

Lecture Note – 2

Precipitation (Background)

Water Vapor

Atmospheric water mostly exists as a gas, or vapor, but briefly and locally it becomes a liquid in rainfall and in water droplets in clouds, or it becomes a solid in snowfall, in hail, or in ice crystals in clouds.

Specific humidity (q_v)

Specific humidity is defined as the mass of water vapor per unit mass of moist air. As mass per unit volume equals density, therefore specific humidity is also defined as the ratio of density of water vapor to density of moist air.

$$\text{Mathematically, } q_v = \frac{\rho_v}{\rho_a}$$

Where,

ρ_v = Density of water vapor

ρ_a = Density of moist air

Vapor pressure

Vapor pressure is the partial pressure of water vapor in the atmosphere.

$$\text{Mathematically, } e = \rho_v R_v T$$

Where,

e = Vapor pressure of water vapor (pascal)

ρ_v = Density of water vapor (kg/m^3)

R_v = Gas constant for water vapor ($\text{J/Kg}^\circ\text{K}$)

T = Absolute temperature ($^\circ\text{K}$)

Saturation vapor pressure (e_s)

For a given air temperature, there is a maximum moisture content the air can hold; the corresponding vapor pressure is called the saturation vapor pressure.

$$\text{Mathematically, } e_s = 611 \exp\left(\frac{17.27T}{237.3 + T}\right) \quad [\text{Raudkivi, 1979}]$$

Where,

e_s = Saturation vapor pressure (pascal)

T = Given air temperature ($^\circ\text{C}$)

Relative humidity (R_h)

It is the ratio of actual vapor pressure to its saturation value at a given air temperature.

$$\text{Mathematically, } R_h = \frac{e}{e_s}$$

Dew-point temperature (T_d)

The temperature at which air would just become saturated at a given specific humidity is its dew-point temperature.

Precipitation

Precipitation denotes all forms of water that reach the earth from the atmosphere.

Formation of precipitation

- Lifting of air mass in the atmosphere so that it cools and some of its moisture condenses.

There are three main mechanisms of air mass lifting:

A. Frontal lifting: Lifting of warm air on one side of a frontal surface over colder, denser air on the other side.

B. Orographic lifting: Air mass rises to pass over a mountain range.

C. Convective lifting: Rising of warmer, lighter air in colder, denser surroundings.

- Condensation requires a seed called condensation nuclei on which the droplets form. Condensation nuclei (0.1 to 10 μm) usually consist of products of combustion, oxides of nitrogen and salt particles.
- The tiny droplets grow by condensation and impact with their neighbors as they are carried by turbulent air motion, until they become large enough so that the force of gravity overcomes that of friction.
- As they begin to fall, further increase in size occurs as they hit other droplets in the fall path.
- However, as the drop falls, water evaporates from its surface and the drop size diminishes, so the drop may be reduced to the size of an aerosol and be carried upwards in the cloud through turbulent action.
- * Aerosol: Remains airborne indefinitely except for precipitation. (size < 3 μm).
- The cycle of condensation, falling, evaporation, and rising occurs on average about 10 times before the drop reaches a critical size of about 0.1 mm, which is large enough to fall through the bottom of the cloud.

- Up to 1 mm in diameter, the droplets remain spherical in shape, but beyond this size they begin to flatten out on the bottom until they are no longer stable falling through the air and break up into small raindrops and droplets. Normal raindrops falling through the cloud base are 0.1 to 3 mm in diameter.

Cloud seeding

It is a process of artificially nucleating clouds to induce precipitation. Silver iodide is a common nucleating agent and is spread from aircraft in which a silver iodide solution is evaporated with a propane flame to produce particles.

Forms of Precipitation

Rain: Consists of liquid water drops mostly larger than 0.5 mm in diameter. On the basis of intensity, rainfall is classified as,

Light: Trace to 2.5 mm/h

Moderate: >2.5 mm/h to 7.6 mm/h

Heavy: >7.6 mm/h

Snow: Snow consists of ice crystals. The average density is 0.1 gm/cm³.

Drizzle: (Sometimes called **mist**) consists of tiny liquid water droplets, usually with diameters between 0.1 and 0.5 mm. Drizzle usually falls from low stratus and rarely exceeds 1 mm/hr.

Glaze: When rain or drizzle comes in contact with cold ground at around 0°C, the water drops freeze to form an ice coating called glaze. Sp. gr. may be as high as 0.8 to 0.9.

Sleet: when rain falls through air at sub-freezing temperature, the frozen rain drops are called sleet.

Rime: Formed by rapid freezing of super-cooled water drops impinging on exposed objects. Sp. gr. may be as low as 0.2 to 0.3.

Hail: It is a showery precipitation in the form of irregular pellets or lumps of ice of size more than 8 mm.