Introduction to Meteorology

37 Climate system

Introduction

Climatic factors are connected to each other in a complex way. Climate system is an interactive system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the biosphere, and the lithosphere.
Climate varies over the years to decades. In order to predict the climate change accurately, a better understanding of the climate system is needed.

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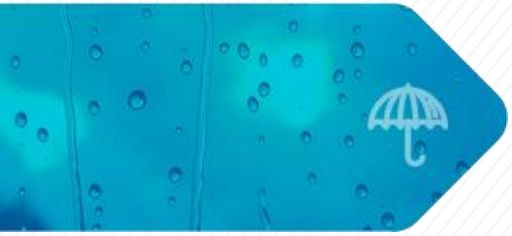


1. Definition of the climate system
2. Climate factors
3. Köppen climatic classification

Learning objectives

1. Explain the difference between climate and weather.
2. Explain how the climate systems are classified.
3. Understand and explain climatic factors.

Learning Activities

1. Definition of the climate system

cryosphere, the biosphere, and the lithosphere. Each component has different properties, physical characteristics, and structures. The climate system is connected through the interchange of elements, such as the energy and water vapor among these five components.

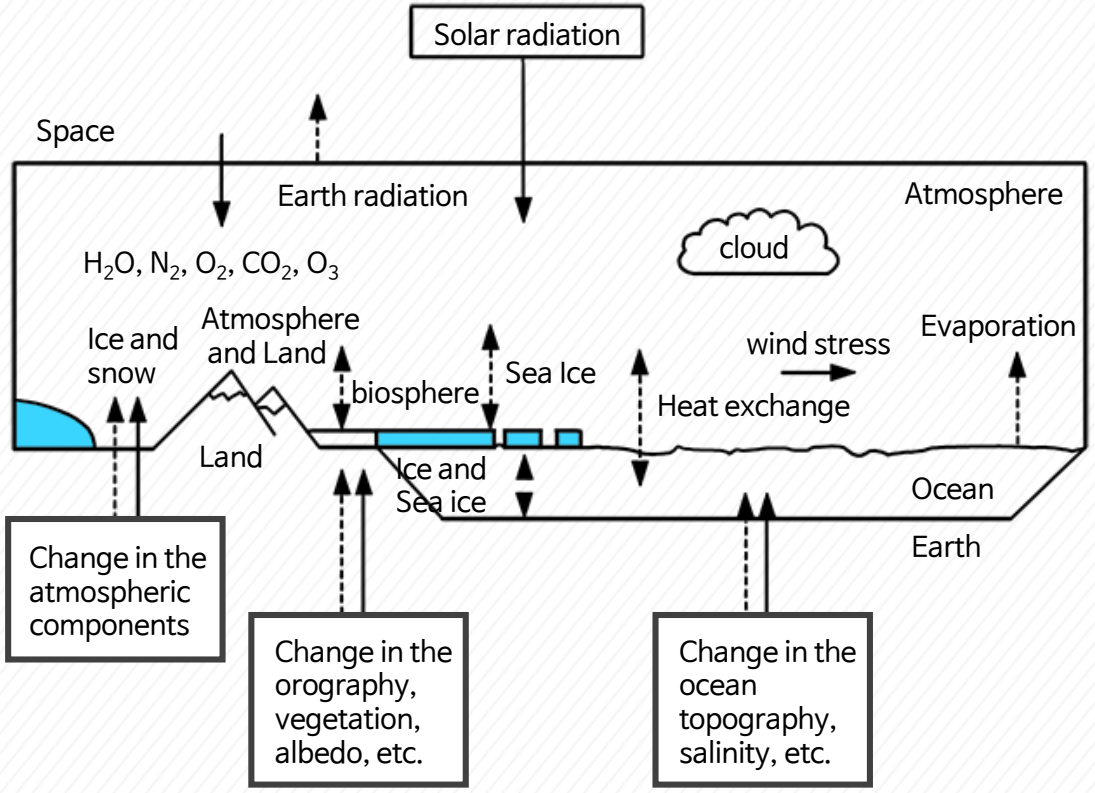
Each component is linked by a highly complex nonlinear interaction and forms a global climate system. Thus any internal change in a system cannot change independently.

Learning Activities

1. Definition of the climate system

The following figure depicts the interaction between the major climate systems. Changes in the atmosphere due to temperature, solar radiation, and precipitation lead to changes in vegetation growth and soil conditions of biosphere, which affects again the atmosphere through albedo and evapotranspiration.

