AQA Geography GCSE

3.1.1.3: Weather Hazards

Detailed Notes

Global Atmospheric Circulation

The way our **atmosphere** circulates around the Earth impacts **global weather and climate patterns**, as the movement of air around the globe influences the **temperature** and **humidity**.

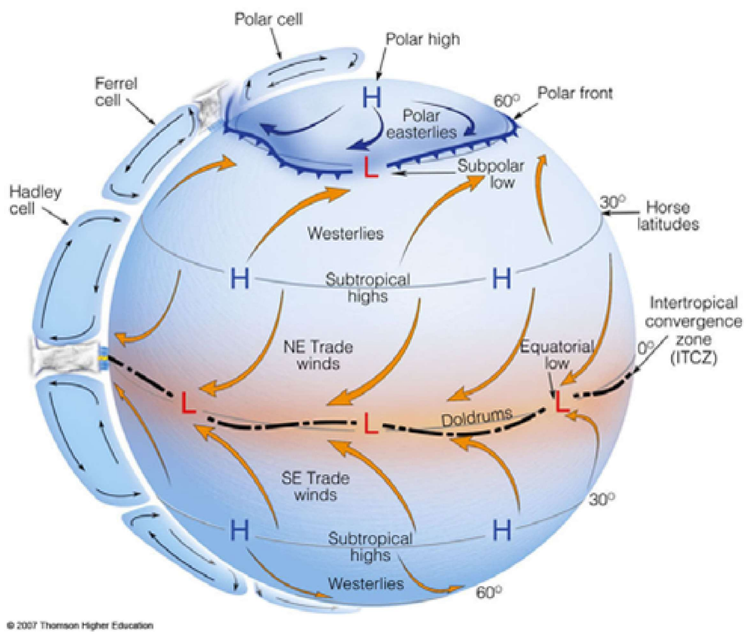
What is Atmospheric Circulation?

The **atmosphere** is the layer of air **surrounding the Earth's surface** which extends **hundreds of kilometres high**. Our atmosphere contains different **gases** (such as oxygen, nitrogen, water vapour and carbon dioxide), water droplets and particles.

Within the Earth's atmosphere, the air is **constantly moving** in **different directions** because of the sun's **energy**, differences in **pressure**, and the **rotation** of our Earth. These movements cause air to **circulate** around our world, following generally quite **predictable** movements. These **patterns** can be **illustrated** by a model of **global atmospheric circulation**.

General Atmospheric Circulation Model

The Global Atmospheric Circulation Model can be seen in the diagram below.



There are **three** distinct patterns of **air circulation** on either side of the equator (0°). These circular air movements are called **cells** (which are the blue sections with black arrows in the diagram). The three cells are:

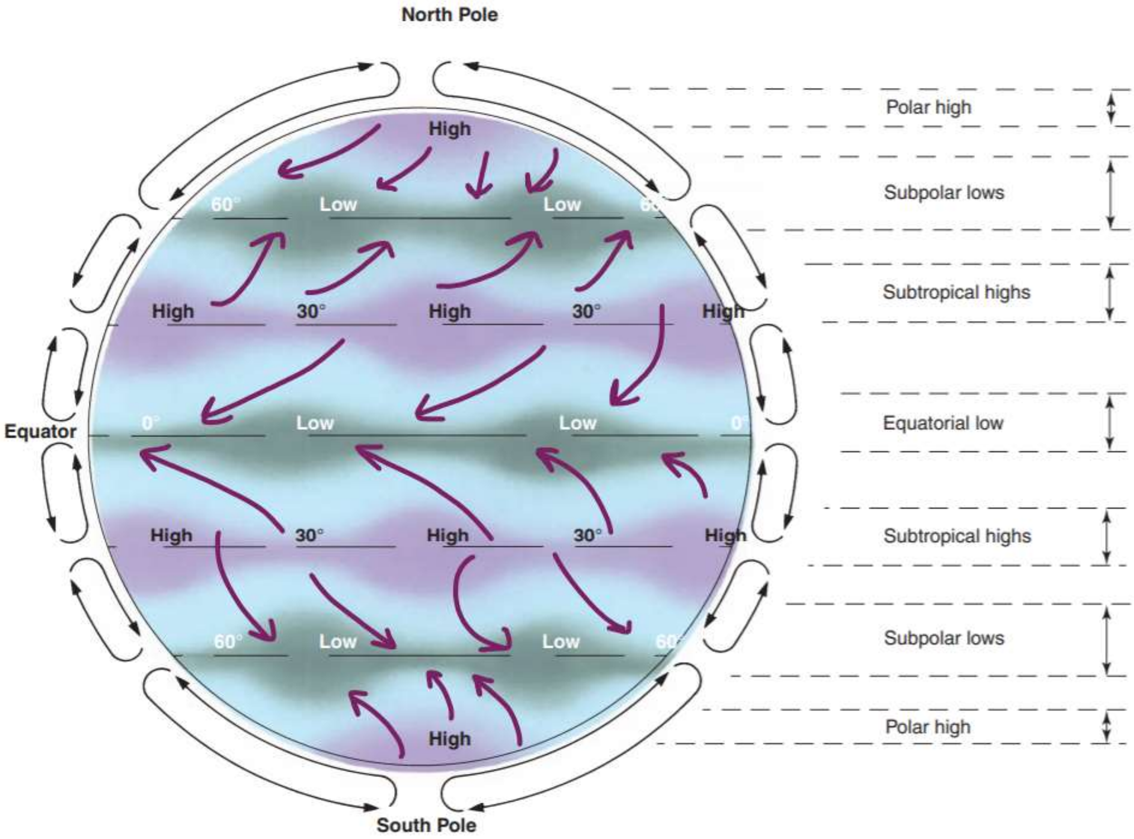
- ➔ **The Hadley Cell:** At the **equator**, hot, moist air rises, moves to higher latitudes (30°) and sinks.
- ➔ **The Ferrel Cell:** At around **60°** either side of the equator, moist air rises, and travels to lower latitudes at around 30° where it sinks, along with air travelling from the equator.
- ➔ **The Polar Cell:** At 60° north or south of the equator, moist air rises, and travels to the poles (90°), where it sinks.

Pressure Belts

These air circulations create **different areas of pressure**.

- When air **rises**, it creates an area of **low pressure underneath**.
- When air **sinks**, it creates an area of **high pressure**.

A diagram of the **global pressure belts** can be seen below.



(Source: adapted from Cengage Learning)

One way to remember these patterns is to think of it like this - when the air is **sinking**, there are obviously more air particles **pushing downwards**, meaning there would be **higher pressure here**.

In contrast, if air is **rising**, the pressure will indeed be **lower** as the air particles aren't **pushing down**.

