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DOCUMENT TITLE
METEOROLOGY FOR AUSTRALIA

CHAPTER 13 – PRECIPITATION

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PRECIPITATION

INTRODUCTION

A cloud droplet held in suspension needs to merge or coalesce with nearly one million other cloud droplets before reaching the size of a typical raindrop.

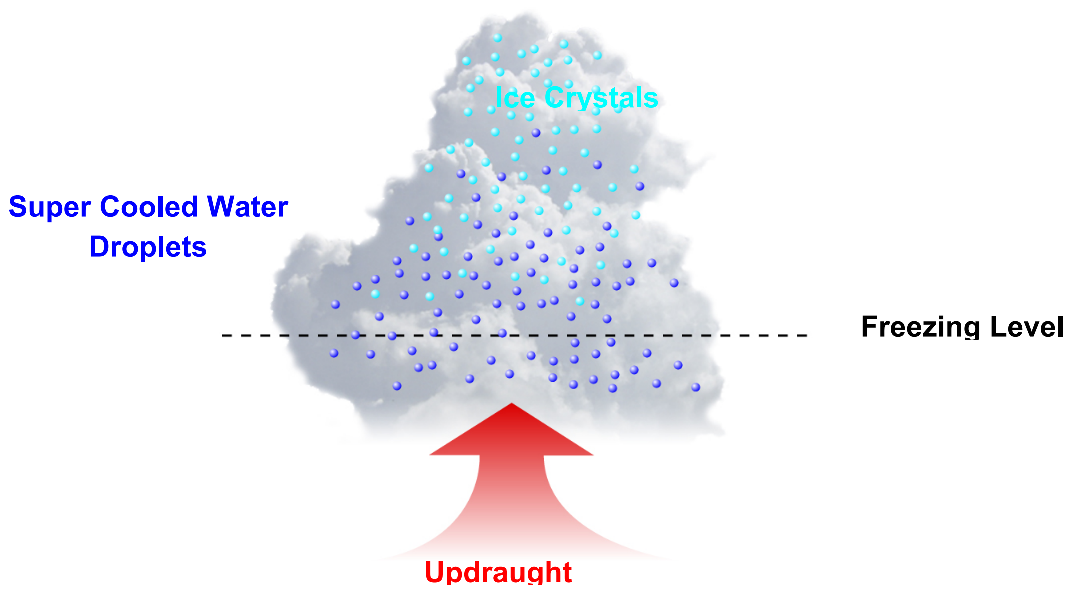
Two theories have emerged in time on how this process may come about, but first some essential knowledge is required to understand these theories.

For a droplet of liquid to freeze, it must first find itself a solid nucleus, otherwise it will remain in liquid form. Likewise, for a gas to sublimate (change directly from a gas to a solid), a solid particle must also be present to act as a nucleus. Now, on with the theories:

ICE CRYSTAL THEORY

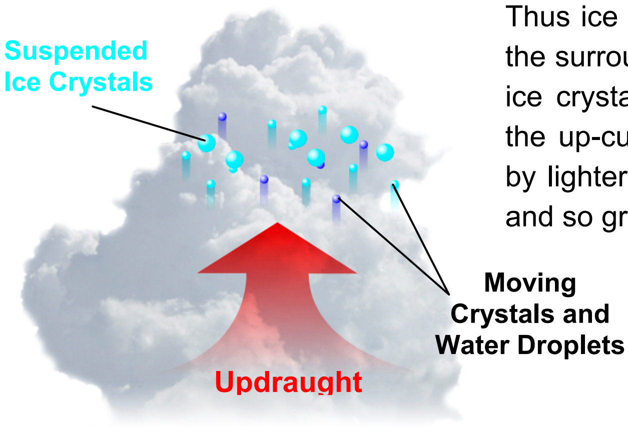
The small water droplets which are carried upwards in a cloud can (and normally do) exist in liquid form at temperatures well below freezing because of the lack of ice-nuclei on which to attach and freeze.

