18CEO406T - GLOBAL WARMING AND CLIMATE CHANGE

UNIT – 1 [S4 to S6]

S4: Weather and Climate Climate parameter- temperature, atmospheric pressure

WEATHER

What is weather?

Weather is the day-to-day state of the atmosphere, and its short-term variation in minutes to weeks. People generally think of weather as the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind

What is Climate?

Climate describes the average weather of a particular part of the world at different times of the year. The climate of a place may be defined as a "composite" of the long-term prevailing weather that occurs at that location.

Climate is the weather of a place averaged over a period of time, often 30 years

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. ..

Atmospheric Pressure

Atmospheric pressure is the force per unit area exerted on a surface by the weight of air above that surface in the atmosphere of earth (or that another planet).

In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point.

On a given plane, low-pressure areas have less atmospheric mass above their location, whereas high-pressure areas have more atmospheric mass above their location. Likewise, as elevation increases, there is less overlying atmospheric mass, so that atmospheric pressure decreases with increasing elevation.

Atmospheric Temperature

Atmospheric temperature is a measure of temperature at different levels of the Earth’s atmosphere. It is governed by many factors, including incoming solar radiation, humidity and altitude.

In the Earth's atmosphere, temperature varies greatly at different heights relative to the Earth’s surface. The coldest temperatures lie near the mesopause, an area approximately 85 km to 100 km above the surface. In contrast, some of the warmest temperatures can be found in the thermosphere, which receives strong ionizing radiation.

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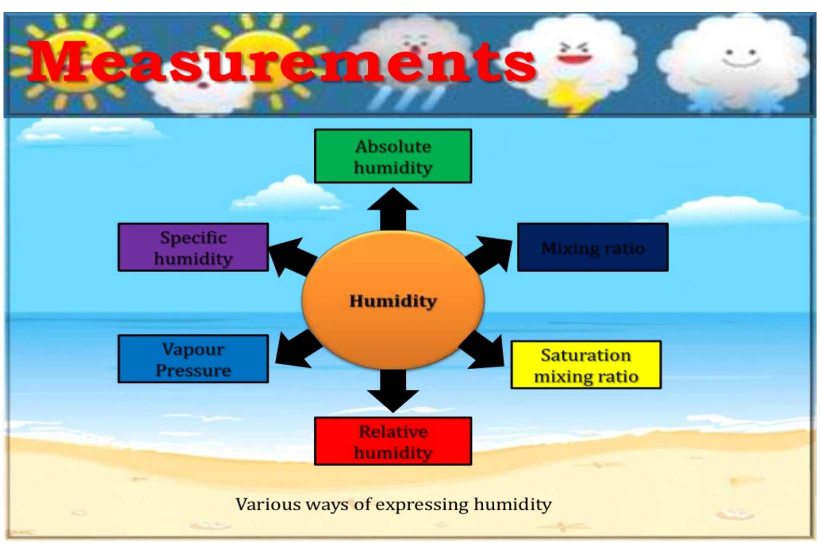
S5: Atmospheric humidity and rainfall, Wind circulation

Atmospheric humidity

Atmospheric humidity is the amount of water vapour carried in the air. It can be measured as vapour pressure, mixing ratio or specific humidity. ... Atmospheric water vapour is also the most important greenhouse gas in the atmosphere.



Various ways of expressing humidity

Types of Humidity

(i) Relative humidity,

(ii) Specific humidity,

(iii) Mixing ratio, and

(iv) Absolute humidity.

Relative humidity

Relative humidity may also be defined as the ratio of actual vapour pressure to that required for saturation at the same temperature.

$$\text{RH} = \frac{\text{Actual vapour pressure}}{\text{Saturation vapour pressure}} \times 100$$

Specific humidity

- It is the ratio of mass of water vapours actually present in the air to a unit mass of air including the water vapour (dry air + moisture). It is expressed as grams of water vapour per kg of moist air mass. The amount of water vapour that air can hold depends upon temperature. Specific humidity at 20°C is 15g per kg. At 30°C, it is 26 g per kg and at -10°C, it is 2 g per kg.
- Suppose, 1kg of air contains 12 grams of water vapours, then the specific humidity of air is 12 g per kg.

