



Met Office



Observations

National Meteorological Library and Archive
Factsheet 17 — Weather observations over land

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Introduction

Meteorological measurements are made in a variety of ways from many different locations over the United Kingdom and around the world. They meet a wide number of requirements which include:

- Input to numerical models which provide forecasts for a few hours to a week or more ahead
- Information on the present state of the weather required for a great many purposes
- Information on the climate of the United Kingdom and the frequency of extreme weather events

This fact sheet describes measurements made at weather stations around the United Kingdom. These surface land observations are particularly important because they represent measurements of the weather that people experience. Other fact sheets in the series describe measurements made over the sea, in the upper atmosphere, by weather satellites, by weather radar and by thunderstorm detection systems.



Figure 1. Land surface synoptic station (Camborne, Cornwall).



Figure 2. Camborne wind tower.



Figure 3. The UK land surface synoptic observing network (*stations operated by the Met Office in May 2010*).

The UK land surface observing network

Observations made primarily for the purpose of providing information on the present state of the atmosphere and for weather forecasts are termed synoptic. Synoptic observations over the land surface include measurements of a wide range of meteorological elements made at observing stations like Camborne in Cornwall (*see figures 1 and 2*). The network of land surface stations where a full set of synoptic observations are made routinely is shown in figure 3.

These are the main land surface observing stations over the UK, but they are not the only ones. There are in addition supplementary stations which provide a more limited range of data to meet specific requirements, for example climate requirements, measurements of temperature and/or wind at a customer's site, and a dense rainfall network to aid water management and flood forecasting.

Synoptic stations

The distribution of synoptic stations shown in figure 3 is approximately uniform ensuring that as few weather features as possible escape detection. The average separation of stations in this network is about 40 km enabling the weather associated with the typical low pressure and frontal systems that cross the UK to be recorded. Some weather features occur on smaller scales (*for example thunderstorms*) and may evade the surface network altogether. For the detection of these satellites and weather radars play an important role.

Observations made at synoptic stations should represent the wider area around the station and not be unduly influenced by local effects. The ideal site should be on level ground with no trees, buildings or steep ground nearby that might influence the measurements. Undesirable influences include the warming effect of buildings on the measurement of temperature and the sheltering or shading effects of trees on the measurement of sunshine and wind. Wherever possible, a station should not be located in a frost hollow where overnight temperatures on still clear nights may be far lower than at neighbouring locations. In a similar way, winds measured at the top of a hill or steep escarpment will be unrepresentative of the wider area.

With few exceptions, the following meteorological elements are measured at all synoptic stations:

- Air temperature at 1.25 m above the ground
- Air temperature over a grass surface or its artificial equivalent
- Air temperature over a concrete surface
- Soil temperature at 0.1 m, 0.3 m and 1.0 m below the ground level
- Relative humidity at 1.25 m above the ground
- Amount of rainfall
- Depth of lying snow
- Mean wind speed, mean wind direction and maximum gust at 10m above the ground
- Atmospheric pressure at the station level and reduced to mean sea level
- Pressure tendency and characteristic
- Visibility
- Amount of cloud
- Type of cloud identified by observer
- Height of cloud base
- Present and past weather
- Duration of sunshine
- Short wave solar radiation intensity
- State of ground and of concrete slab identified by observer

The measurement of almost all the elements on the list is fully automated; data are logged at the station, processed to convert the measurement to a meteorological element in standard format, and transmitted to a central collecting system based at the Met Office's headquarters at Exeter. Each station produces observations at minute intervals and the central database at Exeter contains a large store of minute data from all UK stations. For many purposes this volume of data is too much to handle. For a great many years the standard observing time for synoptic purposes in the UK and for international exchange is hourly, i.e. each station reports 24 observations a day at 0000, 0100, 0200, ... 2200 and 2300 UTC. The central system at Exeter generates hourly observations encoded in internationally agreed formats for onward transmission in real time to users worldwide.

Recent hourly observations may be found on the Met Office's website:

(www.metoffice.gov.uk/weather/uk/observations/)

Although most of the observing process is automated today there are some synoptic stations where a trained meteorological observer provides some input into the observation. Usually this occurs at airfields where aviation authorities require manual oversight of those elements vital for aircraft safety, namely cloud, visibility, wind, present weather and pressure. A trained observer can provide estimates of those elements that are hard to automate, for example visibility, cloud type, cloud amount and state of ground. As there are no sensors to identify cloud type or state of ground these elements are not available from automated sites.

Supplementary stations

In addition to the synoptic stations described above there are an even larger number of supplementary stations that provide a limited observing capability. Examples of these include observing stations:

- Designed to meet the needs of a particular customer;
- In the urban environment;
- Sited at the top of mountains;
- Meeting the requirement for a long climate record.

Some supplementary stations provide observations of no more than air temperature, humidity, wind and rainfall. Where instruments are sited within an urban environment, measurements of wind, temperature and rainfall will often be strongly influenced by the impact of nearby buildings and other urban constructions. The observations should not be regarded as representative of the wider area. Similarly, wind measured at the top of a mountain is only representative of the very local area where an anemometer is sited.

Many stations are maintained to meet the requirement for accurate climate averages at a wide variety of locations over the UK. A long uninterrupted record is essential for this purpose (at least 30 years and preferably longer) and this is achieved at a large number of stations. Some climate stations are automated, sending data in real time, but many rely on an unpaid enthusiast making a daily observation at 0900 UTC from manually read instruments who perhaps only sends the data at the end of the week or month. The principal observed elements for climate purposes are:

- Maximum air temperature at 1.25 m above the ground (0900 UTC to 0900 UTC the next day)
- Minimum air temperature at 1.25 m above the ground (0900 UTC to 0900 UTC the next day)
- Air temperature at 1.25 m above the ground (0900 UTC)
- Grass minimum temperature (dusk to 0900 UTC the next day)
- Soil temperature at 0.1 m, 0.3 m and 1.0 m (0900 UTC)
- Relative humidity at 1.25 m above the ground or the wet bulb equivalent (0900 UTC)
- Rainfall amount (0900 UTC to 0900 UTC the next day)
- Depth of lying snow (0900 UTC)
- Sunshine duration (0000 UTC to 2300 UTC)

Rainfall stations

Measurements of rainfall amount often vary greatly from location to location because of the variable nature of rain producing weather systems and their interaction with high ground. For this reason a high density network of rain gauges is required to define accurately the rainfall climatology of the UK and to identify where flooding events are likely to occur as a result of local heavy storms. By far the most numerous type of supplementary observing station is the rainfall station where the only measurement made is rainfall amount. Some systems are automatic sending data in real time while others rely on manually read rain gauges where the data may be received some time after the event. The responsibility for water management and flood forecasting lies with the Environment Agency in England and Wales and with the Scottish Environment Protection Agency, organisations that operate and fund many of the rainfall stations.

