Primer

A Ministry of Education, Ministry of Environment, and WildBC Project

Contents

Primer

Change is hard to detect, especially from the perspective of one person, in one place, at one time. How is it possible that my actions have any impact on the natural world around me? When each of our actions is combined with those of every other person in our regions, provinces, and countries, the impact of our way of life can be huge.

Introduction

This primer provides a brief introduction to some of the Earth's natural systems that sustain us (e.g., weather and climate systems, the carbon cycle, ecosystems) and indicates how our daily activities and societal actions have affected these systems. After explaining the natural greenhouse effect and how our disruption of the carbon cycle has resulted in an enhanced greenhouse effect, this primer looks at the impacts of climate change. Also covered is how populations of organisms may adapt to changes in their physical environment, how we might adapt to our changing climate, and actions we can take to reduce our impact.

Climate change is happening. Using these lessons to teach about climate change and how to lessen our impact is one of the ways you can take action and help make changes that will positively affect the future.

Weather and Climate

Weather is what we experience: it is the daily change in temperature, precipitation, wind speed, wind direction, cloud cover, humidity and air pressure. **Climate** is what we expect the weather to be, based on many years of recorded weather measurements and observed weather patterns. In other words, **climate** is the *average* weather pattern over longer periods of time, generally tens to hundreds of years.

Climate and weather are a **result of complex interactions** between the Sun's energy and the Earth's air, land and water, that cause air to circulate, moving energy between the equator and the north and south poles. These interactions form a life-sustaining **global climate system**. We now understand that changing parts of this system has important global consequences for our climate and life on Earth.

Regional climates profoundly affect the distribution and the population numbers of organisms on land, in freshwater, and in oceans. Researchers in British Columbia have identified fourteen land-based **biogeoclimatic zones**. Each has a distinct array of plants and animals (the biotic or biological component of ecosystems), resulting from the interaction of global climate patterns with the local geography, such as the types of landforms and water bodies in the area (the abiotic component of ecosystems).

Meteorologists use all available weather data, numerical computer models, and their best understanding of weather processes to predict or forecast future weather. The level of complexity, along with data and knowledge gaps, can cause errors in forecasts. Consequently, we never know exactly what the weather will be until it happens. Similarly, climatologists create complex models to try to gain a picture of what our regional and global climates may be in the future.

Climate Change – Natural and Human Induced

What Has Happened?

During the Earth's 4.6 billion year history, subtle to dramatic global changes in climate patterns have occurred naturally due to several factors, including:

- changes in the Sun's heat output (e.g., solar flares, sunspots);
- recurring cyclic changes in the size of Earth's orbit and how it tilts toward the Sun (i.e., Milankovitch cycles);
- changes in the location of the Earth's continents and oceans (i.e., continental drift);
- and volcanic eruptions which add gases and dust to the atmosphere that change the amount of solar energy Earth receives.

These global factors cause changes in regional weather patterns, especially temperature and precipitation patterns. In other words, **climate change is a change in the average weather patterns that occur regionally or globally**.