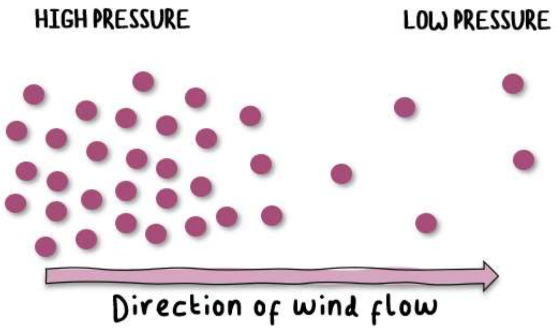
Pressure belts are formed across the globe.

➔ In general, there is **low pressure** at the equator and at 60° either side of it due to the **air rising** here. It rises the most here due to the heat from the sun being most concentrated along the equator.

➔ There is **high pressure** at the poles and 30° either side of the equator due to air sinking here. This is because the air is colder here as it's further away from the sun so is heated less.

What about Wind?

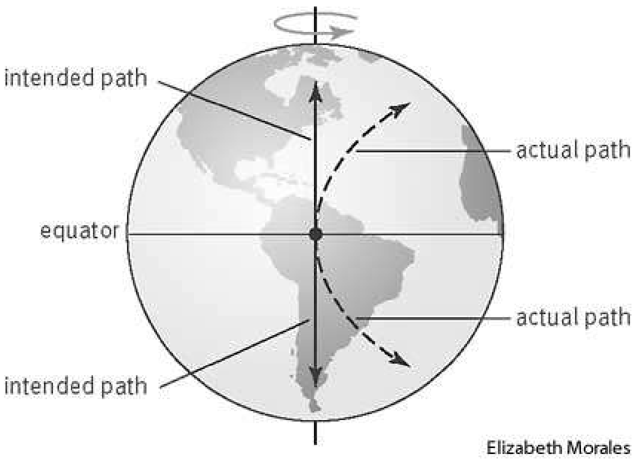
Wind is created when air particles **move**. Air particles will always move from an area of **HIGH PRESSURE** to an area of **LOW PRESSURE**.



This pattern can be seen in the **atmospheric circulation diagrams on the previous page**; the arrows will always move **from high pressure areas to low pressure areas**. For example, the patterns of surface wind move **from** 30° which is high pressure **towards** the **equator** which is **low pressure**.

However, you may also notice that **these winds do not move in a straight line**. Instead, the winds are **deflected** in different directions. This is because the **earth is spinning**, so the winds end up travelling in a curved direction.

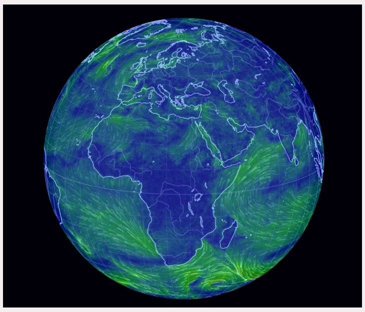
This spinning effect is known as the **Coriolis Effect**. So, the winds are **deflected right** in the northern hemisphere, and **left** in the southern hemisphere.



Thinking Further: Global Winds

[This website](https://earth.nullschool.net/#current/wind/surface/level/orthographic=-332.76,14.64,275) allows you to look at the **global surface winds** in real time. Try to spot the **overall patterns** that you can see on the **atmospheric circulation models**, but also spot any differences in these trends.

Hopefully you can see that **surface winds are not always that simple**, and sometimes don't stick to these patterns.

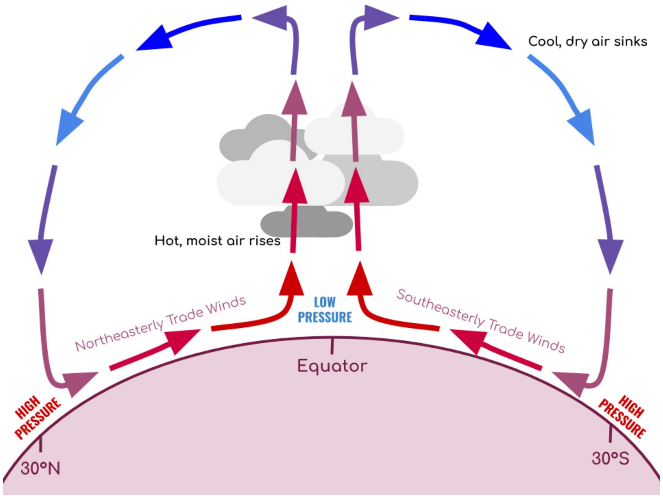


https://earth.nullschool.net/#current/wind/surface/level/orthographic=-332.76,14.64,275

How Does Atmospheric Circulation Affect Climate and Weather?

Pressure belts and surface winds impact the **temperature** and **humidity** in regions throughout the world.

Climate at the Equator



The sun **shines directly on the equator**, meaning it is consistently **warmer** than - for example - at the poles where the sunlight is less direct.

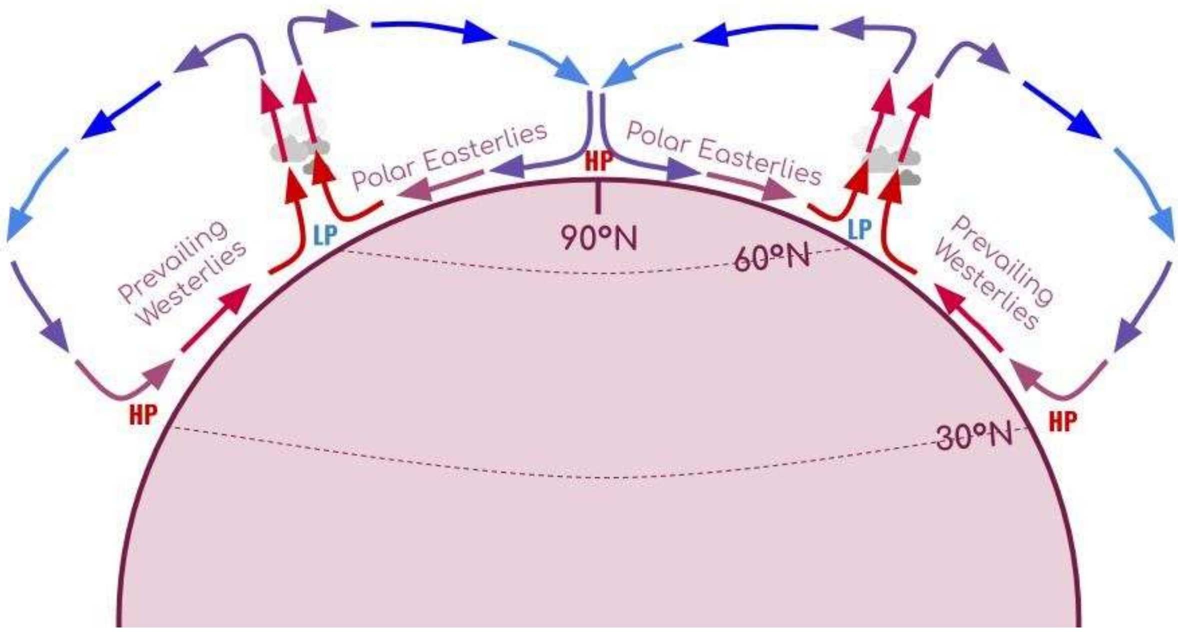
Hot, moist air rises here, creating an area of **low pressure (equatorial low)**. When the moist air rises, it condenses to form rain clouds. This causes the climate at the equator to be **humid** and **very rainy**. Tropical rainforests are found here due to the warm and wet weather.

