The Canadian Smoke Newsletter

2012

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

Welcome to the 2012 Spring/Summer issue of the Canadian Smoke Newsletter.

The Slave Lake, Alberta fire of May 15, 2011 has been at the forefront of attention in the Canadian wildfire community over the past year. The town, which lies 200 km north-northwest of Edmonton Alberta, was devastated by a wildfire which destroyed several hundred homes and displaced thousands of people. This event spawned a provincial report and a significant re-evaluation of procedures for dealing with communities in the wildland-urban interface. This type of damage is highly visible and impossible to ignore. Less visible but no less important to the many Canadians who suffer from respiratory diseases are the health effects of wildfire smoke. Smoke inundations that last for periods on the order of days or weeks are particularly important in this regard. Communities in the central interior of British Columbia underwent many such episodes in the summer of 2010. This issue includes several articles that point to significant potential challenges in the areas where smoke, air quality prediction and health overlap. We hope you will enjoy them.

The next issue of the CSN will be sent out in July of 2013. Until then,

best regards,

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 portion of the Slave Lake fire. Photo courtesy Kevin Parkinson, Alberta Environment and Sustainable Resource Development.

In this issue:

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.

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Photographs of the 2011 Slave Lake Fire

Unless otherwise noted, all photos courtesy of Kevin Parkinson,
Wildfire and Air Operations Officer,
Alberta Environment and Sustainable Resource Development

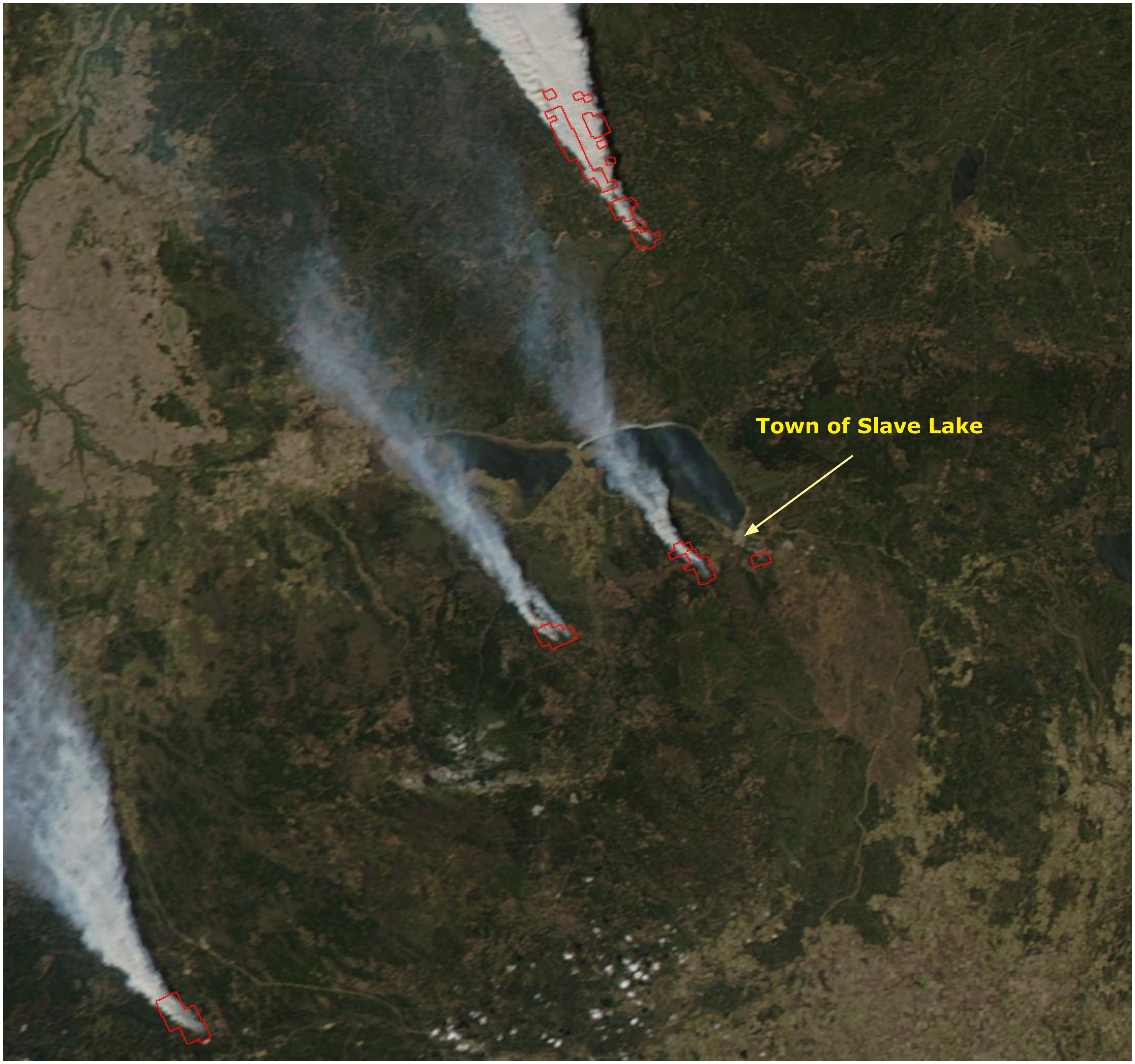

Figure 1. Aqua/MODIS satellite image of fires near Slave Lake, Alberta, courtesy of NASA. Photo taken on May 15, 2011 at 19:45 UTC.

Figure 2. The fire complex at center foreground hides the town of Slave Lake. This photo was taken approximately 20-30 minutes prior to the breaching of the town limits. The larger column to the right moved northeast of the built-up areas and terminated at the lake. The smaller dark column of smoke parallel to the highway (arrowed) denotes the portion of the fire that eventually entered the town itself. The large plume in the distance (left portion of photo) was emitted by fires that had already entered the communities of Wide Water and Canyon Creek. Note the bending of the smoke plumes due to the very strong southeast winds.

Figure 3. Several views of the fire and smoke plumes. Wildfires on that fateful Sunday afternoon were fanned by winds ranging between 50-90 km/h, rendering the fires impossible to control. The final report on the fire by the Alberta government makes mention of a wind gust to 114 km/h that was measured 12 km southeast of the town.

Figure 4. Smoke plumes over residential and commercial sections of Slave Lake. According to the provincial report, air support was grounded at approximately 1600 hours local time on Sunday afternoon due to dangerous wind conditions. The full report on the fires that affected communities around Slave Lake is available at http://www.srd.alberta.ca/Wildfire/WildfirePreventionEnforcement/WildfireReviews/documents/FlatTopComplex-WildfireReviewCommittee-May18-2012.pdf.

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Megafires: Reality or Hype?

by Al Pankratz[1]

1. Air Quality Science Unit, Prairie and Northern Region, Environment Canada

Do megafires exist? If so, what makes a megafire a megafire? And what should be done about them, assuming they do exist?

Conference on Mega-fires

Exploring the Mega-fire Reality 2011 took place at the Florida State University conference centre in Tallahassee, Florida in November of 2011. The conference introduction stated "*In many parts of the world both the area and intensity of wildland fires have been growing alarmingly. However, it is not only the number of fires that is changing, but it is also the nature of these fires that is changing. Global warming, over-accumulation of fuels in fire-prone forests, and growth at the wildland-urban interface all suggest that the fire protection strategies we have used in the past may no longer serve us so well in the future.*"[1] The conference was in the interesting position of discussing a topic which had not been rigidly defined. As a result, attendees were simultaneously concerned with the concept of megafires and what to do about them.

