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Depressions: Two Storms Compared

This **Geofile** will focus on:
- depression formation
- two storms: October 1987 and January 1990
- improvements to weather forecasting.

On 15–16 October 1987 and 25 January 1990, two violent storms hit Britain. They were 'extra-tropical cyclones', i.e. essentially very powerful depressions which, as a result of high wind speeds and rainfall, caused considerable damage and dislocation. Since they were both depressions, the first section of this **Geofile** explains the formation of depressions in general, in order to put the development of these two storms into context.

Depression formation

Depressions are areas of low pressure. They are characterised by a roughly circular pattern of isobars and consist of 'sectors' of warm and cold air. These sectors are separated by fronts. Depressions track (move) to the east at 20–40 mph. They bring cloudy, wet, windy and unsettled weather.

Depressions originate in the Atlantic, west of Ireland. They form when two air masses meet. **Air masses** are large bodies of air having consistent conditions of temperature, humidity and pressure throughout the depth of the air mass. Since different air masses have quite different characteristics, they tend not to mix. The two air masses that are found in depressions affecting the UK are the **polar maritime** and the **tropical maritime**.

Polar maritime (Pm) air masses originate from Canada and Greenland, and so start cold and dry, but their passage over the Atlantic warms them and adds moisture. This makes them **unstable**; the air wants to rise, because it has been heated from below.

Tropical maritime (Tm) air masses start over the warm waters near the Azores. As they move northwards, they are cooled, which makes them stable.

