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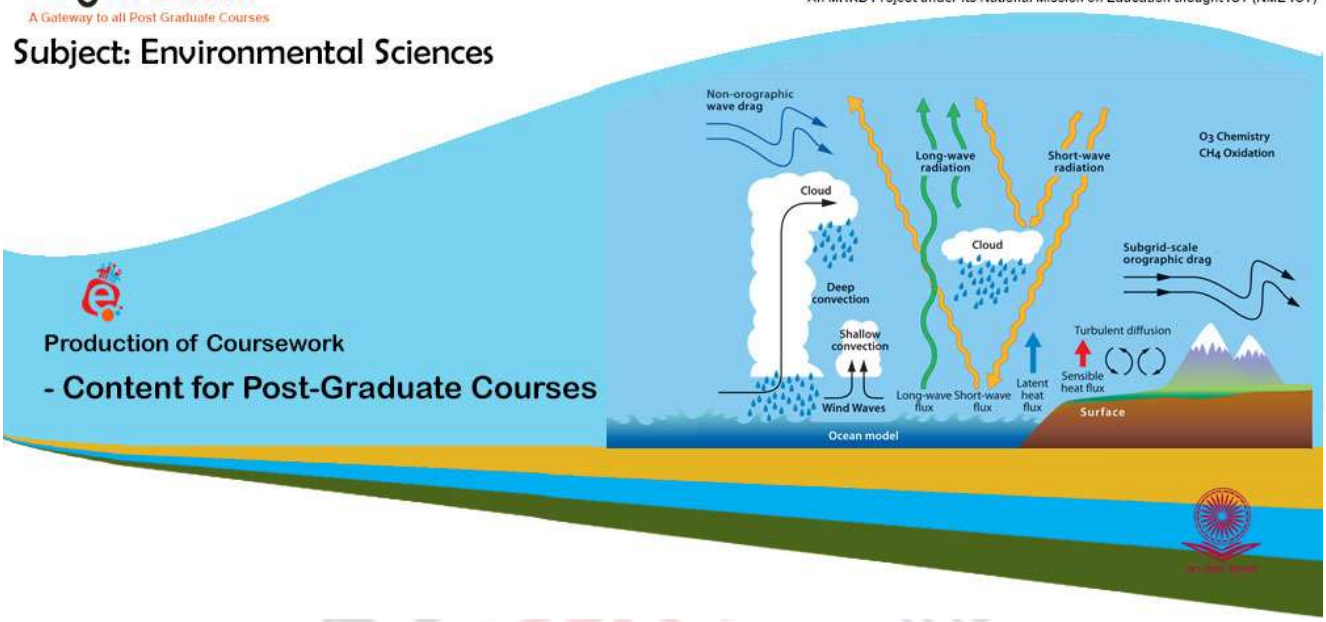
Subject: Environmental Sciences



Paper No: 8 Atmospheric Processes

Module: 14 Clouds- Introduction and Classification

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Description of Module	
Subject Name	**Environmental Sciences**
Paper Name	Atmospheric Processes
Module Name/Title	Clouds- Introduction and Classification
Module Id	EVS/AP-VIII/14
Pre-requisites	
Objectives	• Know what is cloud and its general importance • Understand various mechanisms of cloud formation • Distinguish between different cloud types • Assess the height of the clouds to a great extent • Predict whether a particular cloud is going to give rain or not • Assess the cloud cover in the sky with visual observation • Acquaint with the cloud cover recorder
Keywords	High cloud, low cloud, middle cloud, cirrus, cumulus, stratus, cumulonimbus

Module 14: Clouds-Introduction and Classification

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1 Learning outcomes

After reading through this module, one should be able to:

- Know what is cloud and its general importance
- Understand various mechanisms of cloud formation
- Distinguish between different cloud types
- Assess the height of the clouds to a great extent
- Predict whether a particular cloud is going to give rain or not
- Assess the cloud cover in the sky with visual observation
- Acquaint with the cloud cover recorder

2 Introduction

Water on the earth is always on the move through a chain of events/processes which is also referred as hydrological cycle. It gets evaporated into the atmosphere *i.e.* changes from liquid to vapour phase, from the ocean and the land surfaces like lakes, rivers, ponds and vegetation due to the heat received from solar radiation. The atmospheric water vapour eventually returns back to earth as liquid water in the low and middle latitudes and in solid form like snow or ice near the poles and mountains through the processes of cloud formation and precipitation.

