Valley, and up to New England. Figure 1 shows thick smoke over the Wemotaci area enroute to Quebec City on the afternoon of May 30. The degradation in air quality at Quebec City was short-lived, but was characterized by high concentrations of fine particles as well as numerous other pollutants and a strong smell of smoke. In addition, smoke reduced visibility to 1 km at Quebec City's airport. Information from Santé and Services Sociaux Québec (http:// www.coteairsante.qc.ca, accessed 5 November 2010) indicates that the Air Quality Health Index (AQHI) for the city and its surroundings reached the High Risk category by the end of afternoon of May 30 (Figure 3). The AOHI is an information tool for communicating health risks associated with poor air quality. Running from 1-10+, it is based on three consecutive



PM2.5 concentrations at the sites of Des Sables and St-Charles Garnier between May 28 and June 1.



Figure 4. Hourly variability of PM2.5 concentrations for Ottawa and Montreal Airport between May 28 and June 3.

hourly observations of three pollutants (ozone, particulate matter with aerodynamic diameter < 2.5 microns $(PM_{2.5})$ and nitrogen dioxide). Members of the public are encouraged to self-calibrate using the scale, but in general, the higher the AQHI, the greater the health risk.

The smoke drifted to the west and arrived over Montreal and Ottawa on the morning of May 31, lowering the air quality (Figure 4). PM_{2.5} concentrations in Montreal peaked

at 200 μ g/m³ at 1 a.m. By way of background, PM_{2.5} concentrations on a typical day are below 20-30 μ g/m³. In Ottawa, a maximum of 120 μ g/m³ was reached a few hours later at 8 a.m. A picture of Parliament Hill blanketed by smoke is available at http://www. ottawacitizen.com/health/Photos+Qu ebec+forest+fires/3093592/story.html (accessed 1 June 2010). Public health officials issued smoke advisories in both cities. In the afternoon, prevailing winds shifted to southerly, moving the smoke away from Eastern Ontario. Air



quality was significantly improved on June 1st. Weather records at Ottawa International Airport indicate that 10 mm and 6 mm of rain fell on June 1st and 2nd respectively, helping to wash away residual smoke.

Farther east, strong winds carried Quebec smoke over the northeastern United States after a journey of approximately 1000 km. A river of smoke literally flowed over New England and the North Atlantic Ocean. Air quality was rated as poor to very poor in many parts of Maine, New Hampshire, and Massachusetts. Figure 5 shows hourly PM_{25} concentrations for the three largest cities of those states: Portland, Manchester, and Boston. One headline in the Boston Herald read "Boston getting smoked by Canadian Wildfires". Fine particle concentrations measured in Boston were similar to those recorded in Montreal a few hours earlier. Note that Portland was affected to a lesser extent thanks to its location at the edge of the smoke plume (Figure 6). May 31 was Memorial Day in the US and many people in New England decided to enjoy outdoor activities despite the smoke.

Summary

The 2010 fire season in Quebec provides a good example of the episodic nature of bad air quality due to forest fires. Smoke plumes can suddenly increase background fine particle concentrations and other pollutants to dangerous levels in urban areas located hundreds of kilometers from regions ablaze. Successful advance warnings of these episodes will require monitoring capabilities that are able to pick up sudden surges in that are run every few hours and can fire activity, as well as forecast models react to any new information. §



Figure 5. Hourly variability of PM2.5 concentrations between May 28 and June 3 for the North End neighborhood of Boston, Massachusetts; Manchester, New Hampshire; and Deering Oaks Park in Portland, Maine.



Figure 6. Smoke over New England and the North Atlantic Ocean detected with the MODIS sensor on the Terra satellite, May 31, 15:10 UTC or 11:10 DST (image courtesy of the MODIS Rapid Response Team, NASA Goddard Space Flight Center).

Fall/Winter 2010

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

Verification of the NOAA Smoke Forecasting System: Model Sensitivity to the Injection Height

Paper by Ariel F. Stein, Glenn D. Rolph, Roland R. Draxler and Barbara Stunder; published in Weather and Forecasting, by the American Meteorological Society. Review by Al Pankratz.

