TESTING THE MONTHLY DROUGHT CODE AS A METRIC FOR FIRE WEATHER IN SOUTHEAST BC

PROJECT SUMMARY REPORT

PACIFIC CLIMATE IMPACTS CONSORTIUM

SUMMARY OF RESULTS

The monthly drought code as a metric for fire weather and uncertainties in fire weather projections

Researchers at the Pacific Climate Impacts Consortium (PCIC) have recently evaluated the monthly drought code, which describes the moisture content of deep soil layers using monthly-average data, as a simple metric for fire weather. Relatively few fire activity projections have been done for BC. PCIC researchers also created a suite of future projections of fire weather for southeast British Columbia (BC, Figure 1). The objective of this research was to examine both changes to fire weather intensity and the uncertainties in future projections of fire frequency.

Research results found:

- **There are significant correlations between the monthly drought code and the annual area burned at all five locations that were tested.**
- **These correlations are comparable to those between annual area burned and the monthly drought code's input variables (temperature and precipitation), more complex models and the six other fire weather indices tested.**
- **The monthly drought code is a simple, but effective metric for simulating wildfire severity that requires comparatively little input data. It is found, using the monthly drought code, that a small number of high-quality valley-bottom stations may be able to capture the large-scale features necessary to calculate fire weather indices, without requiring interpolation or high-resolution climate models.**
- **The ability of statistical downscaling to reconstruct the historical monthly drought code varied and was best at drier stations.**
- **Future projections of wildfire frequency have large uncertainties, with some projections suggesting statistically insignificant changes. This is due to the large uncertainty in precipitation projections from the climate models that were used to create the projections.**

Given the complex topography and relatively low density of meteorological observing stations in southeast BC, simulating fire weather in this region is difficult, and because of this, fire weather simulation in this region provides a rigorous test of the monthly drought code. The results of this research suggest that, given its performance and the small amount of input data needed, the monthly drought code could be useful as a metric for fire weather for regions throughout North America.

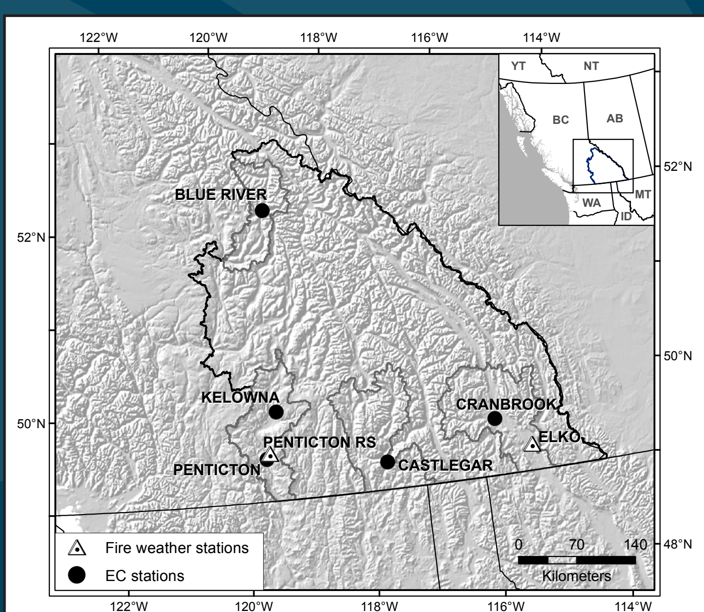

Figure 1: Map of the study area. The combined area of the Columbia, Okanagan and Upper Thompson watersheds is used to calculate the regional area burned (thick black line). Smaller watersheds are used to calculate local area burned (thin grey line).

WILDFIRE AND CLIMATE

Climate influences on wildfires

The climate of a region plays a large role in determining the wildfire risk in that region. A region's climate can determine both the availability of fuel for wildfires and that fuel's moisture. Globally, there is a strong spatial relationship between the distribution of wildfires and patterns in temperature and precipitation. Links have also been found between temperature, precipitation, drought severity, atmospheric circulation (which determines weather and so, the duration of warm spells, lightening and other factors) and the area burned in a region. Research has linked some of the observed increase in wildfires across Canada to anthropogenic climate change.

Because of the relationship between climate and wildfire, a changing climate is likely to have a significant effect on both wildfire severity and frequency. Current climate projections suggest that there will be increases in both fire severity and frequency in North America throughout the 21st century.

