MetLink
Royal Meteorological Society

Weather Measurements

Background Information for Teachers

Making Weather Measurements

This video guide to simple weather measurements https://youtu.be/EpIhimNpbr8 gives an overview of this chapter.

Weather measurements can be included in simple, cheap and engaging fieldwork in any location, even if it's just outside in the school grounds, which should make the weather both relevant and interesting.

Weather data is also a useful addition to many investigations – the weather can affect both physical processes and human ones. Are the responses people give to surveys affected by the weather? How does this extend to other forms of behaviour – how people travel, what activities they choose to do? What impact do microclimates have on land use – and vice versa?

Weather data can be obtained directly (primary sources) using instruments – which may be simple (homemade or cheaply available) or highly precise, professional instruments. Alternatively, much weather data is now available on the web (secondary sources).

Professionally, weather data is now collected by automated weather stations, which digitally record and transmit the measurements they are making.

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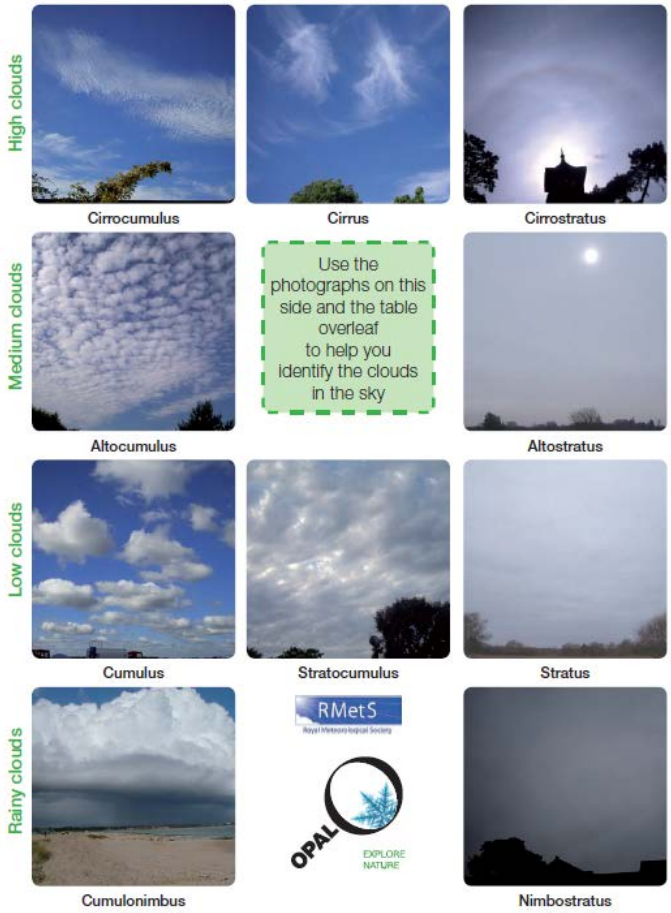
Cloud

Observing the cloud type and amount is a useful way of assessing what is going on in the atmosphere.



If the sky is clear, does that imply High Pressure (chapter 16) or a Tropical Continental air mass (chapter 7)?

If there are cumulus clouds, then there is convection (warm air rising) occurring. Is this because there is a Polar air mass (chapter 7)?

If there are cirrus clouds, is there a warm front on its way (chapter 17)?

If there is stratus cloud, does that imply a Tropical maritime air mass (chapter 7), a warm front (chapter 17) or maybe anticyclonic gloom (chapter 16)?

A cumulonimbus cloud could indicate a cold front (chapter 17) or just a summer thunderstorm (chapter 7).

Cloud amount is traditionally reported in oktas – how many eighths of the sky is covered in cloud. Complete cloud cover is reported as 8 oktas, half cover as 4 oktas and a completely clear sky as zero oktas. If there is low-lying mist or fog, the observer will report sky obscured.

Wind Speed and Direction

With anemometers, you generally get what you pay for. **Cup anemometers** (left) are best because they work whatever direction the wind is coming from. However, they can be expensive and are very delicate. **Propeller anemometers** (right) can be much cheaper. However, the propeller has to be pointed into the wind to get a good reading; the wind direction can be hard to judge when the wind is weak or gusty.

