ADVANCED LEVEL GEOGRAPHY

NATURAL LANDSCAPE: CLIMATIC SYSTEM

Topic 4: Climatic Variation & Classification.

Main Theme:

Are there any places with the same weather and climate?

If not, why are there climatic differences?

(I) Causes of Climatic Variation

A climate is a general weather pattern and to classify them, we can use thermal regimes and precipitation.

Climatic variation on earth’s surface is the result of the interplay of spatial variation of energy budget, atmospheric moisture and the major wind systems.

(1) Variation in Temperature (Thermal Regime 熱狀況):

(Revision on the notes of Topic 1 “Heat Budget” lecture notes)

A number of thermal regimes can be found around the global. They are labelled according to the latitude: equatorial, tropical, mid-latitude, and subartic.

They are also labelled according to their position on a landmass: “Continental” refers to an inland location, “Maritime” refer to locations close to the ocean.
**Contientality** describes the climate of a large land mass, with large ranges in the annual temperature. Continentality becomes stronger with higher latitude, because the insolation shows a stronger seasonal change with increasing latitude.

**Maritime** describes the climate of a coastal area, with small ranges in the annual temperature. Coastal land is modified by the sea influence. Since ocean heats up and cools down slowly than land, so it generate the cooler summer and warmer winter. Of course, the coastal regions are modified by this effect.

(2) **Variation in Precipitation:**

The monthly and annual precipitation affect the characteristics of the climate of different places.

The distribution of annual precipitation can be classified as humid, sub humid, wet, semi-arid, and arid.
Global Distribution of Precipitation

. The area of maximum annual precipitation, over 2000mm per year, extends in a band through the equatorial regions.

. The subtropical deserts and the polar regions have values below 250 mm.

. The mid-latitude regions have intermediate values, generally about 1000 mm per year.
Factor affecting the distribution of precipitation:

(a) Effects of Latitude:

The global variation in the thermal environment in turn determines the pressure distribution.

At the high latitudes, e.g. poles, the low temperatures result in the contraction of air and hence the development of high pressure.

At the low latitudes, e.g. TRF, the high temperatures along the equator result in the expansion of air and hence the development of low pressure.

The spatial variation in the distribution of pressure results in the motion of air (winds) which plays an important role in determine the amount and seasonal distribution of precipitation.

(b) Pressure system:

The global distribution of precipitation is considered to be basically correlated with the planetary pressure systems.

Near to the Horse Latitude and the Polar regions where the pressure is high, precipitation is scarce due to the subsiding air stream.

However, near to the equatorial low pressure belt and sub-polar low pressure belt, precipitation is abundant due to the strong updraft.

(c) Prevailing Wind

In general, the rainfall will be abundant and evenly distributed if the regions are of prevailing onshore wind all the year.

The rainfall will be little or scarce when the regions are of prevailing offshore wind all the year. When regions, usually monsoon regions, lie in the path of rain-bearing onshore wind for one season and in the path of non-bearing offshore wind in other season, the distribution of rainfall will vary seasonally.
(d) Mountain barrier:

In temperate latitudes, rainfall increases with elevation (wind slope) because air expands and cools as it rises, probably resulting in orographic rainfall.

However, in tropical areas, precipitation may decrease with increasing altitude since much of the tropical rainfall is of convective type.

As altitude increases, there will be a corresponding decrease in convection, the amount being received will be smaller.

(e) Effect of Continentality:

Under the influence of prevailing onshore wind, coastal areas will generally receive more precipitation than that of continental regions.

The amount of precipitation will steadily decrease moving inland.

Some coastal areas receive scarce precipitation when there are offshore winds.

The effect of continentality should be considered together with the direction of prevailing winds.

(f) Ocean Current:

It is regarded as local factor as it operates over small area.

A wind blowing over a cold current becomes cooled and may lose most or all of its water vapor through condensation. When the wind crosses over the land, it is not likely to produce rain. This happens off the coasts of southern California.

