Observing the weather

Some advice if you are an amateur, or at a school, and thinking of making weather measurements

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Introduction

If you are interested in the weather, then you can enjoy it even more by making some simple observations of it. You can then see how things change through the day, from day to day and through the year; compare one year's extremes – of temperature or rainfall, for example – with another's. Am I warmer or colder than other places? Did last night's forecast on the TV get it right? There has never been a better time to start making your own observations. Weather instruments are now relatively cheap and easy to set up, and in addition to the traditional "manual" type that has been used for many years, there are now many digital instruments, and even full weather stations, within easy reach of many people's pockets. In this article, suggestions are given as to suitable instruments and methods for taking simple but effective weather records, when it does not really matter if the temperature is a degree or two in error, or the rain gauge does not have the ideal exposure to catch all the rain properly.

It should be made clear from the outset that this article is about making affordable measurements which do not claim great accuracy. If you wish to set up a weather station whose records can be used for a proper climatological study of your area, or perhaps even make you acceptable to the Met Office as an official climatological observer, then this booklet is not for you.

We look at a number of weather variables in turn; temperature, precipitation, etc. In each section we consider a traditional "manual" instruments and then digital electronic instruments. Finally, we look at complete electronic wireless weather stations. In this article we don't consider do-it-yourself instruments; suggestions for these can be found on other pages of the RMetS MetLink website. In general, homemade stuff, whilst great fun to make and good for demonstrating principles of measurement, tends not to be robust enough for the long term outdoor exposure needed to make measurements over months and years.

Finally, we make two general points. Stick to metric units for all the measurements, as they are used the world over (with the exception of the USA). And if you can only make observations once a day, then make them as close to 9am local time (which is 0900 GMT in winter and 1000 British Summer Time) as you can - this is the time that climate stations do it all over the world.

Temperature

Temperature is probably the easiest and most interesting weather variable to measure, so a good first choice. A simple thermometer (Figure 1) works when a liquid (mercury or alcohol spirit) in a bulb expands as the air around it gets warmer, and rises up a narrow glass capillary tube to a height that depends upon the temperature, which can be read off a graduated scale alongside. The scale should be as open and clear as possible, with graduations every whole degree and labels every ten degrees. If possible, the temperature scale should be in degrees Celsius only, as this is now adopted worldwide. The temperature can be read to the nearest whole degree, or possibly half-degree if the scale is clear. Simple thermometers such as the one in Figure 1 cost around £2.

Figure 1   Ordinary spirit-in-glass thermometer. In this case the spirit is alcohol, coloured red for ease of reading.

Maximum and minimum temperature

Recording daily temperature extremes is recommended and for this a maximum and minimum (max-min) thermometer is needed. This will also, of course, serve as an ordinary thermometer, when read at any time. The standard max-min thermometer has a U-shaped tube (Figure 2) and its proper name is a Six's thermometer.

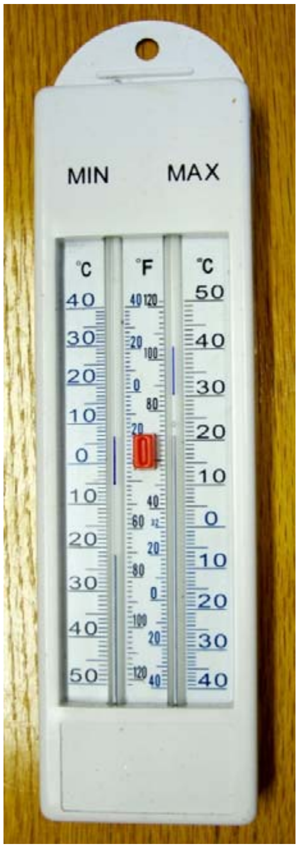

Figure 2: A maximum-minimum thermometer

In it, as the temperature rises the clear spirit in the bulb at the top (hidden from view) expands and pushes a mercury column which, in turn, pushes a little metal pin called an index up the right hand arm of the glass tube. As temperature falls, the mercury column recedes, but leaves the index in place to indicate the maximum temperature (see Fig 3). A similar process indicates the minimum temperature, on the left-hand arm.   Readings can be taken at any time and the indices reset (so they are once again touching the mercury column) afterwards – usually by pushing a button.