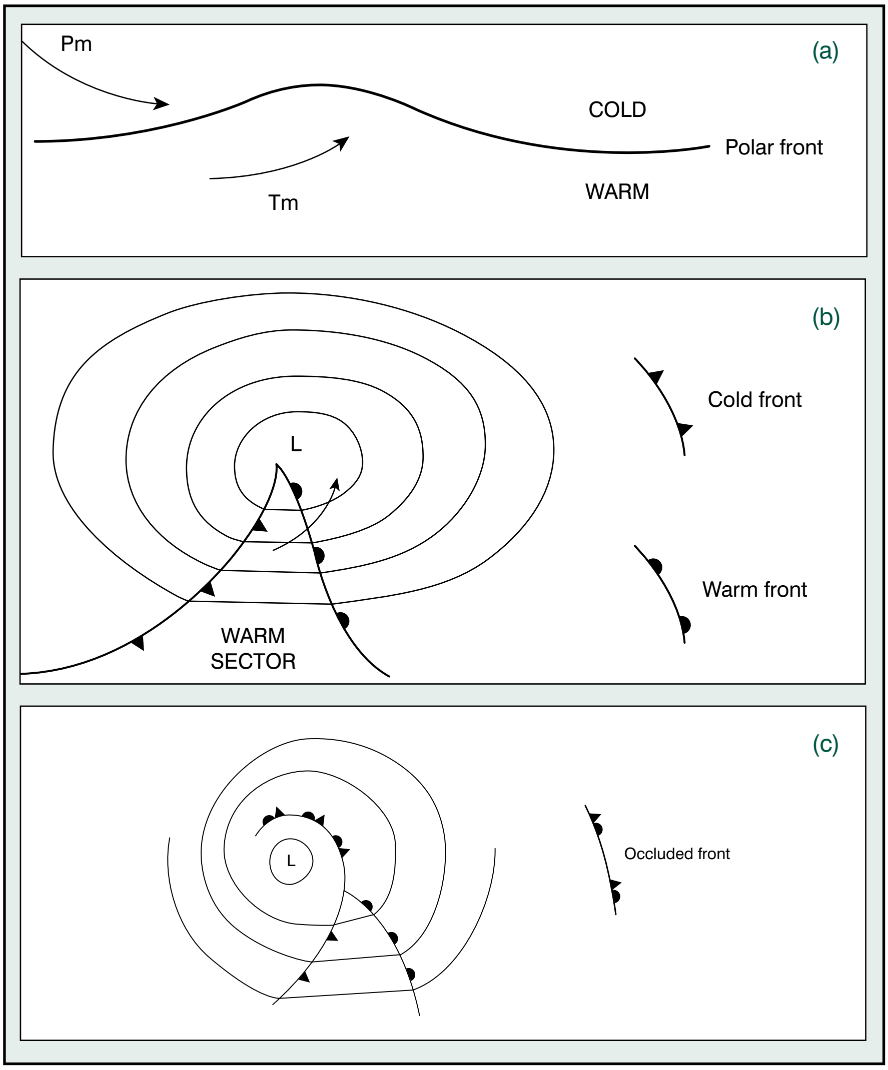

Figure 1: Development of a depression
(a) Embryo (b) Maturity (c) Decay

Although both these air masses have been modified by their passage over water, one is still cold and dry, whilst the other is relatively warm and moist. Where these two air masses meet, a front is formed. This is known as a polar front and, because of its unstable nature, undulations or waves develop, where warm air invades the colder air and colder air invades the warmer air (Figure 1(a)). As the warm air (Tm) is less dense than the cooler (Pm) air, it is lifted off the ground and is forced to rise over the cooler air. This lifting of air produces a lower pressure into which the warmer air is drawn. As a result, it spirals anticlockwise upwards, and a defined 'triangle' of warm air (the warm sector) forms between the cold and the warm fronts (Figure 1(b)). The apex of the warm sector is where the pressure is lowest.

Figure 1(c) shows the occluded stage of the depression. The cold front moves faster than the warm front, and catches it up, lifting it from the surface. Where this has happened, an occluded front forms and the warm sector starts to shrink. The cold front moves faster (40–50 mph) than the warm front (20–30mph), as it is harder for the warmer, lighter air of the warm front to move the denser, cooler air out of the way. The cold front is moving against the warm sector which is less dense and offers less resistance to its forward movement (National Meteorological Library and Archive, Factsheet No 10). When the warm sector has been entirely lifted from the ground and has been cooled so that the temperature differences have evened out, the occluded front disappears and the depression decays.

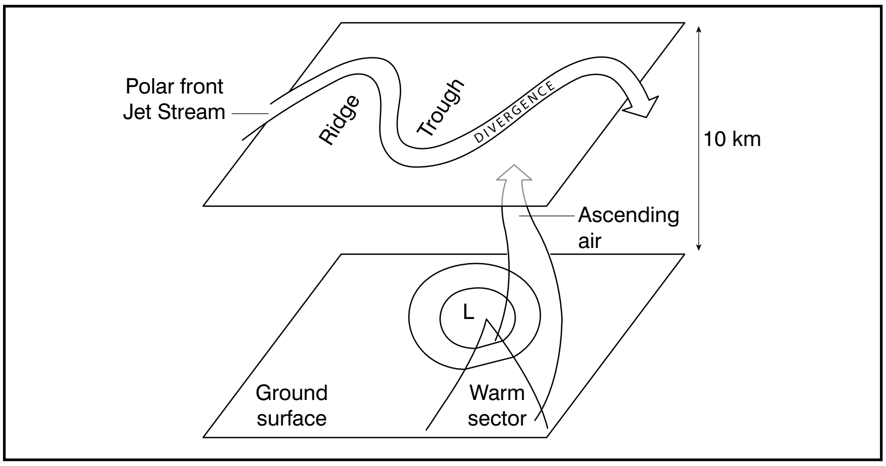

Figure 2: Role of the polar front jet stream in the formation of depressions. Divergence in the jet stream helps to lift ascending air from the warm sector