A wind blowing over a warm current is warmed and the rate of evaporation increases. The wind becomes moist and when it crosses over the land, it will yield rain if it is made to rise.

e.g. if it crosses a mountain range, westerlies winds crossing the warm North Atlantic Drift bring heavy rainfall to northwestern Europe.
Summary: Factors affecting the world distribution of rainfall:

<table>
<thead>
<tr>
<th>Factors</th>
<th>Rainfall is possible</th>
<th>Rainfall is impossible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>High temperature causes air to rise</td>
<td>Low temperature causes air to sink</td>
</tr>
<tr>
<td>Pressure</td>
<td>Low pressure, cyclones</td>
<td>High pressure with sinking air, e.g. anticyclones</td>
</tr>
<tr>
<td>Slope</td>
<td>Windward slope</td>
<td>Leeward slope</td>
</tr>
<tr>
<td>Wind</td>
<td>Onshore wet wind</td>
<td>Offshore dry wind</td>
</tr>
<tr>
<td>Distance from the sea</td>
<td>Coastal area</td>
<td>Inland</td>
</tr>
<tr>
<td>Ocean currents and onshore wind</td>
<td>Warm ocean current</td>
<td>Cold ocean current</td>
</tr>
</tbody>
</table>

(3) Air masses and fronts:

Our climate is affected by the nature and movements of air masses, fronts and cyclonic storms.

Air mass temperature decreases poleward, and the amount of precipitation produced by an air mass is related to its available sources of moisture.

![Diagram of air masses and fronts]

**Figure 4.1** Major air masses and fronts
(II) Climatic Classification

(A) Why classify climate?

The climate we experienced is the result of the action and interaction of climatic elements, notably pressure, wind, temperature and humidity in local.

However, certain characteristics and patterns tend to be repeat in differing parts of the world where the essential factors governing climate are similar.

In seeking a sense of order, the geographer tries to group together those parts of the world which have similar measurable climatic characteristics (temperature, rainfall distribution, winds, etc.)

The aim is to identify and to explain similarities and differences in spatial and temporal distribution and patterns. Then geographers can compare, define and explain different climatic patterns.

Problem of Classification:

1. Climate is invisible
2. Climate description involves subjective assessment
3. The degree of generalization leads to some inaccuracy.
4. The classification does not have an adequate basis
5. Climate boundaries are difficult to delimit.

(B) Climatic regions

They are defined as the regions having striking similarities in their climatic patterns and that records and readings for certain elements in these regions are very similar over a given period.

The climate we experienced is the result of the action and interaction.
(C) System of Classification

(1) Koppen's Classification (柯本分類法)

It was suggested by W.Koppen in 1918 and strictly empirical.

The climatic boundaries are approximately the same as boundaries between major vegetation types.

He selected effectiveness of precipitation for plant growth and appropriate seasonal values of temperature and precipitation as bases for climatic classification.

(a) Major Climate groups:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Climate group</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Tropical Rainy Climates</td>
<td>Hot all the year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coldest month &gt; 18°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winterless climate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annual ppt &gt; Annual evaporation</td>
</tr>
<tr>
<td>B</td>
<td>Dry climates</td>
<td>Dry all the year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evaporation &gt; precipitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No permanent stream originates in the region</td>
</tr>
<tr>
<td>C</td>
<td>Warm Temperate (Mesothermal climates)</td>
<td>Warmest month &gt; 10°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coldest month between-3°C to 18°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Have both summer and winter season</td>
</tr>
<tr>
<td>D</td>
<td>Cold Boreal Forest Climates</td>
<td>Warmest month &gt; 10°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coldest month &lt; -3 °C</td>
</tr>
<tr>
<td>E</td>
<td>Polar Climates</td>
<td>Cold all the year</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>(Microthermal</td>
<td></td>
<td>Warmest month $&lt; 10 \degree C$</td>
</tr>
<tr>
<td>climates)</td>
<td></td>
<td>Have no true summer</td>
</tr>
<tr>
<td>(Snow Climates)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note that four of these five groups (A, C, D and E) are defined by temperature averages, whereas one (B) is defined by precipitation-evaporation ratios. This procedure may seem to be a fundamental inconsistency.