Changes in the atmosphere affect ocean temperature, salinity, currents, and sea ice, and such changes have influence on precipitation and temperature through the heat exchange with the atmosphere. Thus, the five climate systems are all interrelated.



〈The climate system〉

Learning Activities

1. Definition of the climate system

However, despite the five components of the climate system are closely linked, they have different temporal scales. Given any change which perturbs the atmosphere, for example, the atmosphere can react to the perturbation in just a few days owing to its small heat capacity. On the other hand, it takes a long period time (from decades to thousands of years) for the deep ocean to react to the given change. Therefore, the atmosphere and ocean have different time scales of variability.

Consequently, the change of ocean is not crucial in the weather forecast. However, the change of the ocean, as well as other systems, such as the cryosphere, should be considered for climate change projection.

Learning Activities

2. Climate factors

If the surface of the earth were homogeneous, the distribution of climate system would be solely dependent on latitude. However, global climate is affected not only by the latitude but by the land distribution, the wind system, the topography, the distribution of the currents, and the air pressure and air masses. Such elements that control global climate are called climate factors.

Learning Activities

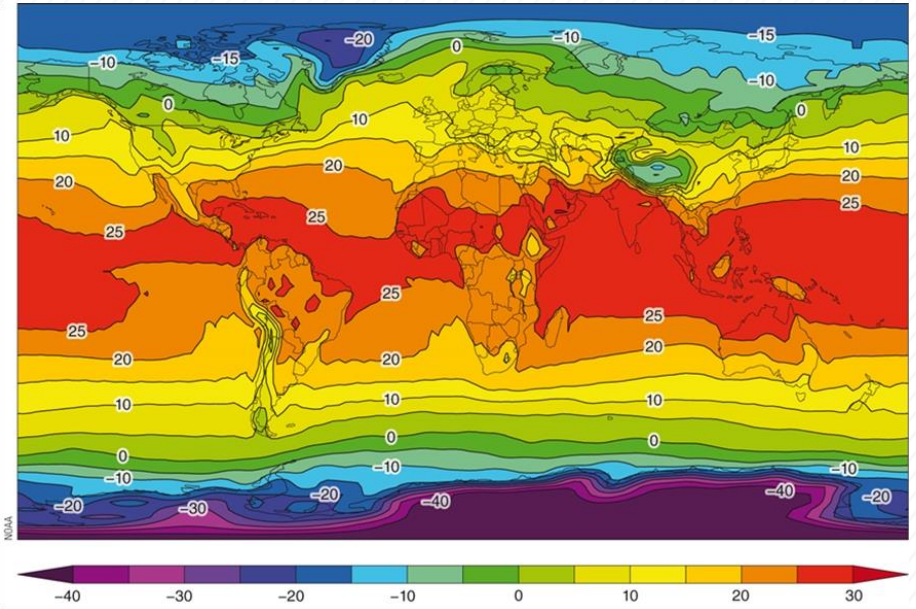
2. Climate factors

1) Latitude

The most important climate factor is the latitude because the incoming solar energy which modulates the temperature depends on the latitude. On average, the annual amount of solar energy reaching the surface is inversely proportional to latitude.

The annual average temperature is high at low latitudes and decreases to higher latitudes.

The seasonal variation of solar energy is small in the tropics, so is the seasonal change in temperature. On the contrary, the incoming solar energy varies considerably from season to season at high latitudes, thus the seasonal change in temperature is large.



〈Annual surface temperature averaged over 1980−2009〉

Learning Activities

2. Climate factors

2) Land and sea distribution

The distribution of land and sea has a profound effect on climate. Because water has higher specific heat capacity than that of soil or rock, it slowly cools and slowly heats up, so the temperature variation of the ocean and lake are relatively smaller than on land.