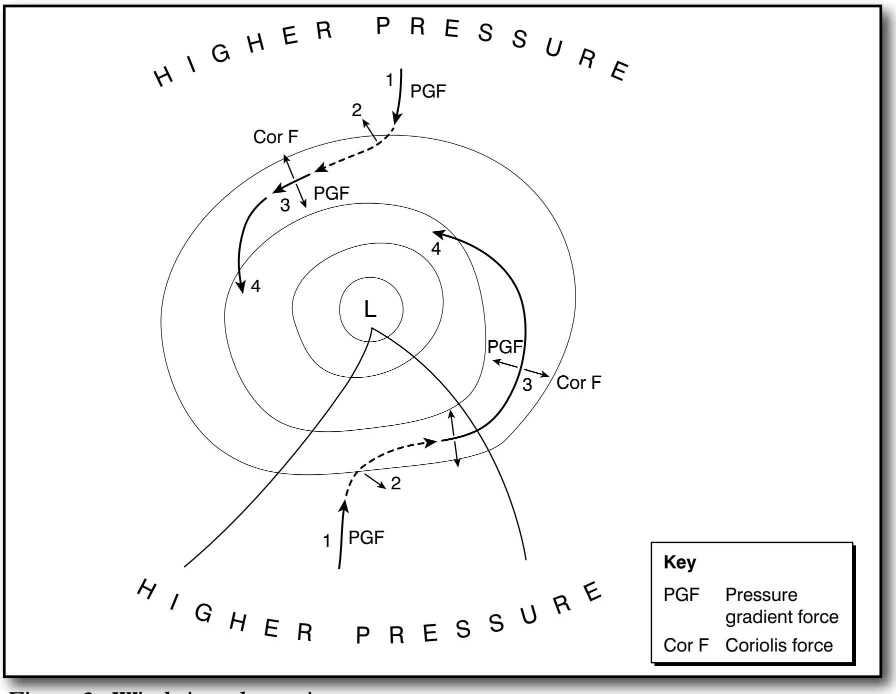

Figure 3: Winds in a depression

This description of depression development is based on the polar front theory, which explained the formation of depressions. The theory was developed between 1919 and 1922 by Norwegian meteorologists. At the time, flows of air in the upper atmosphere – the upper westerlies, or jet streams– were unknown, and so their role in depression development was not appreciated.

The role of the jet stream
Part of the upper westerly winds have zones where the flow of wind is concentrated into narrow cores. These are jet streams. In these cores, wind speeds are very fast – up to 360 kph – and blow just below the tropopause (7.5–14 km height). British weather is governed by the polar front jet stream. The jet stream meanders from side to side, like a river, at a constant height. The effect of this meandering is to create ridges where the jet stream bends polewards, and troughs, where the meander bends towards the equator. On the eastern part of the trough there is **divergence.** This means that air at the surface is drawn up into the jet stream. If the position of the jet stream trough coincides with the developing depression at the surface, then the warm air which is spiralling upwards from the surface is lifted up by the divergence in the jet stream (Figure 2). If this air is removed faster from the depression by the jet stream than it is replaced at the surface, then the pressure will continue to fall and the depression will deepen.

Wind patterns in a depression
Depressions are areas of low pressure, which means that winds blow from the surrounding high pressure towards the lower pressure. The force that moves the air is the pressure gradient force (PGF). (1) As the air moves, it is steered to the right by the Coriolis force (2) until the wind ends up blowing parallel to the isobars. (3) When this happens, the two forces, the PGF and the Coriolis force, are balanced. The wind blows anticlockwise and along the isobars. Nearer the ground, friction has an effect. It slows the wind speed and this weakens the effect of the Coriolis force, so it no longer steers so strongly to the right, and the balance between the PGF and the Coriolis force is upset. As a result, the surface wind now blows across the isobars at a slight angle, in towards the centre of the depression (4) (Figure 3).

In a depression, the isobars (lines of equal pressure) which are closest together show where pressure gradient is steepest (where the pressure differences are greatest). The bigger the pressure difference, the stronger the wind, so tightly packed isobars have the strongest winds.

The Great Storm, 15–16 October 1987

Records suggest that this event was the UK's worst windstorm since 1703. It was the sort of event that we would expect to see once every 200 years. In essence, this storm was an unusually powerful depression. There are a number of reasons why it developed into a storm of such ferocity:

- The tropical air (Tm) was unusually warm. This was due to warm air flowing eastwards out of Hurricane Floyd, and warmer than normal sea surface temperatures in the Bay of Biscay.
- The collision between the cold polar air (Pm) and the unusually warm tropical air created an exceptionally large temperature difference, which helped the warm air to rise rapidly. This rapid ascent caused a correspondingly rapid fall in pressure. It fell by 17 mbar in 12 hours (970 mbar at 12.00 on October 15 to 953 mbar at 00.00 on October 16).
- The jet stream was much further south than normal for this time of the year. Usually it would be positioned over the

