

Adapting to Climate Change In Northern British Columbia

**Proceedings of the Workshop Held
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Prince George, British Columbia**

Sponsored By:

**The BC Ministry of Water, Land, and Air Protection
The Canadian Climate Impacts & Adaptation Research Network-BC
The University of Northern BC**

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1. Workshop Partners

The workshop was sponsored and organized by:

- BC Ministry of Water, Land, and Air Protection
<http://wlapwww.gov.bc.ca/air/climate/index.html>.
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- University of Northern BC
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 - o Contact: Art Fredeen (fredeena@unbc.ca)

2. Introduction to the Workshop

Although many jurisdictions and industries have begun reducing emissions of greenhouse gases, the greenhouse gases already added to the atmosphere since the beginning of the industrial revolution will likely continue to be a major driver of global climate change for centuries to come. Climate models and recent observations indicate the impacts will be felt sooner and reach the greatest extremes in higher latitudes. Climate has changed dramatically during the history of human civilization; however, the current rate of climate change is more rapid than at any time during the past 10,000 years. It is therefore crucial that communities and businesses adapt to climate change in a proactive way to minimize adverse impacts.

Climate change will mean much more to British Columbians than warmer temperatures. It means changes in precipitation, runoff, cloud cover, and extreme weather. These changes will drive changes affecting ecosystems, agriculture, communities, forestry, and many other natural and human systems. Many regions of British Columbia are now experiencing the early signs of climate change. Continued and accelerating change is expected to become more evident during the next few decades. Human activities such as resource management, land use planning, tourism, agriculture, and forestry; and infrastructure such as hydro dams and transmission lines, highways, dykes, and municipal drinking water, storm water and sewage systems will likely be affected. Businesses and communities in British Columbia need to prepare for these changes. In many cases, proactive planning will reduce costs and help communities avoid some of the potential adverse impacts and gain some of the potential economic benefits.

The workshop was intended to bring together scientists, resource managers, and community and business stakeholders to review our current knowledge of climate change in northern British Columbia, and to discuss vulnerabilities, opportunities, information needs, and next steps towards strengthening adaptive capacity in the region.

3. Workshop Description

A limited number of participants were invited in order to encourage informal dialogue following each of the presentations. A total of 40 people, including speakers, researchers, resource managers, municipal representatives, and other stakeholders attended the workshop.

Thursday morning presentations covered past climate and projected climate changes; climate models and how much we can rely on them; climate change impacts on runoff, permafrost and terrain stability; and climate change impacts on aquatic and forest ecosystems. Afternoon presentations discussed climate change and adaptation from the perspectives of the oil, gas, and hydroelectric industries; challenges and opportunities for the agricultural sector; and climate-related issues facing local governments.

Participants then separated into three breakout groups to discuss key vulnerabilities and opportunities related to climate change in northern BC, next steps in developing adaptation strategies, and the information required to support those steps. Finally, a wrap-up session featured a brief summary from each breakout group and a discussion of the next steps in the process.

4. Workshop Agenda

8:30-8:35	Opening Remarks Art Fredeen, University of Northern British Columbia
8:35-8:45	Workshop Goals & Structure Jenny Fraser, BC Ministry of Water, Land and Air Protection Julia James, C-CIARN BC
8:45-9:45	Climate Change in Northern BC <i>Climate Trends in BC, Canada, and the World</i> Bill Taylor, Environment Canada <i>Climate Models: Are they reliable and what do they mean for BC?</i> Ben Kangasniemi, BC Ministry of Water, Land and Air Protection
9:45-10:00	Break & Networking
10:00-11:00	Impacts of Climate Change on Physical Systems in Northern BC <i>Water Resources/Permafrost</i> Paul Whitfield, Meteorological Services, Environment Canada <i>Terrain Stability/Permafrost/Hydrology</i> John Clague, Department of Earth Sciences, Simon Fraser University
11:00-12:00	Impacts of Climate Change on Biological Systems in Northern BC <i>Aquatic Ecosystems</i> Ellen Petticrew, University of Northern British Columbia <i>Climate Change and Forest Ecosystems in BC</i> Dave Spittlehouse, Ministry of Forests
12:00-1:00	Lunch (provided)

1:00-2:30	Sensitivity and Adaptation to Climate Change: Perspectives of Industry & Communities <i>Introduction</i> Stewart Cohen, Adaptation & Impacts Research Group, Environment Canada and Institute for Resources, Environment and Sustainability, University of British Columbia <i>Oil & Gas</i> Brian McBride, BC Oil and Gas Commission <i>Hydro-electric Power Generation</i> Stephanie Smith, BC Hydro <i>Agriculture</i> Jim Tingle, BC Ministry of Agriculture <i>Communities</i> Josh Joslin, Councillor, District of Hudson's Hope
2:30-3:00	Break & Networking
3:00-3:45	Moderated Breakout Sessions - Key vulnerabilities, opportunities - Major information needs - Suggestions for next steps
3:45-4:10	Summary from Breakout Sessions Spokespersons from each group
4:10-4:25	Follow-up Actions Stewart Cohen, Adaptation & Impacts Research Group, Environment Canada and Institute for Resources, Environment and Sustainability, University of British Columbia Jenny Fraser, BC Ministry of Water, Land and Air Protection
4:25-4:30	Closing Remarks Art Fredeen, University of Northern British Columbia

5. Opening Remarks

Art Fredeen
University of Northern British Columbia

Art welcomed the group, and noted that the real value of the process was going to be getting comments from the participants. Art has been involved with climate change research for 12 years, so he has a good perspective on climate change and how it will affect plant systems, but that is only one small part of the whole climate change picture. “I think what’s going to be really interesting for me today is to hear about all the different kinds of impacts on all the different sectors of human society, as well as the natural systems that I work with,” he said.

6. Workshop Goals and Structure

Jenny Fraser
BC Ministry of Water, Land and Air Protection (MWLAP)

Jenny Fraser thanked the group for coming, noting that participants were invited to the workshop to talk specifically about adaptation to climate change. She said that adaptation is a bit like the “kid sister” to mitigation (reducing greenhouse gas emissions). It doesn’t get the same amount of attention as mitigation right now, but it is nevertheless an important part of our response to climate change. Jenny said that the workshop will ignore mitigation, not because it isn’t important but because the goal of the workshop is to focus on projected climate changes and how to adjust to them.

Atmospheric warming is only one aspect of climate change—which also includes changes in other parts of the global climate system including precipitation, cloud cover, ocean currents, and the hydrological cycle. These changes will affect bio-physical systems—such things as the volume of river flows and the timing of flowering—and are expected to have both positive and negative impacts on human systems. She added that historical data suggest that already many parts of BC are starting to experience the impacts of climate change. The MWLAP report, *Indicators of Climate Change for British Columbia 2002*, documents these trends, and was made available to workshop participants. The document is also available on the MWLAP website: <http://wlapwww.gov.bc.ca/air/climate/indicat/>.

The Intergovernmental Panel on Climate Change defines adaptation as “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects.” Both natural and human systems can and do adapt. The adaptation can be responsive (initiated after climate change occurs) or anticipatory (initiated in advance of change). This workshop is primarily interested in the anticipatory kind, which can position communities and businesses to take advantage of potential benefits and minimize negative impacts.

The impacts of climate change will vary from one part of BC to another. Different communities and sectors will be affected differently. Adaptation strategies will therefore also need to vary. For effective adaptation, we need to engage a broad range of people from a specific region. We hope

that workshop participants can help to identify some of the impacts northern BC may be dealing with.

The three goals of the workshop are:

- 1) to share information from climate experts and learn through participant dialogue and responses to this information;
- 2) to identify ways that northern BC is vulnerable to climate change. In this region, temperature change over the last century has been significantly faster than globally, and three times as fast as in Southern BC; and
- 3) to identify ways to move forward on adaptation in the province.

“We hope this will be the beginning of a long and ongoing dialogue,” Jenny concluded.

Julia James
Coordinator
C-CIARN BC

Julia welcomed everybody to Prince George. She emphasized the importance of the diversity in the room to tackle the issues of climate change because the subject needs to be attacked from varied angles and it can't be done from just one discipline or just one institution. That's why C-CIARN wants to create this dialogue by bringing people together and getting them talking about the issues and discussing how we can adapt. “So I'm really happy that you are all here today,” she said.

Julia also introduced the people at the workshop who are part of C-CIARN, including Eric Taylor, the national coordinator of C-CIARN; Art Fredeen (UNBC) and Jenny Fraser (MWLAP) who are on the C-CIARN BC advisory board, and Andre Blais-Stevens (C-CIARN Landscape Hazards).

7. Climate Change in Northern BC

Chair: Julia James, C-CIARN BC

Climate Trends in BC, Canada, and the World

Bill Taylor
Environment Canada

Abstract:

The globally averaged temperature has risen 0.6 degrees Celsius during the 20th century. This amount of warming may appear small, but studies have shown that this seemingly small change in global temperature has had a profound effect on plant and animal behaviours such as egg hatching, flowering dates, and migration patterns; and may have shifted the range of some species northward by several kilometers.

The pattern of climate change in Canada over the past 50 years has been unusual in that western and southern Canada have warmed while the northeastern part of Canada along the Labrador Sea has actually cooled. Most of the warming in the south and the west has occurred during winter, and daily minimum temperatures have increased much more than daily maximum temperatures. Thus, it is said that Canada is not getting warmer, it is getting less cold. This trend in daily minimum temperatures is evident throughout much of British Columbia.

The reasons for climate change are complex, however the buildup of greenhouse gases in the atmosphere since the 1800s is almost certain to be contributing to the unprecedented rate of warming. The Intergovernmental Panel on Climate Change stated in its *Third Assessment Report* published in 2001 that “There is new and stronger evidence that most of the warming over the last 50 years is attributable to human activities.”

Full Presentation:

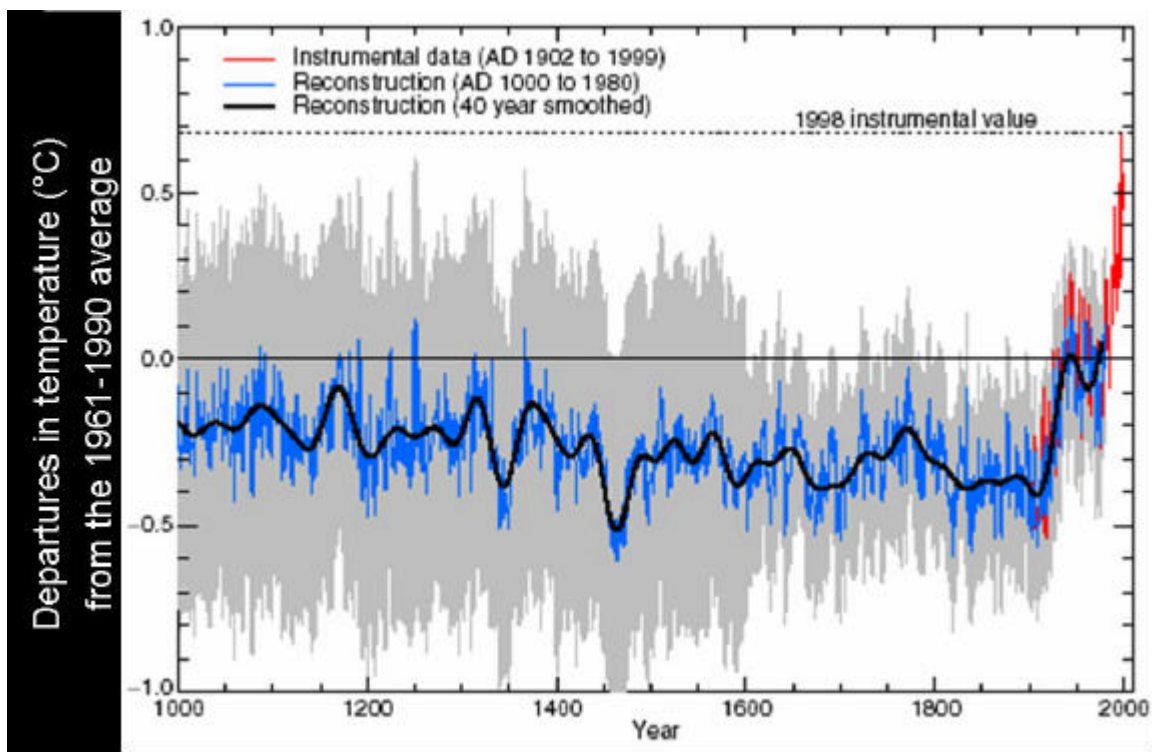
Global climate is changing, and changing very rapidly. While the reasons for that are complex, most scientists agree that the accumulation of greenhouse gases in the atmosphere over the last 150 years or so has contributed in a significant way to that warming and that humans are partially responsible for that.

The material Bill presented comes largely from the *Third Assessment Report*, published in 2001 by the Intergovernmental Panel on Climate Change (IPCC), an international panel of experts formed under the auspices of the United Nations and the World Meteorological Organisation to reach consensus on the science of climate change. The IPCC is recognized as the most credible source for scientific information on climate change.

Evidence of climate change: Is the climate changing?

Accurate global temperature records are available for about the past 140 years comprising what is known as the instrumental record. These measurements are taken with thermometers housed in a Stevenson Screen located approximately 1.5 metres above the ground. To get an idea of a longer temperature record, proxy data from ice cores, coral, and tree rings are used. These proxy data have in common an annual layer of growth dependent on climate (e.g., tree rings) that allow researchers to deduce temperatures.

The IPCC used the instrumental record to produce a chart of variations in the Earth's surface temperature for the past 140 years. It shows temperature departures from the 1961-1990 normal (average). The red bars show that the 1990s were the warmest decade on record and 1998 is the warmest year. The graph also shows an upward trend. The amount of warming—a 0.6°C rise during the 20th century—may seem like a very small amount but nonetheless it is quite significant in terms of the rate of warming. For example, a recent Stanford University study detailed the kind of impacts that a small change in temperature can have in such things as the timing of blooming dates, egg laying, nesting behaviour, and also a change in the range of many species. Scientists have termed these impacts on the natural environment the “fingerprint of climate change,” and the study shows that warming has had a very large impact already. The warming also has not been uniform. There were two periods of warming from 1910 to 1940 and from 1975 to 2000, and there appears to be a slight cooling trend between 1940 and 1975.



Source: Intergovernmental Panel on Climate Change, Third Assessment Report, 2001

The question we're trying to answer is "Is 20th century warming unusual?" To do that, we have to go back and look at some longer time periods, and this is where the proxy data comes into play. A graph of temperatures for the past 1,000 years (see figure) was reconstructed from proxy data from tree rings, ice cores, and coral. The graph shows that temperatures became gradually cooler over the 900-year period from 1000-1900 AD, while 20th century temperatures rose dramatically and are a clear departure from that trend. This graph has often been described as a hockey stick for obvious reasons.

Temperature trends in Canada are similar but it has warmed quite a bit more in Canada than globally. A chart of Southern Canadian temperatures since 1900 is similar to the global trend with two periods of warming separated by a period of slight cooling. Southern Canada is separated from the whole of Canada because a climate observation network did not exist in the North until the 1940s. Southern Canada has warmed 0.9°C versus a global warming of 0.6°C over the past century.

Looking at regional temperatures from 1950-1998 (actually a very short period), the whole of Western Canada shows quite significant warming—it is more than 2°C warmer in BC and the Yukon—but in North-eastern Canada (Labrador Sea) there has been significant cooling. This regional pattern is consistent with hemispheric-scale changes in the circulation of the ocean and the atmosphere which have occurred over the same period.

Looking at trends in daily minimum temperatures, the greatest warming over the past 50 years has been in the winter and especially in the spring (about 3°C). There is also a slight warming in summer, and for a large part of the country fall has seen a cooling trend. When we talk about warming, it is not happening uniformly over the globe and it is not happening uniformly in time. There are both regional and seasonal differences in the temperature trends.

Temperature trends in BC reveal that the interior of BC warmed 1.1°C during the 20th century, with warming more modest on the coast (0.5°C) because of the moderating influence of the oceans, and greater (1.7°C) in the far north of BC. The other interesting aspect of these trends is that the nighttime minimum temperatures are rising faster than daytime maximum temperatures. For most of BC there is no significant trend in daytime maximum temperatures, whereas all parts of BC show a significant increase in nighttime minimum temperatures ranging from 0.9°C along the coast to 2.1°C in the north.

If we want to look for evidence of climate change in the environment to corroborate the temperature record, there's probably no better example than what is happening with glaciers. Wedgemont Glacier in south-western BC has lost a huge amount of mass in the past 20 years. This is very consistent with an IPCC chart showing glacier loss in other parts of the world. There are some places in the world, including some places in BC, where glaciers are actually increasing but generally speaking there is a loss or retreat.

In summary, the world has warmed by 0.6°C, while Canada has warmed by 0.9°C over the 20th century. Canada is generally "less cold" since temperature increases are mainly in winter and spring, and also because nighttime minimum temperatures are rising faster than daytime maximum temperatures. Canada also is wetter, and there have been changes in the "snow

fraction,” with a higher percentage of precipitation falling as rain in spring. There are also large regional and large seasonal differences in the rate of climate change.

Attribution: Why is the climate changing?

On very large time scales, the climate responds in a very profound way to changes in the Earth’s orbit, but those changes really aren’t evident over the short term. We can divide the causes of 20th century climate change into two categories:

- natural forcing factors, including variations in the sun’s output, volcanic eruptions, and internal variability (El Niño – Southern Oscillation, the Pacific Decadal Oscillation, etc.); and
- human factors including greenhouse gases, aerosols (air pollution that actually has a cooling effect), ozone depletion (ozone is a greenhouse gas), and land use change.

