



Haramaya University

School of Geography and Environmental Studies

Geography of Ethiopia and the Horn Module

THE CLIMATE OF ETHIOPIA AND THE HORN

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CHAPTER FIVE

THE CLIMATE OF ETHIOPIA AND THE HORN

Introduction

- Ethiopia as a large country in the Horn of Africa, is characterized by a **wide variety of altitudinal ranges and diverse climatic conditions**.
- In addition, because of its **closeness to the equator and the Indian Ocean**, the country is subjected to large temporal and spatial variations in elements of weather and climate.
- The climate of Ethiopia is therefore mainly **controlled by the seasonal migration of the Intertropical Convergence Zone (ITCZ) and associated atmospheric circulations** as well as by the complex *topography of the country*.
- **Weather** is the instantaneous or current state of the atmosphere composing temperature, atmospheric pressure, humidity, wind speed and direction, cloudiness and precipitation.
- Weather parameters are measured using various instruments.
- In general, the weather that impacts the surface of the Earth and those that live on the surface takes place in the troposphere.
- **Climate** refers the state of the atmosphere **over long time periods, decades and more**.
- It is the composite of daily weather conditions recorded for long periods of time.
- Climate also takes into account the extremes or variations that may occur beyond the average conditions.

Elements and Controls of Weather and Climate

- ▶ All weather conditions may be traced to the effect of the Sun on the Earth.
 - ▶ Most changes in weather involve **large scale horizontal motion of** air which is called **wind**.
 - ▶ Weather is expressed by a combination of several elements.
 - ▶ The climate of a region is ultimately determined by **the radiation, its distribution and temporal fluctuations**.
 - ▶ The long-term state of the atmosphere is a function of a variety of interacting elements.
- Table 5.1.Elements and controls of weather and climate

Elements	Controls
1. Temperature	1 Latitude/angle of the Sun
2. Precipitation and humidity	2 Land and water distribution
3. Winds and air pressure	3 Winds and air pressure
	4 Altitude and mountain barriers
	5 Ocean currents

- ▶ The climate of any particular location on earth is determined by a combination of many interacting factors.
- ▶ These include latitude, elevation, nearby water, ocean currents, topography, vegetation, and prevailing winds.
- ▶ Moreover, the global climate system and any changes that occur within it also influence local climate.
- ▶ Hence, these determining factors are called *controls of weather and climate or climatic controls*.

A. Latitude

- **Latitude** is the **distance of a location from the equator**.
- ▶ The sun shines directly on equator for more hours during the year than anywhere else.

Latitudinal location of Ethiopia and the Horn resulted in;

- ✓ high average temperatures,
- ✓ high daily and small annual ranges of temperature,
- ✓ no significant variation in length of day and night between summer and winter.

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B. Inclination of the Earth's Axis

- ▶ The earth's rotation axis makes an angle of about $66\frac{1}{2}^{\circ}$ with the plane of its orbit around the sun, or about $23\frac{1}{2}^{\circ}$ from the perpendicular to the ecliptic plane.
- ▶ This inclination determines the location of the **Tropics of Cancer, Capricorn and the Arctic and Antarctic Circles.**
- ▶ As the earth revolves around the sun, this inclination produces a change in the directness of the sun's rays;
- ▶ which in turn causes the directness of the sun and differences in length of day and seasons.