THE MONTHLY DROUGHT CODE IS CORRELATED WITH THE ANNUAL AREA BURNED AT THE FIVE LOCATIONS THAT WERE EXAMINED

THE MONTHLY DROUGHT CODE IS A SIMPLE, EFFICIENT AND EFFECTIVE METRIC FOR SIMULATING WILDFIRE SEVERITY

THE MONTHLY DROUGHT CODE AS A PREDICTOR OF WILDFIRE ACTIVITY

Testing the monthly drought code with observations

The monthly drought code is a simple metric for estimating fire weather that describes the moisture content of deep soil layers using monthly-average data. In order to see how well the monthly drought code predicted drought in this complex climatic region, PCIC researchers compared averages of precipitation, maximum daily temperature and the monthly drought code at a number of Environment Canada weather stations to the annual area burned in each station's local watershed. The periods examined were May to September and June to August. The monthly drought code shows the strongest relationship to the logarithm of the annual area burned (Figure 2). The data indicate that the annual area burned increases exponentially when the monthly drought code increases. The monthly drought code also shows a better performance as an indicator of annual area burned than the six other indices of fire weather tested, including the daily drought code.

THERE IS A STRONG RELATIONSHIP BETWEEN WILDFIRES, PRECIPITATION AND TEMPERATURE

THE REGION

Climate and wildfire in southeast BC

The landscape of southeast BC is characterized by large variations in elevation that occur over short distances in some areas. It contains parts of the Columbia and Rocky Mountains, with steep and narrow valleys, and it is characterized by strong gradients in precipitation and temperature. The western part of the study region, including Kelowna and Penticton, experiences relatively little precipitation because it is in the rain shadow of the Coast Mountains (air rises as it passes over the mountains, cools and loses moisture as precipitation, before descending on the other side of the mountain, relatively drier), as does the region in the Rocky Mountain Trench, while the northern and eastern areas generally experience more precipitation.