Supercooled water droplets are thus found many thousands of feet above the freezing level, and for the first few thousands of feet they greatly outnumber the frozen drops, or ice crystals.



Eventually a level is reached at which there is an appreciable proportion of ice crystals, and it is from this level that precipitation begins to fall. As the super cooled water droplets and ice crystals rise, the temperature of the surrounding air eventually falls to the frost point (100% saturation) with respect to the air in contact with the ice surface of the crystals.

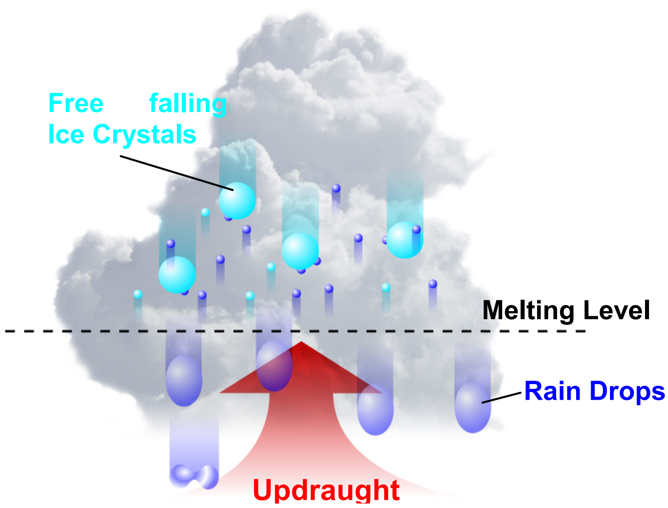
As a result, they cease to sublimate water vapour into the air. At this temperature, the air in contact with the water surface of the droplets has not yet reached its dew point (it occurs at a slightly lower temperature) and so evaporation of water vapour continues. The release of this vapour causes super-saturation of the air with respect to the ice crystals and the water vapour sublimates out as ice onto them.



Thus ice crystals grow in size and weight at the expense of the surrounding super cooled water droplets. Eventually the ice crystals grow large enough for their weight to balance the up-currents in the cloud, and they are then 'overtaken' by lighter ice crystals and water droplets rising from below, and so grow even faster.

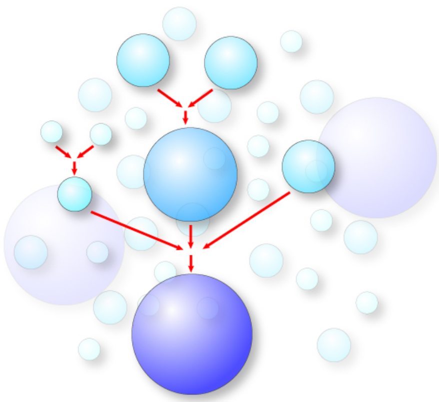
As they subsequently sink in the cloud they sweep up even more droplets and ice crystals until they fall through the melting level and reach the ground as rain.

During their fall they grow very rapidly, and can become so large that they break up, with one original ice crystal reaching the ground as a number of individual raindrops.



This ice crystal theory explains most cases of precipitation, but it does not cater for the instances (mainly at lower latitudes), in which rain falls from clouds which do not extend above the 0°C isotherm. For this situation, the coalescence theory applies.

