CHAPTER 2

CLOUDS

A cloud is a hydrometeor (see 4.2.1) in suspension in the free air and usually not touching the ground. A cloud is composed of minute particles of water or ice, or both. It may also contain larger particles of water or ice and non-aqueous liquid particles or solid particles such as those present in fumes, smoke or dust.

2.1. HISTORICAL NOTE

The classification of clouds is based upon that originated by Luke Howard in 1803, namely cirrus, the thread cloud; cumulus, the heap cloud; stratus, the flat cloud or level sheet; and nimbus, the rain cloud. The details of a more precise classification occupied the attention of meteorologists in many countries during the latter part of the nineteenth century. A classification was agreed at the International Meteorological Conference in Munich in 1891, and in 1896 the first edition of the *International cloud atlas* appeared.

An International Commission for the Study of Clouds was set up in 1921 and produced the *International atlas of clouds and of types of skies* in 1932, preceded by an abridged edition in 1930 for the use of observers to meet the requirements of coding changes. New editions of both publications followed in 1939.

In the 1932 atlas, concepts were introduced that were of very great importance. Clouds in the first atlas had been regarded rather as fixed entities with no individual life history but in the 1932 atlas were acknowledged as dynamic features of the sky, to be considered both in relation to all other clouds present and to their stage of development in time. This radical change in the way clouds should be viewed led to changes in nomenclature which were reflected in the international codes for reporting cloud types. In the atlas an attempt was made to give examples not only of the basic cloud classification but also of the sky types (to which numbers are given in the reporting codes).

A new *International cloud atlas* was published in two volumes in 1956 by the World Meteorological Organization (WMO). The contents of Volume I differed materially from the 1939 atlas. The grouping of clouds in 'cloud families' was abandoned, the classification into genera was maintained, but some details in the definitions were modified. The species and varieties were extended and considerably modified, and a new concept, that of 'mother-cloud' (see 2.3.5), was introduced.

A revised edition of Volume I of the WMO atlas was published in 1975. This chapter is based very closely on that edition from which the listed definitions have been taken.

2.2. OBSERVATION OF CLOUDS

For a synoptic report the observer should identify all the cloud forms present, estimate cloud amounts, and estimate or measure the height of the cloud bases. He should also study the sky as a whole to assess its general appearance. (For a climatological report the observer usually observes only the total cloud amount.)

The observer needs to keep an almost continuous watch on the sky to be able to correctly identify clouds which continuously evolve and change. It is not possible, for example, to identify mother-clouds if no watch has been maintained during their evolution.

The observer should avoid looking directly at the sun since this could cause serious impairment of sight. A cloud-observing visor should be used to detect very thin cirrus clouds which are barely visible against the blue of the sky, and to observe all clouds when there is haze. It must be stressed that the visor does not protect the eyes when looking directly at the sun.

At night the observer should allow two or three minutes for his eyes to become adapted to darkness before making the observation which should be made from a dark place as far as possible from lights, especially when the atmosphere is hazy.

Pictorial guides and coding instructions are given in *Cloud types for observers*. Full details of relevant codes and specifications are given in the *Handbook of weather messages*, Parts II and III.

2.2.1. Observations of clouds from mountain stations. The procedure for observing clouds from mountain stations is the same as that for low-level stations when the mountain station is at a level lower than that of the base of the cloud.

When clouds are observed below station level they should be indicated separately. A description should be given of the upper surface of such clouds; features such as a flat or an undulated surface, or the presence of towering cumuliform clouds above the top of the layer, should be recorded. In estimating the cloud amount, the places where mountains penetrate a patch, sheet or layer of clouds are considered as covered with clouds.

2.2.2. Appearance of clouds. The appearance of a cloud is best described mainly in terms of the dimensions, shape, structure and texture. However, two other factors affect the appearance of a cloud, namely 'luminance' and 'colour', which are briefly noted below.

2.2.2.1. The luminance of a cloud is determined by the light reflected, scattered and transmitted by its constituent particles. This light mainly comes direct from the sun or moon or from the sky; it may also come from the surface of the earth, and is particularly strong when sunlight or moonlight is reflected by ice-fields or snow-fields. Haze affects the luminance of cloud. On a moonlit night, clouds are visible when the moon is more than a quarter full.

Ice-crystal clouds are usually more transparent than water-droplet clouds because of their limited vertical thickness and the sparseness of the ice particles but sometimes, when illuminated from behind, show marked contrasts in luminance; they are, however, brilliantly white in reflected light.

2.2.2.2. The colour of clouds depends primarily on the colour of the incident light. Haze between the observer and cloud may modify colour; it tends, for instance, to make distant clouds look yellow, orange or red. Cloud colours are also influenced by special luminous phenomena which are described in Chapter 11.

When the sun is sufficiently high above the horizon, clouds (or portions of cloud) which chiefly diffuse light from the sun are white or grey. Parts which receive light mainly from the blue sky are bluish-grey. When the illumination by the sun and sky is extremely weak, the clouds tend to take the colour of the surface below them. Cloud colours vary with the height of the cloud and its relative position with regard to observer and sun.

At night, clouds usually appear black to grey unless illuminated by the moon when they present a whitish appearance. Special illumination (fires, street lighting, polar aurorae, etc.) may, however, give a marked colouring to certain clouds.

2.2.3. Height, altitude and vertical extent of cloud.

(*a*) Height of a cloud feature, e.g. the base or top of a cloud, is the vertical distance from the place of observation (which can be on a hill or mountain) to the level of the cloud feature. The height of the cloud base is an important factor in determining the cloud type.

(*b*) Altitude of a cloud feature, e.g. the base or top of a cloud, is the vertical distance measured from mean sea level to the level of the cloud feature.

(*c*) Vertical extent of a cloud is the vertical distance between the level of its base and that of its top.

Surface observers generally report height and aircraft observers report altitude. In order to avoid possible confusion in giving reports of cloud height in plain language, it is Meteorological Office practice to add the phrase 'above ground level' which is routine for actual cloud-height reports (but see 2.2.1 for mountain stations).

2.2.3.1. *Cloud levels*, Observations have shown that cloud levels (with the exception of nacreous and noctilucent clouds, described in Chapter 11) vary over a range of altitudes from near sea level to perhaps 18 kilometres (60 000 feet) in the tropics, 14 km (45 000 ft) in middle latitudes, and 8 km (25 000 ft) in polar regions. By convention, the vertical extent of the atmosphere in which clouds are usually present is divided into three layers: high, medium and low. Each layer is defined by a range of altitudes between which clouds of certain types occur most frequently. The layers overlap and the approximate limits vary with the latitude as shown in the table below. Some clouds usually have their bases in the low level but may reach into the medium or high levels.

Level	Polar regions	Temperate regions	Tropical regions
High	3–8 km (10 000–25 000 ft)	5–14 km (16 500–45 000 ft)	6–18 km (20 000–60 000 ft)
Medium	2–4 km (6500–13 000 ft)	2–7 km (6500–23 000 ft)	2–8 km (6500–25 000 ft)
Low	From the earth's surface to 2 km (6500 ft)	From the earth's surface to 2 km (6500 ft)	From the earth's surface to 2 km (6500 ft)

When the height of the base of a particular cloud is known, the use of levels may assist the observer to identify the cloud.

2.3. CLASSIFICATION OF CLOUDS

This section details a classification of the characteristic forms of clouds. The definitions given apply, unless otherwise specified, to observations made under the following ideal conditions:

(*a*) The observer is at the earth's surface, either on land in areas without mountainous relief, or at sea.

(*b*) The air is clear; no obscuring phenomena such as fog, haze, dust, smoke, etc. are present.

(*c*) The sun is sufficiently high to give normal daylight conditions.

(*d*) The clouds are so high above the horizon that effects of perspective are negligible.

It will be necessary to adapt the definitions to other conditions. In many cases this can easily be done; for example, by night when the moon is in its brighter phases it may play, with regard to the illumination of clouds, a role analogous to that of the sun.

Following the *International cloud atlas*, the cloud forms are classified in terms of 'genera', 'species' and 'varieties'. A description of these terms follows, with an explanation of the subdivisions which can be used to define a particular cloud formation in more detail.

2.3.1. Genera. Cloud forms are divided into 10 main groups, called genera. A given cloud belongs to only one genus. The genera, together with their accepted form of abbreviation, are:

High	Medium	Low
Cirrus (Ci)	Altocumulus (Ac)	Stratus (St)
Cirrocumulus (Cc)	Altostratus (As)	Stratocumulus (Sc)
Cirrostratus (Cs)	Nimbostratus (Ns)	Cumulus (Cu)
	(Ns usually extends to other levels)	Cumulonimbus (Cb)

The following definitions of genera are limited to a description of these 10 main types and the essential characteristics necessary to distinguish a given genus from genera having a similar appearance. It should be noted that, so far as reporting procedures are concerned, it is the main genera that are important, whilst a knowledge of the subdivisions (described in subsequent paragraphs) can assist in coding and in understanding the evolution and transformation of the types of cloud which are observed.

(1) *Cirrus.* Detached clouds in the form of white delicate filaments, or white or mostly white patches or narrow bands. These clouds have a fibrous (hair-like) appearance, or a silky sheen, or both.

Cirrus is whiter than any other cloud in the same part of the sky. With the sun on the horizon, it remains white whilst other clouds are tinted yellow or orange, but as the sun sinks below the horizon the cirrus takes on these colours too and the lower clouds become dark or grey. The reverse is true at dawn when the cirrus is the first to show coloration. It is of a mainly fibrous or silky appearance with no cloud elements, grains or ripples which distinguishes it from cirrocumulus. Cirrus is of a discontinuous structure and of limited horizontal extent which is the distinction between it and cirrostratus. Dense cirrus patches or tufts of cirrus may contain ice crystals large enough to fall to give trails of some vertical extent. If these crystals melt they appear greyish. (See Plates I and II.)

(2) *Cirrocumulus*. Thin white patch, sheet or layer of cloud without shading, composed of very small elements in the form of grains, ripples, etc. merged or separate, and more or less regularly arranged; most of the elements have an apparent width of less than 1°.

This cloud often forms as a result of the transformation of cirrus or cirrostratus. It is rippled and subdivided into very small cloudlets without any shading. It is composed almost exclusively of ice crystals and can include parts which are fibrous or silky in appearance but these do not collectively constitute its greater part. Cirrocumulus is usually associated with cirrus or cirrostratus, particularly in high and middle latitudes. Care should be taken when a layer of altocumulus is dispersing that the small elements on the edge of the sheet are not confused with cirrocumulus. (See Plates II and III.)

(3) *Cirrostratus*. Transparent whitish cloud veil of fibrous or smooth appearance, totally or partly covering the sky, and generally producing halo phenomena.

This cloud usually forms a veil of great horizontal extent, without structure and of a diffuse general appearance. It is composed almost entirely of ice crystals and can be so thin that the presence of a halo may be the only indication of its existence. Its apparent motion is slow, as are changes in its appearance and thickness. Cirrostratus, when not covering the whole sky, may have a clear-cut edge but more often it is fringed with cirrus. A veil of haze may sometimes have the appearance of cirrostratus but the haze veil is opalescent or has a dirty yellowish or brownish colour. Shadows will normally continue to be cast when the sun is shining through cirrostratus, at least when the sun is high; when the sun is less than about 30° above the horizon the relatively longer path through a cirrostratus veil may reduce the light intensity so much that shadows do not form. (See Plates III and IV.)

(4) *Altocumulus*. White or grey, or both white and grey, patch, sheet or layer of cloud, generally with shading, and composed of laminae, rounded masses, rolls, etc. which are sometimes partly fibrous or diffuse and which may or may not be merged; most of the regularly arranged small elements usually have an apparent width of between 1 and 5°.

This genus can be confused with cirrocumulus and stratocumulus. If the cloud elements exhibit any shading, the cloud is altocumulus not cirrocumulus even if the elements have an apparent width of less than 1°. Clouds without shading are altocumulus if most of the regularly arranged elements, when observed at more than 30° above the horizon, have an apparent width of 1 to 5°. (Under similar conditions of observation, stratocumulus elements will have an apparent width of over 5°.) Altocumulus sometimes produces descending trails of fibrous appearance (virga), and coronae and irisation are often observed in thin parts of the cloud. (See Plates IV, V and VI.)

(5) *Altostratus.* Greyish or bluish cloud sheet or layer of striated, fibrous or uniform appearance, totally or partly covering the sky, and having parts thin enough to reveal the sun at least vaguely, as if through ground glass. Altostratus does not show halo phenomena.

Altostratus prevents objects on the ground from casting shadows. If the presence of the sun or moon can be detected, this indicates altostratus rather than nimbostratus. The former has a less uniform base. If it is very thick and dark, differences in thickness may cause relatively light patches between darker parts, but the surface never shows real relief, and the striated or fibrous structure is always seen in the body of the cloud. At night, if there is any doubt as to whether it is altostratus or nimbostratus when no rain or snow is falling, then, by convention, it is called altostratus. Altostratus is never white, as thin stratus may be when viewed more or less towards the sun. (See Plate VI and VII.)

(6) *Nimbostratus.* Grey cloud layer, often dark, the appearance of which is rendered diffuse by more or less continuously falling rain or snow which, in most cases, reaches the ground. It is thick enough throughout to blot out the sun. Low ragged clouds frequently occur below the layer, with which they may or may not merge.

Nimbostratus generally forms from thickening altostratus or when a well-developed cumulonimbus thickens and spreads out. Note that if hail, thunder or lightning are produced by the cloud it is called cumulonimbus. Nimbostratus is a thick dense cloud and can be distinguished from thick stratus by the type of precipitation it produces (see 2.3.6). It is also generally an extensive cloud, the base of which can be partially or totally hidden by ragged clouds (pannus), and care must be taken not to confuse these with the base of the nimbostratus. (See Plate VIII.)

(7) *Stratus.* Generally grey cloud layer with a fairly uniform base, which may give drizzle, snow or snow grains. When the sun is visible through the cloud its outline is clearly discernible. Stratus does not produce halo phenomena except possibly at very low temperatures. Sometimes stratus appears in the form of ragged patches.