(b) Subgroups

Subgroups within the five major groups are designed by a second letter according to the following codes:

S – Steppe Climate: A semi-arid climate with about $38 - 76$ cm of rainfall annually at low latitudes.

W – Desert Climate: Arid Climate (less than $25$ cm) of rainfall annual.

(The letters S and W are applied only to the dry B climates, yielding two combinations, BS and BW).

Subgroups are devised to distinguish particular seasonal characteristics of temperature and precipitation.

<table>
<thead>
<tr>
<th>Climate Subgroups</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>(f)</td>
<td>It is wet all seasons. This modifier is only applied to A, C, D Groups.</td>
</tr>
<tr>
<td>(w)</td>
<td>It is dry in winter of the respective hemisphere</td>
</tr>
<tr>
<td>(s)</td>
<td>It is dry in summer of the respective hemisphere</td>
</tr>
<tr>
<td>(m)</td>
<td>It is basically the rainforest climates in spite of short dry season. Only applicable in A climate.</td>
</tr>
</tbody>
</table>
(c) Climatic regions

Combining the major climate groups and subgroups, 12 climatic regions are
distinguished.

<table>
<thead>
<tr>
<th>Climatic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Af</td>
<td>Tropical rain forest climate</td>
</tr>
<tr>
<td>Am</td>
<td>Monsoon variety of Af</td>
</tr>
<tr>
<td>Aw</td>
<td>Tropical savanna climate</td>
</tr>
<tr>
<td>BS</td>
<td>Steppe climate</td>
</tr>
<tr>
<td>BW</td>
<td>Desert Climate</td>
</tr>
<tr>
<td>Cf</td>
<td>Temperate rainy climate (moist all the year)</td>
</tr>
<tr>
<td>Cw</td>
<td>Temperate rainy climate (dry winter)</td>
</tr>
<tr>
<td>Cs</td>
<td>Temperate rainy climate (dry summer)</td>
</tr>
<tr>
<td>Df</td>
<td>Cold snowy forest climate, moist in all season</td>
</tr>
<tr>
<td>Dw</td>
<td>Cold snowy forest climate, dry winter</td>
</tr>
<tr>
<td>ET</td>
<td>Tundra Climate</td>
</tr>
<tr>
<td>EF</td>
<td>Perpetual frost Climate (icecaps)</td>
</tr>
</tbody>
</table>
(d) Modification on Koppen’s Classification

Further details were given by W. Phol and R. Geiger to modify Koppen’s classification.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>With hot summer, the temperature of the warmest month is over 22°C (only C and D climate)</td>
</tr>
<tr>
<td>b</td>
<td>With warm summer, the temperature of the warmest month is over 22°C (only C and D climate) with at least 4 months having means over 10°C</td>
</tr>
<tr>
<td>c</td>
<td>With cool, short summer. There are fewer than 4 months with means over 10°C (only C and D climate)</td>
</tr>
<tr>
<td>d</td>
<td>With very cold winter; There are fewer than 4 months with means over 10°C But with coldest month under -38°C (D climate only)</td>
</tr>
<tr>
<td>H</td>
<td>Highland climates</td>
</tr>
</tbody>
</table>

(The third order symbols in the modified Koppen’s Classification)

(e) Merits of Koppen’s Classification

The classification system bases on data which are readily available – Temperature and precipitation. Therefore, it permits any location to be easily classified.

Besides, only a limited number of climatic regions are identified.
(f) Limitations

It fails to take account of the causes of the climate described.

It neglects the relations between the location of the climatic regions and those of pressure zones and air mass source regions.

(2) Thornthwaite’s Classification (基查勒分類法)

It was suggested by C.W.Thornthwaite in early 1930.

He selected effectiveness of precipitation, seasonal precipitation and thermal efficiency as bases for climatic classification.

Regional variations in precipitation and thermal efficiency result in the grouping of humidity provinces and temperature provinces respectively.

There are thirteen types in three major groups, as well as a more general highland climate.

