



Introduction to Meteorology

38 Natural and anthropogenic climate change

Introduction



As water flows from high to low, nature tends to move from high to low potential energy. If external forcing is constantly given over a long period of time, the atmosphere will eventually reach a state that meets the given conditions and create a new climate state. If the atmosphere is adjusted for a given condition, it is called the equilibrium state. However, Earth's climate is constantly changing because of the changing external conditions. External and internal conditions are given in a different timescale and intensity. Therefore, the climate also experiences a spatial and temporal change in various ranges. It is still unknown about what these conditions are and how much each condition contributes to the climate variation. Climate change is caused by natural events as well as by human activities.

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1. Definition of climate change
2. Types of climate change
3. Changes due to global warming

Learning objectives



1. Explain the definition of climate change.
2. Describe the concept of natural and anthropogenic climate change.
3. Explain the climate change due to global warming.

Learning Activities

1. Definition of climate change

Although the definition of climate change is very diverse, the simplest is the change of the long-term average of the weather. However, the climate is not just the average of daily weather. Variations over years, seasons, and trends are all part of the climate.

Therefore, climate change can happen even if the average values of temperature, precipitation, wind, etc. do not change. For example, even though the annual mean precipitation does not change, periods of drought and heavy rainfall can vary, which can be considered as a very significant climate change.

The causes of climate change can be broadly divided into two. First is the external causes. If the intensity of incoming solar radiation weakens, the earth climate will become cold. The Little Ice Age is an example.

Second is the internal variability of the earth system. For example, the Pacific Decadal Oscillation (PDO) phenomenon, in which the sea surface temperature over the Pacific warms and cools every few decades can induce decades-long climate change without external forcing.

Both external forcing and internal variability contribute to climate change. The external forcing can be divided into natural causes and anthropogenic causes.

Learning Activities

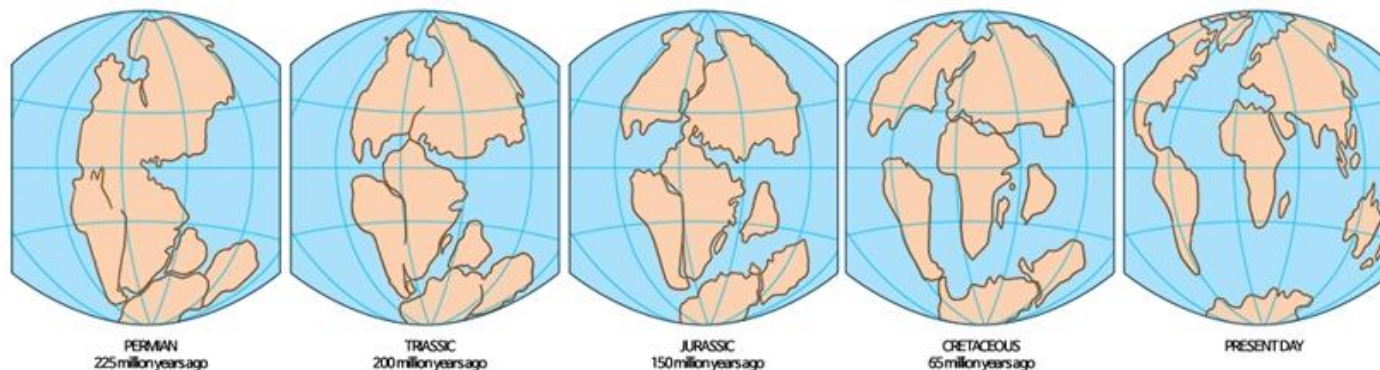
2. Types of climate change

1) Natural causes

Climate change is attributed to natural changes in Earth surface, Earth orbit, solar energy and sunspots, and volcanic eruption.

First is a change in the surface of Earth, such as the slow shifting of the continents and the ocean floors. According to the theory of plate tectonics, the Earth's outer shell consists of large plates. These plates are displaced at a very slow pace of several centimeters per year. As these plates move, the distribution of continents and ocean basins changes and climate changes accordingly.

The map shows the displacement of the landmasses from the past 225 million years to the present. North America in the tropics shifted to a mid-latitude. The movements of the continent can also change the distribution of ocean currents and sea ice, and affect the climate change.



〈Geographical distribution of landmasses〉

※ Source: <http://www.seehint.com>

Learning Activities

2. Types of climate change

A volcanic eruption is also known to have a major impact on the global climate system.

