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GEOFFREY PARSONS

ANTICYCLONES

Introduction

This **Geofile** on anticyclones is divided into three parts:

- characteristics
- formation
- weather.

Characteristics

Anticyclones are areas of **high pressure**, above the average atmospheric pressure of 1013 mb (millibars). They are the opposite of low pressure systems (depressions) and are larger (about 3000 km across) whereas depressions are around 1000-3000 km in size. Anticyclones usually have only one air mass in them; depressions have two: the warm sector which is tropical maritime air and the cold air which is usually polar maritime. Air in anticyclones is sinking, rather than rising as in depressions. The British Isles are influenced by anticyclones for about 25% of the year (Musk, L.F, (1988) *Weather Systems* p.96). On weather maps, both anticyclones and depressions appear as patterns of roughly circular isobars.

Formation

Anticyclones form in a number of ways:

1. 'Thermal' or 'cold' anticyclones
2. Convergence aloft in the Polar front jet stream
3. 'Blocking' anticyclones
4. Poleward extensions of subtropical high-pressure cells.

Of these, 2, 3 and 4 are all linked by convergence aloft (i.e. in the upper atmosphere) that is, they are said to be *dynamic*, whereas number 1 is produced by thermal means. However we classify anticyclones, they are all formed by subsidence, that is, *sinking air*.

1. Thermal or 'cold' anticyclones
Thermal anticyclones tend to occur over land masses in winter and over the polar areas for most of the year – they are less likely to form over the oceans elsewhere, as there is insufficient cooling over water, which tends to retain heat and suffer less variation in temperature. In the interiors of continental areas, the land cools rapidly in winter (e.g. Siberia and Northern Canada can reach temperatures of -40°C and -30°C respectively). This **radiational cooling** leads to the air in contact with the ground being chilled. Just as warm air expands and rises, so cold air contracts and as its density increases, it sinks and so creates an area of higher air pressure. The colder the ground, the greater the depth of the atmosphere that is affected by the chilling. The impact of this chilling may affect the atmosphere to a height of 2–3 km; beyond that, the influence of the cold surface is no longer felt so the anticyclone decreases in intensity with height. These anticyclones are:

i) usually seasonal (in summer the Siberian land mass heats up and produces a thermal 'low' – anticyclones are winter systems here)
ii) over land masses in the northern hemisphere, and
iii) mobile and easily displaced by depressions.

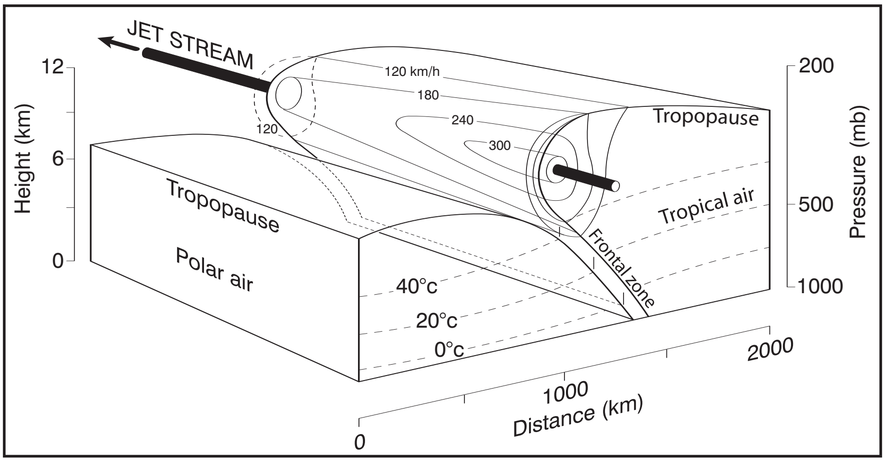
The British Isles may not be influenced a great deal directly by this type of anticyclone, since we are too close to the moderating effect of the Atlantic, which tends to reduce the extremes of cooling needed for this type of anticyclone to form.

