

Unit - 1

CLIMATE SYSTEM

Weather

The atmosphere's characteristics during a short span of time are referred to as weather. Weather refers to the condition of the atmosphere on a specific day, as well as its short term variations in minutes to weeks. Temperature, humidity, precipitation, cloudiness, visibility, and wind constitute weather.

Climate

Climate data comprises statistical weather data that teaches us about average weather and the range of weather extremes for a certain region. Climate, on the other hand, is the average of weather over a period of time and location. In a nutshell, climate is the description of a region's long-term weather pattern. A simple way to remember the difference is that climate is what you anticipate, such as a very hot summer, while weather is what you receive, such as a hot day with thunderstorms popping up.

Need to study climate:

The importance of understanding climate change and climate change is that it will affect people all around the globe. Sea levels are predicted to rise as a result of rising global temperatures, as well as changes in precipitation and other local climatic factors. Forests, agriculture crops, and water supplies might all be affected by a changing area climate. It may also have an impact on human health, wildlife, and a variety of ecosystems. Deserts may develop into existing rangelands, irreversibly altering the nature of several of our National Parks and National Forests.

Types of Climates

Climate experts have divided the Earth into roughly five kinds of climates presently. They are as follows:

1. Tropical
2. Desert/dry
3. Temperate
4. Polar
5. Mediterranean

- A polar climate (also known as a boreal climate) is characterized by lengthy, frequently very cold winters and brief summers. Even in the summer, the temperature never exceeds 50°F (10°C). There are four seasons in temperate areas.
- Summers in this zone are often hot and humid, with thunderstorms, while winters are pleasant. Turkey and the majority of European nations are among the countries with a moderate climate. Deserts. Saudi Arabia and other African nations have just one or two seasons.
- Tropical climates have warm temperatures and only two seasons: rainy and dry. The average year-round temperature in this hot and humid zone is more than 64°F (18°C), with more than 59 inches of precipitation.
- The Amazon Rainforest in Brazil is one example of a tropical climate. In the summer, the Mediterranean climate is hot and dry, while in the winter, it is chilly and damp. Spain is an example of a nation having a Mediterranean climate.
- The climate of a site is affected by its latitude, ground, and height. It's also worth noting whether there are any seas or other major bodies of water nearby. Temperature and precipitation are the most prominent factors used to classify climates.

Wladimir Köppen developed the Köppen climate classification, which is the most widely used. German climate scientist Wladimir Köppen created classification systems for the world's climates in the 1800s and 1900s. For him, precipitation amounts and times of year were only a few variables to consider. Additionally, a region's latitude—the imaginary lines used to measure our Earth from north to south from the equator—was taken into account in the creation of these divisions.

There are a variety of different types of climatic systems. The Thornthwaite approach, in use since 1948, takes into account evapotranspiration in addition to temperature and precipitation. Animal species and climate change are two areas where this information may be used to get a better understanding. More attention is paid to air masses' origins in the Bergeron and Spatial Synoptic Classification schemes.

Climate System

The interplay of five key climate system components determines the Earth's climate: the atmosphere (air), the hydrosphere (water), the cryosphere (ice and permafrost), the lithosphere (earth's top rocky layer), and the biosphere (living things).