THE MONTHLY DROUGHT CODE PERFORMS BETTER THAN THE OTHER INDICES OF FIRE WEATHER THAT WERE TESTED

Though the rest of Canada as a whole has experienced generally positive

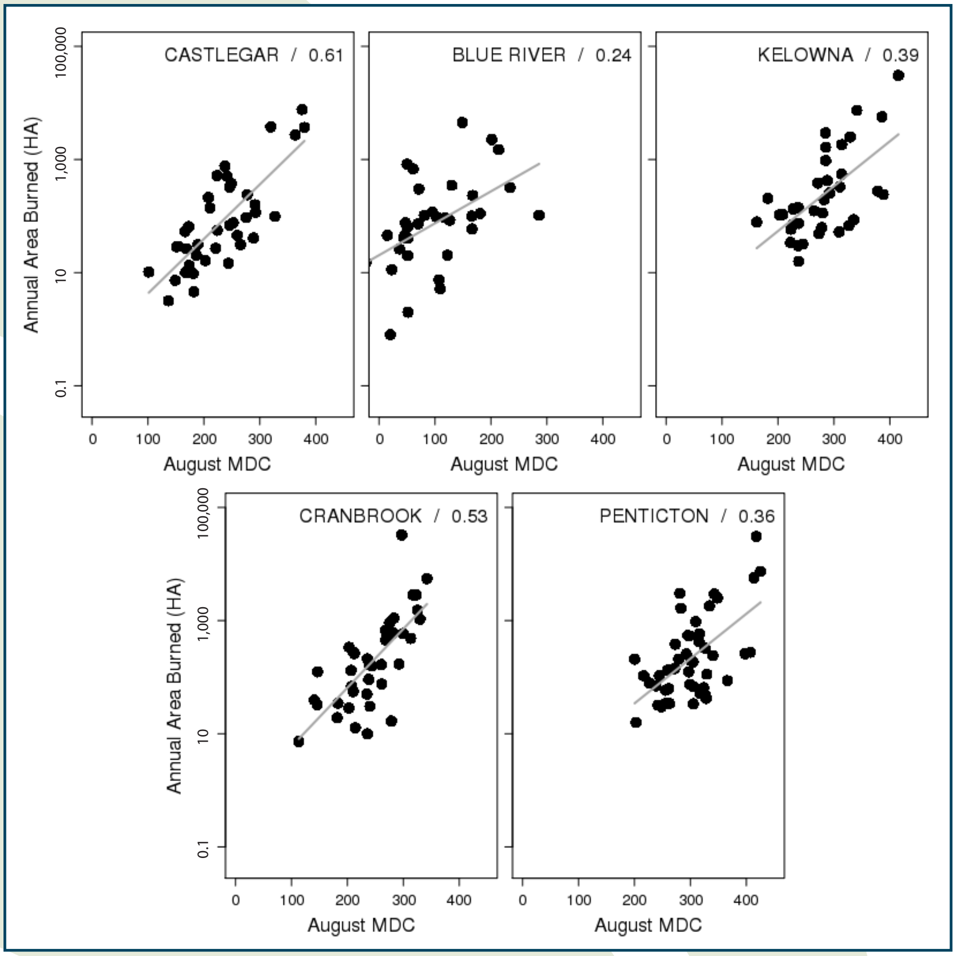

Figure 2: These plots show the correlation (a measure of the statistical relationship) between area burned (in hectares) and the August Monthly drought code calculated at the Environment Canada stations for 1970 to 2009. Annual area burned was calculated by including all fires within each station's local watershed, which are shown in Figure 1. R^2 values are provided next to the station name (R^2 values close to one indicate a stronger linear dependence of the annual area burned on the Monthly drought code). Regression lines are shown in grey.

trends in wildfire activity, wildfire trends in BC are negative. This may be due to more moist conditions caused by increases in summer precipitation as suggested by other studies.

WHILE THE REST OF CANADA HAS EXPERIENCED GENERALLY POSITIVE TRENDS IN WILDFIRE ACTIVITY, TRENDS IN BC HAVE BEEN NEGATIVE, POTENTIALLY DUE TO INCREASES IN SUMMER PRECIPITATION

Temperature in the study region varies with elevation, warmer at low elevations and colder at higher elevations. Because of the varied climate of the region, it contains a variety of fire regimes, ranging from ponderosa pine forests that experience low-severity fires relatively frequently, to subalpine forests that experience fires less frequently, but where the fires that do occur are generally more severe.

HISTORICAL SIMULATIONS AND FUTURE PROJECTIONS

Historical simulations

The ability of downscaled reanalysis[1] data to simulate the mean of the daily maximum temperatures for the month of August varies by the years and region chosen. There is also a variation, by station and time period, in the ability of the downscaling method used here (called Bias Corrected Spatial Disaggregation[2]) to simulate precipitation and the monthly drought code over the three-month period of June, July and August (JJA). So-called R^2 values, which in this case serve as an indicator of the ability of the downscaling procedure to simulate different variables (with values close to 1 indicating better ability) are as follows. For precipitation R^2 ranges from 0.31 for Cranbrook to

1. Reanalysis data is a representation of the historical climate that is generated by assimilating historical weather observations into a global weather forecast model run in hindcast mode.

0.77 for Penticton and the values of R^2 for the monthly drought code range from 0.36 at Blue River to 0.72 for Kelowna. While these values vary, implying that the method works better in some locations than others, all of the correlations are statistically significant at the 5% level, which indicates that we would only expect to see R^2 values of these sizes, by chance, about five times out of a hundred. This gives us confidence that the downscaling procedure captures important aspects of the temperature, precipitation and monthly drought code variation over this period. In addition, the method does well at