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Equinoxes and Solstices

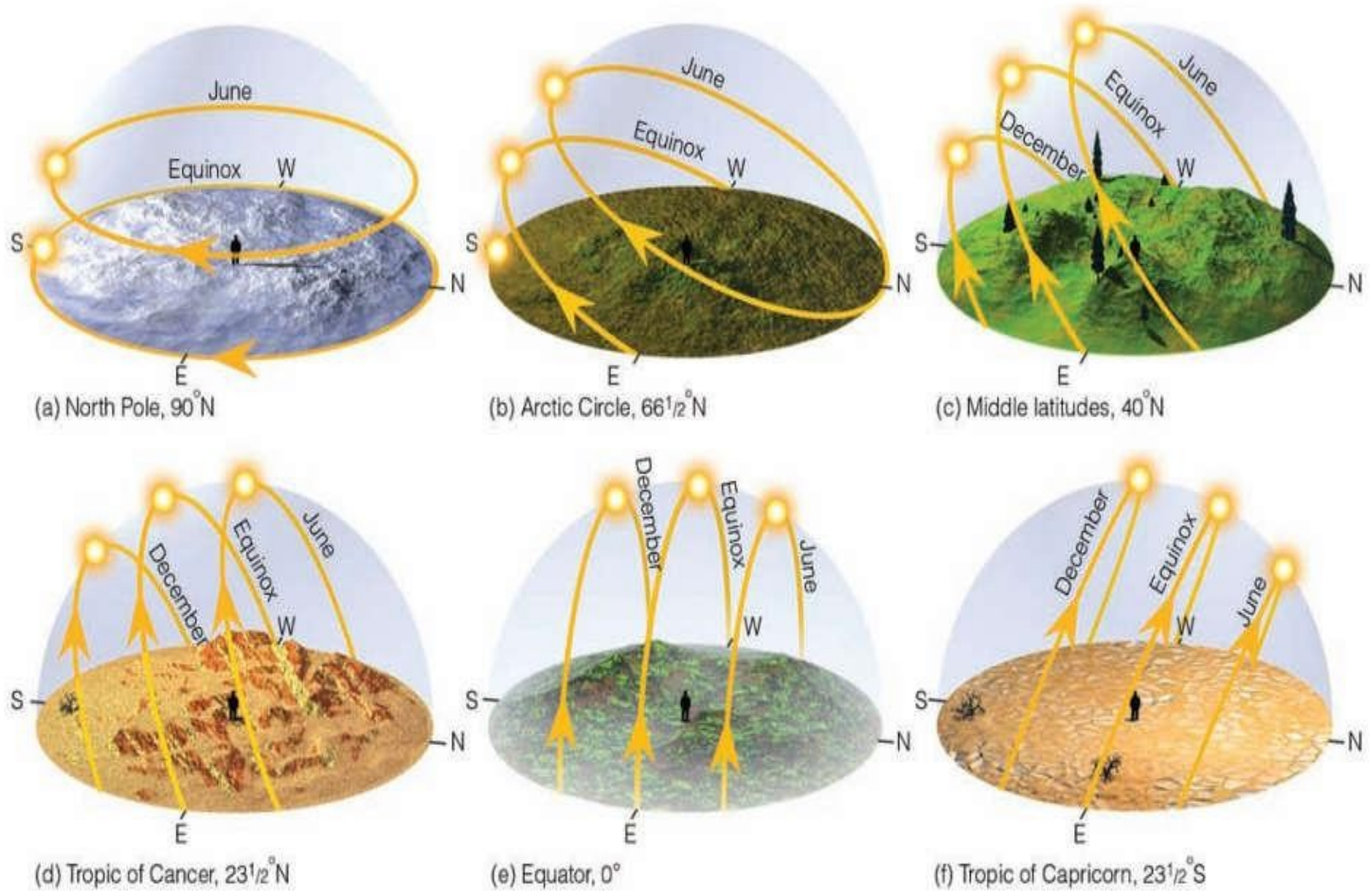
- ▶ An *equinox* is the instant of time when the sun strikes the plane of the Earth's equator.
- ▶ During this passage the length of day and night are equal.
- ▶ Moreover, revolution of the earth along its orbit, the inclination of its axis from the plane of that orbit, and
- ▶ the constant position (parallelism) of the axis causes seasonal changes in the daylight and darkness periods.