Smartphone anemometers can also be either cup-type or propeller-type. Using the smartphone compass, propeller type anemometers can also give wind direction. Some smartphone anemometers struggle to record low wind speeds.

Bubbles are a simple, cheap (and fun) alternative – mark out 5 paces in the direction the bubbles are travelling (roughly 5m) and record the length of time it takes the bubbles to travel that far. The most accurate estimate of wind speed will be obtained if the time is measured several times, and if the same person is used to mark out 5 paces every time the method is used. In conjunction with a compass (traditional or smart phone) the wind direction can also be recorded, by following a series of bubbles and then measuring the bearing back to your starting point – as wind direction is the direction the wind has blown ***from***. Alternatively, draw a chalk compass on the ground and use this to see where the bubbles are blowing to and therefore from.

There are many other ways of making simple wind vanes to determine wind direction.

Wind speed will vary with height from the ground. Measurements should therefore always be made at the same height – for example as high as you can reach. Measurements made with a hand-held anemometer about 2m above the ground should be increased by a third to get the equivalent speed at 10m.

Buildings, vegetation etc. will have an impact on wind speed and direction and so will have an impact on the microclimate around them. Unless you are specifically looking at the impact of the environment on the wind, then wind speed and direction should be measured away from buildings and vegetation.

In addition, the **Beaufort Scale** can be used to estimate wind speed. Different versions exist for use over land and over sea.

Temperature

Digital thermometers are available in many forms and can be very cheap, costing just a few pounds. They are frequently incorporated within other devices (such as phones or watches). However, the same basic points remain true of all but the most expensive thermometers:

- Be careful not to touch the probe whilst using the device (where the thermometer has a probe) or to block the air inlet to the thermometer in instruments without a probe – this is usually a very small hole in the plastic casing.
- Most digital thermometers have an accuracy of +/-3°C. This means that, although you can easily compare measurements made by the same device in different places, to compare measurements made by different thermometers you will need to compare them with each other before you start. To do this, leave them in a dark, enclosed space overnight and record the difference in the temperature they show. Subsequently, you'll need to use that difference to adjust any readings made.
- Digital thermometers will take a while to adjust to new temperatures. You should really allow a minute per degree of temperature change – so a thermometer being taken outside on a cold day from a heated room will take at least 10 minutes to give an accurate temperature reading.
- All thermometers should be shielded from direct sunlight. Traditionally this has been done using a Stevenson Screen, which allows air to flow around the thermometer whilst reflecting much of the sun's light. Placing the thermometer in a shaded place is a good start, away from any walls.
- The temperature at the ground will be different from the temperature a metre or so above the ground – be consistent about the level you use.

Car thermometers can be very useful, particularly when looking at urban temperature patterns. The thermometer is usually located within the wheel arch and so the car should be moving for at least 5 minutes before the temperature is recorded to ensure that the air trapped while the car was parked has been replaced.

Infra-red thermometers are an affordable, robust and easy-to-use option which allow you to record small scale variations in temperature as well as the temperature of distant objects, such as clouds. IR thermometers show the temperature of an object by measuring the heat from it; it doesn't matter how close or far away it is, as long as it fills the field of view. Typically, this means that an object 10m from the thermometer needs to be 1m big to be able to measure its temperature. An object 10km away needs to be 1km

big. To measure air temperature using an IR thermometer, hold a piece of white paper in the air for a few minutes to allow it to adjust to the local temperature, then use the thermometer to measure the temperature of the paper.

USB dataloggers allow data to be collected over a few days for microclimate studies. They contain a sensor (of temperature and humidity for example), processing electronics and a logger with memory that can store many thousands of readings. They are left to record for days or weeks, then plugged into a PC USB port, and the data downloaded usually as an Excel spreadsheet and a graph. They can be weatherproofed using small waterproof containers, allowing them to be left outside for lengthy periods of time.

Pressure

Pressure is a relatively easy weather element to record, as there are no small-scale variations. The pressure recorded inside a building will be the same as the pressure recorded outside. Many simple instruments, such as indoor thermometers and watches, now report pressure. Gadgets which display a simple weather forecast (usually a sun or rainfall symbol) make these forecasts based on pressure changes, equating a falling pressure with a likelihood of rain (see Chapter 9). The **phyphox app** allows phones to be used as pressure logging devices.