When the volcano erupts, an enormous amount of gas and ash can be ejected into the atmosphere. Sometimes, they stay for months to years in the stable stratosphere at an altitude of 15~25 km, blocking sunlight. It decreases the temperature of the troposphere.

The recent largest volcanic eruption was the Mount Pinatubo volcano in the Philippines in 1991. The temperature of the troposphere dropped about 0.5°C.

Because gas released by volcanic activity stays in the atmosphere for several years, it plays a major role in climate variability for many years. However, it is not closely related to global climate change, such as the ice age.



Important for climate variability

Not closely related to global climate change (ex-ice age)

Learning Activities

2. Types of climate change

The third type of climate change due to natural causes is the orbit change. Yugoslavia's scientist, Milankovitch, suggested that the changes in the shape of Earth's orbit as well as the tilt of Earth's axis of rotation are closely linked to climate change.

He explained that the changes in the shape (eccentricity) of Earth's orbit around the sun, changes in the tilt (obliquity) of Earth's axis, and precession of Earth's axis of rotation are responsible for climate change. The combination of these three variations is called the Milankovitch cycle.

It takes nearly 110,000 years for Earth's orbit to stretch from nearly a circle to an elliptical orbit and back again. The lower the eccentricity, the smaller the variation in solar energy received by Earth throughout a year.

The second is the obliquity of the Earth's axis. Earth's orbital tilt varies from about 22.1° to 24.5° in about 41,000 years. The larger the tilt, the more seasonal variation of incoming solar radiation.

The third is the precession of Earth's axis. As Earth rotates on its axis, it wobbles like a spinning top. This wobble, known as the precession of Earth's axis, occurs in a cycle of about 26,000 years. Such rotation is caused by the tidal force of the sun and moon.

Learning Activities

2. Types of climate change

In any combination of the Milankovitch cycle, the annual amount of solar energy reaching the surface does not change much. However, the seasonal mean solar energy can be very different. The seasonal change is closely related to the ice age.

For example, if the seasonal variation is small, the winter will become relatively warm, increasing the amount of water vapor that can be contained in the air. As a result, there will be more snow on the poles. Also, the summer will be relatively cold, and snow melts less in summer. It will become an ice age.

During the recent ice age, the climate is changing with 10,000~100,000 year period, which is consistent with the Milankovitch theory. However, this theory cannot explain the climate change on a relatively short timescale of several tens to thousands of years.

Learning Activities

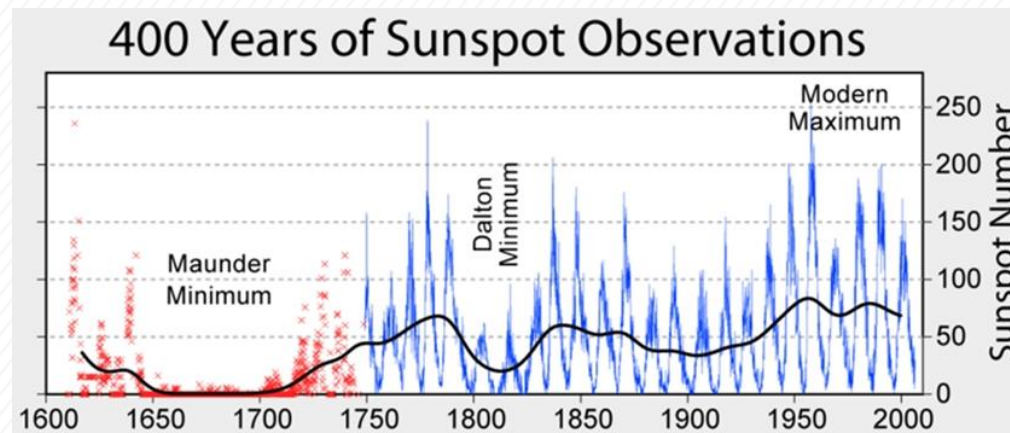
2. Types of climate change

Next is the solar energy and sunspots. If the intensity of solar energy reaching the Earth changes, it will directly affect the climate.

Recent observations using satellites have shown that solar energy changes in several percents in several years. Even a small change in solar energy of about 0.5% over a century can lead to a large change in climate, such as the ice age.

Changes in solar energy intensity can be inferred from the observation of sunspot number. Generally, when the number of sunspots increases, the solar activity is more active, and the intensity of solar energy increases.