Meteorological instruments and the measurements they make

- Stevenson screen

Measurements of air temperature and relative humidity are made in a screen that shields the instruments from direct sunlight. The screen is positioned so that the thermometer is 1.25 m above the ground and its door faces north to ensure that no sunlight falls on the instruments when being read or serviced.



Figure 4. Stevenson screen.

Figure 5. View inside the screen.

The screen type currently in use at Met Office stations (*figures 4 and 5*) is based on an original design by Thomas Stevenson (1818-1887) and relies on natural ventilation. It is constructed of plastic, coloured white outside and black inside, with double roof, floor and side louvers that serve to reduce the amount of heat that would otherwise be conducted from the outer wall to the inner enclosure, especially in strong sunshine.

Free circulation of air throughout the screen allows the temperature of the inner wall adapt to ambient air changes, a design that is not immune from problems in extreme cases. Anomalies may arise when the wind is light and the temperature of the outer wall is markedly different from the air temperature. Although the plastic screen is used widely in the observing network today, screens of different design have been used in the past, a factor that should be taken into account where measurements are analysed to detect subtle changes in the climate mean. At a few stations a wooden version of the Stevenson screen is still in use.

Temperature

- Air temperature

A platinum resistance thermometer (*PRT*) is used for the measurement of air temperature at all synoptic stations and all supplementary stations that employ an automatic system. The thermometer is exposed in a Stevenson screen of the type described in the preceding section, at a height of 1.25 m above the ground and aspirated only by natural ventilation through the side louvers. Figure 5 shows the arrangement of thermometers in the screen. Two PRTs, one for operational use and one for backup, may be seen at the end of the looping black cables.

In addition, there are four liquid-in-glass thermometers in the screen that are used solely for check readings. Temperature measured by a PRT is related to the resistance of the instrument's platinum wire, measured by means of high precision electrical equipment usually located close to the screen. The thermometer is calibrated every eight years providing traceability to the national temperature standard. The long period between calibrations is justified by the excellent stability demonstrated by PRT instruments.

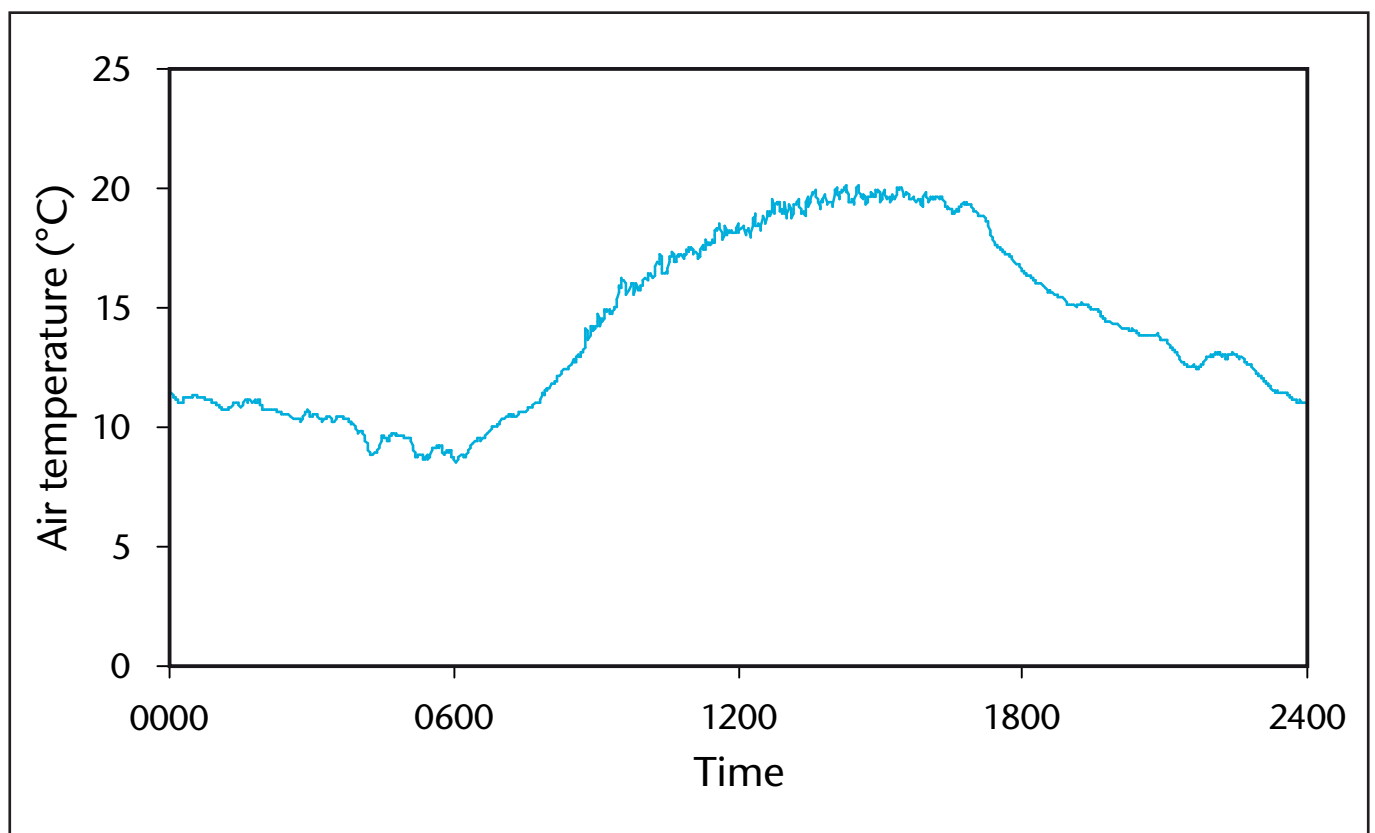


Figure 6. 1-minute values of air temperature at Heathrow Airport on 25 September 2009.