2. Convergence aloft in the Polar Front jet stream
There are two main jet streams in the Northern Hemisphere; the Polar Front jet stream and the Subtropical jet stream. They are cores of very fast moving air traveling at as much as 300km/hr within the upper westerlies (Figure 1). The Polar front jet stream is found just below the tropopause between 9 and 12 km in height, and unlike the Subtropical jet stream is discontinuous. The Polar front jet stream meanders in a series of curves called Rossby Waves. These waves are set up as the jet stream crosses above the Rockies, causing it to move in a snake-like way – there is no change in height, only a shift in latitude. This wave motion has some important effects on the way the air behaves in this curving jet stream. In circumstances where the isobars are straight, the jet stream will also be straight and will blow parallel to the isobars as it is balanced between the pressure gradient force (PGF – the force that makes the wind blow from high pressure to low pressure) and the Coriolis force (which is a steering force, deflecting air to the right in the Northern Hemisphere).

The wind blows in response to the high pressure moving air to the low pressure – the PGF.
As the air moves, the Coriolis force starts to deflect it around to the right, acting at right angles to the direction of flow.

The air flow is now going parallel to the isobars with the PGF and the Coriolis force balancing each other. Although the Coriolis force would still try and deflect the wind to the

Figure 1: The Polar front jet stream – a core of very fast-moving air at about 9 km height



Source: Barry and Chorley, *Atmosphere, Weather and Climate*, 5th edn, Fig. 3.22, p.138