Mixing ratio

It is defined as the ratio of mass of water vapours per unit mass of dry air. It is also defined as the ratio of density of water vapours to the density of dry air. It varies from 1 g per kg in arctic zone to 40 g per kg in humid equatorial zone.

Absolute Humidity:

- It is defined as the weight of water vapours in a given volume of air. It is expressed as grams of water vapours per cubic meter of air (g m^{-3}). Absolute humidity is rarely used because it varies with the expansion and contraction of air. It varies with temperature, even though the amount of water vapours remains constant.

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RAINFALL

- Rainfall is a form of Precipitation. The term "rainfall" is used to describe precipitation in the form of water drops of sizes larger than 0.5 mm. Other forms are snow, drizzle, glaze, sleet and hail. ... Sleet is frozen raindrops of transparent grains which form when rain falls through air at subfreezing temperature.

Convectional Rainfall

- Suppose we are enjoying the rays of sunshine and suddenly, the sky gets darker with the grey cloud. Without any warning the heavens open and it begins to rain, with a thundery feel. This is the convectional rain. It occurs frequently on hot days usually giving cumulus cloud and thundery showers.
- The sun heats the ground which causes the air to warm and become very hot. Then the air rises upwards and becomes cool. Then it condenses to form cumulus cloud.
- When this cloud is saturated, it begins to precipitate giving heavy and thundery showers. Due to this, we get thundershowers on a hot day, as the Sun warms the air and it rises, cools and begins to rain.

Frontal Rainfall

- This rainfall occurs when a warm, tropical air mass comes in contact with a cold, polar air mass. It is very common in Britain and Ireland. Because the air is in the warm front, then it rises over the cold front. The air is cooled and so condenses to form a stratus cloud. Thus when the stratus cloud becomes saturated, it begins to precipitate.

Relief Rainfall

- This type of rainfall is common in places with mountains and sea. Relief rainfall frequently occurs near mountains beside the sea. The moisture-laden wind blows in from the sea because the wind meets a high mountain and hence it is forced to rise upwards. At the height, it is cooled and then the cloud is formed.
- This saturated cloud with water vapor begins to precipitate on the side of the mountain facing the sea. This front side of the mountain is called the windward side.
- The cloud mostly precipitates on the windward side of the mountain. Meanwhile, the cloud meets the other side, which is called the leeward side. Since the cloud has already lost most of its moisture so it rains very little there.
- This makes leeward sides of a mountain very little rains. There is a much more moist climate on the windward sides of slopes. On the other hand, there is a more dry, sheltered climate on the leeward side. This rainfall is common in Hawaii, Sierra Nevada, and the Andes.

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Wind circulation

Winds are produced in response to radiative heating of the atmosphere. These winds constitute an important forcing for ocean currents, which are generated due to momentum transferinto the ocean bywinds. The pressure gradients generated by radiative heatingcould produce wind speeds of about10ms−1in the atmospherejust above the ocean.Yet,there willbeno momentum transfer by winds to ocean layersif there were no friction at the surface.Becauseof the frictional contact,no slipconditionwill be satisfied by the airflow at solid surface boundary; that is, the air in immediate contact with the boundary attains zero velocity.

This will set up a velocity gradient (or shear) near the solid boundary. The shear flowset upin this manneris not stable at higher windspeeds because small disturbances can grow at the expense of mean motion to turnthe flow turbulent. The turbulent eddiesare responsible for the gusty nature of the flow, modify shear fora well-defined mean velocity structure to developafter sufficiently long time. The flow velocity is a function of z, i.e. the distance from the surface inverticaldirection. The shear depends on mean stress τ, density ρand distance z from the ground, and one obtains a logarithmic mean velocity profile.