Cloud can be defined as a visible collection of very tiny droplets of water and or ice crystals suspended in the air, usually at some height above the earth's surface. At any point of time, about 50 per cent of the earth remains covered by various cloud types, about 1 - 2 % of which could be rain bearing. Clouds can grow very tall or take a flat shape. These are typically white but may also appear in different shades of grey to black. Clouds perhaps weigh tens of millions of tons, yet float in the atmosphere - a wonder of the Nature. Clouds are of supreme importance for weather and climate of earth system.

Apart from the hydrological cycle, clouds also play a major role in maintaining earth's radiation and energy balance which are important drivers for weather system and sustaining life on earth. Clouds are the main controller of the earth's normal temperature. In one hand, clouds provide relief from the direct heat of sunlight and on the other hand, it acts as a blanket to warm the earth by absorbing some of the reflected and emitted radiation from earth. Even minor variations in the clouds abundance or location can change the climate too much than the expected changes produced by greenhouse gases, aerosols, or other issues related to global change. In general, net effect of clouds depend the amount of Earth's surface area covered by clouds, their thickness and altitude, condensed particles size, and the portion of water and ice present in them. Depending on the height of occurrence of clouds and its depth, reflective and absorptive properties of clouds change. Thick low level clouds tend to reflect more radiation back to the space; hence, an increase in these low clouds might tend to cool the climate considerably. On the contrary, high level clouds prevent the escape of earth radiation (long wave radiation) from reaching the space i.e. tend to trap long wave radiation leading to heating up of the Earth. It is predicted that a warmer earth would produce more clouds. But the quantum of these changes in various cloud types and their feedback to the environment shall ultimately determine the future course of the earth's climate. Clouds are not merely confined to the earth but are also found on other planets.

The below mentioned information are of great importance and value in the area of atmospheric sciences, especially in weather and rainfall prediction: the amount of sky covered; the direction from which the clouds are moving; the speed of cloud movement; the height of the cloud base; the height of the top of the cloud; the cloud type as per the international classification and the constitution of the cloud.

This module mainly deals with the basics of clouds and its classification.

3 Occurrence of Clouds and their Classification

Clouds can occur at any level of the atmosphere wherever there are sufficient moisture and nuclei for condensation are available. In troposphere, almost all clouds exist, although the tops of some severe thunderstorms occasionally pierce the tropopause. Because of the large range in

temperatures and air movement in the troposphere, clouds vary in structure and composition. Atleast four different types of clouds can be visually distinguished by simple eye observations and without the aid of any sophisticated instruments. These are *viz.*, Cirrus (hair like), Stratus (layered like), Cumulus (heap like) and Nimbus (water bearing).

3.1 Origin of cloud classification

As per available records, the first attempt to classify cloud was made by Lamarck in the year 1802. In the next year *i.e.* 1803, Luke Howard of England published a classification scheme which formed the basis of the modern cloud classification. This was further improved upon by people like Renou (a French meteorologist) and Hildebrandsson (a Swedish meteorologist). Subsequently, the World Meteorological Organization (WMO) has published detailed cloud atlases over the years.

3.2. Modern cloud classification

The present day international classification is based on the altitude of the cloud base and is being followed widely. Clouds are classified into four main groups, *viz.*, low-, middle- and high level clouds and clouds with vertical development. The above classes are further subdivided, either based on texture or other important characteristics, to provide an easier way to identify the various cloud types. Thus, altogether ten types of clouds are identified and followed worldwide (Fig. 1).