Climate at the Subtropics

Dry air sinks at the subtropics, meaning it forms an area of **high pressure**. **Clouds do not form here** because the air isn't rising, so it is very **dry**. This is where we find many of the world's **deserts**. It is very **hot** in the day because of the intense sunlight, but very **cold** at night because there are no clouds to **retain heat**.

Climate at Subpolar latitudes

At around 60° north or south of the equator there is a **low pressure belt**, causing the climate to be cloudy and wet. The climate here is not as warm as the sun shines **less directly** than at the equator.



Tropical Storms

What is a Tropical Storm?

A tropical storm is a **very large**, spinning storm that forms in the **tropics**.

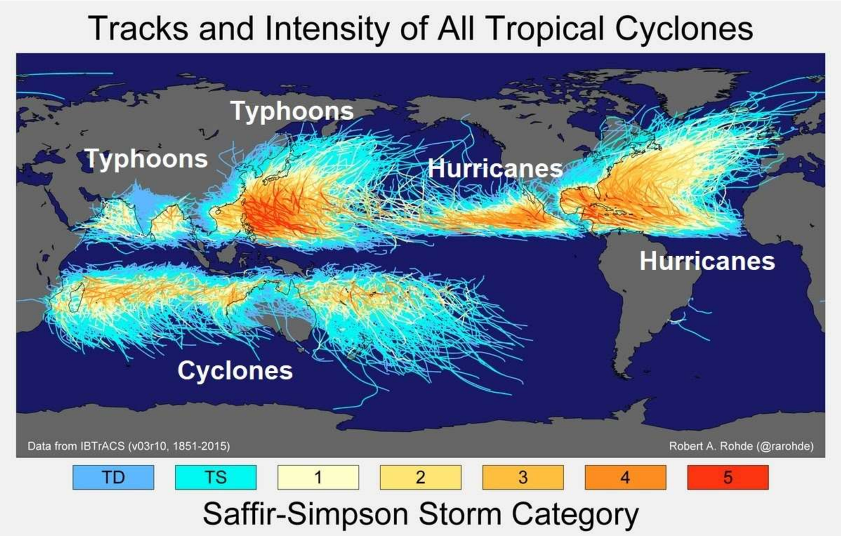
Tropical storms have **high winds** and **torrential rain**, and usually affect **small islands** and **coastal regions**.

Hurricane Florence (2018) from the International Space Station.

Global Distribution of Tropical Storms

Tropical storms are called different things in different regions:

- **Hurricane:** In the **USA** and **Latin America/The Caribbean**
- **Cyclone: Australia (Oceania)** and **Madagascar**
- **Typhoon: India**, **Japan** and **the Philippines**



Causes of Tropical Storms

Tropical storms need **very specific conditions** to form, meaning they will only form in **certain areas.** Tropical storms form between **5 - 30° north or south of the equator**, in warm oceans.

- **Temperature:** Ocean temperatures must be around **26 - 27°C** and at least 50 metres deep. Warm water provides the storm with **energy**. This is why storms form during late summer, when the ocean has had time to heat up.

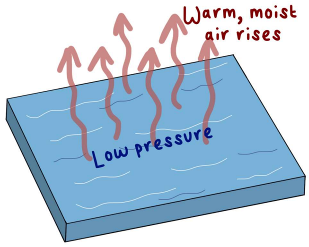
- **Air pressure:** Must be in areas of **unstable air pressure** - usually where areas of **high pressure** and **low pressure** meet - so that warm air rises more readily and clouds can form (this air must also be humid for cloud formation). Warm air rises because it is **less dense** than cold air.

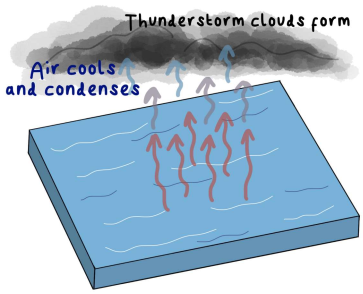
- **Wind shear:** Winds must be present for the **swirling motion** to form, but not too strong or the storm system will be **ripped apart** in the early stages.

- **Rotation:** Tropical storms only form around the equator, between 5 - 30 ° either side of the equator, but tropical storms **will not form on the equator**. The **Coriolis Effect** is the effect of the **Earth's rotation** on weather events. The storm spins because the Earth is spinning; but there is **no Coriolis Effect at the equator**, hence why these storms will only form a certain distance away from it.

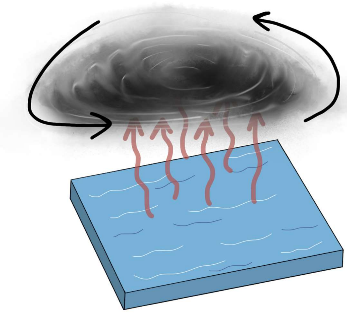
Tropical Storm Formation

1. **Warm, moist air rises**, leaving an area of **low pressure below**. This causes warm air from the surroundings to **move into this low pressure area** and rise too. Overall, **warm air is constantly rising** and accumulating in the atmosphere.

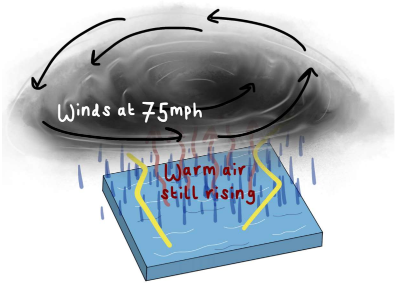




2. When the warm air rises, it eventually **cools**. This moist air will then **condense** and form large **thunderstorm clouds**.



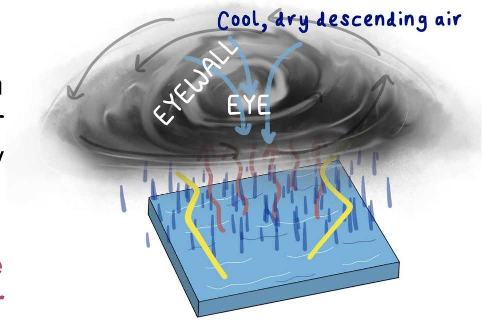
3. The whole system is spinning due to the **Coriolis effect**. In the **southern** hemisphere, the storms spin **clockwise**; in the **northern**, **anticlockwise**.