An example of air temperature over a 24-hour period is shown in figure 6 for a typical sunny day in southern England. Measurements taken every 15 seconds are averaged to provide the underlying 1 minute data. Maximum and minimum temperatures are defined as the extreme 1 minute values during the relevant period. Daily maximum and minimum temperatures normally refer a 24-hour period 0900 UTC to 0900 UTC where they are quoted to the public, such as in newspapers and on the web.

In the example above, the maximum temperature on the 25 September is 20.1 °C (*the maximum value between 0900 UTC on the 25 and 0900 UTC on the 26*). The minimum temperature is 8.5 °C (*the minimum value between 0900 UTC on the 24 and 0900 UTC on the 25*).

At non automated climate stations where the temperature is taken by the human observer, liquid-in-glass thermometers meeting British Standard specification BS692 are used. Air temperature is measured by a normal mercury-in-glass thermometer, maximum temperature by a mercury-in-glass thermometer having a constriction in its bore that holds the mercury in its highest position, and minimum temperature by an alcohol-in-glass thermometer which carries a small index within its bore for marking the lowest temperature reached. The observer resets the maximum and minimum thermometers daily at 0900 UTC.

- Grass minimum temperature

For many years the grass minimum temperature has been defined as the lowest overnight temperature measured by a thermometer, fully exposed to the open sky, suspended horizontally over an area covered with short cropped turf and in contact with the tips of grass blades. With the advent of widespread automation and the lack of daily attention by an observer or caretaker, this set up has proved impractical. At most automatic stations the natural grass surface under the grass minimum thermometer has been replaced by an artificial equivalent. A platinum resistance thermometer is used for the measurement of grass minimum temperature at almost all synoptic stations and all supplementary stations that employ an automatic system (*figure 7*). Alcohol-in-glass minimum thermometers exposed over natural grass are used at manned climate stations.

The term ground frost used in forecasts signifies a grass minimum temperature below 0 °C.

- Concrete minimum temperature

Concrete minimum temperature is measured by a thermometer in contact with a concrete slab (*figure 8*). The slab lies horizontally, fully exposed to the open sky and with its top almost flush with the surrounding ground. Platinum resistance thermometers are used at almost all stations with automatic systems, while alcohol-in-glass minimum thermometers are used at manned climate stations. Concrete minimum measurements have been made at Met Office stations since 1 December 1968 and are mainly relevant to the incidence of ice on runways or roads.



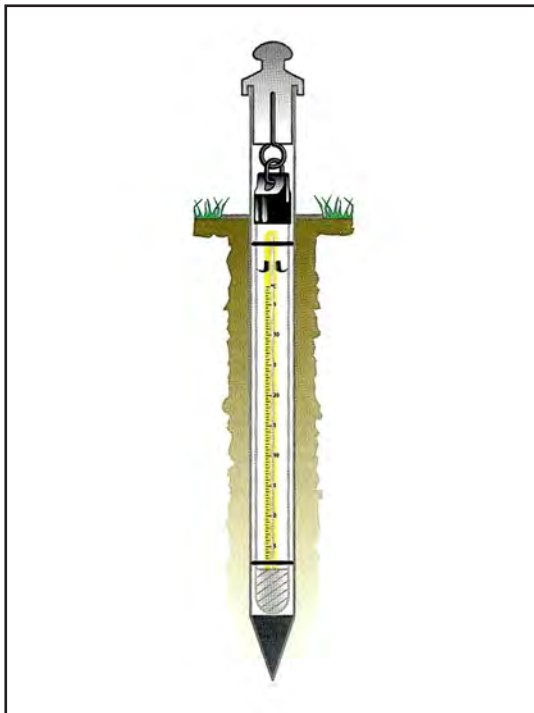
Figure 7. Grass minimum thermometer over an artificial grass surface



Figure 8. Concrete minimum thermometer.

- Soil temperature

At many stations with automatic systems soil temperature is measured at a depth of 10 cm, 30 cm and 100 cm below the ground surface by platinum resistance thermometers. Thermometers at 10 cm and 30 cm are buried by inserting the head at the required depth into the undisturbed soil on the vertical wall on the side of a trench which is then back-filled. This method is impractical for the 100 cm measurement; instead the thermometer is suspended inside a tube with its tip at the appropriate depth. Problems can occasionally arise where the tube becomes flooded due to waterlogged soil or heavy rainfall. To ensure consistency of measurement from site to site, the ground surface above the 10 cm soil thermometer is maintained as bare soil.



At manned climate stations soil temperature is measured by mercury-in-glass thermometers read by the observer. Thermometers for the 10 cm measurement have a right angled bend in the tube so that the bulb may be buried in the soil at the required depth and the scale exposed horizontally above the surface for easy reading.

Normal mercury-in-glass thermometers are suspended inside tubes for the 30 cm and 100 cm measurements (*figure 9*). These thermometers are housed in an extra protective glass sheath and have their bulb set in wax to slow their response while being withdrawn and read by the observer.

Figure 9. Soil thermometer exposed in a tube.

Humidity

Humidity sensors measure the capacitance of a hygroscopic dielectric material placed between two electrodes. Using air temperature, this measurement may be converted to relative humidity or dew point. The sensor (*coloured white and on the left in figure 5*) is ventilated naturally in the Stevenson screen alongside the air temperature thermometer. To avoid contamination by pollution or salt particles, problems most acute in the urban or marine environment, the sensor is shielded by a fine filter which is replaced at regular intervals by service engineers. At intervals of no longer than 12 months, relative humidity sensors are calibrated in the laboratory by comparison with absolute measurements of humidity from a chilled mirror device.