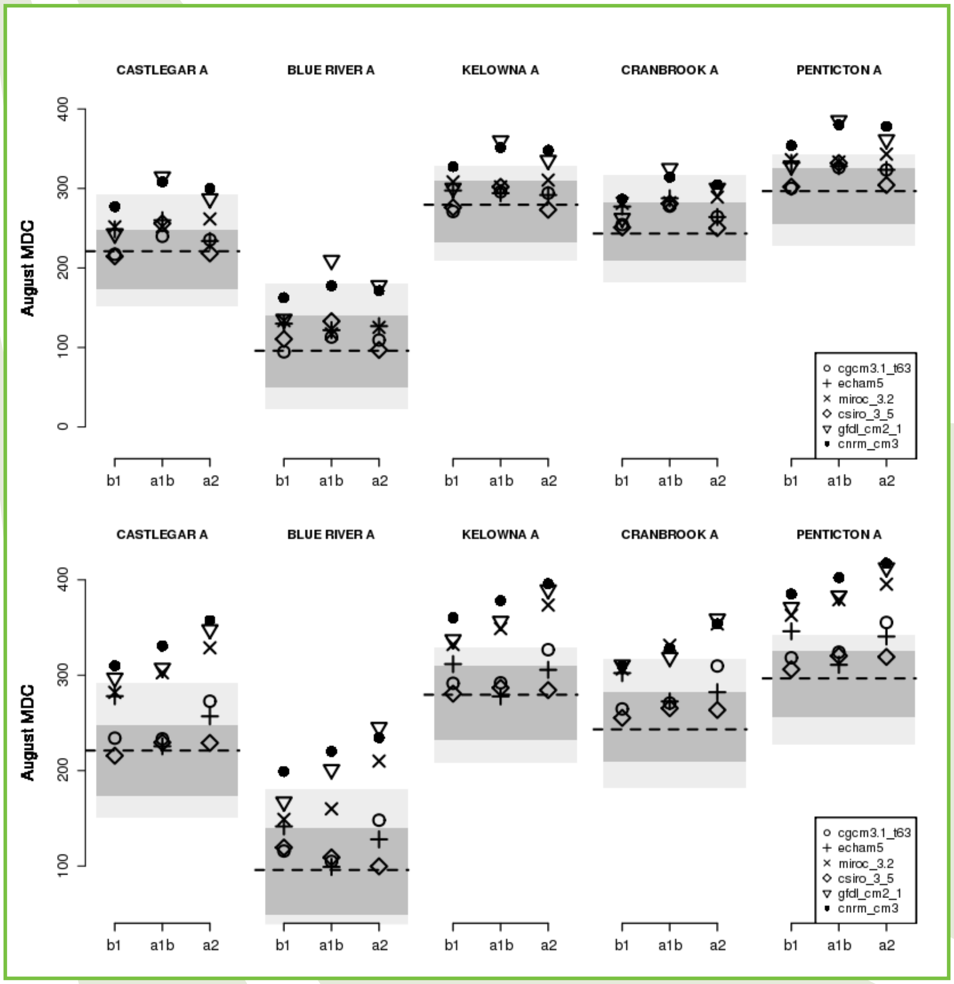

Figure 3: Projected August Monthly drought code for all stations, models[3] and scenarios[4] in the 2050s (top) and 2080s (bottom). Percentiles of historical observations are indicated by the shaded boxes, meaning that the shading indicates the range of historical interannual variability. The light grey box extends to the 10th and 90th percentiles, the dark grey box extends to the 25th and 75th percentile while the dashed line indicates the historical median. The symbols show projected changes to the long term averages, with each one representing the results from a different global climate model.

2. BCSD first takes global climate model data for the region it will be used on and compares that data to observations from weather stations, correcting the model data if it is too warm, cool, dry or wet relative to the weather station data. BCSD then takes the corrected data and renders it onto a finer, regional grid and smaller time scale, using statistical relationships between large-scale climate phenomena and smaller-scale, local climate phenomena. It also preserves consistency with the original large-scale data.

3. Six global climate models are used: CGCM3.1, developed by the Canadian Centre for Climate Modelling and Analysis; ECHAM5, developed by Max Planck Institut für Meteorologie; MIROC, developed by four Japanese research groups; CSIRO Mk 3.5, developed by the Commonwealth Scientific and Industrial Research Organisation; NOAA Geophysical Fluid Dynamics Laboratory's CM2.1 and Centre National de Recherches Météorologiques' CM3.

4. Three IPCC emissions scenarios are used. These are based on assumptions about future energy sources, population, global cooperation and technological development. Briefly, B1 is a low emissions scenario, A1b is a medium emissions scenario and A2 is a high emissions scenario. For more on the these emissions scenarios, see here: http://www.ipcc.ch/ipccreports/sres/emission/index.php

simulating the extreme values that were observed in Kelowna and Pentiction in 2003. If the annual area burned, temperature, precipitation and monthly drought code are calculated for the entire region as a whole, the August value of the monthly drought code shows the strongest relationship to the annual area burned.

Future projections

Projected changes to temperature, precipitation and monthly drought code vary with assumptions about both the amount of greenhouse gases that will be emitted in the future and the choice of climate models that are used to make the projections. Also, projected future changes to both precipitation and the monthly drought code are small compared to the overall range of historical variability.

