18CEO406T - GLOBAL WARMING AND CLIMATE CHANGE

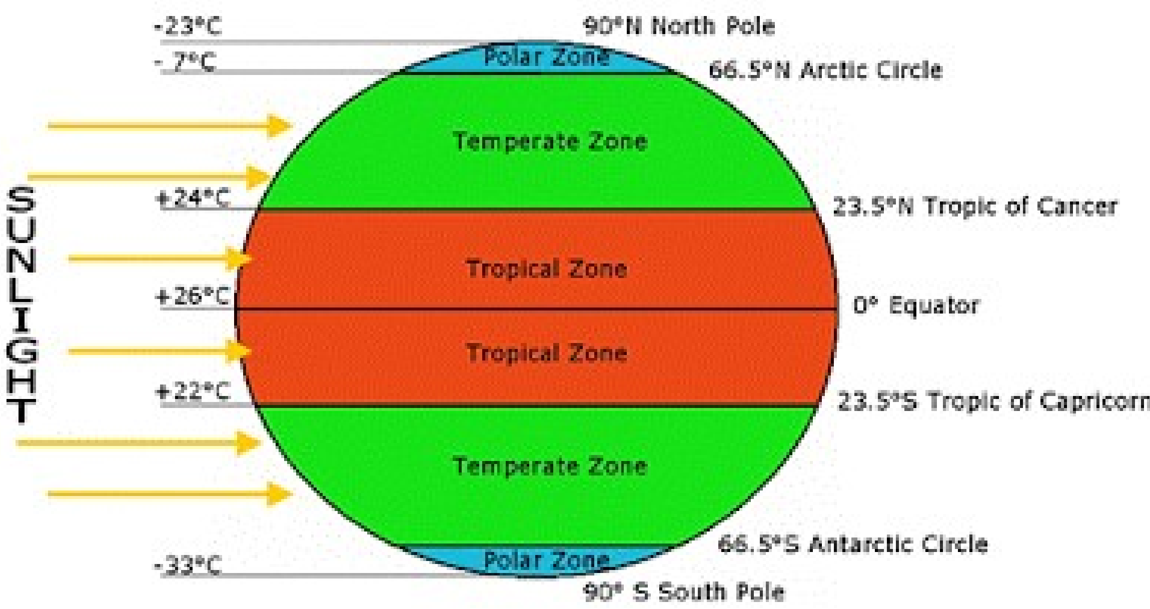
UNIT – 1 [S1 to S3]

S1 : Introduction to earth system – Hydrosphere, lithosphere, cryosphere, atmosphere and biosphere

Introduction to earth Climate

The climate of a place may be defined as a "composite" of the long-term prevailing weather that occurs at that location. In a sense, climate is "average weather". Climate can be measured quantitatively by calculating the long term averages of different climate elements such as temperature and rainfall. Extremes in the weather however, also help us define the climate of a particular area.

We can study climate on a range of geographical scales.



1. Local climate
2. Regional climate
3. Global climate

Local climate:

At the smallest scale, local climates influence areas maybe only a few miles or tens of miles across. Examples of local climatic phenomena include sea breezes and urban heating.

Regional climate:

At larger scales, regional climates provide a picture of particular patterns of weather within individual countries, or within climate zones that exist at different latitudes on the Earth. Climate zones include tropical, subtropical, desert, Savannah, temperate and polar climates. Different climate zones reveal variable patterns of temperature and rainfall

Global climate

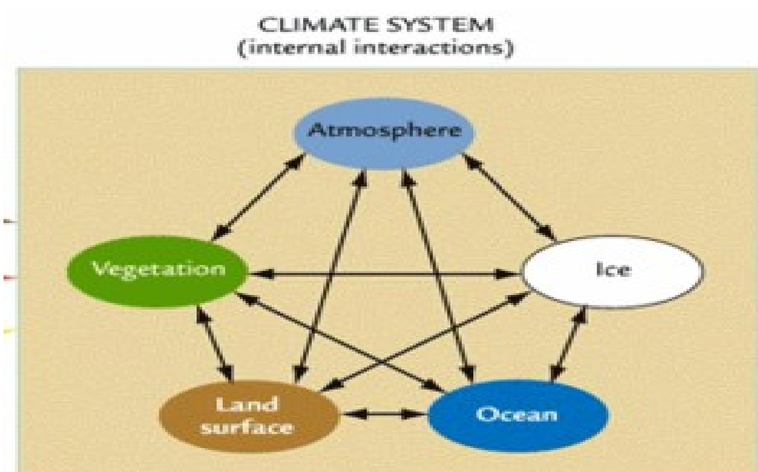
The term "global climate" is used to refer to the general state of the world's climate. Whilst different climate zones may be identified, with different types of weather in different parts of the world, climatologists sometimes like to study the general climate of the whole Earth, for example when investigating evidence for climate change.