Figure 2: Geostrophic wind

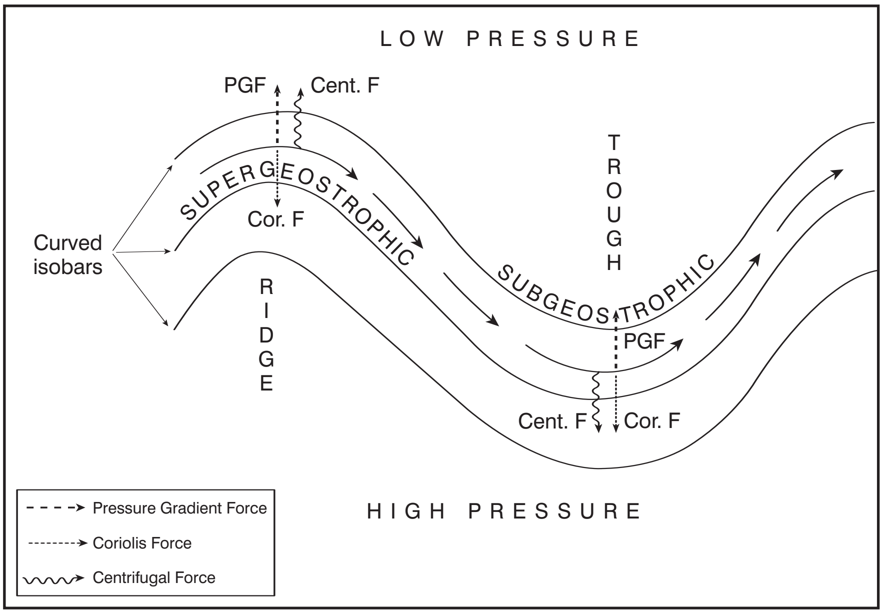


Figure 3: Divergence and convergence in the jet stream

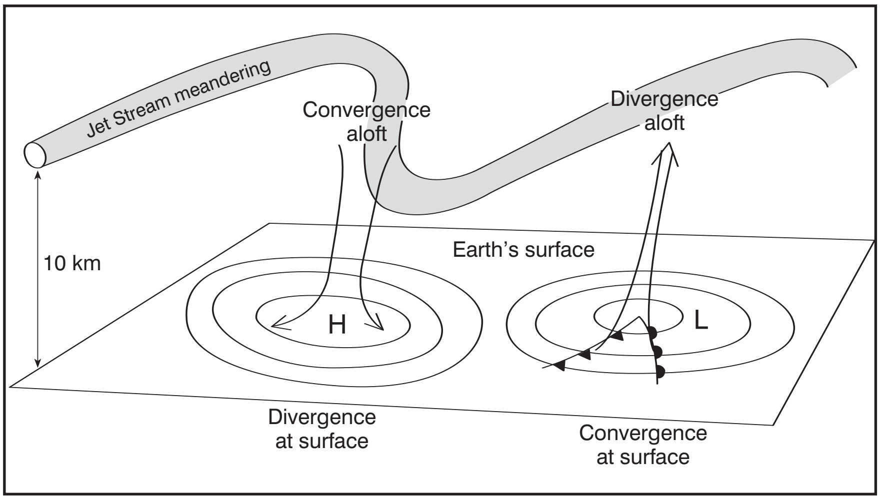
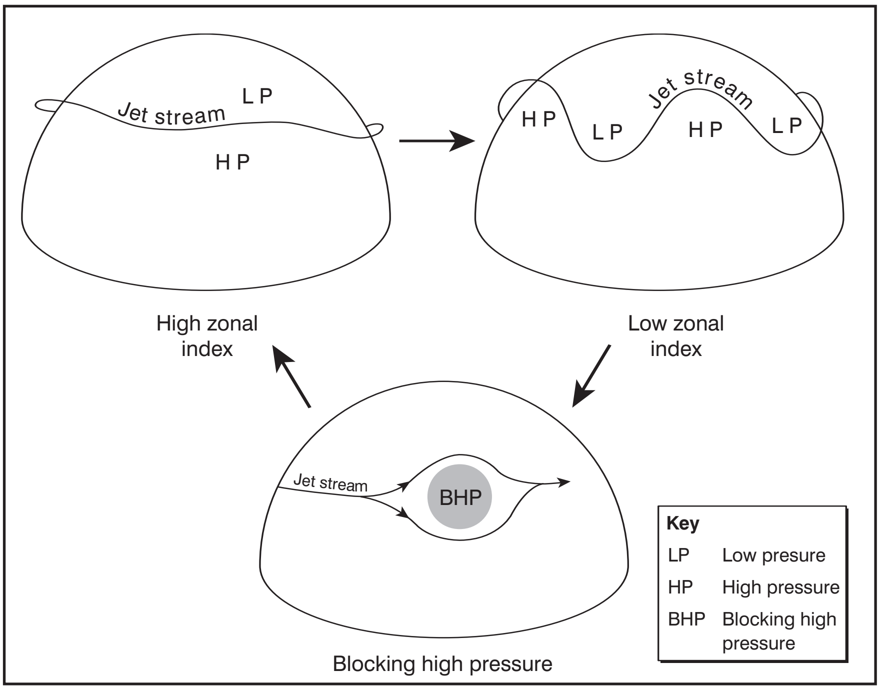


Figure 4: Rossby Waves



right, the wind cannot go any further round as it would be blowing against the PGF.

This balanced wind is known as a geostrophic wind and is the result of straight isobars. We can think of this as a straight jet stream. However, the wave motion of the jet stream means that the jet stream and the isobars curved and this affects the way this geostrophic wind behaves (Figure 2).

The effect of the wave is to introduce another force – the centrifugal force. When the wind moves around the ridge, the PGF has the centrifugal force working with it; this reinforces the effect of the PGF and so the wind blows stronger than we would expect. Such such strong winds are called supergeostrophic.

In the trough the PGF has the centrifugal force working against it and this reduces its effect so the wind doesn't blow as strongly here- these winds are called subgeostrophic.

So the Rossby Waves produce acceleration around the ridge in the jet stream (supergeostrophic flow) and deceleration around the trough, (subgeostrophic flow) . Like traffic on the motorway, fast-moving air 'piles up' into the back of the slow-moving air, creating congestion or convergence aloft (as it is high up in the atmosphere) On the other side of the trough, the opposite occurs and we get divergence aloft (Figure 3).