These factors are all affecting climate change, often at the same time. That is why it is difficult to point to a single cause or provide a simple explanation for changes in the temperature record.

In the atmospheric energy budget, about 31% of incoming solar radiation (shortwave) is reflected back into space and the rest goes into heating the earth and driving ocean currents and atmospheric circulation. Earth itself radiates its own form of energy at longer wavelengths than the incoming solar radiation. In the end, the amount of radiation going out has to equal that coming in; otherwise the temperature of the Earth would rise continuously. It just so happens that greenhouse gases are very efficient at absorbing the longwave radiation the Earth emits. On its way out to space, some of the longwave radiation gets trapped by greenhouse gases and radiated back to the surface, and the surface warms up as a result. This is actually a very good thing, because Earth would be about -18°C without greenhouse gases, or 33°C cooler than it is at present. The greenhouse effect is necessary to support life on earth.

The three most abundant greenhouse gases are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). These three, along with three other greenhouse gases, are being targeted for reduction under the Kyoto Protocol. Despite their low concentration—less than 0.1% in the atmosphere—these greenhouse gases play a significant role in the Earth’s energy budget. The one that gets the most attention is CO₂, because it is the most abundant. Recent increases in CO₂ are due to burning fossil fuels, a primary source of energy for the world.

When the natural sources of carbon (fires, decomposition, and animal respiration) are equal to natural removal processes, or what we call “sinks” (photosynthesis, dissolution in ocean water), there is no net increase in carbon to the atmosphere. However, when fossil fuel production and consumption are added in, there is an imbalance in the carbon cycle because the emissions of gases are larger than the processes that remove them, thus carbon builds up in the atmosphere. In the 1990s, sources of carbon included 6.4 gigatons per year from fossil fuels plus 1.6 gigatons per year from deforestation, while the uptake of carbon was 3.1 gigatons per year on land and 1.7 gigatons per year in the ocean (a gigaton is one billion tons). This imbalance resulted in 3.2 gigatons per year of carbon being added to the atmosphere. Over the past 1,100 years, concentrations of CO₂ in the atmosphere have gone from 280 parts per million by volume

(ppmv) to nearly 360 ppmv, with most of the increase in the 20th century. The CO₂ trend somewhat resembles the “hockey stick” of the temperature trend chart.

The IPCC concluded in 2001 that “there is new and stronger evidence that most of the warming of the last 50 years is attributable to human activities.”

Questions:

Q: noted the nighttime minimum temperature increase, and said that that in the mid-1990s he was measuring US forest productivity across a range of species. In the first year, productivity was close to optimum, but in the second year, temperatures were very warm at night, and productivity decreased by as much as 50% on average.

Q: What about longer-term temperature changes? Was there historically a lot more variation than over the last few hundred years?

A: There is no question that climate has been warmer at other times. The concern is the rate of change in 20th century and that projected for the 21st century. The human-imposed signal and the rate of change is the concern.

Q: Have you been using lake sediment cores, or would you?

A: Richard H. at University of Victoria and also Ian Walker in the Okanagan.

Q: What was the cause of the cooling trend from the 1940s to the 1970s?

A: There was a huge increase in aerosols, and possibly a decline in solar output. We have to take all these forcings into account.

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How Reliable are Climate Change Predictions? What do they mean to BC?

Ben Kangasniemi
Climate Change Section
BC Ministry of Water, Land and Air Protection

Abstract:

Current global climate models (GCMs) couple ocean and atmospheric processes and take into account land surface effects. To enable computer simulations the earth is divided into roughly 4,000 grids each stacked some 20 layers high into the lower atmosphere. Grids are about 400 km across. Calculations of major weather processes are repeated in 20 minute increments for each grid and the results are transferred to the adjacent grid and propagated around the globe. These calculations are repeated for several centuries to create a simulation of global weather processes. There are some 20 global models in current use. The results vary but no one model is considered superior. The results from several models should be used when drawing conclusions about future impacts. The large size of the grids makes it very difficult to interpret the results for smaller regions. The results from several adjacent grids need to be considered before drawing conclusions.

Simulating global climate processes well enough to project future trends is a complex undertaking. Efforts to date have shown that models can reproduce observed historical trends quite well. They have also been very useful in understanding possible human influence on the climate system on a long-term global scale. Modelling has also helped focus attention on the research needed to reduce the most important uncertainties. In order to determine how much we can rely on the current generation of models it is useful to recognize the major areas of uncertainty. These include accounting for:

- Complex cloud formation and radiation interactions that occur at scales not readily resolved by global models
- Balancing the warming and cooling effects of suspended particles and liquids (aerosols)
- Vast pool of carbon cycling in the oceans
- Variations in the reflectivity of land and ocean surfaces to incoming solar radiation due to natural and human activities
- Variations in solar output
- Cooling and warming effect of ozone in different levels of the atmosphere
- Wide range of possibilities for future human greenhouse gas emissions
- Future volcanic activity

Current research is focusing on these uncertainties and model performance is expected to improve over the next 5-10 years.

Full Presentation:

Ben began his presentation by stating “I am not a climate modeller.” However, in his work for the province providing advice on developing climate change policy, it is important for him to

understand what the models are saying. He has spent some time reviewing them and trying to come to an understanding of how reliable they are and how to use them in local adaptation planning.

When he started working on this it became quite apparent that there was a lot of scepticism about how we can predict the future. We have a lot of trouble with the 5-day forecast so how can we talk about the next 50 to 100 years? The presentation covers the limitations and applications of global climate models, provides some information about how we can make that information more relevant at the local scale, presents some results from this part of the world that are relevant, and touches briefly on the trends.

Modelling development is going on all over the world—it's really quite a competitive business. There are many modelling centres working fairly independently, and their competitiveness means that the people that are working on them are using different approaches. Canada has invested in major modelling capability presently housed at the University of Victoria, so there is considerable expertise in Canada on global climate modelling. There are about 20 global models at present, and the top 5 are in Victoria, BC; the United Kingdom; Germany; Princeton, New Jersey; and Boulder, Colorado.

Modelling global climate presents quite a challenge, because we are dealing with an incredibly complex and variable system. As anyone who watches the weather realizes, it's a pretty tough task to look into the future. The work over the past century to develop models of climate and weather for short-term (i.e., weather) prediction has provided a lot of the tools and mathematical means to describe the physical processes. These are now coming into quite significant and practical use in dealing with the question of greenhouse gases driving global change and trying to understand that.

How do models work? Given the complexity of the climate system, modellers have to subdivide the globe into manageable chunks to make these calculations. These grids are approximately 400 km across. Within each of the grids an enormous number of calculations are being conducted in order to simulate what is happening, from a climate perspective, within the grid. Some of the complex calculations going on within each one of these grids include interactions between heating (radiation), temperature, clouds, and winds, and interactions between the atmosphere, the ocean, and the land surface. It is a very complex mathematical exercise to account for all these processes. These calculations are going on in each grid, and the results are transmitted to the next grid. The grids are not just two-dimensional; they go up into atmosphere some 15-20 layers high and also couple the oceans with the atmosphere.

In order for a model to be considered useful, it must demonstrate that it can replicate historical patterns. Any model used by the Intergovernmental Panel on Climate Change (IPCC) or the general scientific community has to prove that it can reach current conditions with initiation two hundred or so years in the past. Then the models are run for another 100 years into the future. Modellers usually refer to these runs as “simulations” rather than “projections.”

Ben provided a graphic example of the results of one of these model runs, in this case possible future precipitation in North America. Due to the coarseness of the grids in the model, the results

come out in chunks that do not necessarily reflect actual conditions on the ground. There are tricks to smooth the results out and make them more realistic. Pointing out the grid where Prince George would be, Ben noted that in order to make reasonable judgements about conditions in this future time slice you need to look at the grid of interest and surrounding grids and make some generalizations about what those conditions are.

Ben suggests caution in using the results. Models were designed first to answer questions about the causes of climate change, and they're doing a reasonable job of that. Those working in the adaptation community are trying to use the models to see if we can learn a little bit more about what the future has in store for specific places on the earth. That's not really what the models were originally intended for, but they have some uses in that regard.

A big limitation in the models, due to their large resolution and coarse scales, is that they do not incorporate the complexity of cloud formation. The IPCC has identified this as a major limitation and a significant amount of research is going into it. But there probably won't be a significant advance in this area until computing power increases enough so that some basic cloud processes can be resolved. Clouds act to reflect incoming solar radiation and also trap the energy leaving the earth's surface, keeping nighttime temperatures higher. The complexity of clouds is really beyond current model ability. Water vapour, in fact the most significant greenhouse gas, is also poorly represented in the models.

Another area of uncertainty involves aerosols. Their distribution is highly variable and very difficult to predict into the future. Some trap heat, while some have a cooling effect, and the relationship between the two categories is not well known. This is another major area of research.

Another big problem with global climate models is that they are physics-based, and can't really accommodate the significant biological processes that are going on. Ben illustrated the importance of biological processes with a picture of a plankton bloom in the Alaskan archipelago, covering a large area of the Bering Sea. Oceans are a really powerful part of the carbon cycle. Three-quarters of the Earth is covered by ocean, and the carbon cycling that the ocean is responsible for is many orders of magnitude greater than the carbon cycling between the human and terrestrial interface. Models are beginning to address that now and considerably more work is needed in that area.

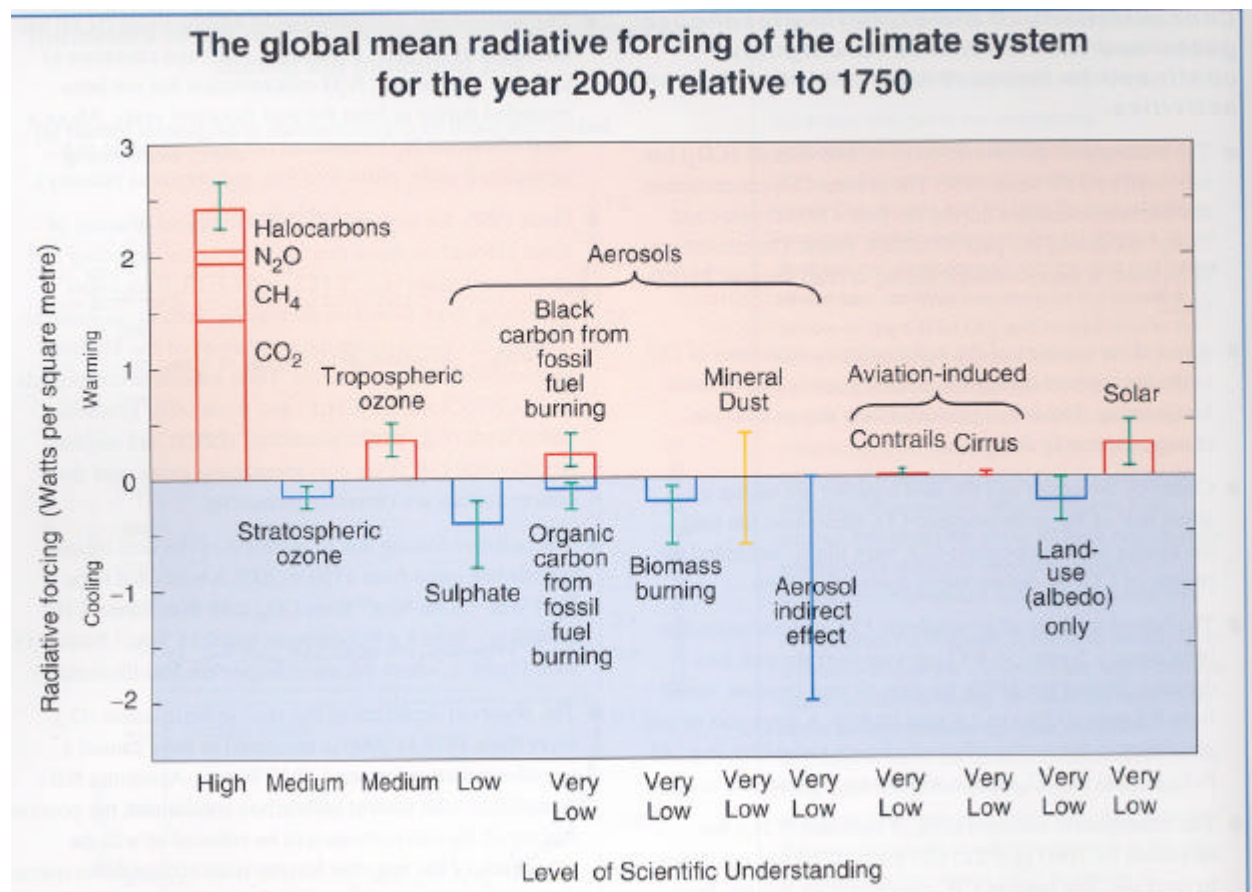
Landscape changes are also important: there are going to be some very significant changes in plant productivity and impacts from droughts that could result in a major change in carbon balance and reflectivity of the earth's surface to incoming radiation. There are a number of biological processes that can be very significant and physics-based climate models are really not able to deal with this complexity at this time.

Albedo (reflectivity) changes also are important. Incoming solar radiation is reflected away from the polar regions because of ice and snow cover. One of the reasons why we see the polar regions warming up most is because there is a dramatic loss of reflectivity (loss of ice and snow cover) in the extreme and northern and southern parts of the globe. Human land use practices or

natural changes can have a big impact on reflectivity and how much radiation stays in the global system.

Cataclysmic events, a natural factor, also play a role. There is a three-year period in the climate record in the early 1990s that shows a significant alteration in the global climate and global cooling that is directly attributable to the eruption of Mt. Pinatubo in 1991. Global climate modellers have incorporated a certain frequency of volcanic activity by looking at the historical record, but it is very difficult to know what the future contribution from this fairly erratic natural source might be.

Ben indicated that the IPCC is pretty honest about describing the range of uncertainties and the extent of our scientific knowledge of most of these factors. The diagram below, from the IPCC report, *Climate Change 2001: The Scientific Basis*, lays out both the range of radiative forcing (positive or negative) expected for a variety of factors, and also presents the level of scientific understanding of these factors.



Most of our knowledge right now surrounds greenhouse gases and our understanding of their chemistry and their ability to absorb the infrared radiation escaping from the earth. This is very, very solid stuff—we know quite a bit about how that affects the climate forcing of the global system. But if you look at the other factors shown, and the bottom scale showing how much we

know about them, and the estimated range of possible impacts that these might have on radiative forcing—some positive and some negative—you can see that there are a lot of other factors that we can't account for in a very numerical fashion or in a modelling exercise.

Another big factor is what future emissions of greenhouse gases will be, because they are a significant part of the kinds of global results that we get from model calculations. There are a wide range of emissions scenarios to plug into the models and calculate what future climate may be like. There are optimistic scenarios, where emissions start declining significantly in the middle of this century, but most of the other scenarios unfortunately forecast a continuing increase in emissions.

Looking at model simulations versus observations of annual temperature from 1850 to the present, we see that there is a mismatch when the model is forced with just natural or with just human factors. When both kinds of factors are used in the model, there is quite a good match. This is the basis for convincing policymakers that we really have to pay attention to the human contribution to climate change.

Ben presented an animation of a 100-year simulation of North American warming from one model, which shows that the most significant warming occurs first in the north. This is different than what you imagine when you think of a 1.5°C global average warming—nobody lives in an average climate. BC experiences a 4° to 5°C increase from 1990-2100 in this particular North American simulation. There are lots of ways to run these calculations; this is just one example for the North American portion of the globe.

There is hope that we can improve the resolution of these projections, and regional climate models offer an opportunity to do so. When the size of the grids is reduced from 400 km down to around 50 km, we can incorporate a considerable amount of terrain detail and get much better resolution. Showing an example of a regional model for the Mediterranean, Ben noted that for people involved with adaptation these kinds of results are more useful. However, there's just no way that current computer capacity can do this for the globe; we can only do this for little chunks. While computer technology may eventually get us there that doesn't seem likely in the near future.

A regional climate model has been developed for western Canada, but the results are not entirely available yet. The results for BC are quite a bit more detailed than in the previous North America simulation. In the area of Prince George, winter average temperatures are projected to be 2° to 4°C higher in 2040-2049 than the 1975-1984 baseline. Snowfall changes are also quite troubling—we see a very dramatic (50-100%) reduction in snowfall in this region.

Downscaling (the process of deriving regional projections from global models) can provide more detail, but we're still limited by the global climate model limitations. Advantages of downscaling include better resolution, adding the effect of local land features, and helping to assess impacts and develop adaptation strategies. Cautions about downscaling include dependence on global model bias, limits to the number of scenarios, and dependence on extensive local weather observations.

To see the full range of model results that represent plausible scenarios for this region, Ben took the global grid and found the area of Fort Nelson as an example of north-eastern BC. A graph illustrates the percentage change in precipitation and temperature projected for three different future time periods by a number of different models. Different model results and scenarios suggest there will be increase in precipitation and temperature, even though there are differences between the model projections, and the increases will be greatest in the North. This will likely result in major hydrological cycle changes, including increases in stream temperature, increases in spring streamflow, decreases in summer streamflow, and decreases in glaciers.

In summary, Ben said that despite model uncertainty there is significant agreement between models, the potential impacts are huge in northern BC, and observations are supporting that trend.

Questions:

Q: How small an area can regional models describe?

A: Modellers can downscale from 300-400 km down to a 50 km grid, but don't seem to be able to do better because of computational limitations.

Q: The regional model you showed us suggested a snowfall reduction of up to 100 percent. Can you explain these projections?

A: I'm having trouble with the snowfall projection; the results are very dramatic. I wanted to just show you the resolution, but didn't want to get into the numbers, because I don't think the Canadian Regional Model is ready for prime time yet.

Q: How can winter snowfall decline when precipitation is expected to increase?