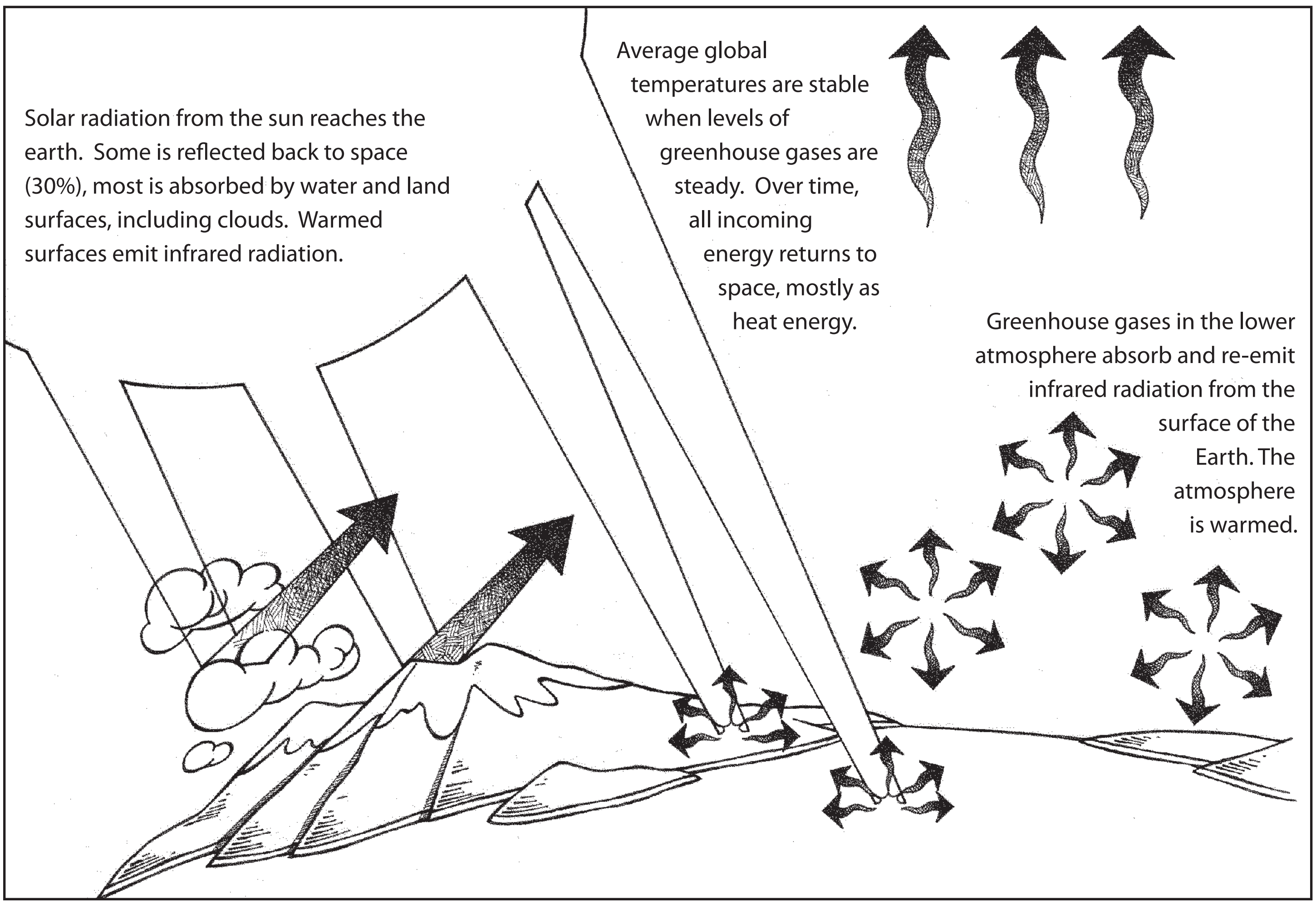
What Is Happening?

Our global climate is changing: there has been an observed increase in global average temperatures since the mid-20th century. This change correlates directly with human activities that have increased the amount of greenhouse gases, thus altering the composition of our atmosphere and how it interacts with the Sun's incoming energy. Also, current evidence indicates that the rate and magnitude of global climate warming has increased over the past 150 years. Thus, scientists conclude that **humans have significantly influenced the climate change we are currently experiencing**. *The question is how and to what extent will the changes impact the natural and human systems that we rely on to survive.*

Climate change manifests itself in three ways:

1. Changes in average weather patterns (e.g., average annual temperature and precipitation),
2. Changes in climate variability (e.g., frequency of recurring El Nino events),
3. Changes in the frequency and/or severity of extreme weather events (e.g., heat waves, drought and weather-related events such as forest fires).

Greenhouse Effect Diagram



Primer

Natural Greenhouse Effect

The Earth's natural greenhouse effect ensures the life-sustaining global average temperature of +15° Celsius; without it, the Earth would be a chilly -18° Celsius. The main naturally occurring **greenhouse gases** are **carbon dioxide, methane, nitrous oxide, and water vapour.** Excluding water vapour, which varies greatly with location and time, the greenhouse gases compose less than one percent (<1%) of the atmosphere. The vast majority of the atmosphere is composed of nitrogen (78%), oxygen (21%) and argon (0.9%). The amount of all greenhouse gases, including trace and human made greenhouse gases (e.g., halocarbons), has increased significantly since the Industrial Revolution.