- The atmosphere is a thin layer of air that surrounds the Earth. It reaches a distance of almost 560 kilometers (348 miles) from the Earth's surface; therefore, we can only witness what happens close to the ground. This "blanket" keeps us warm, shields us from dangerous radiation, and keeps life going.
- It is largely made up of inert nitrogen (78%), oxygen (21%), and argon (2%). (0.9 percent). Some trace gases in the atmosphere, such as water vapour and carbon dioxide, are the most important for the climate system's operation because they act as greenhouse gases, allowing visible light from the Sun to reach the surface while blocking some of the infrared radiation emitted by the Earth's surface to balance the Sun's radiation.
- Surface temperatures increase as a result of this. The transport of water through the atmosphere is referred to as the hydrological cycle. Not only does the hydrological cycle affect precipitation patterns, but it also has an impact on energy flow across the climate system
- All of the liquid water on Earth is held in the hydrosphere, with the majority of it in the world's oceans. The ocean, which covers 71% of the Earth's surface and extends to a depth of roughly 4 kilometers (2.5 miles), can store far more heat than the atmosphere. It includes saltwater with an average salt level of around 3.5 percent, however this varies by location.
- Brackish water may be found in estuaries and certain lakes, while ice and snow hold the majority of freshwater, accounting for 2.5 percent of all water. All portions of the climate system where water is solid are included in the cryosphere. Sea ice, ice sheets, permafrost, and snow cover are all examples of this. Because the Northern Hemisphere has more territory than the Southern Hemisphere, snow covers a bigger portion of that hemisphere.
- The quantity of sea ice in both hemispheres is almost equal. The ice sheets in Greenland and Antarctica, which are around 2 kilometers (1.2 miles) thick, hold the majority of the frozen water. These ice sheets are gradually moving towards their edges. Global wind patterns are shaped by the Earth's crust or lithosphere, notably mountains and valleys: large mountain ranges function as a wind barrier and influence where and how much rain falls. Land closer to the open ocean has a milder climate than land farther away. The land is often considered static in climate models since it changes extremely slowly in comparison to the other factors that make up the climate system.
- The geometry of the oceans is determined by the location of the continents, which impacts ocean circulation patterns. The positions of the oceans have a vital role in managing the passage of heat and moisture throughout the world, and hence in defining global climate.
- Finally, the biosphere is involved in the climate system as a whole. Because vegetation is typically darker or lighter than the soil underneath it, more or less of the Sun's heat is trapped in plant-covered places.
- Water is trapped by vegetation, which is subsequently absorbed by the roots. This water would have drained off into the nearest rivers or other bodies of water if there had been no vegetation.
- Instead, the water absorbed by plants evaporates, contributing to the hydrological cycle. The distribution of distinct vegetation zones is influenced by precipitation and temperature. The carbon absorption from saltwater by tiny phytoplankton is about equal to the carbon assimilation from the atmosphere by terrestrial plants.

- While people are technically part of the biosphere, their huge effect on the globe causes them to be viewed as independent components of the Earth's climate system, the anthroposphere.

Difference between Climatology, Meteorology and Atmospheric Science

Atmospheric science includes both meteorology and climatology. Both include the investigation of atmospheric processes such as air temperature, pressure, and composition. Both meteorology and climatology play an essential influence in people's lives.

- **Climatology**- the study of climate and atmosphere across time. There are several ways to look at this, from a statistical one to a physical one. In most cases, the statistical method focuses on extremes in the climate. It is possible to utilise physical climatology to reconstruct or anticipate the climate.
- Forecasting weather is a major focus in meteorology. They interact with people on television and in forensic meteorology and generate predictions and other information. Many meteorologists focus on improving atmospheric models or other parts of forecasting as a research topic in order to enhance their forecasting abilities.
- Climatology is concerned with long-term atmospheric behaviour over a long period of time, while meteorology is concerned with atmospheric phenomena occurring at any time and over short time periods of a few days or less.
- Climatology investigates phenomena that are connected to subjects outside than atmospheric science, such as geology and astronomy, while meteorology focuses on the atmosphere. Climatology focuses on the history, while meteorology focuses on the current and short term changes lasting a few hours to a few days.

Earth System Science Organization (ESSO):

For its policies and programmes, the Earth System Science Organization (ESSO) in New Delhi serves as the executive arm of the Ministry of Earth Sciences (MoES).