Stratus may develop from stratocumulus when the cloud base of the latter becomes lower or loses its relief or apparent subdivisions. The lifting of a fog layer due to warming or an increase in the wind speed is another common mode of formation. During formation or dissipation it can appear as more or less joined fragments with varying luminance as stratus fractus but this stage is usually fairly short. It is usually composed of small water droplets and, if the cloud is thin, these can give rise to a corona. (See Plates VIII and IX.)

(8) *Stratocumulus.* Grey or whitish, or both grey and whitish, patch, sheet or layer of cloud which almost always has dark parts, composed of tesselations, rounded masses, rolls, etc. which are non-fibrous (except for virga) and which may or may not be merged; most of the regularly arranged small elements have an apparent width of more than 5°. (If a centimetre rule is held at arm's length, each centimetre will approximate to 1°.)

Stratocumulus may sometimes be confused with altocumulus. If most of the regularly arranged elements, when observed at an angle of more than 30° above the horizon, have an apparent width of more than 5°, the cloud is stratocumulus. Generally stratocumulus is composed of water droplets and, when it is not very thick, a corona or irisation is sometimes seen. However, in very cold weather, it may produce abundant ice-crystal virga. (See Plates IX and X.)

(9) *Cumulus*. Detached clouds, generally dense and with sharp outlines, developing vertically in the form of rising mounds, domes or towers, of which the bulging upper part often resembles a cauliflower. The sunlit parts of these clouds are mostly brilliant white; their base is relatively dark and nearly horizontal. Sometimes cumulus is ragged.

Cumulus clouds are detached although, when viewed from a distance, they may appear to have merged owing to the effect of perspective. Owing to their generally great vertical extent, cumulus may spread out and form stratocumulus or altocumulus cumulogenitus or, alternatively, penetrate existing layers of altocumulus or stratocumulus. Providing the cumuliform clouds remain detached from one another, they are still called cumulus. It can sometimes happen that a very large precipitating cumulus directly above an observer will exhibit none of the features normally associated with this genus, and it may be confused with altostratus or nimbostratus. Cloud evolution and the nature of the precipitation (see 2.3.6) can be of assistance in this case. (See Plates X, XI and XII.)

(10) *Cumulonimbus*. Heavy and dense cloud, of considerable vertical extent, in the form of a mountain or huge towers. At least part of its upper portion is usually smooth, or fibrous or striated, and nearly always flattened; this part often spreads out in the shape of an anvil or vast plume.

Under the base of this cloud, which is often very dark, there are frequently low ragged clouds either merged with it or not, and precipitation sometimes in the form of virga.

Cumulonimbus clouds normally develop from large cumulus but they can also do so from stratocumulus castellanus or altocumulus castellanus. When they cover a large expanse of sky the under surface can present the appearance of nimbostratus. The character of the precipitation may be of assistance in identifying the cloud. Cumulonimbus gives showers, very often quite heavy for comparatively short periods of time. If hail, thunder or lightning are observed then, by convention, the cloud is cumulonimbus. The evolution of the cloud can also aid identification. The change from large cumulus with domed tops and a hard outline (produced by water drops) to a top with a softer fibrous outline (produced by ice crystals) marks the change from cumulus to cumulonimbus. This genus may be described as a 'cloud factory'; it may produce extensive thick patches of cirrus spissatus, altocumulus, altostratus or stratocumulus by the spreading out of its upper portions. The spreading of the highest part usually leads to the formation of an anvil; if the wind increases with height, the upper portion of the cloud is carried downwind in the shape of a half anvil or vast plume. (See Plate XII.)

2.3.2. Species. Peculiarities in the shape of clouds and differences in their internal structure have led to the subdivision of most of the cloud genera into species. Altostratus and nimbostratus are the only genera which are not so divided. A cloud identified as of any particular genus may bear the name of one species only. The species are mutually exclusive but when several clouds of one particular genus are present simultaneously these clouds need not all belong to the same species. Certain species are common to several genera; for example, a profile resembling the shape of an almond or a lens is frequently seen in clouds of the genera cirrocumulus and altocumulus (and rarely in stratocumulus); consequently 'lenticularis' is recognized as a species in each of these three genera. The full list of cloud species is given below.

A cloud need not be identified as belonging to any species. When for a cloud of a given genus none of the definitions relevant to the genus is applicable, no species is indicated.

Fractus (fra)

Clouds in the form of irregular and ragged shreds. This terms applies only to stratus and cumulus. (See Plate VIII.)

Nebulosus (neb)

A cloud like a nebulous veil or layer, showing no distinct details. This term applies mainly to stratus and cirrostratus. (See Plate IV and IX)

Stratiformis (str)

Clouds spread out in an extensive horizontal sheet or layer. This term applies to stratocumulus, altocumulus and, occasionally, to cirrocumulus. (See Plates IV, IX and X.)

Lenticularis (len)

Clouds having the shape of a lens or almond, often very elongated and usually with well-defined outlines; they occasionally show irisation (iridescence). Such clouds appear most often in cloud formations of orographic origin, but may also occur in regions without marked orography. This term applies mainly to stratocumulus, altocumulus and cirrocumulus. (See Plate V.)

Castellanus (cas)

Clouds which present, in at least some portion of their upper part, cumuliform protuberances in the form of turrets which generally give the clouds a crenellated appearance. The turrets, some of which are taller than they are wide, may be connected by a common base and seem to be arranged in lines. The castellanus character is especially evident when the clouds are seen from a distance. This term applies to stratocumulus, altocumulus, cirrus and cirrocumulus. (See Plate VI.)

Humilis (hum)

Cumulus clouds of only slight vertical extent; they generally appear flattened. (See Plate X.)

Mediocris (med)

Cumulus clouds of moderate vertical extent, the tops of which show fairly small protuberances. (See Plate XI.)

Congestus (con)

Cumulus clouds which are markedly sprouting and are often of great vertical extent; their bulging upper part frequently resembles a cauliflower. (See Plates XI and XII.)

Calvus (cal)

Cumulonimbus in which at least some of the protuberances of the upper part are beginning to lose their cumuliform outlines but in which no cirriform parts can be distinguished. Protuberances and sproutings tend to form a whitish mass with more or less vertical striations. (See Plate XII.)

Capillatus (cap)

Cumulonimbus characterized by the presence, mostly in its upper portion, of distinct cirriform parts of clearly fibrous or striated structure, frequently having the form of an anvil, a plume or a vast, more or less disorderly, mass of hair. (See Plate XII.)

Floccus (flo)

A species in which each cloud unit is a small tuft with a cumuliform appearance, the lower part of which is more or less ragged and often accompanied by virga. This term applies to altocumulus, cirrus and cirrocumulus. (See Plate V.)

Fibratus (fib)

Detached clouds or a thin cloud veil, consisting of nearly straight or more or less irregularly curved filaments which do not terminate in hooks or tufts. This term applies mainly to cirrus and cirrostratus. (See Plates I and III.)

Spissatus (spi)

Cirrus of sufficient optical thickness to appear greyish when viewed towards the sun.

Uncinus (unc)

Cirrus often shaped like a comma, terminating at the top in a hook, or in a tuft whose upper part is not in the form of a rounded protuberance. (See Plate I.)

2.3.3. Varieties. Special features in appearance and degree of transparency of clouds have led to the concept of varieties. For example, a cloud with a definite wave characteristic would be termed 'undulatus'. The varieties, apart from 'translucidus' and 'opacus', are not mutually exclusive, so a particular cloud may bear the names of different varieties. Certain varieties may occur in clouds of several genera. The full list of cloud varieties is given below, but a cloud need not be identified as being of any particular variety.

The varieties duplicatus, intortus, lacunosus, radiatus, undulatus and vertebratus refer to the appearance; the varieties opacus, perlucidus and translucidus refer to the degree of transparency.

Duplicatus (du)

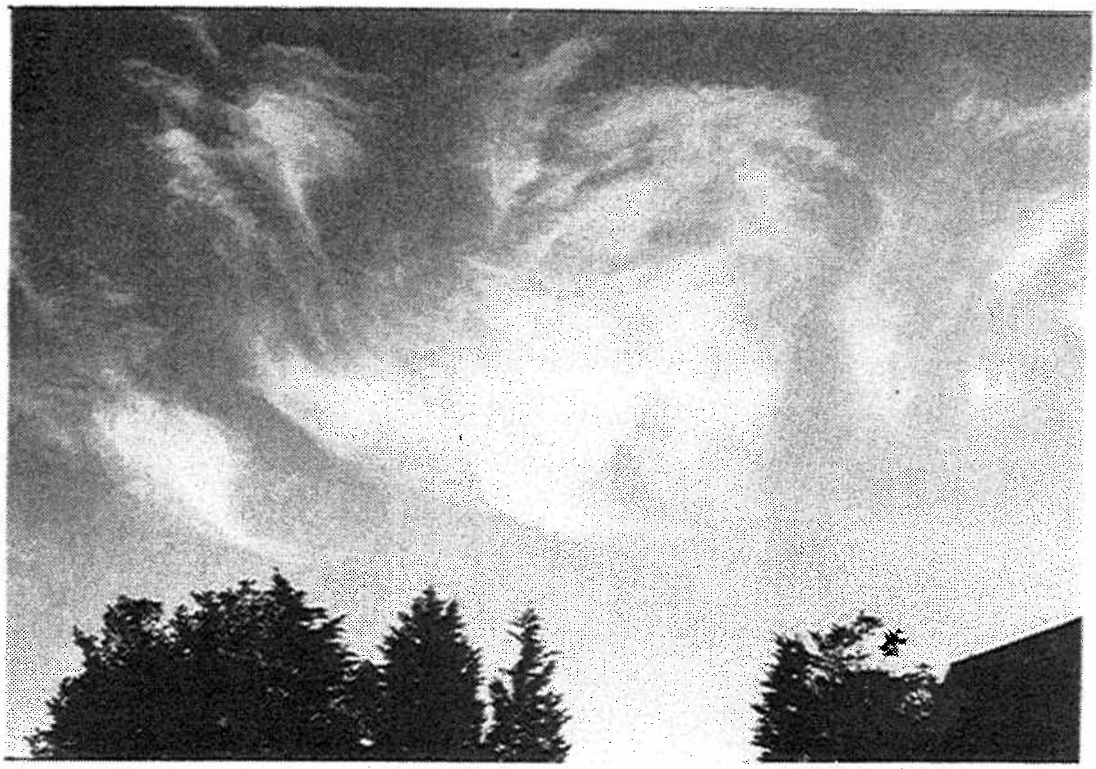
Superposed cloud patches, sheets or layers at slightly different levels, sometimes partly merged. This term applies mainly to stratocumulus, altocumulus, altostratus, cirrus and cirrocumulus.

Intortus (in)

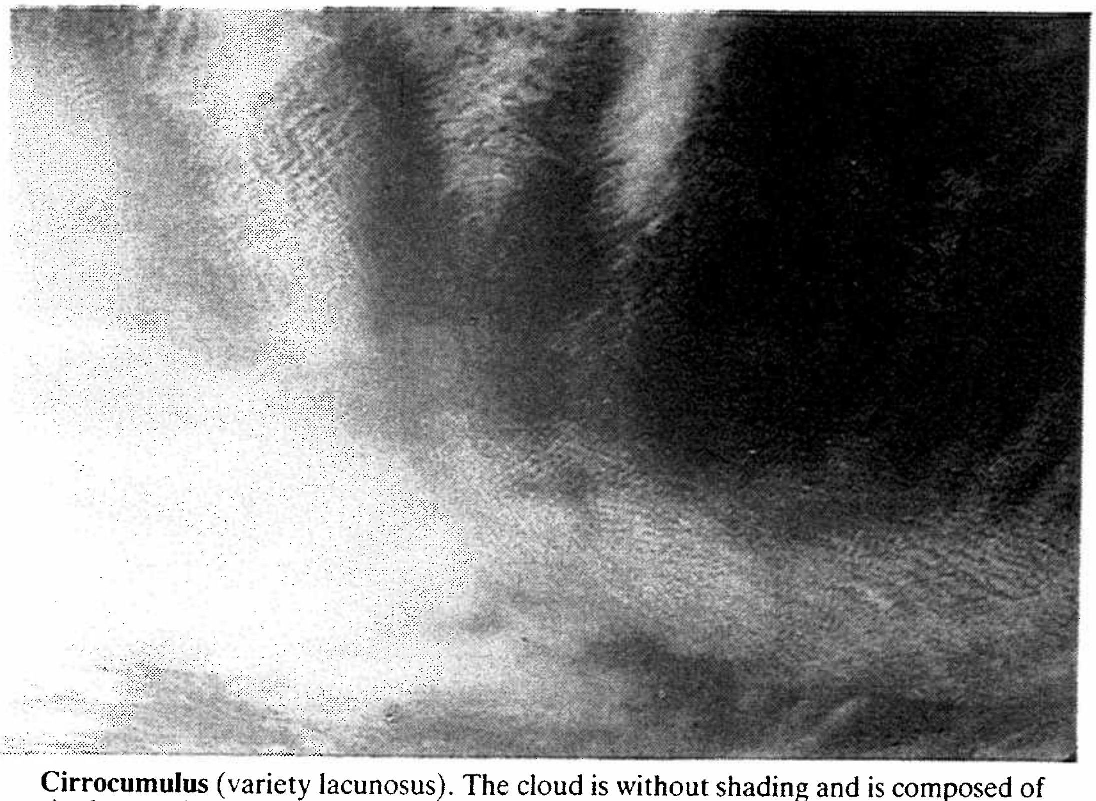
Cirrus, the filaments of which are very irregularly curved and often seemingly entangled in a capricious manner. (See Plate II.)

Cirrus (species fibratus). Fine white filaments nearly straight without hooks or tufts.

Cirrus (species uncinus). White filaments terminating in a hook or a tuft and shaped like a comma in places.



Cirrus (variety intortus). The filaments are entangled in a capricious manner.