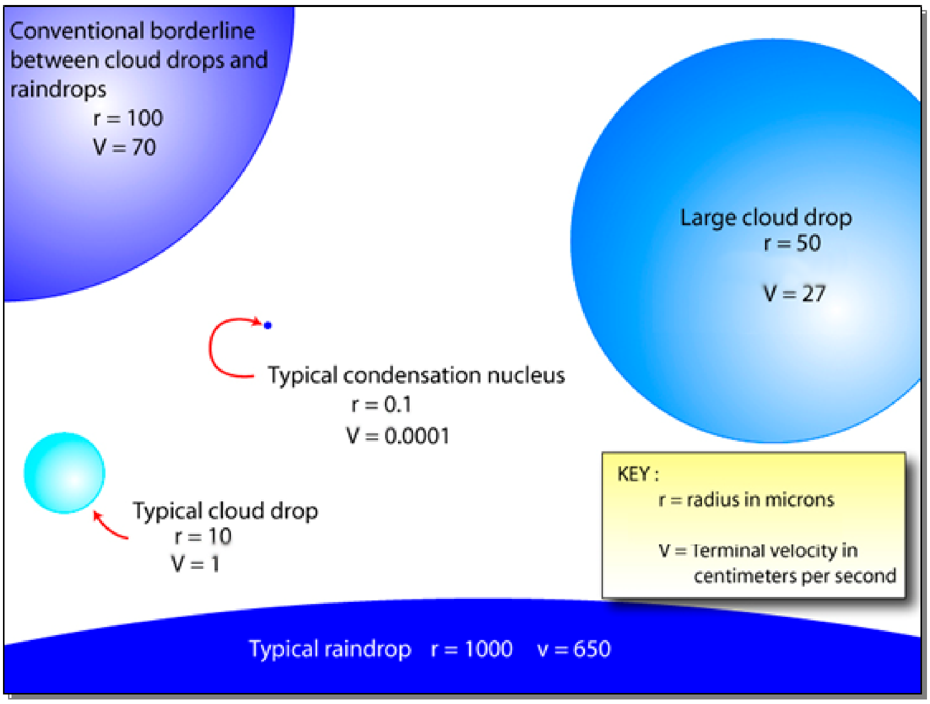
COALESCENCE THEORY



The motion of air within a cloud ensures that random collisions must occur between adjacent droplets. The process of two or more droplets merging to become one larger droplet is called coalescence.

It would take a very long time for enough random collisions to occur to produce drops that are large enough to qualify as drizzle, far less as rain. Additional factors must also be at work.

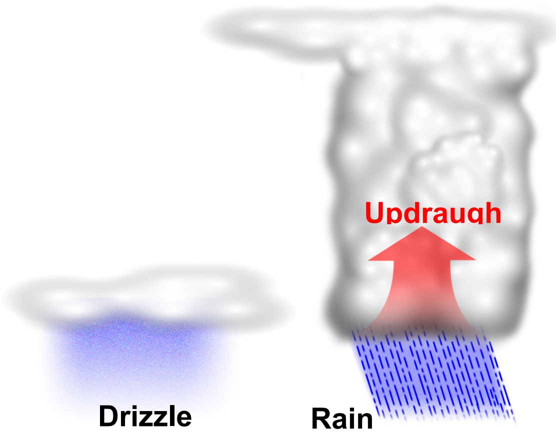
Where the cloud is thick enough, the slightly larger, heavier droplets which form through coalescence near the top of the cloud will sweep up other smaller droplets as they slowly fall. These will themselves tend to break up as they grow, setting in motion a chain reaction. There need only be a few larger droplets, such as those that form on especially favourable condensation nuclei, e.g. salt particles from sea spray, in order to set the whole chain reaction going, causing precipitation in the form of drizzle or light rain.



Size Range of Elements involved in Cloud Physics

REQUIREMENT FOR VERTICAL MOTION

The precipitation theories both rely on vertical motion in order to produce rain (as opposed to drizzle). As the droplets increase in size and weight their terminal velocities increase. Without vertical motion to hold the droplets in suspension in the cloud, they would fall out sooner as the smaller and lighter droplets we call drizzle. With vertical motion, the droplets become larger and heavier and must be falling faster to escape. Therefore appreciable vertical motion results in rain, whereas without such motion only drizzle falls.



FACTORS CONDUCIVE TO A CLOUD GIVING PRECIPITATION

- Strength of updraughts - this determines the droplet size.
- Supply of water vapour - if condensation continues, the number of droplets will increase.
- Density of cloud - droplets grow due to coalescence (fusing together) both when held in suspension and when falling.
- Mechanism causing the formation of the cloud - if this is still continuing, precipitation is more likely to occur.
- Ice in the tops of clouds - to act as nuclei.