- The ESSO offers general guidance to the centers/units and monitors programme execution.
- The ESSO was founded in October 2007 as a virtual organisation with the goal of uniting all meteorological and ocean development operations under one roof, recognising the need of strong coupling among the earth's numerous components, such as the atmosphere, oceans, cryosphere, and geosphere.
- Ocean Science and Technology, Atmospheric and Climate Science, Geoscience and Technology, and Polar Science and Cryosphere are the four primary fields of earth sciences.
- The project's only goal was to look at numerous parts of earth processes holistically in order to better comprehend the variability of the earth system.
- The primary goal of the ESSO is to create and enhance forecasting, weather, climate, and hazard-related phenomena for social, economic, and environmental advantages, particularly tackling climate change research and climate services.
- ESSO is also in charge of technological development for the sustainable exploration and use of marine resources for the benefit of society's socioeconomic well-being, taking into consideration worldwide advancements in the area of marine environment.
- One of ESSO's goals is to support polar scientific research in both the Antarctic and Arctic areas in order to better understand the effects of these regions' phenomena and processes on global climate and weather, notably in the Indian Ocean.
- The ESSO's overarching mission is to be a world leader in knowledge and technology enterprise in the field of earth system science for the benefit of the Indian subcontinent and the Indian Ocean area.
- It is made up of three primary elements: Assist academic and practical research in Earth System sciences, including the atmosphere, hydrosphere, cryosphere, and geosphere, with a focus on the Indian subcontinent and adjacent waters, as well as the Polar Regions.

- Using well-integrated systems, provide the best possible services to the nation in predicting monsoons and other weather/climate parameters, ocean status, and early warnings to natural catastrophes such as storm surge, earthquakes, tsunamis, and other phenomena.
- Encourage the advancement of research and technology for the exploration and exploitation of ocean resources (both living and non-living), guaranteeing their long term viability.
- **These policies/programmes are being pursued through its following centers:**
 - Centre for Marine Living Resources and Ecology (CMLRE)
 - National Center of Coastal Research (NCCR)
 - National Center for Seismology (NCS)
 - National Centre for Medium Range Weather Forecasting (NCMRWF)
 - India Meteorological Department (IMD)
 - National Institute of Ocean Technology (NIOT)
 - Indian National Centre for Ocean Information Services (INCOIS)
 - National Centre for Polar and Ocean Research (NCPOR)
 - Indian Institute of Tropical Meteorology (IITM)
 - National Center for Earth Science Studies (NCESS)

✚ **World Meteorological Organization (WMO):** The United Nations (UN) specialized organization charged with promoting the creation of a global meteorological observation system, the application of meteorology to other sectors, and the development of national meteorological services in developing countries. The International Meteorological Organization (IMO), a nonprofit organization created in 1873 by the leaders of several country meteorological agencies, came before the WMO. The World Meteorological Organization was established by the World Meteorological Convention, which was accepted during the IMO's 12th director's conference in 1947. The World Meteorological Organization (WMO) was founded in 1951 and is headquartered in Geneva, Switzerland. Every four years, the World Meteorological Congress, which includes representatives from all 185 members, gathers to define general policy and implement rules. World Weather Watch, a system of satellites and telecommunication networks connecting land and sea sites for weather monitoring; the World Climate Program, which monitors climate change, including global warming; and the Atmospheric Research and Environment Program, which was created to promote research on issues like ozone depletion, are just a few of WMO's major programmes.

✚ **General Characteristics of the Atmosphere**

The following are the key properties of the atmosphere:

- Air has no colour, no odour, and no taste.
- It's flexible, movable, and compressible.
- We can't perceive its existence until it's moving horizontally.
- Wind is the horizontal motion of air. Air has mass, and atmospheric pressure is the force exerted by it.
- Atmospheric pressure is an important climatic factor.
- The pressure at sea level is 1034 gram per square cms. (14.7 pounds per square inch, to be exact.)

✚ **Significance of the Atmosphere**

The atmosphere is responsible for the existence of all living forms.

- Animals and plants both need oxygen and carbon dioxide.
- The atmosphere is the source of oxygen and carbon dioxide.
- The atmosphere keeps the Earth's water and radiation levels in check.
- The temperature that we choose is maintained by the atmosphere.
- There would have been temperature extremes of about 260°C between day and night if there had been no atmosphere.

- It protects us against ultra-violet radiation from the Sun, which is harmful to both plants and animals.
- It serves as a protective barrier against meteor attacks.
- Weather is created when the currents, movements, and other activities of the atmosphere come together.