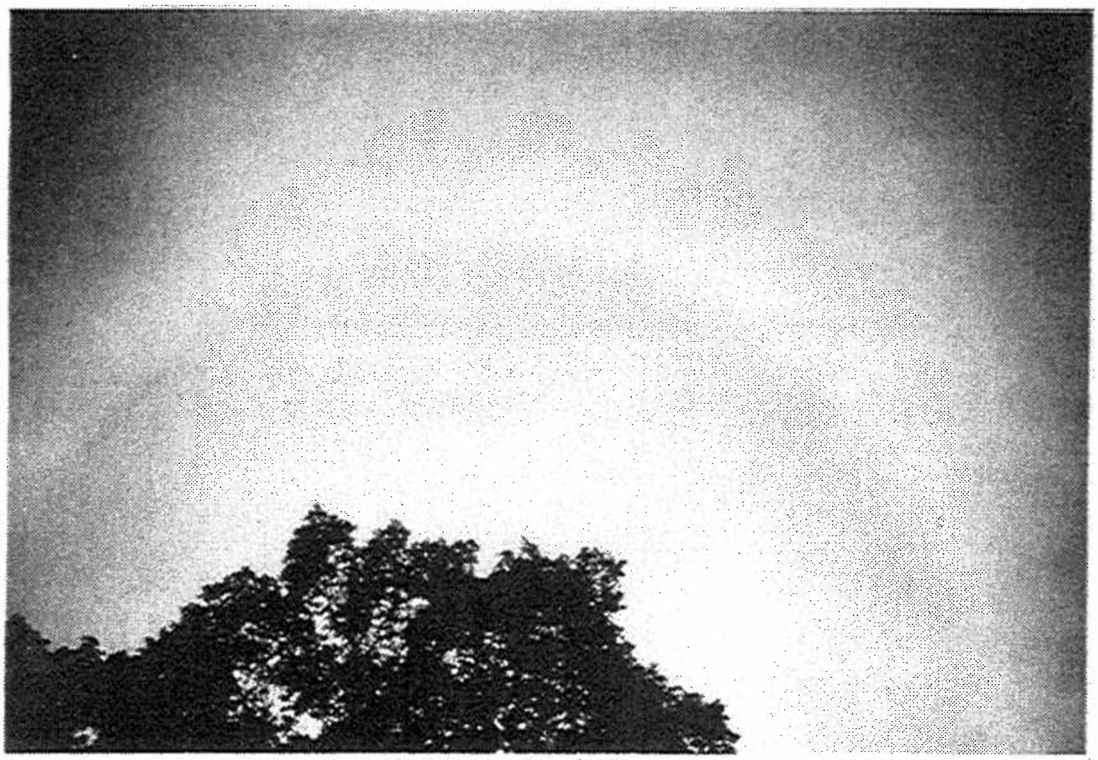


Cirrocumulus (variety lacunosus). The cloud is without shading and is composed of ripples, grains, etc. which identifies it as cirrocumulus. The variety lacunosus is seen at the top of the photograph.

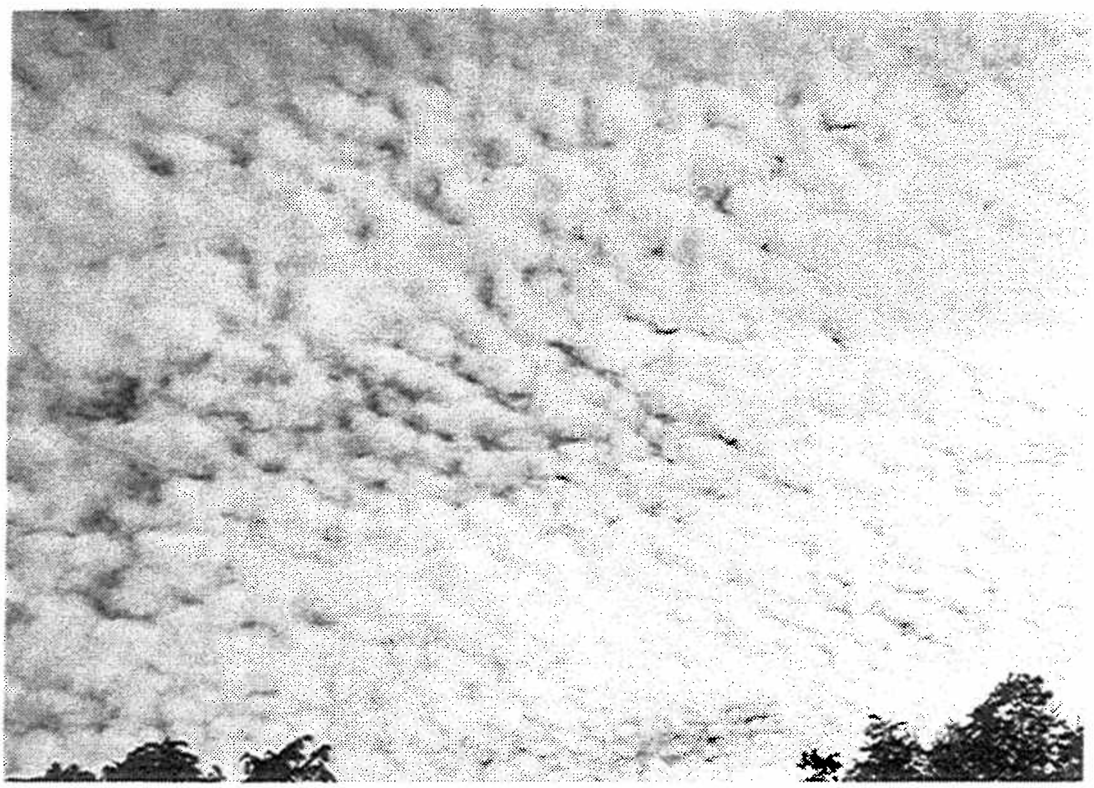
Cirrocumulus (variety undulatus). The cloud elements in this broken sheet are both separate and merged in places.

Cirrostratus. The veil of fibrous cloud typical of this genera is illustrated here, with cirrus fibratus at the top of the photograph.

Plate IV



Cirrostratus (species nebulosus). The appearance of the 22-degree radius halo indicates that the cloud is composed of ice crystals.

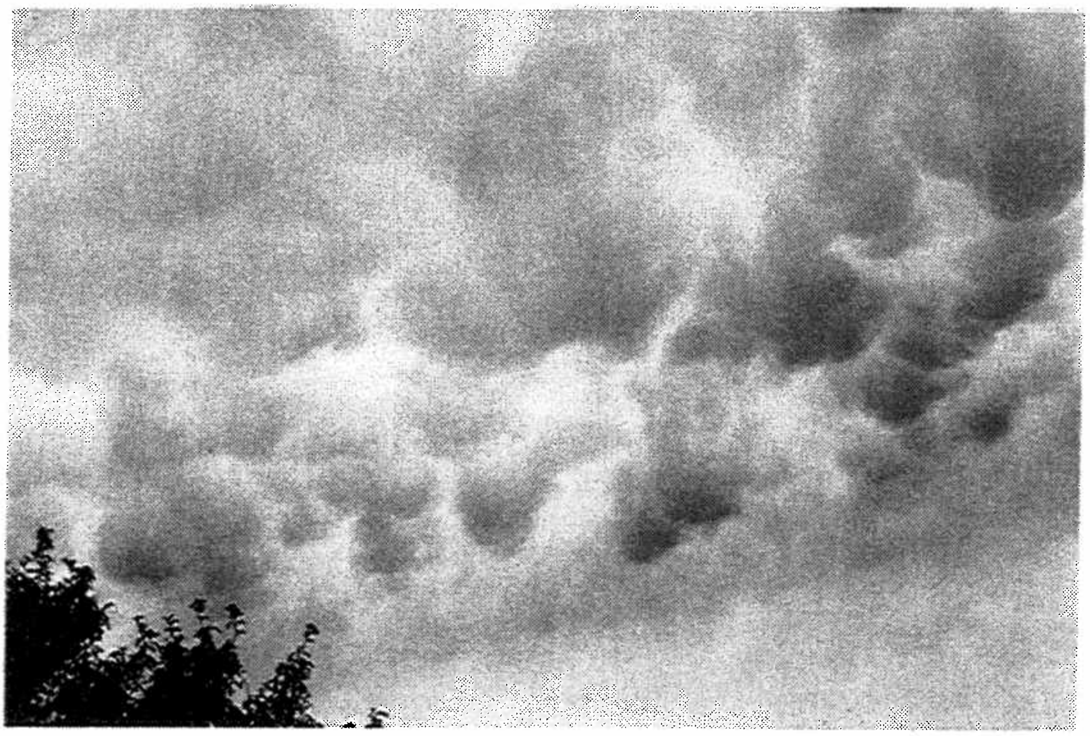


Altocumulus (species stratiformis, varieties translucidus and perlucidus). The elements in altocumulus are larger than those in cirrocumulus and exhibit shading. The cloud depicted is sufficiently translucent to reveal the position of the sun, hence translucidus. The spaces between the cloud elements signify the variety translucidus.

Altocumulus (species lenticularis). The patches of cloud are each in the shape of an elongated lens or almond and exhibit fairly well-defined edges.

Altocumulus (species floccus). These clouds resemble very small, more or less ragged cumulus; they are often accompanied by fibrous trails (virga).

Altocumulus (species castellanus). Altocumulus composed of turrets which appear to be arranged in lines. The turrets generally have a common horizontal base.



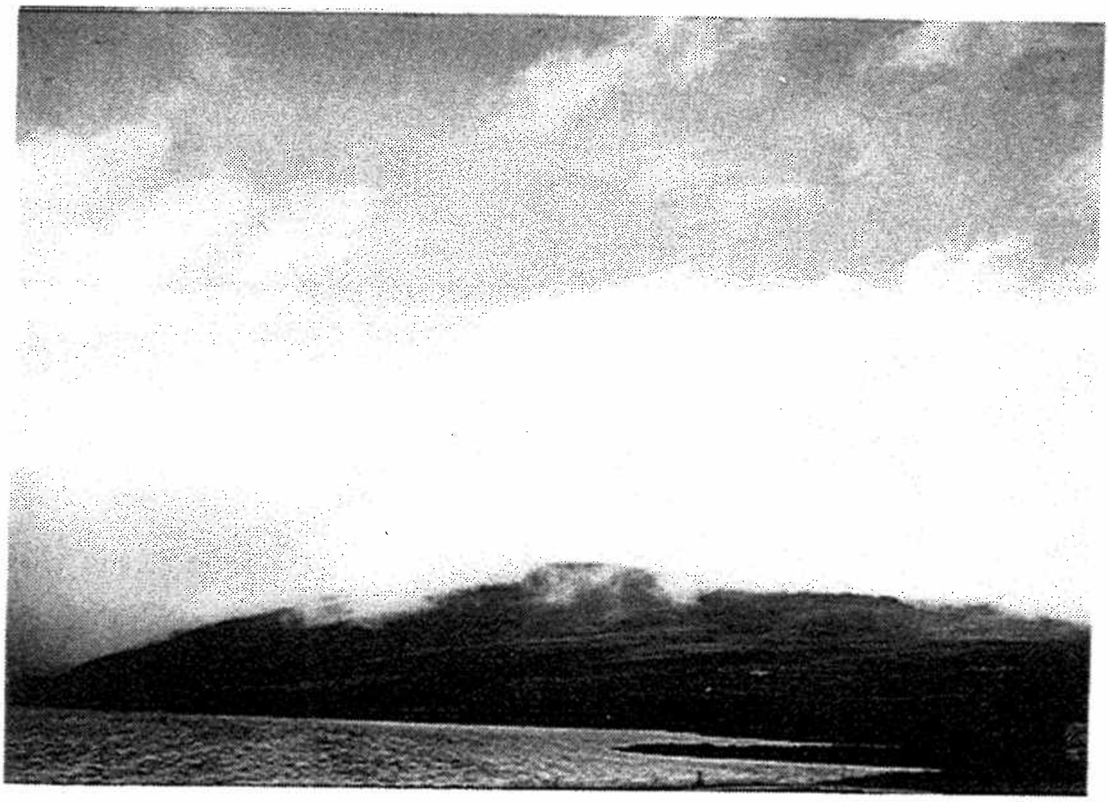
Altocumulus and altostratus (variety opacus with supplementary feature mamma). The sky as a whole featured both genera and this photograph illustrates the well-formed protuberances known as mamma.

Altostratus (variety translucidus). With thin altostratus the sun (or moon) loses its sharp outline, as though seen through ground glass. Note the absence of halo, indicating that the cloud is composed of water drops.

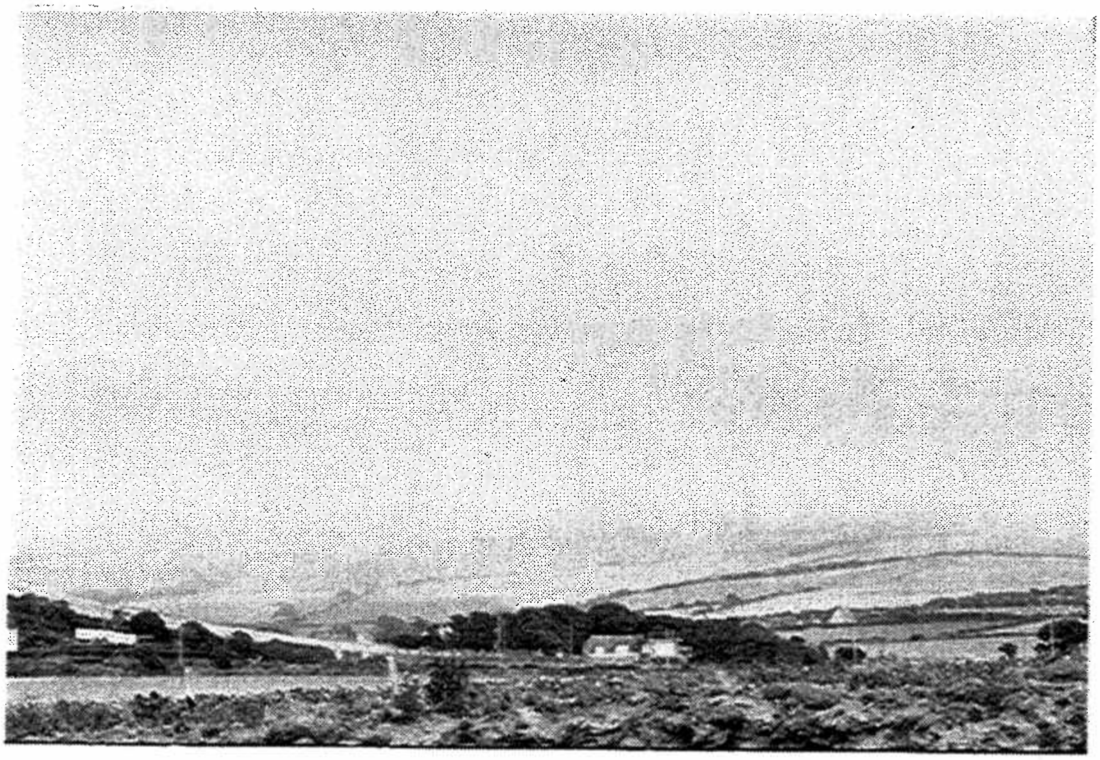
Altostratus (variety opacus). Although there is a broken layer of stratocumulus present in this photograph, the appearance of a thick layer of altostratus is well illustrated.