PRECIPITATION

Types of Precipitation

"A hydrometeor is a meteor consisting of an ensemble of liquid or solid aqueous particles, falling through or suspended in, the atmosphere, blown by the wind from the Earth's surface, or deposited on objects on the ground or in the free air. Precipitation refers to falling hydrometeors that eventually reach the ground. It does not include virga, as virga evaporates before reaching the ground."

There are many types of precipitation, most of which will be familiar to anyone who might live on an island in the temperate regions of the Earth. The major ones we are concerned with are:

1. Drizzle. Small droplets of water (conventionally of a radius of less than 250μ. Frequently falls from stratiform cloud.

2. Rain. Droplets of water larger than drizzle (of a radius larger than 1000μ). Usually falls from cumuliform clouds.

3. Freezing drizzle or freezing rain. Supercooled water droplets that can then freeze on impact with a solid surface.

4. Snow. Precipitation in the form of ice crystals, aggregates of which are called snowflakes.

5. Hail. A precipitation in the form of a ball or a pieces of ice (diameter 5 to 50 mm). Only produced by Cumulonimbus clouds. More detail on the formation of hail can be found in Chapter 21.

6. Sleet. In Australia sleet is defined as rain and snow falling together, or snow melting as it falls.

7. Ice pellets. These are small transparent ice particles (less than 5 mm in diameter). They fall from thick layer cloud such as nimbostratus.

8. Snow pellets. White and opaque grains of ice (2 to 5 mm in diameter)

9. Snow grains. Very small white and opaque grains of ice (less than 1 mm in diameter). They fall mostly from stratus or fog.

Hailstone Sizes

The maximum size of hailstones that have been found on the ground is around 5.5" (14 cm.) in diameter. It is known that hailstones of 4" (10cm.) can be encountered at 10,000' and damaging hail up to 45,000'. On occasions, hailstones may reach giant sizes, weighing up to .76kg each (Sept. 1970, Coffeyville Kansas)

After the initial formation of ice particles at temperatures well below 0°C, growth is mainly due to collision and coalescence with super-cooled water drops. The opaque layers are caused by air trapped within the ice which forms on the particle when the liquid water content of the cloud is small; the clear layers are the result of slower freezing associated with high liquid water content of the cloud. In conditions favourable for the formation of large hail, those stones, which are of such a size that their fall speed is just less than the updraught, will remain in the cloud and thus grow larger.

Different Precipitation Forms

1. Showers
   Falls from isolated cloud. i.e. Cu, Cb. The showers are sudden to begin and end. There are bright periods between the showers.

2. Intermittent
   The cloud cover is more or less continuous but precipitation has breaks regardless of the length of time. Cloud type is usually As, Ns.

3. Continuous
   The precipitation falls without a break. Cloud type is Ns.

Formation of Precipitation

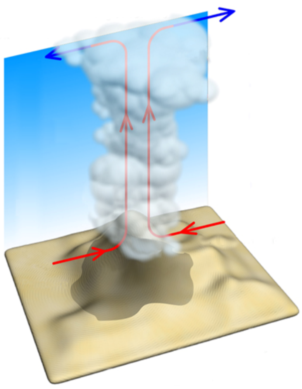
For precipitation to occur, cloud must exist. For this to occur, air must first be caused to rise The classification of rainfall is defined by the trigger that starts the rising process.

1. Convective Rainfall
   This is formed by hot air rising (Cu and Cb clouds). This is common in tropical areas and Northern Australia, but also occurs in temperate regions when conditions are suitable.

2. Frontal Rainfall
   When two air masses meet, the warm air rises over the colder air mass. This is common in the mid-latitude areas in winter.