For the same solar heating rate, land temperaturesrise faster in summer than the sea temperatures and also land coolsrapidly during winter with the diminishing radiative heating. As a result of this contrast, low-pressuresystems during summers and high pressures during winters develop over land areas. Such a flip-flop in atmospheric pressures over land will result in the alteration of pressure systems over the oceans as well.

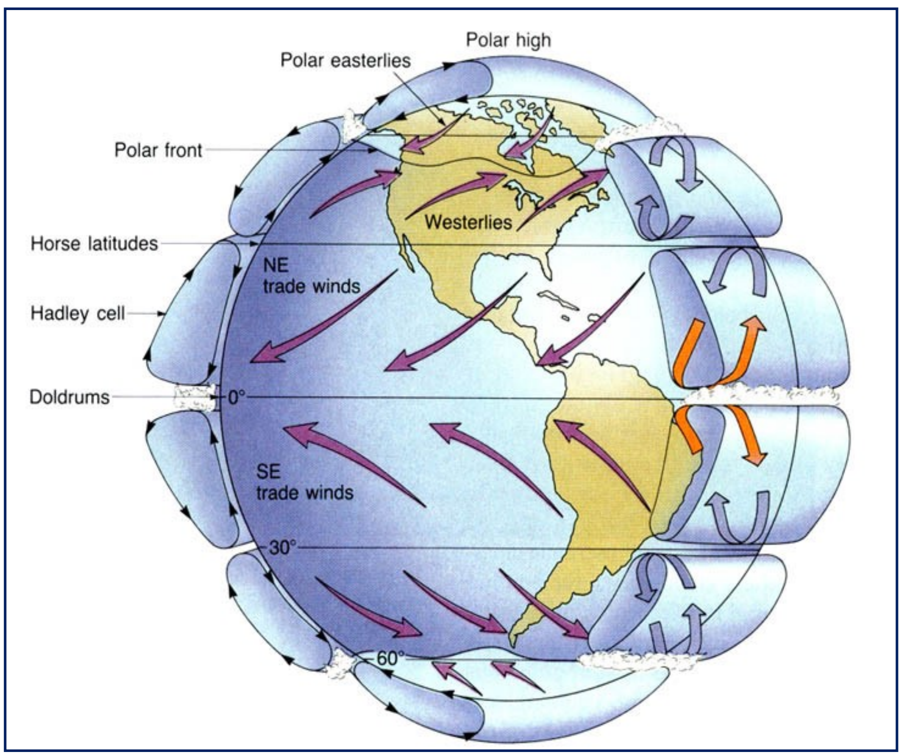
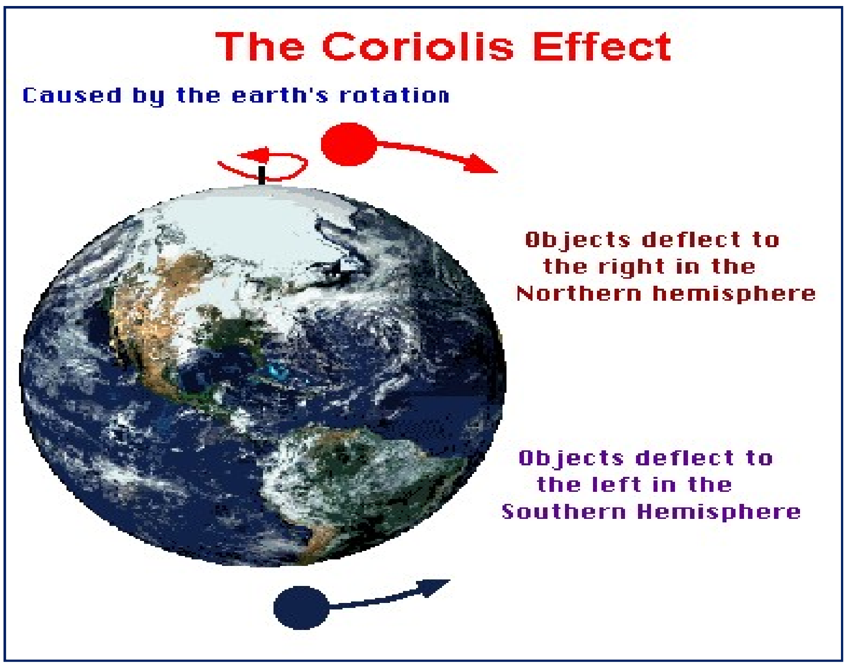


