MetLink
Royal Meteorological Society

Pressure and Wind

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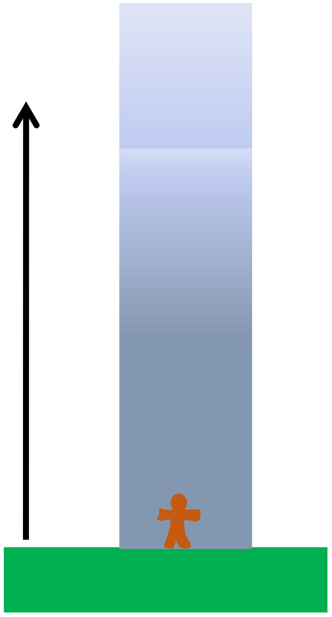
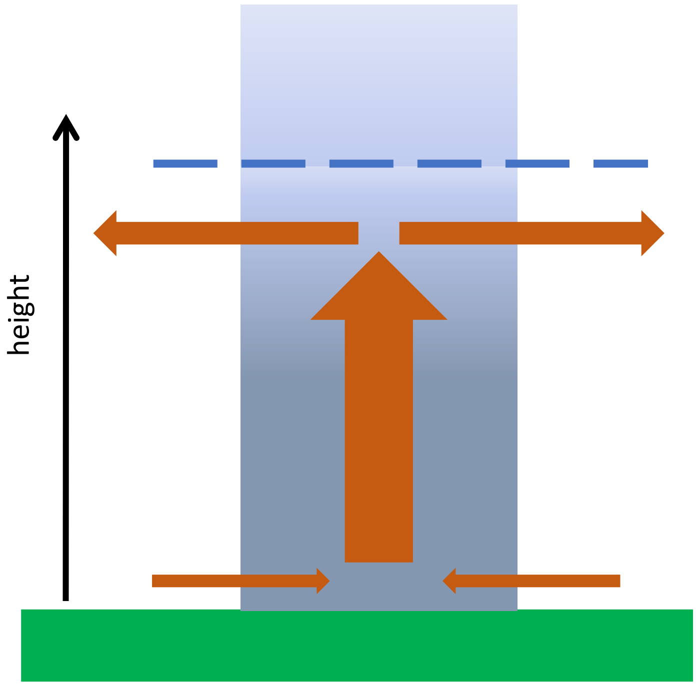
Under Pressure

Air pressure is simply a measure of how much air is above our head at a given time. It is measured in hPa (hectoPascals) or mbar (millibars) – these are equivalent i.e. 1hPa = 1 mbar. Lines of equal pressure are Isobars.

Winds are named by the direction they are blowing **from** and tend to follow the isobars. In general, atmospheric pressure values are higher in the summer than in the winter, but usually vary between 950hPa and 1050hPa. A local pressure is labelled as ‘High’ if it is higher than the surrounding pressure; a local pressure is labelled as ‘Low’ if it is lower than the surrounding pressure. There is no absolute value (e.g. 1000hPa) which differentiates between the two.



If the pressure is less, it simply means that there is less air in the column above our head. In the figure above, the shading indicates the pressure falling with height – if you were to go up in a balloon, there would be less air left above your head and so the pressure is lower.



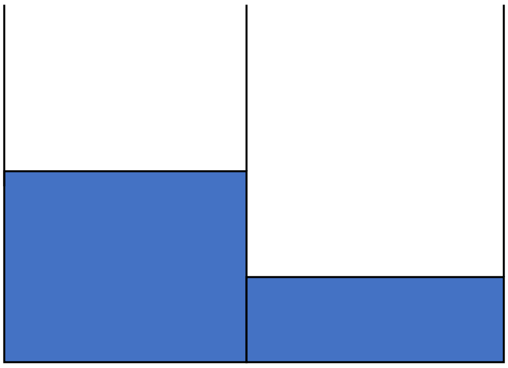
There are various places in the Earth's atmosphere where the air is rising – larger scale areas associated with the Hadley cells, or smaller scale areas associated with low pressure weather systems (depressions and tropical cyclones), or really small scale areas associated with localised convection (e.g. summer thunderstorms).

The tropopause acts as a lid to vertical motion, so the air spreads out horizontally or diverges at this level.

