

DEPRESSION RAINFALL AND ITS EFFECT ON THE BRITISH ISLES

Introduction

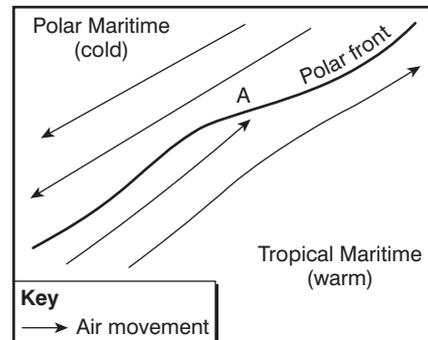
Great Britain's position on the western edge of the Eurasian continent and the eastern edge of the Atlantic Ocean, between latitudes 50 and 60 degrees north, makes it susceptible to the influences of the south and south-westerly airflows associated with the general circulation of the atmosphere.

As a result of this location, Britain experiences a 'cool temperate western margin maritime' climate, with cool temperatures throughout the year – monthly average temperatures lie between 3 and 18 degrees Celsius. Any changes in temperature that occur between January and July are gradual and reflect the increasing influence of the sun as it moves back into the Northern Hemisphere, peaking on June 21 over the Tropic of Cancer. Similarly, falls in temperature are expected to be gradual as the sun lowers in the sky during the latter half of the year and the concentrated heat of the sun is transferred further south.

Throughout this time the influence of the Atlantic Ocean can be felt and Britain's marginal location on the edge of Eurasia and the eastern extremity of the Atlantic Ocean means that the airflows meeting our shores are likely to produce rainfall. Rainfall can be classified as either convectional, orographic or cyclonic in origin. In the UK the most common are orographic (relief) rainfall and cyclonic or depression rainfall. The land mass of Britain possesses high land on the west and north of the country so a combination of the orographic and cyclonic types of rainfall dominate Britain's rainfall regime.

However, it is the influence of the atmospheric activity over the North Atlantic, which is seen as most significant, as this is where the depressions or cyclones are generated. Owing to its origin, polar maritime air is cooler than tropical maritime air. Polar air moves south and tropical air moves north and when these two air masses meet with their different characteristics the

Figure 1: The Polar Front: the meeting of tropical and polar air



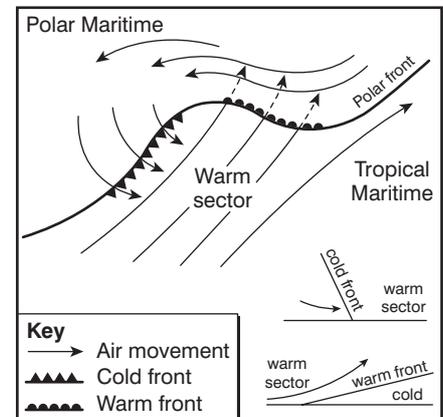
scene is set for the formation of a depression.

This movement was first recognised by the Norwegian meteorologist Jakob Bjerknes at the time of the First World War when he recognised the existence of atmospheric boundaries or fronts from which wave cyclones, or depressions, develop. This wave cyclone or vortex repeatedly forms, develops or intensifies and later dissolves at these polar fronts.

The formation of a depression

Depressions form when two air masses with differing characteristics meet. In the North Atlantic, this is most common between September and April when the influence of the sun is at its weakest due to the sun being overhead in lower latitudes and in particular the Southern Hemisphere. It is the polar maritime and tropical maritime air masses that meet and they are separated by the Polar Front (Figure 1). At the Polar Front, which extends vertically for thousands of metres, the two air masses meet but do not mix. The polar front is not a straight line, and at Point A in Figure 1, the south-easterly air flow can be seen meeting the north-easterly air flow at an angle. It is at this point that the warmer, lighter tropical maritime air rises, because, being warm it has a lower atmospheric weight or pressure. Also, being warmer, it contains more moisture than the cooler polar air mass and, as it rises, it cools and condenses and produces

Figure 2: A maturing depression accompanied by rain along both the warm and cold fronts