The natural greenhouse effect is a result of the interactions between energy from the Sun, the atmosphere, and the Earth's surface. Roughly 30% of the energy from the Sun (i.e., **solar radiation** - mostly **visible light**) is **reflected** back out to space by clouds, gases, snow, ice, lakes, and oceans as it moves through the atmosphere to the Earth. Of the remaining solar radiation, 20% is absorbed by the atmosphere (i.e., gases and clouds) and 50% is **absorbed** by and **warms** dark areas on the surface of the Earth (i.e., the upper layers of lakes, oceans, the soil, rocks, grasslands, and forests). **Heat energy** (in the form of infrared radiation) is emitted from these warmed surfaces back to the atmosphere. For example, imagine sitting on a dark rock in the evening after a hot summer day – the rock is giving off heat to the atmosphere. Some of this **heat energy** returns to space but most is "caught" - **absorbed and re-emitted by greenhouse gases in the atmosphere**. The result is the rise in temperature of the atmosphere. This is similar to the retention of heat inside a gardener's greenhouse, thus it is referred to as the **natural greenhouse effect**.

During periods of global climate stability, a constant average global temperature exists because there is a **balance** amongst the amounts of energy entering the atmosphere, being absorbed by the atmosphere, and leaving the atmosphere.

Carbon Cycle, Greenhouse Gases and Energy

The carbon cycle is key to explaining reasons for our current climate change. **Carbon,** as one of the Earth's elements, combines with other elements and creates carbon based molecules; the amount of carbon is **finite.** Carbon, in various molecules, can be held for relatively short periods of time in **living things (the biotic component of ecosystems)** or it can be stored for thousands of years in the ocean or millions of years in geological formations (e.g., fossil fuels).

The **carbon cycle** is directly linked to energy use by all life on Earth – including humans. **Carbon dioxide (CO_2)**, one of the main greenhouse gases, is released into or removed from the **atmosphere** through the carbon cycle. The amount of carbon in the atmosphere was balanced until humans began to use fossil fuels as a source of energy. In removing carbon from long term storage (the long carbon cycle) and releasing it into the atmosphere (the short carbon cycle), the balance has been tipped, affecting our global climatic systems.

Short Carbon Cycle and Energy Flow through Ecosystems

All life on Earth is based on carbon: in the **short carbon cycle** carbon moves from the atmosphere, through the Earth's **ecosystems**, and back to the atmosphere. Some of the **Sun**'s energy (solar radiation – mostly visible light) is captured and transformed by plants during the process of **photosynthesis** and then **stored** in the chemical bonds of carbon-based molecules called **carbohydrates** (mainly as the sugar glucose). Water (H_2O) and **carbon dioxide (CO_2)** from the atmosphere, freshwater bodies, and oceans **combine** during photosynthesis to make carbohydrates. Oxygen (O_2) is the other product of photosynthesis.