A: You can see a decrease in winter snowfall but still have an overall precipitation increase if the proportion of precipitation falling as snow decreases and that of rain increases.

Q: You mentioned that the results from the Canadian regional model were online somewhere, are they available?

A: Canadian Centre for Climate Modelling and Analysis (CCCMA) site has results (<http://www.cccma.bc.ec.gc.ca/diagnostics/crcm/crcm.shtml>). You can study these and consider them yourself. But you really have to be careful, there's more information available here that is primarily intended for researchers. So if you're looking for locally relevant results to consider in your business practices you really have to work with someone who can interpret these results. As I say, they're not ready for general public use yet.

Q: With the huge variations in the GCMs, do we benefit a lot from downscaling?

A: When you downscale you have to pick a GCM to work with, so if you've picked a wet GCM, and downscale that you get a whole lot of wet detail. If you pick a dry GCM you get dry detail. The danger of downscaling is that you limit yourself to the numbers of GCMs you can work with so you have to be careful—try to pick models that represent both extremes and don't go off in one direction too far. Downscaling right now is more of an exercise to start preparing for how we can adapt locally and how we can think about local impacts. I don't think we can take the regional results of the GCMs to the bank yet but as the GCMs improve the regional interpretation

of them will improve. You're seeing here a work in progress. At the global scale models have given us the answers we need about how humans influence climate. As GCMs improve so will regional interpretation. But to force a reasonable conclusion to a local level—my message is, “not quite yet.” But we need to be aware of these tools and also rely on actual observations.

Q: If there are large Arctic temperature changes, how will this affect sea level rise?

A: Worst case sea level is an 80 cm increase within the scope of IPCC predictions, but there are worse worst case scenarios.

John Clague added: yes, the current projection is 80 cm, but we don't really know how the big ice sheets (Greenland, Antarctica) will respond. A complete collapse of these ice sheets could result in an 8 metre sea level rise but that's a doomsday scenario.

8. Impacts of Climate Change on Physical Systems in Northern BC

Chair: Ben Kangasniemi

Retrospective and Modelling Recent Changes in Streamflow in Northern BC

Paul H. Whitfield
Meteorological Service of Canada
Environment Canada

Abstract:

We combine retrospective analysis of observations taken over an extensive period of time as an analogue for potential future changes in streams and rivers in BC. Selected results from several papers were presented demonstrating trends in amounts, timing, and hydrological features (Whitfield and Cannon 2000a, Whitfield et al 2002). Examples were given that showed that rivers in northern BC are showing increased streamflow throughout the entire year (Whitfield and Cannon, 2000b). At the same time rivers in southern BC are shifting to an earlier onset due to snowmelt driven freshet.

We have demonstrated that these changes can be mostly explained and modeled by climatic data (Cannon and Whitfield, 2001), and examples from these models were presented. Further we demonstrated some of the complexities of the hydrologic response to climatic variations including the complications of permafrost in northern regions.

Full Presentation:

Paul Whitfield presented some results from work he's been doing for the past decade. "My experience is water quality," Paul said, but 12 years ago his boss walked into his office and asked "What happens to water quality in British Columbia if the climate changes?" When you look at water quality, the statistics of climate change and particularly what happens on a landscape is really critical to understanding it.

First, they did retrospective analysis, which is fancy way of saying a look at the past. They developed a different methodology, which his presentation will explain some of the attributes of, so you can actually start to visualize some of the types of changes that have occurred in the recent past. The second focus is on modelling what is going to happen in the future using the past as an analogue. He focused on regional patterns, because while the globe is changing and the models are showing that, what's really important in adaptation and what's really important to ecosystems is what is happening on specific pieces of land. His work focused on modelling streamflow in southern BC and also in northern Canada, as northern areas are significantly different.

Paul showed a slide of monthly streamflow for the Similkameen River in Manning Provincial Park, which is a pristine forested area, and has been since a fire in 1948. They looked at two separate periods: 1974-1985 and 1986-1995. One of the key issues in worrying about what happens on the landscape is making sure you can adjust the signal to noise ratio so you can see

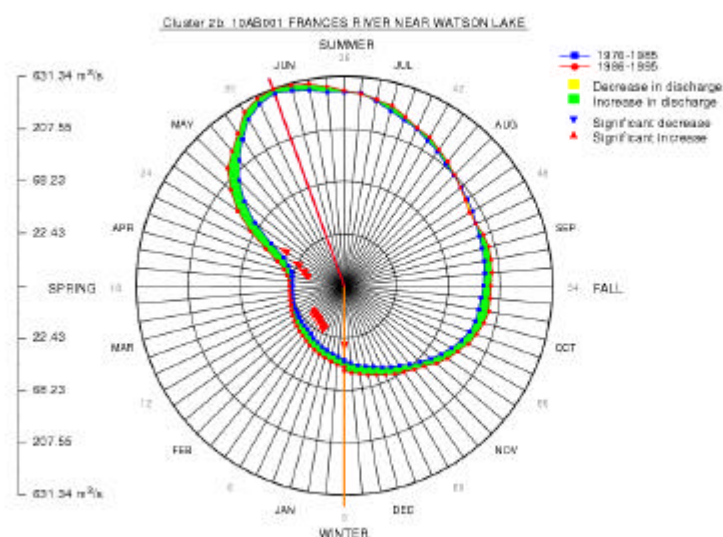
what's actually happening. When they compared monthly data between the two decades, there was no statistical difference. However, they did see that the second decade showed the same pattern of streamflow occurring earlier in time, which is consistent with a warmer climate—probably the snow melting earlier.

Paul and his colleagues found all kinds of cases that behaved like the Similkameen series, and tried reducing the time step to a 5-day average streamflow, and while it was a little noisier because of the finer time step, they started seeing some statistically significant differences. What that says about what is going on in the environment is that it's not issues around the peak but the earlier onset of snowmelt, and decreases in streamflow in September. Those are two of the key features that they started to see throughout south central BC. And it didn't matter what river they looked at in south central BC, they saw exactly the same pattern. That becomes really interesting because what you have is a regional pattern that is consistent across a broad space. So you can start to think about extrapolating from your observed data to places where you don't have data, and make a good guess about what's going to happen.

Later, they extended their research to all of Canada, and found that there are four basic types of hydrology: Pacific Maritime (rainfall driven), two types of snowmelt (mountains or no mountains), and another pattern in southern Ontario. The only type occurring in northern BC is the montane snowmelt type.

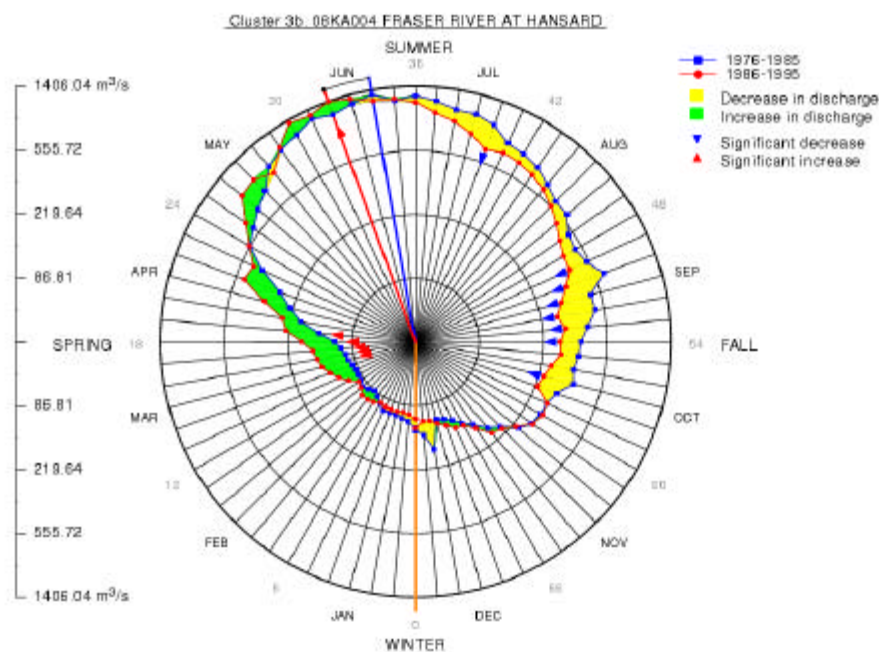
The real significant changes in temperature are not in the summer highs and the winter lows, but the changes during the shoulder seasons (spring and fall). Precipitation patterns are more complex, because geography really impacts on that. Changes in temperature and precipitation result in six different hydrology change patterns across Canada.

In northern BC, they found that streamflow was increasing every period of the year, as shown in the plot below.



If the area between the curves is shaded green, it shows an increase between the two decades, and red triangles show that the increase is statistically significant. They found this pattern across a wide range of northern rivers: the Yukon, Iskut, Liard, Coal, Chilcotin, Atlin, and Bear Rivers, among others. The same pattern was ubiquitous over the whole area. One of the things he finds really interesting is that precipitation changes are not that significant, and yet the streamflow changes are very significant. There is a stronger effect on streamflow from temperature than from precipitation.

The second pattern they found was higher flows from the onset of hydrologic spring (March through June) and then decreased flows through the fall (July to October), as shown below.



This represents a shift forward in time of the annual melting of the snow. Paul likened it to a sponge—in the wintertime put snow on it, then put it out in the sun, and as soon as you get above 0° , the snow starts to melt, the water runs off, and the sponge becomes drier. In the spring you see that earlier melt of the snow and later in the summer you see the drier sponge. This pattern also was ubiquitous across a band through Prince George, including the McGregor River, the Fraser River at McBride and Shelley, the Skeena River, and the Kemano River (there also was a winter rain effect at Kemano).

Further south in BC there is another different pattern.

Paul was trying to develop statistical models to forecast streamflow from climate projections. Hydrologic variables that respond to climate are quite complex, and they use a model called a “neural network” model. Given the magnitude and timing of climate variations, the model

addresses the interactions between temperature and precipitation changes, the different hydrological regimes (rainfall- or snowfall-driven, places with lake storage and other processes, etc.), and watershed size. Watershed size is important because small creeks respond very quickly to changes where a river the size of the Fraser as a whole responds very slowly.

This statistical model is first used to reproduce observed changes, and then used to project the future. For example, snowmelt systems all produce a type of change with much more constancy, whereas with rainfall systems a small change in the area of the watershed can really change the information—the idea is to see if the model can reproduce all of this.

For the climate data input to the model, Paul and colleagues used a data set called the NCEP/NCAR reanalysis, which has a finer time scale and finer spatial resolution than global climate models, but takes observed data and regrid it to look sort of like GCM data. They used the period from 1965-1986 to “train” the model, and then made a blind forecast of 1987-1998 with the model and compared it to observations. This is a rigorous test for how good a model is.

In general, their model reproduced observations quite well for most of the watersheds (both rainfall- and snowfall-driven) they tested, indeed, some results were mirror images. Recent changes in streamflow were well-predicted by the model, showing that they had captured the main characteristics of the systems. The processes that produce the observed change can be built into a statistical model, although they don’t do so well with some of the land effects (especially in small watersheds), and have difficulty capturing individual rainfall events.

However, in the north things got interesting. While the model results versus observations for the Atlin River were good, the Coppermine River (Northwest Territories) showed exactly the reverse result. They found this difficulty over a particular area of the North. So for these watersheds they reversed the training and validation periods (using the latter decade for training and the earlier decade for comparing model results to observations) and that worked.

What is unique about this area? The number one factor they looked at, and are still looking at, is permafrost. There is anecdotal evidence and records from some places (although not close enough to watersheds of interest) showing that in the last few decades the active layer (the part where water moves through the surface) is changing, that is, the volume of permafrost is changing. If you think of the sponge model, and you freeze the sponge, you really retard how water moves through. So if you melt the sponge, more water moves through it more rapidly.

Increased streamflow throughout the entire year, as seen in these northern rivers, suggests that the hydraulic conductivity of the watersheds is increasing. Paul thinks the increased streamflow in the North is controlled partly by hydraulic conductivity and partly by melting of additional storages.

There are numerous implications of the observed changes in streamflow. Low flows at a different time of the year have implications for fisheries: “If you’re a fish you’d really rather have the low flows at 0 degrees rather than at 20 degrees.” There is also the issue of nonstationarity (i.e., the system is not static but changing): for example, people designed all the hydraulic structures, dams, and bridge crossings in BC at a time when runoff was very much

above normal, but since that time, and particularly since 1980, we're seeing much, much lower annual runoff. Some of this is due to water balance, for example at Princeton precipitation is increasing, but in the same basin runoff is decreasing. So the relationship between putting precipitation in a watershed and producing runoff is changing. This is applying at all scales in the province. There is also the issue of break-up timing—for example on the Yukon River at Dawson, in 1890 the break-up was around day 130, but it is earlier now.

It's about changes, and recent changes in climate have resulted in changes in the amount, timing, regional location and extent, and seasonality of hydrologic events.

Questions:

Q: How much have low flows advanced?

A: Historically they were in late March-April, but now they are in August-October (4-5 months later) in some southern rivers.

Q: In northern regions?

A: Flows increased all year

Q: What is your prediction for northern streams once permafrost is gone?

A: That's the \$64,000 question. Don't plan on higher flows persisting, since the permanent stores are draining away. Then the pattern of central BC shifts north, you can look at the progression. Most changes are temperature-driven, not precipitation driven.

References from Abstract:

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Terrain Stability, Permafrost, and Hydrology

John Clague
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Simon Fraser University

Abstract:

Increasing atmospheric concentrations of carbon dioxide (CO₂) and other greenhouse gases are causing complex, poorly understood changes in climate. Much of the Earth will warm during this century, but neither the amount nor the seasonal and regional distribution of warming can be predicted with any confidence. British Columbia will likely warm, but warming may be accompanied by more extreme temperatures and storms due to instability in oceanic and atmospheric circulation.

Any significant increase in precipitation, either seasonally or annually, will lead to a greater incidence of landslides in northern BC. Landslides may be caused by an increase in the proportion of total precipitation that falls as rain as opposed to snow, an increase in the intensity and duration of storms, sustained shifts in storm tracks, and antecedent conditions that are more favourable to landslides (for example, saturation of soils during winter). The types of landslides most favoured by these changes are debris slides, rock falls, debris flows, and some rock avalanches. Although at the smaller end of the spectrum of slope failures, these landslides can seriously impact forest lands and forestry infrastructure, notably forestry roads. Large landslides, including deep-seated translational failures, slumps, and sackungen, may have a delayed response to an increase in precipitation. Other types of failures that can be expected in a wetter climate include reactivation of dormant prehistoric landslides, landslides with smectite-rich rupture zones, and failures of fan deltas. Rivers and streams, especially in high mountains, will likely experience regime changes as a result of increased sediment supply from landslides, melt of ground ice, and erosion of unstable sediment in glacier forefields. Changes in river planform in mountain valleys may alter ecosystems and damage economic infrastructure.

An increase in temperature will melt northern and alpine permafrost and increase incidence of wildfires. Loss of vegetation and roots, which bind soils, may decrease the stability of slopes. Glaciers will retreat under a warmer climate, debuttressing some high mountain slopes and triggering landslides. Outburst floods from glacier- and moraine-dammed lakes are expected to continue.

Data and research are required to allow northern residents to adapt to the changes summarized above. Climate and hydrometric stations that have recently been shut down must be reestablished. Research should be conducted on the connection between modern landslide activity and climate. The role of the decay of mountain permafrost and deep-seated, slow rock spreading on catastrophic landslides also should be investigated. Slope movements should be monitored to determine if movement is increasing.

Full Presentation:

John set the stage by covering some of the same ground as earlier presenters. He showed a graph of Northern Hemisphere temperature change over the past 1,000 years, based on proxy data from a variety of sources. He pointed out that climate is naturally variable, stating that mountain glaciers during the nineteenth century were larger than at any time in the past 10,000 years. The relatively minor changes in climate during the “Little Ice Age” (AD 1200-1900) had huge impacts on people, for example the Norse in Greenland. A global change in temperature of as little as 1°C can have such impacts.

Looking at climate data since about 1900, we can see that climate is changing. There has been natural variation in climate in the last 100 years, for example cooling in the 1940s. However, human-induced changes to the atmosphere are beginning to drive climate change. There is little doubt that Earth is warming, but changes on a local or regional scale are much more poorly understood.

John showed a graph of the rise in CO₂ in the atmosphere and noted its close relationship to climate. “The nay sayers say there’s not a link, but I don’t know where they’re coming from. They’re really ignoring a tremendous volume of data that clearly signals that this is the case.”

There is risk in accepting current climate model predictions – the models are becoming more sophisticated, but they cannot precisely predict future climate. Our current regional modeling efforts are in their infancy and their predictions should be viewed with healthy scepticism. Climate modeling will improve greatly over the next ten years with improvements in high-speed computing and a better understanding of the labyrinth of factors that affect climate.

John is less concerned with computational power than with the lack of a complete understanding of the complex feedback systems that control climate. Climatologists are making progress in understanding and modeling feedback, but John thinks there will be surprises—some processes that produce negative and positive feedbacks have not yet been recognized. His message is that modeling will continue to improve, leading to more reliable predictive models and better forecasts, but we’re not there yet. In the case of northern BC, better models will help advance our understanding of potential impacts of climate change on the landscape, but we must be prepared to revise our thinking as climate science improves.

John’s presentation was based on the premise that climate *will* change. He is not convinced, however, that northern BC will indeed have a wetter winter climate, as is currently predicted; but if that happens, there will be an impact on the landscape and the processes that act on it. The stability of the landscape is very much in equilibrium with the present climate.