Plate VIII

Nimbostratus. The generally grey appearance of this type of cloud, which lacks any well-defined base, is illustrated here. Nimbostratus is thick enough to blot out the sun. Continuous rain or snow, in most cases reaching the ground, accompanies the cloud. Pannus is frequently present.



Stratus (species fractus). Broken stratus cloud in the form of irregular shreds with a ragged appearance.



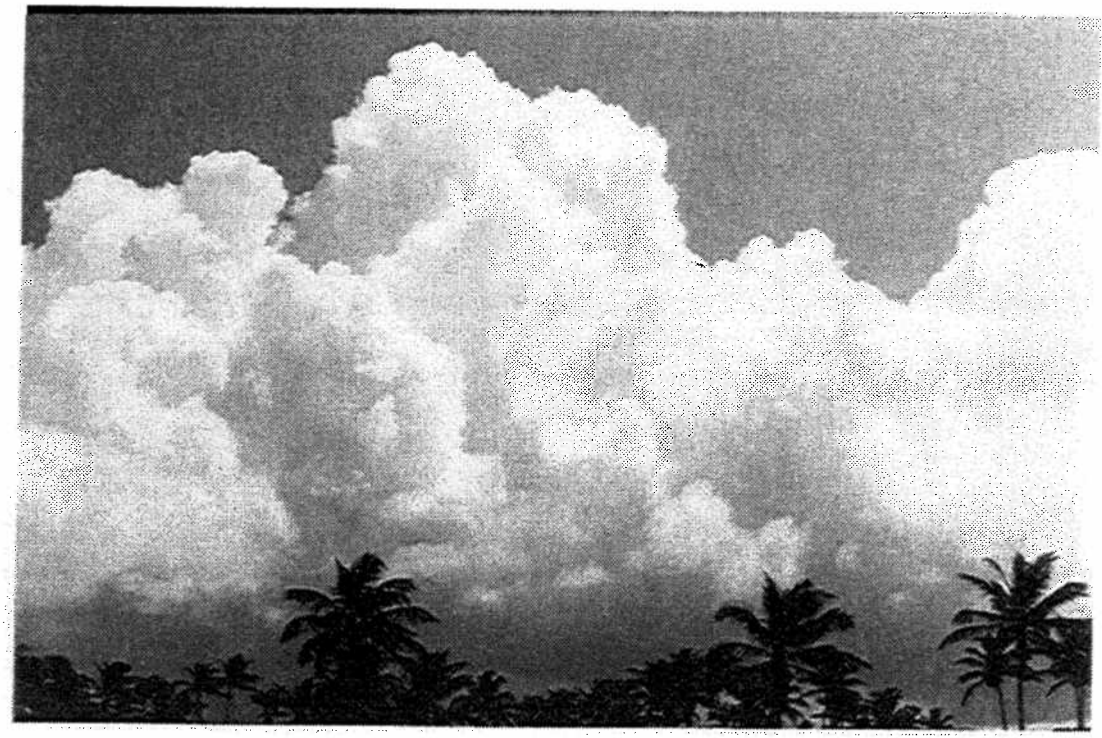
Stratus (species nebulosus, variety opacus). The diffuse irregular base of this cloud is shown up against the mountain.

Stratocumulus (species stratiformis, variety perlucidus). The elements and shading of this genera are illustrated.

Plate X

Stratocumulus (species stratiformis, variety undulatus). The rolls in this sheet are well separated.

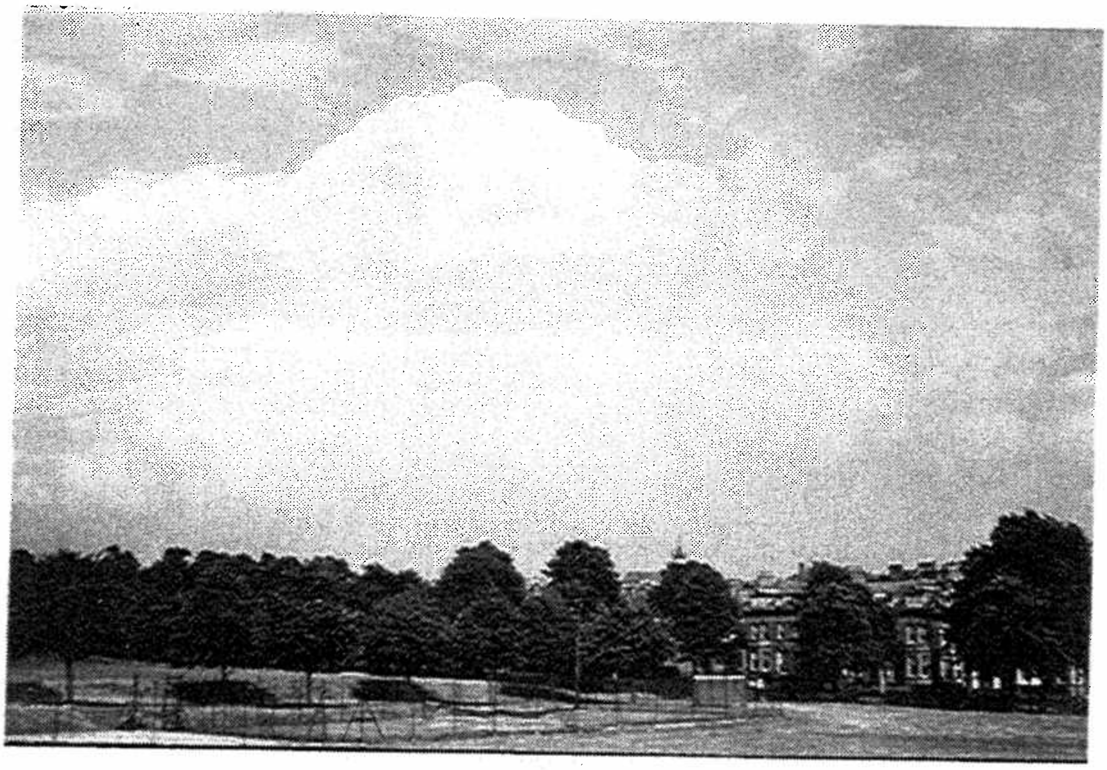
Cumulus (species humilis). A typical example of an early summer-day development of small cumulus. As daytime temperatures rise, their vertical development may greatly increase.



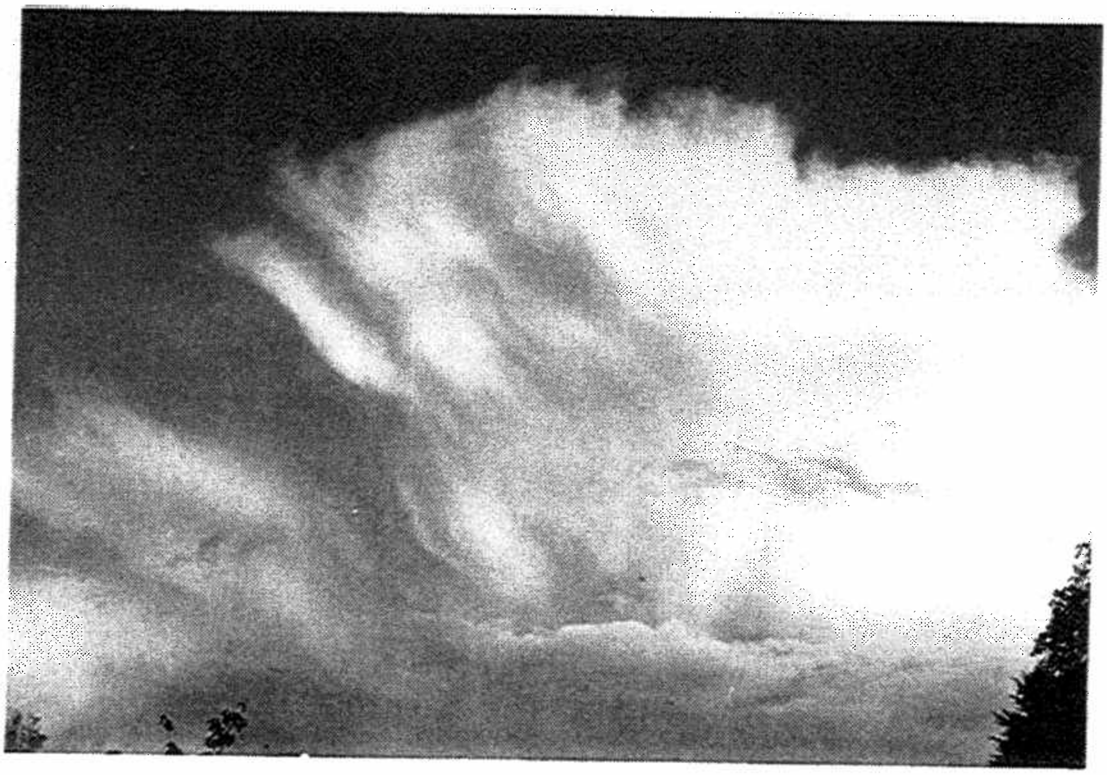
Cumulus (species congestus). The cloud has marked vertical development but the outline is still clear-cut which serves to distinguish it from cumulonimbus species calvus.

Cumulus (species mediocris). A line or street of cumulus showing progressive vertical development. The base is still well-defined with no shower activity obvious.

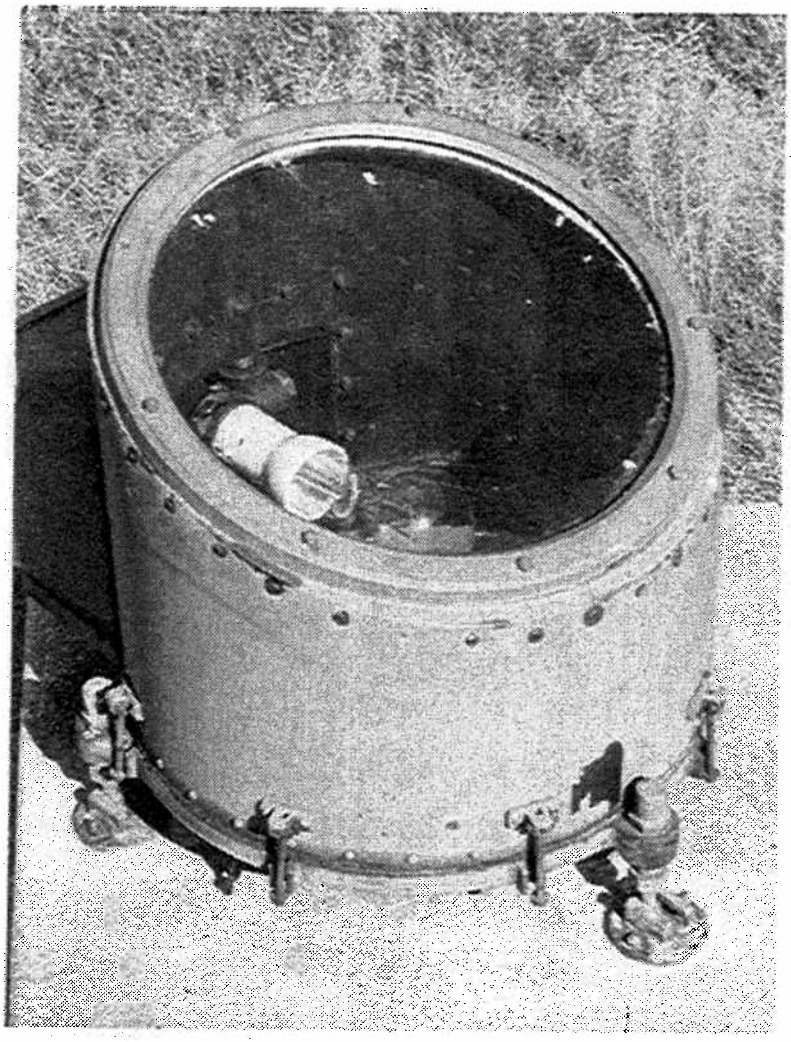
Plate XII



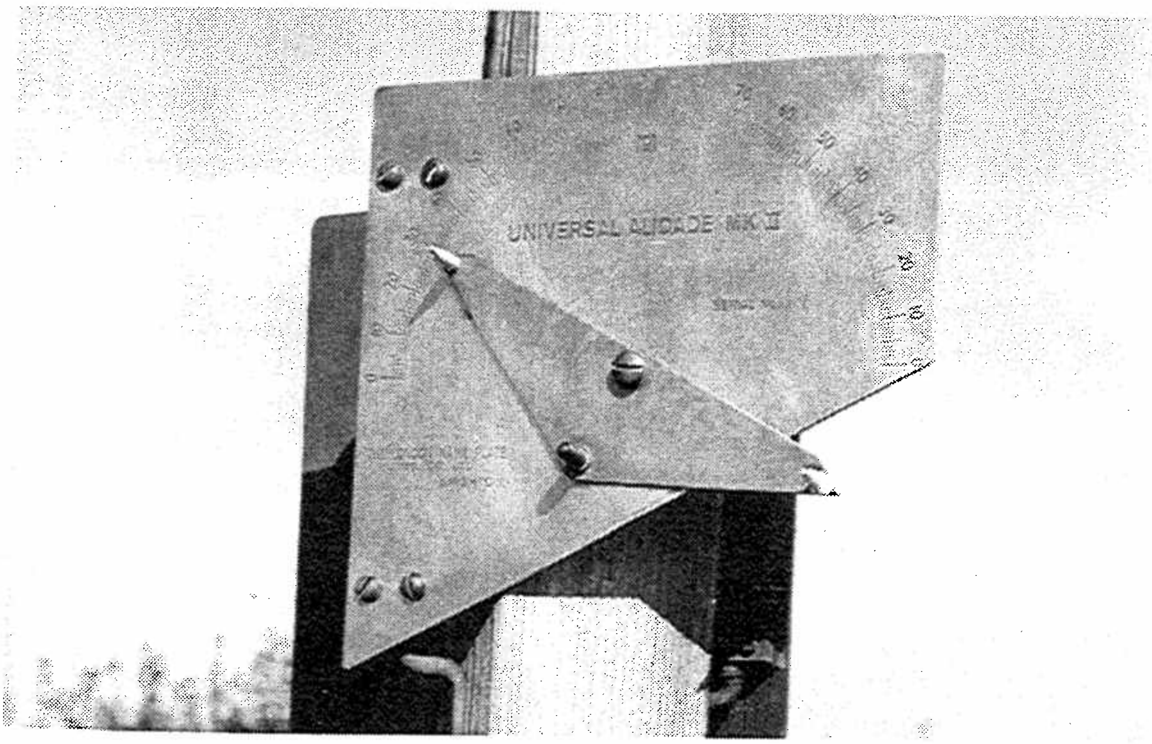
Cumulus (species congestus) with cumulonimbus calvus. A cumulus cloud of the species congestus, with a bulging upper part resembling a cauliflower, dominates the photograph. To the left can be seen the top of a cumulonimbus calvus cloud, the summit of which has lost its sharp outline.