Main points. The following four major issues were addressed at the conference:

1) An apparent increase in the scale and frequency of wildfires and smoke episodes, typified by occurrences in Indonesia in 1997/98, Australia in 2009 and western Russia in 2010

2) The definition of the term "megafire". For the purposes of the conference, the working definition was a fire ranking high with respect to three or more of the following factors:

- very large area burned
- very large carbon emissions (such as smoldering peat fires)
- human health impacts (especially deaths), and
- destruction of homes and towns (see Figure 1)

3) Insights into the nature of megafires, such as:

- their occurrence in conjunction with extreme or record temperatures and drought
- high volumes of available fuels
- the inability of even well-equipped fire fighting organizations to make headway against them

4) How to prepare for and respond to megafires, operationally, organizationally and politically.

Debating the concept

It is safe to say that proponents of the megafire concept are responding to deep concerns about what they see happening around the world. Statistics show that wildfire seasons are lengthening [Westerling, 2006], that ever more resources are being spent on fighting fires, that those investments are in some cases not enough to make a difference, and that the destructive and debilitating effects of fire and smoke are becoming more frequent and more extensive. It is also safe to say that in light of significant warming trends in many areas of the globe, there is significant worry that society will be subject to these outbreaks to an unprecedented extent in the decades ahead, stretching resources past the breaking point, draining treasuries and taking the lives and possessions of ever more people.

Opponents of the megafire concept do not necessarily deny these concerns. They do, however, object to the lack of precision used by proponents of the megafire concept. In order to be studied rigorously, a phenomenon must be characterized and defined so that researchers start from the same point. (The conference was, in part, an attempt to carry out this process of definition.) Opponents would further state that so-called megafires are the same wildfires that the world has known for eons; they are simply occurring more often and are more severe. In essence, there are no fundamental changes in the nature of fires, no emergent behaviours that occur now that did not occur previously. We are simply seeing a change in frequency and scale. By analogy with meteorology, they would say that very strong low pressure systems do not produce something new called mega-rain, they simply produce more intense and widespread rain of the kind we are already familiar with.

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Discussion

If new and previously unseen physical fire behaviour were discovered and documented, this would probably settle the matter in favour of the megafire concept. Has anyone in the fire research community acquired this type of data to date? If not, researchers need to weigh the merits of coining a new term to deal with the increase in fires, costs, damage and deaths in the absence of a definitive new physical discovery. It should be noted that the Fujita scale of tornado severity is a result of a "bookkeeping" decision of this type. Theodore Fujita was able to classify tornado severity by the damage visible and measurable on the ground, and he thereby gave society a shorthand for tornado classification and effects. No new phenomenon was at the root of the Fujita scale, but it has nonetheless come into widespread use.

Can fire scientists make headway with the public, the media, industry and politicians using the megafire term? If it represents a truly new phenomenon, then that phenomenon must be investigated and properly described before the term is unleashed. If instead it represents an incremental (albeit frightening) change in an existing and well-known phenomenon, then the wildfire community awaits a definitive paper which produces defensible statistics on attributes such as damage and deaths that are associated with the proposed category of "megafires". §

Thanks to Brian Stocks, Amber Soja, Johann Goldammer and Dan Binkley for their valuable comments.

References

1. http://www.megafirereality.com/index.asp, referenced Wednesday May 2, 2012.

2. Westerling, A.L., Hidalgo, H. G., Cayan, D.R. and Swetnam, T.W., Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity, Science 18 August 2006: Vol. 313 no. 5789 pp. 940-943.

Figure 1. Fire moves into Slave Lake, Alberta, May 15, 2011. Photo courtesy Kevin Parkinson, Alberta Environment and Sustainable Resource Development.

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AQHI Event over the Southern Prairies, Sept. 9-11, 2011

by Justin Shaer[1]

1. Meteorological Service of Canada, Prairie and Northern Region, Environment Canada

Abstract

On the weekend of September 9, 2011, Regina, Brandon and Winnipeg experienced abnormally high levels of PM2.5 (particulate matter smaller than 2.5 microns). This resulted in peak AQHI (Air Quality Health Index [Stieb, 2008]) values of 7, 6 and 5 respectively. A significant portion of the PM was attributable to forest fires over the northern prairies and around the Idaho/Montana border. Complicating the situation, however, was a plethora of crop fires, each of which contributed additional PM2.5 to the lower levels of the atmosphere. It was known that the overall situation was one that would inhibit proper ventilation, but were the PM events predictable?

Introduction

The AQHI is based on concentrations of three pollutants: NO2, O3, and PM2.5, with stronger weighting given to the first two. During the weekend of the 9th of September, the southeastern Prairies saw above-normal measurements of the PM2.5 component, resulting in high AQHI values. Such events typically require a PM source together with the proper weather conditions such as a synoptic (large scale) weather pattern promoting light winds, low to nil vertical motion and strong thermal capping overnight.

Weather & PM2.5 Source

A persistent high pressure pattern that was in place from Sept.7-11 provided ideal weather conditions for an occurrence of elevated PM2.5. Subsident (downward moving) air inhibited virtually all surface-based vertical motion and warmed as it descended, evaporating any moisture. As a result, clear skies (except for contrails) persisted over the Prairies during this period. Winds at the surface were weak.

Figure 1. Stubble burning in southern Saskatchewan (file photo - Patrick Kyle).

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When a PM source is within the boundary layer (lowest few hundred to thousand feet of the atmosphere), this weather scenario causes the PM to pool instead of moving out of an area. Overnight cooling due to the ground radiating its heat is facilitated by clear skies, allowing strong thermal inversions to form, further trapping and concentrating PM. PM levels in this scenario generally spike overnight. Daytime typically sees improvement as surface heating erodes the inversion and cleaner air aloft is mixed down.

PM from elevated source regions behaves significantly differently. Forest fires that originate relatively far from the affected area and whose smoke is carried above the boundary layer require some means of returning the smoke to the surface after travelling long distances. In this case, that mechanism is provided by daytime turbulent mixing. At night the formation of the inversion cuts off the smoke since the air aloft cannot mix down. The result of this is a spike in PM during the day, rather than at night. It is therefore critical to determine whether the PM has managed to move above the boundary layer or has been trapped below it as it moves.

On this particular occasion, fire analysis maps from NOAA and MODIS imagery both showed numerous hotspots (Figure 2), indicating the potential for widespread distribution of PM2.5. In addition, crop residue burning had been authorized by provincial authorities for September 9-11 between the hours of 11am and 7:30pm (local), with fires required to be completely extinguished by 7:30pm.

Forecasts/Discussions

The AQHI forecasts for these events were problematic. Table 1 (next page) shows forecasts for three prairie locations leading up to and during the event. The largest deviation from reality for a "Today" forecast was a value of 2 (see Winnipeg and Brandon on the 11th, highlighted in red). Regina's event two days earlier was well handled in the "Today" forecast on the 9th (highlighted in blue). However, this event was not predicted by the "Tomorrow" forecast on the 8th, with a significant underprediction of 4.