Sunspot variation has an 11-year cycle and shows decadal variation. During the period between 1645 and 1715, known as the Maunder minimum, very few sunspots were observed and the global mean temperature was about 0.5°C below the long-term average.



Learning Activities

2. Types of climate change

2) Anthropogenic causes

Climate change resulting from human activities will be introduced. The impact of the carbon dioxide and other greenhouse gases and the land surface changes by human activity will be examined.

First, let's talk about carbon dioxide and other greenhouse gases. Although the amount of carbon dioxide is very small compared to nitrogen or oxygen, the role of this gas as a greenhouse gas is very important. Carbon dioxide is a greenhouse gas that transmits the solar radiation and strongly absorbs infrared radiation from the earth, thus it plays a major role in the warming of the lower atmosphere.

From the Industrial Revolution, we have consumed huge amounts of fossil fuel. This consumption of fuel increases the amount of carbon dioxide in the atmosphere and leads to increase in the temperature of the troposphere by breaking the balance of radiation.

Learning Activities

2. Types of climate change

Since forests can remove carbon dioxide from the atmosphere and supply oxygen in the atmosphere, deforestation also increases carbon dioxide. According to the Food and Agriculture Organization of the United Nations (FAO), 16.1 million hectares of forests disappear globally every year.



Disforestation increases carbon dioxide

Learning Activities

2. Types of climate change

If the current increasing trend of atmospheric carbon dioxide level continues, the concentration of carbon dioxide is estimated to be double that before the Industrial Revolution by the end of the century. According to recent climate model simulation, the temperature is expected to rise by 1.5~2.5°C.

In addition to carbon dioxide, the impact of Methane, nitrous oxide (N₂O) and CFC (chlorofluorocarbons) on climate change cannot be ignored.

The amount of Methane is much smaller than that of carbon dioxide, accounting for 1.7 ppm in the atmosphere. However, it is 20~30 times more efficient greenhouse gas than carbon dioxide. It is caused by the activity of anaerobic bacteria. It is more than doubled since 1800 mainly due to the increase in livestock and farmland due to population growth.

There is regional difference of increase in temperature by greenhouse gases. The temperature rise in the polar region is 2~3 times greater than the low latitudes. This is because snow and sea-ice decrease and albedo is reduced. The amount of solar energy reaching the surface increases further, and the temperature rises further, causing a positive feedback.

Learning Activities

2. Types of climate change

Let's learn the desertification and deforestation. The desertification was originally defined as an expansion of the desert area over a long period of time. Recently, desertification has been accelerated by human activities such as agricultural activities.



An expansion of the desert area over a long period of time



Desertification is increasing by human activities such as agricultural activities.

Desertification increases the surface albedo, which may cause local temperature drop. However, surface evaporation will reduce, and temperature will rise accordingly, and accelerate the desertification.

Learning Activities

2. Types of climate change

The evapotranspiration is much larger in the forest than its surroundings. When deforestation occurs, the ecosystem will be destroyed, and the area will become dryer.



**Evapotranspiration is larger
in forest than its surroundings**

It is known that the surface temperature in the place where deforestation occurs increases about 3°C on average. The deforestation affects the global climate change by increasing the carbon dioxide.

Learning Activities

3. Changes due to global warming

1) Changes in water resources and agriculture

As the degree of global warming varies, the precipitation change varies from region to region. Changes in precipitation impact on the agricultural productivity by influencing the water resources. The reduction of precipitation leads to the serious problem resulting from the depletion of agricultural water. The increase in heavy precipitation can induce serious flooding events.

According to the IPCC report, Korea is expected to experience water shortages due to the decrease in precipitation and increase of temperature in Korea.

Due to the increase in temperature in Korea, the period and types of crop production are changing as well. The yield zones for barley, potato, garlic, peach, apple are gradually moving up to the north.