- ▶ **Equinox appears twice a year. Let's see two major equinoxes';**
 - *The Vernal (spring) equinox:* is the day when the point of verticality of **sun's rays crosses the equator northwards.**
 - This equinox experiences in **Northern Hemisphere** when the sun is exactly above the equator.
 - During this period, the length of day and night are equal.
 - **Vernal (spring) equinox** marks the beginning of Spring season. March 21 marks the offset of the vernal equinox.
 - *The Autumn equinox:* appears to happen when the sun crosses equator giving approximately **equal length between day and night.**
 - It appears to happen **when the visible sun moves south across the celestial equator on 23rd of September.** It marks the beginning of Autumn season.
- ▶ **Solstice** is an event **when the overhead sun appears to cross northern or southern points** relative to the celestial equator **resulting in unequal length of days and nights in the hemispheres.**

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- ▶ Both hemispheres during this event has either the most or least sunlight of the year.
 - ***The summer Solstice:*** on June 21st, the **northern hemisphere** has maximum tilt towards the sun experiencing longest daylight of the year.
 - It is the astronomical first day of summer in the Northern Hemisphere.
 - The **sun is at its highest position in the noonday sky, directly above $23\frac{1}{2}$ in the Tropic of Cancer.**
 - ***The winter solstice:*** 22nd of December is the day when the maximum southward inclination is attained in the **Southern Hemisphere.**
 - In this event the sun travels shortest length causing longest night and shortest daylight.
 - In the Northern Hemisphere, it occurs when the sun is directly **over the Tropic of Capricorn, which is located at $23\frac{1}{2}^{\circ}$ south of the equator.**

Figure 5.1. The apparent path of the sun at different latitudes



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C. Altitude

- ▶ Altitude is the **height of location above the sea level**.
- ▶ The average rate at which temperature changes per unit of altitudinal change is known as ***lapse rate***.
- ▶ The lapse rate is limited to the lower layer of the atmosphere named as troposphere.
- ▶ The normal lapse rate is 6.5°C per Km rise in altitude.

Types of lapse rate

i. Dry adiabatic lapse rate

- ▶ The temperature changes occurring in the rising or subsiding air mass are *not the result of additions of heat* to, or withdrawals of heat from outside sources,
- ▶ but rather are the consequence of internal processes of expansion and contraction.
- ▶ This is known as adiabatic temperature change.
- ▶ More precisely, if the upward movement of air does not produce condensation,
- ▶ then the energy expended by expansion will cause the temperature of the mass to fall at the constant *dry adiabatic lapse rate*.
- ▶ The rate of heating or cooling is about 10°C for every 1000 m of change in elevation.
- ▶ This rate applies only to **unsaturated air**, and thus it is called the ***dry adiabatic lapse rate***

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ii. Wet Adiabatic lapse rate

- ▶ The rate at which **rising or sinking saturated air changes** its temperature is less than the dry adiabatic rate.
- ▶ Prolonged cooling of air invariably produces condensation, thereby liberating latent heat.
- ▶ Therefore, rising and saturated or precipitating air cools at a slower rate than air that is unsaturated.
- ▶ This process is called **wet adiabatic temperature change**.
- ▶ The rate of cooling of wet air is approximately **5°C per 1000meters ascend**

iii. Environmental lapse rate or Atmospheric lapse late

- ▶ This refers to the actual, observed change of temperature with altitude.
- ▶ The fact that air **temperature is normally highest at low elevations** next to the earth and decreases with altitude clearly indicates that most of the atmospheric heat is received directly from the earth's surface and only indirectly from the sun.
- ▶ But the lower layer is warmer, not only because it is closest to the direct source of heat but also of its high density.
- ▶ It contains more **water vapor and dust**, which causes it to be a more efficient absorber of earth radiation than is the thinner, drier, cleaner air aloft.
- ▶ This decrease in temperature upward from the earth's surface normally prevails throughout the lower atmosphere called troposphere.
- ▶ The principal exception to the rule is the cause of temperature inversions. The rate of change is **6.5°C/1000meters**

Spatiotemporal Patterns and Distribution of Temperature and Rainfall in Ethiopia

Spatiotemporal Distribution of Temperature

- ▶ Altitude is an important element in determining temperature of Ethiopia and the Horn.
- ▶ Latitude, humidity and winds, with varying magnitude have also significant impacts on temperature conditions in Ethiopia.
- ▶ The spatial distribution of temperature in Ethiopia is primarily determined by **altitude and latitude**.
- ▶ The location of Ethiopia at close proximity to equator, a zone of maximum insolation, resulted for every part of the country to experience overhead sun twice a year.
- ▶ However, in Ethiopia, as it is a highland country, tropical temperature conditions have no full spatial coverage.
- ▶ They are limited to the lowlands in the peripheries.
- ▶ Mean annual temperature varies from over 30 °C in the tropical lowlands to less than 10 °C at very high altitudes.

