

CLIMATE CHANGE

Tampering with the Earth's Thermostat

The 21st century will undoubtedly bring many changes and challenges, some of which may surprise us. But one change is evident already - climate change - and responding to it will certainly be challenging for all of society. Our climate has been relatively stable for millennia, providing the opportunity for our species to prosper and flourish. Now we are confronting the reality that human activities have been changing our atmosphere and have altered the balance of Earth's natural climate system. This fact sheet explains how the Earth's climate functions and describes the growing impact of human activities on climate. With a good understanding of how climate works, it is easier to understand climate change and how it might affect all of us.

Our Livable Planet

The images of Earth from space are startlingly beautiful. Perhaps the most famous is the original Blue Marble image taken by the crew of Apollo 17 in 1972. This image of our blue planet, unique among planets in its abundant water, made the fragility of life on Earth very real to many people. Certainly, without water, life on Earth as we know it would not exist.

But what might be less well known is that it is the Earth's atmosphere that makes abundant water on Earth possible and enables life to flourish. The thin blanket of gases, tiny water droplets and dust particles making up the Earth's atmosphere provides us with oxygen to breathe, precipitation to nourish our ecosystems and a stratospheric ozone shield that protects living things from harmful ultraviolet radiation from the Sun. The atmosphere also acts as an insulating blanket, reducing heat loss from Earth to space, thereby keeping temperatures on Earth warmer than they would otherwise be. This natural phenomenon has been dubbed the greenhouse effect, and it is absolutely essential for keeping surface temperatures on Earth within a range where life can exist.

The Natural Greenhouse Effect

A greenhouse is used to create a warmer growing environment for plants that would otherwise not survive in the colder conditions outdoors. In a greenhouse, energy from the sun passes through the glass as rays of light. This energy is absorbed by the plants, soil and other objects in the greenhouse. Much of this absorbed energy is converted to heat, which warms the greenhouse. The glass helps keep the greenhouse warm, by preventing the warmed air from escaping.

In creating warmer conditions on Earth than would otherwise exist, the Earth's atmosphere acts similarly to the glass in a greenhouse. About 31% of the incoming radiation from the sun is reflected directly back to space by the Earth's atmosphere and surface (particularly by snow and ice), and another 20% is absorbed by the atmosphere. The rest of the incoming radiation is



The Greenhouse Gases

Water vapour (H_2O) is the most common greenhouse gas and is responsible for about 2/3 of the natural greenhouse effect. The amount of water vapour stored in the atmosphere increases as surface temperatures rise, because higher temperatures increase both evaporation and the capacity of air to hold air vapour. Changes in atmospheric water vapour are therefore considered a feedback in the climate system; human activity is not a direct influence to any significant degree.

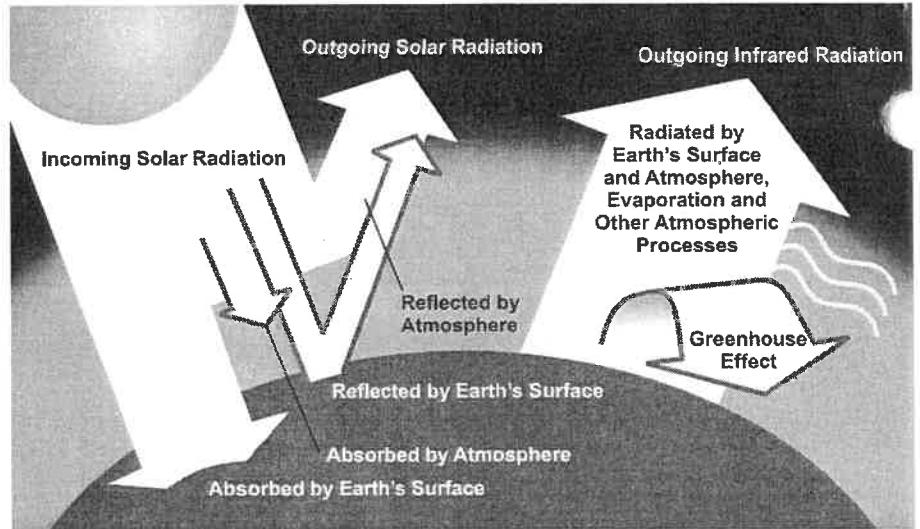
Carbon dioxide (CO_2) is released to the atmosphere through the natural processes of plant and animal life, decay, and the burning of fossil fuels and other materials. It is removed from the atmosphere by the photosynthesis of plants and absorption by the oceans.