The simplest means of assessing the state of the global climate is to measure the global average temperature of the Earth's surface and atmosphere in contact with it

Climate system

The **climate system** is a complex, interactive **system** consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. The atmospheric component of the **climate system** most obviously characterises **climate**; **climate** is often defined as 'average weather'.

The key to understanding global climate change is to first understand what global climate is, and how it operates. At the planetary scale, the global climate is regulated by how much energy the Earth receives from the Sun. However, the global climate is also affected by other flows of energy which take place within the climate system itself. This global climate system is made up of the atmosphere, the oceans, the ice sheets (cryosphere), living organisms (biosphere) and the soils, sediments and rocks (geosphere), which all affect, to a greater or less extent, the movement of heat around the Earth's surface.



Earth's climate arises from the interaction of five major climate system components:

1. Atmosphere (air),
2. Hydrosphere (water),
3. Cryosphere (ice and permafrost),
4. Lithosphere (earth's upper rocky layer) and
5. Biosphere (living things)

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Atmosphere:

The atmosphere plays a crucial role in the regulation of Earth's climate. The atmosphere is a mixture of different gases and aerosols (suspended liquid and solid particles) collectively known as air. Air consists mostly of nitrogen (78%) and oxygen (21%). However, despite their relative scarcity, the so-called greenhouse gases, including carbon dioxide and methane, have a dramatic effect on the amount of energy that is stored within the atmosphere, and consequently the Earth's climate. These greenhouse gases trap heat within the lower atmosphere that is trying to escape to space, and in doing so, make the surface of the Earth hotter. This heat trapping is called the natural greenhouse effect, and keeps the Earth 33°C warmer than it would otherwise be. In the last 200 years, man-made emissions of greenhouse gases have enhanced the natural greenhouse effect, which may be causing global warming.

The atmosphere however, does not operate as an isolated system. Flows of energy take place between the atmosphere and the other parts of the climate system, most significantly the world's oceans. For example, ocean currents move heat from warm equatorial latitudes to colder polar latitudes.

Heat is also transferred via moisture. Water evaporating from the surface of the oceans stores heat which is subsequently released when the vapour condenses to form clouds and rain. The significance of the oceans is that they store a much greater quantity of heat than the atmosphere. The top 200 metres of the world's oceans store 30 times as much heat as the atmosphere. Therefore, flows of energy between the oceans and the atmosphere can have dramatic effects on the global climate.

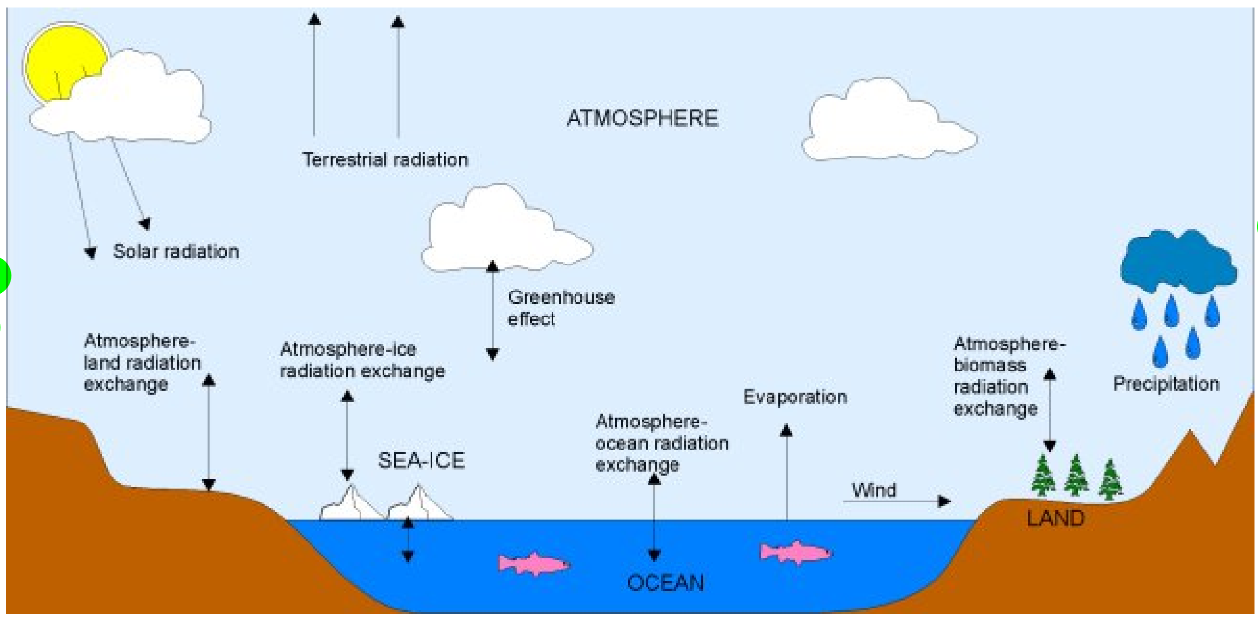

Fig: Earth climate (Atmosphere)

Cryosphere:

The world's ice sheets, glaciers and sea ice, collectively known as the cryosphere, have a significant impact on the Earth's climate. The cryosphere includes Antarctica, the Arctic Ocean, Greenland, Northern Canada, Northern Siberia and most of the high mountain ranges throughout the world, where sub-zero temperatures persist throughout the year. Snow and ice, being white, reflect a lot of sunlight, instead of absorbing it. Without the cryosphere, more energy would be absorbed at the Earth's surface rather than reflected, and consequently the temperature of the atmosphere would be much higher.