If precipitation were to increase by 5% to 10%, there will be a large increase in the number of landslides in northern BC. Precipitation factors include:

- Seasonality—even if there is no net increase in precipitation, a greater proportion of precipitation may fall as rain, or more rain may fall on snow.
- Intensity and duration of precipitation—these factors are closely linked to landslides. Landslides are frequent when a certain intensity threshold is passed. If, in a new climate

regime, the intensity of precipitation has increased, there could be more frequent landslides.

- Antecedent conditions—Is the soil saturated? Has there been a lengthy period of rainfall prior to failure? Has the stability of the slope slowly decreased to the point where an insignificant trigger induces failure?
- Shifting storm tracks—if ocean circulation changes in the North Pacific, storms will take different tracks across North America. We know there are regime changes in Pacific ocean-atmosphere conditions, reflected in phenomena like the Pacific Decadal Oscillation (PDO) and El Niño (ENSO), where a threshold is crossed and climate abruptly changes. There are a whole variety of atmosphere-ocean interactions that are not well understood that could have an impact on climate throughout BC, including the north.

Some types of landslides respond very quickly to precipitation. Debris slides, debris flows, and rock falls are commonly triggered by single storms that persist for only hours, or a day or two at most. These landslides have shallow failure planes—a thin layer of rock or soil fails and then moves down slope. A rock fall, for example, is a landslide in which a small rock mass becomes detached from a very steep slope and bounds downward. Rockfalls are a potential hazard to people and property in many parts of BC, and can also adversely impact forest roads. Debris flows, which are water-saturated masses of flowing sediment or rock debris, are a big problem for the forest industry because of their impact on roads and because they alienate land from forest production. John showed several examples of these types of landslides and their impacts on forests and streams.

Rock avalanches are large, rapidly moving landslides that exhibit a flowing type of motion and travel long distances from their sources. They are far less common, but potentially much more destructive, than rockfalls and debris flows.

There are also delayed responses of slopes to increases in precipitation. Large landslides may occur months or years after periods of heavy rainfall. We are seeing a lot of large landslides in northern BC, which makes us wonder if there might be a long-term climatic control on their occurrence.

Delayed responses also include increased sediment delivery to alluvial fans, which could potentially trigger failures of fan deltas. John showed an example from Troitsa Lake where, in 1999, a portion of a delta slumped into the lake, triggering a small tsunami.

Climate change can also produce changes in river regimes. If glaciers continue to retreat as they have over the last century, the supply of sediment to mountain rivers will change. This may cause changes in the forms of rivers, which in turn can affect aquatic ecosystems, fisheries, and riparian vegetation.

Future changes in temperature can also impact the landscape. Part of northern BC is in the zone of discontinuous permafrost, and this permafrost may be melting under a warming climate. Melting of ground ice can trigger landslides on slopes that have been stable for centuries. In areas that are being developed, such as Fort Nelson, this issue must be considered because ground that is now frozen and stable may not be in another decade or two.

There is also permafrost at high elevations in northern BC. If permafrost in our mountains were to melt—and this is a big concern in Europe—some slopes could fail. The 2002 Zymoetz landslide near Terrace initiated on a high mountain slope that probably is underlain by melting ground ice. The slide severed a natural gas pipeline in the valley below its source, with an economic impact of \$10-27 million dollars. The North has a low population density, but its threads of critical infrastructure, including highways and pipelines, are at risk from landslides.

So much ice and snow have been lost in high mountains due to climate warming over the last century that steep slopes formerly buttressed by glaciers have failed. Another concern with melting glaciers is the potential for outburst floods from ice-dammed lakes.

Data and research needs include:

- Re-establish climate and hydrometric stations (climate data are a critical resource for understanding climate change).
- Study connection between modern landslide activity and climate using meteorological data.
- Study the role of decay of mountain permafrost on catastrophic landslides.
- Study mountain slope deformation—are movement rates increasing?
- Link historic and prehistoric landslide frequencies and magnitudes to past climate

Questions:

Q: Will we see changes in the landscape in the future with changes in temperature alone? Will they be compounded by changes in precipitation?

A: Warming alone will affect permafrost - the zone of discontinuous permafrost is discontinuous for a reason. It's in equilibrium with the climate, so it takes very little warming to cause it to disappear from an area and migrate north. A large chunk of north-eastern BC can, with very minor warming, lose its permafrost, with a potential huge impact on slope stability. There is a lot of instability in the area now that may be driven by changes in the permafrost regime. Potential increased instability should be considered in planning of pipeline infrastructure, forestry operations, and so on. An increase in annual or summer precipitation will aggravate this problem.

Q: What is the contribution of glaciers to Fraser River flow?

A: Glaciers contribute substantially to Fraser River flow in summer, but probably less than the contribution of glacier and snow melt to the flows of Prairie rivers. The summer flows of the Saskatchewan and Athabasca Rivers are dominated by melt of snow and ice in the Rockies. A decrease in the flows of these rivers due to shrinkage and disappearance of glaciers would have negative effects on agriculture and livestock.

9. Impacts of Climate Change on Biological Systems in Northern BC

Chair: Ben Kangasniemi

Biological Response to Increased Temperatures in Aquatic Systems of Northern BC

Ellen Petticrew
University of Northern BC

Abstract:

As current models of climate change for northern British Columbia indicate increased air temperatures, the impact of these changes on the biological components of aquatic systems need to be evaluated. Habitat conditions for shoreline weeds, floating algae, and cold and warm water fishes will potentially be altered. While direct changes to the water temperature of lakes, rivers, and wetlands could modify both species composition and distribution, more subtle changes may come about as a result of the linkages between terrestrial and aquatic systems. In providing some examples, the thermal structure of lake systems was introduced along with predictions of how organisms will respond to increased temperatures. As well, examples of landscape (watershed) disturbances associated with climate change and how they link back to biological responses in rivers and lakes were presented.

Full Presentation:

The material presented by Ellen focused on aquatic systems, including rivers (fast flowing water), lakes (slow flowing water), and wetlands (transitional water bodies). She emphasized that when we look at aquatic systems we really can't separate out the terrestrial component from what's going on in aquatic systems, because the terrestrial component affects such things as sediment delivery, organic matter delivery, landslides, and stream flows.

Assuming a rise in air temperature of 1.1°-1.7° C in northern BC, what impacts will be seen in aquatic ecosystems? Examples will be provided from different rivers and lake systems, but because we don't have a lot of information from northern BC, we're going to be looking at information from some other parts of Canada as well. One of the individuals who have done a lot of work in terms of climate change and aquatic systems is Dr. David Schindler—he is one of the best known Canadian aquatic ecologists. He works on the effects of changes in the boreal forest, and has spent a lot of time (20-30 years) working in the Experimental Lakes Area of northern Ontario sampling a series of lakes that the federal government manages. Dr. Schindler spoke to the Canadian Society of Limnology and Fisheries in 2001 with the message that climate warming will adversely affect both water quality and quantity.

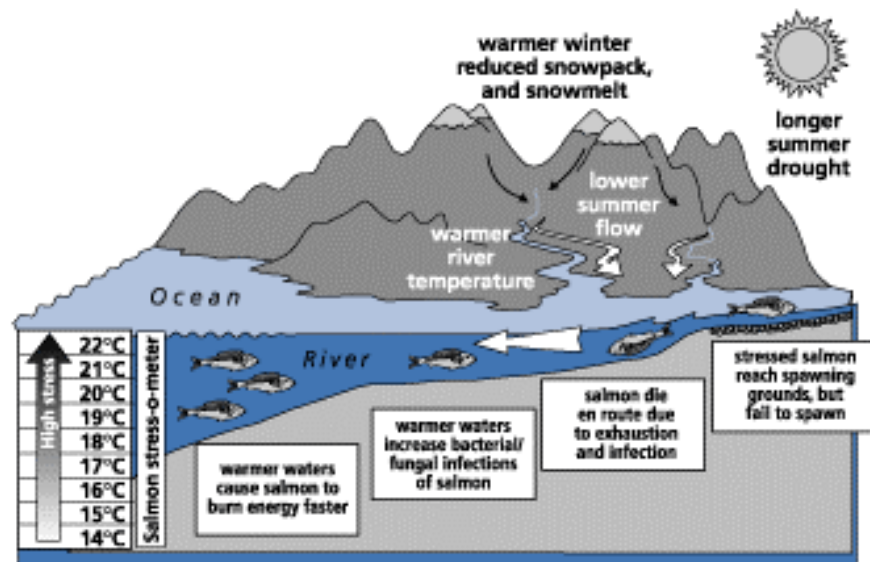
Ellen showed a map of the region around Fort St. James, and noted that as individuals who use lakes for recreation the first thing we generally acknowledge about them is their surface areas. When we consider the effects of any type of change on lakes, both large and small, we need to consider not only surface area, but also water volume and how the lake behaves.

Lakes are receptors of a lot of material that is being transported from its watershed, both inorganic and organic. The type of material will affect lake functioning in terms of light penetration and nutrients available for growth. Lakes can also provide a proxy record of climate through sediment cores (showing pollen counts, diatom communities, and other information) that can be used to identify changes and trends.

When we look at the expected aquatic species response to increased temperature, there are three major aspects to consider:

- Change in timing—any organism which is responding to a certain amount of heating or is being triggered by a certain temperature in which it is able to do its activities (migration, spawning, health at spawning, length of time it takes eggs to incubate in gravel). Also the timing of different reproductive aspects.
- Change in range of occurrence—moving toward warmth, both poleward and higher elevations, this may result in a change in the distribution and types of species in an area (composition and distribution potentially changing)
- Change in morphology—body size, coloration

As an example, Ellen showed a picture of good spawning habitat for Chinook salmon in the Nechako River. If flows drop in spawning season, there would then be less available spawning habitat at this spot because more area would be exposed as gravel bars.



The diagram above, from the MWLAP report *Indicators of Climate Change for British Columbia 2002*, shows the effects of warming on migrating sockeye salmon. Water temperatures of around 20°C become quite dangerous for sockeye—at this threshold they are quite stressed. If they are travelling in warmer waters (and they can travel up to 1,300 km in the Fraser system), they are undergoing stress for long periods of time. Salmon burn fat faster at higher temperatures and warm water also promotes the development of bacterial and fungal infections, so that the salmon may die en route or may not be able to spawn once they arrive at their spawning grounds. Timing is also important—the salmon start to return to their spawning grounds in late July through

August or September, and this also the time when we are seeing lower flows. Also over the past 45 years, temperatures in the Fraser River have been getting higher. The average summer temperature hasn't gone up a lot ($\sim 1^{\circ}\text{C}$) but this is still stressful to the fish.

When we are concerned about organisms living in lake systems and the implications of climate change to lakes, we need to pay attention to how lakes divide into different compartments in terms of heating. Lakes divide into an epilimnion (surface water) and a hypolimnion (bottom water). The boundary between the two is called the thermocline. In the summer, a lake receives its heat energy from the sun, and that solar radiation is attenuated quite quickly to heat the top portion of the lake. In this area the summer epilimnion (top layer) temperatures can be between 15° and 20°C , as about 50% of the incoming solar radiation is absorbed in these surface waters. The hypolimnion (bottom layer) in deep lakes can stay quite cool ($\sim 5^{\circ}\text{-}10^{\circ}\text{C}$). Since warm water is less dense than cold water, the two layers don't mix, particularly in deep bodies of water. In shallow lakes summer wind events can deliver enough energy to mix these two layers, but in most deep lakes they will stay as two separate bodies of water in the summertime.

In assessing the effects of changing temperature on lake functioning we need to consider the volume of the epilimnion relative to the volume of the hypolimnion. If we consider two lakes that have different surface areas what we're doing is potentially changing the heating and increasing the depth or the volume of the epilimnion in both systems. Higher temperatures can increase epilimnion volume, and this is the area of primary production as it receives the light, the heat, and a lot of nutrients coming from the landscape. The nearshore shallow water and the warmer surface waters (epilimnion) is the area where primary productivity either in the form of rooted aquatic plants (weeds in the shoreline) or phytoplankton (blooming algae) is occurring. Cold water fishes appreciate the hypolimnion, while warm water fishes like the surface waters, and so we have compartmentalization—different organisms in these lake compartments.

Another thing that's important to recognize in a lake environment is that when we have stratification that occurs in the summer, what we have then are the two parts of the lake acting separately, and we have high productivity occurring in the surface layer. We need wind energy to make these two different parts combine, and that happens when the lake surface cools in the autumn and the lake becomes a uniform temperature when the wind becomes sufficient to mix the layers. This is called turnover, and essentially the nutrients are then shared between all portions of the lake. This is important in terms of the amount of nutrients available for the whole lake. In this part of the world—the temperate part of the world—this turnover happens twice a year (in the fall and in the spring). What has been changing or may potentially be changing is the fact that if we have a higher incidence of fires because of warmer temperatures in this part of the world, and/or if harvesting takes place which modifies the riparian zone around the lake, this changes the exposure of the surface area for some of these smaller lakes. This means the wind is now able to generate full lake mixing, resulting in earlier turnover or turnover with less wind energy.

Ellen showed a graph of various environmental variables for a 20-year study of one lake in northern Ontario conducted by David Schindler, noting that it is very unusual to have this type of record for a whole lake. Average annual temperatures in the region of these Ontario lakes are similar to here—about 2.5°C while Prince George is about 4°C .

Schindler's data show that air temperature and lake temperature have both increased, while snow depth decreased. The number of ice free days increased, and this longer open water period means there is a longer period of time for primary production to occur in the surface zone and a longer time for the epilimnion to develop. The depth of the thermocline increased (2.5 metres over the 20-year period), while runoff decreased. The implication of decreased runoff is that the flushing rate of the lake has decreased, in other words, it takes a longer time to flush that lake and it will retain more nutrients which will result in higher productivity in this lake system. Thus the biological structure in this lake is changing as a function of warming. Also major ions, water clarity, and algae increased. As the area experienced forest fires during this period, it is hard to separate the effects of fire and climate change, but this may not be necessary as warmer climates in the Prince George region are likely to be associated with increased fire incidence.

Changes in temperature and runoff amounts have implications for lake shorelines and wetland areas. While slopes on many lakes can be quite steep near the shore, in the bay areas—the wetlands—they have very shallow slopes and an accumulation of sediment and organic materials coming in from the watershed. With changes in runoff, there will be changing water levels resulting in changing plant species as well as potential contaminant storage. Since wetlands provide good habitat for different organisms, the implications of contaminant storage and changing plant species has a feedback effect on the types of wildlife (e.g., ducks) who use those wetlands.

It is difficult to disentangle some of the effects of climate change from the other anthropogenic activities that we've imposed on lakes. What we see is that the combination of changing flows—which now don't deliver as much in terms of reduced runoff and a longer snow free period—means there is potentially less dissolved organic carbon (DOC) coming in to the system. DOC acts as a natural sunscreen for aquatic systems, such that the reduction in organic carbon combined with changing ultraviolet penetration due to ozone depletion can result in quite deleterious effects on phytoplankton—the primary producers in the lake.

Questions:

Q: Would changes in DOC and acidification happen in all kinds of watersheds, or only watersheds with certain rocks/soils?

A: It could be a combination of things. The delivery of DOC is what people are worried about. How much DOC is coming in, and how long the lake retains it (retention and processing in the lake). The delivery of DOC from the watershed to the lake is going to be impaired. The lake will have adapted to existing conditions, but if processes in the watershed change, the lake will have new conditions.

Q: Independent of base geology and soils?

A: Geology and soils will affect in-lake processes (how the lake modifies DOC), as they determine much about lake chemistry. But as there is not a wide range of variability throughout BC in the concentrations of DOC in the runoff from the watershed, what is more important is the total amount the lake receives (its annual load) and how long it is retained in the lake (related to

flushing rates). Both of these relate back to changes in the amounts of runoff, which is likely to be affected by climate change.

Q: Does the riparian zone have an effect on Fraser River temperatures?

A: For the main channel, shading would play a less significant role (scale of shading vs. summer temperature); it would be more significant in providing cover for nearshore habitat, and stabilizing banks. In a smaller system, it would play a greater role.

Climate Change and Forest Ecosystems in BC

Dave Spittlehouse
Research Branch
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Abstract:

The trend toward a warmer and possibly wetter environment means that species ranges may move northward and upward in elevation. The earliest responses will be seen at the edge of species ranges, particularly those controlled by the summer water supply. There may be increases in the productivity of northern forests. Disturbances such as fire, insects, and disease are expected to increase in areas where changing climate is stressing the vegetation. This could result in an increase in the need for salvage logging of disturbed stands. Warmer winters will reduce the length of the winter logging season and increases in precipitation could increase the cost of managing water flow and road maintenance. Adaptive actions, based on current forest practices, can be taken to be ready to manage some of the impacts of climate change.

Full presentation:

Dave gave a brief overview of some of the potential changes to ecosystems in BC that we might see through global warming, and finished up discussing what we may or may not be able to do to address those changes. He focused on the large scale, because of the current uncertainty in projections of future climate and a limited knowledge of responses.

Some of the possible future climate changes in BC include:

- Warmer conditions—greater warming in the winter particularly in northern BC
- Increased precipitation in fall and winter
- Spring and summer could be wetter or drier
- Changes increase through the century

Potential changes in forest climate include an increase in temperature, while precipitation change depends on the season. Carbon dioxide (CO₂) levels will increase, but trees may not be able to take advantage of this to improve growth because of acclimation and limiting factors such as nutrient availability. Snow pack is likely to decline in the longer term, although it may remain stable in the short term if precipitation increases offset temperature increases. A longer snow-free season is going to be critical in a number of forestry-related contexts. The growing season will increase but an increase in moisture stress could limit plants taking advantage of the longer growing season.