Cumulonimbus (species capillatus). The distinct cirriform head of a cumulonimbus cloud; the description of capillatus as a disordered mass of hair is particularly well illustrated.

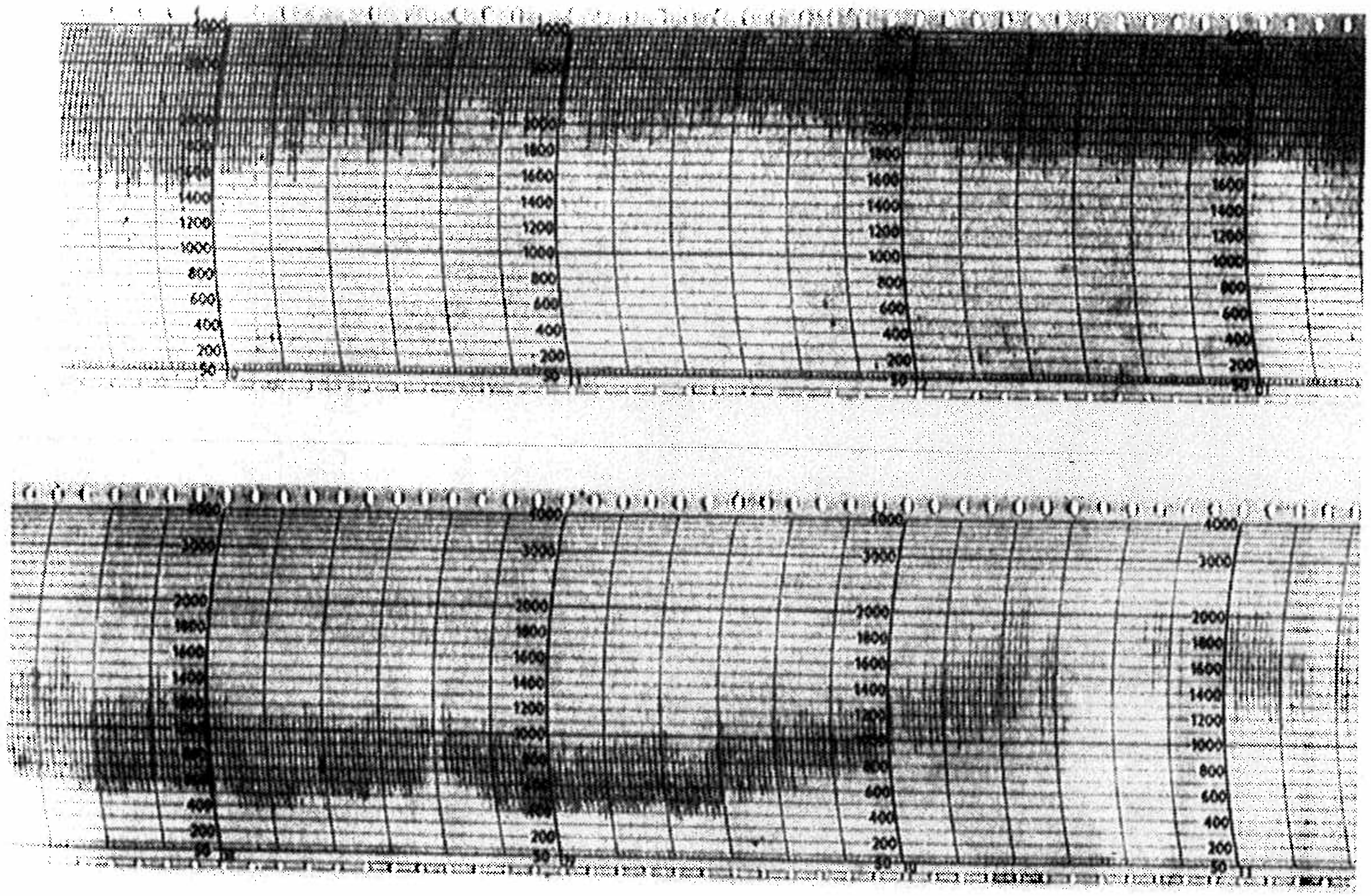


METEOROLOGICAL OFFICE CLOUD SEARCHLIGHT



METEOROLOGICAL OFFICE ALIDADE

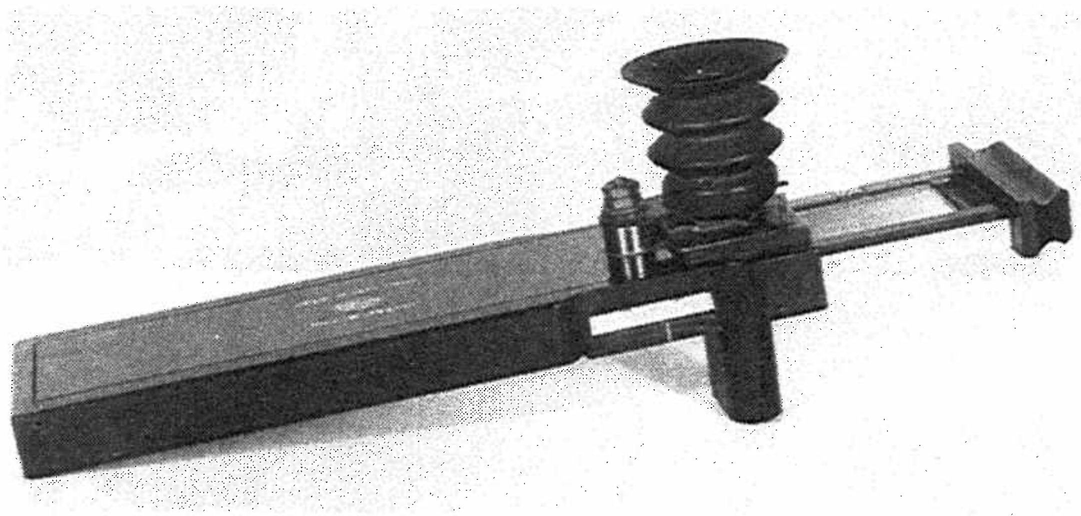
Plate XIV



CLOUD-BASE RECORDER CHARTS

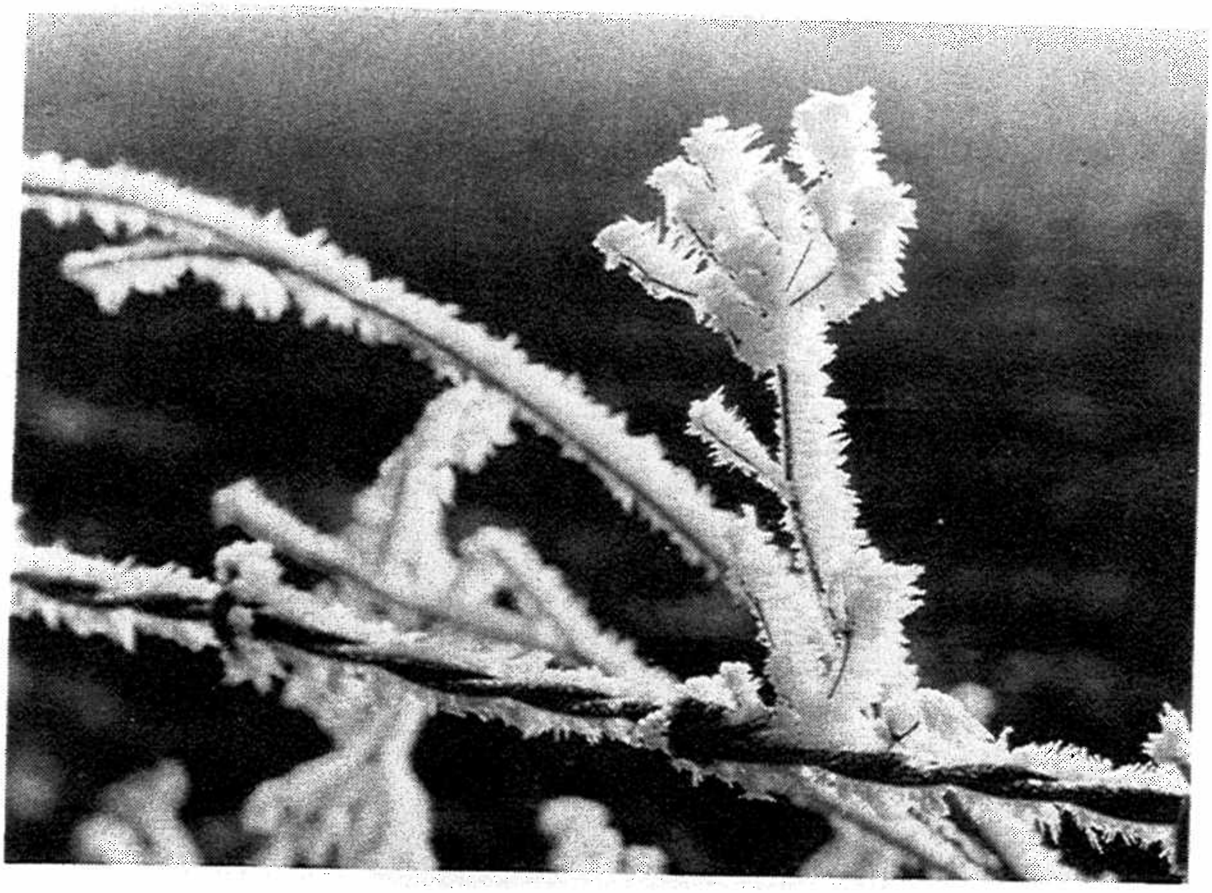
Upper chart: continuous layer of cloud with base varying between 1400 and 2200 ft.
Lower chart: cloud base about 500 ft, lifting with time to about 1300 ft and breaking.

Plate XV



METEOROLOGICAL OFFICE VISIBILITY METER Mk 2

Plate XVI



SOFT RIME, JANUARY 1979
See page 62

GLAZE, FEBRUARY 1979
See page 63

Lacunosus (la)

Cloud patches, sheets or layers, usually rather thin, marked by more or less regularly distributed round holes, many of them with fringed edges. Cloud elements and clear spaces are often arranged in a manner suggesting a net or a honeycomb. This term applies mainly to altocumulus and cirrocumulus (see Plate II); it may also apply, though rarely, to stratocumulus.

Radiatus (ra)

Clouds showing broad parallel bands or arranged in parallel bands which, owing to the effect of perspective, seem to converge towards a point on the horizon or, when the bands cross the whole sky, towards two opposite points on the horizon, called 'radiation point(s)'. This term applies mainly to stratocumulus, cumulus, altocumulus, altostratus and cirrus.

Undulatus (un)

Clouds in patches, sheets or layers showing undulations. These undulations may be observed in fairly uniform cloud layers or in clouds composed of elements, separate or merged. Sometimes a double system of undulations is in evidence. This term applies mainly to stratus, stratocumulus, altostratus, altocumulus, cirrostratus and cirrocumulus. (See Plates III and X.)

Vertebratus (ve)

Clouds whose filaments are arranged in a manner suggestive of vertebrae, ribs or a fish skeleton. This term applies mainly to cirrus.

Opacus (op)

An extensive cloud patch, sheet or layer, the greater part of which is sufficiently opaque to mask the sun or moon completely. This term applies to stratus, stratocumulus, altostratus and altocumulus. (See Plates VI, VII and IX.)

Perlucidus (pe)

An extensive cloud patch, sheet or layer, with distinct but sometimes very small spaces between the elements. The spaces allow the sun, the moon, the blue of the sky or overlying clouds to be seen. The variety perlucidus may be observed in combination with the varieties translucidus or opacus. This term applies to stratocumulus and altocumulus. (See Plates IV and IX.)

Translucidus (tr)

Clouds in an extensive patch, sheet or layer, the greater part of which is sufficiently translucent to reveal the position of the sun or moon. This term applies to stratus, stratocumulus, altostratus and altocumulus. (See Plates IV and VII.)

2.3.4. Supplementary features and accessory clouds. The indication of genus, species and variety is not always sufficient to describe the cloud completely. The cloud may sometimes have supplementary features or may be accompanied by other, usually smaller, clouds which are known as accessory clouds and which may be separate or partly merged with the main cloud. Supplementary features and accessory clouds may occur at any level of the cloud, above it or below it. One or more supplementary features or accessory clouds may occur simultaneously with the same cloud.