1987	1990
18 people were killed.	47 people were killed.
Storm struck overnight.	The storm was during the day with the worst winds in the late morning and afternoon, so more people were about.
The storm had the highest wind speeds in a relatively restricted area of the South and South-East. The wind speeds were comparable (1987 – Shoreham 100 kt, 1990 – Aberporth 93kt).	The area affected was much wider. Most of England and Wales were affected by the strongest winds, with many of these areas recording stronger winds than in 1987.
Insurance losses were £1.4 billion. 150,000 homes had no telephone connection and hundreds of thousands of homes were without electricity, so that 2.3 million 'power disconnection days' were recorded (a measurement used by the electricity industry based on the time a property suffered a lack of power times the number of affected properties). Most damage was done in areas of average wind speeds of 40 knots.	Insurance losses were £1.9 billion. Half a million homes were without power. The greater losses reflect the more widespread nature of the storm affecting so many properties, rather than the result of inflation, and despite the effect of higher claims for expensive London property in 1987. The damage was the result of sustained, high-velocity gusts of wind which progressively weakened buildings.
15 million trees were lost. Sevenoaks in Kent became 'One Oak' as six of the key trees were blown down. They have since been replaced and there are now eight trees in all. The very high losses to trees were due to two factors. It had been wet the week before so trees were rooted in soft ground and secondly, the trees had yet to shed their leaves so they caught the full force of the wind.	3 million trees were lost. The much lower figure is due to the bare trees in January and the winds passed over less wooded areas. A further possibility is that weaker trees had already been removed during the 1987 storm, leaving a less susceptible tree population.
Transport in the South-East was brought to a standstill by fallen trees, branches and general debris which blocked roads and railway lines. A cross-channel ferry was blown onshore at Folkestone and the pier at Shanklin, Isle of Wight, was destroyed.	The winds caused widespread damage but fewer trees had blown over to block transport routes. London as a major transport hub was less affected this time.

Figure 4: Impacts of the two storms compared

north of Scotland, and would guide storms well to the north of the UK, but in October it was moving NE over the Bay of Biscay. This had two effects. First, the storm started further south than is usual for the time of year. This meant that the Tm air would have been warmer. Secondly, the storm moved rapidly NE and was steered by the jet stream over the Channel and into the UK.

- West of the depression, descending air increased the pressure, raising the difference between high and low pressure.
- Winds were boosted by the 'sting jet'. This is an area where air descends from about 3–4 km height into the storm, close to the centre of the depression. Rain falling into the sting jet cools it, increasing its density, accelerating it as it approaches the ground. It can reach speeds in excess of 100 mph at the surface over a small area.

Major features of this storm
There were three unique and major features of the 1987 storm: the very high wind speeds, temperature rises and pressure increases.

Wind speeds: the winds were surprisingly strong. Unusually, the South-East of England was worst hit by these winds. Generally, the area south-east of a line drawn from the Severn to the Humber Estuary records gusts of 55–115 mph during storms. The greatest gusts were felt on the Normandy coast (134 mph), although Shoreham in Sussex experienced gusts of over 100 mph and sustained the highest hourly average wind speed of 85 mph. Strong gusts were experienced for over three hours as the storm passed overhead.

Temperature rises: a steep temperature gradient had been established by the collision of very warm Tm air (due to the tail end of Hurricane Floyd and warm sea surface temperatures) with colder Pm air. As the warm front (the leading edge of the warm sector) passed overhead, some remarkable temperature rises took place. Heathrow recorded a rise of 7°C in one hour, and in Farnborough, Hampshire it rose by 9.1°C in 20 minutes. With the passage of the cold front, temperatures dropped sharply.

Pressure increases: As the storm moved across the UK, there were some startling increases in pressure in the rear of the storm. Over Southern England, pressure increased by 8 mbar per hour and in Portland, Dorset pressure rose by 25 mbar in three hours. This may be linked to the 'sting jet' which, as it accelerated downwards, would have locally increased the pressure when it hit the ground, or to the big difference in temperature between the warm and cold sectors.

It is notable that, despite the very low air pressure, this storm involved only limited precipitation.

A further aspect of the 1987 storm apart from the direct wind-damage impacts related to a number of economic implications. It has been suggested that the lack of people able to get into work on the next day (Friday 16 October) led to panic selling and a rapid fall on the London stock market the following Monday. This precipitated the largest percentage fall in stock market history since 1929. However, there were similar stock market crashes around the world at this time.