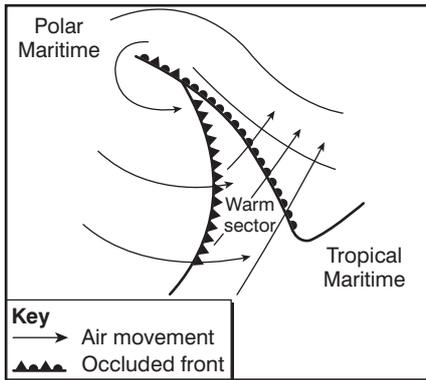
water droplets and consequently clouds. This is the embryo stage of the depression.

By this stage an anti-clockwise circulation of air has been established due to the Coriolis force (as a result of the rotation of the Earth), and a vast segment of tropical air, known as the warm sector, protrudes into the polar front. As the depression matures, two distinct sets of activities occur at the leading and back edge of the warm sector. These are the warm and cold fronts (Figure 2), which are more established by this stage.

At the warm front, warm air gradually rises up over the colder air on the eastern side of the depression centre. It rises into areas of lower atmospheric pressure and cools by expansion. This adiabatic cooling (due to expansion as it rises into areas of lower pressure) brings about the production of clouds as the water condenses. At high altitude cirrus clouds develop. These herald the arrival of the depression and are followed by lower cirrostratus, altostratus and nimbostratus clouds from which heavy rain falls over long periods of time.

Where the warm tropical air is still in contact with the ground, no forced ascent has occurred and the sky will remain clear and often cloudless. However, as the cold air which fills in the void left by the ascending air at the warm front

Figure 3: The faster moving, heavier and colder polar maritime air pushes forward, displacing the warm air on the ground



pushes forward, it forces the warm air off the ground. Rapid ascent takes place that produces a vast swathe of cumulonimbus cloud, which is highly unstable and results in intense rainfall (Figure 3). This is the cold front, where heavier, denser air is displacing the warmer lighter air, and the nature of its actions means that it is moving faster than the warm front and will eventually catch up with this line of activity (Figure 4).

Once all of the warm air has been forced off the ground, an **occlusion** is said to have occurred. This **occluded front** brings with it a period of steady rainfall and the eventual decay or dying out of the depression. It may be replaced by a further depression that will follow the same line or track and lead to another set of similar conditions. The extent of the depressions, which may be 2,000 km in width, means that not all areas will experience the same conditions as it passes overhead. The cross-section of the depression (Figure 5) shows the sequence of clouds as a depression passes. In particular it illustrates the depression prior to occlusion, where the warm sector still exists and no forced ascent has taken place.

Figure 4: A partially occluded front where all the warm air has been forced to ascend as the colder polar maritime air displaces it at the surface

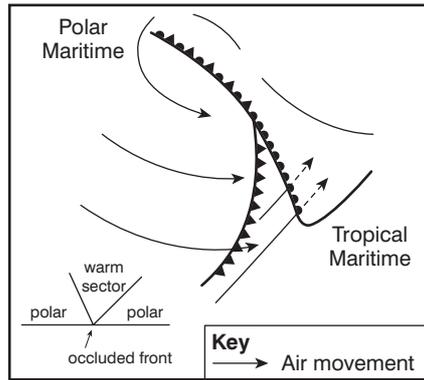


Figure 6 shows a typical mature depression. It has a distinct warm sector in between the warm and cold fronts and an area of occlusion. (The cross-section line X-Y on Figure 6 would have the pattern shown in Figure 5.) However, observers at locations A and B will experience different weather from the depression. The observer at A would experience the conditions associated with the warm front, warm sector and cold front passing overhead in a period of 24 hours, while the observer at location B would only experience conditions associated with the passage of an occluded front.

The changes associated with the passage of a mature depression across the UK in the winter months are summarised in Table 1.

Recent developments in the study of atmospheric circulation.