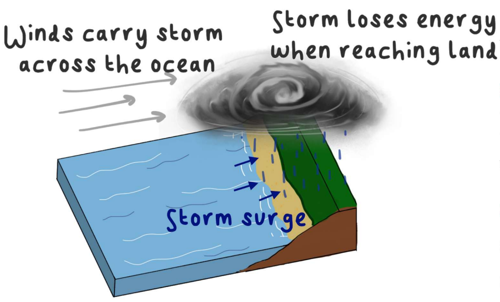


4. The **constant additions of energy** from the warm air causes the storm to spin faster and generate higher wind speeds. At **75 mph** the storm can be classed as a category 1 **tropical storm**.

5. The storm develops an **eye** in the centre. This is an area of **extremely low pressure** where cool, dry air descends. The weather within the eye is relatively **calm and cloud free**.

Surrounding the eye is the **eyewall**, the most **intense and powerful** area of the storm. **Warm, moist air rapidly rises** here, with extremely **high winds and torrential rain**.



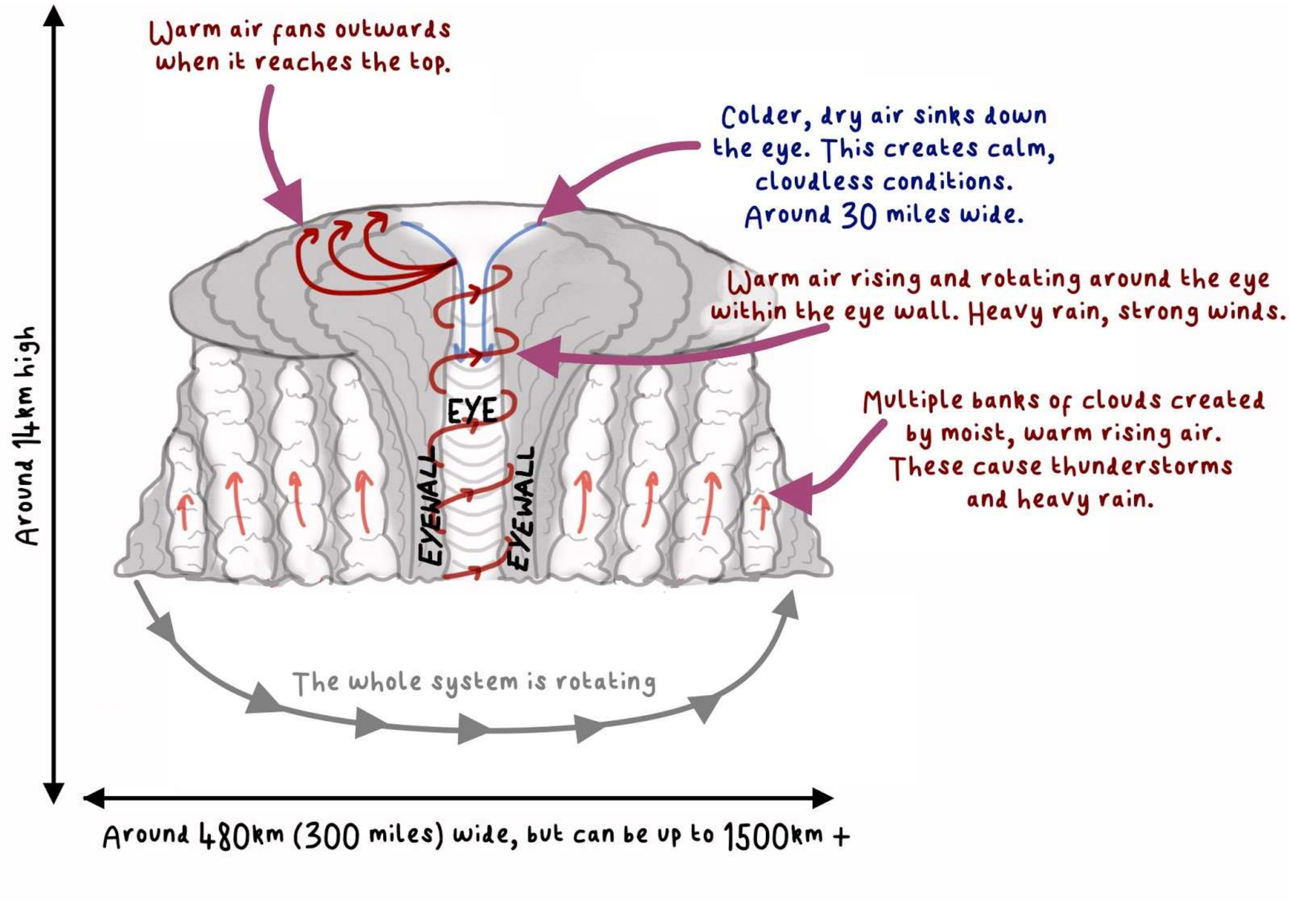


When the tropical storm reaches a coast, the **low pressure and high winds** will cause a large amount of sea water to be pushed onto the coast, which is called a **storm surge**.

When the storm reaches **land**, it no longer has a **supply of energy** (warm, moist air from the sea) and the eye eventually **collapses** and the storm **dissipates**. Heavy rain can persist for days.

Tropical Storm Structure

There are **complicated processes** going on **inside a tropical storm**. Below is a **cross-section of a tropical storm** (imagine if you cut a tropical storm in half and looked in the middle).



There is a huge contrast between **weather conditions** in the **eye** and in the **eyewall:**

- The eye: the eye is characterised by very **calm and cloudless conditions**. Inside the eye there is **extremely low pressure** (can be 15% lower pressure than areas outside of the storm).
- The eyewall: within the eyewall are the **strongest winds, thunder and lightning, and torrential rain**. In very intense storms, **sustained winds** can reach **240km/hour** (150mph), and **gusts** can exceed **320km/hour** (200mph).

The Effects of Climate Change on Tropical Storms

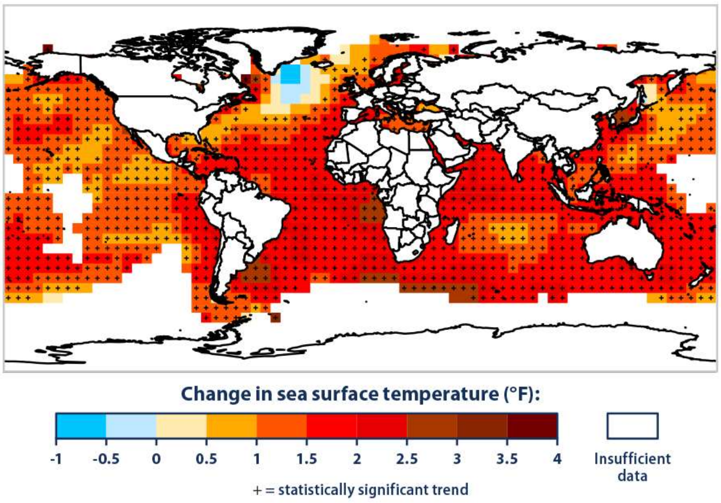
Tropical storms rely on **heat from the ocean** to develop. With **global sea surface temperatures rising**, scientists are researching how the **patterns** of **tropical storms** may be affected.