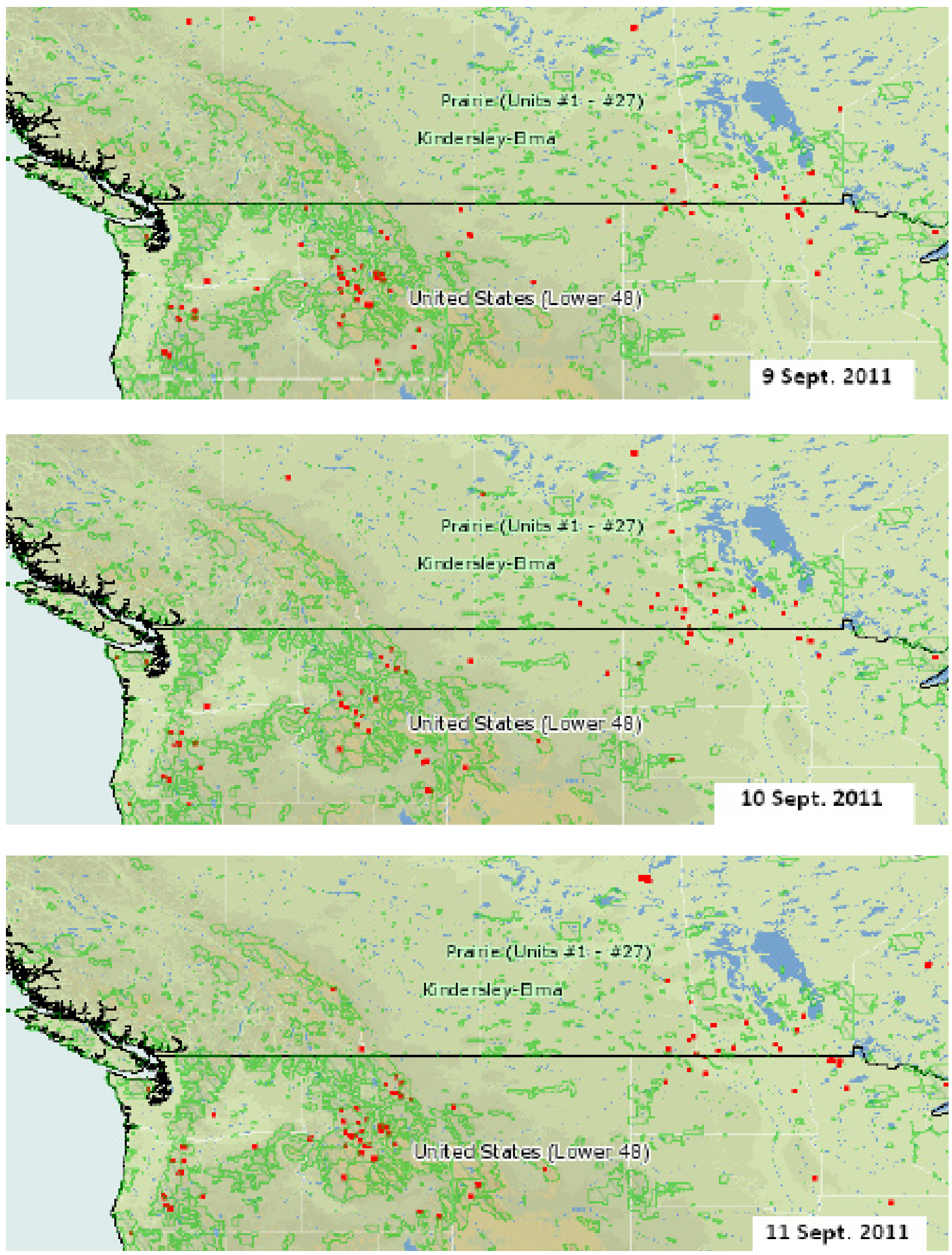

Figure 2. Hotspot maps for Sept. 9-11 courtesy FIRMS.

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Winnipeg			UMOS AQHI Prediction			Transmitted AQHI Prediction			Obs-Ellen		Obs-Scotia	
	Date		today	tonight	tmrw	today	tonight	tmrw	day	night	day	night
Wed	9/7/2011	AM	3.3	3.5	3.4	3	4	3	4	4	3	3
		PM		3.3	2.9		3	3				
Thu	9/8/2011	AM	3	3.3	3	3	4	3	3	5	3	4
		PM		4	3.2		4	3				
Fri	9/9/2011	AM	3.1	3.8	3.1	3	3	3	3	5	3	4
		PM					4	3				
Sat	9/10/2011	AM	3.2	3.4	2.7	4	4	3	3	4	4	4
		PM		3.4	2.6		4	3				
Sun	9/11/2011	AM	2.8	3.1	2.4	3	3	2	4	5	5	5
		PM		2.7	2.1		5	4				
Mon	9/12/2011	AM	2	2.1	2.2	3	2	2	3	2	3	3
Brandon			**UMOS AQHI Prediction**			**Transmitted AQHI Prediction**			**Observed**			
	Date		today	tonight	tmrw	today	tonight	tmrw	day	night		
Wed	9/7/2011	AM	2.8	2.8	2.9	3	3	3	2	2		
		PM		2.5	2.4		3	3				
Thu	9/8/2011	AM	2.6	2.7	2.6	2	2	3	3	3		
		PM		2.5	2.6		3	3				
Fri	9/9/2011	AM	2.7	2.8	3	3	3	3	3	3		
		PM		2.7	2.7		3	3				
Sat	9/10/2011	AM	2.9	3	2.4	3	3	2	3	3		
		PM		2.8	2.4		4	3				
Sun	9/11/2011	AM	2.3	2.4	1.9	3	2	2	5	6		
		PM		2.3	1.8		7	3				
Mon	9/12/2011	AM	2.8	2.8	2.2	3	2	2	2	2		
		PM		1.8	1.9		2	2				
Regina			**UMOS AQHI Prediction**			**Transmitted AQHI Prediction**			**Observed**			
	Date		today	tonight	tmrw	today	tonight	tmrw	day	night		
Wed	9/7/2011	AM	3.2	3.2	3.3	3	3	3	4	3		
		PM		3.2	3.3		4	3				
Thu	9/8/2011	AM	3.3	3.6	3.5	4	4	4	5	5		
		PM		4	3.6		5	4				
Fri	9/9/2011	AM	3.8	3.9	3.9	7	5	6	7	5		
		PM		3.1	4.4		6	6				
Sat	9/10/2011	AM	3.7	3.8	3.4	5	5	4	5	6		
		PM		3.7	3.7		5	4				
Sun	9/11/2011	AM	4.1	3.9	2.9	4	4	2	5	4		
		PM		3.5	2.5		5	2				
Mon	9/12/2011	AM	2.9	2.9	2.6	3	3	3	3	3		
		PM		2.4	2.4		3	3				

Table 1. AQHI guidance, predictions and observations for Winnipeg, Brandon and Regina. (UMOS is an acronym for Updateable Model Output Statistics, based on data generated by the Canadian Meteorological Centre's GEM weather model.)