Factors controlling forest response to climate change include:

- rate and amount of climate change
- species vulnerability—factors affecting this include distribution (where are they on the landscape, are they able to move anywhere, are they isolated); climate tolerance (can they handle a wide range of climate and still survive or are they sensitive to small changes);

habitat needs (climate change will change habitat quantity and quality, not just for animals like deer and elk but also the quality and quantity of material that bugs eat); fecundity (how fast and how well do they breed); and life span (species with a short lifespan will keep breeding and adjusting, for example, squirrels in the Yukon are now breeding earlier to take advantage of an earlier food supply).

- Frequency and size of disturbance—fire, disease, insects.
- Regenerating versus established stands—these may respond differently
- Barriers to movement—could inhibit species moving as the climate changes.

There are several possible responses to climate change in BC's forest ecosystems. There could be an increase in the potential for fire occurrence and intensity, especially more and earlier spring fires.

There could also be an increase in the potential for insects and disease. We've seen what climate variability has done with the bark beetle. It's something we have to deal with now—it's not as though we didn't have to deal with it before. The leader weevil hazard in white spruce could increase dramatically with a 2°C warming—the weevil's growth in the leader is dependent on temperature. This means that the area where it could be a problem could be greater, and this requires changes to management, increased cost of protection, and may also affect timber supply in the long term. The weevil doesn't always kill the tree, but it slows the rate of the tree's growth.

Species will respond differently to a changing climate and there will be changes in the species composition of ecosystems. It's the rate of climate change that is important—whether it is a step change or a slow drift. Once established, forests are quite resilient, so it will be disturbances 30 or 50 or 70 years in the future when the “shock to the system” occurs and we will find out then whether forests can adjust or not.

Alpine ecosystems may experience a shorter winter season and shallower snowpacks. However, lack of soils will limit tree encroachment into alpine areas. Slow regeneration and growth rates will limit the speed of encroachment of trees into alpine parklands.

In northern forests, warmer temperatures and a longer growing season will likely lead to an increase in productivity, at least in the near term. Although there will also be increases in respiration offsetting increases in photosynthesis, and an increase in the ability of things that eat the trees to grow, Dave generally expects a productivity increase in these forests. He gave an example of research in North Saskatchewan where researchers measured the annual flux of CO₂ in aspen. 1998 was a warm, El Niño year, and growth started one month earlier, and even with dry conditions later in the season there was a big increase in CO₂ uptake. But on the coast, in a 55 year old Douglas fir stand, CO₂ uptake was reduced in 1998 because respiration more than offset any increase in photosynthesis. There are now some of these flux measurement sites over conifers in northern ecosystems, so hopefully when they get a longer continuous record we will get a better idea of how these forests will respond to climate change. Productivity increases, however, could be offset by potential fire increases in northern regions.

Interior wet-belt forests may also see a productivity increase in the near term, as well as an increase in fire disturbance. There will likely be earlier peak flows in streams, and lower summer flows. In interior cedar-hemlock, there may be understory shifts. For Engelmann spruce, subalpine fir, and subboreal spruce there will be a trade-off between moisture availability and warming, so we may or may not see many changes. These species are not likely to be pushed out of the temperature range where they can grow. The key in this area will be disturbances and what comes in after them.

In coastal forests, there will likely be no net gains in growth, although there may be reduced productivity at low elevations and increased growth at mid-elevations. It rains a lot, so an increase in winter precipitation won't make much difference to tree growth, although there would be an increase in winter stream flow. There will be an increase in summer moisture stress if predicted reductions in summer precipitation occur. Hemlock grows over a very wide range so some warming won't be too bad. Coastal Douglas fir is at the northern end of its range, so Douglas fir may move northward and upward in elevation depending on how much winter snow damage it suffers.

There is likely to be a bigger change in interior drybelt forests in response to increased moisture stress, and increased disturbance by fire. This could lead to more pine ecosystems and an expansion of the areas of grasslands, as well as increased difficulty for forest regeneration.

Wetlands are affected by the timing of moisture availability (i.e., earlier spring melts, evaporation timing) —so you would have to look at a specific system and see what's really driving the water supply of that system in trying to determine how much of a change there might be.

Overall, a 1997 study suggests that birds and ungulates are likely to gain habitat, while fish are likely to lose habitat.

Forest operations are an integral part of forests and forest communities. If we're getting less snow, and it is warmer in the winter, this will restrict winter logging. There may or may not be some productivity increase. More disturbances may lead to earlier harvests, smaller logs to mill, and also more salvage logs. The government will need to think about charging more for salvage logs if they become a large part of the timber supply.

There is also a concern about the effect of more fires on communities. The government is cutting back on costs, and we're already at the limit of our ability to deal with fires, so any increase will make it worse. We'll have to do more targeting of our resources, and where we fight fires. Maintenance of haul roads and other infrastructure may also be affected. If there is more rain there may be more slides or more sediment runoff, and companies may have to consider improved stabilisation of road surfaces.

So what do we do about it? Forests are going to adapt to whatever climatic conditions eventually occur—called “autonomous adaptation” in the technical literature on adaptation. Society will to some degree have to adapt to or accept what comes—in terms of forestry this means society would be dealing with whatever forests we have for our timber supply and recreation. In some

situations, although it won't be many, society may be able to influence the direction and timing of adaptation—so-called “planned adaptation.” Planned adaptation will mostly apply to commercial tree species or commercially interesting wildlife—for example, after harvesting you might replant a different species or change the provenance to a more appropriate variety. But change is going to happen over the whole land base, so a lot of the adaptation will be autonomous.

Planned adaptation will include strategies and plans to address future problems—this is a risk management issue and we need to think of it as that. Many of the necessary adaptive actions are already part of sustainable forest management. For example, provenance trials to evaluate the capabilities of species from different climatic regimes need to continue so that we can select provenances appropriate for the new climate of an area. Designing fire smart landscapes—landscapes that are less susceptible to large fires through interspersing less and more flammable material over the landscape—will be important. We could also address stand management through sanitation thinning.

Maintaining biodiversity and parks and conservation are areas where we are going to have difficulty doing any intervention. We will have to reassess our approach to conservation. Values and attributes that a park or wilderness area is designed to protect may not exist in 50 to 100 years. For example, we may have to find other ways to preserve the Vancouver Island marmot—perhaps in special refugia or an artificial environment.

All of this is just a part of reassessing our idea of sustainable forest management. Adapting to climate change in forestry involves putting a climate change adaptation focus into management plans. Because the timber harvesting land base is extensive we will likely focus much of our effort on the intensively managed areas.

In conclusion, over the next 50 years, moisture availability will be the critical factor. We will likely see disturbance increases—fire, insects, and disease. The forests in BC are generally getting older so the trees are naturally becoming more susceptible to disturbance. When warming and moisture stresses are added, the potential for disturbance is greater. There is likely to be an increase in forest productivity in some areas though this will coincide with a predicted increase in the global timber supply. Other changes are likely to be responses of species at the edges of their ranges, changes in community composition, and an earlier start to the snowmelt season.

Questions:

Q: In the south-western Yukon, some forests are not very resilient; the spruce bark beetle outbreak has caused 70% mortality in some stands. Maybe due to added drought, the regeneration is not there. There is speculation that this may move to a shrub ecosystem, also after burns. Are some forest types not so resilient? Moisture is important.

A: What is the time frame? It depends on when disturbance occurs, that is, it is unfortunate that those forests were disturbed now when it is so dry. Climax ecosystems are not necessarily always the same in a given place; it might be different under different circumstances. All of these forest emerged during the Little Ice Age. The problem in forest management is that we're fixated on the forests here now, and not thinking about change.

Q: Moisture? Will we see more droughts or less?

A: We don't know, there may be a different frequency. There is a suggestion that with warming there will be a transpiration increase from trees, but this may not necessarily be true.



10. Sensitivity and Adaptation to Climate Change: Perspectives of Industry and Communities

Chair: Stewart Cohen

Introduction

Stewart Cohen

Institute for Resources, Environment, and Sustainability, University of British Columbia
Adaptation & Impacts Research Group, Environment Canada

Stewart pointed out that he has had some experience working in the area of climate change and adaptation, in particular on the Mackenzie Basin Impact Study—a 7-year effort funded by the Green Plan. That was an opportunity to do a major research project around climate impacts and adaptation. Stewart is hoping that C-CIARN activities will be a chance to renew those kinds of efforts at team-building, and create new opportunities to understand some of the complex issues that climate change will lead to. It's in that spirit that he is very pleased to be here to chair this session on climate change impacts for industry and communities, and he expressed his sincere thanks to the speakers who agreed to participate.

Before introducing the first speaker, Stewart made some remarks about the challenge of addressing climate change impacts in industry and communities:

We've heard this morning about what climate science can tell us about future climate change, and what biological and physical scientists can glean from such changes in terms of impacts on water and landscapes and ecosystems. The next step would be to consider how these impacts would affect industry and communities in what might be called a “what if?” exercise. There are uncertainties in our knowledge of future climate change, and future biophysical impacts, but we know enough to begin the process of constructing a plausible, or several plausible, scenarios of such impacts.

The “what if?” question can then lead to some other very interesting questions. What difference would these scenarios make to industry and communities? Does this matter to them? In what ways are industry and communities sensitive or vulnerable to such changes? How can this “what if” be incorporated in the planning, management, and dialogue about the future?

There will be many dimensions to impact scenarios. A change in hydrology could alter utility operations, while unstable permafrost and shorter, wetter winters could affect winter road systems, mines, and pipelines. Changing seasonal characteristics of climate could alter ecosystem cycles, growing seasons, fire and pest risk, and wildlife patterns, with implications for agriculture, for forestry, for parks, and for First Nations. And all this would happen at the same time, at the same place, at varying rates of change.

This means that adapting to this kind of multilayered scenario could be quite complicated. I liken this to a very large onion. You're going to have a lot of layers to peel off, and each of those layers is going to reveal something else to you. Certainly this will be a technical challenge for

scientists, for engineers, and for resource harvesters, but it is also going to be an economic challenge, an institutional one, a social one, and a managerial one—it might even be a legal one. And all this at a time when markets, technology, and population are also changing. It's a daunting task, but in my view it is not impossible.

So I'm hoping that this afternoon's session and the breakout discussions that follow will be the start of a dialogue with researchers and with people who have important local knowledge and a stake in the region. They have this local knowledge through their businesses, through their communities, and through their history. We're not here because we have the answers; we're here because we have questions. And so I hope that through this kind of an event, and hopefully future ones that C-CIARN BC and the rest of the C-CIARN network will have, we can define the adaptation challenge for industries and communities in northern BC, and maybe take the first steps towards coming up with some concrete ideas for some new studies that might lead to options for northern BC to respond effectively to climate change.

Climate Change in British Columbia and how it may Impact the Upstream Oil and Gas Industry

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BC Oil and Gas Commission (OGC)
Fort St. John

First it might be appropriate to define what is meant by the term “upstream” portion of the oil and gas industry. Upstream usually refers to that portion of the oil and gas industry located above, or upstream of refining, distribution and transmission facilities. This would include all drilling production facilities, battery storage facilities, collection, testing and flaring.

I'd like to describe some possible events or impacts to the upstream oil and gas industry as they may occur with a changing climate. Climate change could occur by moving towards extremes, or may be a moderating change to present weather patterns. Some scenarios could include a colder, or milder winters, warmer and drier or, cool and moist summers.

Demand:

Assuming a constant population, a warming trend over the winter months in the northern climates could result in a decrease in demand for heating fuels or possibly a levelling off in demand. Conversely, in southern climates the warming trend may result in an increase in cooling demands in summer months for air conditioning and refrigeration. This could result in an increase in the demand for thermal electric generation, increasing demands for such fuels as thermal coal, or natural gas.

Operations:

Due to the nature of the muskeg soils in the oil patch, particularly north of Ft. St. John and around Fort Nelson, access for operations such as exploration and production drilling is generally limited to a 12-week window during the winter months, from mid-December through to mid-

March. Winter construction allows for near zero impact to soils disturbances, easy access and construction conditions and is the preferred option for these soils.

Operations consist of four phases:

- i.) Seismic activities, to identify the formation.
- ii.) Drilling, which includes road/lease builders and well completions.
- iii.) Construction, which is the installation of gathering lines and group sales lines.
- iv.) Production facilities and gathering systems.

The traditional method of operations was to carry out seismic activities the first year and follow up with drilling, construction, and production the following year. Oil companies have been increasing demands and now frequently carry out all operations in one year.

To further compound the situation, the increased pressure and demands from companies is further aggravated by what appears to be becoming a shorter window of operation. A scenario could now develop where there is more and more equipment and people moving around, leading to a very intense work season. An increasingly intense work season also brings into question the quality of work being carried out, and increased risk of error and potential of mistakes being made. This could raise health and safety issues.

Milder Winter:

A milder winter, as has been the case in recent years, leads to a reduction in the length of the drilling/construction window on muskeg soils. This year the window was only 8 weeks—the rigs didn't get out there until the middle of January. This in turn would result in reduction in production. To offset this change, temporary matted roads and drilling platforms would have to be constructed from mats to gain access. These mats are 12'x8' and constructed of hardwoods like oak, aspen, or some other strong hardwood, or constructed of plastic, and are placed interlocking on top of each other in layers of two or three deep. Depending on actual circumstances, the present economical distance for construction of temporary access and platforms using these mats is 2 kilometres.

A cold winter is also helpful when dealing with willows when constructing access. Willows are a real problem when constructing access as they are extremely flexible and stringy, however under extreme cold conditions (-30°C) they become extremely brittle and are easily snapped off with light equipment during the initial construction of access.

Milder winters also present the possibility of longer and moister springs, impacting both winter and summer drilling. A decrease in winter drilling will place more demands on summer drilling and summer associated impacts.

There is also a concern over a potential lack of snow needed for winter roads, etc.

Summer Drilling:

Moist Cool Conditions:

Summer drilling can be impacted as a result of longer moisture springs, which will affect trafficability and stability of access. Soil types on the east side of the Rocky Mountains are generally much finer than those in the rest of the Province. An increase in the length of the spring thaw could result in extended road closures/restrictions. Increased precipitation during the summer months could result in additional road restrictions to those normally issued during the spring break-up. Additional costs may result with increased maintenance to access roads, or constructing roads to higher standards to ensure long term stability, which further hinders oil and gas development.

A moist cool summer will result in higher than normal water tables in the muskeg. The use of tracked equipment in areas of muskeg will not be allowed by the OGC, due to the impact on the surface and on the permafrost layer.

Warm Dry Conditions:

On mineral soils, warm dry conditions would likely result in easier construction and access to well sites due to the stability of the soils with a lower soil moisture content. In muskeg, dry conditions may also result in low water tables and an increased fire hazard, as muskeg soils are hydrophobic and can become irreversibly dry. Fires in dry muskeg can be extremely difficult to control and extinguish, and can burn for years.

Extended periods of warm weather have the potential of melting the permafrost, which would be further aggravated by fire, removing the insulation layer of the muskeg.

Reclamation and Environmental Management:

Issues around reclamation and environmental management will also be relevant to the mining industry. Depending on a cool moist, or a warm dry climate, plant species will have to be chosen which would be best adapted to the particular moisture regime.

Soil Handling:

Moist Cool Conditions:

Site preparation for drilling platforms, pipelines, and access roads may be affected by climate change. An increase in summer precipitation would likely result in an increase in soil moisture. The soil structure of the fine textured soils on the east side of the Rocky Mountains is easily degraded, or lost through manipulation and movement during conditions of excess soil moisture content. Poor trafficability would make seedbed preparation extremely difficult, limiting the success of revegetation.

Warm Dry Conditions:

While likely less of a problem, germination may be an issue should the climate become warmer and dryer during the summer months. In areas where there was traditionally sufficient soil moisture for spring and summer germination, seedbed preparation and seeding may have to be restricted to primarily fall months. Should these fine textured soils become dry after the soil was

manipulated, or moved under conditions of high soil moisture, they could become nearly amorphous, seriously impacting seed germination and the establishment of a successful vegetative cover.

Erosion and Sediment Control:

As discussed above, seed germination and vegetation establishment may be impacted as a result of climate change. Increased difficulty in the establishment of a vegetative cover leaves the soil exposed for longer periods of time, increasing the risk of surface erosion and sedimentation into aquatic habitat. Modifying traditional methods of seeding and vegetation establishment may have to be modified to reflect the new weather patterns.

Therefore, additional attention will be required for erosion and sediment control for both dryer and moister summer seasons. The use of mulches or straw matting may have to be implemented to protect the soil surface from the erosive effects of raindrop impacts and the potential impacts of sedimentation on aquatic life. In addition, extra care would also be required to ensure there are sufficient sediment control structures in place to collect sediment from leases, as well as in ditches and intercepts, prior to discharge into any watercourse.

Wildlife:

The impacts of a changing climate on wildlife and how that will affect the upstream oil and gas industry would occur over the very long term, even centuries.

A changing climate may result in changing wildlife migratory routes and timing of migration and breeding, possibly the result of changing vegetation and feed species. As a result, drilling times and locations, and also flaring timing, may have to be adjusted to accommodate these new patterns and wildlife habits. It should be recognized that this would be very long term, on the order of hundreds of years. Wildlife would have to learn to find their traditional feed species and learn their new location and when to migrate.

Water use:

An extensive amount of water is used by the upstream oil and gas industry at well sites. Water is needed for the freezing in of winter roads, making up drilling muds (a mixture of water, colloidal clays and other additives to form viscous slurry) that are circulated in the well to lubricate, cool the bit, remove rock cuttings, prevent cave-ins, and avert blowouts of hydrocarbons. Water is also needed for concrete that has to be pumped down the well; it is used for washing the rig, and in boilers for heating equipment and buildings. A significant amount of water can be used as completion fluids for well control, or stabilization. A shallow well may be 500 metres deep and a deep well can run 5,000 metres; both absorbing the appropriate amount of fluid. As a rule of thumb, a lease will require 1 to 2 cubic metres of water for each metre of drilling.