Biosphere:

All land plants make food from the photosynthesis of carbon dioxide and water in the presence of sunlight. Through this utilisation of carbon dioxide in the atmosphere, plants have the ability to regulate the global climate. In the oceans, microscopic plankton utilise carbon dioxide dissolved in seawater for photosynthesis and the manufacture of their tiny carbonate shells. The oceans replace the utilised carbon dioxide by "sucking" down the gas from the atmosphere.

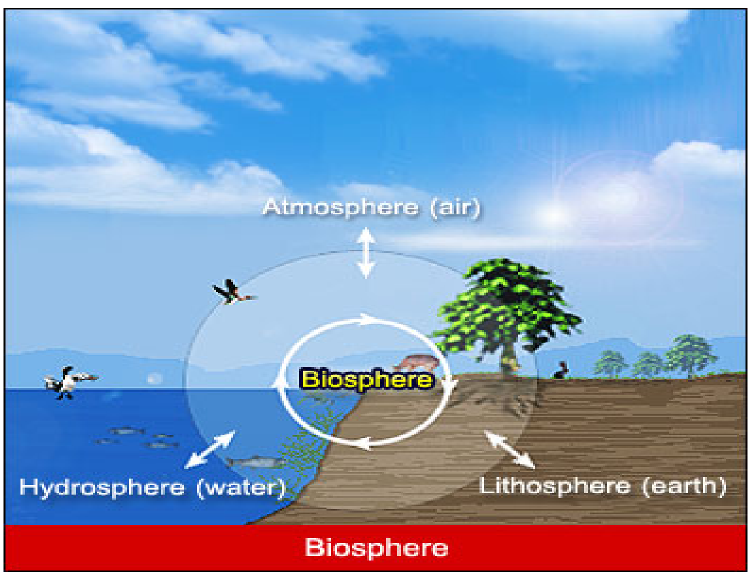

Fig: Earth climate (Biosphere)

LITHOSPHERE

It is believed the lithosphere evolved about 4.6 billion years ago. The lithosphere refers to the solid, rocky crust that covers the entire planet. This solid, rocky crust is composed of a number of different rocks that have been hrouped into three categories based on how they are formed. These three groups include:

- Metamorphic rocks – Metamorphic rocks are formed by heat and / or pressure from pre-existing rocks.
- Igneous rocks – igneous rocks are formed by the cooling of hot molten rock also known as magma. When the hot magma cools it begins to harden meaning once it had fully cooled it create what is known to be an igneous rock.
- Sedimentary rocks – sedimentary rocks are formed from pre-existing rocks. When rocks erode and mix with other dirt, clay and particles then settle together the mix together to form a sedimentary rock.

The lithosphere includes a various number of different landforms such as mountains, valleys, rocks, minerals and soil. The lithosphere is constantly changing due to forces and pressures such as the sun, wind, ice, water and chemical changes.

The earth's surface is composed into two types of lithospheres. There are known as the **oceanic and continental lithospheres.**

The oceanic lithosphere includes the uppermost layers of mantle which is topped with a thin yet heavy oceanic crust. This is where the hydrosphere and lithosphere meet.

The continental lithosphere include the uppermost layers of mantle which is topped with a thick yet light continental crust. This is where the atmosphere, biosphere and hydrosphere meet the lithosphere.

HYDROSPHERE -

The hydrosphere refers to the most important resource which I water. The hydrosphere includes all forms of water in the Earth's environment. The forms of water include things such as the ocean, lakes, rivers, snow and glaciers, water underneath the earth's surface and even the water vapour that is found in the atmosphere. The hydrosphere is always in motion as seen through the movement and flow of water in rivers, streams and the ocean (beach). Plant and animal organisms rely on the hydrosphere for their survival as water is essential. The hydrosphere is also home to many plants and animals and it believed that the hydrosphere covers approximately 70% of the earth's surface

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S1 : Earth system-hydrological cycle and carbon cycle

Hydrologic cycle

The water cycle, also known as the hydrologic cycle or the hydrological cycle, is a biogeochemical cycle that describes the continuous movement of water on, above and below the surface of the Earth.

EXPLAIN WATER CYCLE

- Water exists on earth in all three states, liquid, solid and gaseous state and various degrees of motion. The various aspects of water related to the earth can be explained in terms of cycle known as hydrologic cycle.

- Except for deep ground water, the total water supply of earth is in constant circulation from earth tot atmosphere and back to the earth.