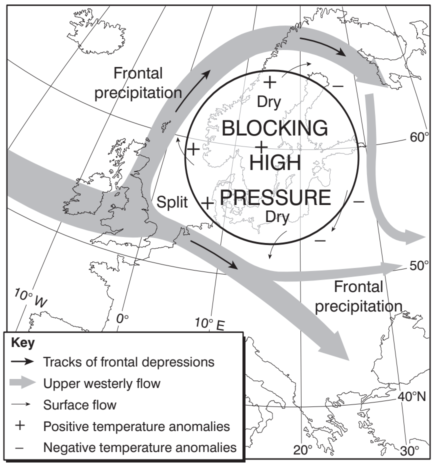
The convergence aloft builds pressure and the air sinks or subsides, creating high pressure as the air pushes down creating high pressure at the Earth's surface. High pressure formed in this manner is often associated with depressions and the anticyclones may be relatively small and quite mobile. They can provide an interval of bright clear weather in between the dull wet weather of low pressure systems. Unlike 'cold' anticyclones these 'warm' anticyclones develop throughout the depth of the troposphere.

3. Blocking anticyclones

The jet stream does not always flow in exactly the same path. Over a period of time, the Rossby Waves become more sinuous and the waves take on a more pronounced meandering pattern (Figure 4).

Initially, the jet stream moves on a relatively straight course, with only a slight meander in the path. This is a