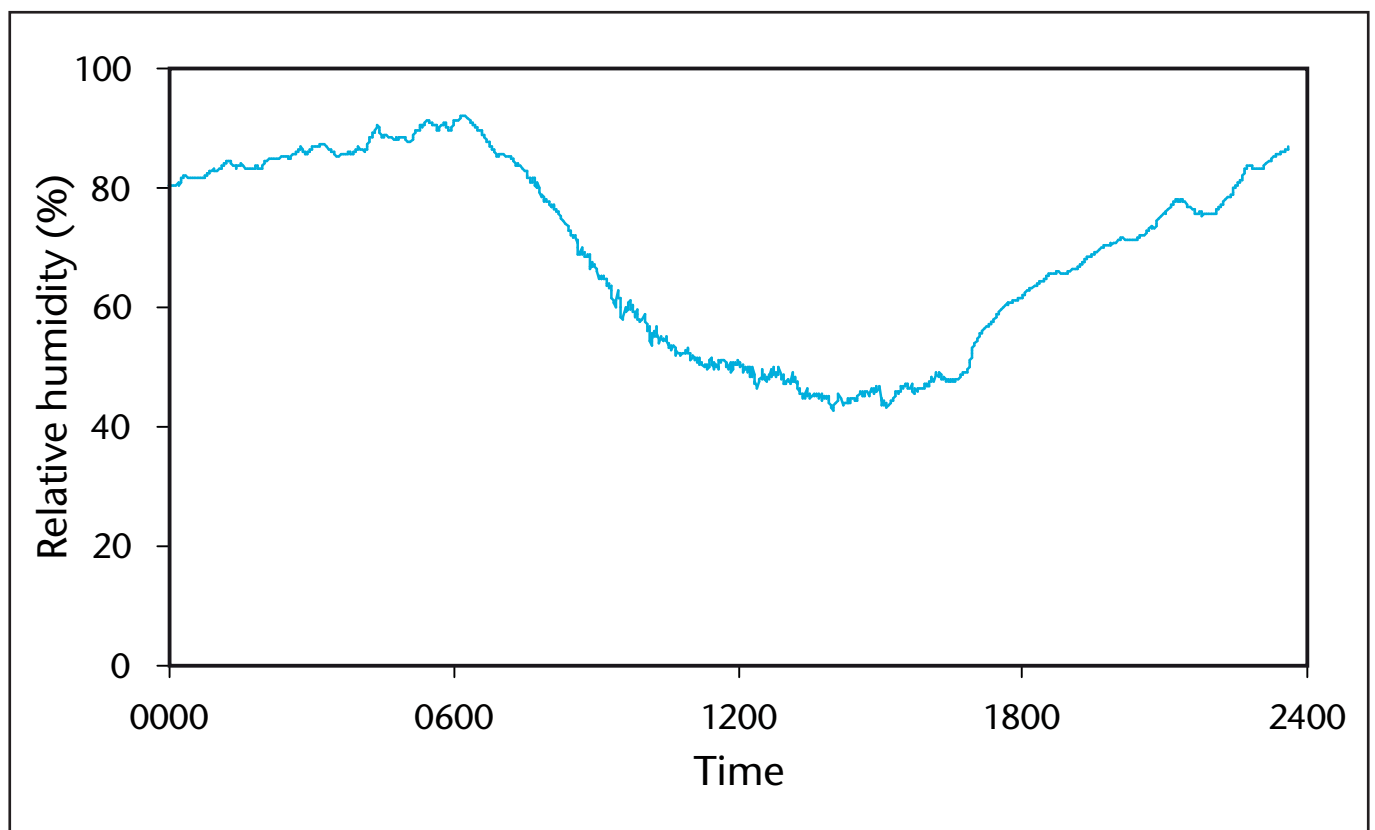


Figure 10. 1-minute values of relative humidity at Heathrow Airport on 25 September 2009.

An example of relative humidity over a 24-hour period is shown in figure 10 for a typical sunny day and clear night in southern England. As the temperature drops during the late afternoon and evening, it approaches the point at which the air becomes saturated. This effect is represented by rising relative humidity. Conversely, the rising temperature after sunrise is associated with falling relative humidity.

At non-automated sites humidity is derived from two thermometers ventilated naturally in the Stevenson screen: a dry bulb measuring the air temperature and a wet bulb measuring the temperature of a thermometer tip wrapped in a moist muslin wick and cooled by evaporation into the surrounding air.

Rainfall

Many different types of rain-gauge have been designed and used. Most consist of a circular collector, delineating the area of the sample, and a funnel that channels the collected rain into a measuring mechanism or into a reservoir where it may be measured at a later time. As the name implies, rain gauges measure rain not snow, hail or other forms of frozen precipitation. The entrance to the gauge through the funnel is narrow to avoid debris clogging the mechanism and undesirable evaporation in hot weather. However, the gauge rapidly becomes blocked in snow and any readings at the time, and during thawing events when melted snow gradually trickles into the gauge, should be treated with caution. Where an observer is present to make a daily precipitation reading, the water equivalent of freshly fallen snow is reported.

- Tipping-bucket rain-gauge

For many years the Met Office has used a tipping-bucket rain-gauge for the automatic measurement of rainfall rate (*figure 11*). The collecting funnel has a sampling area of 750 cm², the rim is set 450 mm above the surrounding ground level and a mechanism records an event each time a rainfall increment of 0.2 mm has been detected.



Figure 11. Tipping-bucket rain-gauge.

- Storage rain-gauge

Since the earliest years of weather records, the de facto standard for the measurement of daily rainfall has been the 0900 UTC reading made by an observer from a 5 inch storage rain-gauge. The gauge has a sharp brass or steel rim of diameter 5 inches (127 mm), sited 30 cm above ground level with a funnel that collects rain in a narrow necked bottle placed in a removable can.

To make the rainfall measurement, the observer empties the collected rain into a graduated glass rain measure. Figures 12 and 13 show the type of storage rain-gauge used widely in the UK. Versions of the 5 inch gauge with greater storage capacity are used at sites where readings may be taken infrequently.

As automated instruments were introduced across the synoptic network in the 1980s and 1990s the 5 inch gauge was still deployed alongside the tipping bucket gauge to continue a long consistent record of measurements for climate purposes.

In recent years this practice has proved impractical and many automatic sites now only report rainfall amount from a tipping bucket gauge. Storage gauges are still used widely at non automated climate stations and rainfall-only stations. Where an observer is not available to provide daily rainfall, readings may be made at weekly or monthly intervals.



Figure 12. 5-inch rain-gauge.