(1) Group I  Low Latitude Climates

(2) Group II  Mid-Latitudes Climates

(3) Group III High-Latitudes Climates
Maps shows Strahler’s classification of climates:

![Maps showing Strahler's classification of climates](image)

*Figure 4.2 Strahler's classification of climates*

The table below shows how Koppen’s and Strahler’s Classification systems can fit together.
<table>
<thead>
<tr>
<th>Group</th>
<th>Strahler's name</th>
<th>Köppen's symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Low-latitude climes affected by equatorial and tropical air masses</td>
<td>equatorial rain forest</td>
<td>Af</td>
<td>equatorial hot-wet</td>
</tr>
<tr>
<td></td>
<td>trade wind littoral</td>
<td>Af (seasonal)</td>
<td>tropical eastern maritime</td>
</tr>
<tr>
<td></td>
<td>tropical monsoon</td>
<td>Am</td>
<td>tropical monsoon</td>
</tr>
<tr>
<td></td>
<td>tropical savanna</td>
<td>Aw</td>
<td>tropical wet-dry</td>
</tr>
<tr>
<td></td>
<td>dry tropical</td>
<td>B</td>
<td>tropical desert</td>
</tr>
<tr>
<td>II Mid-latitude climes affected by tropical and polar air masses</td>
<td>humid sub-tropical</td>
<td>Cfa</td>
<td>warm temperate eastern maritime</td>
</tr>
<tr>
<td></td>
<td>mediterranean</td>
<td>Csa</td>
<td>warm temperate western maritime</td>
</tr>
<tr>
<td></td>
<td>marine west coast</td>
<td>Cfb</td>
<td>cool temperate western maritime</td>
</tr>
<tr>
<td></td>
<td>dry mid-latitude</td>
<td>B</td>
<td>mid-latitude desert</td>
</tr>
<tr>
<td></td>
<td>humid continental</td>
<td>B and D</td>
<td>humid continental</td>
</tr>
<tr>
<td></td>
<td>subarctic</td>
<td>D</td>
<td>cold continental</td>
</tr>
<tr>
<td></td>
<td>tundra</td>
<td>E</td>
<td>cold coastal</td>
</tr>
<tr>
<td></td>
<td>icecap</td>
<td>E</td>
<td>perpetually frozen icesheet</td>
</tr>
</tbody>
</table>

*Table 4.2 Comparing Strahler's and Köppen's classifications*
(3) Miller’s Classification

It was proposed by A.A. Miller who used temperature zones as the foundation of his classification.

His subdivisions are given on the bases of seasonal distribution of precipitation, rainfall total and causes of rainfall.

The classification is simple and broad stand out clearly. However, it suffers from the problem of oversimplification.

Besides, there will be a great number of sub-climates.
(D) Examples of the World's major Climatic Zones

(1) Tropical Rainforest Climate: (Af)

(a) Distribution:

Tropical rainforest are found near the equator (10° N/S) where there is plenty of moisture and heat.

For example, they are found in the Amazon Basin of South America, the Congo Basin of Africa, and in Central America, India, and Malay Archipelago (馬來亞群島) of south-east Asia (Indonesia).

(b) Climatic Characteristics:

Temperature and humidity are high throughout the year with heavy rainfall.

Reason:

It is located in the ITCZ. It is dominated by the equatorial trough with prevailing maritime equatorial (mE) air masses and maritime tropical air mass (mT).
**Insolation:**

Lying at the low latitudes, the sun’s angle of incidence is high all the year. High insolation with equal length of day and night.

Daylight lasts for about 12 hours, but due to cloudiness, the average duration of bright sunshine is only about 5.5 hours per day.

**Length of day:**

There is little variation in the hours of daylight throughout the year.

**Temperature:**

Uniform temperature throughout the year. The mean monthly temperature is around 26°C to 27°C. The diurnal range of temperature which is between 6°C to 12°C.

At night, it rarely falls below 18°C, and by day, it rises to between 30°C and 35°C. The mean annual temperature range is only 1.1°C.