WARMING IS PROJECTED FOR ALL MODELS, WITH RESULTING INCREASES IN THE MONTHLY DROUGHT CODE

Warming is projected for all models and results in increases to the monthly drought code in nearly all of the cases examined in this study (Figure 3), with monthly drought code anomalies most strongly influenced by changes to August precipitation. However, the spread of the monthly drought code results is quite large. Out of 90 projections, 38 show changes to the monthly drought code that are statistically significant at the 5% level by the 2050s. That number increases to 49 of 90 projections by the 2080s. Projected changes in precipitation over the JJA period are small, and do not show a clear increasing or decreasing trend, overall. Those models that project the largest increases to precipitation also project the smallest increases to the monthly drought code, and vice-versa. The drier models show Castlegar shifting to a fire regime similar to that historically seen in Penticton and Kelowna, which have an annual area burned 86% larger than the Castlegar watershed.

METHODS USED

Analyzing historic and projected changes in fire weather

The first part of this study tested the monthly drought code as a predictor of seasonal fire weather. For this, historical data from five Environment Canada stations and two fire stations maintained by BC's Ministry of Forests, Lands and Natural Resource Operations were used. In addition, the research made use of a database of observed wildfires from the Province of BC's Geographic Data Distribution Service. From these data, the monthly drought code was both calculated seasonally, for the aggregate of all stations and for each individual station, and calculated for each month from May to September. The annual area burned for each station's surrounding watershed was also calculated. Correlation coefficients were analyzed to determine if there was a relationship between the monthly drought code and three variables: area burned, temperature and precipitation.

THE WILDFIRE PROJECTION METHOD USED HERE IS POTENTIALLY USEFUL FOR PROVIDING FIRE WEATHER INFORMATION TO RESIDENTS IN BC AND OTHER REGIONS IN NORTH AMERICA

The second part of the study created a suite of future monthly drought code projections. These were made by statistically downscaling future climate simulations from six global climate models. These climate models simulated future climate assuming three different future greenhouse gas emissions scenarios. The downscaling results were then compared to historical observations. The monthly drought code projections were tested for sensitivity to temperature and precipitation changes, to see if the monthly drought code is more sensitive to temperature or precipitation.

THE NEED FOR ROBUST FIRE WEATHER PROJECTIONS

Placing the findings of this report in context

IT IS IMPORTANT TO LOOK AT AS MANY SIMULATIONS AS POSSIBLE, TO FULLY CHARACTERIZE THE UNCERTAINTY THAT ARISES FROM THE DISAGREEMENT IN GLOBAL CLIMATE MODEL PRECIPITATION PROJECTIONS

Previous projections of fire weather vary in the complexity of their approaches. Some projections are made using the raw output of global climate models, some are made by adding the difference between the future and the past climate from the global climate models to the higher-resolution, local climate record and adjusting these values by the changes in elevation, and others use more complex statistical approaches. The majority of the results from these studies project an increase in fire severity or frequency in North America.

Future monthly drought code projections are strongly sensitive to precipitation and have a wide range, due to the differences in precipitation projections among global climate models. This spread in precipitation projections comes from several sources, including uncertainties in future emissions and global climate models.

This report finds that the monthly drought code is a simple and effective metric for simulating fire weather, especially at the regional scale and that it is competitive with more complex techniques. This report also finds that there is a large spread in projected changes to the monthly drought code, with most models showing a statistically significant increase by the 2080s. This projected increase in the monthly drought code results in a shift of the fire regime of Castlegar, in which it becomes similar to the fire regimes of Penticton and Kelowna.

The projected shifts suggest that there is a possibility of fire regimes becoming more severe in the regions investigated. Due to the ease of application and strength of the monthly drought code it could be used to provide some of the information necessary to assist with assessing the impacts of a changing climate on fire weather in other regions.

POTENTIAL FUTURE RESEARCH

The future of wildfire projections

This research suggests both that the technique used is efficient and that it can provide a useful estimate of the potential for wildfire in this region. A logical next step would be to use these methods to project the monthly drought code conditions under all of the available CMIP5 models, to compare results to those for the CMIP3 models. Testing these methods in this manner is important, because the monthly drought code has been shown to be sensitive to precipitation, and with the large disagreement in precipitation in global climate models in this region, it is important to look at as many global climate model simulations as possible to fully characterize this uncertainty.

FOR REFERENCE

D. W. van der Kamp, G. Bürger and A. T. Werner, 2013: *Evaluation of the monthly drought code as a metric for fire weather in a region of complex terrain, and uncertainties in future projections.* The Pacific Climate Impacts Consortium, Victoria, British Columbia, Canada.

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