SIMPLE WEATHER MEASUREMENTS

AT SCHOOL OR AT HOME

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INTRODUCTION

Making observations is an essential part of learning about the weather. This has been recognised by many teachers for years and is now enshrined in British National Curricula. In Geography Programmes of Study, for example, children aged 7 to 11 are required to undertake fieldwork and to carry out investigations that involve the use of instruments to make measurements. In the experimental and investigative parts of Science Programmes of Study, too, weather measurements help provide insight into concepts being taught.

This booklet looks at ways in which simple weather measurements can be made with a minimum of cost or fuss. It has been written primarily as guidance for schoolteachers, particularly those in junior and middle schools. Hence, there are many references to educational aspects and considerations. However, many of the ideas will also be of interest to amateurs thinking of setting up a weather station at home.

Suggestions are given as to suitable instruments and methods for taking crude 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. The readings taken with a simple weather station will still show the general behaviour of the atmosphere, and the act of making measurements, reading scales, plotting results, etc, will be no less valuable educationally than if expensive instruments were used.

So, if you have been dissuaded from making weather observations by the thought of asking the PTA for yet another £100, or if you are reluctant to ask someone to make you an ‘official’ Stevenson screen, then take heart; observations of the sort described in this booklet are cheap, cheerful and instructive. Please note, however, that 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 Meteorological Office as an official climatological observer, then this booklet is not for you.

Some of the instruments described in this booklet can also be used to carry out simple investigations. Another booklet by the same author (*Experimental Projects on Weather Topics*), also available from the Royal Meteorological Society, describes a selection of such investigations, although many of the experiments are intended mainly for teachers of students aged 14 or more. Hence, they require instruments that are somewhat more sophisticated.

TEMPERATURE

If you do not feel inclined to measure more than one weather 'element', then the temperature of the air is a good choice. Two sorts of cheap thermometer are readily available. The first is the usual liquid-in-glass-type, in which the liquid (mercury or spirit) in the bulb expands and rises up a capillary tube to a height that depends upon the temperature, which can be read off a graduated scale alongside. The second type incorporates a bimetallic strip that winds and unwinds as the temperature changes and makes a pointer move over a circular scale.

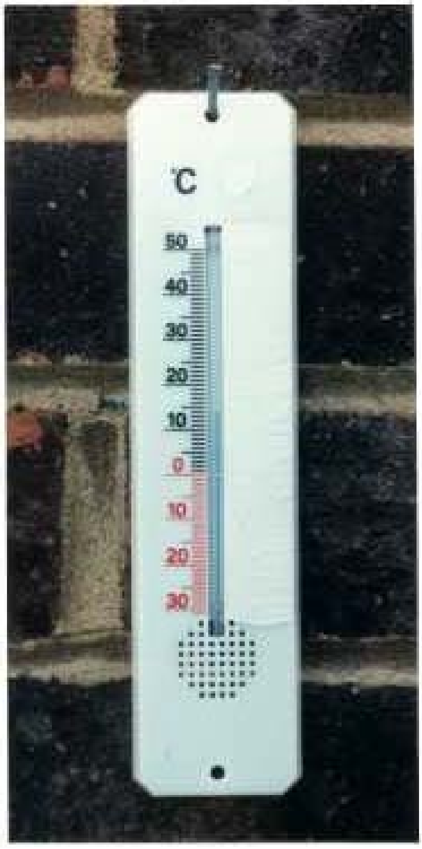

FIGURE 1
Ordinary spirit-in-glass thermometer

Both are acceptable, but the spirit-in-glass type is preferable. They are no more expensive than the bimetallic type and are usually more accurate. The scale should be as open and clear as possible, with graduations every whole degree and labels every ten degrees, as in Figure 1. The temperature scale should be in degrees Celsius only. It is a much more logical one than the Fahrenheit scale. Nought and 100 seem more natural to adopt as freezing and boiling points of water than 32 and 212, and the excursion below zero in winter (which rarely happens in the UK with the Fahrenheit scale) is a good introduction to negative numbers. The temperature should be read to the nearest whole degree at first. Half-degrees will later come naturally. Readings to a tenth of a degree are not necessary for keeping weather records, but may be useful for instructional purposes.

Where should the 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 crude screen – a white-painted box with no base, for instance, or even a short section of white PVC drainpipe (Figure 2). A reasonably sophisticated D-I-Y louvr-ed screen can be bought for about £30 (Figure 3, overleaf). If making a screen is too difficult, then hanging the thermometer on a north-facing wall is the alternative, making sure it is remote enough to be out of the way of 'unauthorised users'. The daily maximum temperature occurs at about 14:00 (use the 24-hour clock for recording all measurements). In winter, the temperature early in the school day (i.e. 09:00) won't be much different from the overnight minimum, so these are good times to take readings if you intend to make regular observations over a few weeks and plot a graph of the results.