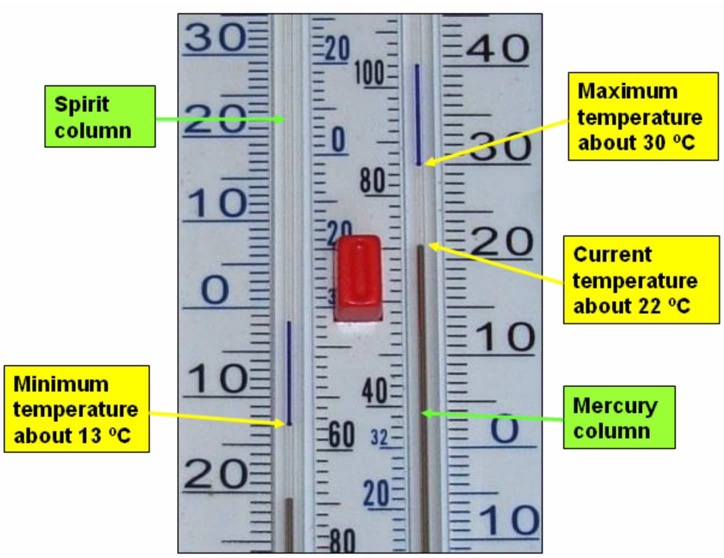

Figure 3: Close up of maximum-minimum thermometer showing current temperature and temperature extremes since it was last reset. In this version, the red button is pushed to reset the indices.

An alternative type is the bimetallic max-min thermometer, illustrated in Figure 4. It is slightly easier to read, but generally less accurate. Both types of max-min thermometer cost around £10.

Figure 4: An easy-to-read maximum-minimum bimetallic thermometer. The air temperature (black pointer) is about 14C, the minimum (blue) since last reset is 5C and the maximum (red) is 26C.

Digital thermometers

A number of relatively inexpensive digital thermometers are now becoming easily available. Some, such as that in Fig 5, are read in situ. Some have the temperature probe on a lead a few metres long (Fig 6), enabling the display to be indoors. Some varieties store the maximum and minimum temperature since last reset. Some digital thermometers are wireless; that is, the temperature sensing element is put in a suitable location outdoors and it transmits temperature to the indoor receiver and display. Costs of these types of digital thermometers are typically £5-10.

When using digital thermometers (or indeed digital instruments of any type) it is important not to confuse precision with accuracy. Although the display (such as that in Figure 6) may have a precision of 0.1°C (in that it can read differences of this amount) its accuracy (that is, how different its reading is from the true temperature) is likely to be much poorer than its precision – maybe a degree or more.

Figure 5: Digital thermometer

Figure 6: Digital thermometer with probe on a lead

Where outside should a thermometer be put?

The only hard and fast rule is that it must be out of direct sunlight, so that it reads the temperature of the air, not the temperature to which it has itself been heated by the sun. It helps if the thermometer can be in some sort of screen – ideally this should be a white-painted box with louvered sides, which protects the thermometer from sunlight yet lets air circulate round it – often called a Stevenson screen. A reasonably sophisticated D-I-Y version can be bought as a kit for about £50, or ready-built for about £90 (Figure 7). Failing that, a box with no base would suffice, or as a last resort the thermometer can be hung on a north-facing wall or fence, but stood off as far away from the wall as possible to allow air to circulate all around it.

Figure 7 A simple louvred thermometer screen (available as a kit or ready built) with maximum-minimum and wet and dry bulb thermometers inside, mounted on a post in a garden lawn.