Although it is possible to make a barometer, either with **liquid in a tube** or a simple **aneroid** type barometer, such instruments invariably respond to temperature changes as well as pressure changes.

So that pressure at different weather stations can be used to draw up a weather map, atmospheric pressure is always quoted as what it would be at mean sea level. Pressure increases/decreases by roughly 1hPa per 10 m decrease / increase in height respectively, although the actual value of the correction to mean sea level will vary with both air temperature and barometric pressure. To accurately set a barometer, you'll need to calibrate it to a local Met Office weather station on a calm day– this will already have been corrected to sea level. Subsequently, you can use your barometer either to record changes in atmospheric pressure (if you leave the barometer in the same place) or changes in altitude (if you carry it up a mountain at a time when the atmospheric pressure isn't changing much). Even simple barometers will record a change in pressure if you move them from the ground to the top floor of a school building.

Because pressure does not tend to have small scale variations, it is the easiest data to obtain from a secondary source close to your area of study. The pressure a few tens of km away will be very similar to the pressure at your area of study on a calm day, because there will only be small differences in pressure across a wide area.

Humidity

Traditionally, humidity was recorded using wet and dry bulb glass thermometers, but these are fragile, cumbersome and tables are needed to calculate humidity. A cheaper

and more practical solution is to use a digital hygrometer – these mainly come with thermometers as well.

Rainfall

Rainfall is easy to measure using simple, cheap manual rain gauges such as that shown above. The rainfall amount should be recorded at the same time each day, and then emptied. To avoid the gauge being blown over by the wind, it should either be placed in a slight hole in the ground, or partially buried in a flowerpot or similar.

It is also possible to make a rain gauge using a large fizzy drink bottle. Cut off the top 10cm or so of the bottle, invert it and push it back into the remaining bottle. The most accurate way to use such a gauge is in conjunction with a measuring cylinder – pour any water into the cylinder on a daily basis. You'll need to account for the aperture of the bottle to convert the ml collected into mm of rainfall.

Automatic, wired or wireless, rain gauges can be purchased, either on their own or as part of a weather station (see below). These work with a tipping bucket – counting the number of times a small bucket (typically holding 0.2mm of rainfall) fills and tips.

If possible, rain gauges should be placed in a well exposed position, away from any walls or trees.

All rain gauges should be checked for slugs, spiders' webs, leaves and other debris on a regular basis.

Complete Weather Stations

A complete wireless electronic weather station can be used to measure pressure, temperature, wind speed/direction, humidity and rainfall. The measuring instruments, typically mounted on a pole attached to an outbuilding, transmit data to an inside display unit. The data can be downloaded continuously or in batches. Such weather stations are best used in one location, showing changes over time.

Cheaper automatic weather stations measure many of the same variables as their more expensive counterparts but do not, generally, record information or allow you to upload it to a computer. They usually also suffer from inadequate thermometer shielding, so will overestimate temperatures when the sun is shining onto the station. They also tend to underestimate rainfall, particularly during heavy rainfall events.

The location of automatic weather stations is often a compromise between exposure, access and security. A wall-mounted station won't make measurements which are as accurate as a station which is located in an open space.

Hand-held automatic weather stations record the same range of variables as their larger counterparts (except rainfall), with the benefit of being more portable, allowing them to be

used in a variety of locations. For accurate wind speed and direction, they should be used in conjunction with a tripod and wind vane. Some models allow data to be downloaded to a computer. Before use, the pressure should be calibrated (see above).