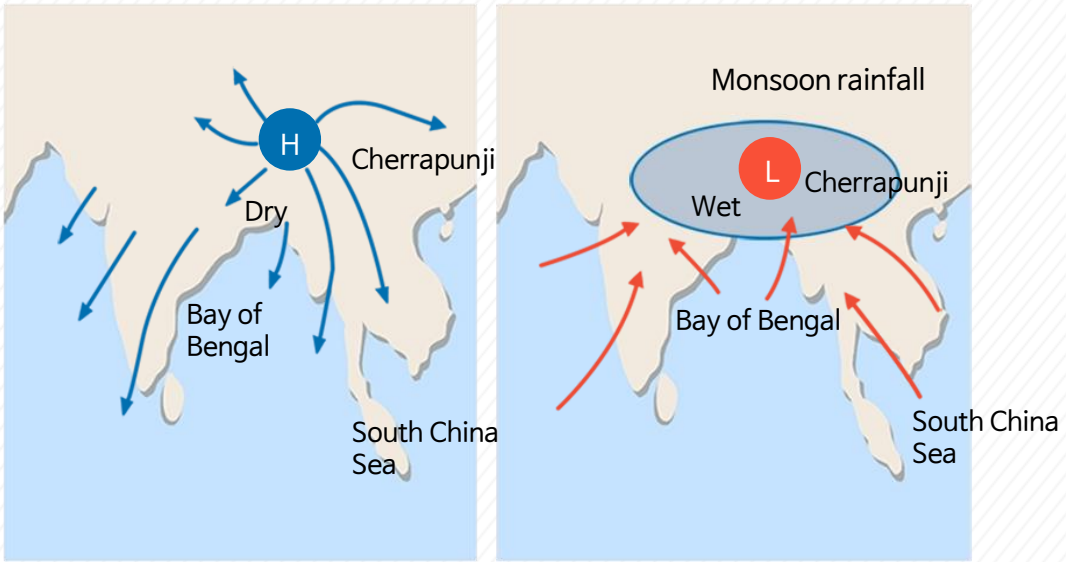
Climate system can be classified into marine climate and continental climate. The marine climate can be considered to be a milder climate than a continental climate, with relatively small annual variations. In other words, summer and winter are not overly hot or cold in a marine climate region.

The differential heating between the land and ocean changes precipitation through the changes in the air pressure and air mass. Compared with the oceans which warm up relatively slowly, the land temperature rises rapidly and the air density decreases, so the atmospheric pressure over the land is lower. Because of the pressure gradient, the humid air from the ocean enters the low-pressure continent and induces a lot of precipitation. It is the opposite during winter.

The circulation generated by the differential heating of ocean and land is called the monsoon circulation. This monsoon circulation has an enormous impact on the climate of many parts of the world.

Learning Activities

2. Climate factors



〈Monsoon circulation in winter and summer〉

This figure shows the Indian monsoon which is the most prominent monsoon system. As you can see from the circulation pattern, the seasonal change depends on the land-sea distribution.

Learning Activities

2. Climate factors

3) Prevailing wind

The contribution of the land–sea distribution on the climate can be modulated by the prevailing wind. For example, if an area is subject to the influence of the wind from the ocean, it will have a marine climate. A region on the leeward side will have a continental climate.

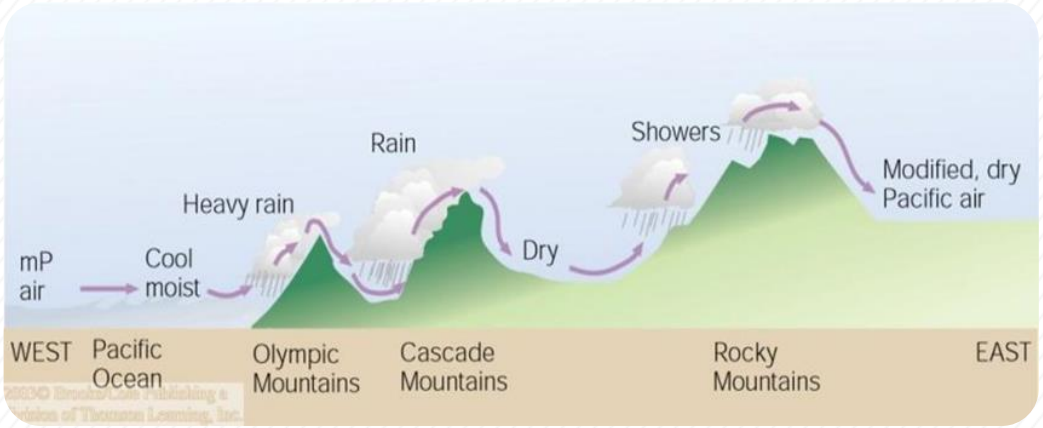
Learning Activities

2. Climate factors

4) Topography

Topography such as mountains and mountain ranges can affect the climate. For example, the mountain ranges along the coastline block the effect of the marine climate.

Such topography causes precipitation on the windward side and dry area on the leeward side. The figure shows the western part of the United States. Rainfall occurs mostly on the windward side, dry area to the east of the Rocky Mountains.



〈Föhn effect〉

Because temperature decreases as altitude increases, higher plateau areas have lower temperatures than the area at the same latitude, forming a so-called alpine climate where the daily temperature variation is large.

