ARTICLES

Climate change in southwestern British Columbia: Extending the boundaries of earth science

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Engaging critical thought is the cornerstone of education

SUMMARY

Humans are altering the composition of the atmosphere, causing climate to change. Scientists predict that by the middle of the 21st century, average global temperatures will be several degrees warmer than today. The change in climate will be the largest and most rapid of the last 10,000 years and will have profound effect on our lives and the ecosystems that support us.

This paper describes a new, graphics-rich, colourful poster dealing with climate change in southwestern British Columbia. The poster, which is being used as a template for six other regional climate change posters in Canada, discusses the science of climate change, possible impacts of climate change over the next 50 years in southwestern British Columbia, and the challenge of dealing with this issue. The target audience for the poster is students in grades 10-12, colleges and universities, their teachers, and the educated general public. In preparing the poster, we were guided by the principle that to educate is to engage critical thought.

RÉSUMÉ

La présence des humains sur Terre altère la composition l'atmosphère, ce qui entraîne des changements climatiques. Les scientifiques prévoient qu'au milieu de 21ᵉsiècle, la température moyenne du globe se sera élevée de plusieurs degrés au-dessus de la moyenne actuelle. Ce changement climatique sera le plus important et le plus rapide des derniers 10 000 ans et affectera en profondeur nos modes de vie et les écosystèmes qui assurent notre survie.

Le présent article décrit une nouvelle affiche très riche en graphiques et en couleurs qui porte sur les changements climatiques dans la portion sud-ouest de la Colombie-Britannique. Cette affiche qui sert de modèle pour six autres affiches sur les changements climatiques d'autres régions au Canada, traite de la science des changements climatiques, de diverses hypothèses d'impact des changement climatiques des prochains 50 ans dans le sud-ouest de la Colombie-Britannique, ainsi que des défis que pose ces changements. La clientèle visée comprend les élèves de la fin du secondaire, les étudiants des niveaux pré-universitaire et universitaire, de leurs enseignants et professeurs ainsi que les couches instruites du grand public. Tout au long de la confection de la présente affiche, nous avons été guidé par la conviction que l'instruction provient d'une réflexion critique.

GETTING THE JOB DONE

The idea of a climate change poster stemmed from two independent initiatives, one by the Pacific Division of the Geological Survey of Canada (GSC) and another by Atmospheric Environment Service (AES). Bob Turner and John Clague of the GSC had just completed their *Geoscape Vancouver* poster and map (Turner *et al.*, 1996, 1998; Clague *et al.*, 1997) and were looking for opportunities to build on their experience of creating geoscience educational products. Eric Taylor and Bill Taylor, two AES atmospheric scientists, had recently spearheaded the British Columbia-Yukon part of the Cross-Canada Climate study (Taylor and Taylor, 1997).

At the encouragement of Sandy Colvine, Director of the GSC Pacific Division, these four people got together in August 1998 to discuss the possibility of producing a poster on climate change issues in British Columbia. They were joined by Nancy Grenier, an Environment Canada communications officer, and Bertrand Groulx, a graphic designer and veteran of the *Geoscape Vancouver* project. This group of six constituted a core group that over the next 13 months took the climate change poster from concept to reality.