Distribution

Distribution refers to **where the tropical storms are formed**, and where they **move to**.

As **sea surface temperatures are rising** in areas where tropical storms **are not usually active**, tropical storms could potentially form **in these areas** in the future. The sea may be **warm enough** to provide **enough energy to form a tropical storm**.

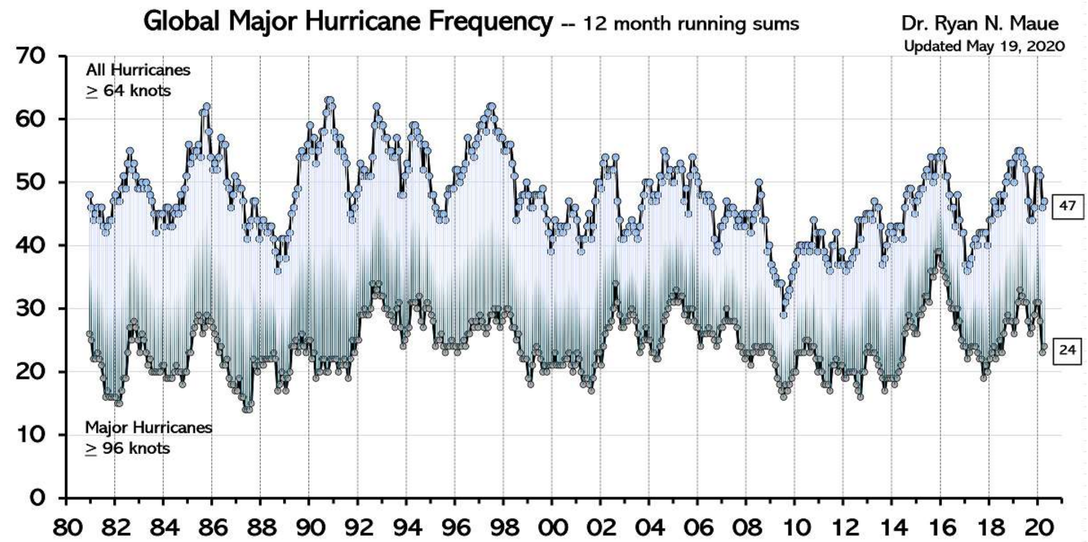
For example, in 2004, **Hurricane Catarina** hit the south-east coast of **Brazil**, which had never been struck by a tropical storm before. Sea surface temperatures were **higher than average** that year, meaning this tropical storm was able to form in the South Atlantic. With sea surface temperatures rising in the majority of places, the locations that tropical storms **typically develop** may **expand** to other regions.



(Source: https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature)

Frequency

Frequency refers to the **number of tropical storms**.



(Source: http://climatlas.com/tropical/)

Studies have shown that climate change has **not** increased the **frequency of tropical storms**. In all regions that experience tropical storms, there has been **no significant increase** in recent decades. Some studies indicate there may even be a **decrease** in the frequency of tropical storms.

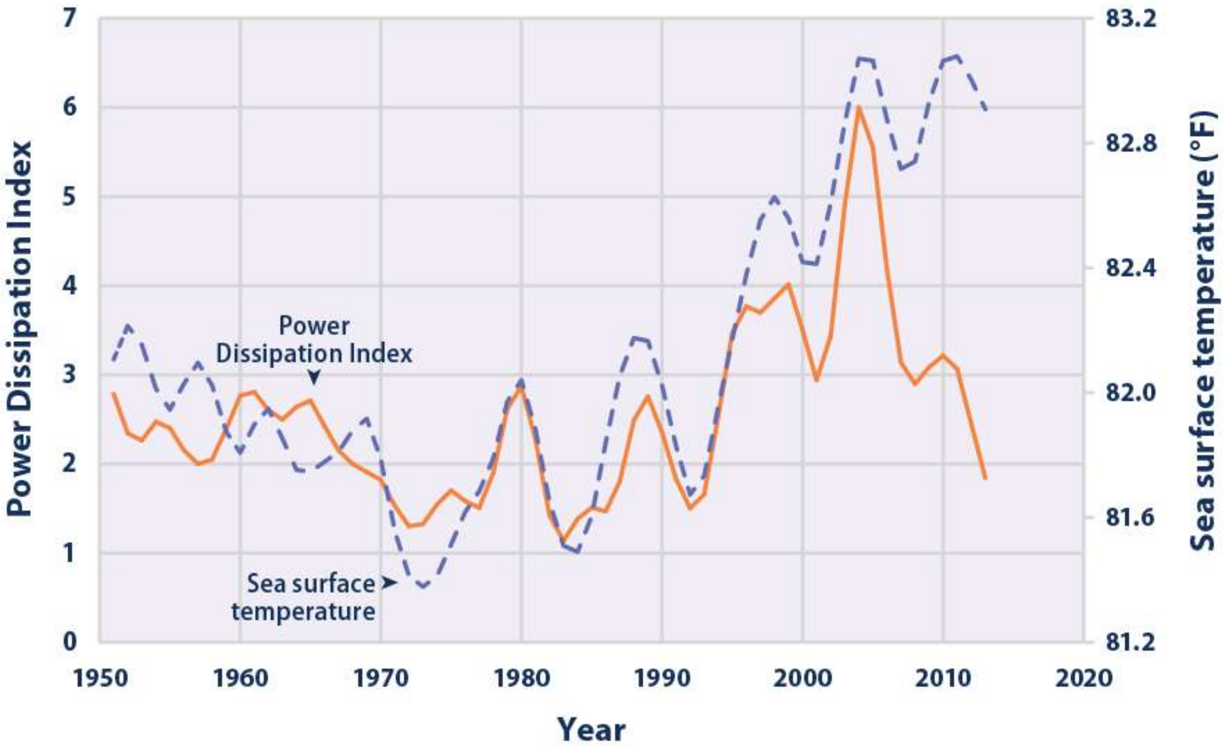
Intensity

The **intensity** of a tropical storm is how **much power** the tropical storm has (e.g. its wind speed) which is measured using a scale of 1-5. Category 1 is the lowest intensity, Category 5 is the highest intensity.

There is significant evidence to suggest that **the intensity of tropical storms** has been increasing in recent years due to **climate change**.