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- ▶ The Bale Mountains are among highlands where lowest mean annual temperatures are recorded.
- ▶ The highest mean maximum temperature in the country is recorded in the Afar Depression.
- ▶ Moreover, lowlands of north-western, western and south-eastern Ethiopian experiences mean maximum temperatures of more than 30°C
- ▶ Daily maximum temperature varies from a high of more than 37°C over the lowlands in northeast and southeast
- ▶ a low of about 10°C-15°C over the north western and south western highlands.
- ▶ The variation in the amount of solar radiation received daily is small throughout the year.
- ▶ But in the case of monthly averages, variation is minimal and the annual range of temperature is small.
- ▶ This holds true in both the highlands and lowlands.
- ▶ In Ethiopia and elsewhere in the Horn, temperature shows seasonal variations.
- ▶ For example, months from March to June in Ethiopia have records of highest temperatures.
- ▶ Conversely, low temperatures are recorded from November to February.
- ▶ Environmental influences have their own traditional expressions in Ethiopia and there are local terms denoting temperature zones as shown in the table below:

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<i>Altitude (meter)</i>	<i>Mean annual Temp (°C)</i>	<i>Description</i>	<i>Local Equivalent</i>
<i>3,300 and above</i>	Below 10	Cool	<i>Wurch</i>
<i>2,300 - 3,300</i>	≥11.5–17.5	Cool Temperate	<i>Dega</i>
<i>1,500 - 2,300</i>	>17.5 – 20.0	Temperate	<i>Woina Dega</i>
<i>500 - 1,500</i>	>20.0 – 27.5	Warm Temperate	<i>Kola</i>
<i>below 500</i>	>27.5	Hot	<i>Bereha</i>

Table 5.2: Temperature versus Altitude

Spatiotemporal Distribution of Rainfall

- ▶ Rainfall system in Ethiopia is characterized by complexities.
- ▶ To encompass the system, it needs an understanding of the position of Inter Tropical Convergence Zone (ITC), pressure cells, and Trade Winds.
- ▶ Thus, the rainfall system in Ethiopia is characterized by spatial and temporal variability.
- ▶ The convergence of Northeast Trade winds and the Equatorial Westerlies forms the ITCZ, which is a low-pressure *zone*.
- ▶ The inter-annual oscillation of the surface position of the ITCZ causes a variation in the Wind flow patterns over Ethiopia and the Horn.
- ▶ Following the position of the overhead sun, the ITCZ shifts north and south of the equator.



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- ▶ As the shift takes place, equatorial westerlies from the south and southwest invade most parts of Ethiopia bringing moist winds.
 - ▶ The ITCZ shifts towards south of equator (Tropic of Capricorn) in January.
 - ▶ During this period, the Northeast Trade Winds carrying non-moisture-laden dominates the region.
 - ▶ Afar and parts of Eritrean coastal areas experience rainfall in this period.
 - ▶ Following the directness of the Sun in March and September around the equator, the ITCZ shifts towards equator.
 - ▶ During this time, the central highlands, southeastern highlands and lowlands receives rainfall as the south easterlies bring moist winds.
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Seasonal or Temporal Variability

- ▶ The rainfall is highly variable both in amount and distribution across regions and seasons.
- ▶ The seasonal and annual rainfall variations are results of the macro-scale pressure systems.
- ▶ The temporal variability of rainfall are characterized by;

i. Summer (June, July, August)

- ▶ From mid-June to mid-September, majority of Ethiopian regions, except lowlands in Afar and Southeast, receive rainfall during the summer season as the sun overheads north of the equator.
- ▶ High pressure cells develop on the Atlantic and Indian Oceans around the tropic of Capricorn
- ▶ Although, the Atlantic contributes a lot, the *Indian Oceans* is also sources of rainfall.
- ▶ During this season, Ethiopia and the Horn come under the influence of the Equatorial Westerlies (Guinea monsoon) and Easterlies.
- ▶ Hence, the *Guinea monsoon* and the *South easterly* winds are responsible for the rain in this season.