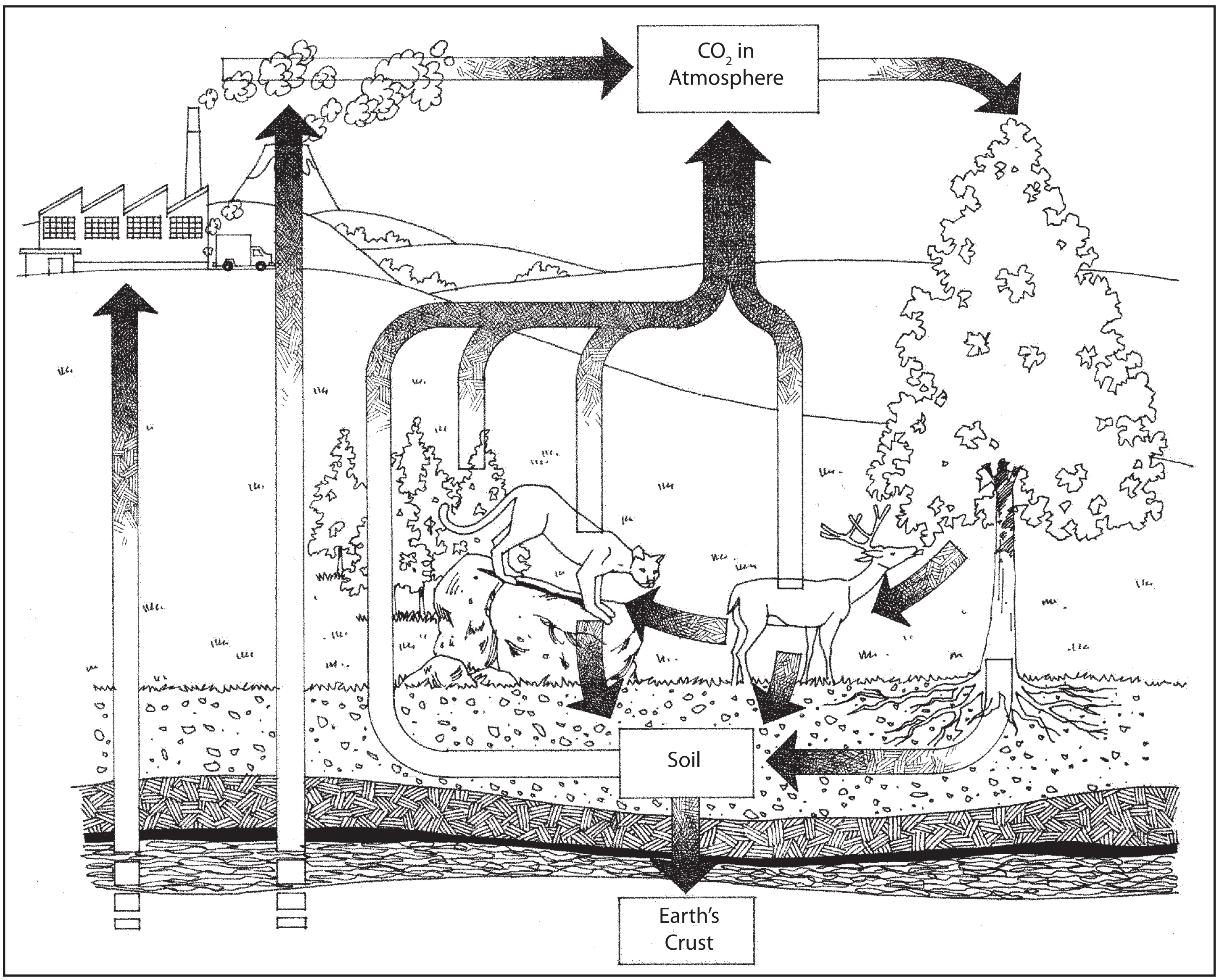
Food chains represent the **flow of energy through ecosystems**, resulting in **carbon dioxide being released back to the atmosphere**. Within ecosystems, plants are **consumed** by animals (herbivores and omnivores) and then potentially consumed by other animals (carnivores) in a **food chain.** Because plants produce food (i.e., carbohydrates) they are known as "producers" while anything that eats plants, or other animals, are "consumers". As each animal digests carbohydrates, they **use oxygen and the stored energy** in the carbohydrates to move, grow and reproduce (**cellular respiration**); they breathe out (respire) **carbon dioxide** and water. Respiration is the complimentary process to photosynthesis; all plants and animals, including decomposers, use energy that originates from the sun during respiration.

Carbon can also re-enter the atmosphere in the form of another greenhouse gas, **methane** (CH_4). Methane is produced during digestion when there is no oxygen present (i.e., under anaerobic conditions) such as bacterial decomposition in muddy swamps or in landfills. Many grazing animals, including cattle, produce large amounts of methane as part of their normal digestion process. Growing rice is also a methane source.

Long Carbon Cycle:
Trapping of Carbon in Sediments and Fossil Fuels

In the long carbon cycle, carbon leaves the Earth's atmosphere and biosphere (i.e., ecosystems) and enters the Earth's crust, (lithosphere or geosphere). In living things, carbon can be

Carbon Cycle Diagram



incorporated into the physical structure of an organism such as: cellulose in wood and calcium carbonate in shells, bones, hard parts of coral, and some marine algae. After the organism dies, the carbohydrates decompose in the soil or the bottom of oceans and freshwater bodies through the short carbon cycle, while the hard **structural components** become part of the sediment. Over time, layers of sediment solidify into **sedimentary rock** such as limestone (dominantly calcium carbonate). Here, carbon can be held for thousands to millions of years.

