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Networks Centres of Excellence – Sustainable Forest Management Project Report

Climate and Fire Relationships in the Central and Eastern Canadian Boreal Forest

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EXECUTIVE SUMMARY

Research Questions and Objectives

Disturbance by forest fire is responsible for the spatial and temporal variations in the forest mosaic of the boreal forest. It has been an integral ecological process since the arrival of vegetation on the landscape. Its drivers, mainly weather and climate (Flannigan and Harrington 1988, Johnson 1992, Swetnam 1993), are crucial to its occurrence and growth. Climate and weather are also important in terms of ignition agents.

Lightning is the key ignition agent for naturally caused forest fires. Lightning is the result of an electrical discharge from a thunderstorm, which itself is a result of the appropriate meteorological conditions, namely, atmospheric instability, moisture and a lifting agent. The weather prior to ignition is also important in determining the fuel moisture that, in turn, will determine if ignition will occur and if the fire will grow. These weather conditions that influence fuel moisture include temperature, precipitation, wind speed and atmospheric moisture (vapor pressure deficient).

Any forest practice that attempts to emulate natural disturbance must take into account the role of climate on natural disturbance and in this case, forest fires. The relationship between climate and fire is dynamic and will continue to change as the climate changes. Additionally, the impact of future warming on the fire regime could be significant (Flannigan et al. 1998, Stocks et al. 1998) and any insights gained from looking at the historically relationships between climate and fire could assist in the development of adaptation plans for climate change. This report describes the progress thus far in terms of characterizing the climate and fire regime and the relationship between climate and fire for the central and eastern boreal forest in Canada over the last 300 years.

Progress

Significant progress has been made in this project on two fronts. First, trends and periodicities in summer drought severity were addressed using data from the instrumental meteorological record (1913-1998) for a transect from central Quebec to western Manitoba (Girardin et al. *in press*). The drought conditions were represented by the Drought Code (DC) of the Canadian Forest Fire Weather Index System (Van Wagner 1987). The relationship and coherency between the DC and ocean-atmospheric circulation patterns were also examined. Second, a 380-year paleoclimatic reconstruction of the DC using numerous tree ring chronologies from eastern Canada enabled us to link climate change with changes in atmospheric circulation (Girardin et al. *submitted*).

Key Findings and Deliverables

1) Trends and periodicities in instrumental Canadian Drought Code monthly average indices, southern Canadian boreal forest

This study summarises the construction of a network of monthly average DC using 62 meteorological stations distributed across the corridor extending central Quebec to western Manitoba, in the range of the southern Canadian boreal forest (Figure 1). These records were used for the construction of regional DC indices in six climatic regions. Linear trends fitted on the regional mean monthly averages revealed no major changes in summer drought severity during the period 1913-1998. A change in the frequency of extreme drought events was however seen in some regions.

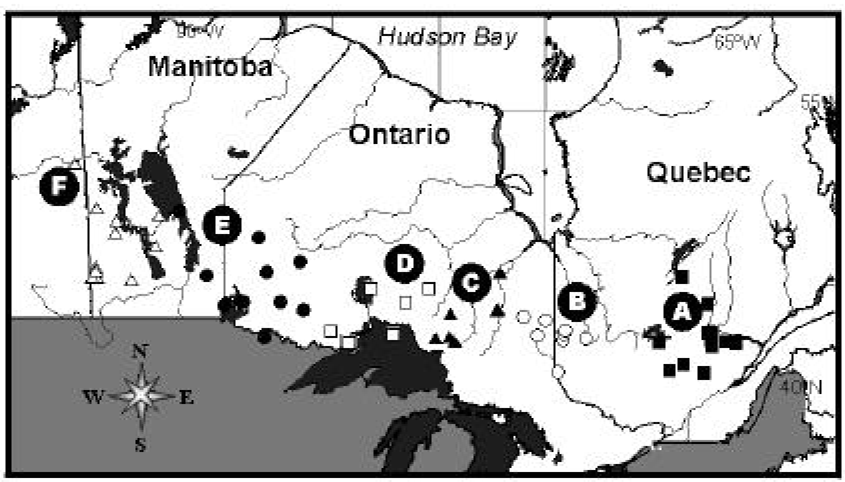

Figure 1. Geographical locations of the 62 meteorological stations used in the DC network (grouped per climatic regions, A-F).