Near the surface, air converges into the column to replace the air being lost through rising motion. However, this converging air is slowed down by friction at the ground.

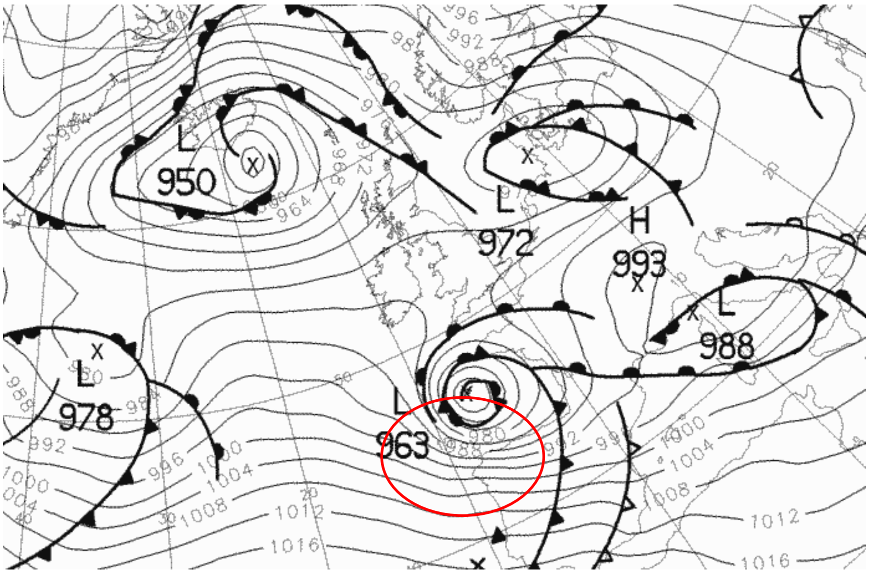
If more air diverges than converges, we end up with less air in the column and the air pressure falls.

This means that we end up with some places where there is less air – low pressure, and other places where the pressure is higher. This is a bit like having two buckets of water:



If one bucket has more water in than the other, then if the barrier between the two is removed, the water will rapidly flow to even out the water level. The higher pressure in the bucket with more water pushes the surplus water to the bucket with lower water pressure.

Exactly the same happens with air – if the pressure is higher in one place than another, then the air will be pushed to where the pressure is lower. Wind. The bigger the pressure difference, the faster the wind blows or the closer the pressure contours are to each other, the faster the wind. The absolute value of pressure in the centre of the depression is less important than the difference in pressure between the centre and the edge of the system. This can be seen on a weather map:



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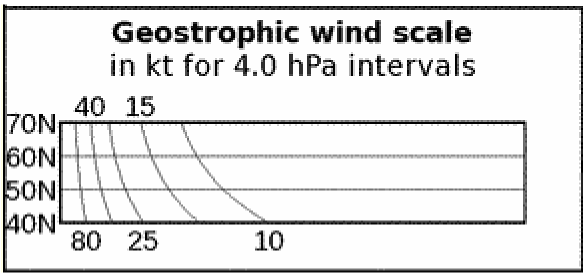
Where the isobars are closest together, for example in the area circled in red, indicating a bigger difference in pressure over a given distance, the wind speed will be fastest.
Very roughly, you can approximate the wind speed by counting the isobars crossing the UK and multiplying by 5km/hr to give the surface wind speed. More accurately, you can use the geostrophic wind scale given at the top of the map:



