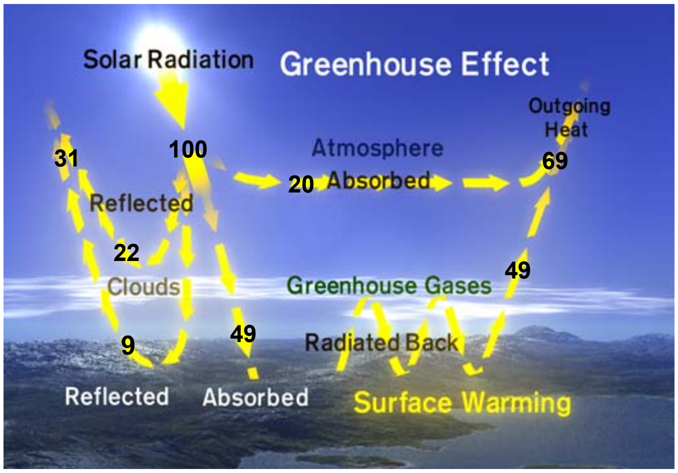
Figure 2.2 The greenhouse effect (Tr 2-2 to 2-4)



Earth absorbs solar radiation as mostly visible light that heats the surface. The diagram is based on 100 units of solar energy entering the atmosphere. Heat from the surface is emitted as long-wave infrared (IR) radiation that in turn warms the air immediately above it. Water vapour, carbon dioxide and other greenhouse gases in the lower atmosphere absorb this IR radiation and radiate it in all directions, including back to Earth's surface. This IR radiation warms Earth's atmosphere an average of 33ºC, more than would occur if the greenhouse gases were not present. Eventually, this radiation dissipates to outer space. This warming of Earth's atmosphere is known as the **greenhouse effect**.

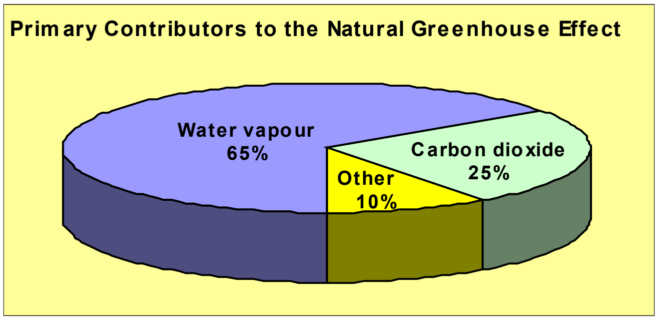
Solar radiation	**Reflected**	**Absorbed**
Clouds	15%	3%
Aerosols and ozone	7%	17%
Earth's surface	9%	49%
Total	31%	69%

The term "greenhouse effect" is a useful analogy to describe the warming of the atmosphere; however, there are differences between the warming of the air in an actual greenhouse (and a car for example) and what occurs in the atmosphere at Earth's surface. The sun warms the air inside a greenhouse and the glass prevents this warm air from rising and leaving. In the atmosphere, the air at ground level is warmed by Earth's surface and this air rises and is replaced by cooler air. This infrared radiation is absorbed by the greenhouse gases within the atmosphere, which causes further heating of the surface. Unlike the greenhouse, the greenhouse effect does not prevent the physical movement of warm and cooler air.

The greenhouse gases consist of less than 1% of the atmosphere and help maintain temperatures warm enough for life to exist. If there were no greenhouse gases, solar energy alone would warm Earth to an average global temperature of about -19°C. However, Earth's average temperature is about 14°C, or 33°C warmer. This additional warming is due to the greenhouse gases and the greenhouse effect.

Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, tropospheric (ground level) ozone and halocarbons. These gases occur in different concentrations and have different warming potentials. They are produced "naturally" and by human activities.

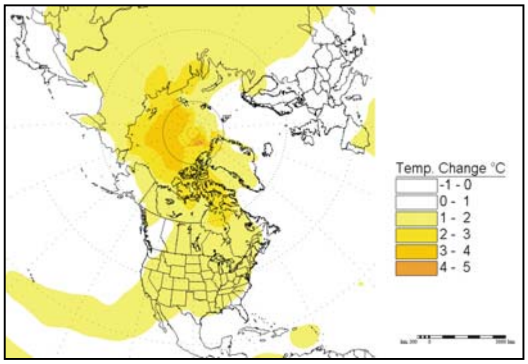
Figure 2.3 The primary contributors to the greenhouse effect (Tr 2-5)



Water vapour is part of the *natural* greenhouse effect. It is the most abundant greenhouse gas and is responsible for about 65% of the warming that occurs in the atmosphere.