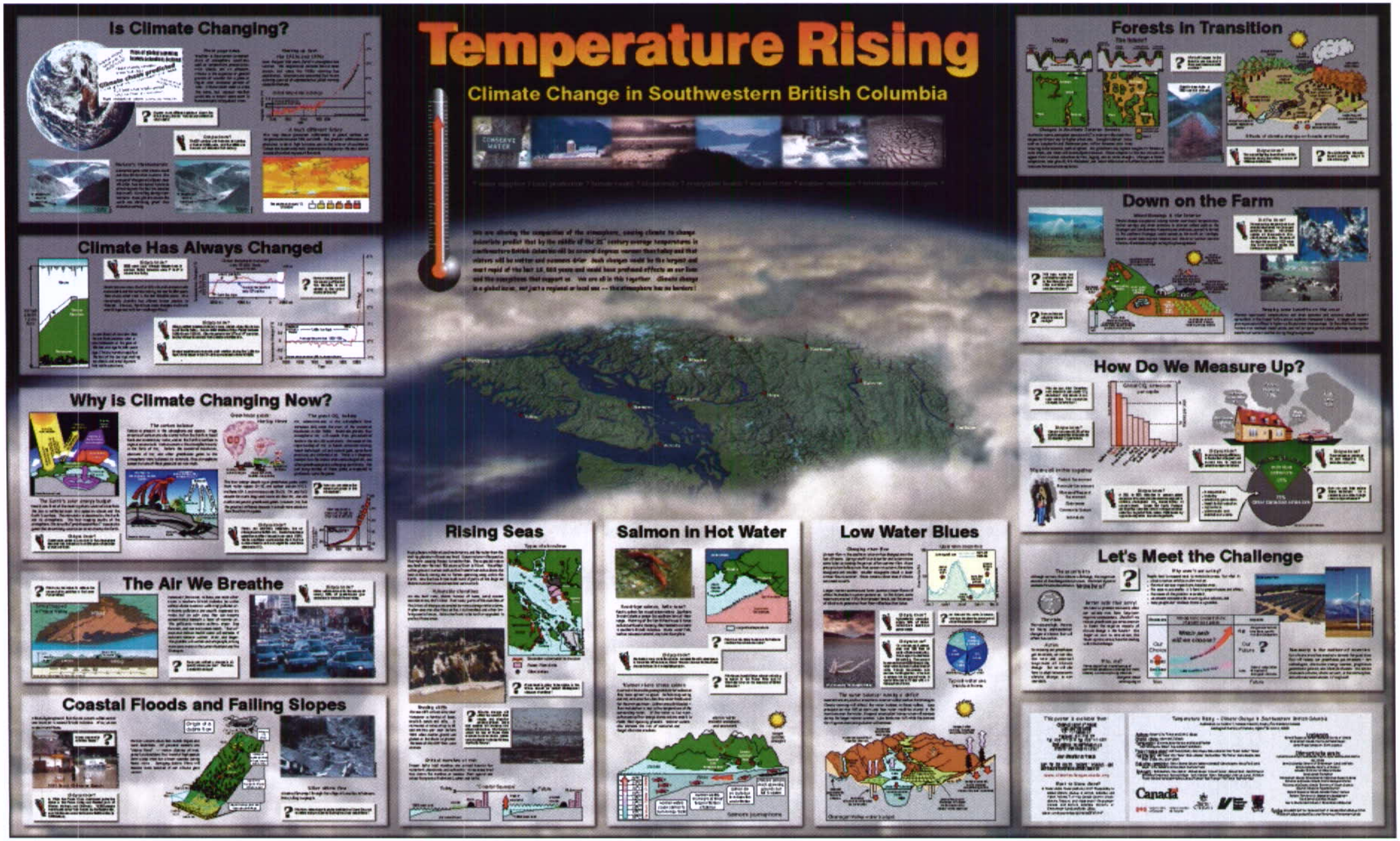


Figure 1 Temperature Rising (reduction of 90 x 156 cm poster; Turner and Clague, 1999).

The core group was aided by a steering committee, consisting of 15 scientists, educators, communication experts, and representatives of environmental groups such as Greenpeace and the Pembina Institute. The steering committee provided scientific information and relevant photographs and graphics, vetted drafts of the poster, and generally kept the core group on track.

POSTER STRUCTURE AND CONTENT

The climate change poster borrows heavily from the *Geoscape Vancouver* poster in philosophy and structure. Effective public communication is predicated on the use of simple, jargon-free language and graphic imagery. *Temperature Rising* is an attractive, full-colour, illustration-rich poster focussing on climate change in southwestern British Columbia (Fig. 1; Turner and Clague, 1999). Like *Geoscape Vancouver,* it consists of an eye-catching central image surrounded by thematic panels.

The central image is an oblique, satellite view of the Pacific Northwest seen through a window in a fabricated cloud cover that extends to the Earth's horizon. At the top of this image is the poster title, an evocative thermometer with an upward-directed red arrow, and a collage of six attention-getting photos. Introductory text presents key messages: by altering the composition of the atmosphere, we are changing our climate. By the middle of this century, average temperatures in southwestern British Columbia will be several degrees warmer than today (Fig. 2), and winters will be wetter and summers drier. This text also points out that these changes will be the largest and most rapid of the last 10,000 years and will have profound effects on our lives and the ecosystems that support us.

The panels surrounding the central image fall into three categories: the science of climate change, potential impacts of climate change on southwestern British Columbia, and the personal and societal challenge of dealing with the issue. In preparing the poster, we were guided by several principles:

- Topics familiar and relevant to residents, such as air pollution, fisheries, agriculture, forestry, and sea level rise, were selected for inclusion since people pay more attention to issues that directly affect them.
- The main messages are carried through photographs and drawings with a minimum of text.
- Block diagrams are used to convey geological relationships and the landscape in three dimensions.
- Much time was spent experimenting with graphic elements such as colour, typefaces, background patterns, and layout to make the poster attractive and something that people would want to display.

Poster Topics

- Is climate changing?
- Climate has always changed
- Why is climate changing now?
- The air we breathe
- Coastal floods and failing slopes

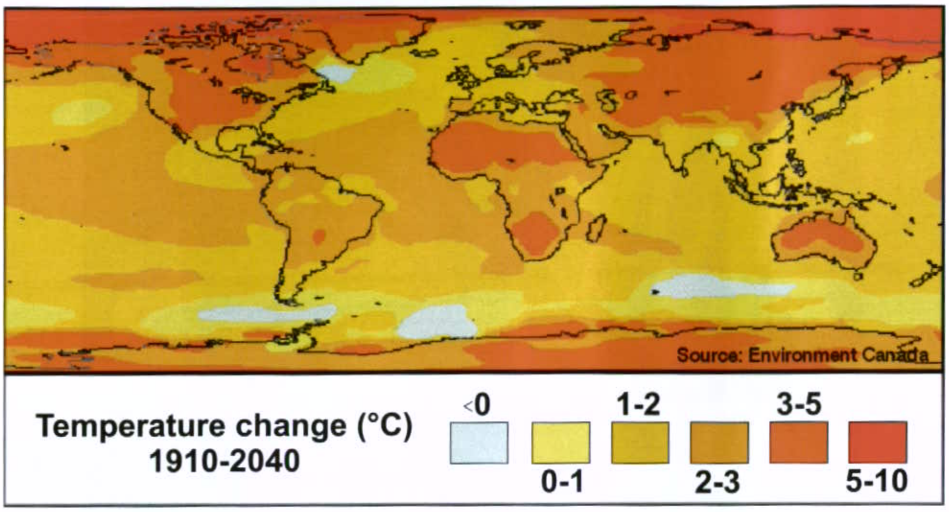


Figure 2 Map showing predicted differences in global surface air temperatures between 1910 and 2040, based on a global climate model. The greatest differences are predicted to be at high latitudes and in the interior of continents (Environment Canada, 1993).