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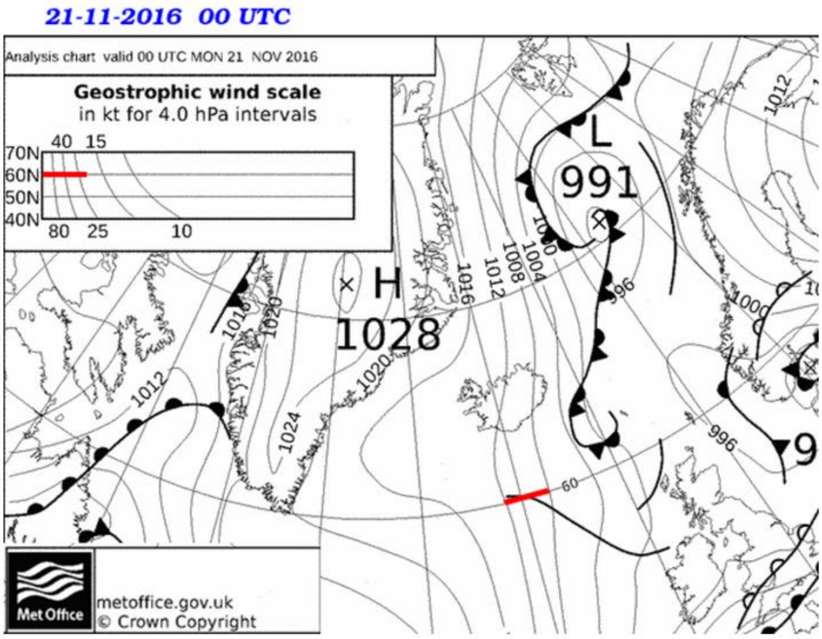
To find the wind speed at a given place, first of all see what latitude you are at – the curved lines of latitude are labelled, at 10° intervals. Then, measure the shortest distance between the contours at that place. In the example shown below, at 60° North, the distance is shown in red.

Now, measure the same distance from the left-hand side of the scale, at the appropriate latitude. Again, this is shown in red in the example below. You can then use the curved lines to read the wind speed – in the example, the same length red line takes you to somewhere between the 15 and 25 knot lines, so the wind speed at the marked place is about 20 knots (1kt =0.5 m/s or 1.2mph).



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The actual wind speed at the ground will always be less than the geostrophic wind speed because of friction. Friction will slow the wind more over land than over water. Rules of thumb suggest that the wind will be 2/3 of the geostrophic speed over water and 1/3 over land, but it will vary considerably.

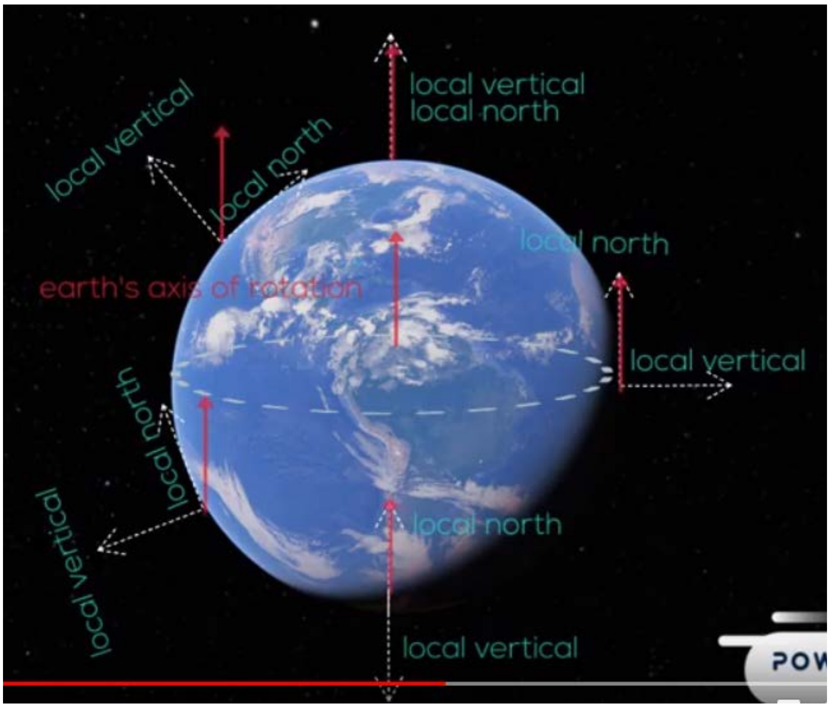
However, we live on a rotating, spherical planet. So, we also need to take **the Coriolis effect or force**, created by the rotation of the Earth, into account.

At the simplest level, the Coriolis effect deflects everything moving in the Northern Hemisphere to the right of its direction of motion, and everything in the Southern Hemisphere to the left.
Put another way "in the Northern Hemisphere, if you stand with your back to the wind then the lower pressure will be on your left".