Learning Activities

3. Changes due to global warming

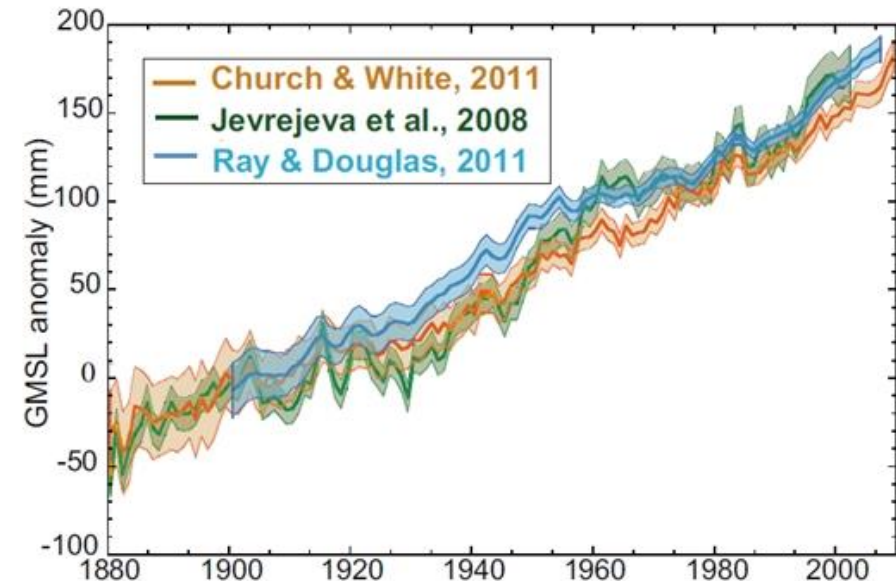
2) Sea level rise

As the temperature rises, the upper surface of the ocean is heated, and the water expands thermally. This expansion of water is the main cause of sea level rise. Moreover, as ice and snow melt in the Antarctic and Arctic, sea level rises.

According to the IPCC report, sea level has risen about 10–25 cm over the last century, and this trend continues to increase.

Because sea level rise is a prolonged process, it is difficult to detect. However, it can be gradually recognized through continuous erosion of coastal areas by storms or typhoons. Recent reports of coastal erosion around the world have also shown that sea level rise is faster than expected.

According to the Korea Hydrographic and Oceanographic Agency (KOHA), the average sea level rise rate in Korea is 2.2mm/yr (The Yellow Sea 1.1mm/yr, South Sea 3.2mm/yr, East Sea 2.2mm/yr, vicinity of Jeju Island 4.9mm/yr).



Learning Activities

3) New weather patterns

Many atmospheric scientists believe that the weather patterns will change as global warming continues. First, as the temperature of the oceans increases, the intensity of typhoons and storms will increase. Second, the circulation pattern will change, and the distribution of precipitation will change accordingly. Third, heatwave and drought will occur frequently.

Summary

1. Definition of Climate Change

- The definition of climate change is very diverse, but the simplest is the change of the long-term average of the weather.
- Climate is not just about the average field but the variations in years, seasons, and trends.

Summary

2. Types of climate change

- Natural causes
 - 1) Plate tectonics
 - The earth's outer shell is made up of several large plates, which move to change the continents and thereby climate.
 - 2) Volcanic eruption
 - When a volcano erupts, an enormous amount of gas and volcanic ash is released into the atmosphere, which greatly affects climate change.
 - 3) Orbit change
 - The Milankovitch cycle explains the climate change by the change in the shape (eccentricity) of Earth's orbit, change in the tilt (obliquity) of Earth's axis, and precession of Earth's axis of rotation.
 - 4) Solar energy and sunspots
 - Recent observations using satellites have shown that solar energy changes in several percents in several years. Even a small change in solar energy of about 0.5% over a century, it can lead to a large change in climate, such as the ice age.
 - Sunspot variation has an 11-year cycle. Generally, when the number of sunspots increases, the solar activity is more active, and the intensity of solar energy increases.

Summary

2. Types of climate change

- Anthropogenic causes
 - 1) Carbon dioxide and other greenhouse gases.
 - Greenhouse gases transmit the solar radiation and strongly absorb infrared radiation from the earth, thus play a major role in the warming of the atmosphere.
 - 2) Land surface change by human activity
 - Desertification: Desertification was originally defined as an expansion of the desert area over a long period of time. Recently, desertification is increasing by human activities such as agricultural activities.
 - Deforestation: When deforestation occurs, the ecosystem will be destroyed and the area will become dryer.

Summary

3. Changes due to global warming

- Changes in water resources and agriculture
 - Changes in precipitation impact on the agricultural productivity by altering the water resources, and causing many losses due to drought and floods.
- Sea level rise
 - As the temperature rises, the upper surface of the ocean is heated, and the water expands thermally. This expansion of water is the main cause of sea level rise.
- New weather patterns
 - Strong typhoon, change of circulation, change of distribution of precipitation, frequent occurrences of extreme weather such as flood and drought are likely to occur in the future.