Definitions of the supplementary features and accessory clouds are given below.

(*a*) Supplementary features:

Virga (vir)

Vertical or inclined trails of precipitation (fallstreaks), attached to the under surface of a cloud, which do not reach the earth's surface. This supplementary feature occurs mostly with stratocumulus, cumulus, cumulonimbus, altostratus, altocumulus, nimbostratus and cirrocumulus.

Praecipitatio (pra)

Precipitation (rain, drizzle, snow, hail, etc.) falling from a cloud and reaching the earth's surface. (Although precipitation is normally considered a hydrometeor (see 4.2.1), it is treated here as a supplementary feature because it appears as an extension of the cloud.) This supplementary feature is mostly encountered with stratus, stratocumulus, cumulus, cumulonimbus, altostratus and nimbostratus. (See Plate XII.)

Mamma (mam)

Hanging protuberances, like udders, on the under surface of a cloud. This supplementary feature occurs mostly with stratocumulus, cumulonimbus, altostratus, altocumulus, cirrus and cirrocumulus. (See Plate VI.)

Arcus (arc)

A dense horizontal roll, with more or less tattered edges, situated on the lower front part of certain clouds and having, when extensive, the appearance of a dark menacing arch. This supplementary feature occurs with cumulonimbus and, less often, with cumulus.

Incus (inc)

The upper portion of a cumulonimbus spread out in the shape of an anvil, with a smooth fibrous or striated appearance.

Tuba (tub)

Cloud column or inverted cloud cone (funnel cloud) protruding from a cloud base; it constitutes the cloudy manifestation of a more or less intense vortex. This supplementary feature occurs with cumulonimbus and, less often, with cumulus. The diameter of the cloud column, which is normally of the order of 10 metres, may in certain regions occasionally reach some hundreds of metres (see definition of spouts in 4.2.1.19 on page 63).

(*b*) Accessory clouds:

Pannus (pan)

Ragged shreds, sometimes constituting a continuous layer, situated below another cloud and sometimes attached to it. This accessory cloud occurs mostly with cumulus, cumulonimbus, altostratus and nimbostratus.

Pileus (pil)

An accessory cloud of small horizontal extent in the form of a cap or hood above the top, or attached to the upper part, of a cumuliform cloud which often penetrates it. Pileus clouds may sometimes be observed one above the other. Pileus occurs principally with cumulus and cumulonimbus.

Velum (vel)

An accessory cloud veil of great horizontal extent, close above or attached to the upper part of one or several cumuliform clouds which often pierce it. Velum occurs principally with cumulus and cumulonimbus.

2.3.5. Mother-clouds. Clouds may form from other clouds, called mother-clouds, in two ways.

Firstly, a part of a cloud may develop and more or less pronounced extensions may form. These extensions, whether attached to the mother-cloud or not, may become clouds of a genus different from that of the mother-cloud. They are then classified as the appropriate genus, followed by the genus of the mother-cloud with the addition of the suffix 'genitus' (e.g. stratocumulus cumulogenitus).

Secondly, the whole or a large part of a cloud may undergo complete internal transformation, thus changing from one genus into another. The new cloud is then classified as the appropriate genus, followed by the genus of the mother-cloud with the addition of the suffix 'mutatus' (e.g. stratus stratocumulomutatus). The internal transformation of clouds should not be confused with changes in the appearance of the sky resulting from the relative movement of clouds and observer.

No mention should be made of mother-clouds if there is any doubt concerning either the origin of the observed clouds ('genitus') or the manner of their development ('mutatus').

2.3.6. Aid to cloud identification. If, especially during the hours of darkness, an observer has difficulty in identifying the cloud types following the onset of precipitation, the table below can be used as a guide to the cloud types which may be present from the nature of the precipitation.

	Cloud type					
Precipitation	As	Ns	Sc	St	Cu*	Cb*
Rain	+	+	+		+	+
Drizzle				+		
Snow	+	+	+	+	+	+
Snow pellets			+		+	+
Hail						+
Small hail						+
Ice pellets	+	+				
Snow grains				+		

*Showery precipitation
Very occasionally rain or snow may reach the earth's surface from altocumulus castellanus.

2.4. CLOUD AMOUNT

The total cloud amount, or total cloud cover, is the fraction of the celestial dome covered by all clouds visible. The assessment of the total amount of cloud therefore consists in estimating how much of the total apparent area of the sky is covered with cloud. The international unit for reporting cloud amount is the okta or eighth of the sky and estimates are made in this unit, with a special qualification for cloud amounts of less than 1 okta and greater than 7 oktas. See code figures 1 and 7 in 2.4.1 below.

The site used when estimating cloud amount should be one which commands the widest possible view of the sky and the observer should give equal weight to the areas overhead and those at the lower angular elevations. On occasions when the clouds are very irregularly distributed it is useful to consider the sky in separate quadrants divided by diameters at right angles to each other. The sum of the estimates for each quadrant is then taken as the total for the whole sky.

2.4.1. Complete range of cloud amounts.

Code figure	Cloud amount
0	None (sky completely cloudless)
1	1 okta or less, but not zero
2	2 oktas
3	3 oktas
4	4 oktas
5	5 oktas
6	6 oktas
7	7 oktas or more, but not 8
8	8 oktas (sky completely covered)
9	Sky obscured or cloud amount cannot be estimated.

Code figure 9 is reported when either the sky is invisible owing to fog, falling snow, etc. or the observer cannot estimate the amount owing to darkness or extraneous lighting. On moonless nights it should usually be possible to estimate the total amount by reference to the proportion of the sky in which the stars are dimmed or completely hidden by clouds, although haze alone may blot out stars near the horizon.

2.4.2. Partial cloud amounts. The observer also has to estimate how many eighths of the sky would be covered by each individual type of cloud as if it alone was the only cloud type in the sky. There are times, for example, when a higher layer of cloud is partially obscured by lower clouds. In these cases an estimate can be made with comparative assurance of the extent of the upper cloud by watching the sky for a short time. Movement of the lower cloud relative to the higher should reveal whether the higher layer is completely covering the sky or has breaks in it. There are of course occasions of great difficulty, more especially at night, in making a reliable estimate; but previous observation of cloud development, general knowledge of cloud structure, and allowing sufficient time for the eyes to adjust to the dark will help the observer to achieve the best possible result. Access to reports from aircraft, if available, can also be of assistance.

It should be noted that the estimation of amount of each different type of cloud is made independently of the estimate of total cloud amount. The sum of separate estimates of partial cloud amounts often exceeds the total cloud amount, and often exceeds 8 eighths.

2.5. HEIGHT OF CLOUD BASE

In the United Kingdom the height of cloud base is recorded in feet but eventually it will be recorded in metres. However, to maintain the procedure which has been used throughout this book, feet 'equivalents' follow reference to heights in metres. The 'equivalents' are the values currently being recorded, but the metres figures do not represent the direct conversion of feet to metres but rather those values which would be recorded if cloud heights were recorded in metres.

Cloud height is difficult to estimate and also at times difficult to measure. At aerodromes the height of cloud base is often the most important fact reported by the meteorological observer. It is therefore essential that observers, especially at aerodromes, should use every means available to attain an accuracy of reporting within 10 per cent of the actual cloud heights up to 1500 m (5000 ft).

Where the station is not provided with equipment for measuring cloud height, the reported heights should be obtained by estimation, following the guidance given in 2.5.3.

Where measuring equipment is available, the height of the cloud base should be checked frequently to enable the height to be given to the accuracy shown above. At night the use of a cloud searchlight makes frequent checks practicable, and the height should be measured for each observation when cloud is present within the limits of the beam. Some stations are equipped with a Meteorological Office cloud-base recorder (see 2.5.6) which is used, day and night, for all observations. Separate instructions are available at such stations.

2.5.1. Definition of cloud base. The definition of the cloud base has given rise to much discussion. The World Meteorological Organization has defined it as 'that lowest zone in which the type of obscuration perceptibly changes from that corresponding to clear air or haze to that corresponding to water droplets or ice crystals'. Observers should regard the cloud base of a particular cloud type as (a) that level at which a pilot balloon is first seen to be obscured by the cloud (care being taken that lower clouds do not confuse the judgement), or (b) the lower limit of the patch of light formed on the cloud type by a searchlight beam, or the lowest value of the pen marks on a cloud-base recorder chart which are appropriate to the cloud type that is being assessed, or (c) when cloud height is estimated, the lowest level down to which cloud of the type reported is judged to extend. Difficulty will mainly arise when the cloud base is diffuse and irregular, as with stratus fractus of bad weather. If there are patches of such cloud coming down to say 30 metres (100 ft), although other portions of the same cloud are at a greater height, the height should be reported as 30 m (100 ft).

2.5.2. Datum for height of cloud base at aerodromes. The height of the cloud base is normally reported as its height above ground level where this datum (ground level) refers to the observation site or the site on which the rain-gauge is installed. On some aerodromes, however, the observation site is appreciably higher or lower than the published official aerodrome altitude. At these aerodromes the cloud height is adjusted to relate to the official aerodrome altitude when the cloud base is 450 m (1500 ft) or below, and the difference between the altitude of the aerodrome and the observing site is 12 m (40 ft) or more. The following table is used to determine the correction to be applied to the observed cloud height, and the adjusted height is entered in the Daily Register as the cloud base.

Difference between altitude of observation site and official aerodrome altitude		Correction to observed cloud height if observation site is			
		higher than official aerodrome altitude		lower than official aerodrome altitude	
m	*ft*	*m*	*ft*	*m*	*ft*
12–21	40–69	+15	+ 50	−15	− 50
22–30	70–99	+30	+100	−30	−100

2.5.3. Estimation of cloud height. At stations not provided with measuring equipment the values of cloud height can only be estimated. In mountain areas the height of any cloud base which is lower than the tops of the hills or mountains around the station can be estimated by comparison with the heights of well-marked topographical features as given in the Ordnance Survey map of the district. It is useful to have, for permanent display, a diagram detailing heights and bearings of hills and landmarks which might be useful in estimating cloud height. Due to perspective the cloud may appear to be resting on distant hills, and the observer must not necessarily assume this reflects the height of the cloud over the observation site. In all circumstances the observer must use his judgement, taking into consideration the form and general appearance of the cloud.

The range of cloud-base heights above ground level applicable to various genera of cloud over the British Isles is given in the table below and refers to level country not more than 150 m (500 ft) above mean sea level. For observing sites at substantially greater heights, or stations on mountains, the height of the base of low cloud above the station will often be less. For instance, at a station in the British Isles between 300 and 450 m (1000 and 1500 ft), the height indicated in the table below would be reduced by about 300 m (1000 ft).

In countries with climates very different from that of the British Isles, and especially in dry tropical conditions, cloud heights may depart substantially from the ranges given. The differences may introduce problems of cloud classification as well as increasing the difficulty of estimating the height. For instance, reports of tropical cumulus clouds of an obviously convective origin, with base well above 2400 m (8000 ft) or even as high as 3600 m (12 000 ft) have been confirmed by aircraft observations. It is noteworthy that surface observers frequently underestimate cloud heights to a very serious degree in such cases. These low estimates may be due to two factors: either the observer expects cumulus cloud to be a 'low cloud' with its base below 2000 m (6500 ft) and usually below 1500 m (5000 ft), or the atmospheric conditions and the form of cloud may combine to produce an optical illusion.

When a direct estimate of cloud height is made at night, success depends very greatly on the correct identification of the form of cloud. General meteorological knowledge and a close watch on the weather are very important in judging whether a cloud base has remained substantially unchanged or

HEIGHTS OF THE BASE OF CLOUD GENERA
ABOVE GROUND LEVEL IN THE BRITISH ISLES

Cloud genera	Usual range of height of base*		Wider range of height of base sometimes observed, and other remarks	
	metres	*feet*	*metres*	*feet*
LOW				
Stratus	Surface–600	Surface–2000	Surface–1200	Surface–4000
Stratocumulus	300–1350	1000–4500	300–2000	1000–6500
Cumulus	300–1500	1000–5000	300–2000	1000–6500
Cumulonimbus	600–1500	2000–5000	300–2000	1000–6500
	kilometres			
MEDIUM			Nimbostratus is considered a medium cloud for synoptic purposes, although it can extend to other levels. Altostratus may thicken with progressive lowering of the base to become nimbostratus.	
Nimbostratus	Surface–3	Surface–10 000		
Altostratus, Altocumulus	2–6	6500–20 000		
HIGH			Cirrus from dissipating cumulonimbus may occur well below 6 km (20 000 ft) in winter. Cirrostratus may develop into altostratus.	
Cirrus, Cirrostratus, Cirrocumulus	6–12	20 000–40 000		

*For stations substantially over 150 metres (500 ft) above sea level, the base of low-level clouds will often be less.

has risen or fallen. A most difficult case, calling for great care and skill, occurs when a sheet of altostratus has covered the sky during the evening. Any gradual lowering of such a cloud sheet may be very difficult to detect but, as it descends, the base is rarely quite uniform and small contrasts can often be discerned on all but the darkest nights.

2.5.4. Measurement of cloud height by searchlight. In this method, illustrated in Figure 1, the angle of elevation E of a patch of light formed on the base of the cloud by a vertically directed searchlight beam is measured by alidade from a distant point. If L is the known horizontal distance in metres (feet) between the searchlight and the place of observation, then the height, h, in metres (feet) of the cloud base above the point of observation is given as $h = L \tan E$.

The optimum distance of separation between the searchlight and the place of observation is about 300 m (1000 ft). If the distance is much greater than this, the spot of light may be difficult to see; if it is much less, the accuracy of measuring height above about 600 m (2000 ft) suffers. A distance of 250–550 m (800–1800 ft) is usually acceptable.

The conversion of the angle of observation into a height in metres for a baseline of 300 m, and in feet for a baseline of 1000 ft, may be made by using Table II (a) or (b) on pages 206 and 207 respectively. Similar tables for any other baseline of L metres or L feet may be prepared by multiplying the values by $L/300$ for metres and by $L/1000$ for feet.