Methane (CH_4) is not as common in volume as H_2O or CO_2 , but is more effective at trapping heat, making it a very powerful greenhouse gas. It is primarily created when matter decays in an oxygen-free environment. The main sources are wetlands, rice paddies, animal digestive processes, fossil fuel extraction and decaying garbage.

Nitrous oxide (N_2O) comes mostly from soils and the oceans. Some is released by burning fossil fuels and organic material. Soil cultivation and fertilizer use add to the amount of N_2O in the atmosphere.

Ozone (O_3) exists naturally in the upper atmosphere where it plays an important role in shielding the Earth from the sun's harmful ultraviolet rays. However, only small traces of ozone occur naturally in the lower atmosphere. In fact, most of the ozone now found at ground level is the result of chemical reactions involving pollutants produced by human activities.

Halocarbons are a group of human-made chemicals containing a halogen (bromine, chlorine, and fluorine) and carbon. They are extremely powerful greenhouse gases.



absorbed by the Earth's oceans and land, where it is converted into heat, warming the surface of the Earth and the air above it. Some of the heat energy – infrared radiation - is radiated back into space, but some of it is kept in by our atmosphere. Particular gases in the atmosphere act like the glass in a greenhouse – they insulate the Earth by preventing the heat from escaping. These 'greenhouse gases' absorb heat and radiate some of it back to the Earth's surface, causing surface temperatures to be higher than they would otherwise be.

Without this natural greenhouse effect, the Earth would be much colder than it is now – about $33^{\circ}C$ colder – making the average temperature on the planet a freezing $-18^{\circ}C$ rather than the balmy $+15^{\circ}C$ it is. The warmth of our climate is crucial because on Earth and in the atmosphere, water can exist in all three of its phases – frozen as snow or ice, liquid as water, and gaseous as water vapour. The cycling of water from one phase to another is critical to sustaining life since it is this cycling of water through the land-ocean-atmosphere system that replenishes the water available to life on Earth. The water cycle is also an important part of what drives our weather and the climate system generally.

The Climate System

The average temperature of the Earth is but one feature of Earth's climate. In a simple way, the Earth's climate system can be thought of as a giant heat engine, driven by energy from the sun. The job of the Earth's climate system is to redistribute heat around the globe. Because of how the Earth is exposed to the Sun, the heating of the Earth by the sun is not uniform. Heating around the equator is greater than it is at the poles. This is why the equatorial regions are hot and the polar regions are cold. This temperature difference is what helps drives weather. As the solar energy enters the climate system, it warms the

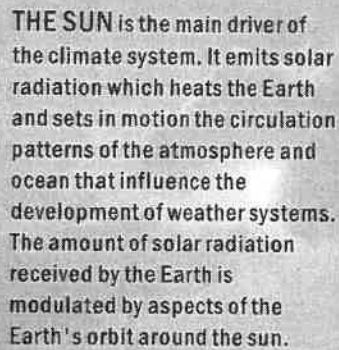
Earth and surrounding air, setting the atmospheric winds and ocean currents in motion and driving the evaporation-precipitation processes of the water cycle. These motions and processes redistribute heat around the globe and generate the weather we experience.

The climate system is in fact made up of the atmosphere, the hydrosphere (water on the Earth's surface), the biosphere (living things), the lithosphere (earth's crust and upper mantle), and the cryosphere (frozen surfaces), all of which are linked together by the flow of energy and moisture between them.

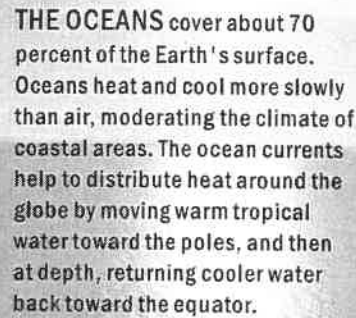


Like many aspects of the natural world, Earth's climate is a delicate balance, a complex system in which many factors interact to produce regional climates and weather systems.