Figure 5: Blocking high pressure diverts depressions around it



Source: Musk, Weather Systems, Fig. 11.5 p 101

Figure 6: The Hadley cells and their seasonal shifting

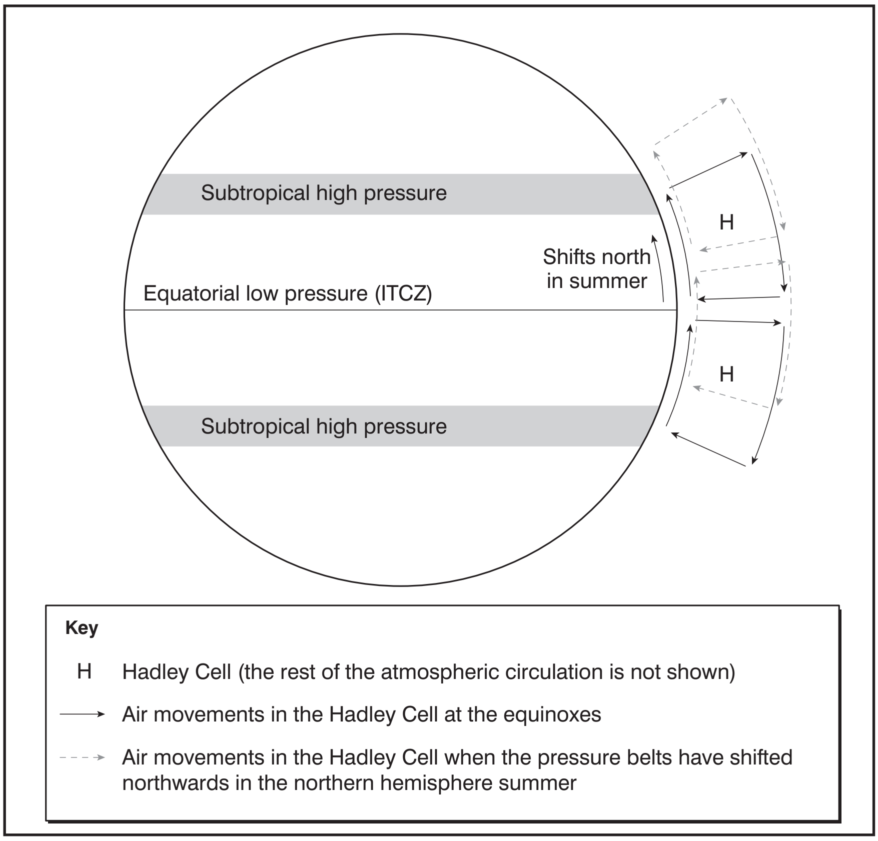


Table 1: Comparison of features of high- and low-pressure systems

Feature	High pressure	Low pressure
Surface pressure	High	Low
Wind direction	Clockwise (northern hemisphere)	Anticlockwise (northern hemisphere)
Vertical air motion	Sinking	Rising
Wind speed	Weak	Strong
Precipitation	Generally dry	Wet
Cloudiness	Stratus or clear skies	Cloudy,variable types
Speed of movement	Slow-moving or stagnant	Mobile,moving west to east
Airflow aloft	Convergence (diverges at surface)	Divergence (converges at surface)

(Adapted from Musk, p.96)

high zonal index where there is a marked contrast between the the air to the south of the jet stream compared to the north. As the meanders become more pronounced, the flow of air in the jet stream has more of a north–south movement and this is a low zonal index. The flow may become so pronounced that some of the warm air is left as a patch of high pressure, as a 'blocking high', rather like an oxbow lake in rivers. The wave pattern runs in a cycle of between 3 to 8 weeks but it is very irregular in the timing of the progression of each stage. Blocking highs disrupt the pattern of westerly airflow at all levels in the troposphere. The upper westerlies have to split to go round them and this means that depressions, which would normally plough steadily eastwards have their route diverted north or south around the blocking anticyclone (Figure 5). Blocking highs may persist for a week or more once they are established.

4. Poleward extensions of sub-tropical high pressure cells

At the Equator, the northern Hadley cell rises, moves northwards aloft and then sinks at about 30°N. A mirror image occurs in the southern hemisphere. On a broad, global scale, the sinking or subsiding air produces a high pressure belt, the Subtropical high at about 30°N and S. In detail, what we get are a series of high pressure cells, specifically the Northern Pacific, the Atlantic and the North African high (Figure 6).

This is the position of the Hadley cell in the Northern spring (black lines on Figure 6). The zone of maximum heating where the Hadley cells meet is known as the ITCZ (Inter-Tropical Convergence Zone). In the Northern summer, the zone of maximum heating moves north and as a result, the Hadley cells shift slightly northwards as does the sub-tropical high pressure belt (dotted lines on Figure 6). This brings the high pressure cells of the Atlantic and North African high closer to the British Isles. Any ridges extending polewards (northwards in this case) could affect the British Isles and we would come under the influence of a poleward ridge of one of these subtropical high pressure cells.

Weather

Surface pressure

Anticyclones are dominated by sinking or subsiding air. This sinking air pushes down onto the Earth's surface and accounts for the high pressure. The sinking air does not quite get all the way down, but usually sinks to within 1.5–0.5 km of the surface. It tends not to get much closer than this because of the turbulence and convection of the air near the ground. The rate of sinking appears to vary between 1 km and 4 km per day (Barry and Chorley, *Atmosphere, Weather and Climate*, 5th edn, p.123 and L.Musk, *Weather Systems*, p.97).

Wind direction

At about 1.5–0.5 km above the Earth's surface the sinking air spreads out or *diverges*. It spirals out from the centre in a clockwise manner:

1. The anticyclone is surrounded by

lower pressure so the air moves from high to low pressure pushed by the pressure gradient force.
2. As the air moves, it is deflected to the right by the Coriolis force
3. As the isobars are curved, the air moves around to the right and it experiences the centrifugal force. This force is working with the PGF and so actually strengthens the wind compared to what we would expect for this isobar spacing. However, the effect is very slight and there is no significant acceleration of the wind due to the Centrifugal force.
4. Since we are near the surface, we have to consider the effect of friction. This slows down the wind and makes the Coriolis force less effective.
5. This means that the PGF gets the upper hand and pushes the wind across the isobars at an angle.
6. As a result, air spirals out across the isobars in an clockwise motion.