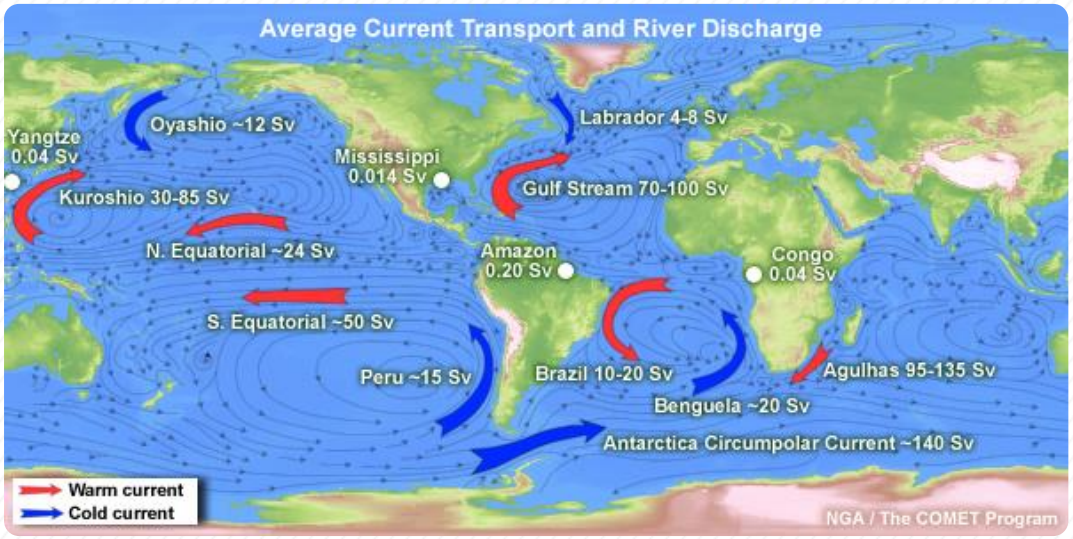
Learning Activities

2. Climate factors

5) Ocean currents

Currents impact on coastal regions. The coastal area located in cold (warm) current region experience much cooler (milder) climate than other areas at the same latitude.

For example, the coastal regions adjacent to the warm current such as the Gulf current, the Kuroshio current, and the Brazil current has milder climate especially during winter than other regions at the same latitude.



〈Major currents〉

Learning Activities

2. Climate factors

6) Air mass

An air mass is an extremely large body of air whose properties of temperature and humidity are similar. Air masses usually cover thousands of square kilometers. Depending on the topography, land-sea distribution, and circulation, unique type of air mass is acquired. The local climate systems are affected by the air mass.

Air masses can be divided into polar and tropical air mass depending on the latitude, into continental and maritime air mass depending on the surface characteristics, and into cold and warm air mass depending on the air temperature.

Learning Activities

3. Köppen climate classification

The general way to distinguish climate is with using the temperature and precipitation because these two variables are most commonly used. A widely used classification of world climates based on the temperature and precipitation was devised by Wladimir Köppen, the German scientist.

Köppen climate classification has been modified and refined since 1918. Köppen related the distribution and type of vegetation to monthly averaged temperature and precipitation. So the Köppen climate is determined by temperature and precipitation, but basically by vegetation type. Later, Trewartha modified the Köppen classification index as introduced below.

Learning Activities

3. Köppen climate classification

1) Climate classification (A~E)

Köppen scheme identifies five major climatic types, each designated by a capital letter (A to E). The classification is based on the latitude, surface condition, etc.

Tropical moist climates (group A): All months have an average temperature above 18˚C. It is between the equator and the Tropic of Cancer (Tropic of Capricorn).

Dry climates (group B): It is a region where the amount of evaporation exceeds the amount of precipitation. It is classified into the arid and semi-arid depending on the degree of dryness, or into hot arid and cold arid depending on the latitude.

Moist mid-latitude climates with mild winters (group C): the average temperature of the coldest month is between -3 ℃ and 18 ℃. Its extent is from 30 60 degrees mainly on eastern and western borders of most continents. It is further divided into three types: Mediterranean, humid subtropical, and marine.