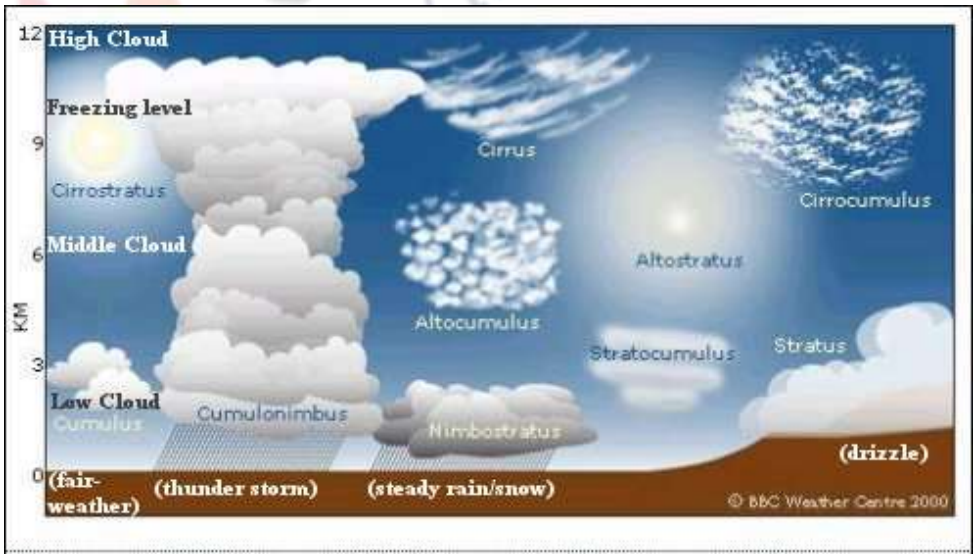

Fig.1. A comprehensive depiction of the ten different cloud types occurring at three levels of atmosphere

Depending on the latitudinal belts, the height of occurrence (formation and extension) from the earth surface of the three levels of cloud varies slightly which is presented in table 2.

Table 2. Height (Km) limits of the cloud in different regions

Levels	Polar	Temperate	Tropical
High	3 – 8	5 – 13	6 – 18
Medium	2 – 4	2 – 7	2 – 8
Low	Surface to 2	Surface to 2	Surface to 2

4 Detailed description of clouds

Detailed description which includes appearance and properties of different types of cloud is given below. Standard symbols which are internationally recognized are provided inside the parenthesis after each cloud's name.

4.1 High level clouds

These clouds are in high altitudes and primarily composed of fine ice crystals as the temperatures are so low. These clouds are typically thin and white in appearance. However, when the sun is at low angles on the horizon, these clouds at times may appear in a magnificent array of colors. Three types of clouds are included into this group as given below.

4.1.1 Cirrus (Ci)

- Fibrous, thread-like or white feather like and resembles curly hair and appear in patches.
- Shape or pattern varies considerably depending on horizontal or vertical direction of wind flow at cloud level.
- Form at temperatures below - 40 ^{o}C and consist entirely of ice particles.
- Brilliant white colour because of ice crystal
- Difficult to judge the contrast between the top and base.
- No precipitation at ground level , only particles streaks (known as fall streaks) are often observed below
- Produce "halo" and other optical phenomena and thick enough to hide the sun.

4.1.2 Cirrostratus (Cs)

- Milky, translucent cloud veil of ice crystals sometimes cause “halo” appearances around the moon and sun.
- Depending on thickness, sunlight can transmit through C sand more widespread than cirrus
- Resemble cirrus clouds as both are brilliant white and lack contrast between the top and base.
- First visible indication of an approaching weather front (rather bad weather).
- They may progressively thicken to altostratus and then nimbostratus with lowering of cloud base as the front approaches.

4.1.3 Cirrocumulus (Cc)

- Small, rounded white puffs that appear in long rows.
- Small ripples in the Cirrocumulus clouds s resemble the fish scales and brilliant white with a spotty appearance
- No precipitation and many features resemble those of cirrostratus
- Found in a similar altitude range as cirrus but more broken in appearance
- Usually seen in the winter and indicate fair and cold weather but in tropical regions, they may indicate an approaching hurricane.

Fig.2. Cirrus

Fig.3. Cirrostratus

Fig.4. (below- right & left). Cirrocumulus

4.2 Middle level clouds

Because of their lower altitudes, they are composed primarily of water droplets with varying thickness from relatively flat sheets of cloud to a more cumuliform appearance. At very low temperature or cold condition, these cloud consists of ice crystals. These clouds are brighter and less fragmented in appearance due to short distance from the ground and the higher composition of ice crystals. These clouds move with slower speed than lower level clouds by wind.; however, the speed is apparently. There are three types under this group as detailed below.

4.2.1 Altocumulus (Ac)

- These are white or grey or both white and grey, patch sheet or layers of cloud, composed of rounded masses, rolls, partly fibrous or diffuse and produce no “halo” phenomena
- Altocumulus clouds differs from stratocumulus by elements size and may occur at different level at the same time but their movement depends on the wind direction at that level.
- Altocumulus clouds also develop within the structure of Cumulonimbus (thunderstorm producing) clouds.
- Precipitation within altocumulus can develop rapidly at the rear even though the cloud may be moving fairly rapidly. This will obviously influence the duration of rainfall as well as the normally large cloud base.

