An Overview of Climate Change and Related CFS Tools for Forest Adaptation

John Pedlar and Dan McKenney
Adaptive Silviculture for Climate Change Workshop
Petawawa Research Forest, Pembroke, Ontario
July 16-17, 2019
- we are a multidisciplinary team at GLFC with research interests that include climate and climate change, invasive insects, forest regeneration, economic analyses, etc.
- climate data provides the foundation for much of our research
- today I will provide an overview of climate change at global, national, and regional scales and also provide an overview of some of the climate change adaptation resources that have been developed at the CFS
- Our group has been developing spatial climate products (grids/maps) for over 25 years, collaborating with scientists at ECCC, NOAA, and ANU.
- This work started with humble efforts to develop climate models for Ontario, but has grown to include continental scale models for a wide range of variables and time steps, including future climate projections.
- Due to cybersecurity issues, there have always been challenges with making our data easily available for users; recently, collaborations with ECCC and the Prairie Climate have allowed some of our products to more easily accessible; we still get lots of email requests from across the continent (2-3 new ones per week).
Another flagship product has been our Plant Hardiness Zone website. This effort involves 2 main areas; the first is the mapping of Canada’s Plant Hardiness Zones using modern mapping techniques and climate data; the second involves the compilation of a Plant Hardiness Database, which includes more than 3 million occurrence records for more than 3,000 plant species across NA; this data is used to generate climate envelope models, which provide a simple summary of current and future climate habitats for plant species. These models provide maps of the potential distribution of plants in relation to climate; we are also working on models that include other influences – for example we have a side project on species migration with Dr Louis Iverson of the USFS and his team.
I’d like to switch gears and talk about climate change and draw your attention to a recent report that was released by ECCC.

This report provides a high quality summary of the state of the science on climate change in Canada.

Dan McKenney was involved in reviewing the report and I’ll draw heavily on the information and graphics provided in the report during my talk.
- Based on ice core reconstructions, carbon dioxide levels are thought to be at their highest levels in the last 800K years; and it may be as long as 3 M years since current levels were last seen on earth
- When we talk about GHG emission paths this is what it is all about….they are still tracking higher than the highest scenarios
- So why is that important?
- The increased CO₂, in combination with other greenhouse gases such as methane and nitrous oxide, form a layer in the atmosphere that prevents heat from escaping to space, effectively acting as a blanket to warm the earth.
- The line chart shows the relationship between temperature from 3 different global temperature databases and radiative forcing driven by GHG concentrations in the atmosphere; note that there is clearly a correlation between temperature and radiative forcing, but also significant variation related to things like volcanic eruptions and climate cycles such as ENSO (i.e., El Nino and La Nina).
- Uncertainty is a key issue in relation to climate change assessments and its implications on natural biota like forests.

- This figure shows some of the main sources of uncertainty, including:
  - Scenario uncertainty, which is the largest source considered here and involves the emissions pathway that society follows over the coming decades;
  - Model uncertainty relates to the variation between different GCMs when projecting future climate conditions; and
  - Internal variability, which refers to climate and volcanic cycles that can impact climate conditions.
- Starting with projected change in global mean annual temperature, we see a few important patterns here
- First, there is a huge difference between the degree of warming depending on the emissions pathway that is followed: 1-3 C for RCP 2.6 and 5-10 C for RCP 8.5
- Second, temperature increase is much larger toward the poles, particularly in the northern hemisphere
- This situation, known as polar amplification, is due to a few things:
  - First, the albedo effect, in which white surfaces such as snow and ice are known to reflect more light back to space, whereas darker surfaces are known to absorb more light
  - Other factors may include altered jet stream transport of warm, moist air to arctic regions and the related formation of low level clouds that hold heat in the region
- Note that the stippling indicates agreement across 80% of the models included in the experiment
- More good news; the latest round of GCM runs has forecasted an even warmer future for the planet; running about 0.5 – 1°C hotter than previous runs