Sometimes, the tissues of plants, algae and marine zooplankton, are only partially consumed and decomposed in the short carbon cycle. Settling in swampy areas, lakes, and oceans, these remains become buried under layers of sediment and eventually become **trapped** in sedimentary rock. Over hundreds of millions of years these energy-rich carbon molecules (mostly carbohydrates) form **fossil fuels** such as coal, natural gas and oil deposits within the Earth's crust.

In the long carbon cycle, the only major **natural release of carbon dioxide** to the atmosphere happens during volcanic eruptions. Carbon escapes sedimentary rock through erosion or dissolving in water (weathering). In both cases, carbon can potentially re-enter the short carbon cycle by being utilized by plants.

*The amount of carbon on Earth is finite and **finely balanced** amongst the Earth's components by the carbon cycle.* The vast **majority** of carbon has been locked or sequestered in the **Earth's crust** for millions of years, while the remaining small fraction of carbon cycles through living things in ecosystems to the atmosphere or ocean and back to ecosystems. As humans extract and **burn fossil fuels** (**combustion**), complex carbon molecules are broken down releasing their stored energy for use. In this process **carbon dioxide** and water are released to the atmosphere (this is similar to cellular respiration). As we extract and use more fossil fuels, more carbon dioxide is released from the long carbon cycle into the atmospheric part of the short carbon cycle. The result of these human actions is the **tipping of the carbon cycle balance**.

Enhanced Greenhouse Effect and Human Induced Climate Change

Increasing Greenhouse Gases

The use of fossil fuels as a source of energy, large scale agriculture, and other human activities have resulted in a marked increase in the amount of greenhouse gases in the atmosphere since the Industrial Revolution. The amount of carbon dioxide (CO_2) now by far exceeds the natural range of atmospheric carbon dioxide over the last 650,000 years. The same is true for methane (CH_4) due to agricultural activities and fossil fuel use. The use of nitrogen-based fertilizers and the production of chemicals with a nitrogen base have led to an increase in nitrous oxide (NO_2) concentrations. Also, as forests are cleared for agriculture, human settlements, and other purposes, less carbon dioxide is removed from the atmosphere through photosynthesis. Additional carbon dioxide is released to the atmosphere when the wood is burned or left to decompose.

Though much less abundant than carbon dioxide, methane, nitrous oxide, and other trace greenhouse gases such as synthetically created halocarbons (e.g., chlorofluorocarbons or CFCs) are much more effective at absorbing and trapping heat energy within the atmosphere, leading to further increases in the average global temperature. Roughly, methane is tens of times; nitrous oxide hundreds of times; and some halocarbons thousands of times more effective at absorbing heat energy (infrared radiation) than carbon dioxide.

Enhanced Greenhouse Effect

With increased greenhouse gases in the Earth's atmosphere, more heat energy (infrared radiation) from the Earth's surface is absorbed and re-emitted resulting in an **enhanced greenhouse effect.** This increases the average global temperature and affects other aspects of the global climatic system, including regional climates. *The **Intergovernmental Panel on Climate Change (IPCC)**, established by the United Nations to assess scientific information related to climate change, has concluded that most of the warming observed over the last 50 years can be attributed to burning of fossil fuels, land clearing and other human activities that release greenhouse gases into the atmosphere.*

Primer

Observed Changes

The observed rate of global warming, 0.6°C during the 20th century, is likely faster than at any other time in the past 1000 years. **Climate research has provided data specific to British Columbia, including**:

- From 1895 to 1995, average annual temperature increased on the coast by 0.6°C, in central and southern interior regions by 1.1°C, and in northern BC by 1.7°C (nearly three times the global average). In particular, minimum temperatures increased: winters in BC are becoming less cold
- From 1900 to 2004, the observed trend is summers in the southern interior region have warmed 1.0 - 2.5°C
- From 1929 to 1998, average annual precipitation increased in southern BC by 2 to 4 percent per decade
- Between 1945 and 1993, lakes and rivers became free of ice two to six days earlier in the spring
- Between 1895 and 1995, two large glaciers in southern BC retreated by more than a kilometer each
- Between 1941 and 2001, ocean surface temperatures along the BC coast increased by 0.9°C to 1.8°C
- Between 1888 and 1992, the number of days available to plants to grow (growing degree days) increased by 5 to 16 percent across the province.