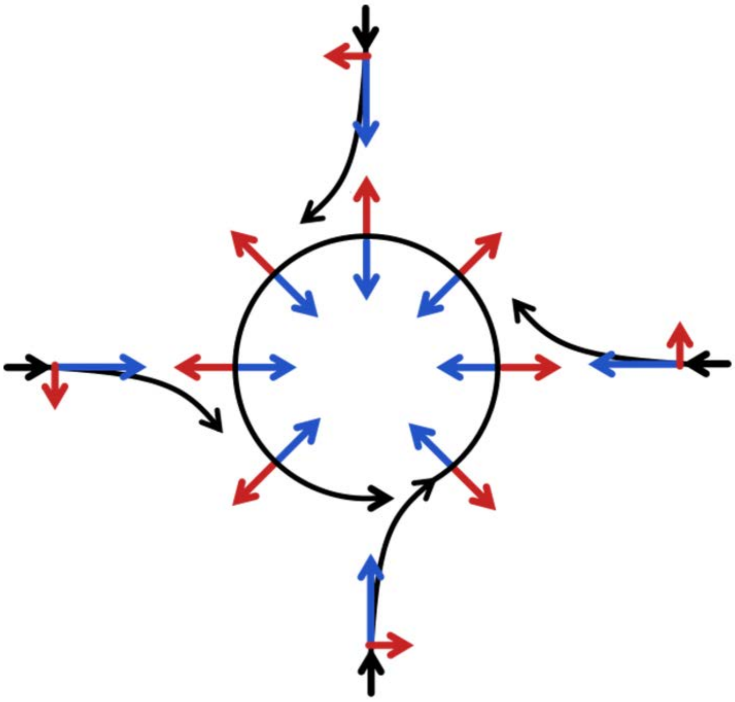
Think about a person standing at the Equator. In the course of a day, the planet rotates once, meaning that you travel a colossal 2π x R (the radius of the Earth – around 6370km) = 40,000km through space – a speed of about 1700km/ hr. You don't notice that you are travelling so fast, because the air around you is travelling at the same speed, so there is no wind. On the other hand, if you are standing at a Pole, all you do in the course of a day is turn around on the spot, you have no speed through space and similarly the air around you is stationary.

Now, think about really fast moving, Tropical air which is being pulled towards the poles by a pressure gradient. As it travels polewards, it moves over ground which is rotating more slowly, and so it overtakes the ground, and looks like it is moving from west to east. Similarly, slow moving polar air will be left behind by the rotating Earth and look like it is moving from east to west if it is pulled equatorward by a pressure difference.

It turns out that whichever direction the air is moving in, it is diverted by the Coriolis Effect. It is simply the result of observing the atmosphere from the surface of a rotating, spherical planet. The Earth's axis of rotation is in the same direction as the local vertical at the North Pole, but at 90° to it at the Equator.