ii. Autumn (September, October and November)

- ▶ **Autumn** is the season of the year between summer and winter.
- ▶ The exact position of the ITCZ changes over the course of the year, oscillating across the equator.
- ▶ In autumn the ITCZ towards the equator weakening the equatorial westerlies.
- ▶ During this season, the south easterlies from Indian ocean showers the lowlands in southeastern part of Ethiopia. shifts

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➤ *iii. Winter (December, January and February)*

- In winter, the overhead sun is far south of equator.
- During this season, Northeasterly winds originating from the landmass of Asia dominantly prevail Ethiopian landmass.
- However, it has no significant coverage compared to other seasons.
- The northeasterly winds crossing the Red Sea carry very little moisture and supplies rain only to the Afar lowlands and the Red Sea coastal areas.

➤ *iv. Spring (March, April and May)*

- In this season, the noonday sun is shining directly on the equator while shifting north from south.
- The shift of the ITCZ, results in longer days and more direct solar radiation providing warmer weather for the northern world.
- In this season, the effect of the northeast trade wind is very much reduced.
- Conversely, the southeasterlies from the Indian Ocean provide rain to the highlands of Somalia, and to the central and southeastern lowlands and highlands of Ethiopia.

Rainfall Regions of Ethiopia

Based on rainfall distribution, both in space and time, four rainfall regions can be identified in Ethiopia and the Horn. These are:

i. Summer rainfall region

- ▶ This region comprises almost all parts of the country, except the southeastern and northeastern lowlands.
- ▶ The region experiences most of its rain during summer (kiremt), while some places also receive spring (Belg) rain.
- ▶ The region is divided into dry and wet summer rainfall regions.
- ▶ Hence, the wet corresponds to the area having rainfall of *1,000 mm* or more.
- ▶ The High altitudes and the windward side experience such rainfall amount.

ii. All year-round rainfall region

- ▶ It has many rainy days than any part of the country.
- ▶ It is a rainfall region in the southwestern part of the country.
- ▶ The wetness of this region is particularly due to the prepotency of moist air currents of equatorial Westerlies called the *Guinea Monsoons*.
- ▶ Both duration and amount of rainfall decreases as we move from southwest to north and eastwards.
- ▶ Months in summer gain highest rainfall whereas the winter months receive the reduced amount.
- ▶ The average rainfall in the region varies from *1,400* to over *2,200 mm/year*.

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iii. Autumn and Spring rainfall regions

- ▶ *Southeastern lowlands* of Ethiopia receive rain during autumn and spring seasons
- ▶ when both the north easterlies and equatorial westerlies are weak.
- ▶ The **south-easterlies** bring rainfall from the Indian Ocean.
- ▶ About *60 percent* of the rain is in autumn and *40 percent* in spring.
- ▶ The average rainfall varies from less than 500 to 1,000 mm.

iv. Winter rainfall region

- ▶ This rainfall region receives rain from the northeasterly winds.
- ▶ During the winter season, the Red sea escarpments and some parts of the Afar region receive their main rain.

Agro-ecological Zones of Ethiopia

- ▶ As a result of the diversified altitude and climatic conditions, Ethiopia possesses divers agro climatic zones.
- ▶ This system divides the nation into five major climatic zones namely *Bereha*, *Kolla*, *Woina Dega*, *Dega* and *Wurch*

Zones	Altitude (m) Mean annual	rainfall (mm)	Length of growing periods (days)	Mean annual temperature (°C)	Area share (%)
<i>Wurch</i> (cold to moist)	>3,200	900-2,200	211–365	Below 10	0.98
<i>Dega</i> (cool to humid)	2,300 - 3,200	900-1,200	121–210	≥11.5–17.5	9.94
<i>Weyna Dega</i> (cool sub humid)	1,500 - 2300	800-1,200	91–120	>17.5 – 20.0	26.75
<i>Kola</i> (Warm semiarid)	500 - 1,500	200-800	46–90	>20.0– 27.5	52.94
<i>Berha</i> (Hot arid)	<500	Below 200	0–45	>27.5	9.39

Table 5.3: Agro Ecological Zones of Ethiopia

- ▶ **Climate change** refers to a change in the state of the climate that can be identified (e.g. Using statistical tests) by changes in the mean and/or
- ▶ the variability of its properties and that persists for an extended period, typically decades or longer. ,
- ▶ It refers to any change in climate over time, due to either natural variability or human activities.