◄ **FIGURE 2**
A white plastic drainpipe makes a good home-made thermometer screen

If you want to record true daily temperature extremes (and this is recommended), then a maximum and minimum (max-min) thermometer is called for. This will also, of course, serve as an ordinary thermometer. Again, there are two types: liquid-in-glass and bimetallic. The maximum and minimum pointers of the bimetallic dial type are easier to read, but the liquid-in-glass type (proper name: *Six's thermometer*) is easier to obtain. In the latter type, a mercury column is pushed around by the expansion of spirit and leaves behind little markers ('indices') to show the maximum and minimum temperatures. Readings can be taken at any time and the indices reset afterwards, either magnetically or by tilting. Both types of max-min thermometer cost around £10. Figure 4 shows a good example of the bimetallic type. The max-min thermometer should be exposed as for the ordinary thermometer.

FIGURE 3
This simple louvred thermometer screen is available as a kit

FIGURE 4
An easy-to-read maximum-minimum bimetallic thermometer

The temperature of the soil, at a depth of about 10 cm, can be measured easily with a relatively cheap soil thermometer. The range of soil temperature is much less than that of air temperature, both over the course of a day and through the year, and the maximum and minimum will occur at different times to those in the air.

A number of relatively inexpensive digital thermometers are now becoming easily available. Many have the temperature probe on a lead a few metres long, enabling the display to be inside the classroom or house. Some varieties will store the maximum and minimum temperature since last reset. The probe can also be used to measure soil temperature and, for example, the temperature of a stream or pond.

RAIN AND SNOW

Just about anything can be used to collect rainfall, even old tin cans (with no sharp edges). The amount of rain collected can be measured simply by dipping something into the water and measuring what depth of it is wetted – in millimetres. Whilst this is very simple (and free), there is one disadvantage that can be overcome by using a slightly more sophisticated design. Depths of a millimetre or two (typical of a day's rainfall) are difficult to measure, so, by using a water storage container with a collecting funnel of larger diameter, the depth of water collected will be correspondingly increased. For example, a 75 cm^2 funnel (about 5 cm radius) feeding a 12 cm^2 container (about 2 cm radius) will give about 6 mm depth of water for every 1 mm of rain.[1]

A plastic funnel stuck into the top of a small fizzy drinks bottle will do the trick.. Better still: bury a largish tin can 10 cm or so into the ground and put the bottle into this with the collecting funnel sticking out of the top.

Many different types of rain-gauge are available fairly cheaply. A simple conical-shaped combined collector/measure can be bought for three or four pounds (Figure 5). The only disadvantage with these open rain gauges is that some of the rainfall can evaporate before it is measured. Even better will be a purpose-built rain-gauge, available for about £15 complete with measuring cylinder (Figure 6). If funds (about £50) are available, a digital rain-gauge might be worth considering, in which every millimetre of rainfall is clocked up on the display. As with the digital thermometer, the rainfall collector can be several

FIGURE 5
A simple plastic rain-gauge

FIGURE 6
A cheap plastic rain-gauge
with funnel and measuring cylinder

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[1] This may provide a useful introduction to areas and volumes, or it may be just an unnecessary complication, depending on the age of the pupils.

metres or more from the display. Rain-gauges can be put anywhere more than 5 or 10 metres from buildings, the more open the better.

In many parts of Britain, especially the south, there are very few days when the snow lays more than a few millimetres deep. When it does, though, it is a big talking point. The depth can be measured quite easily with a simple ruler (without a 'dead space' on the end, of course), preferably in a place where the snow has not drifted in or out. Bringing, say, a beaker full of snow indoors and melting it will show the large difference between snow depth and the corresponding amount of rainfall.

PRESSURE

Books on D-I-Y weather instruments often show barometers made from jam jars with rubber balloons stretched over them. The expansion and contraction of the air as the pressure changes makes a pointer move over a paper scale. The trouble with this device is that the air in the jar also expands and contracts when its temperature changes, and this may give a bigger effect than that due to the pressure changes.

For a reasonable long-term record of pressure, the simplest and cheapest device is the ordinary aneroid barometer often seen on hallway units. They cost from about £10. Again, to avoid the confusion of two units of measurement, stick to millibars only. The inches scale can be painted out if necessary. To complicate matters further, the official unit of pressure is now the hectopascal (hPa), identical in value to a millibar, but millibars will be around for a long while yet. Figure 7 shows a clearly-marked instrument.

FIGURE 7
A simple, clearly-marked, 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. You can calibrate your barometer, and adjust it to sea-level pressure at the same time, by ringing up the nearest *Weathercall* service just after midday (when updating of the service occurs), preferably on a clear and calm day when the pressure will not be changing rapidly or varying much from place to place.