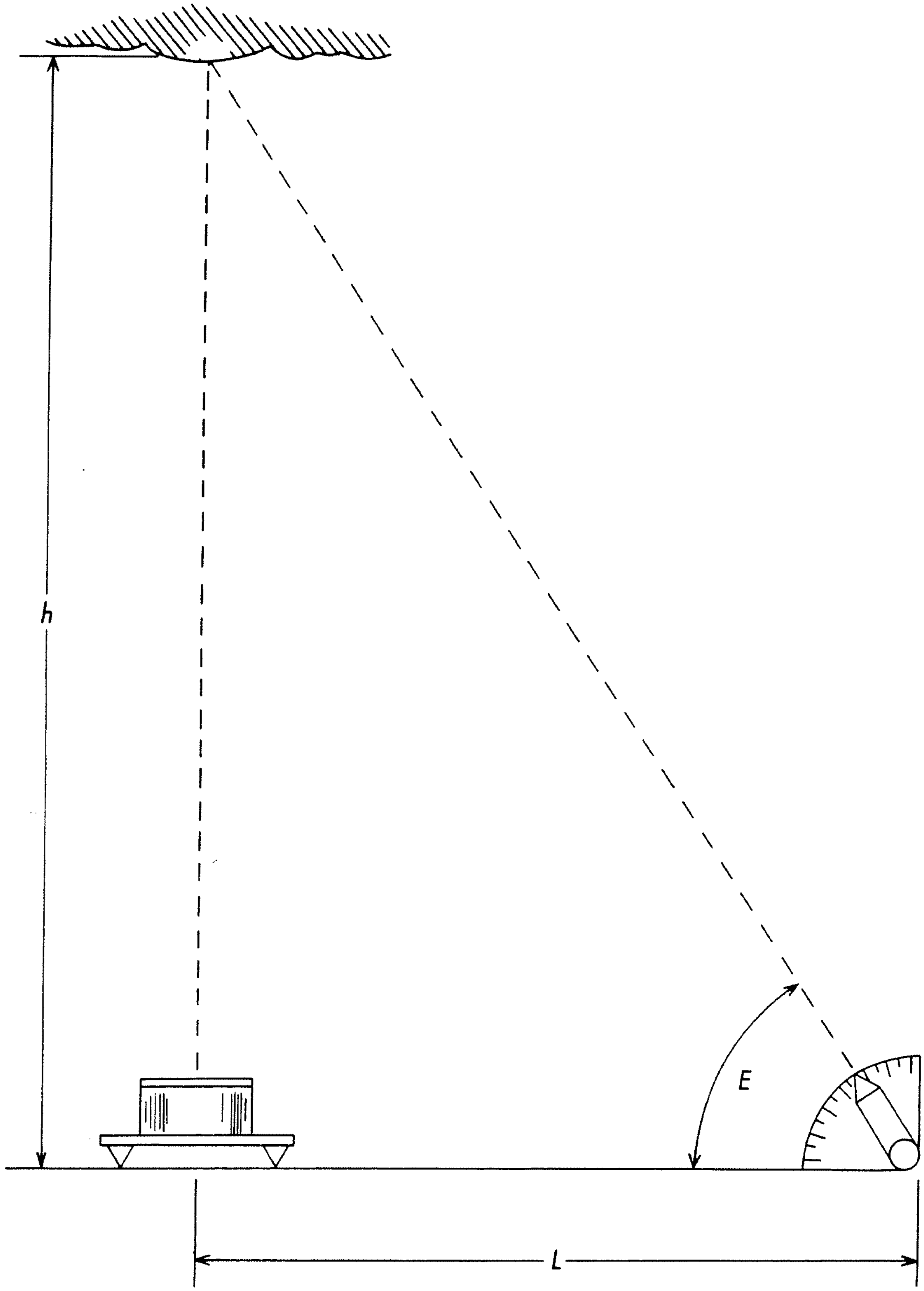


Figure 1. Principle of cloud-height measurement with searchlight

The searchlight is to be used for all observations not made in daylight when the cloud is suitable. On a dark overcast night, cloud heights up to about 3000 m (10 000 ft) can be measured with acceptable accuracy (Figure 2(a)). The site chosen for the instrument must not be affected by extraneous lighting.

On many occasions some care will be necessary to ensure that cloud which terminates the beam at a particular instant represents the height of the lowest layer of cloud. In order to increase the chances of detecting small amounts of low cloud the beam should be observed over several minutes. If there are fragments of cloud below a main cloud layer and the beam can be seen illuminating the fragments (Figure 2 (b)) and the base of the main layer, then all heights should be determined.

When tenuous, ragged or fragmentary very low cloud is present the searchlight will produce a diffusely illuminated section in the upper part of its beam rather than a definite horizontal spot. Below this illuminated section the lower part of the beam is usually only faintly visible (Figure 2 (c)). During rain, however, the lower part of the beam will be more clearly visible because of the illumination of the raindrops. In poor visibility the lower part of the beam may be even brighter and the contrast between it and the illumination on the low cloud above not very well marked (Figure 2 (d)). In such cases the measurement of the height should be made by sighting the alidade (see 2.5.4.2) on the bottom of the brighter section of the beam, i.e. where the beam exhibits an appreciable increase in brightness with height (X in Figure 2 (c) and (d)).

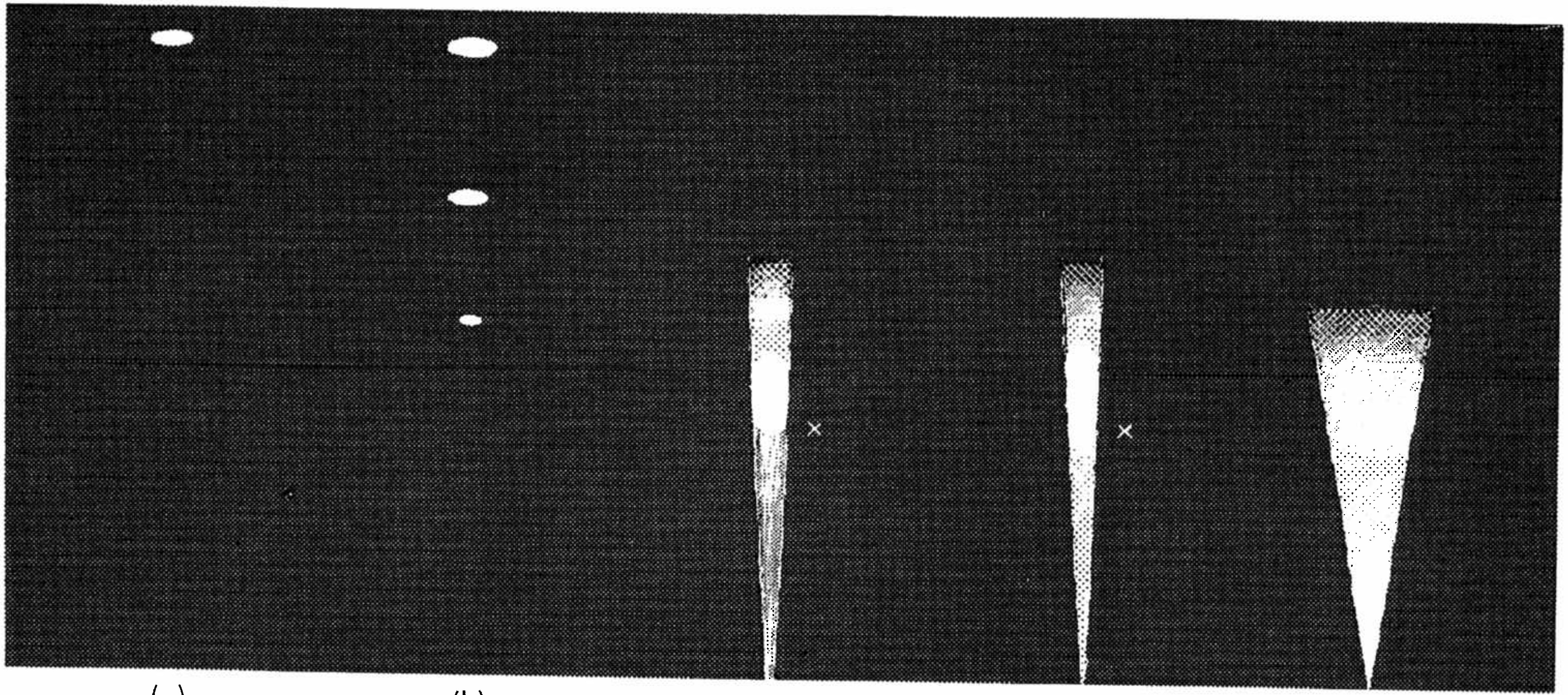
In very heavy rain, sleet or snow it is sometimes impossible to get any bright spot on the searchlight beam (Figure 2 (e)), and the 'point' where the beam disappears in these conditions may provide no useful indication of the height of cloud.

Snow lying on the sloping glass window of the standard cloud searchlight may obliterate the beam. If the lamp is allowed to burn long enough, the heat generated will usually cause the snow to slide off.

At stations where frequent observations are made during the hours of darkness, the searchlight can be left switched on. Being left switched on has no marked effect on the life of the bulb and also prevents condensation taking place inside the searchlight. Where the searchlight is used only at, say, 3-hourly intervals it should be switched off as soon as an observation has been completed. If it is used only at fixed times the searchlight may be sited near a source of mains electricity and controlled by time-switches to avoid the high cost of cabling. This arrangement is unsuitable at aviation stations.

Spare searchlight bulbs must be kept readily available for immediate replacement of unserviceable bulbs.

2.5.4.1. *Standard cloud searchlight.* The standard cloud searchlight used in the Meteorological Office (see Plate XIII) consists of a parabolic silvered-glass reflector, 40·6 cm (16 inches) in diameter, mounted in a strong cylindrical case, the base of which has three adjustable feet for levelling purposes. The top of the case is inclined to the horizontal and is covered by a piece of glass pressed tight between two packing rings. The metal ring which clamps the glass in position is provided with a slot at the lowest point to allow rain-water



(a) Definite patch seen on dark overcast nights. Cloud-base heights up to 3000 metres (10 000 ft) can be measured with the cloud searchlight.

(b) Main cloud base and cloud fragments illuminated. The beam should be observed over several minutes and all heights determined.

(c) (d) With very low cloud a diffusely illuminated section may appear in the upper part of the beam with the lower part just visible (c). In rain the lower part of the beam is more clearly visible and in poor visibility may be even brighter (d). The alidade should be sighted on X, the bottom of the beam's brightest section.

(e) In very heavy rain, sleet or snow no accurate reading may be possible if there is no definite bright spot on which to sight the alidade.

Figure 2. Measurement of cloud base with searchlight

collected on the glass to run away. The lamp, which is usually 24 volts, 500 watts, works at a very high efficiency and consequently has a rather short life. There is adequate provision for focusing the lamp. Full instructions for setting up the instrument, adjusting the verticality of the beam, and general maintenance are available from the Operational Instrumentation Branch.

Whenever a bulb is changed the verticality of the beam must be checked. A 24-volt tubular or strip heater may be installed inside the instrument to eliminate condensation. Alternatively, a number of silica-gel desiccators may be used, but these must be changed as soon as the crystals need regenerating.

2.5.4.2. *Alidade.* The angle of elevation is measured by means of an alidade. The standard alidade (see Plate XIII) consists of an engraved brass arc attached to a bracket which should be screwed to a post or corner of a building so that the plane of the engraved arc is accurately aligned with the searchlight beam. A movable pointer rotates about the centre of the arc and is provided with sighting points near each end. The observation is made by moving the pointer until the lower edge of the spot of light on the cloud base is in line with the two sights. The angle of elevation is then read from the engraved scale of degrees. It is essential of course that the line joining the two zero graduations on the scale should be truly horizontal.

2.5.5. Measurement of cloud height by balloon. Cloud height may be measured in daylight by determining the time taken by a small rubber balloon, inflated with hydrogen or helium, to rise from ground level to the base of the cloud. The base of the cloud should be taken as the point at which the balloon appears to enter a misty layer before finally disappearing.

The rate of ascent of the balloon is determined mainly by the free lift of the balloon and can be adjusted by controlling the amount of hydrogen or helium in the balloon. The time of travel between release of the balloon and its entry into the cloud is measured by means of a stop-watch. If the rate of ascent is n metres per minute and the time of travel is t minutes, the height of the cloud above ground is $n \times t$ metres, but this rule must not be slavishly followed. Eddies near the place of launching may prevent the balloon from rising until some time after it is released. Normally the stop-watch is started on the release of the balloon and therefore the elapsed time between release and the moment when the balloon is observed to have left the eddies will need to be subtracted from the total time before determining the cloud height. Even apart from eddy effects, the rate of ascent in the lowest 600 m (2000 ft) or so is very variable. Determinations of the height of very low clouds by pilot balloon are often appreciably in error on this account.

Although the height of base of medium cloud is sometimes obtained as a by-product in the measurement of upper winds by pilot balloon, the balloon method is mainly applicable to low clouds. Where no optical assistance is available in the form of binoculars, telescope or theodolite, the measurement should not be attempted if the cloud base is judged to be higher than about 900 m (3000 ft) unless the wind is very light. In strong winds the balloon may pass beyond the range of unaided vision before it enters the cloud.

Precipitation reduces the rate of ascent of a balloon and measurements of cloud height by pilot balloon should not be attempted in other than light precipitation. The result of an ascent in light precipitation should be considered as a guide for estimating the probable height of the cloud base rather than as a measurement.

The following instructions are addressed to observers at stations where pilot-balloon equipment is used for the measurement of height of cloud.

2.5.5.1. *Equipment.* The standard equipment for the measurement of height of cloud using hydrogen comprises:

Hydrogen cylinder with lever key	Balloon filler Mk 8
Pressure gauge and adaptor	Rawhide mallet
Rubber tubing	Stop-watch
Large adjustable spanner	Type CP10 balloons (10 gram, red)
Fine adjustment valve	Type CP30 balloons (30 gram, orange).
Earthing equipment	

2.5.5.2. *Hydrogen cylinders: safety precautions.* Being the lightest of gases, hydrogen is very prone to leak from the containing cylinder. Hydrogen is highly inflammable in air, and hydrogen–air mixtures are highly explosive for a wide range of ratios of hydrogen to air; a small spark of low energy is sufficient to cause ignition. Great care must be taken to comply with the instructions given in 2.5.5.3 to 2.5.5.7.