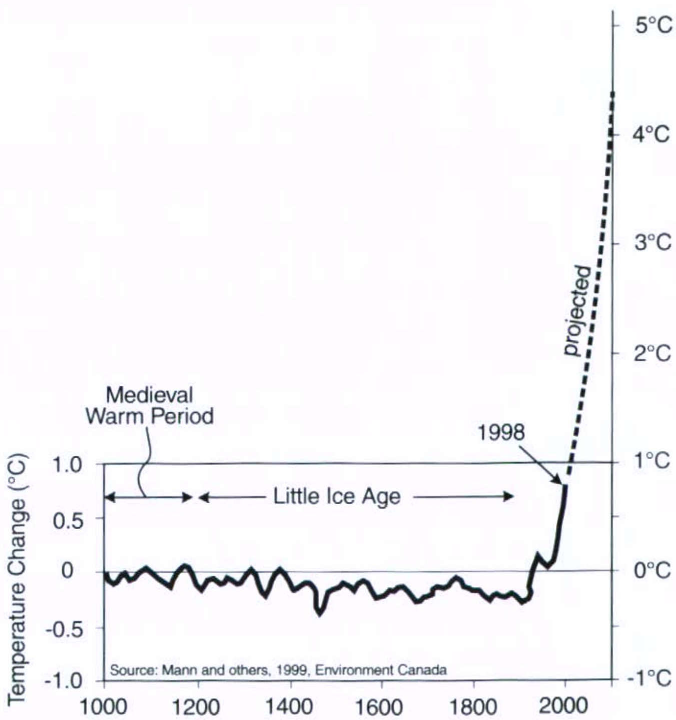


Figure 3 Average northern hemisphere temperatures during the last millenium and projected temperature rise over the next 100 years (adapted from Mann *et al.,* 1999).

- Rising seas
- Salmon in hot water
- Low-water blues
- Forests in transition
- Down on the farm
- How do we measure up?
- Let's meet the challenge

SCIENCE OF CLIMATE CHANGE

Three panels deal with the science of climate change. Each of these panels is framed around a question or an assertion intended to engage the viewer in critical thought: Is climate changing?; Climate has always changed; Why is climate changing now? [The sources of statements on climate change and its impacts are Intergovernmental Panel on Climate Change (1996), and Taylor and Taylor (1997).]

Is Climate Changing?

Although the jury is still out, most atmospheric scientists are now convinced that we are entering a period of rapid climate change. Average surface temperatures over much of the Earth are 0.5-1°C warmer now than they were in the late 1800s at the end of the Little Ice Age (Fig. 3). Scientists are debating whether warming during the 20th century is part of the natural rhythm of climate or is the early sign of human-induced greenhouse warming. The hot years of the 1980s and 1990s, however, are so unusual (Fig. 3) that a natural cause seems unlikely. Eleven of the last 16 years were the warmest years of the last century, and 1998 may have been the warmest year of the last 1000. This period has also been one of numerous extreme weather events, including the 1997 Red River flood, the 1998 Quebec ice storm, and devastating hurricanes and floods in Central America and Venezuela. Scientists are quick to point out that awareness of weather catastrophes has improved in recent decades due to improved media coverage and that, with population and economic growth, society is at greater risk of such catastrophes. Nevertheless, some scientists have argued that extreme weather events have increased in recent years, consistent with predictions that these events will become more common as climate shifts to a new regime.

Climate Has Always Changed

A key contribution that earth scientists make to the climate change debate is that climate is naturally variable on all time scales and that this variability makes it difficult to discriminate human-induced from natural climate change. For more than one billion years, Earth's climate has alternated between glacial ("ice house") and nonglacial ("greenhouse") states. The most recent of major glacial periods, the late Cenozoic, culminated in the Pleisto-

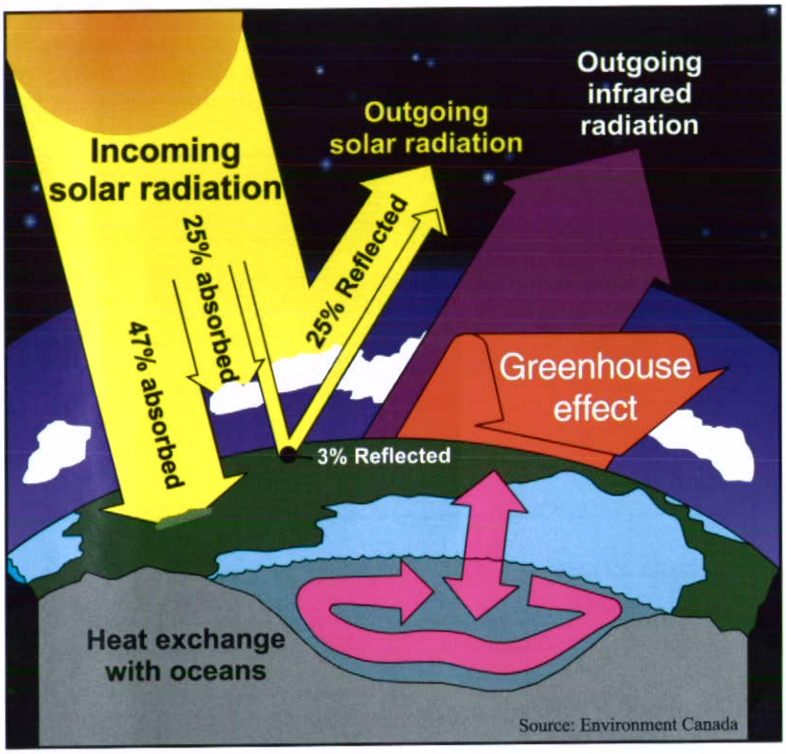


Figure 4 Earth's solar energy budget (Environment Canada, 1993).