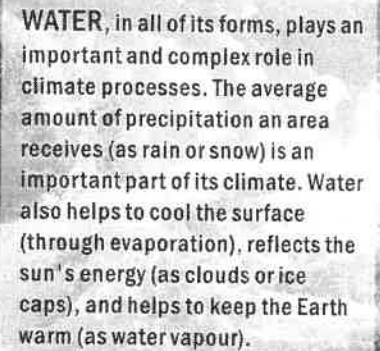
The main elements of the Earth's climate system



THE SUN is the main driver of the climate system. It emits solar radiation which heats the Earth and sets in motion the circulation patterns of the atmosphere and ocean that influence the development of weather systems. The amount of solar radiation received by the Earth is modulated by aspects of the Earth's orbit around the sun.



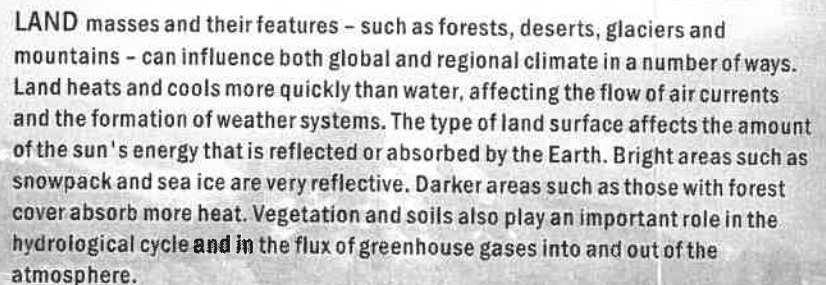
THE OCEANS cover about 70 percent of the Earth's surface. Oceans heat and cool more slowly than air, moderating the climate of coastal areas. The ocean currents help to distribute heat around the globe by moving warm tropical water toward the poles, and then at depth, returning cooler water back toward the equator.



WATER, in all of its forms, plays an important and complex role in climate processes. The average amount of precipitation an area receives (as rain or snow) is an important part of its climate. Water also helps to cool the surface (through evaporation), reflects the sun's energy (as clouds or ice caps), and helps to keep the Earth warm (as water vapour).



THE ATMOSPHERE acts like a protective blanket, keeping Earth warm and screening out many of the sun's harmful ultraviolet rays. Made up of distinct layers, the atmosphere acts as a storehouse for various gases and particles. Both the composition of the atmosphere and air circulation patterns have a major effect on climate and weather systems.



LAND masses and their features – such as forests, deserts, glaciers and mountains – can influence both global and regional climate in a number of ways. Land heats and cools more quickly than water, affecting the flow of air currents and the formation of weather systems. The type of land surface affects the amount of the sun's energy that is reflected or absorbed by the Earth. Bright areas such as snowpack and sea ice are very reflective. Darker areas such as those with forest cover absorb more heat. Vegetation and soils also play an important role in the hydrological cycle and in the flux of greenhouse gases into and out of the atmosphere.

Weather and Climate

The difference between climate and weather is that whereas weather describes an event occurring at a particular time and place – a storm moving in over a city for example – climate describes the typical weather that a location experiences based on study of weather conditions over long periods of time. An oft heard expression is that 'climate is what you expect, and weather is what you get'.

Different regions of the Earth are characterized by different climates. Canada's climate is described as temperate, meaning that most of the country experiences four seasons. Our geography affects the climate from region to region. For example, the Pacific Ocean, westerly winds, and the Rocky Mountains act together to give Canada's west coast mild weather and lots of rain.

Climatologists study elements of the

Earth's climate to better understand how climate works, how the Earth's climate has changed over time, and what we might expect in the future. As scientists learn more, forecasters also benefit as they get new tools and information to help them do a better job of predicting both the climate and the weather.

Do people affect climate?

We often say that we cannot do anything about the weather, but it's clear that human activities do have an impact on the Earth's climate, and hence weather. Over time, the growing human population has changed the face of the world: converting wilderness to agricultural land, building large urban areas, and cutting down or burning jungles and forests. Changing the nature of the land surface affects its interactions with the other elements of the climate system.