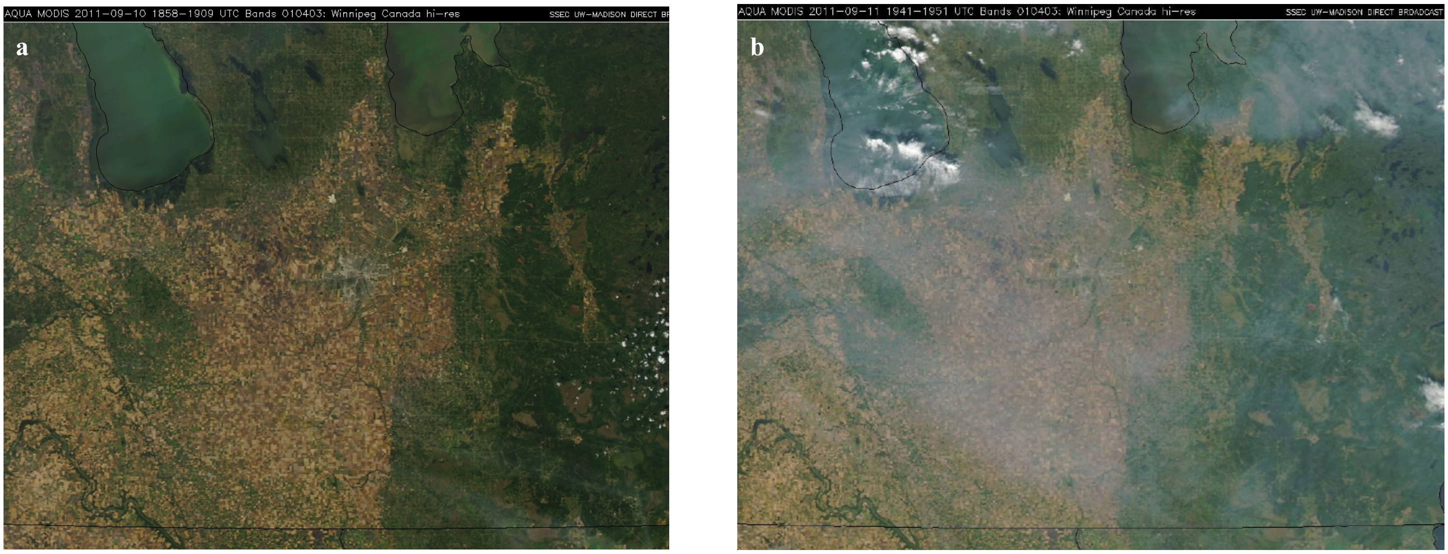

Figure 3a), Southern Manitoba without smoke, September 10, 2011. Figure 3b), Southern Manitoba under smoke, September 11, 2011. MODIS image courtesy NASA.

Model guidance was of little help in improving these forecasts.

It seems fairly clear that one of the best ways to improve AQHI forecasts in the future would be to acquire better situational awareness with respect to fire sources. Just knowing that poor ventilating weather conditions exist cannot substantially improve the forecast; however, having a good picture of smoke emissions or advection within an area can improve the forecast greatly. This is easier to do in the case of large forest fires which are usually visible in satellite imagery and which can be handled via dispersion models.

Agricultural burning, on the other hand, presents challenges due to a lack of fire data. Crop residue fires helped make the 9th-11th of September an event, but how would a forecaster achieve the required situational awareness for this type of burning without significant investment in crop fire monitoring and communications infrastructure? At present, even if a forecaster knows that a burn authorization exists, he or she does not know how many fires will actually be lit, or where they will occur. With more cases similar to this event under his or her belt, a forecaster might gain a somewhat better ‘feel’ for the potential number of fires, but whether this would make a significant difference in the end is debatable.

Conclusions

A persistent upper ridge with little flow created stagnant conditions that contributed to an elevated PM 2.5 event during the weekend of September 9-11, 2011. Forest fire smoke created poor air quality over a large area, and was elevated locally by the burning of crop residue, causing local levels of PM2.5 to spike. Peak AQHI levels reached 7 for Regina on the 9th, while a 6 was recorded in Brandon on the 11th. Winnipeg hit a peak AQHI reading of 5 on the 11th as well.

Although forest fire smoke can be handled through situational awareness, the major unknown is the burning of crop stubble. Ideal conditions for a PM event may exist, but without a significant source, an event will not occur. Better situational awareness and familiarity may assist forecasters for future events, but the lack of some very basic information is a significant hindrance to success. Given the serious nature of health effects in response to smoke exposure, forecasters will need to be creative in finding ways to overcome data gaps and improve their forecasts. §

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1. Stieb, D. M., Burnett, R.T., Smith-Doiron,M., Brion,O., Shin, H. H., Economou, V., A new multipollutant, no-threshold air quality health index based on short-term associations observed in daily time-series analyses, J Air Waste Manag Assoc., 2008, March, 58(3): 435–450.

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The Western Canada BlueSky Wildfire Smoke Forecasting System: Continued Development, Evaluation and Operation

by Steve Sakiyama[1]
1. British Columbia Ministry of the Environment

Previous editions of this Newsletter provided the background of the Western Canada BlueSky Wildfire Smoke Forecasting system and its first season (2010) of operation. The system is based on the US Forest Service BlueSky framework, and consists of data and models of fuel consumption, emissions, fire, weather, and smoke dispersion all linked into a single framework operated at the University of British Columbia. Hourly forecasts for up to two days into the future are generated for ground-level concentrations of PM2.5 from wildfires. The output is available from a BC government website (www.bcairquality.ca/bluesky/) and is visualized in the form of animations over a map of Western Canada.

The system relies on two key inputs: wildfire characterization via satellite detection of hotspots together with fuel estimates provided by the Canadian Wildfire Information System (CWFIS), and weather forecasts produced by the University of British Columbia using a numerical weather prediction model (MM5). This information is used by a transport and dispersion model (HYSPLIT) to produce hourly PM2.5 concentrations up to 48 hours into the future (see: http://www.bcairquality.ca/bluesky/BlueSky-Smoke-Forecasts-for-Western-Canada.pdf). This article provides an update on system developments since the last Canadian Smoke Newsletter article, and outlines plans for the future.

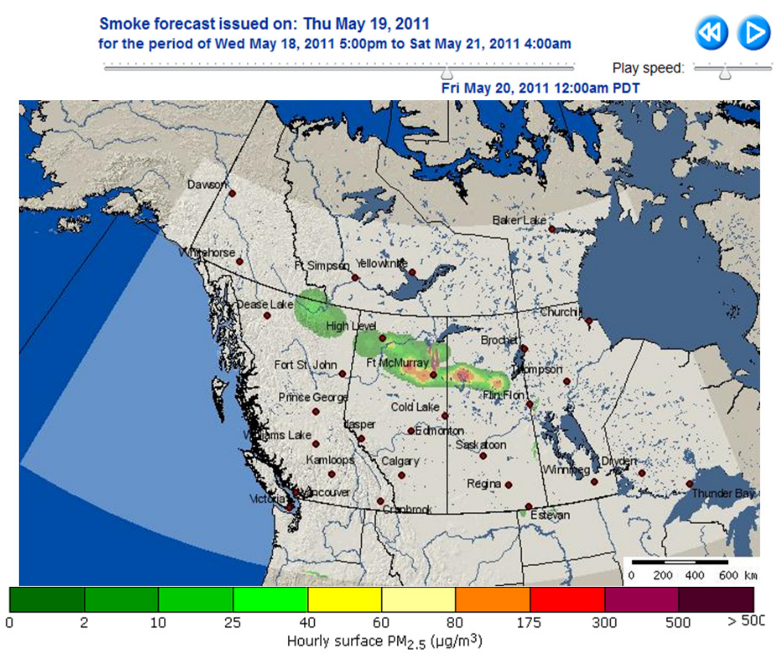

Figure 1. Western Canada BlueSky Wildfire Smoke Forecast Domain (lighter area). Colours depict forecast hourly smoke (PM2.5) concentrations for 12:00 PDT Friday, May 20, 2011

2011-2012 Highlights

Domain Expansion: The initial (2010 pilot) system only included British Columbia and Alberta. In 2011 the domain was expanded to include all of the Western provinces (BC, Alberta, Saskatchewan, Manitoba) as well as northwestern Ontario, southern portions of the Yukon, Northwest Territories, Nunavut and portions of the US states along the border. This larger domain not only provided smoke forecasts for the additional areas, but also meant that smoke moving into Western Canada from bordering regions could be accounted for.

The domain expansion required the use of nested grids within MM5 as well as accommodation for the nesting in the BlueSky framework. The BC and Alberta portions of the domain use a 4 km grid resolution in order to better account for the effects of rugged terrain on the meteorological fields. Outside this area, the grid resolution is 12 km. In addition, the domain expansion also required an extension of the original CWFIS hotspot domain in order to include the wildfires in the bounding areas. The expanded domain is shown as the lighter shaded region in Figure 1. Colours represent smoke concentrations (refer to the colour key at the bottom of the image). The forecast time is seen in the title at the top of the images.