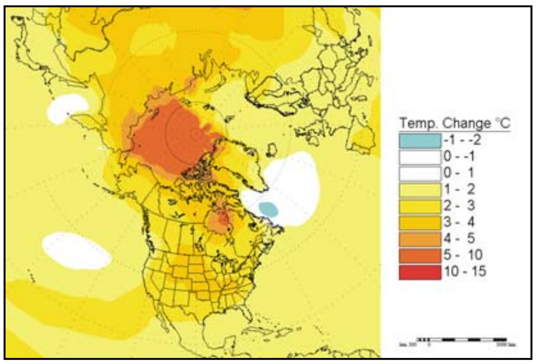
The *enhanced* greenhouse effect refers to the human-induced increase of the atmospheric concentrations of greenhouse gases and the concern that this increase will enhance the natural greenhouse effect.

Figure 3.6 Projected temperature changes between 1975–1995 and 2010–2030 (Tr 3-6)
Combined Effects of Projected Greenhouse Gas and Sulphate Aerosol Increases — Canadian Model



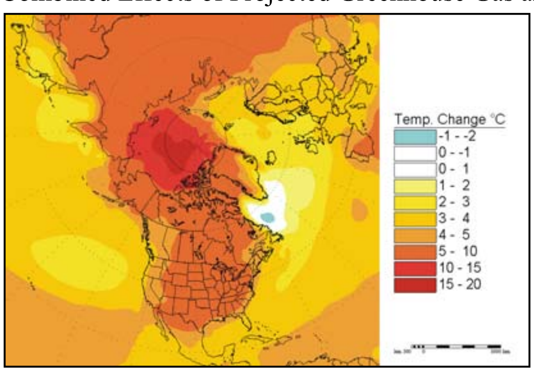
Like all General Circulation Models, the Canadian GCM projects greater warming over land than oceans and at high latitudes rather than low latitudes. The warming by about 2020 averages 1ºC to 2ºC over most of the Northern Hemisphere land areas and 2ºC to 4ºC over Arctic ice-covered waters. European temperatures show less warming than North America because of the weaker movement of air into the region from warm tropical ocean currents. Snow and ice feedbacks are the primary reason for enhanced polar warming.

Figure 3.7 Projected temperature changes between 1975–1995 and 2040–2060, Tr 3-7
Combined Effects of Projected Greenhouse Gas and Sulphate Aerosol Increases — Canadian Model



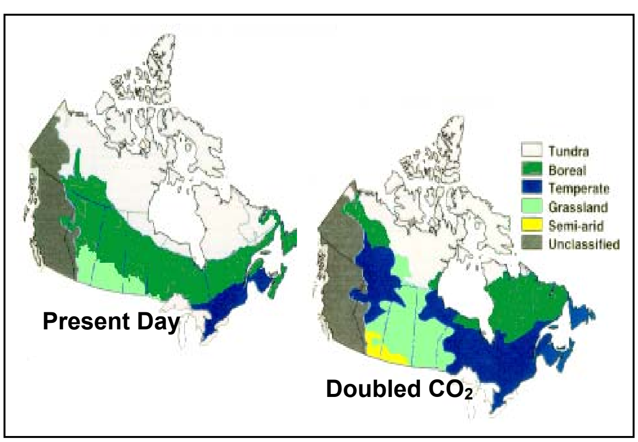
By about 2050, warming projected by the Canadian General Circulation Model 1 experiment for Central North America and Asia exceeds 3ºC, with ice-covered waters in the Arctic Ocean warming by more than 5ºC. Off the Labrador coast, a slower ocean circulation and reduced flow of warm water from the tropics northward causes an area of cooling.
Courtesy of The Canadian Centre for Climate Modelling and Analysis of the Atmospheric Environment Service, Environment Canada.

Figure 3.8 Projected temperature changes between 1975–1995 and 2080–2100 (Tr 3-8)
Combined Effects of Projected Greenhouse Gas and Sulphate Aerosol Increases — Canadian Model



By about 2090, most continental regions of the Northern Hemisphere are projected to warm by more than 5ºC, and Arctic waters by 10ºC to 20ºC. The area of cooling off Labrador is still evident. European warming continues to be moderated by a weaker Gulf Stream. The Arctic Ocean is entirely ice free in summer.
Courtesy of The Canadian Centre for Climate Modelling and Analysis of the Atmospheric Environment Service, Environment Canada.

Figure 3.9 Changes in biome boundaries with a doubling of pre-industrial levels of CO_2 to 560 ppm (Tr 3-9)



Adapted from Environment Canada, 2000

Climate determines where most plant species grow and flourish. As climates change, biome boundaries, with time, will gradually move. A projected doubling of CO_2 (from the pre-industrial level of 280 ppmv to 560 ppmv) is expected to reduce boreal forests in Canada, while the area of grasslands and temperate forests increases. Due to their long life span, forests migrate very slowly. Therefore, the transition of forest biomes to new climatic zones and biomes would be out of step with changes in climate. This is likely to cause dieback and loss to insects, diseases and fire in those ecosystems where climate change imposes the greatest stress. Changes to biomes are likely to be much more complex than those illustrated here, since the direct effects of increased CO_2 and other factors, such as changes in precipitation, will also influence ecosystems. Changes in ecosystems can also, in turn, significantly affect regional climates.
Courtesy of Environment Canada, 2000.