The use of DC in large spatial-scale climatology was also demonstrated. Composites and coherency analyses indicated that the North Atlantic Ocean and the North Pacific Ocean demonstrates the strongest relationships and coherency with the drought variance during the period 1950-1997 (Figure 2). The coherency with the North Pacific (mainly with the Pacific Decadal Oscillation, PDO) however occurs in a decadal scale and the DC data length limited the interpretation of the causal effect. Given that the PDO modulates in frequencies of 20-50-year per cycle, validation of the regional climate response to this pattern requires the use of long paleoclimatic records. This problematic is addressed in the second study.

2) Drought in eastern Canada as related to atmospheric circulation for the last 300 years

Results from this study suggested that climate change in eastern Canada at about 1850 coincided with, in addition to a northward displacement of the jet stream, a shift toward less pronounced interdecadal climate variability in the Pacific climate system (Figure 3; D'Arrigo et al. 2001). This shift implies a decrease in the frequency of negative phase of PDO anomalies (episodes of cooler waters along the North Pacific coast and warmer ones in the interior Pacific; see Figure 2) during which many seasons of large area burned do occur. As recent changes in the Pacific climate may suggest a reversal of the PDO in 1998 toward cooler waters along the coast (Hare and Mantua 2000), upcoming studies should give further insights on the relationships between regional climate and this circulation pattern.