Wind speed
The wind speeds are generally low. This is because of the wide spacing of the isobars giving us a gentle pressure gradient. There is little change in pressure over a wide area, so reducing the pressure gradient force.

Cloudiness and precipitation
Anticyclones are characterised by sinking air. As the air sinks, it is compressed. Just as a thermal or packet of rising air expands and cools, so the sinking air compresses and warms. This warming is **adiabatic** – that is, there is no exchange of heat to or from the packet of air to its surrounding air. The change in temperature is brought about only as a result of compression. This air originates high up in the atmosphere where the air is dry. The warming experienced by the subsiding air reduces the relative humidity still further and any water droplets may be evaporated so skies are clear and cloudless. The sinking air also inhibits the movement of air rising from the surface so clouds are unlikely to form. The lack of clouds reduces the chance of precipitation. Hence anticyclones have clear skies with little rainfall.

Summer anticyclones
Anticyclone conditions in summer give us largely cloud-free days, with occasional cumulus bubbling up caused by strong heating of the ground which generates local thermals and small-scale patches of unstable air, light winds and little rain. Temperatures are high, as few clouds block the insolation, and the days are long, giving us more time to receive this sunshine. Nights are clear, so heat can escape to space, cooling the ground and forming mists. In blocking anticyclones these conditions can persist, to give days that get gradually warmer and warmer. This happens because we have longer days to receive more heat than we lose during the shorter nights. So as time passes, temperatures can build up and each day starts a little warmer than the one before. In this way heatwave conditions can develop.

Winter anticyclones
Winter weather in anticyclones can bring cold, bright, frosty weather. Little precipitation is usual, given the lack of clouds. Night-time temperatures are low as clear skies mean that heat can escape to space. This **radiative cooling** means that the ground becomes progressively colder as the night wears on, and if temperatures drop below 0°C then any dew may turn to frost. In winter, the day/night length is reversed, and over time we get a gradual cooling as we lose more heat in the longer nights than we gain in the shorter days. In winter, too, the effect if the sun is weakened by low angles of incidence. This combination means that temperatures may get progressively colder if the anticyclone persists.

Anticyclonic 'gloom'
Not all anticyclones bring bright, clear weather. Sometimes the reverse is true when we are subject to days of low stratus cloud, giving gloomy, cold weather with mist or fog. These conditions are the result of the subsiding air. As we have seen, the air sinks until it gets to between 0.5 and 1.5 km of the surface. Due to compression, it warms as it descends. If the air near the ground is cold then we have a situation where the air above is warmer than the air below. This is not the usual situation and it is called a **temperature inversion**.

Since this inversion is the result of sinking air, it is known as a subsidence inversion. The result is that air rising from the surface may be trapped beneath the inversion, and any clouds that form will not be able to rise up but will have to spread out, giving a low, relatively thin, stratus cloud that blankets the sky and blocks out the sun – hence the 'gloom'.

At night, temperatures may fall low enough for fog to form. Not only does the inversion make it hard for the fog to disperse upwards, but the light winds are also unlikely to help blow it away. To make matters worse, the blanket of stratus will reduce insolation levels, lowering temperatures, so making it more difficult to evaporate the fog. These conditions were responsible for the problems at Heathrow before Christmas in 2006, when thick fog meant that many domestic flights were cancelled or delayed.

Conclusion

It is important to realise that anticyclonic weather conditions are quite varied and in many ways provide us with as many problems as those associated with low pressures.

Focus Questions

1. Using height/temperature diagrams, explain why anticyclones don't always bring good weather.

2. Describe and explain the relationship between Rossby Waves of the jet stream and high pressure at the surface.

3. Explain how, in winter, the temperature may get colder and colder when anticyclones persist for some time.

4. Draw a diagram and annotate it with labels to explain wind direction in an anticyclone.