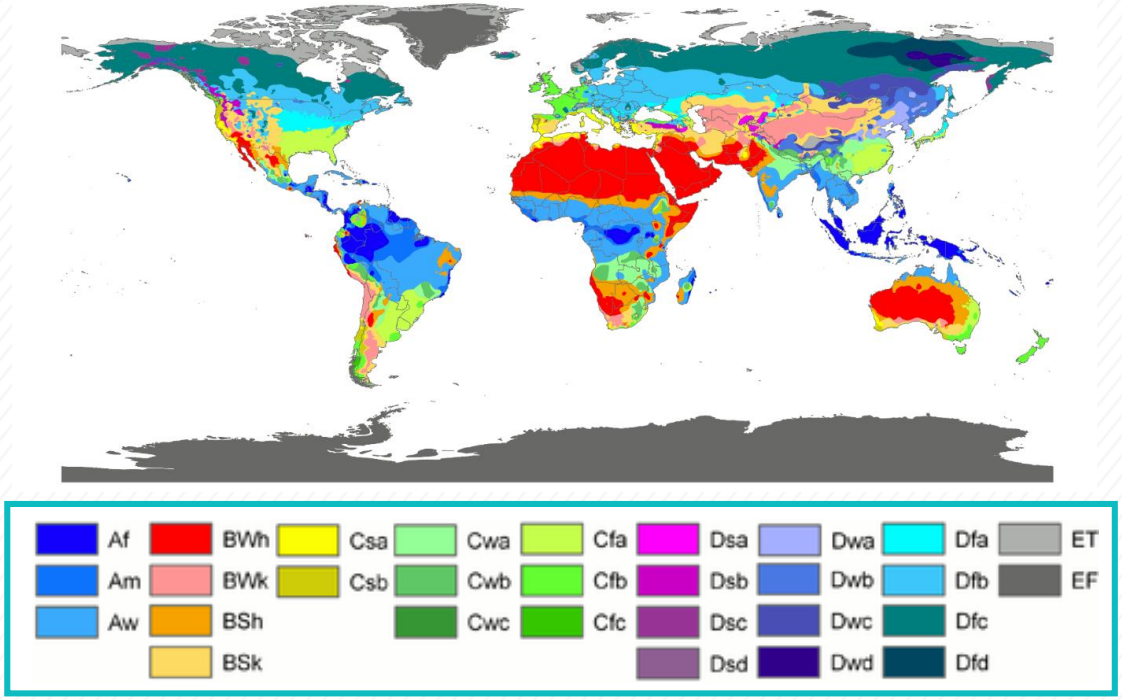
Moist mid-latitude climates with severe winters (group D): It is generally mild in summer, often severe in the winter, with the monthly average temperature of the coldest month lower than -3˚C. It can be divided into a humid continental and subpolar. This climate type can be found on the large continents (e.g., Europe, Asia, North America) between 40 and 70 degrees, but not in the in the Southern Hemisphere. The annual temperature range is very large.

Polar climates (group E): The average monthly temperature is below -10 ℃ year-round. It is located north of 70 degrees (Canada, Alaska, northern Asia, Greenland, and Antarctica). It is divided into polar tundra and polar ice caps.

Learning Activities

3. Köppen climate classification

The worldwide distribution of climatic regions is shown below. Group A is centered on the equator and C to E from the subtropics to the polar regions. The precipitation is considered only in the group B.



Summary

1. Definition of the climate system

- Climate system consists of five major components: the atmosphere, hydrosphere, cryosphere, biosphere, and lithosphere.
- The climate systems are connected through the interchange of elements, such as the energy and water vapor between these five components.
- Each component is linked by a highly complex nonlinear interaction and forms a global climate system.

Summary

2. Climate factors

Factors that control global climate are called climate factors.

- Latitude
  - The most important climate factor is the latitude because the incoming solar energy which controls the temperature depends on the latitude.
- Land and sea distribution
  - Because the specific heat capacity of the land is smaller compared to that of the water, the temperature fluctuation of land is larger than that of the sea. Climate system can be classified into mild marine climate and continental climate. The thermal difference between land and sea induces pressure gradient and the wind (and precipitation) variation.
- Prevailing wind
  - The contribution of the land-sea distribution on the climate can be affected by the prevailing wind. Regions can be divided into marine climate and continental climate regions depending on the wind source.

Summary

2. Climate factors

- Topography
  - Topography such as mountains and mountain ranges also has a large impact on the climate. The mountain ranges along the coastline block the effect of the marine climate. Topography impacts local precipitation and alpine climate.
- Ocean currents
  - Currents impact on coastal areas. The coastal areas located in cold (warm) current region experience much cooler (milder) climate than other areas at the same latitude.
- Air mass
  - Air masses can be divided into several types depending on the source region.

Summary

3. Köppen climatic classification

- Köppen climate classification has been modified and refined since 1918.
- Köppen climate is determined by temperature and precipitation, but basically by vegetation type.