Soil temperature
The temperature of the soil, at a depth of about 20 cm, can be measured easily with a relatively cheap soil thermometer, such as that shown in Figure 8, costing about £10. It should be read soon after it is removed from the ground, before the air has a chance to cool it down or warm it up. The range of soil temperature is much less than that of air temperature, both over the course of a day and through the year.

Figure 8: A soil thermometer, which is pushed into the ground so that the bulb is at a depth of 20cm.

Humidity
The air always contains water vapour and the amount present at any time is known as the humidity. The most commonly used measure of humidity is relative humidity (RH), which is defined as the amount of water vapour in the air as a percentage of that required to saturate it completely. Air has a relative humidity of 100% when it is saturated – for example during thick fog. Instruments which measure humidity are called hygrometers.

In the absence of any fronts, etc, relative humidity will generally be at its lowest value for the day when the air temperature is highest – around early afternoon – and at its highest when air temperature reaches its minimum – sometime before sunrise.

Many weather stations measure relative humidity with two thermometers known as a "wet bulb" and "dry bulb". The dry bulb is just an ordinary liquid-in-glass thermometer (as discussed in the earlier section). The wet bulb is an identical thermometer but has its bulb wetted continuously by a muslin sleeve (known as a wick) dipped in distilled water in a reservoir. Air passing over the wet bulb evaporates some of the water and cools it, by an amount that depends upon the humidity of the air. To demonstrate this cooling, wet your finger and blow on it. When the RH is 100%, the air is saturated so no more water vapour can be evaporated into it, and the two bulbs will read the same temperature. When the air is relatively dry, larger amounts of water will be evaporated, and the wet bulb will be cooled by a few degrees. The relative humidity can be found by noting the difference between the wet- and the dry- bulb and then looking up the RH value in a set of tables, so it's not a straightforward reading from a scale. This type of device, (properly called a Mason's hygrometer - Figure 9) can be purchased for about £20.

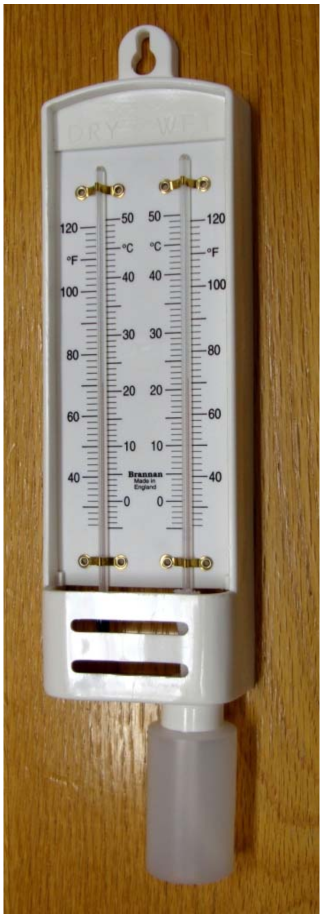

Figure 9: A typical wet-and-dry-bulb hygrometer. The wet bulb, on the right, is kept wet using distilled water in the white plastic reservoir underneath.

There is also a version, called a whirling psychrometer, in which the wet and dry bulb thermometers mounted together are whirled around like a football rattle before taking readings (Figure 10). This costs about £60.

Figure 10. This type of wet- and dry- bulb thermometer is known as a whirling psychrometer

RH can be read directly using a dial hygrometer. These use materials which change their dimensions as the RH changes, such as hair or paper which stretch when wet and shrink when dry. Hygrometers using hair can be very accurate, but also quite expensive. Paper hygrometers although less accurate, are only a few pounds, and will be good enough to show how RH varies through the day, for example (Figure 11).

Figure 11: Simple and cheap paper hygrometer, reading RH directly in percent.

Electronic humidity sensors with digital readout of relative humidity can often be found in a package accompanying a temperature sensor, with data from both transmitted wirelessly to an indoor readout. They are obviously more convenient to read, but will not be as accurate as, the wet-and dry-bulb hygrometer. A typical example, costing around £25, is shown at Figure 12.