Twice Per Day Forecasts. At present the computational cycle that produces the forecasts begins at midnight Pacific Time. Run times vary depending on the number of fires. During intense periods with hundreds of fires, the runs are typically complete before 0600 PDT. Since the CWFIS hotspot information is updated six times per day, a second noon-hour forecast run will be added for the 2012 fire season in order to capture rapidly changing fire situations and account for them in the smoke forecasts.

Source Processing with SmartFire2 (SF2). Since the system relies completely on the satellite detects of fires and uses a rudimentary model to establish the area burned, there can be considerable uncertainties in this critical input as clouds may obscure wildfire detection and assumptions about burn size may not apply. Through the application of the SF2 module (developed by the US Forest Service), actual observed fire information can be used in combination with the satellite-based data to produce fire characteristics based on the strengths of both information sources. In addition, SF2 includes a clumping algorithm that combines hotspots that are associated with the same fire complex, the goals being to better represent the source and to reduce computational time (which can be considerable when there are thousands of wildfires). These computational savings are needed before other features can be added, such as a further domain expansion to encompass Ontario and the inclusion of carry-over smoke (smoke from the previous forecast period).

Development of a Prescribed Fire Tool (Playground). Through funding provided by Parks Canada, BlueSky provides a platform for a new tool that can be used to inform prescribed (R_x) burn decisions by employing modules from a similar US system (called Playground). A burn manager can input the proposed R_x burn characteristics (location, size, fuel, etc.) via a web portal and request the system to provide an image animation of the resulting forecast smoke impact area and concentrations for that burn scenario. If the smoke is forecast to affect populated areas, then the burn may be deferred to a later time. Alternate burn scenarios can be input and the resulting smoke forecasts examined. A prototype is currently in testing mode. An example of the Playground webpage is shown in Figure 2.

Evaluation. One of the challenges in evaluating such a system is to determine appropriate metrics to assess performance (i.e. some may be related to the overall system operation, and some may be related to the forecast accuracy). Considering the uncertainties associated with each of the series of models used in the system (the weather forecast model, source characterization, smoke transport and dispersion), there are a number of potential sources of error in the forecast. For example, an error of 1 degree in wind direction can result in a significant difference in the concentrations at a specific location far downwind. In this case, even though the overall impact patterns, concentrations and timing may be perfect, the accuracy may be poor for that particular location due to error in the exact plume placement.

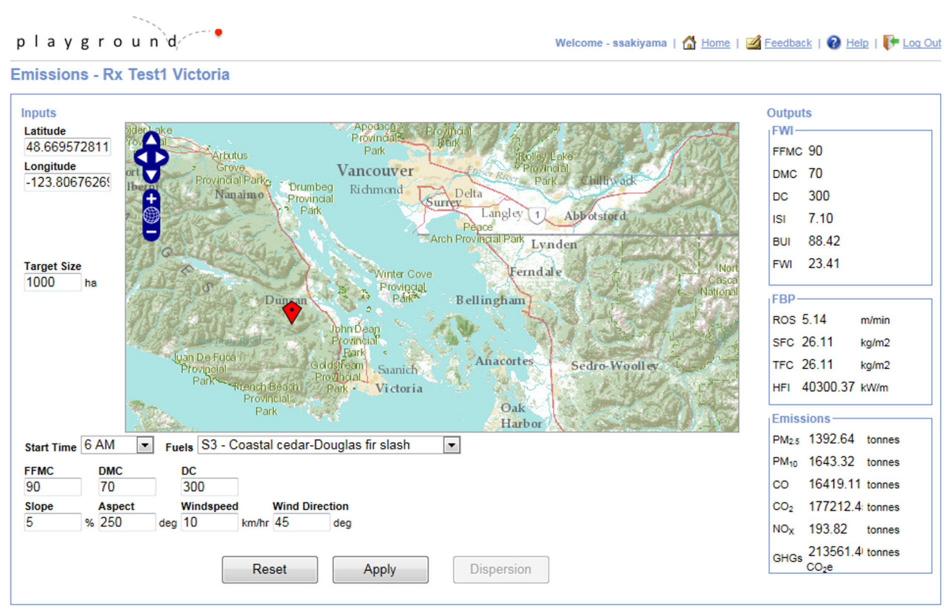

Figure 2. Prescribed Burn Tool (Playground): Web Portal for Prescribed Burn Information Input.

A qualitative first-order evaluation using MODIS satellite images of smoke over Western Canada for case days was carried out in 2011, and helped to confirm that the pieces of the system were collectively working together as they were designed to do. It also indicated that the locations of the wildfires were captured correctly for those case days where smoke impacts were extensive, and showed that in general, smoke plumes were moving and behaving in directions consistent with the forecast meteorology and the actual observed smoke distribution – although there were numerous instances where the predicted plume footprint missed the specific locations where smoke was observed.

Second order assessments involved comparisons of the predicted PM2.5 (particulate matter smaller than 2.5 microns) concentrations in space and time with measurements by ground-based, air quality monitoring stations. Alberta Environment (V. Klikach and D. Lyder) compared forecasts for case days with observed concentrations from several air quality monitoring stations. In the course of this work they also found that there was qualitative agreement between satellite images of smoke and the smoke forecast, with some notable exceptions in situations where carry-over smoke was important (something that the system currently does not completely handle). They also pointed out that observed PM2.5 may include significant contributions from other non-wildfire sources (such as vehicles), and that care must be exercised when comparing measurements to the smoke forecasts. Another study being carried out by the University of British Columbia (Jiayun Yao) is currently examining BlueSky forecasts in combination with PM2.5 measurements and respiratory health indicators in two communities that experienced high wildfire smoke concentrations during August 2010. This research is investigating the use of the system as a predictive tool for respiratory health risk associated with wildfire smoke.

Future Plans

There are both technical and policy related matters that are on the BlueSky to-do list, namely:

1. The conversion of forecast output animations to layers for ArcGIS.
2. Parallelization of HYSPLIT in order to achieve the computational efficiencies required for further domain expansion and other system development.
3. Inclusion of carry over smoke in order to improve accuracy. This depends in part on Task 2 and on success in hotspot clumping through the application of SmartFire2. At present the system is unable to fully carry over smoke from the previous to the current forecast scenario.
4. A governance and support structure. The system was created and is currently supported through an informal partnership of several agencies. To this point, no formal governance structure has been set up by the provincial BlueSky funding partners due in part to uncertainty regarding plans by Environment Canada (EC) for a future national smoke forecasting system. Given this situation, there is a need to consider a formal support structure for the future. Approximately $25K is needed annually to produce forecasts twice/day for the current domain. A sustainable funding model would likely include small contributions from many different agencies and the active involvement of partner agencies to provide direction to the project now that it has survived (and grown) in its first two years of life.

Summary and Acknowledgements

Thanks to ongoing involvement and funding from a number of provincial partner agencies, the Western Canada BlueSky Smoke Forecasting System has survived and thrived in its first two years of life, and has made the transition from a pilot to a more mature operational system (with all its good parts and warts). Although it remains experimental, new science and additional evaluations will point out areas where the system can be expanded and enhanced. A more formal governance and support structure needs to be considered in light of the uncertainty regarding EC's plans at the national level.