4.2.2 Altostratus (As)

- Altostratus appears as flat, smooth, grayish or bluish cloud sheets or striated, fibrous layers with uniform appearance, totally or partly covering the sky.
- Develop at any timeas a thick or thin layerthroughsun can be seen and does not produce “halo”.
- Under an altostratus sheet, shadows of objects on the ground are never visible.
- Indicative of an approaching cloud mass associated with a cold front.
- Produce precipitation and whenprecipitation becomes persistent, it becomes nimbostratus.
- Sometimes, altostratus develop during the afternoon and extend to cover most or all of the sky. By late afternoon, evening or during the night, precipitation will occur.
- Like Ac, altostratus forms part of thunderstorms within or below the lower part of the anvil region. As the anvil of the thunderstorm passes overhead, the altostratus begins to appear normally with a grey base but becomes increasingly dark.

4.2.3 Nimbostratus (Ns)

- Water bearing cloud (Nimbo= water) with light to heavy showers
- Widespread light grey or white sheet of cloud that produces persistent rain or showers for considerable time.
- Lack contrast due to light colors and very difficult to measure apparent speed and direction.
- Thickness may be more than 4 km and associated with warm fronts (the forward edge of an advancing mass of warm air is referred to as warm front).
- Nimbostratus can develop or occur with most other types of clouds.
- Nimbostratus can develop from altostratus if it becomes sufficiently thick to produce precipitation.

Fig.5. Altocumulus clouds

Fig.6. AltoStratus

Fig.7. Nimbostratus

4.3 Low level clouds

These are mostly composed of water droplets because of their low altitude but at sufficient low temperature, these clouds may contain ice particles and snow. Low clouds are not well defined and because of clear turbulent motion, they have ever-changing structures. They are faster than high or medium level cloud and movement direction is same as wind direction at ground level. The two types belonging to this group are discussed below.

4.3.1 Stratus (St)

- Fragmented and thin layer or sheet, grey colour with fairly uniform bases, which may give drizzle, ice prisms or snow grains, no halo formation except at very low temperature
- Lack contrast and vertical growth like cumulus and stratocumulus and move in the wind direction
- Same characteristics as fog but never appear on the ground.
- Depending on wind turbulence, cause different weather conditions including thunderstorms and thunderstorm development.

4.3.2 Stratocumulus (Sc)

- As low as 450 meters to more than 1 km or higher, puffy, grey and with more horizontal spread with darker base like cumulus and entirely of liquid drops, enough thick to obscure the sun or moon.
- Rare precipitation from stratocumulus but turn into nimbostratus and cumulus to produce drizzle particularly in hilly or coastal areas.
- Sometimes, stratocumulus appears in the form of rolling patches of cloud aligned parallel to each other. They can also appear in the form of broken clouds or globules. The sun, moon and generally the sky can be observed through the breaks of these clouds.
- The amount of stratocumulus covering the sky depends on the amount of moisture concentrated at that level.

4.4 Clouds with vertical development

- The base of this type of cloud may be as low as 300 meters above the ground and composed of composed of water droplets when the temperature is above freezing but when the temperature is below freezing point, these clouds may consist of ice crystals and super-cooled water droplets. These clouds can grow tall till the limits of troposphere or even exceed it at times. Huge amount of energy is released within the cloud itself through the condensation of water vapor. Cumulus and Cumulonimbus clouds are the two main type under this category and are described below.

Fig.8. Stratus

Fig.9. Stratocumulus

4.4.1 Cumulus (Cu)

- Most familiar type of vertical cloud; they appear white, puffy type like pieces of floating cotton and known as “fair weather clouds”.
- Cauliflower-shaped with dark and flat bases and bright, rounded towerstops.

Cumulus Humilis

- One variant of cumulus clouds without towers or protuberances and indicative of fair weather.

Cumulus Congestus

- Top of this type of cumulus clouds resemble the head of a cauliflower.
- These generally form by air rising as a result of surface heating. Most often, these clouds are found during daytime and dissipate at night. They generally produce only light precipitation.
- These clouds grow upward and can develop into giant cumulonimbus clouds that are associated with thunderstorms.
- Usually form at altitudes starting from about 300 meters above the ground to 1.5 km.

4.4.2 Cumulonimbus (Cb)

- These are most massive and tallest, heavy, dense clouds with a considerable vertical extent (typically between 600 meters and 1.5 km and sometimes upto tropopause), in the form of a mountain or huge towers (classic anvil appearance).
- Produce thunderstorm in summers associated with heavy rain, snow, hail, lightning and even tornadoes.