Figure 12: Outside measurements of temperature and RH, from sensors at the end of a wire, are sent by the transmitter (white, right) to the indoor receiver and display unit (silver, left).

Rain and snow

Rain and snow, together with other forms of water falling from the sky such as hail and sleet, are collectively known as precipitation. Several different types of rain gauge are available fairly cheaply.

A simple conical-shaped open gauge (often called a "sprinkler" gauge, because it is used to measure how much water lawns get from a sprinkler hose) can be bought for a few pounds, but it has the disadvantage that some or all of the rainfall can evaporate before it is measured. To prevent this, professional rain gauges use a funnel to collect the rain and channel it into a collecting vessel underneath. A plastic version using this principle works well and is shown in Fig 13. The collecting cylinder is also used to measure the amount of rain – because it has a smaller diameter than the rain gauge funnel then the measuring scale will be exaggerated, so 1mm of rain may take up, say, 4mm on the measuring cylinder – this makes it easier to read. These are available for under £20.

Figure 13. A relatively cheap plastic rain gauge with funnel and measuring cylinder (which goes inside the rain gauge when in use)

Digital rain gauges
As with thermometers, digital remote-reading wireless rain gauges, such as that shown in Figure 14, are now reasonably priced, around £20. These use the tipping bucket principle, where rainfall collected by a funnel drips onto a simple collector, which tips every time (say) a millimeter of rain has fallen. Each tip is detected and transmitted wirelessly to an indoors display.


Figure 14. A tipping-bucket wireless rain gauge, with display which goes indoors.

Rain-gauges can be put anywhere more than 5 or 10 metres from buildings and fences, the more open the better. Digital wireless gauges can be put on a garage roof, for example.

Snow
In many parts of Britain, especially the south, lying snow is becoming less-and-less common, but when it happens, it is a big talking point. The depth can be measured quite easily with a simple ruler (without a ‘dead space’ at the end, of course), preferably in a place where the snow has not drifted in or out (Figure 15). Bringing a beaker full of snow indoors and melting it will show the large difference between snow depth and the corresponding amount of rainfall. 10cm of snow is equivalent to roughly 10mm of rainfall.

Figure 15. Depth of snow being measured with an ordinary ruler

Pressure
To see how different types of weather are associated with changes in atmospheric pressure, the simplest and cheapest device to use is the ordinary aneroid barometer, seen in hallways up and down the country. Unlike all the other weather observations, this one doesn't have to be made outside as the pressure inside and outside will be the same. Read the pressure in millibars (mb) rather than inches; more recently the official unit of pressure has been changed to the

hectopascal (hPa) – but it is identical to the millibar. The change in pressure over the last 3 hours – known as the tendency – is as important as the actual pressure itself; hence the use of terms such as "falling rapidly" or "rising slowly" in the Shipping Forecast. Figure 16 shows a clearly-marked instrument. They cost from about £18.

Figure 16. A simple, clearly-marked, barometer

How can I calibrate my barometer?
Atmospheric pressure is simply the weight of the column of air above your barometer, so this will depend on how high your house or school is above sea level. Lifting up the barometer by about 8 metres gives a decrease of about 1 mb (1hPa). You can calibrate your barometer, and adjust it to sea-level pressure at the same time, by looking at the pressure measured at the nearest official Met Office station. Met Office observations for UK stations can be seen at http://www.metoffice.gov.uk/weather/uk/observations/ Only do this on a calm day when the pressure will not be changing rapidly or varying much from place to place.

Wind

Wind is the horizontal movement of air. Its speed is measured with an anemometer, and its direction (the direction *from* which it blows) is shown by a wind vane. Wind speed is generally measured in units of knots (kt) (= 1 nautical mile per hour). The metric unit is metres per second (m/s) and, rather handily, 1m/s equals almost exactly 2 knots. Wind direction can be noted using the eight compass directions (north, north-east, east, etc) or in degrees from true north (so 090º is an easterly wind, 225º is a south-westerly, etc).