Below is a graph showing the relationship between the average **Power Dissipation Index** of tropical storms compared with **sea surface temperatures**. It appears that as sea surface temperatures rise, the intensity of tropical storms are rising also.

An increase in the number of Category 4 and Category 5 hurricanes is **likely in the future**, and wind speeds of the average tropical storms are projected to increase by **up to 10%** in the future.



(Source: www.epa.gov/climate-indicators/climate-change-indicators-tropical-cyclone-activity)

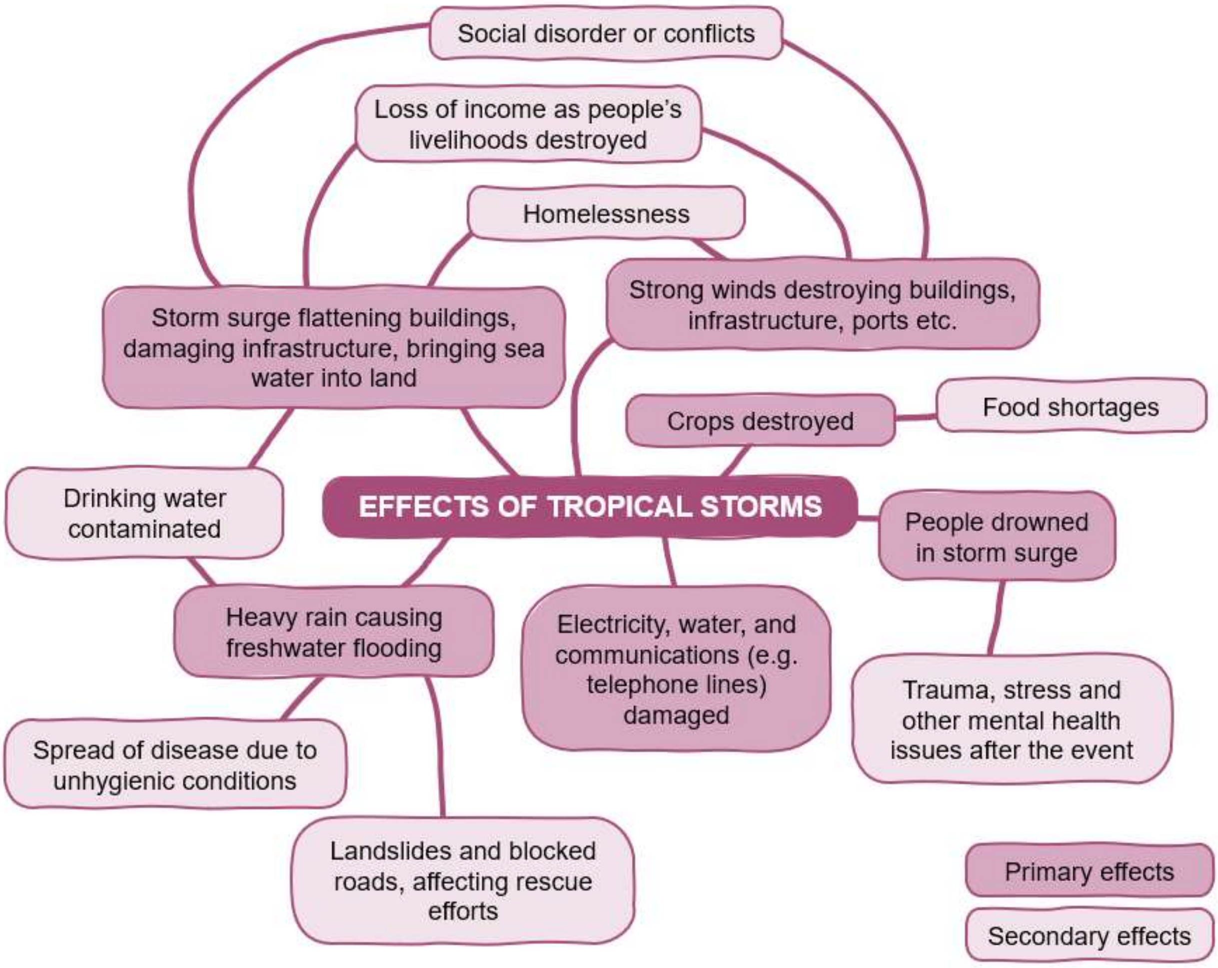
Power Dissipation Index (PDI): A measure of a tropical storm's **intensity**. PDI accounts for a tropical storm **strength**, **duration** and **frequency**. The points on the graph are a **five year average**.

Effects of Tropical Storms

Tropical storms can be very damaging to **people, the environment, and the economy**. Like with **tectonic hazards** (3.1.1.2) the effects of a tropical storm can be divided into **primary effects** and **secondary effects**.

Primary effects: The effects that are **directly caused by the tropical storm** itself. For example, strong winds knocking over power lines.

Secondary effects: The effects that are a **result of the primary effects**. For example, landslides caused by the flooding.



The devastation of **Typhoon Haiyan**, a Category 5 tropical storm that hit the **Philippines** in **2013**. Pictured is the city of **Tacloban**, on the Philippine island of Leyte, after the typhoon hit.