- The earth' water circulatory system is known as hydrologic cycle. It is the process of transfer of moisture from atmosphere to earth in the form of precipitation, conveyance of precipitated water by streams and rivers to oceans and lakes and evaporation of water back to the atmosphere.

- The group of numerous arcs which represents the different path through which water in nature circulates and is transformed is known as hydrological cycle.
- These arcs penetrates into three parts of total earth system, Atmosphere, Hydrosphere and lithosphere.
- Hydrological cycle can be represented in many different ways in pictorial or diagrammatic forms.
- The hydrological cycle has no beginning or end as the water in nature is continuously kept in cyclic motion.

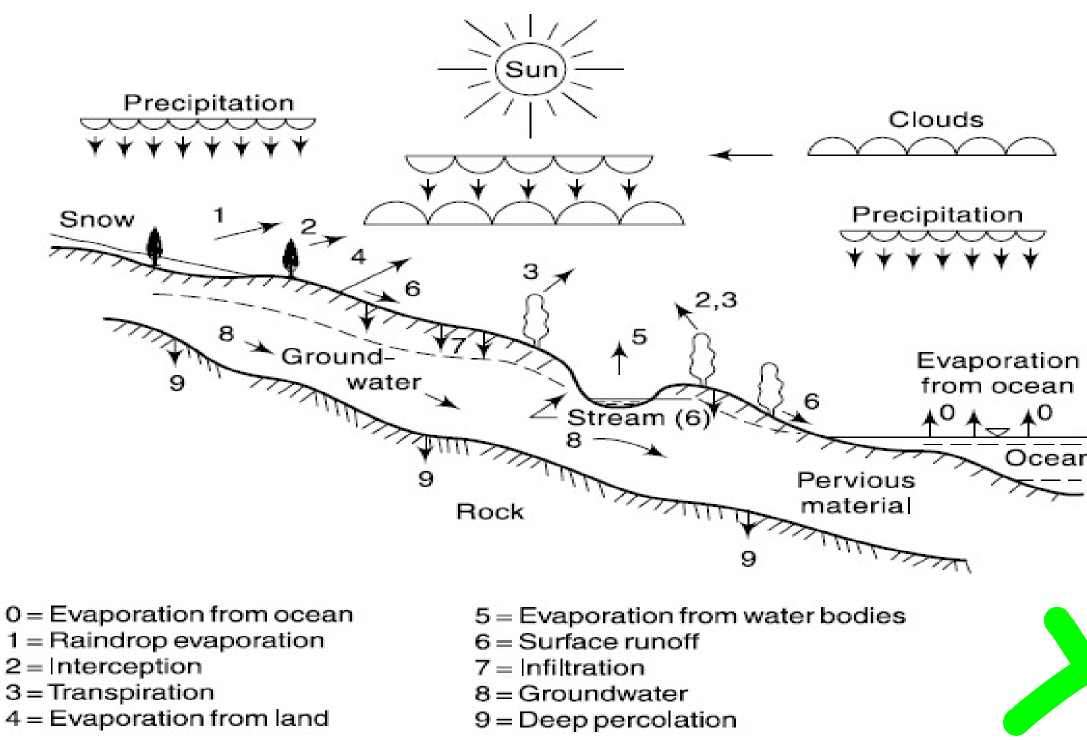

Fig. 1.1 The Hydrologic Cycle

Thus the hydrologic cycle may expressed by the following equation as

Precipitation [P] = Evaporation [E] + Runoff [R]

Provided adjustment is made for the moisture held in storage at the beginning and end of the period.

Precipitation [P]

- Precipitation may be defined as **fall of moisture from atmosphere to the earth surface in any form.**
- The precipitation reaching the ground surface after meeting the needs of infiltration and evaporation moves down the natural slope over the surface and through rivers and streams to reach the oceans.
- Precipitation may be **two forms**

i. Liquid Precipitation – Rainfall
ii. Frozen Precipitation – Snow, Hail, sleet, freezing rain

Measurement of Precipitation

It can be measured by rain gauge. The rain gauge may be

i) Recording type rain gauge [Weighing bucket, Tipping bucket, Floating type]
ii) Non- recording type rain gauge[Symon's Raingauge]

Evaporation [E]

- **Evaporation** from the surfaces of ponds, lakes, reservoirs. ocean surfaces, etc. and transpiration from surface vegetation i.e., from plant leaves of cropped land and forests, etc. take place. These vapours rise to the sky and are condensed at higher altitudes by condensation nuclei and form clouds, resulting in droplet growth.

- It is the process by which water from liquid state passes into vapour state under the action of sunrays.
- Transpiration is the process of water being lost from the leaves of plants from their pores.

Thus **total evaporation inclusive of transpiration** consists of

i. Surface evaporation
ii. Water Surface evaporation [Rivers, oceans]
iii. Evaporation from plants and leaves [Transpiration]
iv. Atmospheric evaporation

A portion of water that reaches the ground enters the earth surface through infiltration, enhance the moisture content of soil and reach the ground water body.