Pressure is a difficult concept to convey to children and is not an element that we can relate directly to our sensations – unlike, say, temperature. Nevertheless, the different pressure regimes do have different types of weather associated with them. Accordingly, measurement of barometric pressure is worthwhile.

HUMIDITY

Humidity is a measure of the amount of water vapour present in the air. Relative humidity (RH) is the amount as a percentage of that required to saturate the air completely. These are difficult concepts to explain to children, but by making simple measurements we can get across the message that there is water vapour in the air at all times. This may lead on naturally to a discussion of the water cycle, clouds and rain.

'Proper' weather stations use two thermometers, one an ordinary thermometer, the other a thermometer with its bulb wetted continuously by a muslin sleeve dipped in a water reservoir. Air passing over this 'wet bulb' evaporates some water and lowers the wet-bulb temperature by an amount that depends upon the humidity of the air. To demonstrate this cooling, wet your finger and blow on it. 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. This type of device, called a Mason's hygrometer (Figure 8) can be purchased for about £12. There is also a version, called a whirling psychrometer, which is whirled around like a football rattle before taking readings (Figure 9). This costs about £40.

FIGURE 8
Humidity is measured most accurately with a wet- and dry- bulb thermometer

FIGURE 9
This type of wet- and dry- bulb thermometer is known as a whirling psychrometer

All in all, there is a lot to be said for the simple dial humidity gauge, costing only £3-4 and reading RH directly. It will not be as accurate as the wet- and dry- bulb device, but the strip of paper which it uses responds well to changes in moisture and readily shows the way the relative humidity varies during the day. Most dials are clearly marked in percentage relative humidity. Figure 10 shows a good example. It is a good idea to wrap it in a damp cloth for a while and then set the dial to read 100%.

Like paper, human hair stretches when moist and shrinks when dry. Humidity recorders use this principle, and weather books often show how it can be used to construct a simple hygrometer in the classroom.

FIGURE 10
A simple paper hygrometer

WIND

The direction from which the wind blows can be estimated relatively easily by looking at smoke from chimneys or at flags or church weather-vanes. Alternatively, you can try to make your own weather-vane and put it up as high as possible. Several elementary books on weather give constructional details. Figure 11 shows a vane made with a piece of plastic cut out and mounted on a large gate hinge as a bearing. It is sensitive enough to respond to light breezes, yet robust enough to withstand strong gales. To find the wind direction, we obviously need to use a compass to orient ourselves. North should then be marked permanently. A nail is used on the upright of the vane shown in Figure 11.

FIGURE 11
A simple home-made weather-vane

If the school has a flag-pole, then a simple flag is all that is needed. Better still will be a wind-sock, quite easily made from nylon. A wind-sock has the advantage that some indication of the wind speed is given as well, by how straight or droopy the sock is. Figure 12 shows how a wind sock at an airfield looks in different wind strengths.

FIGURE 12
A wind-sock on an airfield shows pilots wind strength and direction

If there are trees or other suitable indicators around, wind speed can be estimated roughly by using the Beaufort Scale (given in most books on weather). Measuring it quantitatively is rather more difficult, as the exposure of any measuring device has to be correct. Near buildings, eddies cause anemometers to behave peculiarly – stopping and starting quickly – and this is unsatisfactory, even for a crude weather station. However, sensible measurements are certainly possible if your anemometer can be raised above building height or placed a good distance away from buildings.

Again, constructional details for a three-cup anemometer will be found in many books. The simplest method of making measurements is to count the number of times the cups go round in a fixed period (say, 20 seconds). This is made easier by painting one of the cups a contrasting colour. Another sort of anemometer commonly described is the one with a flap that is deflected upwards by an amount which depends on the wind strength. It is probably slightly easier to construct than the cup-type, and it can be calibrated using a borrowed anemometer.

The cheapest sort of commercial anemometer is known as a ventimeter, in which the wind blows into an orifice at the bottom of a tube and raises a plate up the tube. These devices cost about £12 each. The tube is marked with a wind-speed scale, as shown in Figure 13, and there is a compass in the base, so that wind direction can be read off when the orifice points into wind. Figure 14 shows a similar simple device, with a ball in a tube to indicate wind speed. This is a Dwyer wind-meter, which costs about £25. It has the advantage of a lower starting speed than the ventimeter, but it does not have a compass built in. It is also relatively easy to take to bits (but the bits are easily lost).

FIGURE 13 ►
The ventimeter can measure wind speed and indicate wind direction

◄ FIGURE 14
The Dwyer wind-meter has a low starting speed

FIGURE 15 ►
A simple, but accurate, cup anemometer

More-accurate hand-held anemometers of the cup-type are commercially available but costly – at least £80. Figure 15 shows a good, but expensive, one that measures wind speed over 10 seconds and then displays it on a digital display for long enough to note it. Given the poor exposure which is typically available for hand-held measurements, it is doubtful that the expense of an accurate anemometer like this is justified for everyday use.