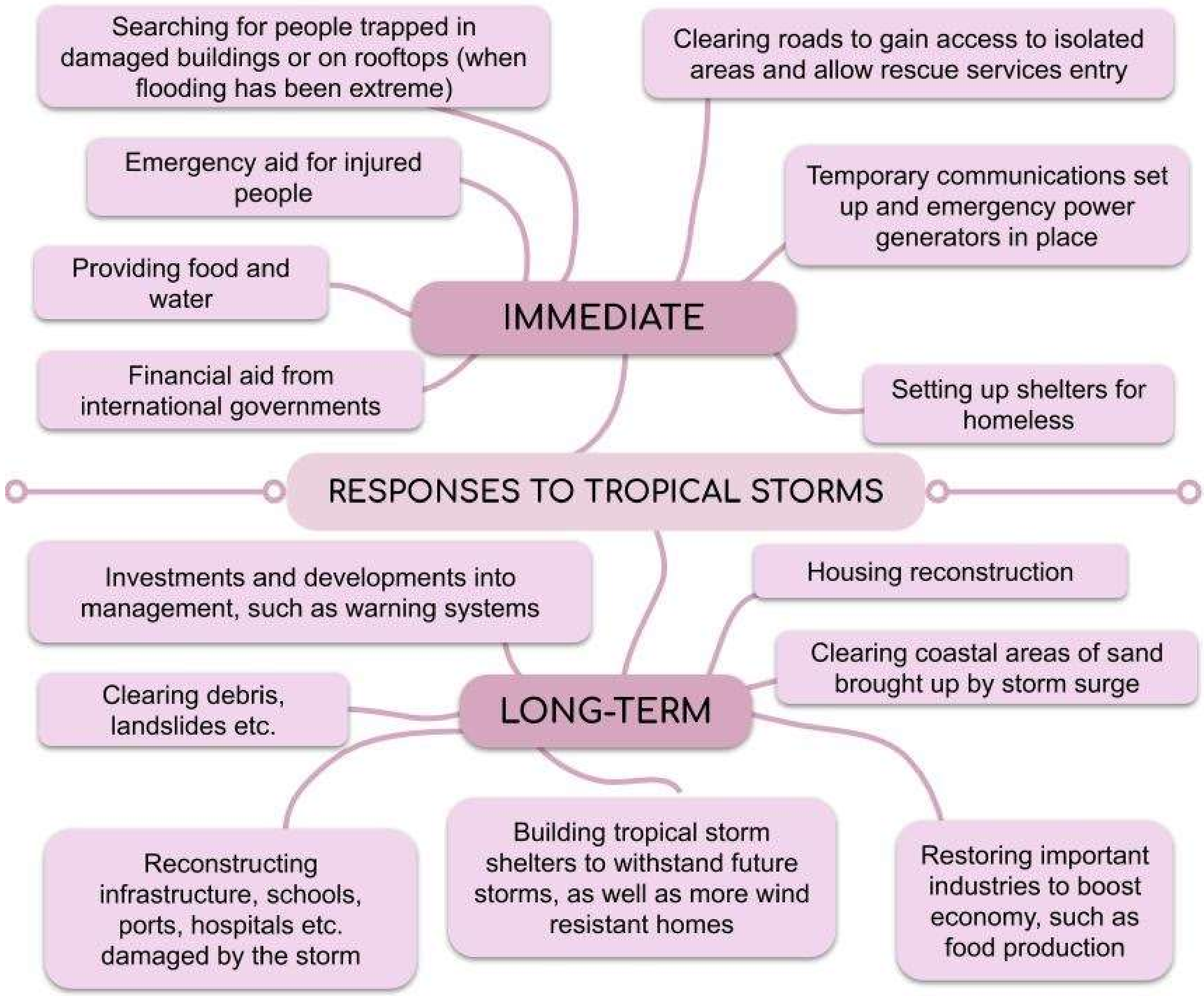
(Source: Tigeryan—iStock/Thinkstock)

The Responses to Tropical Storms

The term **'responses'** refers to how the **local community**, the **government**, and **international organisations/governments react** to a hazard so that the **effects** can be reduced as much as possible. Responses are either classed as **immediate** or **long-term**.

Immediate responses: Actions taken **as soon as the hazard happens** and in its immediate **aftermath** (hours, days, and potentially a week or so after the event). Immediate responses usually aim to **reduce loss of life** and provide **vital aid and resources**. For example: **search and rescue, medical care, food and water, shelters** for those who have lost their homes.

Long-term responses: Actions taken **after** the immediate responses when the effects of the hazard have been minimised (weeks, months, and years after the event). Long-term responses aim to **restore normality** and **reduce risk** in the **future**. For example: **rebuilding** infrastructure and homes, **cleaning up** the effects of the hazard, building **defence** mechanisms, setting up **warning systems**.



Tropical Storm Management

It is possible to **manage** the effects of a tropical storm by implementing **strategies** that prepare the population at risk. There are four ways to manage tropical storms:

- **Monitoring:** detecting and recording **warning signs** of storm formation and movement
- **Predicting:** using **monitoring** as well as **historical trends** and **computer based modelling** to predict **where** the tropical storm will hit, **when** it will hit, and the **duration** of the storm.
- **Protecting:** Increasing the **resistance of a population** to the tropical storm by **physically designing** things that will **withstand the effects.**
- **Planning:** Having **systems** in place, such as evacuation routes, so that if a tropical storm does occur, the population is prepared in advance.

Monitoring

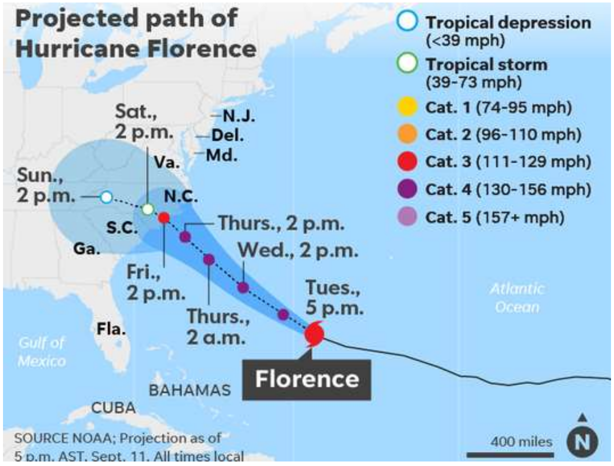
As tropical storms form away from land, it is possible to track **cloud formations** and **movements** using **satellite technology**. Scientists monitor the areas where **tropical storms usually form** to see if one is on the way. Also, it is possible to monitor the **route a tropical storm is taking**, to see if there is potential for the tropical storm **to make landfall**.

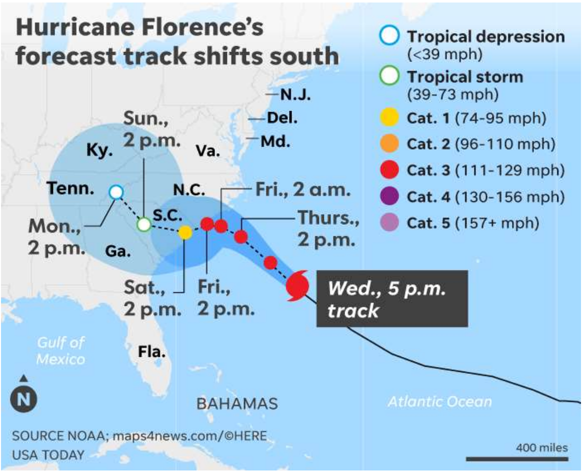
Hurricane Igor forming off the coast of the Caribbean, 2010.

Predicting

Using **monitoring** and **computer modelling**, It is possible to predict **the route** a tropical storm is going to take as well as **its intensity** up to days in advance. The population can be informed of **the estimated time** that the tropical storm will hit them, and can take action accordingly.

These predictions become **more reliable** as the storm gets closer. For example, below is a typical **predicted** forecast of a tropical storm (Hurricane Florence, 2018). The forecast to the left was made a day earlier than the forecast to the right. Notice how the forecast changes as the tropical storm gets closer.





It is also possible to predict **how high a storm surge will be** by analysing the intensity of a storm, which is important for making decisions regarding who is at **risk** and needs to be **evacuated.**

Protection

Building and infrastructure design can help to **protect people and property** from **the effects of tropical storms**. For example:

- **Sea walls** can be built on coast lines to **block storm surges**
- **Storm drains** can be constructed to divert water after **high levels of rainfall** to reduce the risk of flooding
- Power lines, doors, windows, transformers etc. can be **reinforced** to be resistant to **high winds**
- Houses can be built **on higher ground** or even on **stilts** to reduce flooding risk.