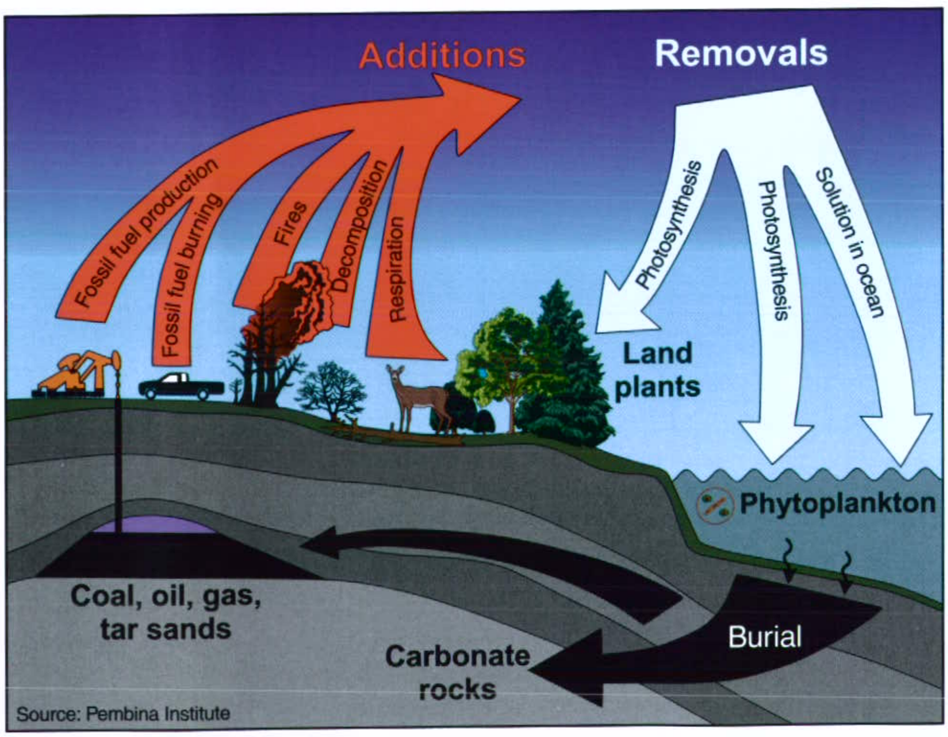
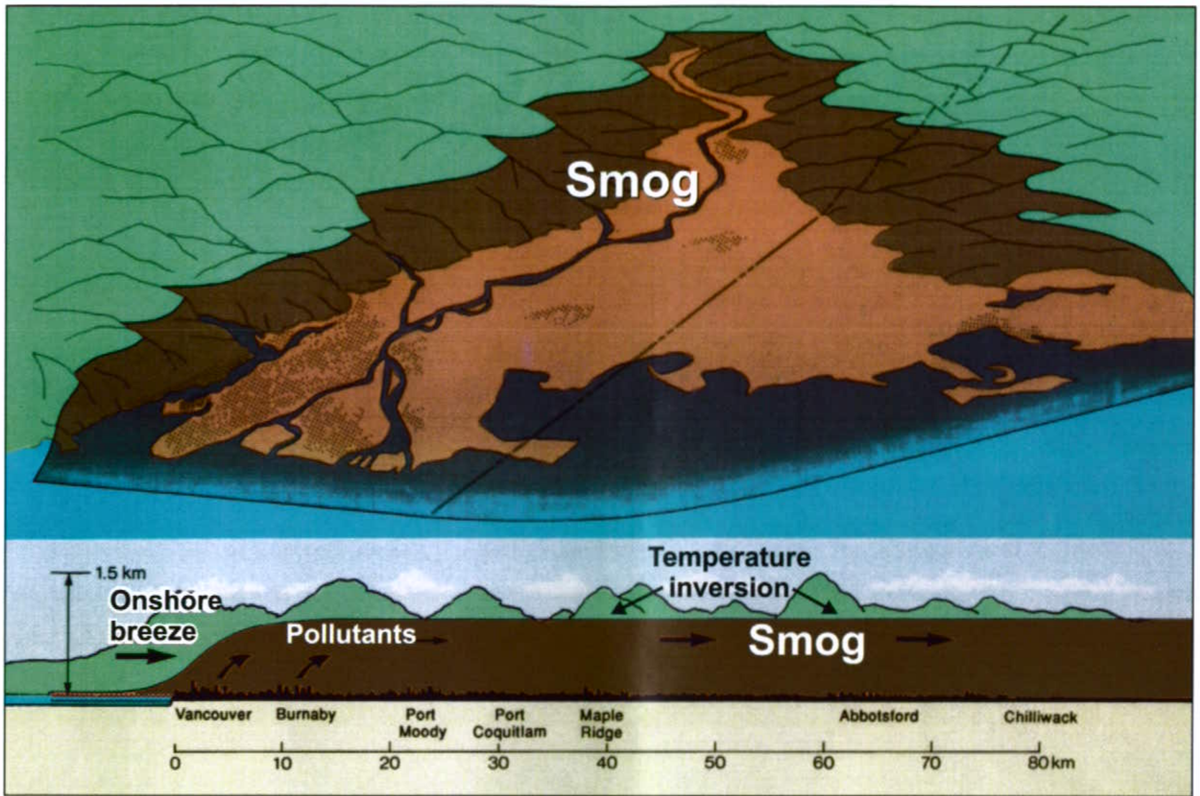


Figure 5 Earth's carbon balance (Mussell *et al.*, 1999).



Source: Greater Vancouver Regional District, Environment Canada

Figure 6 Pollutants can be trapped beneath a layer of warmer air in the Fraser Valley east of Vancouver. Airborne pollutants are typically carried east from Vancouver by prevailing westerly winds (Turner and Clague, 1999).

Figure 7 Eroding sea cliff at Point Grey, near Vancouver. The cliff is formed of loose sands and silts. It retreated at rates of up to 60 cm per year before 1982, when coarse gravel was placed at the shore to protect the base of the cliff from wave erosion (University of British Columbia, Campus Planning and Development).

cene Epoch, with the episodic growth and decay of the large continental ice sheets in the middle latitudes of the Northern Hemisphere. As pointed out on the poster, what is now Vancouver was buried beneath nearly 2 km of glacier ice as recently as 15,000 years ago. Climate change of smaller scale has occurred throughout the present interglaciation (the Holocene). Insolation in the Northern Hemisphere was greater and climate was warmer during the early Holocene than it is at present. In contrast, a variable, but cooler climate characterized parts of the late Holocene, culminating in the so-called "Little Ice Age" that began in the 13th century and ended in the mid-19th century (Grove, 1988).

Why Is Climate Changing Now?

Water vapour, carbon dioxide, and some other gases strongly affect the temperature of the Earth's surface. Nearly one-third of the incoming short-wave radiation from the Sun is reflected back into space by clouds and the Earth (Fig. 4). The remainder is absorbed by the Earth and its atmosphere. Atmospheric carbon dioxide and water vapour, however, absorb long-wave radiation emitted by the Earth. This heat-trapping mechanism is referred to as the "greenhouse effect." An extreme example of the greenhouse effect is the atmosphere of Venus, our planetary neighbour. Venus' atmosphere is 98% CO_2, and surface temperatures on the planet reach 430°C.