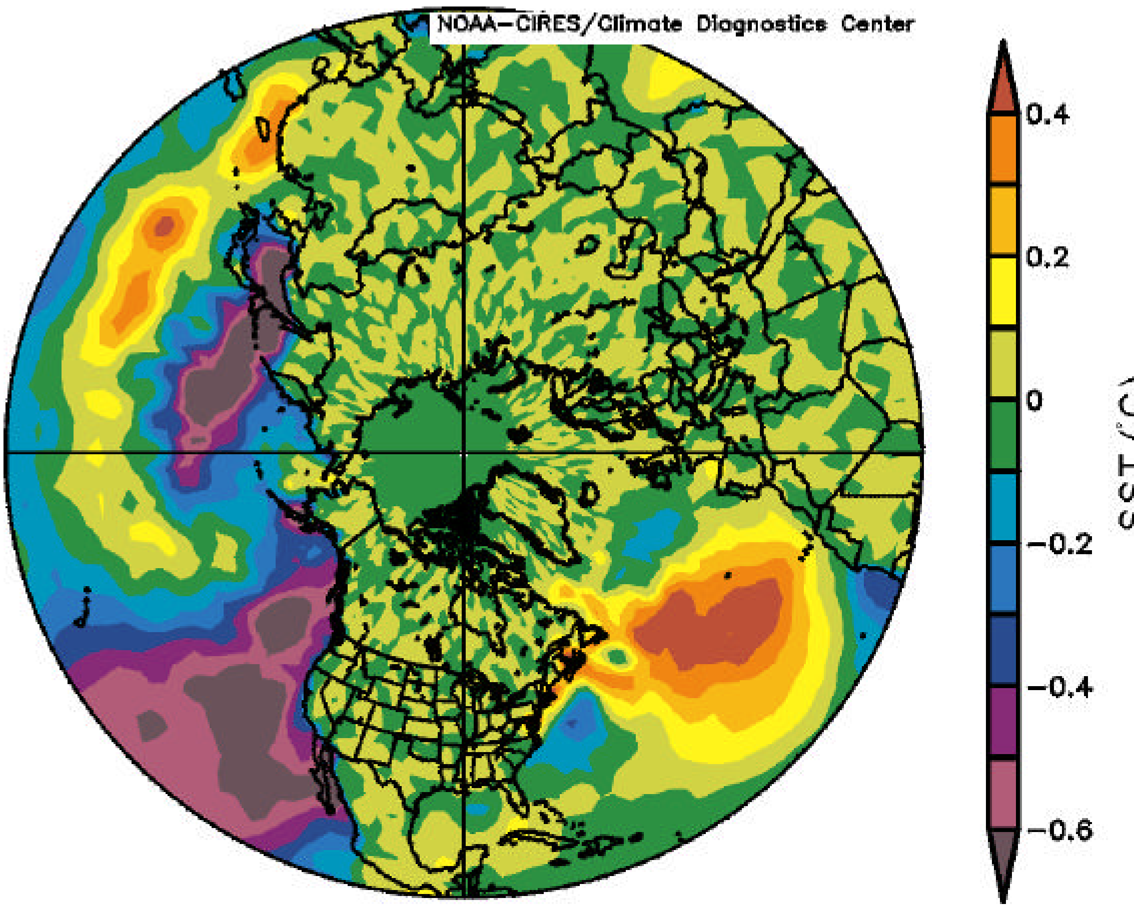

Figure 2. Reynolds reconstructed May-July Sea Surface Temperature (SST) composite mean (period 1950-1997) (source: Kalnay et al. 1996). The map indicates that severe drought seasons across the eastern and central Canadian boreal forest occur in conjunction with water along the North Pacific coast cooler by 0.6^{o}C and waters in the interior Pacific and North Atlantic oceans warmer by 0.4^{o}C (refer to the colour scheme). Note the configuration of the North Pacific Ocean, which strongly resembles the Pacific Decadal Oscillation pattern (PDO). Years used in the analysis are the seven driest years minus the seven years of lowest drought conditions (refer to Girardin et al. *in press* for further details).

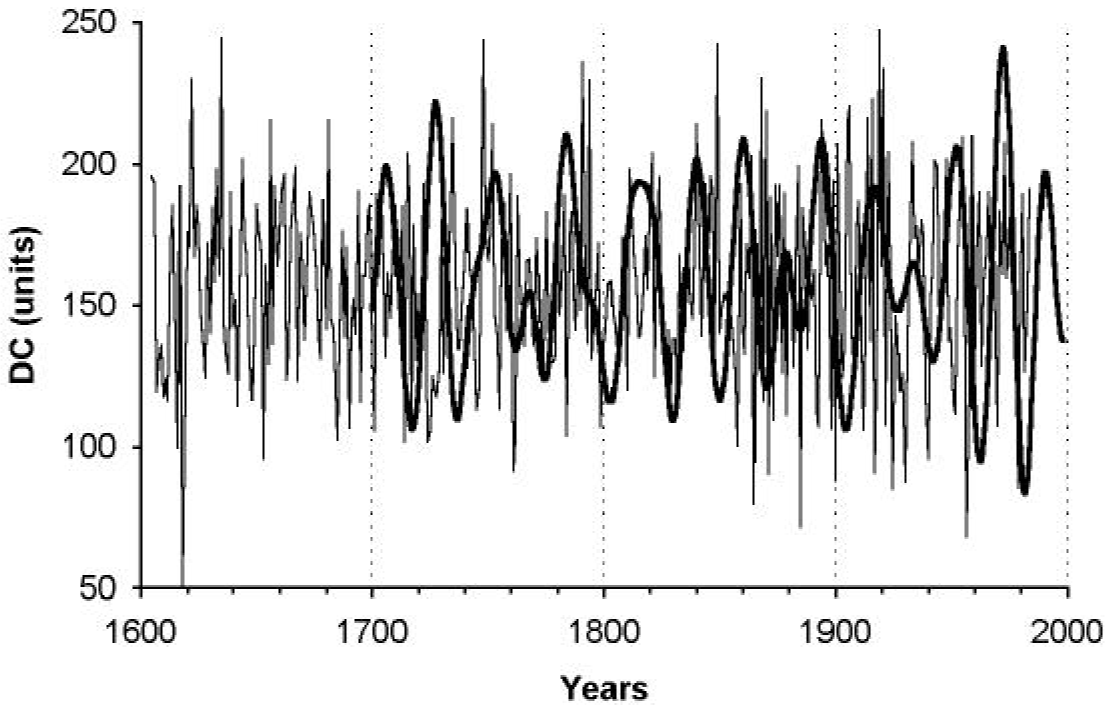

Figure 3. 380-year reconstruction of the Drought Code (DC; thin line) from the Abitibi Plains, eastern Canada (modified from Girardin et al. *submitted*). The 17-32-year waveform associated with the PDO is also shown (thick line). Note the coupling between the PDO waveform and the DC from around 1740 to 1850.