The atmosphere is an area of study that meteorologists are constantly refining. More recent studies have identified upper air currents that aid the development of depressions. In the upper atmosphere, between 8,000

and 12,000 metres, are rapid air currents that travel from west to east. One such set of currents, known as jet streams, is located between 30 and 50 degrees north and south of the equator, and separates the Ferrel and Polar cells. These are responsible for the tropical and polar air masses from which the depressions develop. The greater the temperature difference between the Ferrel and Polar cells, the stronger the jet stream will be, and this will be reflected in the strength of the subsequent depression.

These jet streams, or 'meandering rivers of air', have been identified in both hemispheres and are also known as Rossby waves. There are between 3 and 6 such waves in each hemisphere and they are formed by relief barriers, the uneven land-sea-land interface and thermal differences. Cyclonic activity can result from an airstream flowing from west to east over a mountain barrier such as the Rockies. As the air is forced to rise over the mountains it becomes compressed between the mountain peaks and the tropopause. On descent it expands and begins to spin in an anticlockwise direction (in the northern hemisphere), and a cyclonic trough or depression develops. This may last over the eastern part of North America for some time and lead to the polar front jet stream developing wind

Figure 6: A typical depression

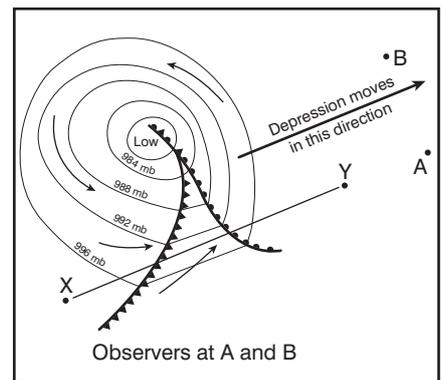
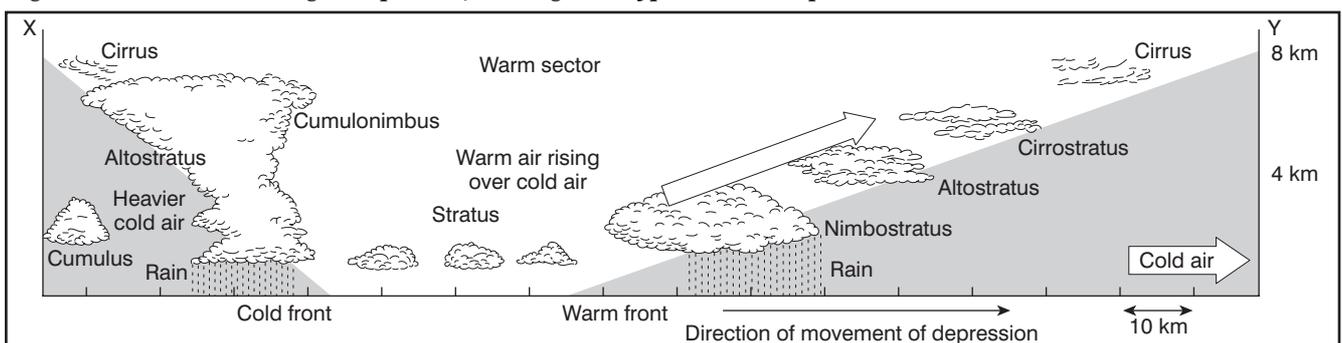


Figure 5: Cross-section through a depression, showing cloud types and air temperatures



Source: adapted from Digby, Global Challenge (Heinemann)

Table 1: Changes associated with the passage of a depression.

	Ahead of the warm front	The passage of the warm front	The warm sector	The passage of the cold front	The cold sector
Pressure	A steady fall	Continues to fall	Steadies	Starts to rise	Continues to rise
Temperature	Quite cold but begins to rise	Continues to rise	Quite mild	Sudden fall in temperature	Remains cold
Cloud cover	Cloud base gets lower and thicker (cirrus and altostratus)	A low thick cloud base (nimbostratus)	Cloud thins and breaks	Cloud thickens, often cumulonimbus	Thinner cloud with occasional cumulus
Wind speed and direction	Speed increases and direction backs on itself	Winds continue to veer back and become strong and blustery	Winds remain steady with less backing on itself	Wind speeds increase sometimes to gale force, sharply veering	Winds are squally
Precipitation	Initially none, but rain falls closer to the front, sometimes as snow	Rain continues, sometimes heavy	Rain either stops or becomes drizzle	Heavy rain, sometimes accompanied by hail, thunder or sleet	Showers clearing

speeds in excess of 200 km per hour in summer and 400 km per hour in winter.