Thanks go to our many partners, in particular BC Ministry of Environment, Alberta Environment (V. Klikach, D. Lyder), Natural Resources Canada (K. Anderson, P. Englefield), Parks Canada (J. Cochrane), University of British Columbia (G. Hicks), and Sonoma Technology Inc. (S. Raffuse) for their efforts in developing science-based tools to help meet critical information needs for a variety of public, commercial and government interests that are affected by wildfire smoke. §

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Western Partnership for Wildland Fire Science

by Mike Flannigan[1]

1. University of Alberta Department of Renewable Resources

The establishment of a western Canadian centre for innovative fire science research has taken place as a result of a shared vision by Natural Resources Canada, Alberta Environment and Sustainable Resource Development, and the University of Alberta. This achievement reflects and supports the Canadian Wildland Fire Strategy that was developed in 2005 by the federal, provincial and territorial governments. The Strategy promotes measures to enhance fire hazard mitigation, preparedness and recovery activities. It also encourages maintenance of a highly effective fire suppression program, in particular by applying forest fuel reduction practices around communities and homes.

The three Western Partnership for Wildland Fire Science (WPWFS) partners agreed to share resources and collaborate on development of a centre that addressed their priority research needs. The result is a program of research and education that we hope will become an international leader in wildland fire science and will help shape fire management in Canada and around the world.

The Partners

The Canadian Forest Service (CFS) is an arm of the government department known as Natural Resources Canada (NRCan). The CFS conducts research on wildland fire behavior and the ecological role of fire, monitors and predicts national fire activity, and assists in development of national wildland fire management strategies in support of the jurisdictions responsible for firefighting.

The mission of Alberta Environment and Sustainable Resource Development (AESRD) is to apply leading practices in management, science, and stewardship to attain a balanced and responsible use of Alberta's natural resources. The Wildfire Management Branch achieves this goal through the application of science-informed fire management practices, particularly in the fields of fire behavior, fire effects, prescribed burning, and fuel management.

The focus of the School of Forest Science and Management at the University of Alberta (U of A) is on understanding and managing landscapes and associated resources through programs in conservation biology, forest biology and management, forest economics, protected areas and wildlife management, and wildlife ecology and management.

The Program

The Western Partnership for Wildland Fire Science is focusing on four long-term directions.

1) Education: Building wildland fire management and science capability and extension of science knowledge in Canada by expanding the graduate and undergraduate program in wildland fire science, technology, and management. This will be accomplished by:

- providing post-graduate projects and scholarships, and
- developing a knowledge-based centre of excellence for wildland fire education and research.

2) Science: Advancing the physical, ecological, social, and economic sciences in wildland fire to develop the information and knowledge needed to support improved wildland fire management, planning, prevention, and appropriate response by Canada's wildland fire management agencies. This will require:

- physical fire science research to advance understanding of fire behaviour, fire weather, fuel management impacts and climate change impacts in order to improve fire weather and fire behaviour forecasting, risk assessments, and prediction of effects from prescribed fire and wildland fire
- better understanding of the biophysical aspects of fire and

the interactions of other natural disturbances and ecological processes required to sustain healthy and productive forest ecosystems, and

- better understanding of the social and economic impacts and risks of alternative wildland fire and fuel management strategies.

3) Scientific Applications and Communications: Packaging, promoting, and delivering scientific information so that partners, cooperators, the public and the science community can understand and use it effectively. This will involve paying attention to:

- application of knowledge through development of tools and techniques,
- integration of knowledge through risk and trade-off analysis and the discerning of ways to assist regional, provincial, and national wildland fire planning, and
- delivering knowledge in peer-reviewed publications and reports and by technology transfer tools.

4) Partnerships and Collaboration: At the heart of the WPWFS will be the development of productive partnerships to support improved capacity and investment in wildland fire science and technology by:

- building on existing partnerships, and
- brokering new partnerships.

Present Status

The WPWFS program has been up and running since 2010. Currently, 14 graduate students and 2 research associates are associated with the partnership. We are always looking for good students who are interested in pursuing studies in wildland fire. Existing projects include lightning prediction, climate change, vegetation succession as related to the effectiveness of FireSmart treatments, landscape fire modelling, mountain pine beetle regeneration, vegetation green-up modelling and fire occurrence prediction.

We are currently reviewing the fire courses offered by the Department of Renewable Resources and are hoping to add new courses related to fire science and management, fire behaviour and fire ecology. The western partnership website at http://www.ualberta.ca/~wcwfs/ has a good overview of some of our activities.

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WESTERN PARTNERSHIP FOR WILDLAND FIRE SCIENCE

"The Western Partnership for Wildland Fire Science is an international leader in wildland fire science, contributing to shape fire management in Canada and around the world."

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Evaluation of the BlueSky Smoke Forecasting System and Its Utility for Public Health Protection in BC

by Jiayun Yao[1]

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Smoke from forest fires is a major contributor to extreme events of particulate matter (PM) air pollution in North America, and fire smoke exposure has been associated with respiratory and cardiovascular effects. Current tools to assess smoke exposure in Canada include PM measurements from regulatory air monitoring networks, and products generated from satellite data. For example, the Hazard Mapping System (HMS) (http://www.osdpd.noaa.gov/ml/land/hms.html) implemented by NOAA provides a semi-quantitative estimate of PM from smoke plumes detected by multiple remote sensing platforms. These tools, however, have their own limitations. While forest fire smoke can impact large populations, the available monitoring networks may not provide adequate coverage for estimation of health impacts, and the instruments may fail during smoke events with extremely high concentrations. On the other hand, detections from HMS can cover very large areas, but they represent the smoke in the total column of the atmosphere, which can be different from the ground-level conditions of most concern. A system that could supplement real-time regulatory monitoring and remote sensing data would be a valuable tool for public health, especially if it could predict ground-level concentrations in advance.

The Western Canada BlueSky Smoke Forecasting System (BlueSky) (http://www.bcairquality.ca/bluesky/) is a modeling framework that provides hourly forecasts of ground-level PM2.5 concentrations from wildfire smoke up to 60 hours in advance. Its domain has been expanded from Western Canada eastward to Ontario since its official launch in 2010 [Province of British Columbia, 2011]. This system has been in development since 2008, based on an existing framework created by the U.S. Forest Service AirFire Team. Meteorological forecasts from MM5 are combined with fire locations as well as consumption and emissions information from the Canadian Wildland Fire Information System, and are input to the HYSPLIT model to compute smoke dispersion. The output is an estimate of ground-level PM2.5 concentrations every 4 km^2 in British Columbia and Alberta, and every 12 km^2 throughout the rest of the model domain. So far, there has not been any quantitative and systematic evaluation of the system performance (although qualitative assessments have taken place). Our research aims to fill this gap and to assess the utility of BlueSky for public health protection. We focused our analysis on the 2010 fire season which included several large smoke episodes in British Columbia.

Forecast Evaluation

Our project addresses two questions. First, how do predictions from BlueSky compare with smoke measurements? Specifically, how do the PM2.5 estimates compare with measurements from the regulatory monitoring network, and how do the predicted plume shapes compare with those observed by satellite? Second, is there an association between BlueSky-generated PM2.5 predictions and measures of respiratory health in smoke-impacted communities? If so, this would support the use of BlueSky predictions to inform decision making for mitigating public health impacts from wildfire smoke.

For the first question, we conducted statistical analyses to assess both the spatial and temporal relationships between daily average BlueSky predictions and ground-level PM2.5 measurements from the regulatory monitoring network. For the spatial analysis, model forecasts were compared with observed values from all ambient air quality monitoring stations at a fixed time. For the temporal analysis, we compared the time series of model predictions and ambient air quality measurements at fixed locations. In addition, agreement between the location and size of smoke plumes predicted by BlueSky and observed from HMS was examined using a spatial statistic called the figure of merit in space (FMS), calculated as the intersection of the two plume types (areas covered by both) divided by their union (areas covered by one or the other or both, Figure 1, next page).

