

2. Causes of Climate Change

Introduction

When looking for causes of climate change, one is interested in any process that can disturb the energy balance between incoming radiation from the Sun and outgoing terrestrial radiation from the Earth (the global energy balance). This is called *climate forcing*, and is the focus of this fact sheet. *Climate forcing* “forces” the climate to change.

Climate Forcing Mechanisms

Climate forcing can be separated into internal and external types. External forcing operates from outside the Earth's climate system, and includes changes in the global energy balance due to variations in the Earth's orbit around the Sun, and changes in the amount of energy coming from the Sun. Internal forcing operates from within the climate system, for example the change in the global energy balance due to changes in the composition of the atmosphere.

Orbital Variations

On timescales of a millennium and longer, changes in the character of the Earth's orbit around the Sun can significantly affect the seasonal and latitudinal distribution of incoming solar energy. These are known as the "Milankovitch Cycles" and are an example of external climate forcing. The change in energy receipt can amount to 10% or more in certain locations. The Milankovitch Cycles force the changes between ice age and warmer conditions on Earth, on time scales of 10,000 to 100,000 years. The last Ice Age occurred 18,000 years ago.

Solar Variability

Solar variability is another example of external climate forcing. Physical changes within the Sun may alter the intensity or character of the incoming solar energy. There is no doubt that variations do occur in various characteristics of the Sun on a range of time scales. The 11-year cycle in the number of sunspots on the face of the Sun is well known. But other parameters, including the solar diameter, vary too, and over different time scales. What is less clear is whether or not these changes produce significant variations in the total solar output. The total solar energy received by the Earth, or solar constant, has only been measured accurately since the advent of the satellite era. In addition, changes which have been detected over the past 20 years are small in magnitude ($\ll 1\%$), potentially too small to act as a mechanism of climate change. While the change in solar energy may be greater on longer time scales, this is only a speculative possibility.

Volcanic Activity

Volcanic activity is an example of internal climate forcing. Explosive volcanic eruptions can inject large quantities of dust and sulphur dioxide, in gaseous form, into the upper atmosphere, the stratosphere, where the sulphur dioxide is rapidly converted into sulphuric acid aerosols. Whereas volcanic pollution (from smaller eruptions) in the lower atmosphere is removed within days by rain, the volcanic dust and aerosols in the stratosphere may remain for several years, gradually spreading over much of the globe. Volcanic pollution results in a 5 to 10% reduction in the direct solar beam, largely through scattering as a result of the highly reflective sulphuric acid aerosols. Large eruptions, such as the Mount Pinatubo (Philippines) eruption in 1991, can bring about a global cooling of up to 0.3°C lasting for up to 2 years.

Atmospheric Composition

The changing composition of the atmosphere, particularly its greenhouse gas content, is a well-known example of internal climate forcing. Greenhouse gases absorb terrestrial, long-wave radiation from the Earth and re-emit this radiation up to space and down to the surface. The increase in the amount of downward energy warms the surface creating the greenhouse effect. A change in the greenhouse gas content of the atmosphere will affect the energy balance of the climate system. For example, if the amount of carbon dioxide is increased, more out-going radiation will be trapped in the atmosphere. To restore the energy balance between energy coming from the Sun and energy leaving the Earth, the temperature of the atmosphere rises. This enhances the Earth's natural greenhouse effect. Changes in the concentrations of greenhouse gases can occur in numerous ways. Natural changes in the carbon dioxide content of the atmosphere occurred at the end of the last Ice Age in response to the Milankovitch Cycles. Mankind, through energy generation, changing land use and other processes, has produced a substantial change in the atmospheric composition over most recent centuries, and it is feared that this continuing change will lead to a major shift in global climate (global warming).

Conclusion

This fact sheet has reviewed a number of causes of climate change, including Milankovitch Cycles, solar variations, volcanic activity and the changing composition of the atmosphere. The different mechanisms of climate change affect the global energy balance over different time scales. The Milankovitch Cycles operate over thousands of years whereas volcanic eruptions change climate over at most 2 to 3 years. Recently, climate change due to man-made emissions of greenhouse gases has raised fears about future global warming over the next 100 years.