Human activity has also directly changed the composition of the atmo-

sphere. People have, for a long time, burned large amounts of biomass (wood and combustible agricultural products and by-products) for heating and cooking. However, during the last 150 years or so – our 'Industrial Era' – the combustion of huge amounts of fossil fuels (such as oil, natural gas and coal) has become central to almost all modern economic activity. It has also become the signature feature of human interference with the climate system. The combustion of biomass and fossil fuels, substances that contain large amounts of carbon, releases carbon dioxide to the atmosphere, increasing the atmospheric concentration of this potent greenhouse gas. These and other human activities are also causing increases in the atmospheric concentration of other greenhouse gases, such as methane and nitrous oxide. The consequence is that we have increased the insulating properties of the atmosphere. In effect, we have added double glazing to the greenhouse.

Enhancing the greenhouse effect

It is this 'enhanced greenhouse effect' that is causing the Earth to warm gradually. As long as the energy entering and leaving the climate system stays the same, the Earth's average temperature will remain relatively constant. However, by enhancing the natural greenhouse effect we are changing the rate at which energy leaves the climate system and global temperature will increase until the system reaches a new equilibrium. In effect, we are cranking up Earth's thermostat.

Sometimes the increasing temperature trend is referred to as 'global warming'. However, the increasing amounts of greenhouse gases will have an impact on the Earth's climate that far exceeds just a change in temperature. We have learned that a change in one part of the climate system can lead to a series of reactions that can disrupt normal weather patterns around the world. The term 'global climate change' more clearly describes the situation the world is facing.

Climate is always changing

It is true that the Earth's climate has always changed. In fact, the saying 'the only constant about climate is change' reflects this truth. However, the different factors that can cause climate change operate on very different time scales. Continental drift – the movement of Earth's tectonic plates – has changed the position of land masses on Earth over timescales of hundreds of millions of years, influencing ocean circulation and the formation of major ice sheets. Changes in the

earth's orbit around the sun occur on timescales of tens and hundreds of thousands of years, influencing the amount and seasonality of solar radiation the Earth receives. Factors such as these have been instrumental in shaping past climates of Earth, such as the great Ice Ages, or the long warm period that characterized Earth's climate when dinosaurs roamed the world. However, the enhancement of the natural greenhouse effect through human activity is affecting Earth's climate now, will continue to do so in the coming centuries, and is likely to bring about changes in climate that are far more rapid than any experienced in human history. This makes global climate change an issue for citizens of the world today and tomorrow.

Understanding climate change

The basic physics of the enhanced greenhouse effect are well understood, and some of the fundamental questions about its consequences have been answered. We now know that:

1. Human activities are responsible for increasing the concentrations of greenhouse gases in the atmosphere.
2. The Earth will continue to warm in response to past and future GHG emissions.
3. Increasing temperatures will lead to changes in other aspects of the Earth's climate, which may disrupt weather patterns around the world.

But many questions remain. Scientists in Canada and around the world are working hard to further understand the

mechanisms and consequences of climate change. What people do with this knowledge is for individuals, governments, business and community leaders to decide. Since climate change is a global problem, everyone must be involved in the solution. There are two complementary approaches that can be taken: mitigating or reducing greenhouse gas emissions to slow climate change, and adapting or coping with the effects of climate change. Both strategies are necessary.

The Intergovernmental Panel on Climate Change

Deciding what to do about climate change depends on many factors. Making sure that action taken on climate change is informed by the most up-to-date science is, however, a critical part of the decision-making process. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) to provide authoritative advice to governments on climate change. Since then, three major reports have been published by the IPCC, which have synthesized the knowledge of the scientific community on climate change at different points in time. The IPCC's Fourth Assessment Report will be released in 2007. Many Canadian scientists have been involved in the preparation of the IPCC report. Their ongoing work and that of other scientists around the world is crucial for helping us deal with our changing climate.

Sources:

The brochure is an update to a brochure of the same title published in 1999 (ISBN: 0-662-28315-5.) Additional sources for this revised text were: *Canada's Perspective on Climate Change: Science, Impacts and Adaptation* (1999; ISBN 0-662-28147-0), and *An Introduction to Climate Change: A Canadian Perspective* (2005; ISBN 0-662-41247-8).

ISBN: Paper: En56-143/1-2007E
978-0-662-45065-8

PDF: En56-143/1-2007E-PDF
978-0-662-45066-5

Ce document est également offert en français.

For more information: www.ec.gc.ca