Fig: Global wind pattern

Coriolis force

- Due to the rotation of the earth, wind and ocean currents are deflected to the right in the northern hemisphere and to the left in the southern hemisphere. This effect is known as the "Coriolis force."
- The deflection leads to highs and lows of sea level directly proportional to the speed of the surface currents
- The Earth would have two large Hadley cells, if it did not rotate.
- Rotation of the Earth leads to the Coriolis Effect
- This causes winds (and all moving objects) to be deflected:
- To the right in the Northern Hemisphere
- To the left in the Southern Hemisphere



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S6: Ocean circulation, Atmospheric stability and lapse rate

Ocean circulation

Ocean circulation is the large scale movement of waters in the ocean basins.

There are two main types of ocean currents: currents driven mainly by wind and currents mainly driven by density differences. Density depends on temperature and salinity of the water.

1. Horizontal circulation
    1. Surface currents
    2. Deep currents

    (Cold and salty water is dense and will sink. Warm and less salty water will float)

2. Vertical circulation
    1. Upwelling
    2. Downwelling

Horizontal currents:

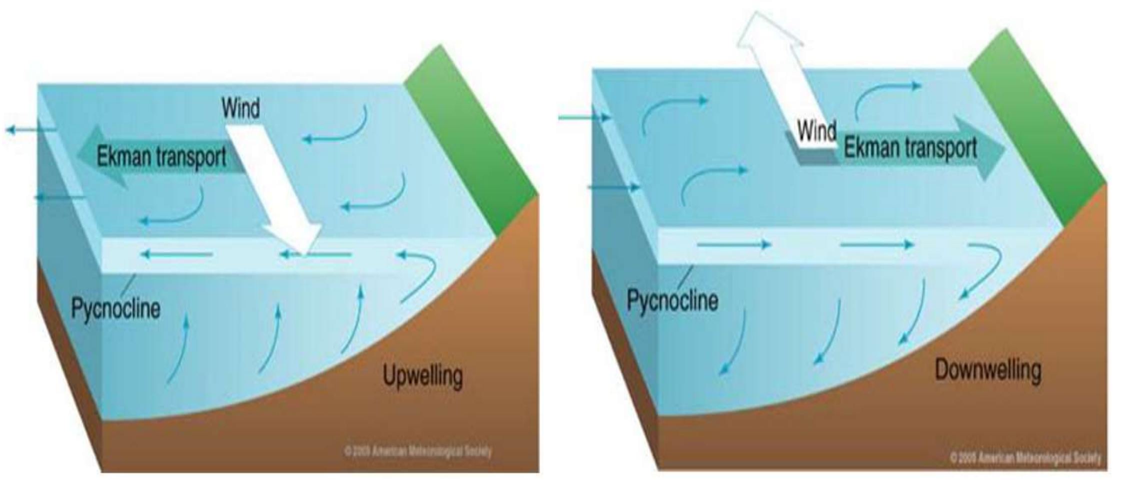
Winds drive surface circulation, and the cooling and sinking of waters in the polar regions drive deep circulation.

Surface circulation carries the warm upper waters poleward from the tropics.

Heat is disbursed along the way from the waters to the atmosphere. At the poles, the water is further cooled during winter, and sinks to the deep ocean. This is especially true in the North Atlantic and along Antarctica.

Deep ocean water gradually returns to the surface nearly everywhere in the ocean. Once at the surface it is carried back to the tropics, and the cycle begins again. The more efficient the cycle, the more heat is transferred, and the warmer the climate.