Simple anemometers
The simplest sort of anemometer is known as a Ventimeter (Figure 17) which is orientated into wind by the user. The wind blows into an orifice at the bottom of a tube and raises a plate (coloured red in the figure) up the tube, which is marked with a wind-speed scale. There is also a compass in the handle, so that wind direction can be read off. Unfortunately, these do not seem to be manufactured any more, although the Society has a stock of about 20 for loan to members.

Figure 17: A ventimeter for measuring windspeed and (with the compass in the handle) wind direction.

Cup anemometers

More accurate measurements can be made with a cup anemometer, where three cups are blown around by the wind and the rate at which they rotate is measured and converted into wind speed. With mechanical cup anemometers, such as the one shown in Fig 18, the wind speed is read by a pointer moving over a scale.

Fig 18: A mechanical cup anemometer, showing the scale and red pointer.

In the digital version, such as those shown in Figure 19, each costing around £80, the LCD display shows both the current wind speed and that averaged over the previous few tens of seconds.

Figure 19: Two makes of digital cup anemometers with LCD displays

Where should I try and measure the wind speed?
Wind speed and direction are strongly influenced by obstacles such as houses and trees, which create turbulence. Official measurements are made at a height of 10 metres above the ground and well away from any obstacles. This is unlikely to be possible for an amateur, but the more open the area from which the measurement is made, the more representative it will be of undisturbed flow. Wind speed increases as we get higher above the ground; a rough rule of thumb is that measurements made with a hand anemometer about 2m above the ground should be increased by a third to get the equivalent speed at 10m.

Wind socks
A simple way of judging wind direction is to use a flag or a wind-sock, which can open be mounted high up and therefore out of the way of some of the turbulence from buildings. A wind-sock has the advantage that some qualitative indication of the wind speed is given as well, by how straight or droopy the sock is. Figure 20 shows how a wind sock at an airfield looks in different wind strengths.

Figure 20. A wind sock on an airfield shows pilots wind strength and direction

If there are trees or other suitable indicators around, wind speed can also be estimated roughly by using the Beaufort Scale (given in most books on weather).

Visual observations

In addition to the observations described above, which all use instruments, we can also make visual observations, particularly of cloud and visibility.

Cloud amount (i.e. the proportion of sky covered by cloud) is conventionally measured in eighths, but this may be too detailed for everyday use. Using four states of sky is sufficient – for example, ‘clear’, ‘partly cloudy’ (i.e. less than half cloudy), ‘mainly cloudy’ and ‘completely cloudy’. You will not be surprised at how often it is completely cloudy and how seldom it is completely clear!

Cloud type can be as simple or as complicated as you want. There are ten basic types of cloud, and illustrations can be found in a number of books and on charts, such as the cloud chart sold by the Royal Meteorological Society.

Visibility is measured at an official weather station by reference to a number of known landmarks at 100m, 1km, 2km and 10km. If you can see beyond 10km then the visibility is described as "good"; below that it is "poor". When visibility is below 2km we have a mist, below 1km is fog and below 100m is thick fog – but note that different definitions are used at sea and in the Shipping Forecast.

Weather Stations

Anything that uses sensors outside (even just temperature), with a link to a digital readout inside, tends these days to be called a weather station. We prefer to reserve this term for a more comprehensive collection of sensors - at a very minimum temperature (which also will include maximum and minimum), humidity, rainfall and wind speed. Although these sensors can be connected by a cable to a display indoors, a wireless (radio) link is much more convenient, and usually has a range of 50m – sometimes much more.

Figure 21: A wireless weather station measuring temperature, humidity, rainfall, wind speed, wind direction and pressure, transmitted to an indoors display unit.