Current Trends of Climate in Ethiopia

- ▶ Besides spatial and temporal variations in different parts of the country, Ethiopian climate experiences extremes such as drought, flood etc.
- ▶ Ethiopia ranked 5th out of 184 countries in terms of its risk of drought.
- ▶ In the country, 12 extreme drought events were recorded between 1900 and 2010.
- ▶ Among the 12, seven of the drought events occurred since 1980.
- ▶ The majority of these resulted in famines.
- ▶ The severe drought of 2015-2016 was exacerbated by the strongest El Nino that caused successive harvest failures and widespread livestock deaths in some regions

The Greenhouse effect



Trends in Temperature Variability

- ▶ Over the last decades, Ethiopia has experienced climatic changes.
- ▶ Mean annual *temperature* has shown 0.2°C to 0.28°C rise per decade over the last 40-50 years.
- ▶ *A rise in average temperature of about 1.3°C has been observed between 1960 and 2006.*
- ▶ The rise has spatial and temporal variation.
- ▶ Higher rise in temperature was noted in drier areas **in northeast and southeast** part of the country.
- ▶ Notably the variability is higher in July-September.
- ▶ The number of 'hot days' and 'hot nights' has also shown increment.

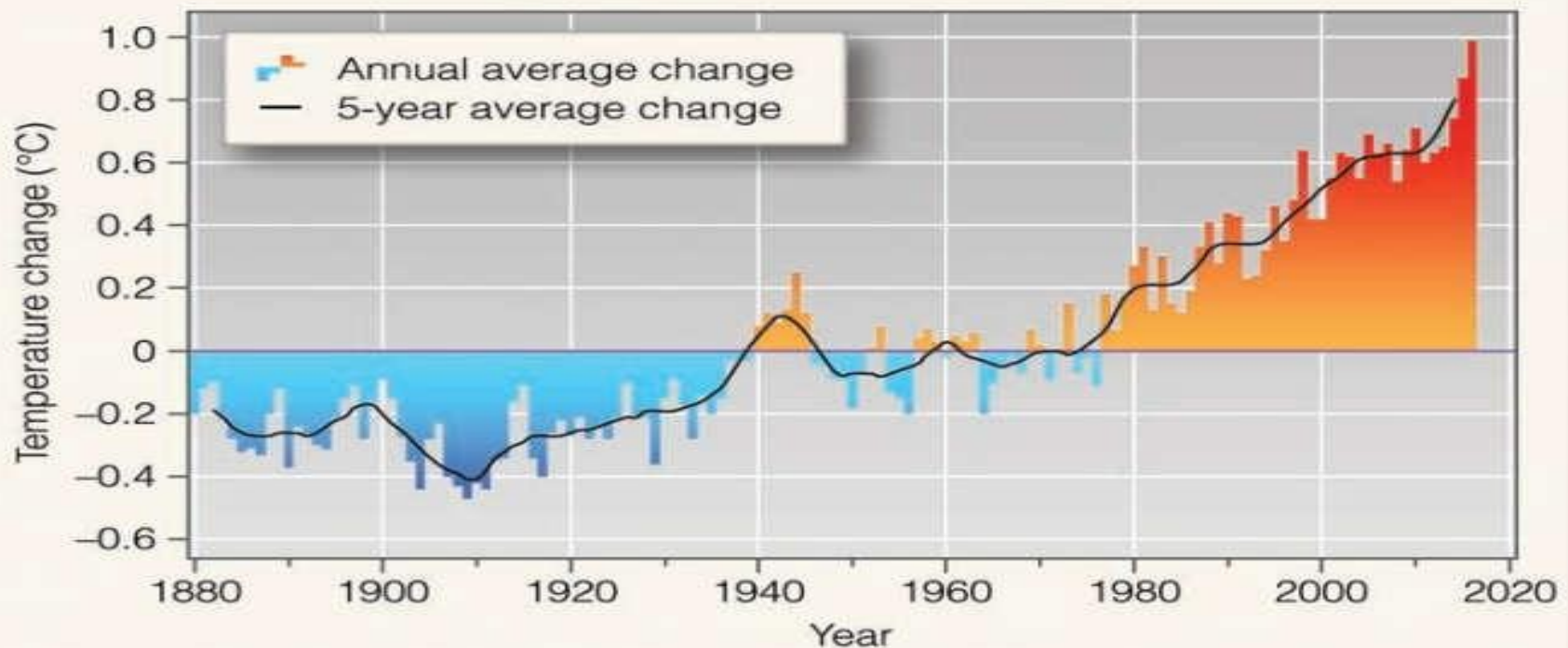
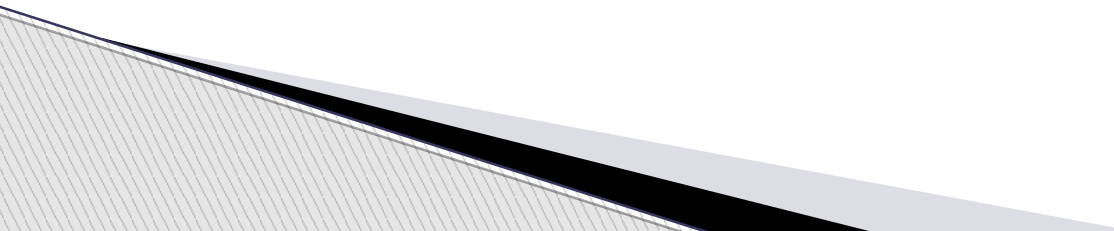