A cool wet summer may not present a problem; however a dry warm summer—particularly extended dry conditions—could have serious implications for the oil and gas industry. There are other competing users and natural resources requiring the same water resource. These may include municipal water intakes (Dawson Creek), the agricultural/rural community, First Nations, fisheries, and aquatic requirements.

Minimum stream flows need to be maintained for fisheries purposes and to maintain other licenses on a watercourse. Low flows could seriously impact winter road construction. Increased costs may be incurred by hauling in of water for these various uses required at a well site.

Northern Alberta is already experiencing water shortages and conflicts with the various users requiring the same water resource. The OGC, at the request of Dawson Creek, will not issue Section 8 permits for water withdrawal from the Kiskatinaw watershed. This is the primary source of water for Dawson Creek and the surrounding residents.

All of this increases costs to the industry, particularly if they have to haul water.

Coal Bed Methane (CBM)

As part of bringing a CBM well into production, a significant amount of water is produced from the well. Normally this produced water is treated to meet water quality criteria and discharged to an appropriate receiving location. Decreased flows in streams could mean longer dilution zones to the point of compliance, additional treatment, or hauling produced water to a different disposal site.

Questions:

Q: What are the costs associated with these changes?

A: Up in the millions—this is very significant—a single well costs \$2-\$3 million. There are 150 new wells this year despite the shorter season (50 more than normal, an all-time record), but this is mostly because companies are opening up proven reserves.

Q: Autonomous adaptation vs. proactive/planned (look ahead and change how you do business). Do you see businesses in this industry adapting autonomously? Or will regulatory structures or investment priorities start changing?

A: As the environment changes, like any other industry the oil and gas industry will have to adapt with the changing environment and would have to have the foresight to recognize some of these changes. It is becoming a reality now in northern Alberta—the last 3 to 4 winters have been very mild.

BC Hydro & Climate Change

Stephanie Smith
Hydrologist
Generation Resource Management
BC Hydro

BC Hydro has 29 major hydroelectric projects around the province. A dozen or so are coastal projects—basically quite small, “run of the river,” although we do have some small storage associated with most of them. That is, there is some capacity to store water but it tends to fill up very quickly and run out very quickly. The dominant weather in this area is rain-driven—most of the water comes in the fall/early winter, but there is a bit of snowmelt as well. The issue in this area would be mainly with precipitation coming as rainstorms.

The other main area is in the Columbia system, where there are a number of large storage projects and hydroelectric generation projects. The main one is Mica Dam and Kinbasket Reservoir—it has multi-year storage, is winter snowpack dominated, and there is also glacier inflow. Columbia projects are also affected by the Columbia River Treaty—an international agreement with the US to provide flood protection and water storage for the Columbia River. This system could be heavily impacted by climate change with changes to snow accumulation patterns and the changes we’ve seen in glacier volumes.

In northern BC, what we’re interested in are the Peace River projects. There are two projects—the main one is Williston Reservoir which is our largest reservoir. It has multi-year storage, which means we can operate it over a number of years and that is our planning horizon. The Peace River area provides about one-third of BC Hydro’s generation capacity, and has an equal distribution of rain-dominated (summer) and snow-dominated (spring freshet) inflow. That will have an effect on how climate change will impact these two components.

Climate factors important to BC Hydro’s system include:

- Wetter winter—more rain as opposed to snow
- More extreme rain events—very important in planning for flood protection
- Rain at higher elevations—affects snowpack
- Smaller snowpacks
- Earlier spring freshets—changes when you get water and possibly how much volume you get at certain times of the year
- Reduced summer flows—an important one for BC Hydro—we have a lot of fishery resources downstream from our projects and we may have to supplement summer flows with water from our reservoirs
- Longer periods of poor air quality—with longer, drier, hotter summers this will impact our natural gas resources, for example at Burrard we have to curtail generation if air quality gets to a certain level in the lower mainland

What are the implications of these changes for BC Hydro’s system? We are already in the business of managing water resources over a broad range of flow regimes so broad scale changes

can be incorporated into the long-term planning. We already get high water years, low water years, enough water in the Peace, not enough water in the Columbia—this is what we do for our business. So that's not as much of a concern for us into the future.

What does concern us are changes to the variability, particularly in the weather. We saw last summer that in Williston we were expecting fairly close to normal inflow for the freshet and we ended up in the summer with some extremely high inflow from some large storm events that moved through in the summer, so we ended up spilling. And “spill” is a four-letter word at hydroelectric plants.

There's going to be increased variability—higher highs and lower lows—and we need to figure out how to include that into our planning. In the Columbia, if we lose the glacier input and our inflow goes down by 20% in a reservoir, we would have to build other resources to offset the lost generation, which we can do. But if we have unprecedented floods or droughts, then that could cause safety hazards or management problems. Pretty much all of our planning is based on historical data—so we expect that what's happened in the past is what's going to happen in the future—and if that's not true, we would need to figure out how to look at the past and how we would need to look at it differently for planning into the future. For example, if you want to build a spillway, you're going to look at the probable maximum flood, and that's based on historical records. If we think that the statistics around that are going to change, we need to figure out how we can incorporate those changes.

Stephanie showed a slide of the Williston Reservoir watershed. This is a huge watershed—the headwaters of the Peace River that ultimately flows into Lake Athabasca and from there into the Mackenzie drainage. There are two projects in the north—the WAC Bennett dam with 2,700 megawatts of capacity, and another 700 megawatts or so at Peace Canyon Dam downstream. Peace Canyon Dam has a small watershed area, a 3 metre operating range, and serves to regulate flows coming downstream from Bennett dam. Williston Reservoir has a watershed area of 70,000 km²; 39,500 million cubic metres of “live” storage (storage that we can draw upon, there's water below that that we don't use); an average annual inflow of 29,300 million cubic metres (less than the storage, which tells us its multi-year storage); and a 30 metre operating range. This was the ninth largest reservoir in the world, although that may not be true anymore. On a global scale this is a huge body of water. The inflow is 50% snow melt and 50% rain, but we'll be looking at that ratio starting to change.

BC Hydro did a study as part of the 1994 Mackenzie Basin study, based on a scenario of doubled carbon dioxide (CO₂) levels. Hydro has a watershed model for Williston Reservoir so we thought we'd put together the output from the global climate models with the watershed model to see what the impacts could be. This was an older generation of climate models so I'd be curious to redo this with the current models that are out there and see what the changes might be.

The climate model projected a 3.8°C increase in annual average temperature and an 11% increase in precipitation, with a 14% decrease in snowfall and a 41% increase in rainfall. With higher evaporation, some of this precipitation increase is lost, so runoff only increases by 6%. The range in runoff variation from year to year is currently greater than this 6%, so we weren't

too concerned about that. The change in timing could be significant—if we see earlier spring runoff and later freeze up, this will change when the water comes into the reservoir.

One climate model grid square is about the size of the watershed. BC Hydro used 6 grid points from the climate model, and used statistical methods to relate the model node information back to the watershed climate stations so that we could run the climate scenario through the watershed model. If we could use some of the regional models to scale that down and give us more information that might be useful. The modeling exercise was all about inflow, and our power generation is directly linked to how much inflow there is.

The other main issue for the projects in the North is the ice on the Peace River. The Peace River flows through Alberta to Lake Athabasca, and the ice begins developing up in the north end of the Peace River (downstream) and works its way back (south) towards the dam. There are problems with ice jam flood events at the town of Peace River, Alberta. To reduce the chance of flooding the town, there has been a long period of research into how we can modify the outflows from the Peace River projects to help control the development of ice as it moves up toward the town and past the town to prevent these ice jams from forming.

What we currently do is limit outflow from Peace Canyon during freeze-up and break-up when the ice front is moving through the town of Peace River. Control flow starts when the ice front nears town (10 miles downstream of Peace River because it takes a couple of days for water to make it from Peace Canyon to the town), and ends when the ice is upstream from Dunvegan. We maintain a steady flow as the ice develops, such that the river level at the town does not exceed a threshold value. BC Hydro will maintain the reduced outflow for as long as it takes for the ice cover to consolidate upstream of Dunvegan which is usually over a 20-70 day period depending on how cold it is. Ice development is entirely related to what the air temperature is and what the flows are in the river. We can't control the air temperature but we can control the flow.

This year in particular has been a very warm winter, and the ice has been very slow in developing. We didn't go on control flow until much later than we normally would (only two weeks ago), and we're expecting that the ice may never get past Dunvegan and we will have to stay on control flow throughout the winter, until the ice starts to retreat and moves down past Peace River again.

This is not an inexpensive operation for us. Since Williston provides a large portion of BC Hydro's power, the costs are significant. We lose about 10,000 megawatt-hours (MWh) of generation per day while we're on control flow, and we could be on for 60 or 70 days. The current market value for energy is US \$40 per MWh. You can do the math, but it turns into hundreds of thousands per day. Another issue is that winter is when energy prices are highest, domestic demand is the highest, and we can't generate enough energy when we have the need for it. If we can't generate power from the north during the winter, we have to remove the water from the reservoir before the freshet comes through, so we have to generate it out in the spring. All projects have water in the spring, and prices come down. This displaces energy from a high-value time (winter) to low-value time (spring).

It also increases the risk of a spill in the summer. If water is stranded in the reservoir because we weren't able to generate it out in the winter, there will be higher reservoir levels in the spring, and if you can't generate the water out fast enough you may end up spilling it. Also, because we can't generate at Williston during the winter, we have to generate that energy from somewhere else, in particular in the Columbia, so we may have to sacrifice our reservoir levels in the Columbia to meet the electricity needs for the province. Or we may have to buy power elsewhere because we don't have enough ourselves—we may have to buy from the US at these high prices.

The main issue is the length of time we remain on control flow, but there are also issues about how long this period extends into the spring, leaving water trapped in reservoir that we can't generate out. So the climate change scenario, if we even use this year as an example, with a warmer winter we go on control flow much later, and we're expecting not to go off this year probably until early April. So I think that's a fairly major management issue for us.

Another issue concerns other users of the water in our reservoirs. We manage our reservoirs currently to try to balance the needs of all of the users and also the energy production. Impacts to any of these users would impact us if we have to manage differently under a change in climate. Stakeholder interests include:

- Recreation—we manage reservoir levels to provide recreation opportunities on the reservoir particularly during the summer, we like to have the reservoir up nice and high.
- local economy—for example, there is a lodge that operates on Kinbasket Lake, and last summer the water was far away from the lodge and they really couldn't function.
- fisheries management—particularly downstream, we want to maintain a good flow and maintain good habitat for fish downstream, so any changes to that might change how we operate.
- First Nations traditional use of resources—we are trying to maintain the quality of their resource for them, also there are First Nations communities around Williston Reservoir that rely on it for transportation as well. So fluctuating reservoir levels will affect them.

BC Hydro may have to manage flows differently for other interests impacted by climate change.

We do have a water use planning process. We have a license to operate in each of the reservoirs, and to renew our licenses we have to go through this planning process, where we bring all the stakeholders together and we all agree what we think is the best use for the water in the reservoir or the best way to manage the reservoir. We are already talking to the people around the reservoirs—it's good that we have this dialogue already so if we need to make changes in the future hopefully it will be easy because they have an understanding of our operations and we have a better understanding of what their needs are.

To speak to the research community, the following are some of BC Hydro's needs:

- Reduction in the uncertainty and clarity on variability of future climate—a scenario of what climate will look like in 2050 is not very useful for us. We have to operate right now, and I need to figure out what's going to happen this year with water supply, for example.
- Advice on how to weight past records for current water supply management—what we currently do for our forecasting procedures is take a look at what happened in the past.

We look at every single year from 1960 to 2001 and we weight them all equally, as having an equal chance of happening this year. What I need advice on is if that's not true, if we're less likely to get a year like 1960 than we are 1998, then how do we weight more recent years differently than past years? Or should we throw past years away if they aren't representative of the current hydrological regime?

- We need to keep track of what the impacts of climate change on other interests in our watersheds might be and how that may affect operations—fish, forestry, recreation
- Tools to make better operating choices—balancing climate change risks against other risks.

BC Hydro can offer expertise in watershed models for all of our watersheds, hydrology, also dam safety, geotechnical experts (i.e. landslides), and so on. We already have some modeling tools available that could take climate change scenario information and run it through watershed models like we did for the Mackenzie Basin study. Our water use planning process has a number of tools designed to help with trade-off analysis. We're just making those operational now to see if we can use them in real time to balance our energy needs and other issues in the watershed.

BC Hydro also has a lot of data. There are over 100 stations in our climatology network—some in conjunction with other collecting organizations like Water Survey Canada—with hourly precipitation, temperature, flow, and snow water equivalent from 1980 to the present. The data is available free of charge, with the caveat that there is not much quality review, the data is noisy, a lot of it is taken at high elevations, and only in watersheds of interest to Hydro. We are working at cleaning up the data to make it more usable for ourselves and then also for others. We also have an extensive ice monitoring program along the Peace River. Hydromet data and other information are available on BC Hydro's website, www.bchydro.com.

Questions:

Q: On the monitoring issue, there has been a recognition the last two days that monitoring networks are suffering a bit, and in decline, but we also recognize that hydro, highways, forestry, a number of agencies have their own networks, but the data doesn't go to a central place and the quality control and methodologies are different—do you think there's an opportunity there to bring those networks together to optimise their use for all the agencies?

A: It could be a challenge to do, for real time information there's an emergency weather net that tries to grab all that information as well as post it on the internet, so if there's a flood going on you could go and look at Ministry of Highways stations for your area for example. But to put it all into one data base and then quality control it—we can't even do our own—so unless there's somebody that wants to step forward, there's no money in it so it wouldn't be very lucrative.

Stewart: This is a research infrastructure challenge.

Impacts of Climate Change on Agriculture in Northern BC

Jim Tingle, P.Ag.

BC Ministry of Agriculture, Food, and Fisheries

Prince George

I want to tell you about the industry that's not recognized as an industry but which is the future of the area. We'll take your climate change and thrive on it. I want to talk about land, and acreage, and crops, and industries. There are opportunities in agriculture to solve your hydro problems, to solve your fisheries problems, to solve your forestry problems. In time, Prince George could be the food basket of BC. We've got the land, and we've got the capability. We just need a few more people who want to farm.

From the Cariboo northwards we have 57% of the provincial beef herd. The Cariboo and Highway 16 produce more forage than any other area of the province, including the Peace River. The Bulkley/Nechako Regional District had the largest 5-year (1996-2001) growth in cattle and calves. In the Fraser-Fort George Regional District, investment in agriculture and farm gate receipts have doubled in the last 10 years, and last year we had many new farmers come in from Alberta. We have stable forage production, we have the Agricultural Land Reserve (ALR), and we're only using about a quarter of the land designated for agriculture in crops. We also have the Farm Practices Protection Act. This protects farmers in two ways—as long as you're practicing a normal farm practice, you're protected, and the Ministry of Highways won't allow a residential development if it will negatively impact your farm. So this offers security to the agriculture industry.

So I could ask Joan Chess of the Fraser Basin Council: "What is the number one agricultural commodity in the province?" And she'd say "salmon." But number two is beef. We require a steady growth in land over time, and we've reached a point on Highway 16 where the limit to growth is pasture. Mark Yawney and others have been working on arability studies, and have "found" an additional 80,000 hectares of arable land for agriculture on Highway 16.

This is some data from John Wilson's presentation at the BC Natural Resources Seminar last November. For Class 5 clay soils capable of growing forage, like hay, the gross revenue over 100 years on 120 hectares would be \$1.71 million for pine, \$4.72 million for hay, and \$10.45 million for beef (20 year average data). That's one study—another one from the Peace River shows similar returns. Wayne Ray, on his own land in Fort Fraser, suggests an annual return per hectare of \$96 for pine, \$400 for hay, \$500 for barley grain, and \$550 for beef. These are the kind of returns that we have to get from some of the crown land designated for agriculture, but which we're having trouble releasing from the Crown. There are opportunities on the beetle wood logged lands at Fort Fraser; I'll talk a little bit more about that later.

I want to talk about two crops in the Prince George area, the one is food or vegetables, and the other one would be the beef industry. Northern Farm Products near Stoner grow 11 acres of vegetables—they have as much revenue off 11 acres of vegetables as they do off 1,100 acres of beef. They have the sweetest carrots in town, and they market them from mid-September through mid-January.

In 1968 the Experimental Farm had a test station on Foreman Flats (class 2, Fraser silt complex) and grew a wide range of vegetables and field crops, including field ripened tomatoes (a special variety selected for short seasons). There are 37,000 acres of Fraser silt soils in the Prince George area, and we're only using 182 of those for horticultural production at this time.

Crops grown last year in the Fraser Fort George Regional District include potatoes, carrots, beets, broccoli, rutabagas, cabbage, Brussels sprouts, peas, beans, raspberries, strawberries, and crab apples. With a warmer climate, you could grow field tomatoes, sweet corn, onions, and pole beans. There won't be a lot of increase in the range of crops—probably just a few of these warmer season ones. Looking at hardiness zones in Canada, if we go down just a little bit further we've reached the zone at Kersley (just south of Quesnel). We've done a lot of field corn testing at Kersley, we've got these 37,000 acres of predominantly Fraser sandy loam and Fraser silt near Prince George for agriculture, and we've got Chief Lake area soils to the North. We could be growing vegetables on a further 100,000 acres just north of town if we picked up 5 degrees in temperature.

So I thought I would take some of this data on current crop yields and extrapolate northwards with the 5 degrees. But I gave up on that because there are other limitations to why we're not growing more food in this area. At Kersley, yields for corn silage are 6-12 tons of dry matter per acre depending on the warmth of the year. In cold wet rainy years yields are 6 tons, in a nice warm year 12 tons. In 1972 we tested corn silage on Foreman Flats; we got 7.5 tons of dry matter. We tried it again in 1973 and we got just under 2 tons, with the same amount of heat. The first year the heat came in May and June, while the second year it came in July and August, so the timing of the heat is important.