Composition of the Atmosphere

Permanent gases, Variable gases, Aerosols

1. Permanent gases

- stable concentration in the atmosphere.
- account for around 99 percent of atmospheric mass. occur in a constant proportion in the lowest 80 kilometers of the atmosphere.
- Despite the fact that individual molecules move between the atmosphere and the Earth, the overall concentration stays constant. uniformity of chemical composition.
- The Homosphere is the atmosphere below 80 km and is frequently regarded to be the whole atmosphere; the Heterosphere is the atmosphere above 80 km. $N_2 + O_2 = 99\%$ of atmospheric volume below 80 km.
- They are chemically active. Ar, Ne, He, Xe < 1% and are chemically inert.
- Nitrogen is supplied and withdrawn from the atmosphere extremely slowly, with a 42 million-year residence time.
- While N_2 is largely inconsequential for most meteorological and climatic processes, other N-containing gases, such as NO_2 , are critical to the Earth's climate.
- Oxygen is essential for the survival of practically all living things on the planet. It has a 5000-year residency time.

2. Variable gases (distributions vary both in time and space)

They account for less than 1% of the atmosphere below 80 km. some of these gases have a significant influence on the atmosphere's behaviour.

3. Water Vapor (0.25%)

- Water vapour has a lot of variation in both space and time. Evaporation, condensation, and precipitation continuously cycled between the atmosphere and the ground.
- Evaporation and condensation store and release enormous quantities of heat.
- Water vapour only has a 10-day residence period.
- WV density is highest at the surface and quickly falls as one rises.
- The importance of WV for clouds cannot be overstated.
- Radiant radiation released from the Earth's surface is absorbed by WV.

4. Carbon Dioxide (0.036%)

- Plant and animal respiration, organic material degradation, volcanic eruptions, and both natural and anthropogenic (human-caused) combustion all contribute to the supply of CO_2 . Photosynthesis, the process by which green plants transform light energy into chemical energy, removes it.
- As a by-product, oxygen is released into the atmosphere. CO_2 has a residence duration of 150 years. It is a good absorber of longwave radiation emanating from the surface of the Earth. Since 1958, its content in the atmosphere has grown by 18%.

5. Ozone (0.01%)

- O_3 is a strange molecule with three oxygen atoms. It is formed when individual O atoms contact with an O_2 molecule and is found in extremely low quantities in the stratosphere.
- O_3 is necessary for absorbing the sun's deadly UV rays. It breaks down into its essential components $O + O_2$ as it does so. Ozone is a pollutant near the surface, but only in trace levels.

6. Aerosols

- They are created by both natural and artificial processes and are tiny solid or liquid droplets (excluding water particles) in the air.
- Aerosols often have a few days to many weeks of residence duration.
- Aerosols are formed by chemical processes, wind-generated dust, volcanic ejections, sea spray, and burning, and serve as condensation nuclei, the core around which water may condense in clouds (e.g., fine ash).
- precipitation removes carbon dioxide from the atmosphere.

Vertical Structure of the Atmosphere

The atmosphere is split vertically into five layers depending on temperature and height above the Earth's surface, structured like spherical shells. Each zone has its own set of physical and chemical features, such as density, pressure, chemical and electrical properties, and temperature.

The five layers are as follows:

- The troposphere
- The stratosphere
- The mesosphere
- The ionosphere
- The exosphere

➤ **The Troposphere:**

The term troposphere is derived from the Greek word *tropein*, which means to turn or alter. The troposphere is where all of the earth's weather happens. The troposphere has the features listed below.