The main greenhouse gases, aside from water vapour, are carbon dioxide, methane (CH_4), and nitrous oxide (N_2O). CH_4 and N_2O absorb far more long-wave radiation than CO_2 and thus are much more potent greenhouse gases. However, CO_2 has the greatest influence because it is much more abundant than the other two gases.

So what determines the amount of CO_2 in Earth's atmosphere? Huge amounts of carbon are stored in the Earth in fossil fuels and sedimentary rocks, on the surface in vegetation, peat, soils, and in the oceans (Fig. 5). Carbon occurs in the atmosphere mainly in the form of CO_2. Before the Industrial Revolution, additions of CO_2 to the atmosphere were roughly balanced by removals, and atmospheric concentrations of these gases did not vary much. Since the 1700s, however, CO_2 concentrations in the atmosphere have increased 30%, and concentrations will probably double from pre-industrial levels in the next 40-60 years (Intergovernmental Panel on Climate Change, 1996). The cause of the rapid buildup of CO_2 is human activities, notably burning of fossil fuels, agricultural practices, and deforestation. The continuing buildup of these gases is expected to be the main cause of climate warming.

A DIFFERENT FUTURE

Most atmospheric scientists now agree that increases in greenhouse gases will cause the Earth's surface to warm. However, there is considerable uncertainty and debate about the rate and magnitude of warming, and about regional variations in the warming. Furthermore, the impacts of warming on the Earth's hydrological regime remain uncertain.

Progress is nevertheless being made in predicting climate responses to increases in greenhouse gases, largely through construction of sophisticated general circulation models (GCMs) with the aid of powerful high-speed computers. The most recent GCMs indicate that continents will warm more than oceans and high latitudes will warm more than low latitudes (Fig. 2). By about 2050, the North Pacific is projected to warm by 1-2°C, whereas parts of the North Atlantic may cool because of changes in ocean circulation. Precipitation is also expected to change, with projected increases in the tropical and sub-tropical Atlantic and in the Arctic, and decreases over many continental areas.

All of this will change ocean circulation and salinity. As climate warms,

Figure 8 Distribution of shorelines vulnerable to erosion and flooding, southern Strait of Georgia and eastern Juan de Fuca Strait (Turner and Clague, 1999; source of information, Clague and Bornhold, 1980).

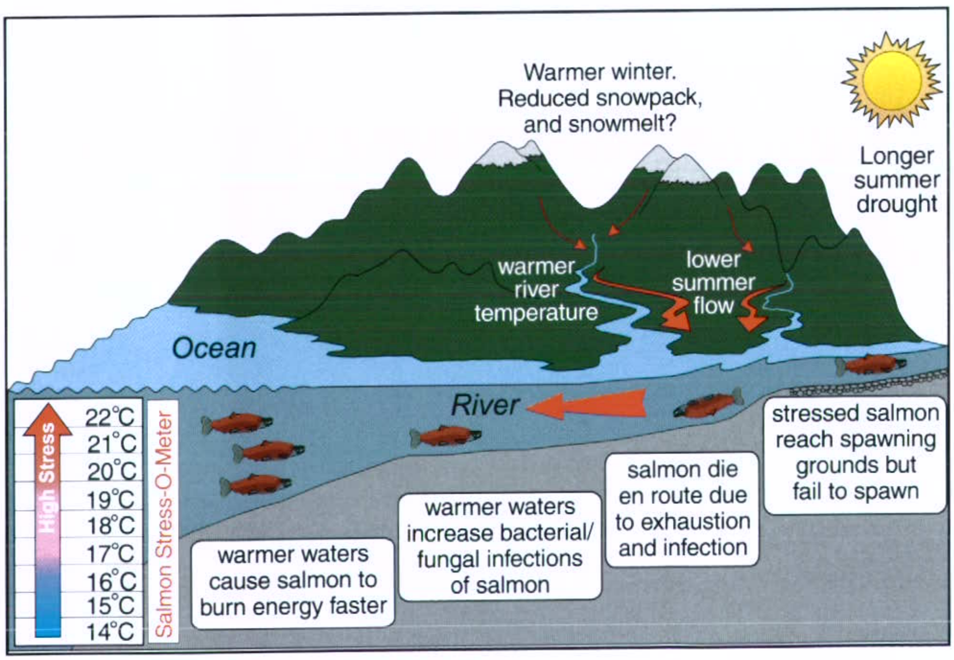


Figure 9 Possible impacts of a warmer climate on salmon as they move upriver to spawn (Turner and Clague, 1999).

we may see a stronger El Niño pattern established in the Pacific Ocean. The tropical Pacific is projected to warm by 4-5°C by the end of the 21st century, whereas the North Atlantic either will not warm or will be cooler than today. An increased high-latitude freshwater flux and changed temperatures may slow down thermohaline circulation in the North Atlantic, and temperatures in northern Europe may either warm much less than in other continental areas or even decrease.

What are the projections for Canada? The GCMs suggest that much of Canada will be an average of several degrees warmer in the middle of this century than during the 20th century (Fig. 2). The largest changes are predicted for Arctic Canada, although pronounced warming is likely to occur as well in the southern underbelly of Canada. The models predict that southern British Columbia will have longer, warmer, and perhaps drier summers and warmer, wetter winters. The number and severity of fall and winter storms may increase because warmer air masses are able to

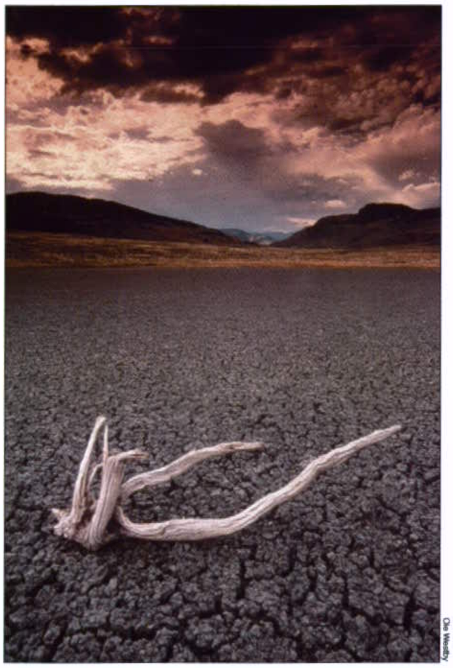


Figure 10 Dry lake bed near Okanagan Falls in southern Okanagan Valley; photograph taken in the summer in the mid-1990s (Ole Westby).