Figure 5.2: Global mean temperature anomaly.

Trends in Rainfall Variability

- ▶ Precipitation has remained fairly stable over the last 50 years when averaged over the country.
 - ▶ However, these averages do not reflect local conditions which are extremely divergent and the natural variability in rainfall in the country makes it difficult to detect long-term trends.
 - ▶ Rainfall variability is increasing (and predictability is decreasing) in many parts of the country.
 - ▶ In some regions, total average rainfall is showing decline.
 - ▶ For instance, parts of southern, southwestern and south-eastern regions receiving Spring and Summer rainfall have shown decline by 15-20% between 1975 and 2010.
 - ▶ This has strong implications for crop production, which becomes clear when assessing the change in areas that receive sufficient rain to support crop production.
 - ▶ Changes in temperature and rainfall increase the frequency and severity of extreme events.
 - ▶ Major floods have been a common occurrence, leading to loss of life and property in numerous parts of the country.
 - ▶ Warming has exacerbated droughts, and desertification in the lowlands of the country is expanding.
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Causes of Climate Change

- ▶ The causes of climate change are generally categorized **anthropogenic/manmade and natural causes.**

A. Natural Causes

- ▶ Climate change has many natural causes, such as variations in the energy budget,
- ▶ the position of Earth relative to Sun, the position of continents relative to the equator, and even whether the continents are together or apart.
- ▶ Here are some of the major natural causes:
 - ❖ **Earth orbital changes:** The earth is tilted at an angle of 23.5° to the perpendicular plane of its orbital path.
 - Changes in the tilt of the earth can lead to small but climatically important changes in the strength of the seasons. More tilt means warmer summers and colder winters.
 - ❖ **Energy Budget:** Although the Sun's energy output appears constant, small changes over an extended period of time can lead to climate changes.
 - Since the Sun was born, 4.55 billion years ago, the star has been very gradually increasing its amount of radiation so that it is now 20% to 30% more intense than it was once.
 - ❖ **Volcanic eruptions:** volcanic eruption releases large volumes of sulphur dioxide, carbon dioxide, water vapor, dust, and ash into the atmosphere.
 - The release of large volume of gases and ash can increase planetary reflectivity causing atmospheric cooling.