- It stretches for an average of 12 kilometers from the earth's surface (7 miles).
- Its height at the Equator is about 16 kilometers in normal circumstances. It's around 8 kilometers at the Poles. Its height varies from location to location and season to season.
- The pressure fluctuates between 1000 and 200 millibars (29.92 in. to 5.92 in.). As you climb higher, the temperature drops until you reach the tropopause (top of the troposphere), which is about 200 millibars or 36,000 feet.
- The average lapse rate is 6.5 degrees Celsius every kilometer, or 3.6 degrees Fahrenheit per 1000 feet.
- The temperature ranges from 15°C (59°F) at the surface to -57°C (-71°F) in the tropopause, with the layer ending when temperature no longer changes with height. The tropopause represents the transition from the lower atmosphere to the upper atmosphere.
- It comprises about 75% of total gaseous mass, as well as all moisture and dust particles.
- The troposphere is 70 percent and the stratosphere is 21 percent. We wouldn't be able to exist because of the reduced density of molecules further up. Up to the jet stream, wind velocity rises with height, peaking at the tropopause.
- Because of the presence of water vapours, many forms of clouds, anti-cyclones, cyclones, thunderstorms, and other phenomena occur in this layer. Up to the tropopause, the moisture concentration declines with height.
- Above the tropopause, in the stratosphere, the air is substantially dryer. It is also known as the convective zone because the sun's heat is carried upwards primarily by convection and mixed by updrafts and downdrafts.

➤ **Tropopause:**

Tropopause = the transition between the troposphere (below) and the stratosphere (above). By definition, temperature remains constant with height since it does not decrease, as in the troposphere, or increase, as in the stratosphere. The lowest 10-kilometer lapse rate is 0.

- The tropopause reaches its highest heights at the Equator, which is about 18 kilometers, due to warm temperatures and well-developed thermal mixing.
- The coldest temperatures occur immediately above the Equator, rather than at the poles. The height of the tropopause varies with meteorological conditions in the middle latitudes.
- The average height in January is around 12.5 kilometres in latitudes 45°N and S. In July, it's 15 kilometers. In the Tropics, it is highly defined, while in the Polar Region, it is less so. Most clouds and storms reach their maximum height at this point.
- It denotes the typical upper limit of atmospheric property transmission. A severe temperature inversion characterises it.
- As you climb further above this zone, the temperature begins to rise somewhat.

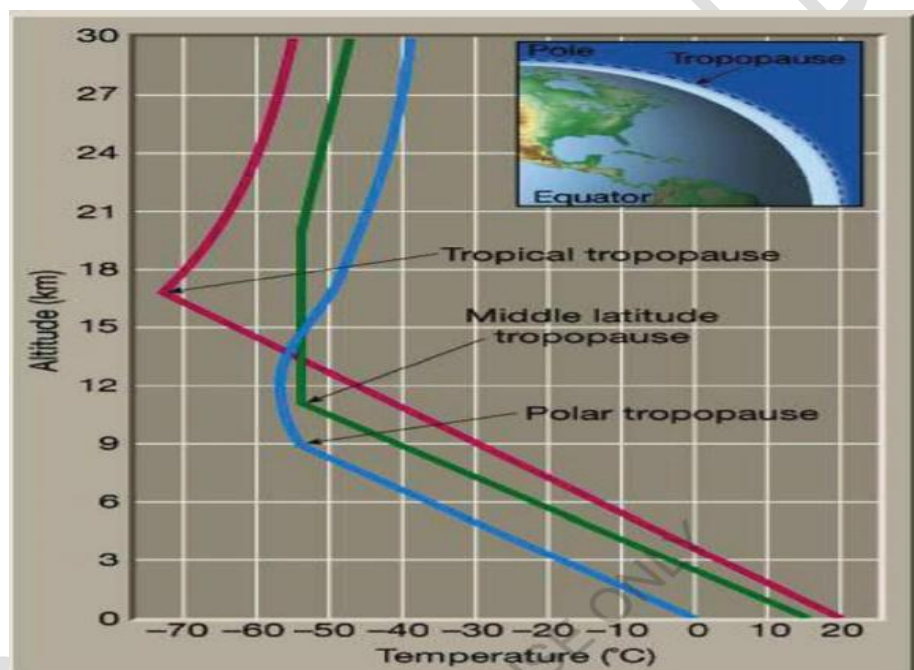


Figure 1. 6 Observed lapse rate and the tropopause

➤ The Stratosphere:

- The stratosphere is the next highest layer, ranging in thickness from 11 to 31 miles (17 to 50 kilometers) above the earth's surface, depending on location and weather.
- At the Poles, the layer's thickness is the thickest.
- The ozone layer of the planet is found in the stratosphere. Ozone, a kind of oxygen, is essential for human life because it absorbs a significant amount of ultraviolet sun radiation.
- The lower stratosphere contains only the tallest clouds (cirrus, cirrostratus, and cirrocumulus). The temperature in the lower stratosphere is isothermal, meaning that it does not fluctuate with height.
- This temperature scenario exists up to a distance of around 30 kilometers. Beyond 30 kilometers in height, the temperature rises. This is the stratosphere's top layer. Because vertical mixing is prohibited with an inversion layer, multiple layers are not blended (= stratified, thus the layer's name).