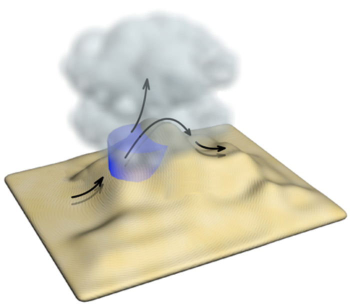
3. Orographic Rainfall
   Air is forced to rise over a mountain range forming orographic cloud from which precipitation can fall.

CONVECTIONAL



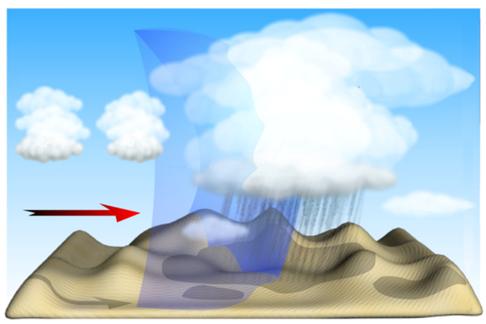
Heated air rises in Convection currents

OROGRAPHIC



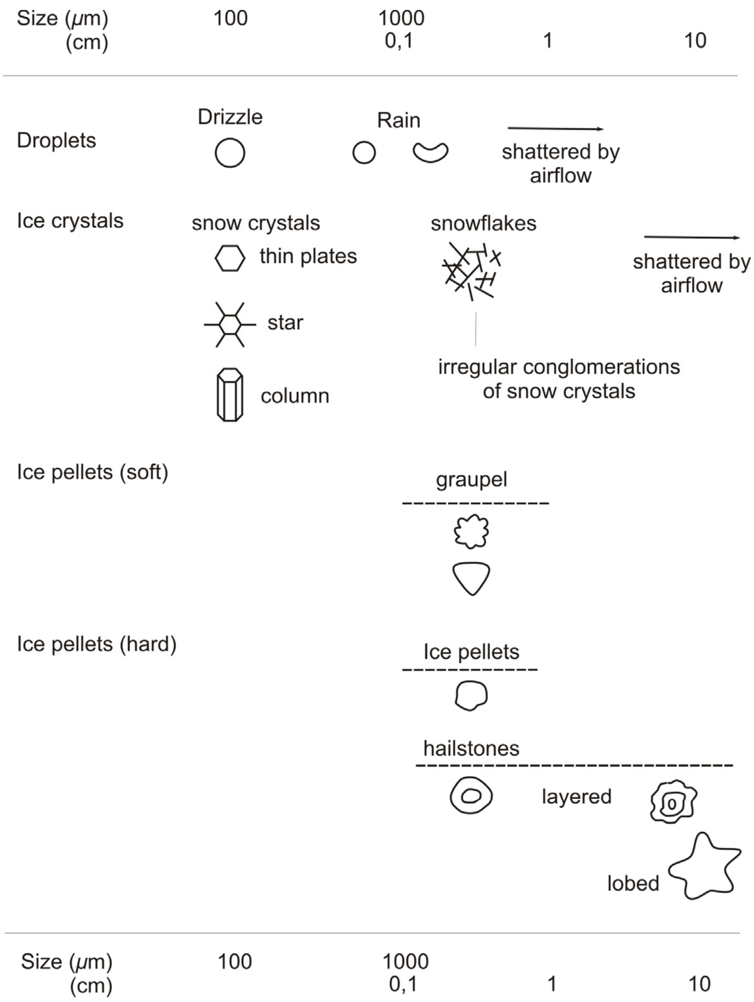
Moist air forced to rise over higher ground

FRONTAL



Warm moist air mass forced to rise above cold front

VARIOUS PRECIPITATION FORMS AND THEIR RELATIVE SIZES



TERMINAL VELOCITIES OF PRECIPITATION

Diameter,μ	Fall rate, ms^{-1}	Drop Type
5,000	8-9	large raindrop
1,000	4.0	small raindrop
500	2.8	fine rain
200	1.5	drizzle
100	0.3	large cloud drop
50	0.076	medium cloud drop
10	0.003	small cloud drop
2	0.00012	incipient drop
1	0.00004	large nucleus