**Precipitation:**

It has heavy rainfall in all months. No dry season. The mean annual rainfall is high, over 2000mm. The rainfall distribution is even over the year with no dry season.

The air is always unstable because of:

~ converging tropical air masses, causing warm, unstable air to rise, plus the convectional air rising due to the heated ground surface, convectional rain type is common.

~ There is uplift onshore wind brings relief rainfall also. Huge cumulonimbus clouds build up, causing heavy rainstorms, often accompanied by thunder. These are very common on late afternoon at the time of maximum convection.
The daily routine is often:

~ cooler nights with nights of high humidity resulting in dew;

~ morning haze with low mist over swampy land, clearing quickly,

~ mid-morning cumulus cloud develops, increasing in size and density.

~ during the late afternoon. There is heavy downpour of rain.

~ the skies clear once more.

Rainfall in Malaysia is typically equatorial one.

Vegetation type:

There is a luxuriant growth of rainforest when there is high solar radiation, heavy rainfall, a constant moisture budget surplus, rapid decay of leaf litter and recycling of nutrients.

Trees there are tall with many different species.

(2) Tropical Desert: (BW)
(a) **Distribution:**

They are situated between approximately 15 N/S and 30 N/S on the Western sides of the continents, or in their tropical interiors. The great deserts of the **Saharan Desert**, the **Kalahari**, central and western Australia, the **Atacama**, the Middle East, and south-western North America are all found in such location.

Of all the climatic groups, the dry climates are the most extensive covering about one-quarter of the earth’s land surfaces.

(b) **Climatic Characteristics:**

Desert temperature are characterized by their extremes.

Arid region is a region where the amounts of water available through rain, soil moisture and ground water is not enough to balance the loss caused by run-off, evaporation and transpiration by plants.

**Reason:**

It is dominated by cT air mass in high pressure cells over the Tropic of Cancer and Capricorn, the subsiding air is stable and dry.

At 30 N and S there is stable air, the air subsiding, blanketing any air rising through convection. As the air sinks, it is warmed adiabatically, clouds disappear and no rain occurs. Permanent anticyclones are formed at the ground and large desert zones are created.

Trades from the horse latitudes blow offshore at the western edge of the continent.

Some tropical deserts are also affected by cold currents. The cold or cool onshore wind can carry relatively little moisture which further reduce the amount of precipitation, for example, the Atacama Desert. The Canaries current helps to keep the western Sahara dry.
**Insolation:**

The main arid zones of the world are located at latitudes where the annual amount of incoming radiation is greater than the outgoing terrestrial radiation, so they have a positive radiation balance. The reason are:

~ at low latitude, the angle of incidence of sun’s ray is high

~ the sky is normally cloudless due to little condensation.

~ sparse vegetation cannot keep the insolation from reaching the ground.

**Temperature:**

The temperature is high in summer due to high insolation.

The mean maximum temperature in summer may reach 65°C in Sahara.

Daytimes, especially in summer, receive intense insolation from the overhead sun, intensified by the lack of cloud cover and the bare rock or sand ground surface. (This is due to intense insolation, the lack of cloud cover, and vegetation).

Very high potential evapotranspiration, evaporation is larger than precipitation every month.

However, the night is clear and cold because of the outgoing radiation, with the temperature dropping to 4 °C. Thus the diurnal range of temperature is very large between 17°C to 22°C.

Greater ranges are always recorded in the heart of Sahara. The annual range is about 20 – 30 °C while the diurnal range may be over 50°C. Both are very large.

**Precipitation:**

The annual rainfall totals less than 250 mm. The annual rainfall is very low. The amounts of moisture are usually small and precipitation is extremely unreliable.
This is due to the influence of subtropical high pressure with subsiding air from the Hadley cell. Hence, trade winds are offshore with tropical continental air masses originated here.

Rain occurs in connection with violent convectional storms due to maritime tropical or equatorial air masses. It is irregular, heavy and of short duration, often causing flooding and soil erosion.

Rain is localized, with no widespread desert rain.