- Heat source = ozone layer absorption of UVB (240-320 nm light). This zone is characterized by high wind speeds.
- Cirrus clouds arise in the lower stratosphere on occasion. 12 This stratum is devoid of meteorological phenomena. Stratopause is the transition zone between the stratosphere (below) and the mesosphere (above) (above).
- Troposphere and Stratosphere both refer to the "lower atmosphere."

➤ **The Mesosphere:**

- The mesosphere is located between 31 and 50 miles (17 and 80 kilometers) above the earth's surface. Temperatures in the mesosphere plummet to roughly -100°C as altitude rises.
- The mesosphere is also the layer where a large number of meteors burn up when they reach the Earth's atmosphere. They appear like shooting stars from Earth.
- Mesopause is the transition between the mesosphere (below) and the ionosphere (above). The Thermosphere: The temperature rises as one rises in height. Because of the Sun's might. Temperatures in this part of the world may reach 1,727 degrees Celsius.
- The dispersed air particles in this layer become electrically charged as a result of radiation, allowing radio signals to bounce off and be received beyond the horizon (see ionosphere).
- The ionosphere and exosphere are two distinct regions of the thermosphere.

➤ **The Ionosphere:**

- The ionosphere and exosphere are two distinct regions of the thermosphere. Ionosphere: 70-640 km (about 400 miles = 640 km).
- It has a lot of ions and free electrons in it (plasma). Auroras may be seen in the ionosphere. The Aurora Borealis, often known as the northern lights, is caused by particles from the sun colliding with the Earth's atmosphere.
- The temperature drops as one rises in altitude.

➤ **The Exosphere:**

the outermost layer of the Earth's atmosphere, ranging in altitude from 400 miles (640 km) to 800 miles (1280 km).

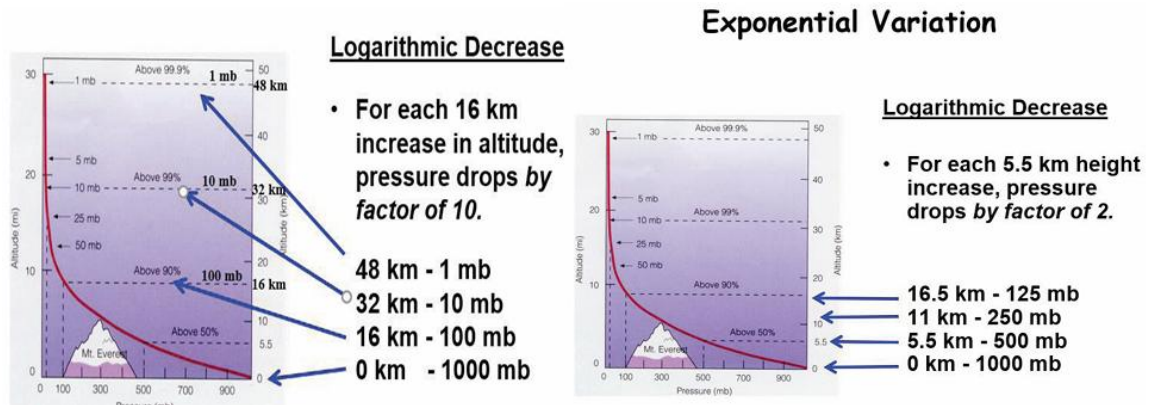
- The critical threshold of escape is the lowest border of the exosphere, when atmospheric pressure is extremely low (gas atoms are very widely separated) and temperature is very low.
- Atoms and molecules escape into space at this area.
- The exosphere is nearly devoid of air. There is virtually little "air" there. Even if the air is very hot, thin air does not transmit much heat to objects in the air.
- The temperature is high when the particles are travelling extremely quickly.
- The temperature is lower when particles bounce around more slowly. Because the particles in the exosphere move so fast, the temperature there is quite high. The exosphere, on the other hand, would be rather chilly to humans. T
- here are extremely few particles in the exosphere since the "air" is so thin - it's virtually a vacuum. When particles collide with our skin and transmit heat energy to us, we feel heated.
- Even though each particle is relatively "hot," there are too few particles in the exosphere to transmit much energy. When a lot of sunlight shines on an object in the exosphere, it becomes heated.
- Because the sun is so brilliant up there, items that are exposed to it rapidly heat up. Objects in the shadow, on the other hand, might get very chilly.