This activity is reflected in the depressions that affect the UK, and where differences in temperature between the air masses either side of the Rossby wave and jet stream are greater, more intense storms develop.

In Britain, 1997 saw a deep depression that produced very strong winds and intense rainfall. It was classed as a 100-year event. 1998 and 2000 again saw intense storm activity, which led to questions being asked about whether the overall frequency of such storms was the result of global warming. Polar ice melt possibly lowers the temperature of the polar air mass, bringing about greater differences between it and the tropical air mass it meets over the North Atlantic, so resulting in more extreme weather conditions.

A case study of the 2000 storms

Autumn 2000 was the wettest since records were first kept in 1766, with 503 mm of rain falling. In England and Wales, October saw 188 mm of rain and November recorded 182 mm, leading to a figure that was 251 mm more than that expected in an average autumn.

The first series of frontal systems swept over the country between 9 and 12 October, when a complex low pressure cell developed between Northern Ireland and Scotland, which was accompanied by heavy rain and wind, moved south. In Kent and Sussex it led to 100–150 mm of rain falling between 11 and 12 October. Further depressions continued to track over the country leading to the ground becoming saturated and flooding being widespread.

A further cyclogenesis (depression) developed on October 26 in the north-west Atlantic between Greenland and Iceland, from which an extensive cold front stretched south-westwards. From this developed a series of strong wave depressions which tracked over the UK between 28 and 30 October.

The parent low (see Figure 7) produced three ‘daughter’ depressions which tracked across the UK bringing heavy rain, strong winds and flooding.

- The first ‘daughter’ crossed on 28 October. Tropical maritime air accompanied the passage of the warm front, producing 8 mm of rain in south-east England. The following cold front, hitting Wales and then England,