Runoff [R]

- Runoff is the portion of precipitation that is not evaporated.
- When moisture falls to the earth surface as precipitation, a part of it is evaporated from the water surface, soil and vegetation and through transpiration by plants and remainder precipitation is available as runoff which ultimately runs to the oceans through surface or sub-surface streams.

Classification of run off

i. Surface run off
ii. Sub surface runoff
iii. Ground water flow or base flow

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Carbon cycle

The carbon cycle is most easily studied as two interconnected subcycles:

- One dealing with rapid carbon exchange among living organisms.**[Biological carbon cycle]**
- One dealing with long-term cycling of carbon through geologic processes.**[Geological carbon cycle]**

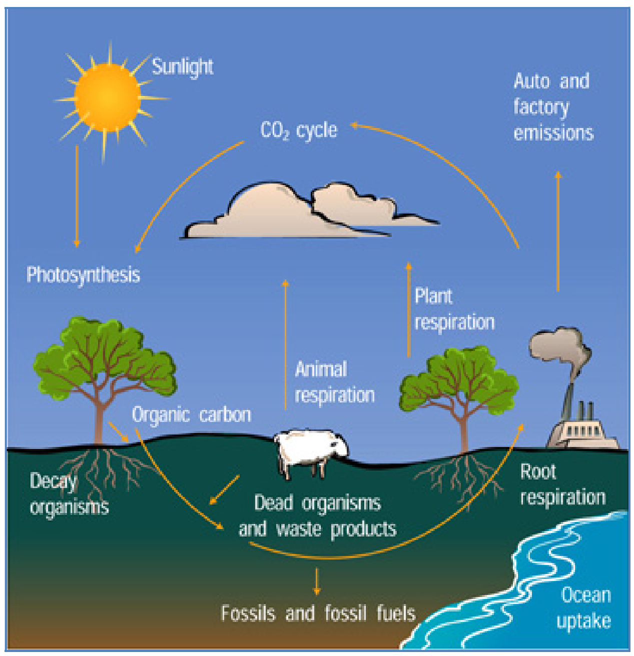


Fig: Carbon cycle

Biological carbon cycle

Carbon enters all food webs, both terrestrial and aquatic, through **autotrophs**, or self-feeders. Almost all of these autotrophs are photosynthesizers, such as plants or algae.

Autotrophs capture carbon dioxide from the air or bicarbonate ions from the water and use them to make organic compounds such as glucose.

Heterotrophs, or other-feeders, such as humans, consume the organic molecules, and the organic carbon is passed through food chains and webs. Carbon can cycle quickly through this biological pathway, especially in aquatic ecosystems. Overall, an estimated 1,000 to 100,000 million metric tons of carbon move through the biological pathway each year.

In the first step, through photosynthesis (the process by which plants capture the sun's energy and use it to grow), plants take carbon dioxide out of the atmosphere and release oxygen. The carbon dioxide is converted into carbon compounds that make up the body of theplant, which are stored in both the aboveground parts of the plants (shoots and leaves), and the below ground parts (roots).

Photosynthesis: Energy (sunlight) + $6CO_2$ + $H_2O \rightarrow C_6H_{12}O_6$ + $6O_2$

In the next step, animals eat the plants, breath in the oxygen, and exhale carbon dioxide. The carbon dioxide created by animals is then available for plants to use in photosynthesis. Carbon stored in plants that are not eaten by animals eventually decomposes after the plants die, and is either released into the atmosphere or stored in the soil.

Respiration: $C_6H_{12}O_6$ (organic matter) + $6O_2 \rightarrow 6CO_2$ + 6 H_2O + Energy

Large quantities of carbon can be released to the atmosphere through geologic processes like volcanic eruptions and other natural changes that destabilize carbon sinks. For example, increasing temperatures can cause carbon dioxide to be released from the ocean.

Geological Process of carbon cycle

The geological pathway of the carbon cycle takes much longer than the biological pathway described above. In fact, it usually takes millions of years for carbon to cycle through the geological pathway. Carbon may be stored for long periods of time in the atmosphere, bodies of liquid water—mostly **oceans— ocean sediment, soil, rocks, fossil fuels, and Earth's interior.**

The level of carbon dioxide in the atmosphere is influenced by the reservoir of carbon in the oceans and vice versa. Carbon dioxide from the atmosphere dissolves in water and reacts with water molecules in the following reactions:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_3^{2-} + 2H^+$$

The carbonate—CO_3^{2-}—released in this process combines with Ca^{2+} ions to make calcium carbonate $CaCO_3$ a key component of the shells of marine organisms. When the organisms die, their remains may sink and eventually become part of the sediment on the ocean floor. Over geologic time, the sediment turns into limestone, which is the largest carbon reservoir on Earth.