- For example, one side of a satellite (the sunny side) may be very hot, while the other (in the shadow) could be quite cold.

Density and Pressure Variation

Density and Pressure decrease rapidly with height.

Air is compressible, i.e., its density varies.



Heat Balance of Earth Atmosphere

- The energy balance between the Sun's entering energy and the Earth's outgoing energy is known as the earth-atmosphere energy balance.
- Shortwave light and ultraviolet energy are two types of energy produced by the Sun. Some of it is reflected back to space by clouds, some is absorbed by the atmosphere, and some is absorbed at the Earth's surface when it reaches the Earth.
- However, since the Earth is far colder than the Sun, the infrared light it emits is much weaker (long wavelength). On bright sunny days, we may observe this energy radiating into the sky as heat rising off a scorching road, causing shimmers.
- The energy balance between the Earth and the atmosphere is reached when the energy received from the Sun equals the energy lost by the Earth back into space.
- The Earth maintains a consistent average temperature and, as a result, a stable climate in this fashion. The energy balance is as follows, using 100 units of energy from the sun as a baseline:

Table 1. 1 At the top of the atmosphere - Incoming energy from the sun balanced with outgoing energy from the earth.

Incoming energy		Outgoing energy	
Units	Source	Units	Source
+100	Shortwave radiation from the sun.	-23	Shortwave radiation reflected back to space by clouds.
		-7	Shortwave radiation reflected to space by the earth's surface.
		-49	Longwave radiation from the atmosphere into space.
		-9	Longwave radiation from clouds into space.
		-12	Longwave radiation from the earth's surface into space.
+100	Total Incoming	-100	Total Outgoing

- Let's start at the top of the atmosphere, where we can view the overall balance of the Earth-atmosphere system.
- The atmosphere's budget is likewise balanced, since it receives 156 units and loses 156 units. Incoming solar radiation (100 units) is balanced by departing shortwave reflection from the Earth's surface and atmosphere and outgoing longwave radiation from the atmosphere and surface. Absorbed incoming solar radiation, absorbed longwave radiation from the surface, and latent and sensible heat transfer from the surface are all examples of received energy.
- The surface gets 145 units and loses 145 units as a result of the atmosphere losing longwave energy to space and counter adiation to the surface. Direct solar radiation absorbed at the surface and longwave radiation from the atmosphere make up the incoming energy. Latent and sensible heat transfer to the 16 atmosphere, as well as longwave radiation to the atmosphere and space, are examples of exiting energy. Infrared radiation attempting to escape from the Earth and return to space is absorbed, which has a significant impact on the global energy balance.
- The atmosphere absorbs more energy and stores it at its surface than it would if there were no atmosphere. The surface loses 102 units of longwave energy to the atmosphere, but receives 95 units of counter-radiation. These flows form a loop that catches and returns the majority of the heat radiation that escapes the surface, maintaining warm surface temperatures.
- The moon's average surface temperature is 0°F (-18°C) since it has no atmosphere. The average surface temperature of the Earth, on the other hand, is 59°F (15°C). The greenhouse effect is the name given to this heating effect.