SUNSHINE

You may have seen – at holiday resorts, for example – a device used for measuring the number of hours of sunshine in a day. One type that may be seen consists of a glass sphere (similar to the crystal ball beloved of fortune tellers). Called a Campbell-Stokes sunshine recorder, this focuses light from the sun onto a piece of card, on which, if the sun is bright enough, a burnt trace is left (Figure 16).

FIGURE 16
Card from a Campbell-Stokes sunshine recorder
showing the burnt trace caused by the focusing of sunlight onto the card.

An alternative, cheaper (and easier-to-use) type of instrument (known as a Jordan sunshine recorder) uses a closed can with a pinhole on one side to let sunlight in. On the inside of the can, there is a sheet of light-sensitive paper that darkens when the sun shines. These recorders are available commercially at a price of about £50, but a home-made one can be very successful. Any kind of tin can be used, so long as it has a lid; a cocoa tin is ideal. Drill a small hole (of about half a millimetre diameter) in the lid and leave the can out in the sun with the hole pointing upwards. For better results, drill a hole in the side and mount it so that the hole can be pointed roughly at where the sun will be at midday. Figure 17 shows one sort of device, hinged on a base to cope with the sun's position through the year at a range of elevations.

FIGURE 17
A simple home-made Jordan sunshine recorder

A sheet of photographic paper wrapped around the inside of the tin will clearly record the sun's movement across the sky. Calculating the number of sunshine hours involves complicated geometry, but a glance at the trace will allow you to describe the day in simple terms such as 'sunny', 'mainly cloudy', 'overcast in the morning, clearing in the afternoon', etc. The paper darkens when taken out of the can and must not be developed, as it then turns black all over. A permanent record can be made with a photocopier, but only once or twice, because this, too, darkens the paper.

VISUAL OBSERVATIONS

In addition to the observations described above, which all use instruments, we can also make visual observations. The most obvious ones are of cloud and visibility. Cloud amount (i.e. the proportion of sky covered by cloud) is conventionally measured in eighths, but this is 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. As this chart is laminated, it can be used out of doors in all weathers. Should you not wish to use the official Latin names for the clouds, you can describe clouds simply as 'high', 'low', 'layer-type', 'bubbly', etc.

Visibility is measured at an official weather station by reference to a number of known landmarks at different distances. Again, this is probably too complicated, but three or four landmarks at, say, 100 m, 1000 m, 2 km and 10 km will allow the visibility to be described as 'thick fog', 'fog', 'poor visibility' and 'good visibility', respectively. By definition, fog is present if the visibility is less than 1 km.

Automatic Weather Stations

An automatic weather station usually consists of a number of outdoor weather sensors which communicate with an LCD display unit indoors, which can in turn often be linked into a PC to store and display data. 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. The price will depend upon how many weather elements are measured; for example, just outdoor temperature (including maximum and minimum) might be around £15, just rainfall around £30, temperature and humidity around £40. Even a station which displays the six main weather elements (temperature, humidity, wind speed and direction, rainfall and pressure), can now be bought for about £100. 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!

The link between the instruments outdoors and the display inside may well be by wireless, removing the need to feed a wire into the house or school, although the range will be 100m at best, and often well below this. 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 0.1degC whereas its accuracy may be no better than a degree or more). A professional automatic station reading six elements 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 the case of wind measurements, for example) in a better exposed location than would be possible with hand instruments. If a PC link is available 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 readings 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 minus 5degC temperatures or 30 knot winds feel like, is lost. And actually seeing the liquid in a thermometer contracting in cold weather, or pouring rain from a collector to a smaller-diameter measuring cylinder, for example, naturally leads to discussion of these topics and the maths and physics behind them. There is also some satisfaction in having braved bitter winds or lashing rain to get the results!

The RMetS doesn't actually recommend specific instruments or manufacturers, but some well known makes are Oregon Scientific, TechnoLine/LaCrosse, Irox and (at the more professional end) Davis.

CONCLUSION

The measurements and observations outlined in this booklet can form the basis of many interesting constructional and experimental projects and are probably the only ones that can be made without taking on a lot more work and/or expense. Measurements of the more-esoteric weather elements are of limited value in teaching anyway.

Although it is fun to make your own instruments (and thus highlight principles of operation), home-made devices are rarely robust enough to stand up well to continuous outdoor use. For making measurements over a long period, simple commercial instruments are worth the additional expense.

A flick through the catalogues of educational suppliers will show that a good number of simple weather instruments are available ex-stock – and instruments can also be bought in garden centres and over the counter in High Street shops. Simple instruments are advertised, too, in the Christmas catalogues of charities.