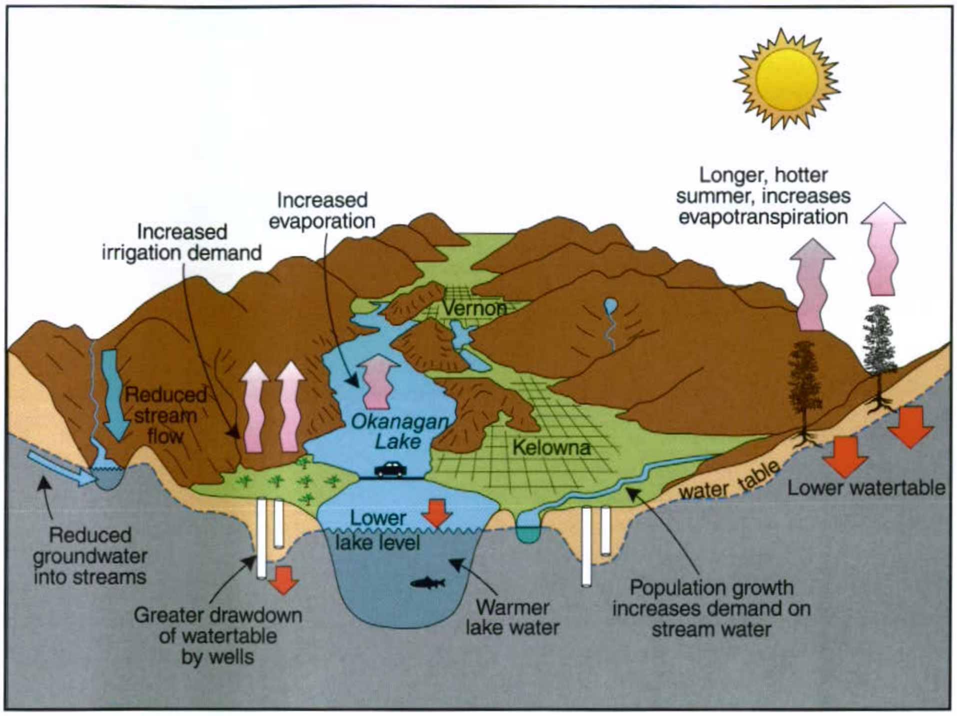


Figure 11 Okanagan Valley water budget (Turner and Clague, 1999).

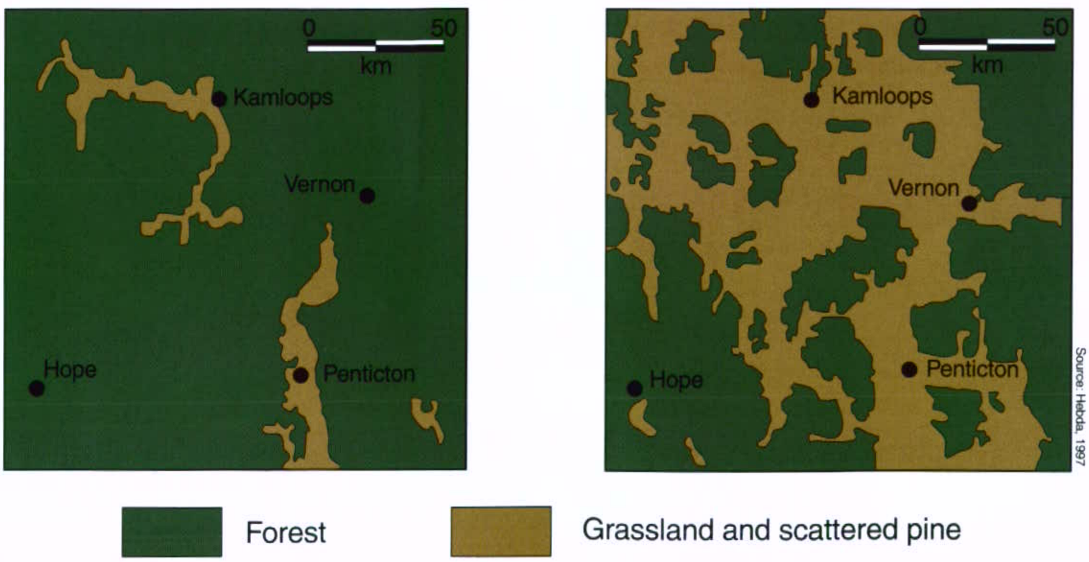


Figure 12 Possible expansion of grasslands in southern British Columbia under a warmer drier climatic regime. (**left**) distribution of grasslands at present; (**right**) possible distribution of grasslands at the end of the 21st century (Turner and Clague, 1999; source of information, Hebda, 1997).

hold more water.

Such predictions, of course, carry considerable uncertainty, but it is worth considering the likely impacts of such a different climate.

IMPACTS

Six panels on the poster address some possible or expected impacts of climate warming in southwestern British Columbia.

Air Quality

Vancouver, Penticton, Kelowna, and some other cities in southern British Columbia lie within valleys bounded by mountain walls that trap polluted air (Fig. 6). Airborne pollutants are usually dispersed by winds, but on calm days they can become concentrated beneath a layer of warmer air aloft. "Bad air" days and related health costs will increase if summers become warmer, drier, and longer, as predicted by GCMs.