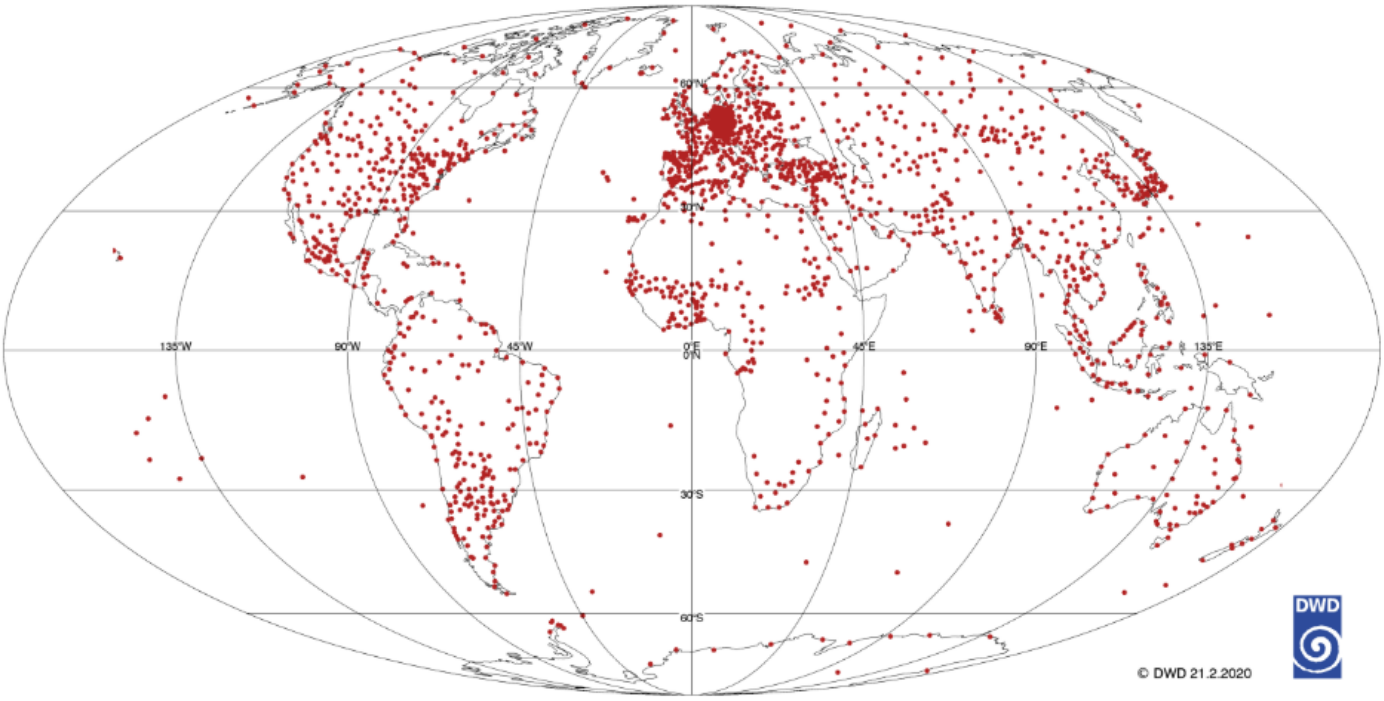
A newer development is the availability of an (almost) complete weather station that plugs into a smartphone. These can measure and log temperature, humidity, windspeed and pressure, although (perhaps not surprisingly) not rainfall. The accuracy of such devices is relatively untested.

Past Climate Change

In order to understand how the climate has changed in the past, we need weather measurements from the time before most of these instruments existed. For these purposes, we have to use climate proxies, such as the information stored in ice cores or bogs, tree rings and shells.

Further information: https://www.ncdc.noaa.gov/news/what-are-proxy-data , https://www.metlink.org/wp-content/uploads/2018/05/Advanced-Guide-to-Calibration-and-Natural-Climate-Proxies.pdf

Most countries have networks of weather stations, although there is significant variation in the network density. Some countries maintain stations in remote areas such as Antarctica.



Stationen für Globalkarte der Temperaturanomalien
Zahl der verarbeiteten CLIMAT-Stationen: 1879
Januar 2020

Stations for Global Map of Temperature Anomalies
Number of processed CLIMAT Stations: 1879
January 2020

Sources of Information

A video guide to simple weather measurements https://youtu.be/EpIhimNpbr8

Setting up a school weather station https://www.metlink.org/observations-and-data/weather-stations/

You can download a cloud wheel to help with cloud identification here https://www.metlink.org/teachers/cloudwheel-cutout/