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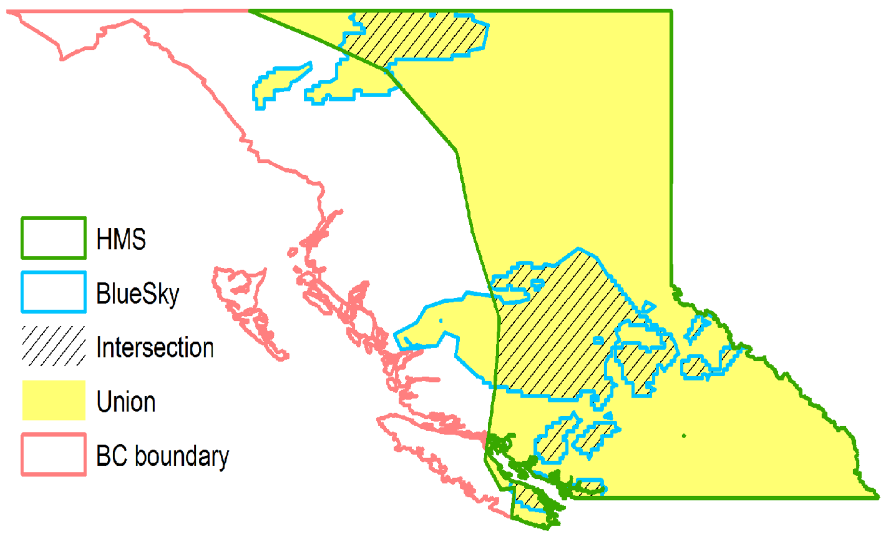

Figure 1. Diagram illustrating the calculation of the Figure of Merit in Space (FMS). AHMS = area of HMS plume and ABlueSky = area of BlueSky plume. AHMS ∩ ABlueSky is the intersection of the plume areas of HMS and BlueSky (area in hatching), and AHMS ∪ ABlueSky is the union of the two plume areas (area in yellow).

For the second question, Poisson regression was performed between BlueSky predicted PM2.5 concentrations and (1) counts of prescriptions dispensed to relieve symptoms of obstructive lung diseases, and (2) counts of outpatient physician visits for respiratory diseases. These two measures can serve as indicators of population sensitivity to wildfire smoke exposure.

Preliminary results suggest reasonable but inconsistent agreement between BlueSky and both PM2.5 measurements and plumes observed by remote sensing. The correlation coefficients for different days and locations ranged from -0.39 to 0.93. Generally, good agreement tended to occur during the middle of a fire smoke event (Figure 2) and at locations that were heavily and constantly impacted

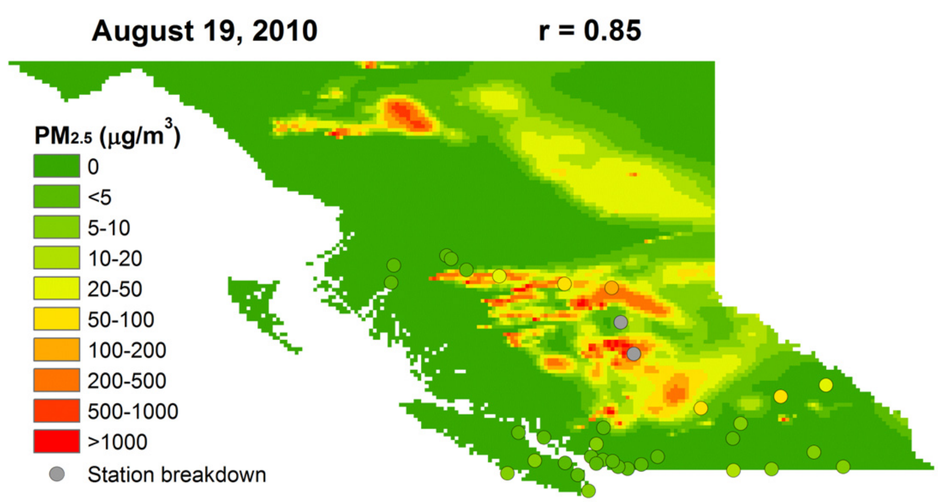

Figure 2. An example of good agreement between BlueSky predictions and monitoring network measurements from August 19, 2010. The background color represents PM2.5 concentrations predicted by BlueSky and the color of the circles represents PM2.5 concentrations measured by air quality monitoring stations. The scale of the color is the same for both predictions and measurements. The grey circles indicate monitoring stations that malfunctioned due to high PM concentrations.

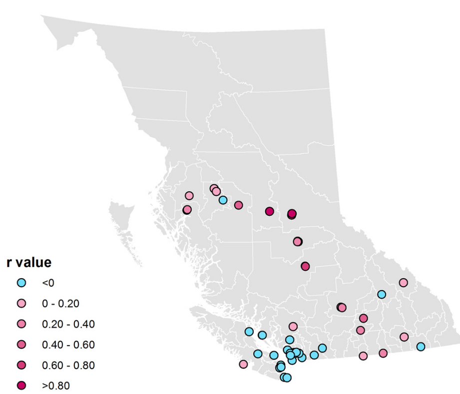

Figure 3. Correlation (r) computed from time-series data between BlueSky predictions and PM2.5 measurements from the regulatory monitoring network in British Columbia. High r values are observed at locations in the interior of the province, which was heavily impacted by smoke in 2010.

by fire smoke (Figure 3). For the comparison between BlueSky and HMS plumes, high FMS scores were observed in the middle of the fire smoke events (Figure 4). Overall, the size of the BlueSky predicted smoke plumes tended to be smaller than those observed by HMS.

Figure 5 shows plots of respiratory reliever dispensation counts for the Cariboo-Chilcotin local health area of British Columbia, a region that was heavily impacted by forest fire smoke plumes in 2010. The figure also includes PM2.5 concentrations predicted by BlueSky and measured by an ambient air quality monitoring station in the area. Peaks of dispensation counts coincide with peaks of predicted and measured PM2.5. The same association was also observed in other smoke impacted areas, and between BlueSky predictions and counts of physician visits for respiratory diseases. We are currently assessing these associations with more sophisticated statistical analysis to provide a quantitative measure of the strength of the relationship. In addition, we are currently monitoring the 2012 fire season activity, and will incorporate additional fire event data into our analyses.

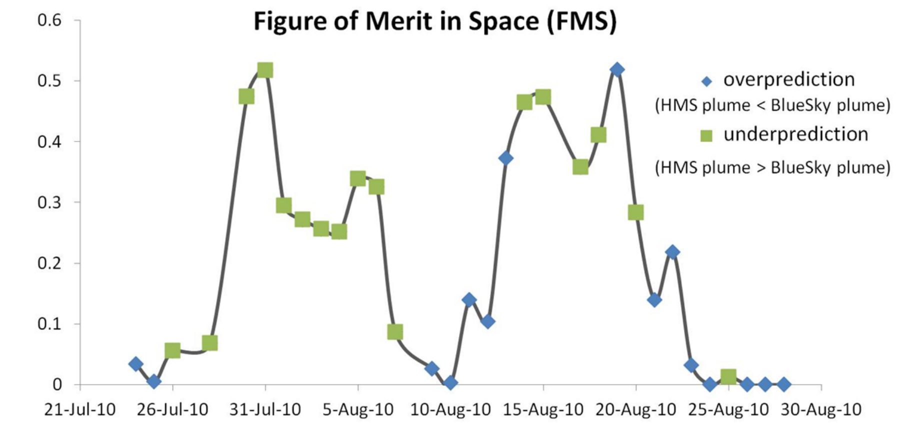

Figure 4. Figure of Merit in Space (FMS) scores comparing plumes predicted by BlueSky with plumes observed by HMS. The FMS is calculated as the intersection divided by the union of the predicted and observed plumes (Figure 1).