- There is currently debate as to whether this effect is real or is an artefact of recent improvements to the models, which include: finer resolution to model processes such as ocean currents and related climate cycles such as ENSO

- This issue will hopefully be resolved over the next year or two
- In Canada, patterns are similar to those noted for the global maps, with greater heating in the far north and increases of 1-3°C under RCP2.6 and 5-9°C under RCP8.5

- In the Pembroke region, MAT is projected to increase by 4.3°C on average by the 2051-2080 period and about 6°C by the end of the century

- Note the significant annual variation in MAT values, indicating that there will be much warmer and cooler years in the future, but by about 2050, even the cooler years are warmer than what we’ve experienced in the past
- It’s important to keep in mind that CC is not only going to change the mean condition, but also extreme events.

- This figure shows the expected return of time of extreme temperature events; under RCP 2.6 an event that currently happens once every 50 years would be expected to happen once every 10 years by 2050; under RCP 8.5, an event that currently happens once every 50 years is expected to happen once every 5 years by 2050 and once every year by the end of the century.
- Change in annual precipitation is variable at a global scale; with strong increases in polar regions related to the increased water holding capacity of warmer air in these regions; precipitation declines are projected for much of South America, Southern Europe, northern and southern Africa, and Australia.

- Note that the stippling indicates agreement across 80% of the models included in the experiment.
- In Canada, annual precipitation is projected to increase across the country, typically between 0 and 20% across much of southern Canada and up to 50% in the far north.

- In the Pembroke region, annual precipitation is projected to increase by 9% on average by the 2051-2080 period and by about 10% by the end of the century.

- Again, annual variation is high, indicating that there will be years that are much wetter and drier than the average.
Regarding extreme events, this figure shows the expected return of time of extreme precipitation events; under RCP 2.6 an event that currently happens once every 50 years would be expected to happen once every 25 years by 2050; under RCP 8.5, an event that currently happens once every 50 years is expected to happen once every 20 years by 2050 and once every 5 years by the end of the century.
- When looking at separate temperature and precipitation maps it can difficult to tell if there is an overall drying or wetting trend.
- Water balance metrics, such as the standardized precipitation evapotranspiration index shown here, provide a sense of the balance between changes in precipitation and temperature.
- This map, produced by Cook et al. 2014, shows strong drought potential in much of the southern hemisphere, Africa, Europe, and the U.S., with modest drought projections for Canada.
- These maps look more closely at the Canadian situation using maps of a Climate Moisture Index (or CMI) that is essentially the difference between precipitation and potential evapotranspiration.

- The maps on the left show the projected change in CMI for the end of the current century; CMI is projected to decline across much of the country, except in the far north and coastal areas.

- At Pettawawa, CMI is projected to decline by 15.1 cm under RCP4.5 and 28.3 cm under RCP8.5; but what do these numbers mean for trees at PRF?

- Ted Hogg at NOFC has worked extensively with CMI and has discovered that, in the Prairies, the boundary between forest and ‘parkland’ (i.e., discontinuous forest cover) coincides with a CMI value of zero; in other words positive CMI values are needed to maintain consistent forest cover; note that under RCP8.5 climate moisture regimes are projected to be borderline for supporting forests by the end of the current century!
- So what do all of these climate changes mean for forests?
- Clearly one of the potential outcomes is direct mortality as a result of extreme weather events such as droughts, late spring freeze events, floods, and wind storms.
Changes in climate can also impact forest growth.

A strong pattern that has emerged from our work with provenance data is that growth responses to climate warming are strongly dependent on where populations are found with the species range.

The graphic shown here is for black spruce and it indicates that northern populations are expected to be able to absorb significant amounts of climate change before showing declines, while southern populations are expected to show strong, near-term declines.
CC is also expected to indirectly impact forests through altered fire regimes.

This work shows the projected increase in annual area burned and fire frequency for "homogeneous fire zones".