For anybody who's tried to make hay around Prince George, we've got to have better weather predictions and a few days or even a little longer to grow corn at Prince George. But it would take the 5 degree change to increase corn heat units from around 1,300 at Prince George to the 1,900-2,300 at Kersley. That's the kind of increase it's going to take to move the selection of crops northward.

The maximum measured yield of alfalfa mix for hay at Vanderhoof is 8.5 tons per acre, for irrigated hay, while the average irrigated yield is around 6 tons at Kersley and Vanderhoof. Just as a matter of interest, we can produce alfalfa hay more economically in this area than they can at Kamloops, because it's too hot at Kamloops for alfalfa hay production.

In the past 35 years we have evaluated short season varieties—we've been able to grow wheat at Vanderhoof on Class 5 soils, although soil specialists here will say that's not possible; but through selection of short season varieties it is. We've modified our fertilizer recommendations—we are down to recommending 1 or 2 or 3 pounds of boron depending on soil test levels of 0.5 parts per billion. We've done a lot of work on zero tillage and I challenge the researchers here that there are opportunities to look at forage and zero till for your carbon. I'm horrified to think that on March 7th there's a carbon credit workshop coming here that wants to replant trees on farmland. We've looked at extending the grazing season—there are opportunities here with the light snowfall in November and December to graze oat swaths or

standing corn—we can lower our production costs by grazing in November and December, and there are some people doing that locally. We're also trying to improve our riparian area management—we've got "green farms" on Highway 16.

Some of the current limitations to beef industry expansion—we need more land for pasture and grazing. I saw a picture last week of a clear cut on beetle land at Fort Fraser where a one-inch snowfall covered the stumps—so why aren't we going in there and disking or rotovating it, planting grass, and there's our pasture—no replanting, no land clearing, no stumpage issues, it's just a common-sense approach. We have high stumpage on agricultural land, a lack of log sale opportunities, and a negative margin on timber harvest so there just aren't the dollars left for land clearing. Stump removal on beetle land might not be a limitation, maybe that's an opportunity. We will need a little more water for irrigation and livestock watering. But there are also opportunities there. Increasing water storage on private land might help alleviate some of those August-September flows. And with hydro transmission being separated out, there are opportunities in the Robson Valley for new hydro developments. There's a research report from the prairies about using methane gas from manure to produce hydro, and perhaps that's an opportunity for the Vanderhoof area.

So the limit is not the potential for food production or beef production, it is farmers. They're the most endangered species in Canada. In 2002 the average age of the BC farmer was 57. I was horrified when a treaty negotiator said last week that farming was a lifestyle in Prince George, but the more I think about it, maybe he was right. We have somebody that wants to grow food on market garden scale, they need about 5-7 acres, they can make a living at that, or 20 acres for field scale vegetables, but they're going to work a lot more than 35 hours a week. And what we're seeing is that farm children are moving off the farm, it's too much work. We had a really nice supper last night—a \$30 restaurant meal—and the farmer's share of that \$30 is under \$2. We're not paying enough for food. In Canada food freedom day is February 6th but it takes until July 6th to pay our taxes.

Peter Mills is an agrometeorologist at Beaverlodge Research Station who says that with 5 degrees warming, 60 million acres of land in northern Canada could be used for agriculture. Compare that to 70 million acres farmed on the prairies today.

We have all kinds of opportunities for food production in the North; it's just a matter of the will to make it work.

Questions:

Q: Has there been any work done on how much atmospheric CO₂ is taken out by sequestration in forests vs. annual hay crops?

A: I don't know and I know that we do have a lot of web site sources for that information and I haven't had a chance to look at it. But the other thing I toss out to the researchers in the room is that I believe very strongly in multiple use of the land. Our agroforester, for example, would say that perhaps 400 stems of trees plus grass for beef grazing is actually the most profitable system. There are a lot of agricultural research funds that you can access if you can get a buy-in by the farming community. Research on zero tillage at Dawson Creek on clay soil showed that we can

double soil organic matter on barley crops after ten years with zero till using Roundup and fertilizer. What can you do on perennial forage crops? There's lots of room for studies.

Art Fredeen: My research suggests that converting forests to pasture results in a loss of one-half the carbon to the atmosphere, so pasture holds about half the carbon of forest soils. There is concern on my part, I guess, about converting forests to pasture.

Q: Are there infrastructure limits to adapting to climate change in terms of farm operations, service centres, like that?

A: It depends on the type of farm. For example, we don't have a federally inspected slaughterhouse in this area so if we want to export beef products across provincial boundaries we need a federally inspected plant. Some of the local places are shipping jerky offshore, but they're bringing in inspected beef from Alberta to make the product. We do have lamb going from Prince George to the Vancouver restaurants right now; within province sale only requires Provincial inspection. We have some limits on various food products for provincial quota, for example you can't have more than 400 chickens without an egg quota, things like this. But if you have kids or know people that want to start farming, Prince George is the place to come to; we can get you started in this area. You're going to need a job with MWALP to buy that first piece of land.

Q: You think there will be a move of people from the prairies who have suffered drought?

A: We saw that last year already, we have several new farmers in Prince George who came from Alberta.

Stewart Cohen: That's an interesting question—can one place gain from somebody else's loss? Whether it's a spatial change or whether it's a sectoral change in the same place—there are equity issues that we need to talk about. I just see that as a question, I don't necessarily have the answers.

Communities

Josh Joslin
Councillor
District of Hudson's Hope

Part of being a municipality is making decisions, so what are the impacts of climate change? Some of the obvious ones are snow clearing—do you change your budget, do you change the equipment you buy, how is that going to happen, how does that work? Do you change the salt mix, or how much you put in because that depends on temperature?

Another one for us is spring runoff and flooding—if we continue to get this kind of late start to winter and then a bunch of snow toward the end and then a quick melt—last year we almost flooded out a subdivision. There are concerns about water supplies—is it going to be too dry, is that going to be a problem? So we have to look at our water supply, we have to look at filtration systems, we have to look at algae, we have to look at private wells.

We'll have to plug the car in less—that's a good thing. Much of our town is surrounded by forests (sandy soil, dry lodgepole pine) so forest fires could be a real concern especially in early spring when the chinook winds blow through and they blow hard and dry. Another thing would be dust/air quality—that could really impact us because we also have a coal bed methane issue—and that could mean a lot of roads and a lot of dust.

There are concerns about the weed season—we are in an agricultural area and if you change the climate a few degrees does that mean things will grow there that didn't grow before? Here's a funny one: believe it or not, one of the biggest problems we have is one of our biggest tourist attractions, which is deer. People come to town and say that's so cute, look at that deer, that's great. But there isn't anyone who lives in Hudson's Hope that doesn't curse the deer because they're either running into them in their cars or chasing them out of their gardens. So what kind of change might we see in the deer population?

And really that's about all I can say, I just came here to listen and learn and just throw out some things we have to think about as municipalities.

Questions:

Q: I'm just wondering of all of the things that you listed, what would be the things that you think that you need to think about now? That have longer-term implications? Because some of those things you could probably adjust from year to year as things change, but is there anything you see as maybe having a longer horizon that you would want to think about?

A: Anything around water quantity and quality, that's a big issue with municipalities. And that's also a big infrastructure cost. And that means you've got to go after money, and funding, and that takes time.

Q: Where does your drinking water come from?

A: Right now it comes mostly from the Peace River, we also have some spring water, and right now we're in the middle of a big water use study.

Q: Is it worth picking up on that topic that Jim Tingle mentioned which is the potential increased opportunity for agriculture but also noting that there's a difference in the production of irrigated versus non-irrigated, and in a scenario of a warmer climate the availability of irrigation might be actually very serious. In this "what if," this is a question of how do municipalities and irrigated agriculture share a water resource? Is the region prepared for that now, and what would it take to have that kind of infrastructure available so that you could figure this out?

A: It gets even bigger than that, because we're facing the possibility of coal bed methane development, and that was just touched on by Mr. McBride, but that requires massive water disposal, and that could have serious aquifer ramifications and so it's a huge issue.

11. Breakout Session Summary

In the afternoon, conference participants were assigned to one of three working groups. A facilitator then led each group in a 45-minute discussion focused on the following four topics:

1. Identify communities of interest (specific business sectors, for example) in northern BC that are likely to be most affected by climate change.
2. Identify communities of place (municipalities, villages, valleys, and regions, for example) in northern BC that is likely to be most affected by climate change.
3. If you were to develop an adaptation strategy (reduce vulnerability) for your business or community, what would be your next step? What information or tools would you need?
4. What organizations can meet these information needs? What role can northern BC organizations play in enhancing adaptive capacity in northern BC?

1. Communities of interest

Participants identified a wide range of industries and other sectors that may be affected by climate change. These included agroforestry, recreation, guide outfitting, fisheries, hunting, trapping, hydroelectric power generation, and municipalities (storm sewers, road maintenance, snow removal, water treatment). All of the groups identified water quality and quantity (both surface and groundwater), and the implications for communities, industry, and wildlife, as a key area of concern.

The groups identified a number of sectors that might experience both positive and negative effects, including agriculture (more warmth and extended growing season versus more and/or new pests and diseases); forestry (Douglas fir might expand its range versus the potential for more forest fires, landslides, and pests); the oil and gas industry (more demand for natural gas versus shorter operating season, etc.); air quality (less winter pollution from wood

burning versus more summer smog); and tourism (longer, warmer summer season versus loss of winter tourism activities that depend on snowpack).

For some sectors, participants suggested that most of the impacts would be negative. These included traditional land use (hunting, fishing, etc.) and grizzly bears (shorter hibernation season could lead to more human-bear conflicts and ultimately shorter lives for the bears). In other cases, participants felt that the impacts would generally be positive. These included the technology sector (boost in alternative energy development) and retirement populations (retirees might stay in the North rather than moving south, or southern retirees might move north if the South becomes too hot).

2. Communities of place

All three groups identified communities, industries, and infrastructure in areas with high landslide potential as particularly susceptible to climate change impacts. Other places that participants felt would be impacted by climate change included communities and businesses on reservoir edges (water level changes); communities in or near flood plains; communities in or near forests (forest fire concerns); and ski and snowmobile destination communities. One group suggested that communities dependent on a single resource (forestry, for example) would be more vulnerable.

Participants also identified specific regions where climate change impacts would be felt, including muskeg areas, permafrost areas, north-eastern BC (more drought potential), and the North in general because of the likelihood of greater temperature increases. The Prince George area could benefit from increased farming potential. Salmon-bearing rivers, lakes, and spawning grounds would also be impacted.

3. Next steps in developing adaptation strategies

One group suggested providing a framework that people could use to analyse the vulnerability of their specific sector or community to climate change. The framework could provide the expected range of variation that the sector or community might have to cope with, and provide a workbook and examples to allow preparation of adaptation strategies good for 20 to 40 years, as well as a way to identify what the highest priorities are.

Participants also emphasized the importance of public education and outreach in spreading the word and getting the public more involved in the adaptation process. One participant suggested that the proceedings of this workshop could be used as the basis for presentations to the public, municipalities, and others.

Because water quality and quantity are key issues, these have the potential for “no regrets” adaptation strategies such as water conservation programs. Other ideas for next steps included place-based versus sector-based land-use planning as way to incorporate concerns.

Place-specific studies (e.g., Prince George, specific ski communities) would be a useful way to get more information. Participants suggested Port Simpson (landslides) and Dawson Creek

(water supply, unstable watershed) as possible communities where such studies could be conducted. However, several participants expressed concerns about how communities might perceive implications of risk—in particular how perceptions of landscape hazards could affect real estate values.

Other information needs included studies of multiple land uses such as done by Land and Resource Management Plans, for forestry, agriculture, oil and gas sectors and other integrated studies. Participants felt that small community access to information and expertise, and the need for funding as well as information were also key issues. Participants also identified new technology grants or technology transfer, flexible government policies, and a better relationship between policymakers and stakeholders, as important to the adaptation process.

4. Organizations that can help meet information needs

Participants suggested a number of different organizations that could help to meet some of the information needs identified previously. These include stakeholders, universities, people on the land, research institutions, applied researchers, policymakers, sectoral organisations (e.g., agriculture, forestry), and stewardship groups (non-governmental organisations, clubs). Groups that could help to enhance adaptive capacity in northern BC include aboriginal groups (traditional knowledge, knowledge of place); local governments; BC cattlemen, agrologists, and resource associations; and other northern BC organisations.

12. Follow-Up Actions

Stewart Cohen

Institute for Resources, Environment, and Sustainability, University of British Columbia
Adaptation & Impacts Research Group, Environment Canada

I'm just glad to see this kind of event happen and attract people from the region. It's an opportunity to share a lot of local knowledge with those that do research but don't know nearly as much about the place as the people who live here, work here, have businesses here, and have history here. What I think I heard from this afternoon was that perhaps it is pretty easy to list potential problems—even in the short amount of time that you had there's a wide range of issues that came up and many of these problems, and the way they've been identified, could only have been identified by people who know the region well.

The question is how to choose priorities. And if we're going to move to the next step of actually picking cases—like Jenny asked—pick a case, pick a location where this would be a good candidate to organize something around—whether it's Fort Simpson or Dawson Creek or some other community. I think that's going to be the challenge for us to move to the next step: picking a good candidate case that we can collect a lot of people around, and ideas, and tools where some of the recent historical experiences are obvious, and give us a clue about where we want to learn more about what's going on.

If collectively we can figure that out, how to choose priorities, how to identify a good candidate case, then I think we can move to the next step. That is organizing a work plan around it—finding people who might be willing to participate in an exercise like that and then the network comes in and tries to find ways to get it funded. And then you’ve created a new research project that wouldn’t have happened otherwise, which meet the needs and interests of people in the region but also addresses science. So if this process gets us a little bit closer to that then I think that we’ve made a very good start.

That’s what I think that we need to figure out, is how to choose the priorities, how to choose a good case; whether Dawson Creek is the case we ought to try to run with. Do we need another day to pick that? Or do we know enough to come with a good theme idea and then have an event around that? So I’m still left toying with that, but I think we’ve got a good list on the table now and we can think about how to move this debate to next step.

Getting the message out is obviously a big part of it. And everybody here can be part of that getting the message out to people who weren’t here—people who do research, people who operate businesses, people who are involved with resource management in the region—they can become part of the dialogue. And the guidelines for adaptation and vulnerability assessments are a good idea. The challenge is translating that into something concrete. And that’s going to be part of this too. A good start, I’ve learned a lot, I appreciate everybody’s participation.

Jenny Fraser
Ministry of Water, Land, and Air Protection

I have similar things to say. First, we conceived of this workshop as the beginning of a dialogue—that is, our first opportunity to meet face-to-face some of the people who are living and working in this region and who have real, special knowledge of it. We can only do so much by e-mail and the telephone. When we can actually meet, and have an opportunity to have a little bit of conversation over coffee and food and so on, things start to happen. I certainly feel that I’ve made a couple of really useful connections in terms of people that I might be able to work on projects down the road with, and people that I can provide information and support to.

The second point is that because the impacts of climate change are so place-specific, and every place is different, we need to really focus in on specific geographical areas in order to be able to make sense of it and think about how to adapt. And so I would echo Stewart’s interest in trying to identify a place or maybe perhaps several places in northern British Columbia that we could gather some people together to look at in-depth—because ultimately what’s needed is that deeper knowledge of the way that place might be vulnerable to climate change and it’s out of that knowledge that we can start to think of how to develop adaptation strategies. But it’s really hard to do in the abstract; we really need a specific place in order to do it. My vision is that once you start having these place-specific case studies you might be able to generalize and to get that knowledge out to other places and help them think about adaptation.

Stewart: Doing a study of place has a great advantage over just doing studies of things, we need the expertise about the things (water, so on), but place combines all the things, and what people want out of a place may or may not create new conflicts—so every place is trying to satisfy the objectives of many different interests, and when you study place then you begin to attack that. I like the idea of building teams to do that, and I’ve heard the comment made by other people that you have to find ways to build teams and get some integration.

Maybe by identifying a candidate place it may be easier to collect teams around it , and also to find someone that is willing to champion the team-building process in that place because that person would know the place well and would know the players that have knowledge and inside information. The network can then back them up with other people that might have knowledge that is needed. But looking at how to build that kind of team is another part of the challenge.

Jenny: I’m actually wondering if out of this meeting we might have a few volunteers that would at least like to have a conference call or two to talk about a possible place?

Participant: We have to be careful; people are very sensitive to things that would say this is a high-risk area. It’s a good exercise but there are certain aspects of concern.

Stewart: In talking about identifying case studies, I would hate to think that the moment a case study is identified people will think “uh oh we’ve got to get out of here” because the only reason we’re going to study this place is because there’s danger signs all over. But that’s really not the point. We’re not so clairvoyant already that we know where the danger is and every place will have some vulnerabilities and we just want to learn what they are. And we do it in a “what if?” context, because the uncertainties prevent us collectively from having really firm predictions of climate change, but “what if?” can allow us to put that aside a little and learn about what the potential issues are. There may be some short term strategies arising out of the process that may resolve some short-term problems. If we can identify a case without raising fear that this case was chosen because we know already that for sure that there’s big problems—I think it’s a communication issue—we’ve got to be really careful about how we communicate why this particular place might be a candidate.

Participant: There’s also a need to be sensitive to, or work with, other existing or new initiatives.