- Formed under conditions of deep convection and produce at least one pronounced shower.
- At lower levels these clouds consist of liquid drops, but as altitude increases the cloud progresses through mixed phase and fully icy/glaciated conditions.

Fig.10. Cumulus

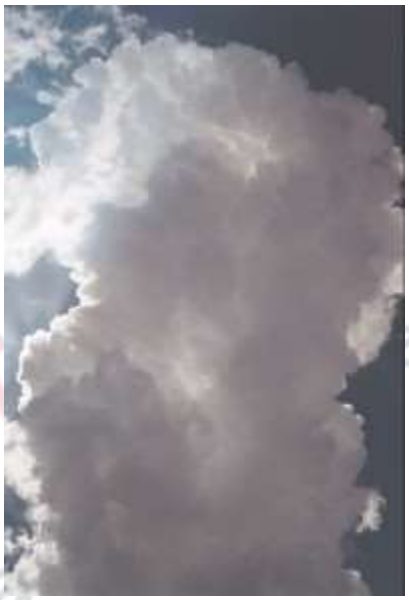

Fig.11. Towering Cumulus

- Under the base of this cloud which is often very dark, there are frequently low rugged clouds either merged with it or not and precipitation sometimes are in the form of virga (rain that evaporates before it reaches the ground). It appears in streaks or shafts extending from the bottoms of clouds. It can be often seen over a desert, where low humidity and high temperatures can cause rain to evaporate high in the sky.

Fig.12. A typical Cumulonimbus cloud

Fig.13. A typical Cumulonimbus seen from 11.5 km above earth's surface

4.5 Other cloud types

4.5.1 Orographic clouds

This type of cloud is formed when air is forced to rise over elevated terrain; cloud base is dependent on prevailing conditions, but is similar in range to that of other low level clouds. Orographic clouds are often in contact with the ground at the hill top. These clouds often do not produce precipitation but larger systems may produce drizzle. When heavier rain occurs that could be due to thicker cloud above. Orographic clouds may contain liquid or ice depending on prevailing conditions and terrain altitude.

Fig.14. Orographic cloud

4.5.2 Noctilucent clouds

These clouds are very thin and composed of ice crystal. These are the highest clouds in the atmosphere, located in the mesosphere at an altitude of approximately 85 km. They are only visible when illuminated by light from below *i.e.* after the sun has gone below the horizon. They are most commonly observed in the summer months at latitudes between 50° and 70° north and south of the equator.

6 Summary

- Cloud is the visible collection of water droplets and or ice crystals suspended in the air, usually at some height above the earth's surface.
- Clouds play an important role in the global hydrological cycle, radiation and energy balance of the earth.
- A modest-size cloud, one kilometer in diameter and 100 meters thick, has a mass equivalent to one B-747 jumbo jet. But, with all that mass being spread over such a large volume of space, the density, or weight (mass) for any chosen volume, would be considerably small and it doesn't fall on to the earth because the rising air (responsible for its formation) keeps the cloud floating in the air.
- Clouds can occur at any level of the atmosphere wherever there is sufficient moisture to allow condensation to take place. Almost all clouds exist in the Troposphere where most weather phenomena occur.
- Mainly ten types of cloud are recognized internationally based on height of occurrence in the atmosphere and growth. These are cirrus, cirro stratus, cirro cumulus, alto cumulus, alto stratus, nimbo stratus, stratus, stratocumulus, cumulus and cumulonimbus.
- Depending on the distance from the equator, high, medium and low clouds can occur at 3-18 km, 2-8 km and upto 2 km, respectively from the ground surface.
- High clouds (cirrus, cirrostratus and cirrocumulus) are primarily composed of fine ice crystals. These are typically thin, fibrous, thread or feather like and appear white.
- Middle clouds (altocumulus, altostratus and nimbostratus) are primarily composed of water droplets though may also contain significant quantities of ice crystals. These appear brighter and less fragmented in appearance due to their distance from the ground and the higher composition of ice crystals.
- Low clouds (stratus and stratocumulus) are mostly composed of water droplets. Stratus clouds appear fragmented and thin, can also be in the form of a layer or sheet. These clouds usually look grey with a fairly uniform base and may give drizzle, ice prisms or snow grains.

- Cumulonimbus clouds show great vertical growth with its base sometimes as low as about 500 meters from the ground. Thunderstorms in summer's time are associated with such type of cloud.