Figure 7: Infra-red satellite image for 0600 UTC, 27 October 2000

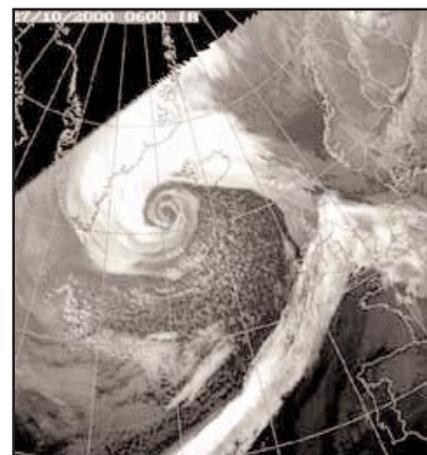


Figure 8: 0000 UTC, 30 October 2000

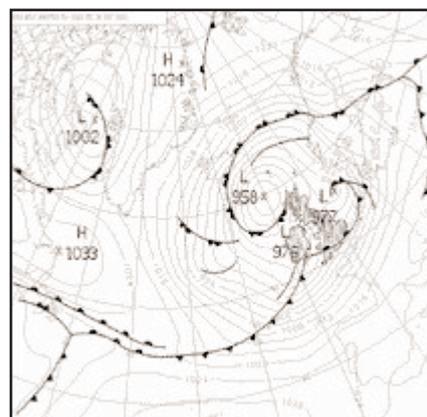


Figure 9: 0600 UTC, 30 October 2000

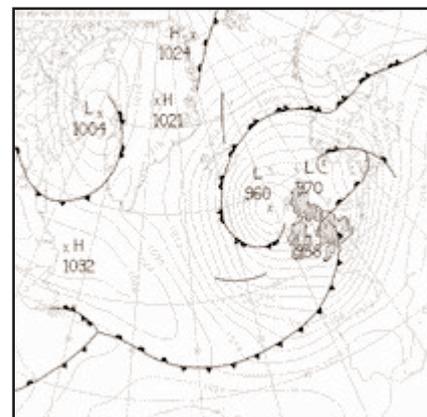
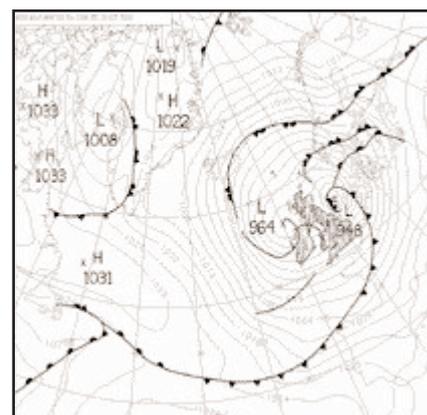


Figure 10: 1200 UTC, 30 October 2000



brought gale force winds and a tornado in Bognor Regis. In late evening the cold front had passed over the North Sea bringing cooler conditions.

- On 29 October the day started with clear skies, but depressions were gathering to the south-west. The first of these swept quickly towards the north-east, covering most of the country and producing heavy rain and strong winds, reaching 87 mph in south-west England. By midnight it too had tracked into the North Sea.
- The deepest depression was building over the Atlantic Ocean by midnight, and 30 October was to experience the strongest of the depressions (see Figures 8,9 and 10). The strongest winds are at the centre of the depression as a result of the steep pressure gradient between the edge and the centre of the depression. At Mumbles in South Wales, winds reached 96 mph as the cold front passed overhead, and rainfall in excess of 50 mm was not uncommon. In northern England, near the apex of the depression, where the warm and cold fronts are only separated by a small band of warm sector air, temperatures rose rapidly by 5–7 degrees C as the warm sector passed overhead, only to fall by up to 10 degrees C within an hour as polar air replaced the sector of warm tropical air. This fall in temperature led to the precipitation falling as sleet or snow instead of the rain which had been experienced elsewhere, and hurricane force winds were experienced before the storm lost its intensity as it reached the Norwegian side of the North Sea.

Conclusion

In order to understand fully the weather patterns of the British Isles, it is essential to comprehend the formation and behaviour of depressions. Not only do they dominate our day-to-day weather, but they cause most of our extreme weather events.

FOCUS QUESTIONS

1. Complete the following summary of how a depression is formed by highlighting the correct words written in **bold** script:

Where the warm air meets the colder polar air it gradually slides **up/over/below** the **lighter/denser** air mass, the boundary between the warm and cold air producing a **gentle/steep** angle with the ground surface. All along this invisible boundary called the **warm front/cold front**, the warm moist air is **heated/chilled** and clouds begin to form.

At **high/low** altitudes the clouds are thin wispy bands of **stratus/cirrus**, while at lower altitudes **stratus/cirrus** clouds are formed, followed by **nimbostratus/cirrus** clouds. From these clouds steady rain falls. Where there has been no ascent of the warm air and it is still in contact with the ground, the sky is **clear/overcast**.

At the rear of the warm sector, **cold/warm** air pushes forward and causes the remaining air in the warm sector to rise. Thus all **warm/cold** air will have been lifted off the ground. This is the **cold front/warm front** and is characterised by the development of **cirrus/cumulonimbus** clouds from which sometimes heavy, clearing showers fall. Once all of the warm air has been lifted off the ground an occlusion is formed and this is usually marked by **thick/thin** cloud cover and more persistent rain.

In time the occlusion and the whole of the depression will pass over, often to be replaced by a similar such system, especially between **April and September/September and April**, the time of most depression activity.

2. Using Figure 6, describe the changing conditions by observers A and B as the depression passes overhead. Discuss cloud cover, type, wind direction and speed and any changes in temperature that may be experienced.
3. Construct a series of diagrams to show how a depression develops, evolves and dies.
4. Visit the Meteorological Office web site www.metoffice.gov.uk to investigate the use of satellite images by weather forecasters.
5. Study the weather affecting your area for a week and note the changes in wind speed and direction, cloud cover and precipitation.