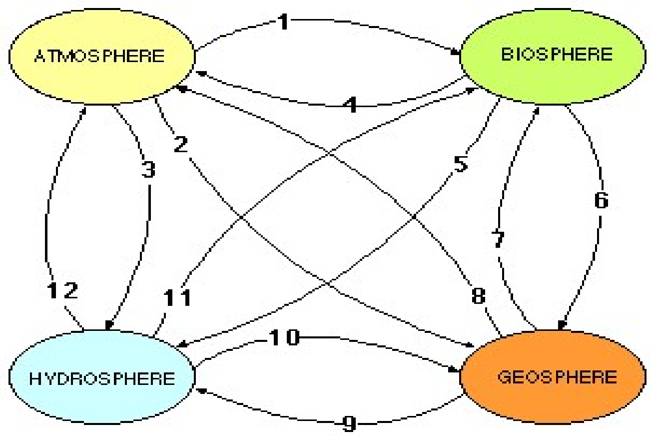
S2: Importance of earth system and climate

Earth System Science is a relatively new field of study that focuses on the operation of the whole Earth, including the **atmosphere, hydrosphere, biosphere, and geosphere.** These four spheres can be thought of as four machines or systems that are connected together to make one larger machine -- the whole Earth system. Earth System Science is especially concerned with the interactions between these different spheres and how these interactions control the global climate. This field of study incorporates and integrates material from traditional geology, meteorology, oceanography, ecology, atmospheric chemistry, and other fields.

	Major Influences on the Global Climate
Atmosphere	CO_2 and H_2O control greenhouse; clouds and aerosols control amount of sunlight reaching surface; global circulation determines climatic zones
Biosphere	Land plants transfer CO_2 from atmosphere and soil; oceanic plants transfer CO_2 from atmosphere to ocean floor; plants affect albedo of surface; land plants transfer H_2O from the soil to the atmosphere; plants and microbes enhance weathering of rocks, which consumes atmospheric CO_2
Hydrosphere	Atmospheric H_2O controls greenhouse and cloud cover and transfers heat energy; surface water controls plant growth and thus albedo and CO_2 transfer; oceans transfer heat and regulate atmospheric CO_2; glaciers control albedo, sea level, and deep ocean circulation patterns
Geosphere	Locations of continents controls ocean circulation, global weather patterns; mountains affect regional weather and are main locations of weathering which removes atmospheric CO_2; volcanoes return CO_2 to the atmosphere; volcanic aerosols block sunlight; sea-floor spreading rates control sea level

In addition to understanding how different parts of the Earth System affect the global climate, it is important to understand how these different parts are linked together &emdash; how they are interconnected. The graph below represents these interconnections in the form of connecting arrows; each arrow represents some set of processes that operate within one of the Earth's four "spheres" that influences the "sphere" that the arrow points to

Connections Within The Earth System



Explanation of Connections

1. Atmospheric chemistry and temperature affect organisms
2. Atmospheric chemistry and temperature affect weathering of rocks
3. Atmospheric temperature affects evaporation
4. Photosynthesis affects atmospheric CO_2 concentration
5. Plants aid weathering (physical and chemical) of rocks
6. Plants control water transfer from soil to atmosphere
7. Weathering and erosion controls nutrient supply to life in the oceans
8. Volcanic eruptions add CO_2 and aerosols to atmosphere
9. Locations of continents controls circulation pattern of oceans
10. Rainfall and runoff erode the land surface
11. Soil water limits plant growth
12. Ocean circulation controls how much CO_2 is removed from atmosphere

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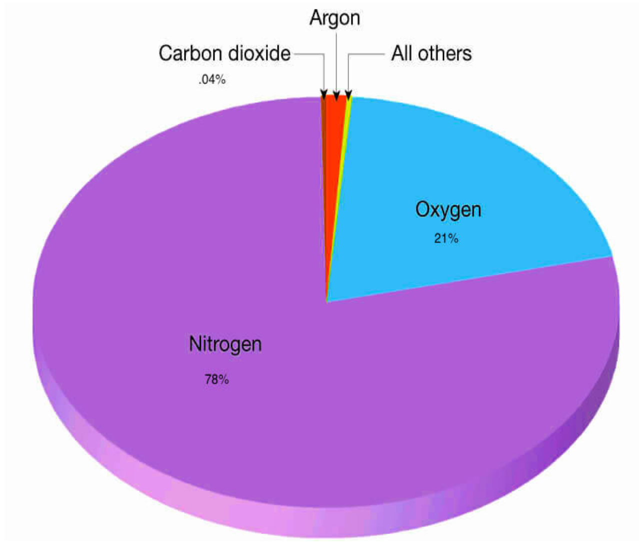
S3: Atmosphere and its composition, different strata of atmosphere and temperature profile

Atmosphere and its composition

The earth's atmosphere is a very thin layer wrapped around a very large planet. The three major constituents of dry air are **nitrogen (N_2) oxygen (O_2) and argon (Ar), which account respectively for 79 percent, 21 percent and 1 percent of the molecules.**