2.5.5.3. *Storage of hydrogen cylinders.* Cylinders of hydrogen should, if possible, be stored in the open near the filling shed. They should be covered to protect them from the weather but they should be adequately ventilated. Where exposure to the direct rays of the sun could result in a dangerous rise in pressure (especially in tropical and subtropical regions) they should be sheltered by a roof supported on four corner posts forming an open-sided building.

If storage in the open is impracticable, a scheme for indoor storage should be prepared in accordance with advice from Meteorological Office Headquarters.

2.5.5.4. *Care and use of hydrogen cylinders.* The presence of oil and grease on cylinders containing gases can lead to serious explosions. As the valve caps on hydrogen cylinders are interchangeable with those on a wide variety of other cylinders, it is strictly forbidden to use lubricants to ease the removal of caps from cylinders. The valve-protection cap should be fitted at all times except when a cylinder is actually in use. The pressure of hydrogen in a cylinder should be tested immediately the cylinder is received. The procedure is as follows:

(*a*) Unscrew the cylinder cap by hand. If the cap does not unscrew easily, tap round the full circumference of the cap with a rawhide or similar non-ferrous type of mallet. This tapping with the mallet must be confined to directly over the cap/collar threads. If the cap will not then unscrew, the full cylinder should be returned to the supplier.

(*b*) Remove with a brush any dust or corrosion from the valve and orifice of the cylinder. Wire brushes made of ferrous material must not be used for this purpose.

(*c*) Fit the pressure-gauge adaptor to the main tap (left-hand thread), tightening it by hand or by using a rawhide or wooden mallet, not by using a hammer or other object containing ferrous material. Then screw the pressure gauge into one end of the adaptor and the fine-adjustment valve into the other.

(*d*) Fit the key on to the cylinder cap and turn counter-clockwise not more than a quarter of a turn to release the hydrogen. The main valve of the cylinder should be opened or closed by hand; if this cannot be done, a rawhide or wooden mallet may be used to strike the valve key, but no hammer or object containing ferrous metal may be used.

(*e*) Note the pressure on the dial of the pressure gauge and then turn off the hydrogen, closing the cylinder valve tightly, and unscrew the pressure gauge and adaptor after making sure that the valve is not leaking. In the United Kingdom or other cool or temperate regions the pressure in a full cylinder should be about 120 atmospheres (or 1800 pounds-force per square inch (lbf/in^2)). If it is much greater than this, the excess should be allowed to escape gently, care being taken that the gas escapes to the open air and does not accumulate in an enclosed space. If the pressure in a new cylinder is less than 100 atmospheres (1500 lbf/in^2) a report should be made to the issuing authority.

For tropical or subtropical regions the pressure in a full cylinder should be only 100 atmospheres. Any excess pressure should be reduced, as indicated above, and any cylinders in which the pressure is less than 80 atmospheres (1200 lbf/in^2) are to be reported to the issuing authority.

Cylinders are not to be discharged below a pressure of 100 lbf/in^2. If the cylinder is completely emptied, air may get in and the water vapour would damage the inner lining.

2.5.5.5. *Balloon-filling shed.* The filling shed should, if possible, be a detached building having a sloping ceiling or roof with adequate ventilation from the highest point. The electrical wiring of buildings where hydrogen is handled should be external to the buildings and carried out in accordance with current regulations. Advice should be sought through Meteorological Office Headquarters before altering old buildings or erecting new ones.

A notice should be painted in bold red letters on the door of the shed:

EXPLOSIVE GAS
NO NAKED LIGHTS
NO SMOKING

No open flames, electric fires, running motors, etc. are permitted inside the shed, neither should combustible material be stored there.

The appropriate station authority must be informed of the use to which the building is to be put and invited to make any additional modifications which may be regarded as necessary by that authority.

2.5.5.6. *Earthing system.* When hydrogen is being discharged, the cylinders should be earthed, as should the balloon filler, except when the gas in the balloon is being adjusted for 'free lift'. A static charge of electricity is developed when hydrogen is being discharged or balloons are being filled and, especially in dry weather, the charge may build up sufficiently to cause a spark which could ignite the hydrogen.

Each hydrogen cylinder must be connected by a cable to an approved 'fixed earthing system'. A 'movable earthing system', supplied by the Meteorological Office (Met O 4, Western Road, Bracknell, Berkshire) must be connected to the balloon filler on each occasion a balloon is filled.

Each of the earthing systems must be examined by the particular designated authority at six-monthly intervals. In addition, a monthly check must be made at the station to see that all connections are firm and free from corrosion, holding screws are tight and the wire is in good condition. Specific instructions are issued to stations concerned.

2.5.5.7. *Inflation of balloons.* To inflate Type CP10 (10 g) balloons:

(*a*) Fit the pressure-gauge adaptor to the cylinder main tap and screw down tightly (see 2.5.5.4(*c*) above).

(*b*) Fit the fine-adjustment valve to one end of the hexagon body of the adaptor and the pressure gauge to the other, screwing each up tightly. The tap to this fine-adjustment valve must be used to control only the flow of hydrogen—the cylinder key being used to turn the hydrogen on and off. The hydrogen pressure must not be allowed to fall below 100 lbf/in^2; when the pressure falls to this value the cylinder should be sent for recharging. New fine-adjustment valves incorporate a pressure-reduction valve.

(*c*) Clip the movable earthing system to the balloon filler and insert the valve of the filler into the 6 mm (¼-inch) tubing connected to the fine-adjustment valve. The valve of the cylinder should then be opened momentarily to blow out particles of dust which might damage the balloon.

(*d*) Shake out any french chalk from the selected balloon, then fit the neck of the balloon over the nozzle of the filler. If the neck is rather large it may be made to fit more closely to the filler by rolling the neck back a turn or two.

(*e*) Turn on the flow of hydrogen with the cylinder key; then, by gently turning on the tap of the fine-adjustment valve, allow the hydrogen to fill the balloon. Fill until the balloon does not quite support the filler, then turn off the hydrogen with the cylinder key and examine the balloon for pin-holes. If any pin-holes are found, the balloon should be taken outside and the hydrogen allowed to escape through the neck, and the deflated balloon disposed of; on no account should it be released with the neck open. If no leaks are found, resume filling until the filler is raised just clear of the ground, then turn off the flow of hydrogen with the cylinder key and close the fine-adjustment valve gently until finger-tight.

(*f*) The operator must remove any electrostatic charge from his person before approaching the inflated balloon. This can be achieved by grasping an earthing point for a few seconds. The inflated balloon is not to be rubbed with the hand or allowed to rub against clothing. Remove the balloon and filler from the rubber tubing and unclip the movable earthing system from the filler. By means of the valve in the filler, release hydrogen until the balloon just supports the filler. Stand well away from the door of the filling shed to minimize the effects of draught when testing the balloon for balance and as a precaution against the balloon being carried away through the open door before the filler has been removed.

(*g*) Remove the filler, firmly pinching the neck of the balloon between the thumb and forefinger to ensure that hydrogen does not escape. Seal the balloon by stretching its neck and tying it firmly into a knot.

(*h*) Test for hydrogen leakage by placing a wetted finger over the end of the neck.

The balloon is now ready for release. If not required for immediate release it must not, under any circumstances, be allowed to ride against the ceiling; for parking purposes it is to be tethered to some object by a short length of string and is to be left free to move about in draughts without coming into contact with other objects.

When released, the balloon will rise at approximately 120 metres (400 ft) per minute. It should be released from a site which is free from obstacles in a downwind direction, i.e. the direction in which the balloon will travel.

Type CP30 (30 g) balloons are filled in the same way, but a special weight (weight B from the Mk 8 filler set) is screwed on to the filler; the balloon, when filled, will rise at approximately 150 metres (500 ft) per minute.

2.5.5.8. *Use of helium.* At stations supplied with helium for the filling of cloud-height balloons, the equipment supplied is the same as for use with hydrogen with the following exceptions. Because the threads on a helium cylinder are right-handed, an adaptor is supplied for screwing into the cylinder; the left-hand threaded fine-adjustment valve is then screwed into the adaptor. The earthing equipment is not supplied because helium, being an inert gas, does not form explosive mixtures.

The only precautions necessary are those which are normally taken with high-pressure cylinders: store in a cool place and do not drop the cylinder on a hard surface. Cylinders should never be discharged completely.

2.5.5.9. *Storage of balloons.* Balloons should be stored in a dark place at a temperature of between 5 and 25 °C. The balloons are usually wrapped in cellophane and packed in cartons which should not be opened until the contents are required for use. The cartons should be stored on shelves free from splinters and protruding nails. The shelves must not be near a source of heat or running electric motors. If the balloons are properly stored they should not deteriorate appreciably over a period of two or three years but bad storage conditions will ruin balloons in a period of weeks.

2.5.6. Cloud-base recorders. The Meteorological Office cloud-base recorders, Mk 3A and Mk 3B, illustrated diagrammatically in Figure 3, have been designed to aid observers in providing more accurate estimates of the heights of the cloud bases that they report. Observers should note that the cloud-base recorder can only record what is directly above the instrument and then only up to a limited height. Additionally, the reading of cloud base is influenced by the properties of the cloud and the setting of the receiver; the instrument is not an absolute device. The observer must consider the whole sky and only use the recorded information as a guide in arriving at the estimate of cloud

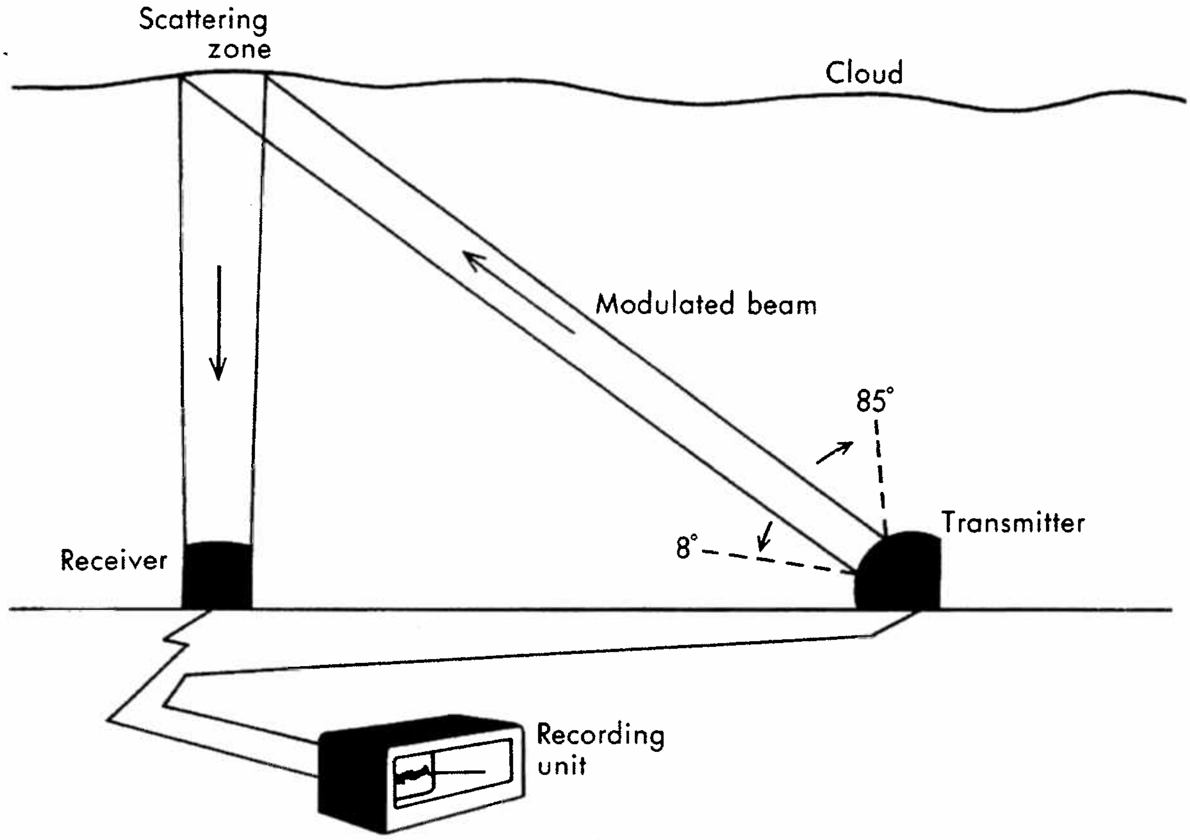


Figure 3. Meteorological Office cloud-base recorder system

heights to be reported. The equipment is fully automatic and capable of unattended continuous operation both by day and by night.

The complete system consists of three units: a transmitter, a receiver and a recorder. The transmitter and receiver are remotely switched from the recorder which may be positioned away from the operating site by up to 1000 m for the Mk 3A and up to 24 km for the Mk 3B, although distance varies with cable impedance.

The transmitter emits a modulated light beam which sweeps in a vertical plane through elevation angles from 8° to 85°, and back to 8° once a minute. The receiver looks vertically upwards in the same plane and is sensitive only to light produced by the transmitter. In the recorder unit, a pen traverses a chart in step with the sweep of the transmitter, and is made to mark the chart whenever the receiver detects light from the transmitter beam which is reflected and scattered by cloud. The pen marks the chart during both upward and downward sweeps; when the base line from transmitter to receiver is 100 m (350 ft), the marks indicates light-scatter from cloud in the range 15 to 1200 m (50 to 4000 ft). More than one mark can be made during a single sweep. At the lowest point for each scan, the beam is deflected along a horizontal path and reflected from a bar into the receiver. This signal produces a zero mark for each scan on the chart.

The chart is printed with a height scale and it is the lowest value of each pen mark that represents the response to cloud base. Plate XIV illustrates two examples of cloud-base recorder charts.

These recorders will eventually be superseded by a cloud-base recorder using a laser technique.