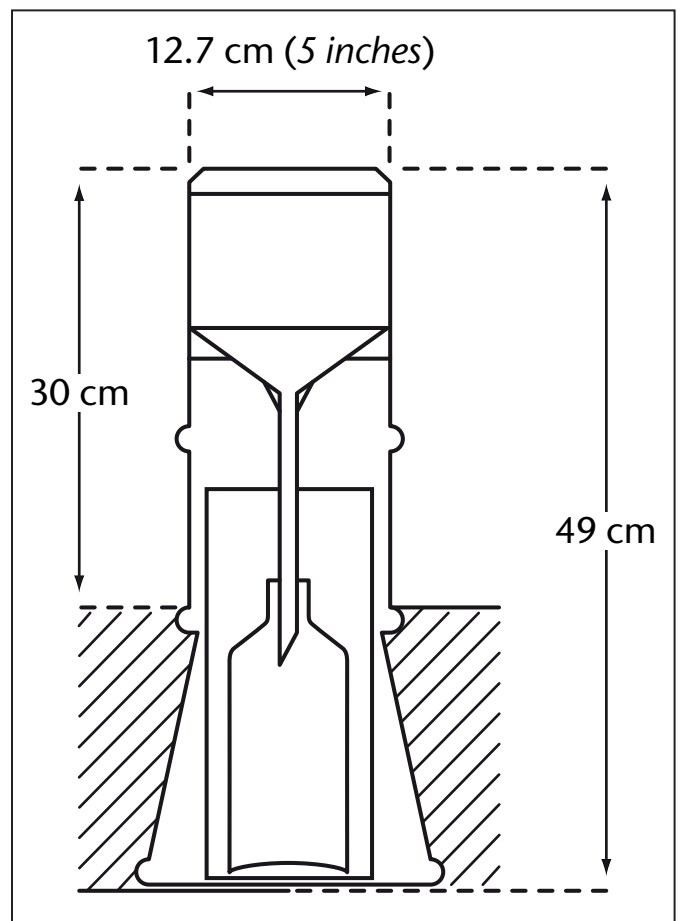


Figure 13. Cross-section of a 5-inch rain gauge.

Snow depth

A snow depth sensor (*figure 14*) is an electrically-powered active device with on-board data-processing that measures the distance between the sensor and the ground surface beneath it.



Figure 14. Snow depth sensor.

An ultrasonic transducer transmits pulses and listens for the returning echoes from the surface. The distance measurement is based on the time delay between transmission of the pulse and the time of the return of the echo. An independent temperature measurement is required in order to compensate for the temperature-dependent variation of the speed of sound in air.

The sensor output is normalised to zero under conditions of no lying snow. The measurement is made over an artificial grass surface having approximately the same thermal properties of a grass surface but which avoids spurious readings caused by the slow growth of grass. At manned stations without automated sensors, snow depth is measured periodically by the observer using a measuring rod at a number of representative locations.

Wind

Wind over the land surface should ideally be measured at a height of 10 m above ground level at the top of a mast or some other supporting structure that has small impact on the local flow of air. Wind is the horizontal movement of air and is specified by its speed and direction. The normal unit of wind speed is the knot (*nautical mile per hour* = 0.51 m sec^{-1} = 1.15 mph). Wind direction is measured relative to true north (*not magnetic north*) and is reported from where the wind is blowing. An easterly wind blows from the east or 90 degrees, a southerly from the south or 180 degrees and a westerly from the west or 270 degrees. Wind speed normally increases with height above the earth's surface and is much affected by such factors as the roughness of the ground and the presence of buildings, trees and other obstacles in the vicinity.

The optimal exposure for the measurement of wind is over level ground of uniform roughness with no large obstacles within 300 m of the tower. In practice few sites in the observing network meet this requirement exactly for all incident wind directions, but most are reasonably representative of an open site.

Wind speed is normally measured by a cup anemometer consisting of three or four cups, conical or hemispherical in shape, mounted symmetrically about a vertical spindle. The wind blowing into the cups causes the spindle to rotate. In standard instruments the design of the cups is such that the rate of rotation is proportional to the speed of the wind to a sufficiently close approximation. At intervals of no longer than five years, anemometers are calibrated in a wind tunnel to identify any departures in the relationship between spindle rotation and wind speed specified by the manufacturer. Calibration corrections are applied to the measured wind speed.

Wind direction is measured by a vane consisting of a thin horizontal arm carrying a vertical flat plate at one end with its edge to the wind and at the other end a balance weight which also serves as a pointer. The arm is carried on a vertical spindle mounted on bearings which allow it to turn freely in the wind. The anemometer and wind vane are each attached to a horizontal supporting arm at the top of a 10 m mast (*figure 15*).

Where wind measurements are made in extreme weather conditions, such as on the top of mountains, a heated sonic anemometer is used (*figure 16*) having no moving parts. The instrument measures the speed of acoustic signals transmitted between two transducers located at the end of thin arms. Measurements from two pairs of transducers can be combined to yield an estimate of wind speed and direction. The distortion of the air flow by the structure supporting the transducers is a problem which can be minimized by applying corrections based on calibrations in a wind tunnel.



Figure 15. Cup anemometer and wind vane.

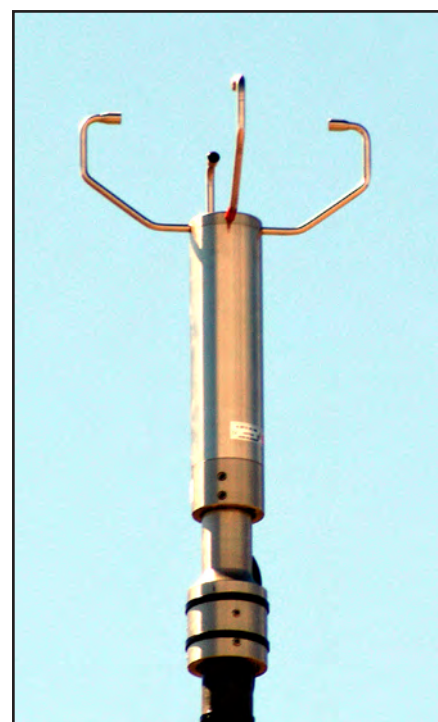


Figure 16. Sonic anemometer.

Because wind is an element that varies rapidly over very short periods of time it is sampled at high frequency (*every 0.25 sec*) to capture the intensity of gusts, or short-lived peaks in speed, which inflict greatest damage in storms. The gust speed and direction are defined by the maximum three second average wind speed occurring in any period.

A better measure of the overall wind intensity is defined by the average speed and direction over the ten minute period leading up to the reporting time. Mean wind over other averaging periods may also be calculated. A gale is defined as a surface wind of mean speed of 34-40 knots, averaged over a period of ten minutes. Terms such as 'severe gale', 'storm', etc are also used to describe winds of 41 knots or greater.