Composition of the Atmosphere	Other Components of the Atmosphere
• Nitrogen 78.08% • Oxygen 20.95% • Argon 0.93% (9300 ppm) • Carbon Dioxide 0.035% (350 ppm) • Neon 18 ppm • Helium 5.2 ppm • Methane 1.4 ppm • Ozone 0.07 ppm	• Water Droplets • Ice Crystals • Sulfuric Acid Aerosols • Volcanic Ash • Windblown Dust • Sea Salt • Human Pollutants

Different strata of atmosphere

Based on temperature, the atmosphere is divided into five layers:

i) Troposphere
ii) Stratosphere
iii) Mesosphere and
iv) Thermosphere
v) Exosphere

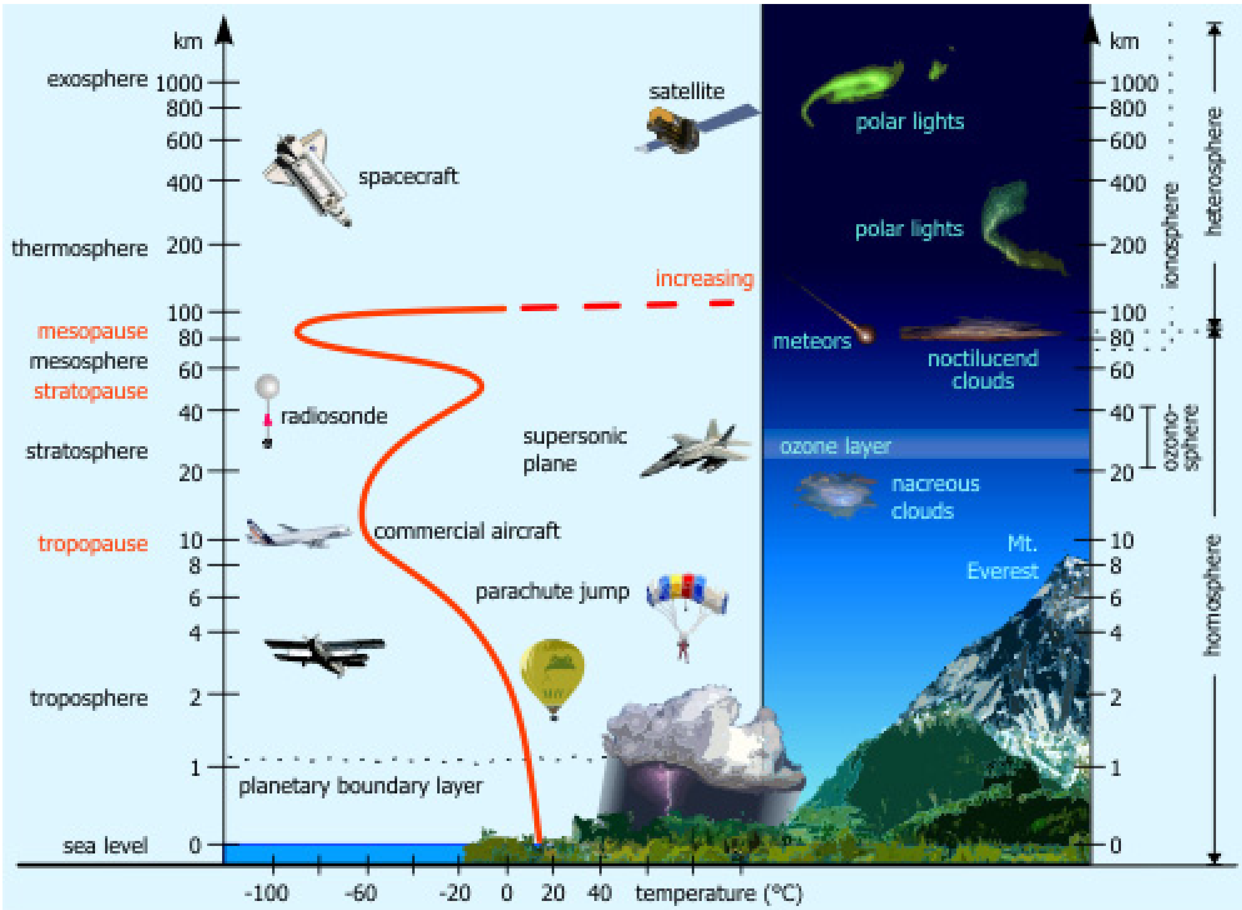


Fig: Different layers of Atmosphere

i) Troposphere

"**Tropos**" means change.

This layer gets its name from the weather that is constantly changing and mixing up the gases, in this part of our atmosphere.This layer is the closest to Earth's surface.

On average the troposphere extends, from the ground to about 12 kilometers or 7.5 miles high.The troposphere contains, about 75% of all of the air in the atmosphere, and, almost all of the water vapor, which forms clouds and rain. In this layer, air is made up of approximately 78% nitrogen, 21% oxygen, and 1% argon with small amounts of additional gases, including water vapor and, carbon dioxide.

(ii) Stratosphere

"**Strat**" means layer.

This layer of our atmosphere has its own set of layers. The boundary between the stratosphere and the troposphere is called the tropopause. It is the region where airplanes fly.