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B. Anthropogenic Causes

- ▶ The growing influence of human activities on the environment is being increasingly recognized, and concern over the potential for global warming caused by such anthropogenic effects is growing.
- ▶ The warming of earth planet in the past 50 years is majorly driven by human activities.
- ▶ The industrial activities that our modern civilization depends upon have raised atmospheric carbon dioxide levels from 280 parts per million to 400 parts per million in the last 150 years.
- ▶ Human induced greenhouse gases such as carbon dioxide, methane and nitrous oxide have caused much of the observed increase in Earth's temperatures over the past 50 years.
- ▶ The decomposition of wastes in landfills, agriculture, ruminant digestion and manure management, synthetic compounds manufacturing,
- ▶ clearing of land for agriculture, industrial activities, and other human activities have increased concentrations of greenhouse gases.
- ▶ The major gases that contribute to the greenhouse effect include *Water vapor*, *Carbon dioxide (CO₂)*,
- ▶ *Methane*, *Nitrous oxide*, *Chlorofluorocarbons (CFCs)*.
- ▶ Although, methane is less abundant in atmosphere, it is by far more active greenhouse gas than carbon dioxide.

Consequences of Climate Change

- ▶ In many parts of the world, climate change has already caused loss of life, damaging property and affecting livelihoods.
- ▶ The impact of climate change is higher in low income countries,

Impacts on human health: The change can cause increased heat related mortality and morbidity,

- ▶ greater frequency of infectious disease epidemics following floods and storms, and
- ▶ substantial health effects following population displacement to escape extreme weather events.
- ▶ Climate change also raises the incidence malaria.

Impact on water resources: Climate change is leading to melting of snow and glaciers that increases rise in sea level,

- ▶ increase drought and floods, distorts wind flow pattern, decreases water table.
- ▶ More frequent and longer droughts reduce the amount of run-off into rivers, streams and lakes.

Impact on Agriculture: changes in temperature and rainfall patterns as well as significantly affect agricultural production.

- ▶ Climate change increases physiological stress and fodder quality and availability.

Impact on Ecosystem: climate change affects the success of species, population, and community adaptation.

- ▶ The rate of climatic warming may exceed the rate of shifts in certain range species, these species could be seriously affected or even disappear because they are unable to resist.

- ▶ Climate change is one of the most complex issues facing us today.
- ▶ *So even if we stopped emitting all greenhouse gases today, global warming and climate change will continue as it has natural source of emission.*
- ▶ Hence, there has to be response mechanism to reduce the impact of extreme events.
- ▶ There are three major response mechanisms to climate change namely *mitigation, adaptation and resilience.*

Mitigation and its Strategies

- ▶ Mitigation measures are those actions that are taken *to reduce and control greenhouse gas emissions changing the climate.*
- ▶ Moreover, it implies reducing the flow of heat trapping greenhouse gases into the atmosphere,
- ▶ either *by reducing sources of these gases or enhancing the “sinks” that accumulate and store these gases(such as the oceans, forests and soil).*
- ▶ *The goal of mitigations is to avoid significant human interference with the climate system.*
- ▶ There are some mitigation measures that can be taken to avoid the increase of pollutant emissions.
 - ≡ Practice Energy efficiency
 - ≡ Increase the use of renewable energy such as solar
 - ≡ Efficient means of transport implementation: electric public transport, bicycle, shared cars etc.

Adaptation and its Strategies

- ▶ Adaptation is simply defined as adapting to life in a changing climate.
- ▶ It involves adjusting to actual or expected future climate.
- ▶ **The goal is to reduce our vulnerability to the harmful effects of climate change** such as extreme weather events or food insecurity.
- ▶ It also encompasses making the most of any potential beneficial opportunities associated with climate change (for example, longer growing seasons or increased yields in some regions).

Some of the major adaptation strategies include:

- ▶ building flood defences,
- ▶ plan for heat waves and higher temperatures,
- ▶ installing water-permeable pavements to better deal with floods and storm water
- ▶ improve water storage and use are some of measures taken by cities and towns.
- ▶ landscape restoration and reforestation,
- ▶ flexible and diverse cultivation to be prepared for natural catastrophes
- ▶ preventive and precautionary measures (evacuation plans, health issues, etc.)