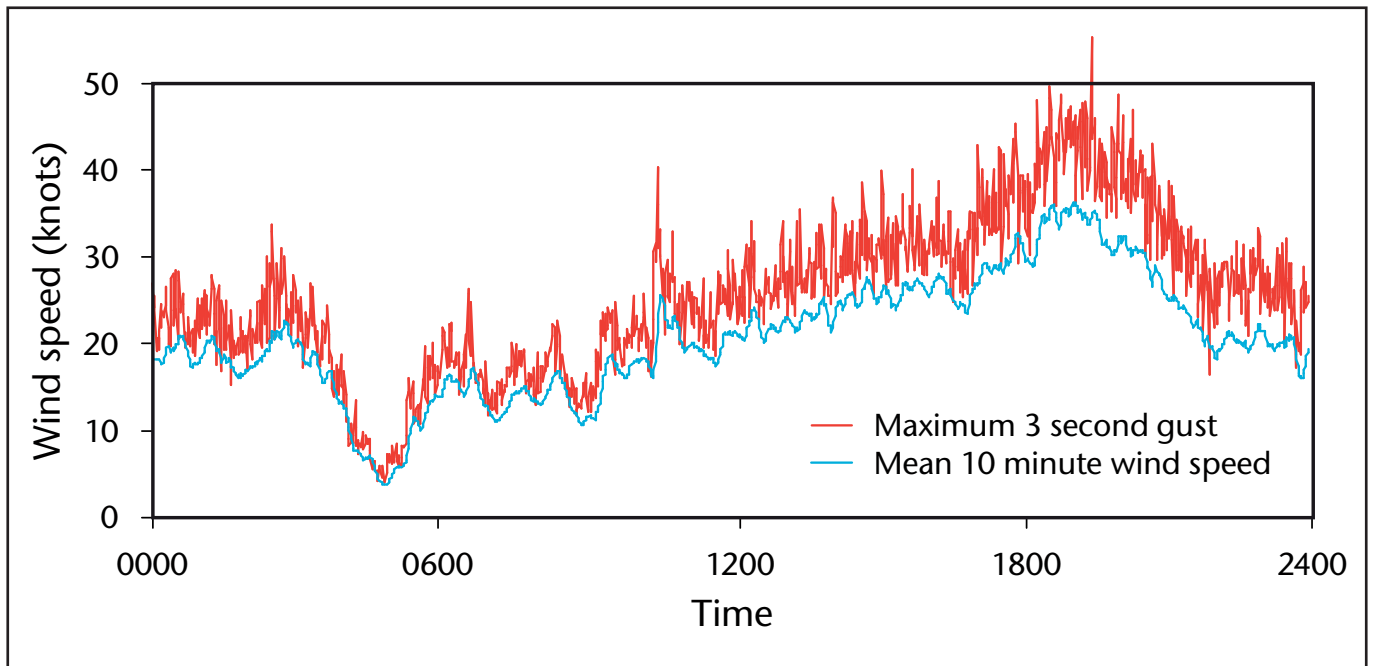


Figure 17. Wind speed at Prestwick airport on 22 November 2009.

Wind speed on a particularly stormy day in November 2009 is shown in figure 17. The maximum 3-second gusts shown in red are typically 20-40 percent higher than the 10-minute mean wind speeds shown in blue.

Atmospheric pressure

Atmospheric pressure is measured by a barometer that employs a silicon capacitive pressure sensor having excellent repeatability and long term stability characteristics (figure 18).

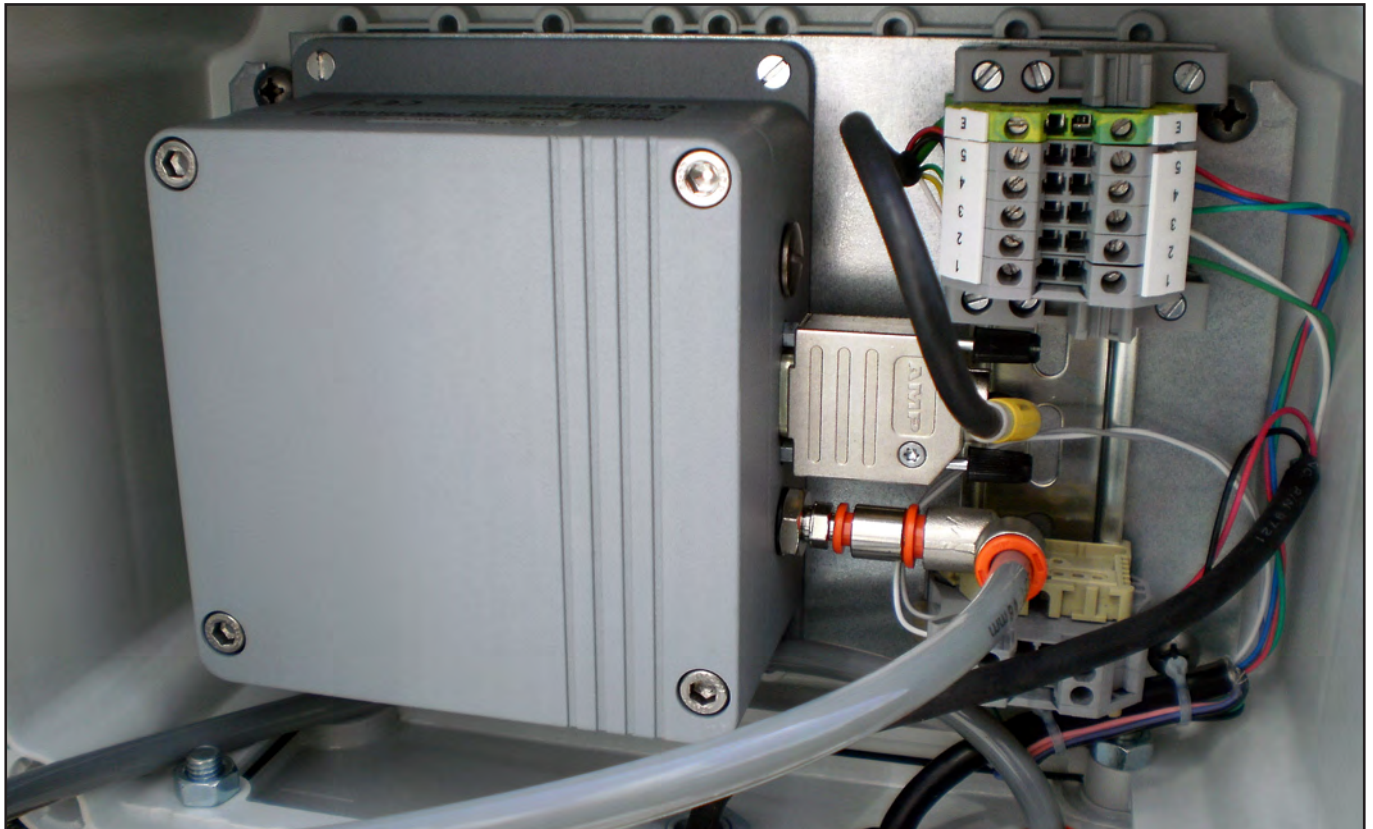


Figure 18. Pressure sensor.