The Greenhouse Effect

- If concentrations of greenhouse gases (such as CO₂) in the atmosphere are changed, then the earth's equilibrium temperature will also change. If there were no greenhouse gases, the earth's temperature would be far lower in equilibrium (0°F instead of 59°F).

Global Climate Change

- The global energy budget aids in our comprehension of the potential impacts of climate change on Earth. Consider, for instance, how the conversion of agricultural lands into urban and suburban areas and the clearance of forests for farming would reduce surface albedo. In such scenario, the ground would absorb more energy, increasing its warmth.
- This would then augment counter radiation by increasing the flow of surface longwave radiation into the atmosphere, where it would be absorbed. The greenhouse effect would most likely be amplified as a result of the overall impact.
- The Earth's surface and atmosphere cool as a result of increased shortwave reflection back to space caused by low clouds. These might lead to an increase in high, thin clouds, which increase longwave absorption and warm the atmosphere, raising counter radiation and strengthening the greenhouse effect.
- Our climate system depends critically on the energy fluxes that connect the Sun, Earth's surface, atmosphere, and space, and human activity has the potential to drastically alter these flows.
- The Intergovernmental Panel on Climate Change (IPCC) stated in 2007 that: The average temperature of the planet is rising (1.33°F in the last 100 years).
- Compared to earlier this century, temperatures are rising more quickly now.
- While severe cold occurrences are declining, extreme warm events are rising.
- The world's snow cover is dwindling. Human-caused greenhouse gas emissions are most likely to blame for everything mentioned above.

Air Temperature Change

Add (remove) heat to (from) the air parcel (adiabatic processes) leads to change in air temperature with following processes:

- **Conduction:** Heat is transferred between molecules by conduction. Contact is necessary for this energy transfer procedure. The conductivity of air is weak. Having little thermal conductivity. On vast spatial scales, conduction is not an effective way to transmit heat in the atmosphere.
- **Convection:** Convection is the mass motion of a fluid that transfers heat (such as air or water). When a hot fluid travels away from the heat source while carrying energy, convection is created. In certain locations (like the tropics), convection is an effective method of heat transport for the atmosphere, but it is an ineffective process in other regions (such as the polar regions). 18 Figure 1. 11 Convection
- **Radiation:** Solar energy, which travels from the Sun to the Earth through empty space and serves as the primary energy source for Earth's weather and climate, is transferred as heat through the emission of electromagnetic waves that transport energy away from the emitting item. Radiation transfer is a significant means of energy transmission between the atmosphere and the earth's surface as well as between various layers of the atmosphere.
- Radiation transfer accounts for nearly all energy exchange between the Earth and the rest of the cosmos.
- Radiation energy comes in an infinite number of wavelengths.
- We can divide these wavelengths into a few bands.
- 1 micrometer (μm) = 10^{-6} meter (m) Planetary Energy Balance Solar Energy Absorbed = Terrestrial Energy Emitted Determine Earth's Surface Temperature

✚ **Solar and Terrestrial Radiation Energy** is radiated from every item throughout a wide variety of wavelengths, not only at a single wavelength.

- The maximum intensity of solar energy is radiated at a wavelength significantly shorter than that of the greatest energy released by the Earth.
- The sun radiates more energy than the Earth.
- Wavelength and Temperature The hotter the objective, the shorter the wavelength of the peak radiation.

✚ **Shortwave and Longwave Radiations**

- Solar radiation is often referred to as "shortwave radiation".
- Terrestrial radiation is referred to as "longwave radiation".
- Units of Air Temperature Fahrenheit ($^{\circ}\text{F}$) Celsius ($^{\circ}\text{C}$) $\rightarrow ^{\circ}\text{C} = (^{\circ}\text{F}-32)/1.8$ Kelvin (K): a SI unit $^{\circ}\text{K} = ^{\circ}\text{C} + 273.15$

✚ **Absolute Zero Temperature**

- The temperature at which molecules are completely immobile is known as absolute zero, which occurs at -273°C .
- This absolute temperature serves as the "zero" temperature for the new temperature scale known as the Kelvin Scale (K): $\text{K} = ^{\circ}\text{C} + 273$