The Impact of Climate Change

Regional climates may experience severe and abrupt changes. Changes in the physical conditions (abiotic) of ecosystems will have consequences for the living components (biotic).

Ecosystems: Adaptation and Impacts

Most species of organisms can adapt over many lifetimes to gradual changes in the physical component (abiotic) of their environment (e.g., shifts in temperature and precipitation patterns). The ability of a species to adapt is influenced by its reproductive rate and the amount of genetic variability within that population. During gradual climate change events, often a few species are not able to adapt and become extinct. *The concern is that the current rate of climate change is occurring so quickly it may result in the extinction of many species.*

Early evidence generally confirms predicted shifts in the biogeoclimatic zones of British Columbia. **Plant** populations are expanding into and becoming established in areas where they were not previously found, often along the northern or higher altitude ranges for that species. At the other edge of the range, some species may disappear as mature individuals die and are not replaced by seedlings. The Western Red Cedar is an example of a species that is expected to shift north; individuals at the southern edge are already dying. Many **animal** species are also predicted to shift or expand their range as they follow their food sources. The impact on food chains within ecosystems could be dramatic.

Predicted Ecosystem Impacts for British Columbia

- Sea-levels rising over low-lying areas, caused by sea surface warming (i.e., water expansion) combined with glacial and ice-cap melting, affecting many saltwater marsh, estuary, and marine ecosystems, including the ocean distribution and migration patterns of salmon
- Reduced stream flow in late summer and early fall due to reduced snow pack and earlier melting, may lead to declining water quality and higher water temperatures, thus posing a threat to cold water fishes
- Warmer winters and longer growing seasons may change local species distribution and population size
- Spring events such as unfolding of leaves and laying of eggs are happening earlier and may affect associated species such as pollinators and predators
- Changes in the frequency and intensity of fires, diseases, and pests, such as the current mountain pine beetle outbreak in BC, may affect species distribution and population size of some associated species.

Human Systems: Adaptation and Impacts

Humans rely on natural ecosystems for critical resources, including food and water. As ecosystems respond to climate change, human systems for water, resource extraction, agriculture, and others will be affected. As much of our infrastructure is built based on the assumption of a stable, predictable environment, changes may have severe consequences.

Primer

The complexity of the systems involved in climate change means that there is considerable uncertainly regarding the actual rate and degree of change. Currently, the best information from government and university researchers suggests that during the 21st century **British Columbians can expect**:

- average winter temperatures to increase by 2-3ºC in the south and by 4-5ºC in the north
- summers throughout the province to warm by 2-3 ºC by 2050
- minimum daily temperatures to continue to warm faster than maximum daily temperatures
- precipitation changes: more precipitation in northeastern BC, southern and coastal regions to become drier in the summer, and slightly less winter precipitation in the southern interior by 2050
- a reduced snow pack in southern BC at mid elevations
- an earlier spring freshet (flood due to rain and/or rapid thaw) on many snow-dominated river systems
- reduced summer stream flows, particularly on snow-dominated river systems
- glacial retreat and disappearance in southern BC
- large scale shifts of the range of species northward and upslope, resulting in a loss of some ecosystems, including some wetland and alpine areas
- changes in habitat quality and availability
- an increase in growing degree days.

Changes in natural disturbance patterns associated with a changing climate will likely have socio-economic costs greater than those already incurred from the BC forest fires of 2003 and the mountain pine beetle outbreak. The weather anomalies of the past years provide insight into the types of impacts British Columbia may expect from climate change if warmer drier summers, changes in precipitation patterns, and increased weather variability become the norm. There will likely be additional impacts such as new diseases that migrate with rodents, birds and insects that are expanding their ranges.

All around the world initiatives to educate citizens about how to reduce greenhouse gas emissions are growing. Simple, mindful changes in our daily activities can reduce the amount of energy we use. Examples include using buses, bikes and feet more frequently, turning down the heat in our homes, and shopping for local foods and products. Individual, collective and societal action may mitigate our impact and give us hope for a sustainable global ecosystem.