Ben: A general note following up on the discussion here: I think we should all look at our own agency and for opportunities in our own working context to see what the next steps could be. Certainly from the provincial government’s viewpoint—and we’re part of sponsoring this—the reasons for that is to help government develop a strategy for British Columbia—a strategy that goes beyond water land and air protection and that is a really broad, multi-agency strategy and we’re working in Victoria with the other agencies on that. It takes a lot of the kind of experience we’re developing here to facilitate further adaptation around the province and working with C-CIARN is a key step for us to achieve that.

Julia: I would like to thank our collaborators, the University of Northern BC and the Ministry of Water, Land, and Air Protection. It is through this kind of collaboration that we can go further

ahead. I'd also like to thank the students, Stacey Johnston and Irene McKechnie, who helped with registration and participation throughout the day.

Jenny: Thanked Ben Kangasniemi for organizing.

13. Closing Remarks

Art Fredeen
UNBC

I'm really proud of C-CIARN BC and the UNBC crowd for the job that they did today. I wanted to mention one person who hasn't been thanked yet—actually two people. I think we've reached a very interesting point right now. I believe there's an individual in [Environment Minister] David Anderson who really pushed hard for ratification, and he went against certainly a lot of people in Alberta, and certainly a lot of interests around the country. As I see it, it is one of those issues that could bring together humanity; it's a pollutant that is shared equally across all of us, although the effects will not be equal. Certainly the North and the Arctic could get hit very hard by this, and they are under-represented in their population. But at least it is a pollutant where the impact of climate change will be felt by everybody, and since Canada is one of the highest resource-using countries per capita in the world, I think we have to accept our place in that, and I think by ratifying this treaty—this protocol—I think we've made a really important step.

Also, nobody has thanked Eric Taylor who has been here for both the forestry workshop and this workshop. It is that kind of commitment on the part of individuals just like you and me that I think can make a difference. We're in a position now where we've actually ratified and we're the only North American country that has ratified, and I really think that's a courageous thing on the part of Canada. I also think it's a very big opportunity for Canada right now—there are so many opportunities that are going to come out of this ratification. I think it's a good thing for us, and not just an image thing. We could get ahead on a lot of these renewable technologies—there are a lot of technological things where Canada can now get a leg up because we have to. We're very creative, we're very resourceful, and we will find solutions to a lot of these problems.

I wanted to just thank all of you for taking the time out of your busy schedules to come and participate in this, I think it opens the beginning of change for us in North, who are under-represented in the province of BC, to actually have our interests and ideas known to the rest of the BC and the rest of the world. I hope we can do this again in the future when we're actually seeing some positive results of the cooperation that we're talking about.

Ben: Eric pointed out that at the federal level, Natural Resources Canada has really invested a lot in C-CIARNs across Canada. Here in BC is just one example—there are C-CIARNs across the country and for various sectors, so that's a significant investment and it's really starting to pay off now in the kind of groups that are created here and the kind of actions that spin off this.

14. Summary of Workshop Evaluations

Participants were asked to complete an evaluation form at the close of the workshop. Following is a brief summary of their replies to the following questions.

1. How well did the workshop meet your expectations?

Fourteen participants said that the workshop met or exceeded their expectations. Respondents also said that it widened their understanding of the impacts of climate change in northern BC; that there was too much “scientists speaking to scientists;” and that a better balance between scientists/researchers and people from the community/sectors was needed; and that it provided a significant amount of information, but it is very important to also address it at the grass root level.

2. Which aspect of the workshop was most useful to you?

Three participants rated everything as very useful, ten participants rated the presentations as being most useful to them, and three specified the technical presentations. Two participants rated the breakout session and the plenary as most useful, three participants rated information on specific issues as most useful, and one participant rated the breaks as very useful. Other comments stated that both plenary and breakout sessions were important; the perspectives of Industry and Communities were most useful; the introduction of landslides and floods as topics related to climate change in the North was useful; getting information about changes happening now and in the future from a perspective other than commercial forestry was useful; information on changes in streamflows and temperatures was useful; and the breakout session was excellent because of the communication it allowed.

3. Provide an evaluation of the morning presentations.

Fourteen participants rated the morning presentations as excellent or good. John Clague’s landslide presentation rated especially highly. One respondent complained that the presentations left too little time for the breakout session.

4. Provide an evaluation of the afternoon breakout session.

Seven participants rated the breakout session as being too short, while two rated it as very useful. One respondent noted that the questions discussed at the session were a bit vague for place-specific answers, and that it might have helped to rank the affected sectors and communities. Another felt that it was unfocused, and one felt that more time should have been spent discussing adaptation strategies rather than listing communities and businesses, and suggested that having a geographic example to work with might help.

Some respondents also commented on the afternoon presentations, noting in particular that speakers should have stayed with discussing the impacts of climate change on their sector rather than promoting their sector, and that the agricultural presentation was too general, optimistic, and inaccurate.

5. What action do you plan to take as a result of this meeting?

Communication emerged as a key response to this question, including developing more northern education links on this topic, and sharing the information from this workshop with communities or groups that respondents are members of. One respondent planned to discuss the need for climate change planning in long term water quality monitoring strategies, while another planned to look at and document changes in flow patterns. One respondent plans to buy real estate in Yellowknife.

6. What is your major concern in respect to climate change impacts and adaptation in northern B.C.?

Water resources and landscape hazards emerged as important concerns, as did a lack of public education and understanding of the subject. Other concerns included the impact on ecosystems of shorter winters and wetter, longer springs; economic development issues; and “dealing with unpredictability, bugs, disease, weather, heavy rain, and mud around the farm.” One respondent worried that people would become greedy and try to make huge personal gains through the change process rather than helping those most vulnerable, noting that the change can be managed if people pull together. Another noted that the media does not do a good job of educating the public on impacts, tending to sensationalize the issues and extreme events, treat all perspectives equally, and ignore the hinterland regions. Forest productivity, community health, fish populations, and the ability of aboriginal people to adapt were also mentioned as concerns. Finally, the current uncertainty in model projections of regional impacts was also cited as a concern.

7. Please provide your name and contact information if you are interested in becoming a member of the C-CIARN BC network.

Nine participants wanted to become members of C-CIARN BC.

8. Other suggestions or comments

Respondents emphasized the need for more time for interaction and discussion, even suggesting that the meeting could have been two days long. One respondent suggested making small subgroups from the breakout sessions to review and prioritise group summaries. One felt that the study of place is excellent idea, and that C-CIARN should get an invitation from the municipality or regional district to conduct a study. One suggested looking at the positive side of global warming, while another emphasized continued communication outside of government and academia. One felt that more community representatives speaking to local issues would have been useful. Another stated that the topics were very diverse, and more focus was needed—perhaps by working on one or two scenarios and looking at impacts and possible solutions. One respondent suggested compiling all scientific studies of all areas (oil and gas, hydro, etc.) and providing it to the public and other users.

Appendix A: Workshop Participants

Lelani Arris, Writer
Ross Benton, Canadian Forest Service
Brian Blackman, Peace/Williston Fish & Wildlife Compensation Program
Andree Blais-Stevens, Geological Survey of Canada/C-CIARN Natural Hazards
Bruce Carmichael, MWLAP
Joan Chess, Fraser Basin Council
John Clague, Simon Fraser University
Sue Clark, North Central Municipal Association
Stewart Cohen, UBC and Environment Canada
Heather Cullen, MSRM
Vanessa Egginton, Independent Researcher, MOF
Jenny Fraser, MWLAP
Art Fredeen, UNBC
Dennis Fudge, MWLAP
Marten Geertsema, BC Ministry of Forests
Mike Gill, Environment Canada, Pacific Yukon
Scott Green, UNBC
Chris Jackson, UNBC
Julia James, C-CIARN BC
Josh Joslin, District of Hudson's Hope
Ben Kangasniemi, MWLAP
Virginia Karr, Fraser Headwaters Alliance
Yvonne Lattie, Gitxsan Nation
Gina Layte Liston, City of Prince George
Anne Martin, Chair of Winter Cities
Brian McBride, Oil & Gas Commission
Susie McDonald, Wild BC
Marsh Ness, District of Hudson's Hope
Greg O'Neill, Ministry of Forests
Ellen Petticrew, UNBC
Del Reinheimer, MWLAP
Jim Schwab, Ministry of Forests - Forest Service
Stephanie Smith, BC Hydro
Dave Spittlehouse, Ministry of Forests
Bill Taylor, Environment Canada, Pacific Yukon
Eric Taylor, C-CIARN National
Lee Thiessen, Ministry of Water, Land & Air Protection
Jim Tingle, BC Min Agriculture Fisheries & Food
Paul White,
Paul Whitfield, Meteorological Service of Canada, Vancouver

Appendix B: Breakout Group Discussions

Editor's note: This appendix contains more detail about the discussions in each breakout group. To protect the privacy of the participants, comments are listed in bullet form rather than attributed to specific people.

Red Group

Facilitator:

Art Fredeen

Participants:

Brian McBride
Jenny Fraser
Bill Taylor
Jim Tingle
Ross Benton
Sue Clark
Chris Jackson
Paul White
Yvonne Lattie
Stacie Johnston

Sectors Affected:

- Agriculture
- Agroforestry
- climate change will boost agricultural output of Prince George area
- Industry has tools to deal with problems but individual farmers may not
- Forestry
- Oil and gas industry
- Traditional use – hunting, fishing, etc.
- Recreation
- Guide Outfitting
- Fisheries
- Hunting
- Trapping
- Hydroelectric power
- adjustments made due to impacts different for people
- aboriginals will feel effect more, more difficult to adapt, historical attachment to the land
- dependency on water may determine impacts
- air quality
- read a study suggesting we may have a smog belt around the northern hemisphere. Also, extreme events – the energy trapped by greenhouse gases may lead to more intense events.

- land use
- negative impacts on hydro energy
- effects only on existing dams, but opportunity for other hydro development
- coping with change has costs, there will be a transition period, but result could be better (cheaper), short versus long term.
- some have ability to move, those who can't may be negatively impacted
- uncertainty with change
- sticking to sectors limiting, look at end goal of everyone has power, place to live, etc.
- BC hydro controls water, here can't make own hydro power, in US can sell hydro to companies, forestry doing same to farmers
- regulations, rate of change. Can we adjust/change with rate of environmental change?
- balance in resources
- technology sector will benefit, innovations in technology
- traditional land use will suffer. Rest could be positive or negative, comes down to regulations and rate of change
- alternative power sources will benefit (wind, solar)
- tidal hydroelectric power, i.e. Bay of Fundy
- California driving buses with fuel cells

Places affected

- permafrost, muskeg areas
- Prince George will benefit for food production if future warming, could be food basket of BC
- Douglas fir good for forestry, may extend range
- salmon-bearing rivers/lakes/spawning grounds
- reservoir edges, water level changes, i.e. businesses along waterfront, communities with waterfront
- Telkwa etc., see a decline in property values
- extreme events probable
- Low-lying areas due to fluctuating water levels
- ski communities will see less snow, tourism, high elevation areas
- north versus south
- North-eastern BC more likely to be affected by drought
- north most affected by higher temperature as seen in models

Adaptation strategies, information requirements

- multiple land use studies (LRMP), forestry, agriculture, oil & gas
- integrated studies
- maybe multiple uses more profitable
- flexible government policies
- education—public education. Need increase in general public knowledge, change in technology to more environmentally friendly, motivate change in people
- Public has good ideas too
- New technology grants or transfer

- multiple land use studies useless unless have flexible land use planning
- target should be economic growth, bring governments together
- policy makers need better relationship with stakeholders
- government into too broad, not every day
- getting information in from places, place-specific studies, e.g., Prince George, specific ski communities

What organizations can assist?

In providing information:

- Stakeholders
- Universities
- People on land, every day level
- Research Institutions
- Applied Researchers
- Policy Makers
- Sector Organizations (agriculture, forestry)
- Stewardship Groups (NGOs, clubs)

In enhancing adaptive strategies:

- Aboriginal groups
- Local government
- BC cattlemen, agrologists, resource associations, all organizations with funding
- Northern BC organizations
- Aboriginal traditional knowledge and knowledge of place
- NW Tribal Treaty Nations

Blue Group

Facilitator:

Martin Geertsema

Participants:

Ellen Petticrew

Virginia Karr

Jim Schwab

Dennis Fudge

Paul Whitfield

Del Reinheimer

Greg O'Neill

Eric Taylor

Potentially affected communities and sectors:

- tourism will improve in north
- wetter summers mean fewer tourists
- less snow equals loss of skiers and snowmobilers, varies across the north. Smithers has more snow because it is coastal but greater risks to individuals, e.g. avalanches.
- fishing—fewer fish because of rising temperatures
- Any gains? Maybe in the south, better skiing in the north, maybe
- warmer in winter
- maybe a lag time, tourists coming up from south, more resorts on lakes in Cariboo and Quesnel, aimed at Europeans, wilderness experiences.
- real temperature changes in spring and fall, extends tourist season
- farming—isolation advantages lost, pests arriving and exotics
- more retirement people, too hot in Okanagan, new industry? E.g. Elliot Lake in northern Ontario
- people staying rather than people coming to retire, less snow
- cedar industry (forestry and quality of wood)
- non-renewable resource
- insects
- oil & gas, linked to forestry often
- water
- communities on floodplains
- communities by forests, fire issues
- communities on permafrost, discontinuous permafrost, mountain permafrost
- mosquito problems when muskeg melts
- pipelines on permafrost, Mackenzie valley, sporadic permafrost
- communities on fans, alluvial fans, debris flows
- population shifts because of malaria mosquitoes, West Nile virus, public health

- grizzly bear hibernation getting shorter? Will they live shorter lives? Get shot sooner? Not proper forage, impacts on communities
- Peregrine falcons in the Yukon, spring comes earlier, parasites are more advanced when birds arrive, chicks lost to parasites
- trans-arctic shipping route to Europe/Asia
- increase in number of large landslides could affect all sectors. Corridors through mountains, natural gas pipelines
- Copper River watershed, landslide flooded river, access still not restored after one year
- is there an increasing trend?
- cluster in the last 5 years, devegetates land, can be harvestable trees, caused by increased melting of permafrost
- can it be studied to make it more predictable? Climatology, e.g. certain predisposing weather patterns
- risk to communities at base of mountains, slides can run 3-4 km, run at good speeds
- block/dam rivers, catastrophic outbursts/dam failure, floods
- rain on snow effects, bank erosion leads to landslides
- not freezing the banks
- can we make ourselves less vulnerable—future research
- risks may change with changing climate. Need to understand relationship between climate change and changing risks
- Are risks in the past the same as risks in the future?
- risk assessments done in the Robson Valley. People appalled, drops property values. Is this a political decision?
- What does a risk assessment need in it? With climate—how would this be done? Insurance companies affected, land values decrease, people stop investing in markets, what are people's options?

Biggest Problems:

- fire, interface with communities, loss of trees
- water, quality and quantity, ground water—communities that use it as a drinking source
- slides—impacts on forest industry
- roads on slopes decaying
- fire—more winter fires
- fire season getting longer, wetter summers equals fewer fires?
- dead wood from pine beetle, etc.
- air quality improves—warmer winters equals less smoke from wood heaters, increased cloud cover in nighttime equals fewer inversions.

Role of organizations:

- education (public/professionals)
- industry

(group ran out of time)

Green Group

Facilitator:

Julia James

Participants:

Lee Thiessen
Vanessa Eggington
Josh Joslin
Marsh Ness
Dave Spittlehouse
John Clague
Bruce Carmichael
Anne Martin
Brian Blackmann
Mike Gill
Stephanie Smith
Lelani Arris

Affected sectors/communities:

- Surface water supplies in lakes, changes in algae/phytoplankton. Temperature change a factor? Changes what we have to do to treat it, also sediment concern
- Algae in Peace River, chlorinate fibre get PCMs?
- municipalities and infrastructure: storm sewers—increased snow melt, severe rain, etc.; road maintenance—fewer pothole problems; snow management.
- Problems moving north—for solutions look 100 miles south to what they do to deal with
- doesn't always follow
- all communities are vulnerable, more isolated, that depend on single resource
- winter recreation, economic impact, dual resource community—forestry, tourism—also in very small communities the lack of political clout to get help to adapt to change. Effect of landslides on rural residences, very large concern
- Rain—landslides, highway infrastructure (built on mud) (Peace River area)
- Peace River bad area
- Effect on real estate values—i.e., reaction to Regional District hazard study
- Risk analyses—people still want to be in first row, even if people know they still want to live there
- Compensation or lack thereof
- With big disasters government steps in—if people don't consciously know it they intuitively know it
- Indirect effect on gas industry—increase in drilling, increase in demand, in future adaptation in US, mitigation side (utilities out of coal and oil) and running air conditioning more, plus US desire to get away from international oil supply, creates demand pull. International trading

- hydro take account recharge to reservoirs, policies for releases, storage, some adaptation planning

Steps to move to effective adaptation strategies:

- Give people framework to do analysis. Examples from Barry Smit: range of variation with which to cope, ready to decide which fork to take. Workbook/examples, strategies good for 20 or 40 years. Analysis of what is highest priority
- what is forest industry doing? All this massive amount of fibre from beetle outbreak? Harvest & store? How would you do it?
- guideline/framework—generic way to think—generally apply?
- land use planning good way to incorporate concerns, place-based vs. sector-based, risk management
- Douglas fir coming to area, plant something different? Implications for equipment in mills, etc. What's happening with results?
- Proceedings available, to funders also
- Costs of doing nothing high
- take report and present—anything that impacts us is important
- outreach and education
- variety in BC, changes will be very different, tougher to put regional/local differences in information needs.
- issues facing communities now, what first steps working toward
- Concern over water—say start with water conservation programs
- help to look at examples of communities
- don't have access to info and expertise in small towns
- water quality and quantity issue for all communities
- need a “no regrets” strategy
- getting baseline data very hard to get, very expensive to do—how to get and how to get funding