**Humidity:**

Relative humidity is low, below 50% in the daytime. It may drop to 10%.

High air temperatures allow an enormous capacity for moisture, so there is great potential evapotranspiration. However, only limit water is available, so there is little chance for saturation to take place. There is little or no cloud.

Frost and dew are formed by condensation in early morning hours when temperature falls. The amount of dew may be as high as 250mm. It is the main source of water supply for many low-to-ground crops and vegetation.

**Winds:**

Strong, hot, dry dusty winds connected with sandstorms are common. Winds are strong because:

~ the wind is not slowed by vegetation because of its scarcity and low height.

~ there are no barriers like mountain to block the passage of the wind.

~ in the dry conditions. Loose particles can be picked up easily by the wind.
Vegetation:

Vegetation here has to have a high tolerance to the moisture budget deficit, intense heat and often salinity. They are xerophytic.

(3) **Tundra / Arctic Climate: (ET)**

![Graph showing temperature range]

**(a) Distribution:**

They extends across the northern coastlands of Eurasia (e.g. Siberia), and Canada of North America (e.g. Alaska), and includes some of the smaller offshore islands of the Arctic Ocean. (latitude ranges 50 – 70 N). It is generally confined within the Arctic Circle.

**(b) Climatic Characteristics:**

The characteristics are long bitterly cold winters and short cool summer. On average, there is a deficit in the heat budget of the tundra region. The incoming solar radiation ranges from 150 – 220 langleys per day while the outgoing radiation is around 400 langleys per day – a daily deficit of 180 to 250 langleys.

Large heat deficit found in winter.
Reason:

In winter, the angle of incidence is very low and days are extremely short since the sun is very low. In fact, beyond the Arctic Circle, it fails to rise at all in mid-winter. Consequently, conditions are very cold.

In the winter, cP air mass, which is cold, dry and stable - can take the temperature down to –50 °C. The major characteristics of this climate is that is has no true summer.

During the high sun season, the days are long and the clear skies allow maximum sunlight to be received, but the angle of incidence is very low and enormous amounts of heat energy are used up in melting snow. Hence, the short summer remain cool and no month averages more than 10°C.

Length of day:

The length of day varies greatly. In winter, there are almost 24 hours darkness. The sun touches the horizon at noon and then drops from sight.

In summer, there are almost 24 hours daytime. There is “midnight sun”. Eskimos sleep whenever tired and not according to day and night.

This wide range of insolation over the year, with either very long periods when the sun’s ray are cut off completely, or with periods when insolation is present almost constantly, affects vegetation growth as well as human activities.

Temperature:

The tundra has a severe climate with a long, bitterly cold winter (about 9 months) and a short, cool summer.

It has about 2 – 4 months of average temperature above freezing. The average temperature of the warmest month is between 0°C to 10°C and winter temperatures are as low as -35°C to -40°C.
The annual temperature range is often great. Annual temperature ranges of inland places are everywhere greater than those of coastal places. This is because in summer the sun rays warm the and more quickly than the sea, and in winter the land cools more quickly than the sea.

Daily temperature ranges are small as there are few sunlight hours in winter and large number in summer.

Despite the long hours of insolation, the angle of the solar incidence is so low that the heat received is slight. Furthermore, much of this heat is used in melting the ice rather than in heating the ground and the air lying above. The winters are dark, giving a growing season which is rarely more than three months long.

Precipitation:

precipitation is very light, because:

~ Under the influence of polar anticyclones, the high pressure of the polar ice caps creates subsidence of the air.

~ the low temperature reduces the rate of evaporation so the air is dry.

~ the temperature also prevents the melting of snow and ice so no water is freed to become precipitation.

The warmer air in summer can carry more moisture, and so occasional rain does fall together with ice crystals and snow.

Annual precipitation is about 250-500mm. The ground is saturated with water since the permafrost prevent normal absorption.

Winds:

Cold wind create a wind-chill, and protection against exposure to this wind is very important.
Vegetation:

The absence of a true summer causes these lands to be treeless. Instead, the vegetation consists of a summer growth of mosses, lichens, sedge grasses, and low flowering plants, with dwarf conifers appearing inland and equatorward where summers are longer and warmer.