This house is an example of a 'hurricane-proof' home. It is built on **stilts** to ensure it is high up and away from the dangers of flooding. The building is made out of **concrete** which is resistant to very strong winds. Windows and doors can also be **reinforced** to be resistant to heavy winds, and resistant to **breaking** if they are hit with flying debris.

(Source: jorgefontan.com/hurricane-proof-house-design/)

Planning

Places that are frequently at risk to tropical storms usually **have plans in place** to ensure the population is safe.

- **Hazard Mapping:** Identifying the areas that are **most at risk** and taking action (e.g. coastal areas and areas near waterways) For example, ensuring **important buildings** such as hospitals and nuclear power plants are built away from high risk areas.

- **Evacuation Routes and Safety Protocols:** Creating **evacuation routes** and developing **warning systems** ensures the population is **prepared** for a storm and will be **alerted** when one is coming e.g. **hurricane sirens** signal to people that they must take shelter.

- **Raising awareness:** If the community is **aware of the risk** they face from **tropical storms**, they can **lower their risk** by planning in advance (getting important supplies, organising documents, being aware of their local shelter).

In the USA, there is a **National Hurricane Awareness Week** every year which aims to educate communities on the dangers of the upcoming hurricane system.

Weather Hazards in the UK

What is a 'Weather Hazard'?

When we talk about the **weather** of a place, we are usually referring to the **daily conditions** that a place experiences, such as the **temperature**, how **windy it is**, **how much cloud cover** there is/ how **sunny** it is, and if there's any **precipitation** (rain, snow, hail etc.).

On the other hand, the **climate** is a **long-term trend** in temperature, humidity etc. (usually calculated over a 30 year period or longer).

A weather hazard is a **weather event** that is **so extreme** it causes **risk to lives or property**. The **UK** experiences different types of **weather hazards** even though its **climate** is not considered extreme.

Types of Weather Hazards the UK Experiences

Prolonged Rainfall

Especially in winter, the UK experiences **long periods** of **rainfall**. When there is **a lot of rain** over **long periods of time**, it can cause **river flooding**. When rivers and streams **reach their capacity**, they overflow, causing damage to **properties and infrastructure**.

The picture to the right is an image taken in Cockermouth after the 2009 Cumbrian Floods. The region experienced **unprecedented rainfall**, causing **many rivers** to **overflow** and flood nearby towns.

(Source: Environmental Agency)

Thunderstorms

The UK sometimes experiences **intense thunderstorms** (usually - but not always - in the spring and summer months). Lightning strikes associated with thunderstorms can cause damage to property and can be lethal if they hit someone. Also, thunderstorms usually have **intense, torrential rainfall** which can result in **flash flooding**.

There was a period of **many intense thunderstorms** in the UK in the summer of 2014. A lightning strike took the roof off this house in Chelmsford.

(Source: https://www.bbc.co.uk/news/uk-28382702)

Extreme Cold & Heavy Snow

The UK can experience long periods of **extremely cold weather** in winter, although extreme cold events are becoming **less frequent** in recent years. Cold weather can bring **heavy snow** and **sub-zero conditions**, which are a risk to the population, especially the elderly. Snow and ice can also majorly **disrupt travel** and cause **accidents**.

In 2010, the **UK** experienced a long period of **extremely cold weather**, with a mean December temperature of -1°C. Temperatures fell to over -20°C in some places!!

Snow falling in Sheffield, 2010.

Strong Winds

The UK experiences **strong winds**, often due to the **remnants of storms** from other areas. For example, old hurricanes can travel across the Atlantic Ocean and hit the UK as a weaker storm. Strong winds can **blow over trees**, disrupt **power lines** and cause **damage to houses**.

The image to the right was taken during a period of **strong winds** in October 2013. The winds brought down a tree, crushing this car in London.

(Source: GETTY images)

Droughts & Extreme Heat

The UK experiences **long periods of extreme heat**, which can be a **risk to health** and **limit water supplies**. High temperatures can cause **heatstroke** which may be **fatal**, especially among the elderly.

In 2003, there was a very severe **heat wave** across Europe. Over 2000 people are thought to have died in the UK as a direct result.

A crowded beach during the heatwave (Source: AP)

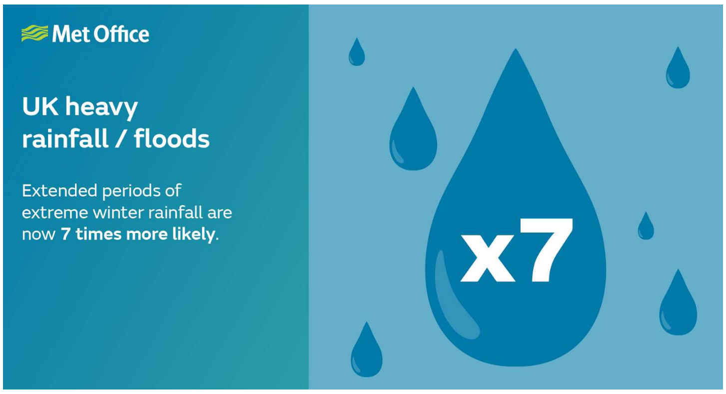
Is the Weather Becoming More Extreme in the UK?

There is evidence that **extreme weather events** are becoming more **frequent** and more **intense** in the UK. This is thought to be because of several reasons:

- There is **more energy** in the atmosphere (it is getting warmer), which fuels **storms**.
- It is getting **hotter**, which is causing more **intense** and **frequent** periods of **hot weather**.
- The way atmospheric circulation affects **moisture** and **pressure** is changing due to **climate change**, which has led to **altering precipitation patterns**.
- There is evidence that the **weather patterns** in the UK are getting **stuck** due to the changing climate, meaning we are experiencing **prolonged** weather events more frequently. The UK's weather is controlled by the **jet stream** (fast flowing air currents) that moves west to east across the UK. Sometimes, the jet stream can be **blocked** and become **stuck**, which causes **the weather patterns** to be stuck over the UK until it moves again. This can cause **heavy, prolonged rainfall** to fall, or can cause **high temperatures** for many weeks.

Below are some examples of how the UK's weather is becoming more extreme.

In the UK, rainfall has become **more intense** in recent years. Studies have shown that this may be due to **climate change** affecting **atmospheric circulation**, and altering rainfall patterns. This may lead to **flooding events** becoming more frequent and extreme. **Strong wind** and **storms** may also become more common due to the **increasing intensity** of tropical storms.



Prolonged periods of hot, dry weather are becoming more **common** in recent years in the UK. It is projected in the future that **warmer summers** will be more frequent in the UK, and **heatwaves** will be more severe as well as more frequent. The **average summer temperature** is projected to rise by 3-4°C in the UK.