25 January 1990 Storm

The January 1990 Storm started out as a weak depression on 23 January which crossed the Atlantic quickly due to a powerful jet stream moving at 180 kt. There was a strong temperature gradient as the weather had been warmer that year, and this resulted in the fast jet stream. By 24 January, the low had deepened to 992 mbar, and a day later it had hit southern Scotland and was now 953 mbar. Such rapid drops in pressure are the result of powerful jet streams which can remove the warm air as it spirals upwards. As the depression moved quickly towards the UK, the cold front began to overtake the warm front and the occluded front started to curl back around the centre of the depression. At the tip of the occluded front the isobars were closest together and here, on the southern and western part of the depression the winds reached average speeds of 46–57 mph over large areas of central England. The winds were strongest reaching average speeds of 70–75 mph on the west Wales coast. Aberporth recorded gusts of 93 kt, whilst many parts of southern England had several gusts of 107 mph. There were steep pressure rises of 20 mbar at the passage of the cold front associated with the air sinking from the jet stream.

Damage in the 1990 storm was considerably less severe than in 1987. Fewer trees came down – the weaker ones were already down from the previous storm. People were given better warning on this occasion, took note of it, and were therefore better prepared.

Improvements to weather forecasting

The October 1987 storm was not well forecast. Most computer forecasts were particularly poor at picking up the signs of very rapidly developing and deepening depressions out in the Atlantic. This is partly due to:

- Lack of observations in the Atlantic, where the early warning signs of the critical early development taking place can be detected.
- Reductions in the forecasting budget meant that a weather ship in the Bay of Biscay had been cut.
- These extra-tropical depressions are notoriously unpredictable; they can deepen very rapidly, move quickly and can change course without warning.
- The previous weather had been wet; forecasters were more worried about the possibility of flooding rather than the wind. Also, in the days preceding the storm, all the indications were that the storm would miss the UK.

In the longer term, we can regard the 1987 storm as a very rare event. The last storm of this size to affect this part of England occurred in 1703, suggesting that we would expect such an event once every 200 years. However, storms of this ferocity occur quite regularly in the far north and south west of the UK which is far more used to this type of extreme weather. The key characteristic of this storm, in terms of impact and forecasting, was that it hit the south and east of England. Being more aware that severe storms can hit areas which are not usually associated with these events is an important aspect in the improvement of forecasting.

Following the 1987 storm, an internal enquiry was carried out and a number of improvements were made. Some of them were the result of the enquiry, which recommended that forecasters had the most powerful computers possible, whilst others were the result of improvements in science and technology such as the refinements to models of how the atmosphere works and behaves and our ability to access weather information 24 hours a day. The BBC provides bulletins on the web, mobile phones, radio and TV.

In the 1980s the Met. Office supercomputer was able to do 100 million calculations per second. Now supercomputers work at half a million times faster at 200 trillion calculations per second. This increase in computing power has meant that weather models are more detailed and can be run more frequently. The UK detailed forecast used to run twice a day in 1987. Now it runs four times a day and with greater detail so that more local information can be put into forecasts. (Liam Dutton's Channel 4 blog October 2012)

The number of automated weather buoys located offshore in the west and south has increased which give a better picture of advancing storms. Satellite data not only provides us with colourful pictures but the information gained from satellites such as temperature, humidity and wind speeds at different heights is now incorporated into computer models directly. This means that a more accurate knowledge of what the atmosphere is doing now will make it easier to build a more accurate forecast.

The last area in which improvements have been made has been in the Warnings and communications issued by the Met Office. Weather warnings operate on a system of levels which are colour coded to improve clarity and impact. The emergency services need to get weather warnings quickly and now it can be done at a county scale; before it was at a regional scale.

Today the Met Office four-day forecast is as accurate as the one day forecast thirty years ago.

Further reading

Burt, S.D. and D. A. Mansfield (1988) 'The Great Storm of 15–16 October 1987', *Weather* 43: 90–110.

McCallum, E. (1990) 'The Burns' Day Storm, 25 January 1990', *Weather* 45: 166–173.

Google the internet for film footage from these storm.

Focus Questions

1. Consider the ways in which the October 1987 storm was unusual. Make comparisons with the January 1990 event and with the normal characteristics and behaviour of depressions.

2. Research further into one or both of these storms. Many people in South East England have eye-witness recollections and a good deal has been written. For example, a school from Worthing, on a field trip to Dorset staying in mobile homes, had an incredible adventure, though, fortunately, all were safe in the end.