Condensation, freezing and deposition

Although water is present in some degree almost everywhere in the troposphere, it is usually unseen, in the form of vapour. Whenever clouds appear, they provide visual evidence of the presence of water in the atmosphere. In many cases they indicate future trends in the weather.

- A mixture of dry air and water vapour is known as moist air. Most clouds are formed by the cooling of moist air. Therefore those atmospheric processes which produce cooling of the air may also result in the formation of clouds.

Condensation

If more water is allowed to enter a space which has already been saturated at a given temperature, condensation of water vapour will occur.

- When moist air is cooled below its dew point, water droplets condense on minute particles present in the air. These are known as condensation nuclei and include dust, smoke, sea salt, ions etc.
- In some cases, these nuclei have a special affinity with water and are said to be hygroscopic. Salt particles from sea spray are of this type and condensation may occur before the relative humidity reaches 100%.

Freezing

Pure liquid water, if undisturbed, can be cooled to the temperatures well below its freezing point and still remain liquid.

- These water droplets in the atmosphere that are cooled below 0°C, and do not necessarily freeze are said to be supercooled.
- Cloud droplets commonly occur in the supercooled state at temperatures as low as -20°C.
- On occasions, supercooled cloud droplets may even occur at temperatures down to -35°C.
- Small droplets may be cooled to temperatures of about -40°C before freezing occurs. However, water in contact with foreign solid materials or small suspended particles will freeze at considerably higher temperatures.
- In the atmosphere, certain types of suspended particles may act as nuclei for the freezing process. A particle which initiates the growth of an ice crystal by the freezing of supercooled water about itself is called a freezing nucleus.

Deposition

Water vapour may also change directly to a solid without passing through the liquid state. This process is known as deposition. It is also sometimes referred to as sublimation, but this term really refers to the reverse process, in which a direct change from ice to water vapour occurs.

Deposition is not as common as condensation. Nuclei on which deposition takes place are less numerous then condensation nuclei.

Any particle upon which an ice crystal grows by the process of deposition is called a sublimation nucleus. Many experiments have been conducted to determine whether certain particles act a freezing nuclei or sublimation nuclei. It has never been demonstrated that sublimation nuclei, as distinct from freezing nuclei, exist in the atmosphere.

Clouds with strong up currents often contain a relatively high proportion of water drops which are carried up before they have an opportunity to freeze, but the iced crystals grow more rapidly than the water drops because adiabatic cooling of the ascending air maintains a state of saturation with respect to water and therefore super saturation with respect to ice.

In meteorology, it is therefore usual to use the term freezing nuclei when referring to ice-forming nuclei. A thin film of water forms on the surface of the nucleus and then freezes. The film is so thin, however, that droplets are difficult to detect. As a result, the ice crystal forms as if from a vapour.

Ice-forming nuclei are also referred to as ice nuclei. The fact that water droplets occur so frequently in clouds at temperatures below 0°C indicates that ice nuclei are rarer than condensation nuclei. Nuclei that cause the formation of ice crystals in clouds at temperatures above -40°C are not the same particles as those responsible for the condensation of water vapour into cloud droplets.

The majority of freezing nuclei in the atmosphere probably originate at the Earth's surface as wind-blown soil particles of particular types. Certain clay minerals seem to be most important, and it is likely that turbulent mixing could distribute them fairly uniformly up to high altitudes.