Floods and Landslides

Warmer, wetter winters may bring an increase in the number of floods, especially in coastal British Columbia. Small streams are especially susceptible to this change in climate as they respond quickly to intense storms and to rain-on-snow events. In contrast, the largest rivers, such as the Fraser River, have large drainage basins, and crest in late spring and early summer. They are less likely to respond in the same way as small streams to a change to a warmer, wetter winter climate.

Wetter winters mean less stable slopes and more landslides. Debris flows, slumps, and rockfalls will become more common if our climate gets wetter.

Sea Level Rise

Most mountain glaciers will shrink as climate warms, and water from the melting glaciers will raise sea level. The effects of climate warming on the regime of the Greenland and Antarctic ice sheets, which hold 99.7% of the water that is locked up in glaciers, is less certain. A worst-case, although unlikely, scenario involving collapse of the marine-based West Antarctic ice sheet over a period of perhaps a few hundred years due to destabilization of buttressing ice shelves at its margin, would raise sea level 6-8 m. Sea level will also rise due to thermal expansion of ocean waters.

Given uncertainties in the amount of glacier melting and ocean warming, only a very broad range of values can be given for future sea-level rise. A rise of 10 cm to 1 m over the next 100 years is most likely, barring collapse of the West Ant-

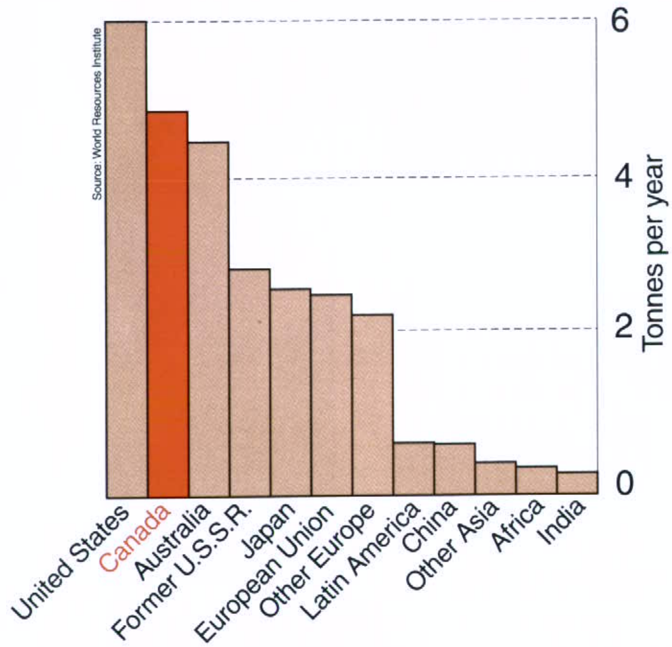


Figure 13 Per capita carbon dioxide emissions for different countries and regions (Turner and Clague, 1999; source of information, World Resources Institute).

Figure 14 A bad situation unfolds slowly (Wackernagel and Rees, 1996).

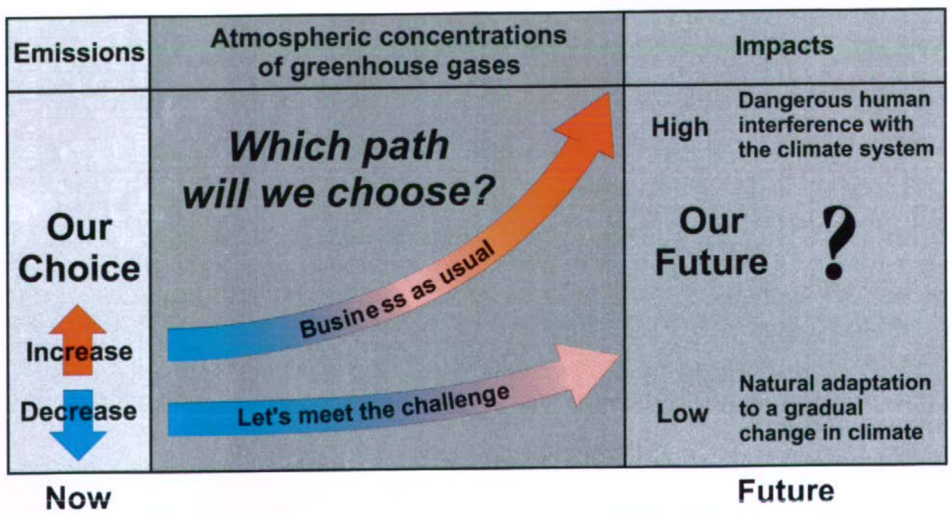


Figure 15 Future consequences of the choice we make today about curtailing greenhouse gas emissions (Turner and Clague, 1999).

arctic ice sheet. The impact of this sea-level rise will be greatest in areas where the Earth is slowly subsiding due to tectonic forces and sediment compaction, such as the Fraser River delta, just south of Vancouver. Conversely, the impact will be less in areas of rapid uplift.

Rising seas will erode shores of loose sediments. Parts of the coastline of the Strait of Georgia are bordered by bluffs of unconsolidated Pleistocene sediments that, even today, are eroded by waves during winter storms (Figs. 7, 8). A rise in sea level will substantially increase the erosion.

Higher seas may also flood deltas, tidal marshes, and other low-lying coastal areas. Fraser delta tidal marshes are important habitat for waterfowl, shorebirds, and salmon fry. Even a small rise in sea level may drown the marshes or squeeze them against sea dykes that protect communities on the delta plain from flooding.

Salmon

Pacific salmon live in cool ocean waters, and southern British Columbia is near the southern limit of their range. Warming of the North Pacific Ocean could force salmon northward, reducing their numbers in rivers in southern British Columbia. Warm-water fish, such as tuna and mackerel, may take their place.