Winds blowing across the ocean surface push water away. Water then rises up from beneath the surface to replace the water that was pushed away. This process is known as “upwelling.”
Upwelling occurs in the open ocean and along coastlines. The reverse process, called “downwelling,”



Importance of ocean circulation

- ocean currents have a major impact on the global climate. They cause the relative mildness of the Western European climate, for example.
- Ocean and atmospheric currents form a coupled dynamic system. Instabilities of this system, the El Nino Southern Oscillation (ENSO) in particular, produce important climate fluctuations.
- Ocean currents not only distribute heat, but they also play a crucial role in the global ecosystem by storing CO_2 and recycling nutrients.

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Atmospheric stability

- Atmospheric stability is a term used to qualitatively describe the amount of vertical motion of the air in the lower atmosphere (the troposphere). In broad general terms, the atmospheric stability can be characterized by these four categories:
- A *very stable* atmosphere is one that has very little vertical motion of the air.
- A *stable* atmosphere is one that discourages vertical motion but does have some motion of the air.
- An *unstable* atmosphere is one that encourages continual vertical motion of the air, upwards or downwards.
- A *neutral* atmosphere is one that neither discourages nor encourages vertical motion of the air and is often referred to as *conditionally stable*.

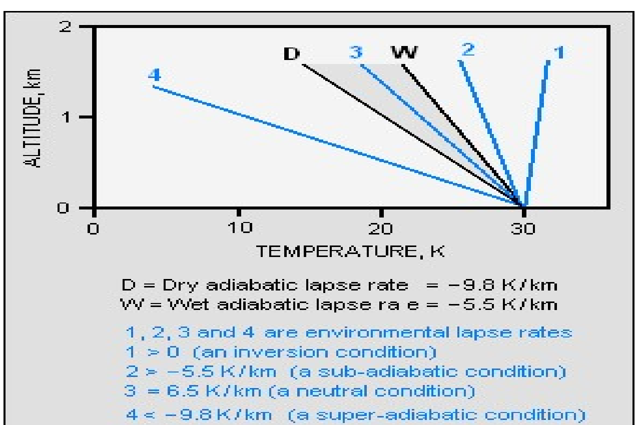
Importance of understanding atmospheric stability

- An understanding and knowledge of atmospheric stability is important for many reasons. What follows is a brief discussion of some of those reasons:
- Probably one of the most important reasons is that atmospheric turbulence and mixing plays a major role in air pollution dispersion modeling. Turbulence and mixing is provided by an unstable atmosphere and thus enhances the dispersion of air pollutant, while a stable atmosphere inhibits turbulence and results in very poor dispersion of air pollutants.
- A stable atmosphere inhibits rain fall, while an unstable atmosphere encourages rainfall and thunderstorms.
- A stable atmosphere also inhibits forest fire activity and an understanding of atmospheric stability helps explain certain aspects of forest fire behavior.

- A certain amount of atmospheric instability is important for glider pilots, since without it the thermals needed for glider flight would not form. Understanding of atmospheric stability is also important for the safety of glider pilots because high atmospheric instability may lead to thunderstorms.
- The atmospheric stability has a large impact on the deposition and drift of aerially applied sprays of various farm crop protection materials.

Atmospheric lapse rate

- The **atmospheric lapse rate** refers to the change of an atmospheric variable with a change of altitude, the variable being temperature unless specified otherwise (such as pressure, density or humidity).
- Lapse rates are usually expressed as the amount of temperature change associated with a specified amount of altitude change, such as 9.8 K per kilometre, 0.0098 K per metre or the equivalent 5.4 °F per 1000 feet.
- If the atmospheric air cools with increasing altitude, the lapse rate may be expressed as a negative number. If the air heats with increasing altitude, the lapse rate may be expressed as a positive number.



Source: Milton Beychok

Various lapse rates defining the change of atmospheric temperature with altitude.