The Stratosphere layer, extends from the tropopause to about 50 kilometers (32 miles) above the Earth's surface.This layer contains a thin layer of ozone molecules which forms a protective layer and absorbs harmful ultraviolet radiation, from the Sun. The high-altitude weather balloons flying into the stratosphere for monitoring atmospheric conditions and climate research.

(iii) Mesosphere

"**Meso**" means middle.

This layer is located above the stratosphere and below the thermosphere. It is the third layer in our atmosphere which is 35 kilometers (22 miles) thick. The transition boundary which separates the mesosphere, from the stratosphere is called the stratopause. In the mesosphere fewer air molecules to absorb incoming electromagnetic radiation from the Sun. Most meteors burn up in this atmospheric layer.

(iv) Mesosphere

"**Thermo**" means heat.

This layer has extremely high temperatures, and located above the mesosphere, and below the exosphere. The boundary between the mesosphere, and the thermosphere atmospheric regions, is called Mesopause. It is the coldest part of Earth's atmosphere. The thermosphere, extends from the mesopause to 700 kilometers (435 miles) above the surface of the Earth. The thermosphere is the thickest layer, in the atmosphere. Only the lightest gases, mostly oxygen, helium, and, hydrogen are found here. The aurora, and satellites mostly occur in this layer.

(V) EXOSPHERE

"**Exo**" means outside.

The exosphere, represents the outermost layer of Earth's atmosphere. It extends, from the top of the thermosphere to 10,000 kilometers (6,214 miles) above Earth's surface.

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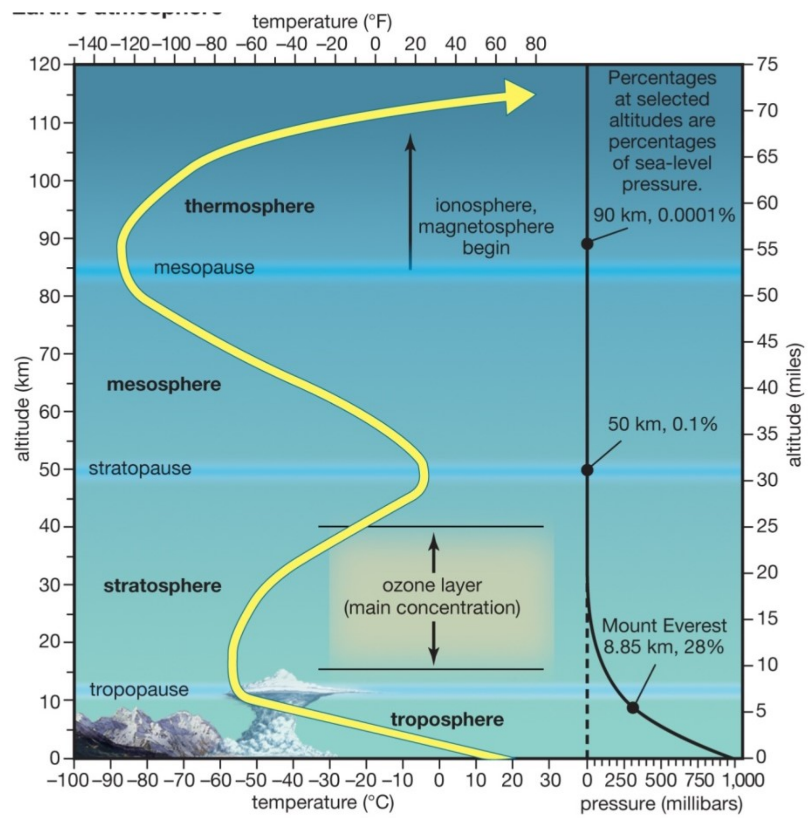
Temperature profile



Atmospheric Composition - affects Air Temperature:

Air temperature also changes as altitude increases. The temperature differences result mainly from the way solar energy is absorbed as it moves through the atmosphere.Some parts of the atmosphere are warmer because they contain a high percentage of gases that absorb solar energy. Other parts of the atmosphere contain less of these gases and are cooler

Heat and Temperture:

Temperature: Average energy of molecules or atoms in a material.
Heat: Total energy of molecules or atoms in a material.
It's possible to have large amount of heat but low temperatures and high temperatures but little heat.
The Arctic Ocean has a large amount of heat (because of large mass) even though the temperature is low. Air in an oven at 500ºF has high temperature but little heat.
However if you touch anything solid in the oven you'll get burned. Same temperature but much larger amount of heat. The earth's outermost atmosphere is extremely "hot" but its heat content is negligible.
It takes time for things to warm up and cool off.

Temperature Scales	Absolute Temperature
1) Fahrenheit a) Water Freezes at 32 F b) Water Boils at 212 F 2) Centigrade or Celsius a) Water Freezes at 0 C b) Water Boils at 100 C 3) Two scales exactly equal at -40	Kelvin scale uses Celsius degrees and starts at absolute zero Absolute Zero specify - 273ºC / - 459ºF.