Most forested regions of Canada, including the PRF, are projected to experience increases of 2 – 4 times in fire frequency and area burned by the end of the current century.
- One of the real unknowns with climate change is how it will affect forest pests
- Mountain pine beetle is a native species that is expanding due to climate change
- Recent infestations have killed more than 10 M ha of lodgepole pine forest in western Canada
- MPB has shown the ability to shift hosts and attack jack pine: so will it move to eastern Canada?
- Interestingly, our climate envelopes for this species suggest that the most suitable climate habitat will be in the far north (i.e., mostly north of the working forest) by the middle of the current century
- This is a highly studied insect with much more detailed models suggesting climate in eastern Canada will be amenable to the insect over the course of the century
- We haven’t heard as much about the southern pine beetle in Canada, but it also causes significant damage to pine plantations in the southern United States.

- Our climate envelopes indicate that significant portions of eastern Canada will likely have suitable climate for this species within the next 30 years; as such, it poses a potential threat to timber species in eastern Canada, including white, red, and jack pine.
I’d like to switch gears now and talk about some of the climate change adaptation tools that have been developed at CFS.

Most of these tools have been developed in conjunction with the Forest Change Program which has helped to fund some of our work.

This is a CFS program that was initiated in 2010 with three main deliverables: namely a tracking system, an adaptation tool kit, and a number of regional integrated assessments; today I'll speak briefly about the Adaptation tool kit which is available at the web address shown here.
The adaptation toolkit pulls together a variety of tools and resources to aid in climate change adaptation, including: data, web applications, and knowledge products (read examples from slide).
- Seedwhere is a climate-based tool that we have been working on for some time.
- The idea here is to identify locations with climate similar to a point of interest; this is important for matching seed sources with planting sites in order to avoid maladaptation when regenerating a new forest.
- Historically, the rule was to use local seeds when regenerating a site, but under climate change that rule no longer holds as local climate is rapidly changing.
- As shown in the figure, Seedwhere allows users to visualize where seeds could be procured from and/or deployed to under climate change.
- Provenance trials consist of various seed sources being planted at a number of test sites; thus they provide insights into how different populations will respond to climate change.

- We have obtained provenance data from a number of sources and have analyzed them using Universal Response Functions, which were originally developed by Tongli Wang and co-workers in BC.

- These relationships allow us to predict the best seed source for a given planting site; unlike the simple climate-matching approach shown on the previous slide, this approach employs empirical growth-climate relationships which do not always follow the patterns that simple climate matching would dictate.

- These URFs have recently been included in the SeedWhere web application.
- We are also in the process of adding an economic aspect to the Seedwhere web application.
- This functionality makes use of the URFs shown on the previous slide to quantify the expected growth of a given seed source, which is ultimately expressed as an economic gain (or loss!).
- Finally, we are in the process of developing a global version of Seedwhere.
- The final tool I’d like to discuss is our Forest Insect and Disease Mapping Project

- For this work, we have gathered insect occurrence data for Canada from Forest Insect and Disease Survey (FIDS) records, as well as private research databases, and records from the Global Biodiversity Information Facility (GBIF)

- These sources have provided us with occurrence data for more than 20,000 insects; many of which have species distribution models under current and future climate; as noted climate envelop models have limitations but also provide valuable insights

- A publically accessible web application is online

- However note it remains a work a progress and we are in the midst of writing this work up.
Summary

- Canada (including PRF!) is projected to experience increased temperature, higher precipitation, and more extreme weather over the next century.
- The degree of change is very much dependent on the emissions pathway we follow over the coming decades.
- Warmness is expected to outpace wetness, resulting in a drier future (possibly approaching prairie-like conditions at the PRF!)
- A variety of adaptation tools are available at the CFS Forest Change web portal (including Seedwhere, Species Models, climate data, etc.)
- Can we help forests resist, persist, and/or transition at the PRF?