Once the preserve of the professional, or at least the rich amateur, recent advances in technology and production mean that simple (sometimes called "family" or "hobby") weather stations are well within the reach of most amateurs and schools. Even a station which displays the five main weather elements (those mentioned above plus pressure, for which the sensor is indoors in the display unit) can now be bought for about £50 – although the accuracy will be limited. In particular, the thermometer shield (often a miniature version of a Stevenson screen) is often not very good at preventing sunlight from warming up the temperature element, so in bright sunshine errors of a few degrees are possible. In addition to giving the basic measurements, quite often the display unit will also calculate quantities such as wind chill, dew point, etc. Sometimes it will also give a weather forecast, though based as it is on only local conditions, this must be taken with a big pinch of salt!

At the sort of prices quoted above it is not surprising that the manufacturer does not give details of accuracy, so this might be quite modest, although perfectly adequate for many applications in teaching or for the interested amateur. (Note that precision is often quoted, which is very different; for example, outdoor temperature might be displayed with a precision of 0.1°C whereas its accuracy may be no better than a degree or more). A professional automatic station reading the six main weather variables may well cost £500 or more, but you will get the benefits of a known accuracy for all the measurements, and probably higher reliability and longer lifetime.

There are many advantages to an automatic weather station. Weather observations can be made more quickly and conveniently, which might mean they can be taken four times a day in schools instead of just once. The sensors can be placed well out of the way and reduce the chances of vandalism - and in a better exposed location than would be possible with hand instruments. If the weather station is accompanied by a link to a PC, usually though the USB port, the data can be stored every hour or more frequently. This opens the door to using the data for all sorts of projects, from simple averaging ones to looking at correlations between different measurements such as wind direction and temperature - although of course manual observations could be entered into a PC and the same sort of projects undertaken.

The main disadvantage of an automatic weather station is that it removes the observer from the real elements being measured, and thus the experience of what -5ºC temperatures or 30 knot winds feel like, is lost. And actually seeing the liquid in a thermometer contracting in cold weather, or seeing the rainwater collected in the rain gauge clearly demonstrates the principle behind these measurements. There is also some satisfaction to be taken from having braved bitter winds or lashing rain to get the results!

The Royal Meteorological Society doesn't actually recommend specific weather stations or manufacturers, but some well known makes are Oregon Scientific, Kestrel, TechnoLine/LaCrosse, Irox and (at the more professional and flexible, and hence more expensive, end of the spectrum) Davis.

Where to buy weather instruments and weather stations

If you are at a school, a flick through the catalogues of educational suppliers will show that a good number of simple weather instruments are available ex-stock. Instruments can also be bought in garden centres (although they tend to be relatively expensive here) and over the counter in High Street shops. Instruments can be bought from several non-specialist sites on the web; they may be a bit cheaper but this way of purchasing doesn’t have the advantage of being able to see and hold before you buy. Specialist suppliers generally carry a wide range and will have the expertise to give advice on the pros and cons of particular types. The Royal Meteorological Society does not recommend specific suppliers, but here are some websites you might wish to have a look at:

www.weathershop.co.uk
www.r-p-r.co.uk
www.brannanshop.co.uk
www.westmeters.co.uk
www.metcheck.co.uk
www.maplin.co.uk

Once you have bought your instruments and started to take observations, you might want to record them using the Royal Meteorological Society's 3-year Weather Watcher's Log Book; see http://www.shop.rmets.org/product_info.php?products_id=101

Other useful websites

If you want to find out more about the instruments and methods used to make Met Office observations then a handy booklet from them is available on line at: http://www.metoffice.gov.uk/corporate/library/factsheets/factsheet17.pdf

If you want to compare your observations with ones made every hour by the Met Office, then go to this site: http://www.metoffice.gov.uk/weather/uk/observations/

If you want to compare with other amateurs, try some of the local schools "Grids for Learning", for example London http://weather.lgfl.org.uk/ or Lancashire http://www.lancsngfl.ac.uk/weather/current.php. There are many others on the web if you want to Google them. Don't be too surprised if some of the amateur observations look wrong; most amateurs do not have the time to keep checking their observations to make sure there aren't any errors.