NOAA's Smoke Forecasting System (SFS) is composed of the HYSPLIT dispersion model, the BlueSky framework for emission processing and the Hazard Mapping System (HMS). This paper compares the SFS to satellite and surface measurements using four case studies, and assesses the impact of adjusting smoke plume heights on forecast accuracy.

Case Studies. Forecast assessments used two comparison methods.

- 1) HYSPLIT concentration predictions in the lowest 100 meters (added to CMAQ PM_{2.5} results for Case 1 only) vs. hourly PM_{2.5} obs obtained from the AIRNow database.
- 2) HYSPLIT predicted column integrated concentrations from the surface up to 5 km above ground level (AGL) vs. the HMS observed 5 μ g/m³ concentration contour, scored by the daily mean Figure of Merit in Space (FMS) which is the intersection over the union of the predicted and observed plumes.

Case 1. Smoke originated from large fires over portions of the western and north-western US from September 1-15, 2006.

Papers of Interest

The smoke subsequently advected over large portions of North America.

Case 2. Smoke was emitted over southern California between October 21-27, initially moved over adjoining areas of the state as well as Baja California and the Pacific Ocean, then over southern Nevada and western Arizona.

Case 3. Between 17-21 April, 2007, two large brush fires over southeastern Georgia emitted smoke that travelled across Florida, the adjoining Atlantic Ocean, portions of Cuba and the Bahamas and over the Gulf of Mexico.

Case 4. On the 23rd and 24th of September, a large wildfire in the Los Padres National Forest in southwestern California generated smoke which initially spread south, west and east of the fire location, then moved over the adjoining Pacific Ocean with an extension into Arizona and New Mexico on day two.

HYSPLIT emissions evaluated in the case studies used base case (BC) settings for plume rise, i.e., particle emission release height was assumed to be the final buoyant rise height calculated by the Briggs method, and fire heat release was determined using the PM_{2,5} emissions model in BlueSky. The release height was then modified as necessary to conform to a rule that assigned upper limits according to stability criteria (height not to exceed twice the mixing depth under neutral or stable conditions, and not to exceed .75 times the mixing depth if conditions were unstable). FMS and PM_{2.5} comparisons are found in Table 1.

	FMS Scores: Column Integrated to 5 km AGL	Surface Layer PM2.5 vs Obs
Case1	usually above 5%, some days above 11.6% (study avg)	gross features captured, significant over and under prediction
Case2	quite good, as high as 40.1%	initial high overprediction, improvement toward end of period
Case3	higher than study avg of 11.6%	underprediction, but captured onset and relative magnitude
Case4	22.5% on first day dropping to 1.7% on second day	effects at three stations were expected but none were noted in any observations

Table 1. FMS and PM2.5 scores vs HMS and observations respectively.

Sensitivity Study. Two different types of sensitivity runs were carried out for Case 1 to assess the impact of different injection heights on the FMS scores.

Fixed Heights. The first method used five fixed plume emission heights, namely 100, 750, 1500, 3000 and 5000 meters AGL. No particular height consistently outperformed the others for the entire period from September 1-15.

Variable Heights. Three different settings were used. VAR1 used release heights calculated using the Briggs method, up to a maximum height of 3000 meters. VAR2 released at 100 meters AGL and also at the height used in VAR1. VAR3 had releases at up to four heights (100, 750, 1500, 3000 meters), allowing those that were at or below the limit imposed by the Briggs fire heat calculation. All methods improved FMS scores, but VAR1 was the best and was used henceforth for analysis purposes.

As a result of what was learned with Case 1, the models were rerun for Cases 2-4 using VAR1 parameters. FMS and PM25 scores for Case 2 showed no significant change vs BC. Scores for Case 3 showed significant degradation, in part as a result of relaxed release height restrictions that allowed injection of smoke into winds moving in an entirely different direction from that of the BC. In case 4, the satellite analysis was reproduced more accurately, due to injection of the plume into westerly winds aloft, whereas the BC had confined the plume below the planetary boundary layer (PBL) where it was controlled by easterly winds.

Conclusions. The authors emphasize the importance of making accurate estimations of plume height when attempting to determine concentrations at or near the PBL. They note that numerical techniques may never provide all the information needed to the accuracy required, and suggest a search for additional approaches such as satellite-based model initializations. They also advise operational forecasters to compare HMS analyses with model initializations to give a sense of how well the SFS is handling smoke.