A warmer climate also poses problems for salmon as they move upriver to spawn (Fig. 9). Salmon stop eating and rely on stored fat when they enter fresh water for the swim upstream. Salmon are cold-blooded animals; their metabolism is tied to the temperature of the surrounding water. If the water is too warm, salmon use up their energy stores and are unable to reach their spawning grounds. Warmer water also increases the risk of bacterial and fungal infections in salmon.

The Water Balance and Stream Flow

Summers are dry and hot in the interior valleys of southern British Columbia (Fig. 10), and climate warming will affect the water balance in these valleys (Fig. 11). Less precipitation may fall as snow, in which case less water will be stored in the mountains over the winter. Evaporation and plant transpiration will increase during the longer, warmer summers. Lake levels may fall, while the demand for irrigation and municipal water will increase, especially in valleys such as the Okanagan that are experiencing explosive population growth.

Stream flow in the southern British Columbia interior has changed over the last 30 years (Leith and Whitfield, 1998). Spring runoff starts earlier and autumn rains come later, extending the period of low summer flow. More precipitation falls as rain than as snow in autumn, therefore snowpacks are smaller. Smaller snowpacks result in lower streamflow in summer. These trends will continue if climate continues to warm.

Longer, warmer summers and lower summer stream flows may affect hydroelectric power generation. In the future, some reservoirs may not fill to their present levels and the amount of electricity generation from them will be less than today.

Forests

As climate warms, some plant species in British Columbia will extend their range northward and to higher elevations. Drought-resistant trees such as Douglas fir *(Pseudotsuga menziesii)* and Ponderosa pine *(Pinus ponderosa)* will be favoured over trees requiring more moisture such as spruce *(Picea)*. Grassland may replace Douglas fir forests in some areas (Fig. 12) and trees will invade alpine meadows. Plants adapted to the new climate regime will appear first in areas disturbed by fire, logging, and extreme drought. Changes in forest composition, tree growth, fire frequency, and insect infestation will affect how and where trees are harvested and replanted.

Agriculture

Climate change is expected to bring warmer year-round temperatures, wetter springs, and drier summers to important agricultural areas in southern British Columbia, including the Fraser Lowland and the Okanagan and Similkameen valleys. Vineyards and orchards, currently limited to the southern Okanagan, could spread as far north as Kamloops in the Thompson valley. Severe winter cold may be reduced, but the drier warmer summer climate will increase drought during the growing season. Warmer winters may also increase insect pests. Wetter springs on the coast may delay planting, reducing the benefits of warmer weather during the growing season.

Never doubt that a small group of committed people can change the world. Indeed, it is the only thing that has.

Margaret Mead

MEETING THE CHALLENGE

Canadians rank second in per capita CO_2 emissions (Fig. 13); we represent 0.5% of the world's population, but produce 2% of global CO_2 emissions. One reason for our high carbon emissions is our cold winters, but the main reason is our profligate use of energy.

A 50-60% reduction in present global emissions of CO_2 would be required to stabilize atmospheric CO_2 concentrations at current levels. Under the Kyoto Protocol, participating countries set an average emission reduction target of 5.2% below 1990 levels by approximately 2010; Canada's target is 5%. Far from reaching these targets, however, Canadian CO_2 emissions will likely be larger than 1990 levels by 2010.

The last, and perhaps most important, panel of the poster addresses the issue of meeting the challenge posed by climate change. Many people question whether we should act to reduce greenhouse gas emissions. Some people are not convinced that our alteration of the atmosphere will actually cause climate to change. Others point out that the magnitude and rate of change are unknown. Individual and societal inertia in response to this issue are also caused by other factors: 1) the situation is unfolding in slow motion; it is not perceived as an immediate crisis (Fig. 14); 2) the most serious impacts are decades away; 3) the issue is so complex, it's hard to pinpoint cause and effect; 4) the cause of the problem is invisible; 5) we assume someone else is working on a solution; and 6) some of the impacts may be positive (people living in Winnipeg likely might say, "bring on those warmer winters").

So why should we act? The risks are high and we need to proceed cautiously when our actions may have longterm negative consequences (Fig. 15). The precautionary principle tells us that we should reduce greenhouse gas emissions now to lessen the negative impacts of climate change on our children and grandchildren. The longer we wait to take action, the fewer options we may have for dealing with climate change.

We can slow the rate and eventual magnitude of climate change by reducing our greenhouse gas emissions. But we will also have to adapt because some climate change is now inevitable. Carbon dioxide molecules have lifespans of decades or even centuries in the atmosphere.

PRODUCTION AND MARKETING

Production of the climate change poster required collaboration of scientists working for the Geological Survey of Canada, Environment Canada, the Canadian Forest Service, Agriculture and Agri-Foods Canada, Fisheries and Oceans Canada, British Columbia Ministry of Environment, Lands and Parks, British Columbia Ministry of Forests, Royal British Columbia Museum, and Simon Fraser University. Input was provided by several other groups including the Greater Vancouver Regional District, David Suzuki Foundation, Pembina Institute for Appropriate Development, and the Sea to Sky School of Environmental Education. The production team included a graphic designer, two contract draftspersons, and the GSC digital cartography unit in Ottawa.

Two drafts of the poster were circulated to scientific advisors for review. Following review and approval by contributing government agencies, final digital files were transferred to the GSC in Ottawa. The poster was translated into French, and both English and French versions were printed. The entire process from conception to public release took 13 months.

It's one thing to produce a poster, but quite another to ensure that it is used. We involved educators in the production of the poster and have marketed it extensively. The poster is available through GSC offices in Vancouver, Calgary, and Ottawa. The poster, teachers' resources, and additional information on climate change may be accessed at: www.climatechangecanada.org. Thanks to a grant from the Climate Change Action Fund, the poster is available to teachers at no cost and may be purchased by others for only $5. We launched the poster in a secondary school and have given climate change workshops for teachers in collaboration with the Greater Vancouver Regional District. We have also teamed up with the Pembina Institute and Greater Vancouver Regional District to ensure further distribution of the poster. We are now preparing ancillary products for teachers, including overhead and slide sets of the poster images.

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