The accurate measurement of atmospheric pressure is of fundamental importance in meteorology and has particular relevance for the safety of aircraft landing at airports. To ensure any errors are kept to the absolute minimum, the instrument contains three separate pressure sensors and internal instrument software checks for any differences between the three independent measurements.

The deployment of a pressure sensor in the field must be undertaken with great care. Any movement of air across the vent that connects the sensor to the ambient environment will cause a drop of pressure caused by a simple dynamical effect described by Bernoulli's principle. Similarly, the pressure in still air within a building will be affected by the flow of air round the building or indeed by an air conditioning system. To avoid erroneous measurements, the pressure sensor is exposed via a static pressure head (*figure 19*), a device designed in such a way that the dynamical effects of wind are minimised.



Figure 19. Static pressure head.

Atmospheric pressure varies greatly with height, dropping near the surface by about 1 hPa (*or 1 millibar*) for each 10 m in the vertical. To make sense of pressure readings from a network of barometers across the UK, each exposed at a different height above sea level, all values of station level pressure are converted to an estimate of the pressure at mean sea level, using a formula that takes into account the air temperature. Mean sea level pressure, station level pressure and the pressure tendency during the previous three hours are reported from all synoptic stations every hour. Tendency is defined by one of ten categories: steady, rising, falling, rising then falling, etc.

Visibility

For a great many years meteorological visibility was estimated by the human observer judging the appearance of distant objects against a contrasting background, usually the sky. Various rules have been established for how visibility should be judged:

- An object should not merely be seen but should be identifiable against the background as a specific object
- Visibility should be estimated at ground level where there is an uninterrupted view of the horizon
- If the visibility varies from one direction to another, the lowest value should be reported
- For the purposes of aviation the prevailing visibility should be reported

Today, most synoptic observing stations have sensors which provide a measurement of visibility where the station operates in fully automatic mode. At the smaller number of stations where there is still a human observer (*e.g. at airfields*) the sensor acts as an aid in the estimation of visibility. Visibility sensors measure the meteorological optical range which is defined as the length of atmosphere over which a beam of light travels before its luminous flux is reduced to 5% of its original value. In most instances this is approximately equivalent to, but not the same as, visibility measured by the contrast of a distant object against its background.

A typical visibility sensor used at synoptic observing stations is shown in figure 20. It applies the forward scattering characteristics of light to measure the extinction coefficient of a beam generated by a high intensity xenon strobe transmitter directed at a volume of air close to the sensor. Reasonably accurate measurements are possible over a range of visibility extending from a few tens of metres to a few tens of kilometres. The use of light within the visible spectrum allows the sensor to most accurately simulate human perception of visibility.



Figure 20. Visibility sensor.

Cloud

Cloud is an aggregate of very small water droplets, ice particles or a mixture of both. In most cases cloud water droplets have a diameter less than 200 microns as particles larger than this generally fall out of the atmosphere as rain or drizzle. The large scale distribution of cloud is best measured from space in either the visible or infra red part of the spectrum and such imagery is widely available on the web (www.metoffice.gov.uk/satpics/latest_uk_ir.html). Satellite imagery is very revealing in many ways, but it has its limitations for the measurement of cloud, in particular:

- Extensive high cloud can mask important features in the distribution of low cloud
- It is often not possible to distinguish between shallow low cloud and fog
- There is no way of measuring cloud base from space, an element of critical importance for aviation and other purposes

To meet these shortcomings cloud base measurements are made from all surface synoptic stations.

- Cloud type

The standard method for classifying clouds is based on the World Meteorological Organisation criteria (*see fact sheet number 1 – Clouds, for a summary*). The classification is made in terms of the level of the cloud (*high, medium or low*) and various cloud genera specified by the cloud form and its features. Common types of cloud include cumulus, cumulonimbus, stratocumulus and stratus at low levels; altocumulus, nimbostratus and altostratus at medium levels and cirrus, cirrocumulus and cirrostratus at high levels. As there are no automated systems for the detection of cloud type, its reporting is only possible where the human observer is present.

- Cloud amount

At any time different types of cloud at different heights above the ground may be visible from an observing station. To cater for such variability both the total cloud amount and partial cloud amounts are reported. Total cloud amount is the fraction of the sky covered by cloud of any type or height above the ground. Partial cloud amount is the fraction of the sky covered by each type or layer of cloud as if it was the only type or layer of cloud in the sky. If a number of different layers of cloud are present the partial amount of each one will be reported. The sum of partial cloud amounts may exceed the total cloud amount or indeed exceed 100% of the sky.

Cloud amount is reported in oktas or eighths with the additional convention that:

- Zero oktas represents the complete absence of cloud
- 1 okta represents a cloud amount of 1 eighth or less, but not zero
- 7 oktas represents a cloud amount of 7 eighths or more, but not full cloud cover
- 8 oktas represents full cloud cover with no breaks
- 9 oktas represents sky obscured by fog or other meteorological phenomena

A cloud base recorder (*see the section below*) is used to estimate partial cloud amount. For each layer of cloud identified by the instrument a time weighted average is used to derive the average amount. Such measurements are by their nature only representative of the cloud that has passed directly above the instrument, not of the total sky that is on view from the station. Total cloud amount is only reported from stations where the human observer is present.

- Cloud base

Cloud base is readily measured by instrument to a reasonable level of accuracy. The type of cloud base recorder used widely at synoptic observing stations is shown in figure 21.



Figure 21. Cloud base recorder.