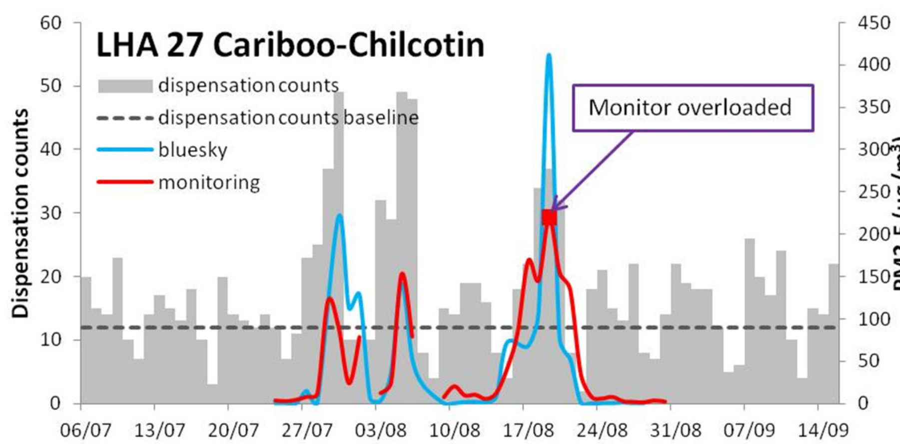

Figure 5. Gray bars indicate the daily counts of dispensations for respiratory reliever medications (low days are weekends and holidays). The broken black line indicates the average daily counts in July, August and September from 2003 through 2010. The blue and red lines indicate the PM2.5 concentrations predicted by BlueSky and measured by the monitoring stations, respectively. On August 19th, the monitoring instrument was overloaded by the intense smoke, resulting in unreliable records.

Acknowledgements

I would like to thank Drs. Michael Brauer and Sarah Henderson for their support on the study and for reviewing this article; George Hicks for his help in accessing the BlueSky data; and the Environmental Health Services group at the BC Centre for Disease Control (BCCDC) for providing the health outcome data. §

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Papers of Interest

High Resolution MODIS Aerosol Retrieval During Wildfire Events in California for Use in Exposure Assessment

Poster prepared for the 2011 American Geophysical Union conference in San Francisco, California by Sean M. Raffuse, Michael C. McCarthy, Kenneth J. Craig, Jennifer L. DeWinter, Loayeh K. Jumbam, Scott Fruin, W. James Gauderman and Fred W. Lurmann. Review by Al Pankratz. Copies of the poster can be obtained by emailing Sean Raffuse at sraffuse@sonomatech.com.

As already mentioned in this issue of the Canadian Smoke Newsletter, assessing exposure to smoke is a key factor in health studies. To that end, researchers require accurate observational data from smoke images. However, difficulties can arise when the Aerosol Optical Depth (AOD) products generated by standard algorithms are inadequate for certain geographical regions. Standard retrievals of AOD from Moderate Resolution Imaging Spectroradiometer (MODIS) data use the Collection 5 (C005) algorithm. These retrievals are available in 10 km x 10 km grid cells. This relatively coarse information can be used to predict surface PM2.5 concentrations, but correlations between PM2.5 and AOD over California are poor, due to failures to resolve small-scale variations that occur when individual wildfire plumes affect urban areas. Specifically, the failures have to do with the algorithm's underestimation of the 0.66/2.13 µm surface reflectance ratio (ξ0.66) for urban areas, resulting in overestimation of AOD.

The authors mitigated these issues by applying a method developed by Drury et al. (2008) to derive nadir-scaled ξ0.66 at 500 meter resolution (for the June-August period). This method has a higher dynamic range than the standard algorithm. To assist with this work, local aerosol optical properties were studied using data from the Aerosol Robotic Network [AERONET; Holben et al., 1998] sun photometer network. Measurements at five sites in California between 2003-2007 were subjected to cluster analysis [Omar et al., 2005]. One cluster typical of polluted aerosols and a second cluster typical of biomass aerosols were found. The biomass cluster was dominated by smaller particles. The model was further refined by the use of a relaxed cloud filter [van Donkelaar, 2011], due to the tendency of the C005 algorithm to mistake heavy smoke for clouds.

Daily AOD values from the Terra and Aqua satellites were averaged and processed using the improved algorithm (see middle panel - Figure 1). The method of deriving PM2.5 estimates from these AOD values was based on regressions obtained in the following manner:

1. For each 500-m pixel, a skewed AOD mean was calculated using a 5x5 pixel kernel (2.5-km resolution).
2. Day-specific regressions between AOD and PM2.5 were obtained after adjusting the data by removing three-sigma outliers and forcing the intercepts through zero.
3. Bulk robust regressions were obtained across the entire 37-day analysis period. These regressions were applied wherever day-specific regression r-squared values were below 0.35.

To assess the accuracy of the new algorithm, predicted PM2.5 values were compared with 10 am - 2 pm averages of ground-measured PM2.5 concentrations, yielding r-squared values of 0.4. Graphs showed significant scatter, with some very high AOD values predicted for situations where low PM2.5 concentrations were observed. Figure 2 shows an example of daily AOD-derived PM2.5 concentrations compared to observations at Chico, CA.

Summary. The new AOD product showed considerable success in reproducing the pattern of midday PM2.5 concentrations measured at California air quality monitoring sites. On half of the days where significant smoke was present, the r-squared statistic was greater than 0.5. Some challenges remain. On days without significant smoke, the product had no predictive power., and AOD and surface PM2.5 were unrelated when the aerosol did not mix down to the surface. Nevertheless, the model significantly improved the ability of researchers to characterize intra-urban differences in PM2.5 exposure for health studies. §

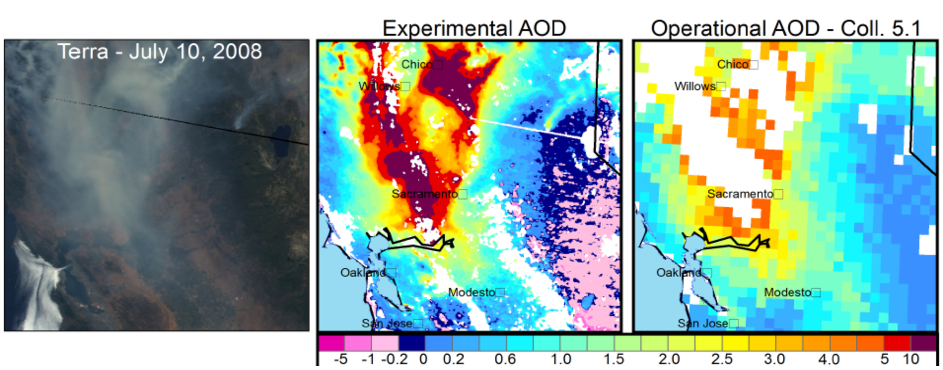

Figure 1. Visual MODIS image at left. Experimental algorithm AOD results are presented in the middle panel. Standard algorithm results are shown at right.

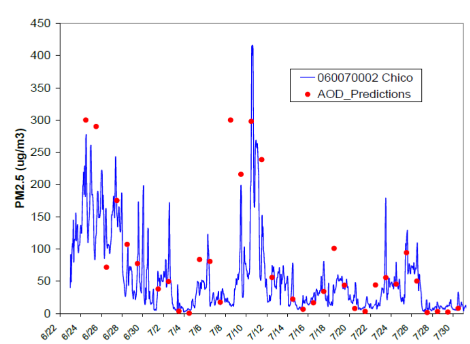

Figure 2. AOD-derived PM2.5 predictions vs observations at Chico, CA.