Soils are permanently frozen just below the surface because of the weak summer thaw.

This presents great problems for human development.

(E) Climatic changes:

The combination of climatic elements changes with time and space.

Studying the trends and variability of climatic data will show noticeable change in terms of cycles, fluctuations or long-term climatic trends.

Climatic changes:

A. Types of Changes:
   1. Short term changes:

      ~ Theses occur as cycles such as the recurrence of drought in semi-arid areas, or as fluctuation such as the occurrence of a single year of great precipitation. The climatic conditions of some parts of the earth surface since the beginning of man’s written history may be studied with some precision by referring to man’s written record, growth rings of old trees, migrations and sizes of human populations, archaeology and study of plant succession in some cases.

   2. Long term changes:

      ~ These changes extend for long periods, usually measurable in geological time. They have been studied by dating fossilized fuels, flora and fauna in the main, but many suggestions about them are not very definite because of the long term periods involved and the difficulty of obtaining data.
The most noticeable long term changes has been associated with the Ice Ages, the most recent of which began 1 million years ago and ended about 11000 years ago. There are many possible consequences of long term climatic changes, e.g. change in water supply, change in river flow, and possible effects on sea level.

B. Causes of climatic changes:

1. Astronomical Causes:

These are causes that involve the amount, type or distribution of solar energy interception by the earth.

   (a) changes in the amount of solar output. i.e. solar constant
   (b) Variations in the earth’s orbit around the sun.

The astronomical factors must have been important in causing the appearance and ending of the Ice Ages. They cannot explain climatic change over a short time period (20 000 years or less)

2. Changes in the atmosphere (Chemical / physical)

(a). Carbon dioxide: This is capable of absorbing more outgoing terrestrial radiation and returning the radiation back to the lower atmosphere, thus increasing heat. In general an increase of 10°C in Co₂ may mean an increase of temperature by 1°C. It appears that the heating effects of Co₂ have been stronger at least over continental areas. In the last 70 years, world measurements of carbon dioxide have shown an increase of 10%. This would naturally lead to an increase of heat absorption by the atmosphere from the earth’s outgoing longwave radiation and warms the lower atmosphere.

Sources of increased Co₂ are increased combustion of fossils fuels such , petroleum and natural gas due to increase in human populations, expansion of forestry and agriculture, and a number of industrial processes. The warming effects of Co₂ are especially marked over the higher latitudes and over individual cities, where a larger amount of fuels has been burnt.
(b) **Aerosols:**

They are mainly capable of producing more condensation nuclei increasing precipitation, and lower lowering atmospheric temperature to a slight extent.

Source of Aerosols: A large amount come from volcanic eruption, incomplete combustion, burning of forests, poor agricultural practices, increase soil erosion.

(c) **Heat releases due to human activities:**

Power generation, nuclear bomb testing, industrial and combustion processes, as well as increased respiration due to an enlarging population, all tend to give out greater heat to the troposphere. Their effects are localized in most cases, and may result in the production of urban heat island.

(d) **Changes to the earth surface**

These occur naturally on a large sub continental scale, and artificially on a local scale because of human activities.

~ **Mountain building:**

During each major mountain building period in the earth history, there had been a lowering of temperatures.

In addition, the mountain barriers would check the climatic exchange between polar and equatorial regions, thus producing a larger climatic differences, e.g. Himalayas and other fold mountain ranges in W and NW China.
~ **Depletion of ice cover:**

It would increase the amount of solar energy absorbed by the earth surface. It is because ice is a good reflector of solar radiation.

(e) **Small scale changes:**

These are mainly produced by human action, and involve some change to the earth surface and hence the temperature, humidity and precipitation characteristics of the lower troposphere.

~ changing the albedo of the earth surface by agricultural practices and urbanization.

~ clearing tropical rainforest

~ overgrazing of arid/ semi arid lands

~ irrigating arid lands

[END]