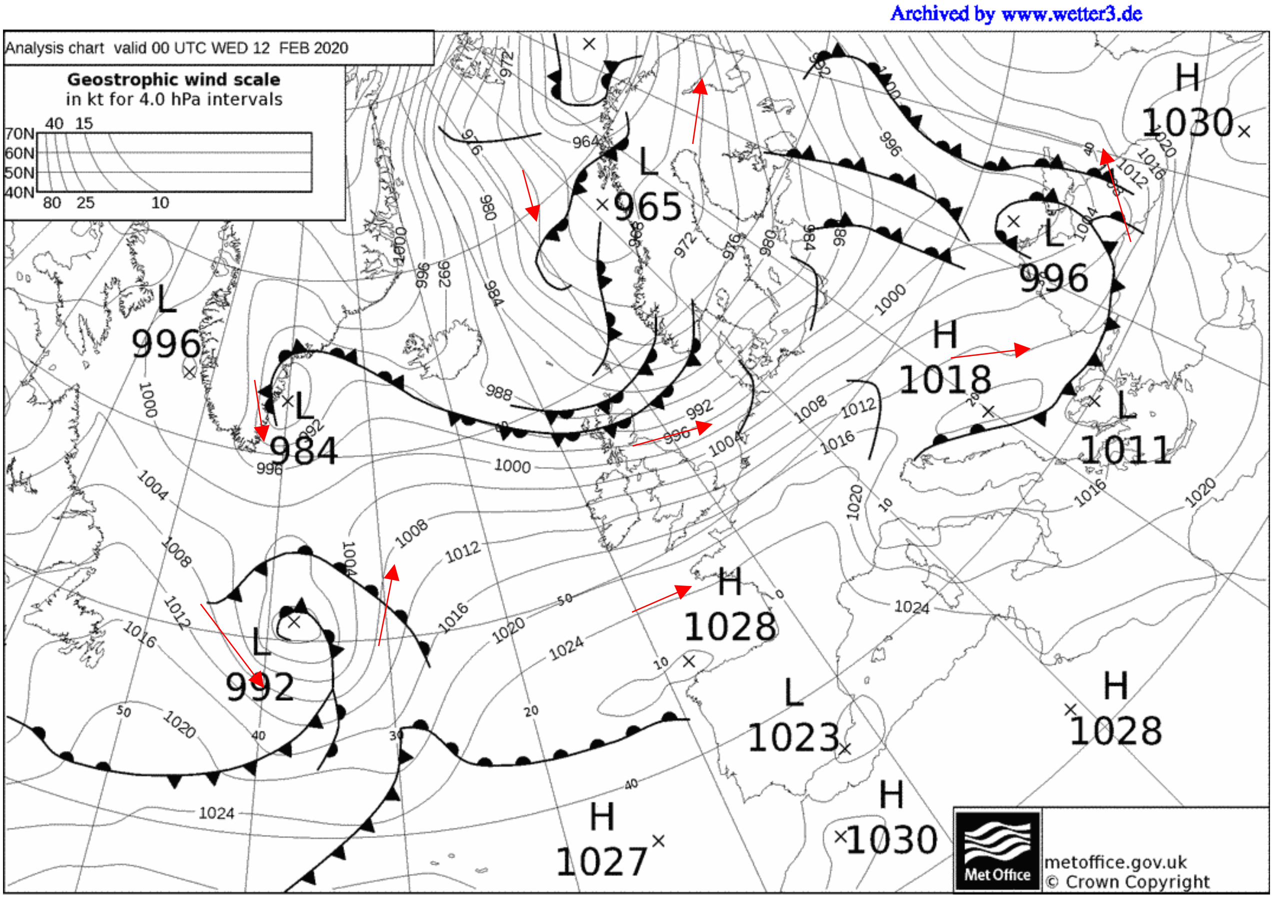
As the air blows from high to low pressure the Coriolis force acts on it, diverting it, and we end up with air following the pressure contours and blowing around low pressure in an anticlockwise direction and around high pressure in a clockwise direction in the Northern Hemisphere.



Schematic representation of the flow around a Low pressure area. The black arrows show the direction the air is moving in. The pressure difference pulls the air into the Low (blue arrows). The Coriolis force pulls the air to the right of the direction of motion (red arrows). The two forces are in balance when the air flows in an anticlockwise direction around the Low.

In the Northern Hemisphere, this means that air is blown around low pressure in an anticlockwise direction and around high pressure in a clockwise direction, in general following the isobars rather than blowing across them.

So, if we have a weather chart such as:



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We know that the wind is following the isobars across the map. To work out which way, you simply need to consider the pressure systems – remembering that the wind blows around a Low in an anticlockwise direction and a High in a clockwise direction. It should be possible to put arrows on the isobars, as shown, which comply with those rules everywhere on the map (N.B. some tiny pressure features may only cause a dent in a pressure contour rather than actually causing rotation around them). The wind follows the pressure contours, continuously changing direction as it is diverted by each pressure system.

Near the ground, friction slows the air down a bit so that, in practice, the wind does actually blow ever so slightly towards the centre of the depression.

Sources of Information

RMetS Coriolis explainer https://youtu.be/zH4nrgozVGk

Some examples of good demonstrations of the Coriolis effect:
https://youtu.be/7DVL0ugj1O4 and https://youtu.be/mPsLanVS1Q8

Current and archived pressure charts http://www1.wetter3.de/Archiv/archiv_ukmet.html
Earth.Nullschool.net – select pressure and wind. Great for showing depressions rotating in opposite directions in the two hemispheres.