It employs a pulsed diode laser LIDAR (*light detection and ranging*) technology whereby short laser pulses (*eye safe*) are sent out in a vertical or near vertical direction. The backscatter caused by reflection from the surface of cloud, precipitation or other particles is analysed to determine the height of the cloud base. Many modern cloud base recorders are capable of detecting up to three cloud layers simultaneously.

Present and past weather

The various meteorological elements described so far (*temperature, humidity, rainfall rate, visibility, cloud amount, etc*) describe different aspects of the weather occurring at any one time.

The term present weather is used to summarise all these aspects into a single element represented as code figure. Definitions for the internationally agreed codes for present weather may be found at

www.wmo.int/pages/prog/www/WMOCodes/Volumel1.html#Volumel1.

Two code forms for present weather are defined, one for use by the human observer and one for automatic instruments.

Present weather may be summarised as falling into a number of different categories:

- Showery precipitation with thunderstorm
- Showery precipitation without thunderstorm
- Frozen precipitation
- Freezing rain or sleet
- Rain
- Rain and drizzle
- Drizzle
- Fog or ice fog
- Duststorm, sandstorm, drifting or blowing snow
- Precipitation, fog, ice fog or thunderstorm at the station during the preceding hour but not at the time of observation
- Other meteorological phenomena

Instruments used widely in the synoptic surface network for the measurement of present weather are shown in figures 22 and 23 below; one is essentially a forward scattering visibility sensor and the other a sensor for detecting the presence of recent precipitation. Output from these two instruments together with measurements of air temperature, relative humidity and rainfall rate are analysed to derive the present weather code that best fits the data. The measurement of present weather is difficult to automate with the result that the human observer where present at the station may on occasions need to correct the reported value. Past weather codes define the dominant weather during the preceding hour, three hours or six hours.



Figure 22. Present weather sensor.

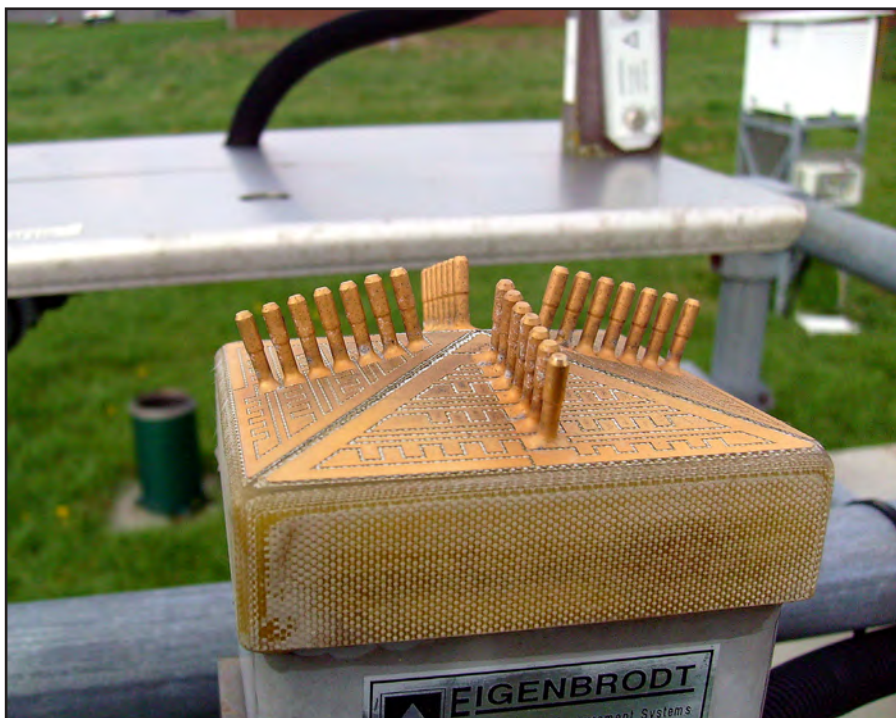


Figure 23. Precipitation detector.

Sunshine and radiation

- Radiation

Four different components of radiation in the atmosphere are measured routinely at some synoptic land stations:

- Global radiation – total downwelling short-wave radiation (*visible wavelengths to 4 μm*), measured on a horizontal surface
- Diffuse radiation – global radiation minus the direct component from the sun, also measured on a horizontal surface
- Direct radiation – radiation coming from the sun and not the rest of the sky, measured at normal incidence
- Long wave radiation – downwelling infra-red wavelengths from 4 μm upwards

Global radiation is measured by a pyranometer (*figure 24*). Measurement of the diffuse components requires a tracking device that ensures that the sun is obscured by a ring or a tracking shading device (*figure 25*) and is only undertaken at a few principal radiation stations. All instruments operate by directing incoming radiation onto the black-painted upper surface of a thermopile. This generates a temperature gradient across the thermopile which in turn produces a voltage proportional to the intensity of the radiation.

The correct exposure of any radiation or sunshine instrument at the observing site is very important. Ideally the horizon should be level in all directions, although the poleward arc is less important for sunshine and direct radiation measurements. In practice this is rarely the case and sites need to be assessed and graded according to the distribution of obstacles around the horizon.

All instruments are calibrated by reference to absolute cavity radiometers, standard radiation instruments that are maintained by the Met Office. These standards are precision pyrhemeters incorporating an electrical heater on the sensing element, the input of which can be measured very accurately. Intercomparisons made at Davos Switzerland ensure traceability to the world radiation standard.

- Sunshine

For a great many years the only instrument for measuring sunshine duration was the Campbell-Stokes sunshine recorder (*figure 27*). The original instrument was invented by Campbell in 1858 but the later card-holding version was a development by Stokes in 1879.

Most of the climate record was collected using this instrument and it continues in widespread use today at many non-automated climate stations. A glass sphere focuses the sun's direct radiation on a graduated card and the length of the burn trace on the card corresponds to the duration of sunshine.

This method of measurement significantly overestimates sunshine duration on days when the sun is frequently shaded by passing clouds. At many automated stations a modern sunshine sensor is used in its place (*figure 26*). It uses an array of differently exposed photodiodes to estimate the intensity of direct radiation. A threshold intensity of 120 Wm^{-2} defines the occurrence of full sunshine.



Figure 24. Pyranometer for measuring global radiation.



Figure 25. Tracking pyranometer.



Figure 26. Sunshine duration meter.



Figure 27. Campbell-Stokes sunshine recorder.

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