One concern highlighted by Girardin et al. (*in press*) and more particularly by Girardin et al. (*submitted*) is the instability of the relationship between atmospheric circulation and regional climate. These studies pointed out that climate in eastern Canada encountered at least two shifts in its main drivers over the past 250 years, one around 1850 (see Figure 2) and a second around 1960. Because the relationship between atmospheric circulation and regional climate did not meet the requirement of stationarity, the results cannot be directly applied to long term climate prediction. They may however be used to identify the important spatial variability structures for further study. In regards with short-term fire season predictions, further examination of the relationships between the patterns of climate variability and Canadian temperature, precipitation, and drought variability on a daily basis must be conducted. This mainly because fire occurrence is more dependent on short-term local weather (dry spells and wind events) than seasonal weather (Flannigan and Wotton 2001).

Advancement of Knowledge in the Field

The advances in these two studies are significant. In the study on multicentury drought variability in eastern Canada the results suggests that broad-scale atmospheric circulations are important in meteorological conditions like drought. Weather, and specifically drought, is related to fire (Flannigan and Harrington 1988) so it is likely that these same atmospheric patterns will also influence forest fires and vegetation dynamics. The study using a transect from Quebec to Manitoba using instrumental records from 1913 to 1998 does show decadal scale cycles in the DC with respect to atmospheric circulations. Additionally, this work showed a good relationship between drought severity and area burned across this transect.

Benefits

These studies are providing insight on the underlying relationships between climate and fire. Also, these two studies are building blocks for the development of a dynamic vegetation, climate and disturbance model. The relationships between climate and drought as being explored in these two studies are fundamental for tree growth as well as disturbances like forest fires. Such a dynamic vegetation – climate – disturbance model could help describe the potential impacts of climate change and allow adaptation strategies to be explored.

Management/Policy Implications

Incorporating forest fires and climate change into forest management is becoming a major concern. Some significant work on how to incorporate fire into forest management has already been undertaken (e.g., Bergeron et al. 2001) but there are still many aspects that bear further study. As mentioned previously, the results of this work can be used in the development of a dynamic climate – vegetation - disturbance model that can address impact, adaptation and policy changes in forest management.

Opportunities and Problems

Opportunities exist to apply this type of research over larger and/or different regions and over longer temporal scales (where available). The major obstacles are related to data. The instrumental record of weather data is relatively short for most of Canada and using proxy data like tree rings for longer time periods has caveats as well.

Future follow-up or related research

There are a number of follow-ups and related research items.

1) Using fire-climate relationships similar to those above will allow us to model future fire activity using simulations of future climate obtained from General Circulation Models and Regional Climate Models. Previously, future fire weather has been addressed (Flannigan et al. 2001) and more recently initial estimates of future area burned have been derived from this method (Flannigan et al. 2002). This type of work will allow us to

estimate the impact of global climate change on the fire regime that may have a significant impact on the development of guidelines for a forest management approach based on natural disturbances.

2) Future efforts are required to address spatial and temporal scales to uncover the linkages between climate and fire in order to understand and predict the future changes in the fire regime and its influence on the diverse management scenarios. The fire regime is dynamic, as it is strongly linked with weather/climate that is always changing (Weber and Flannigan 1997; Flannigan and Wotton 2001) and any natural disturbance based management system has to take this dynamic nature into account. Additionally, this work lays the footing for studies to address interactions between disturbances like fire, forest insects, disease and windthrow.

3) In fire-dominated landscapes, a natural disturbance based management approach is possible only if current and future fire frequency allows for a substitution of fire by forest management. This question can be addressed by comparing current and future fire frequency to historical reconstruction of fire frequency from studies realised in the Canadian boreal forest. Current and simulated future fire frequencies using a 2 and 3xCO2 scenarios are for most sites lower than their historical fire frequency suggesting that forest management could be potentially used as a means to recreate pre-industrial landscapes that were mainly controlled by fire regimes. There are however important limitations to the current even age management. This work has commenced and a paper has been submitted to the journal Ambio.

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