CIE Geography A-level

9: Hazardous Environments

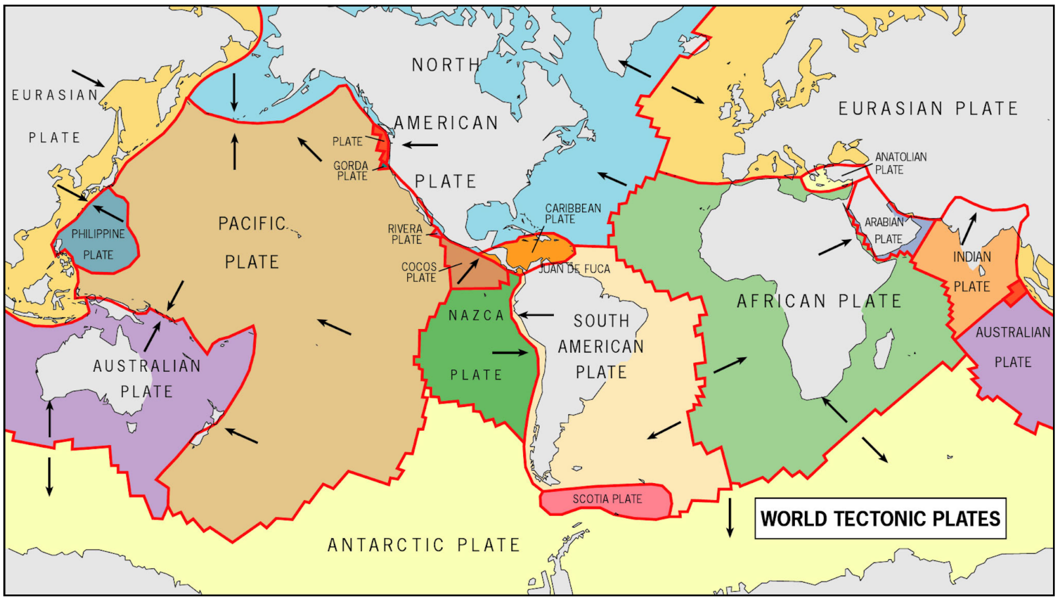
Detailed Notes

Tectonic Hazards

Global Distribution of Tectonic Hazards

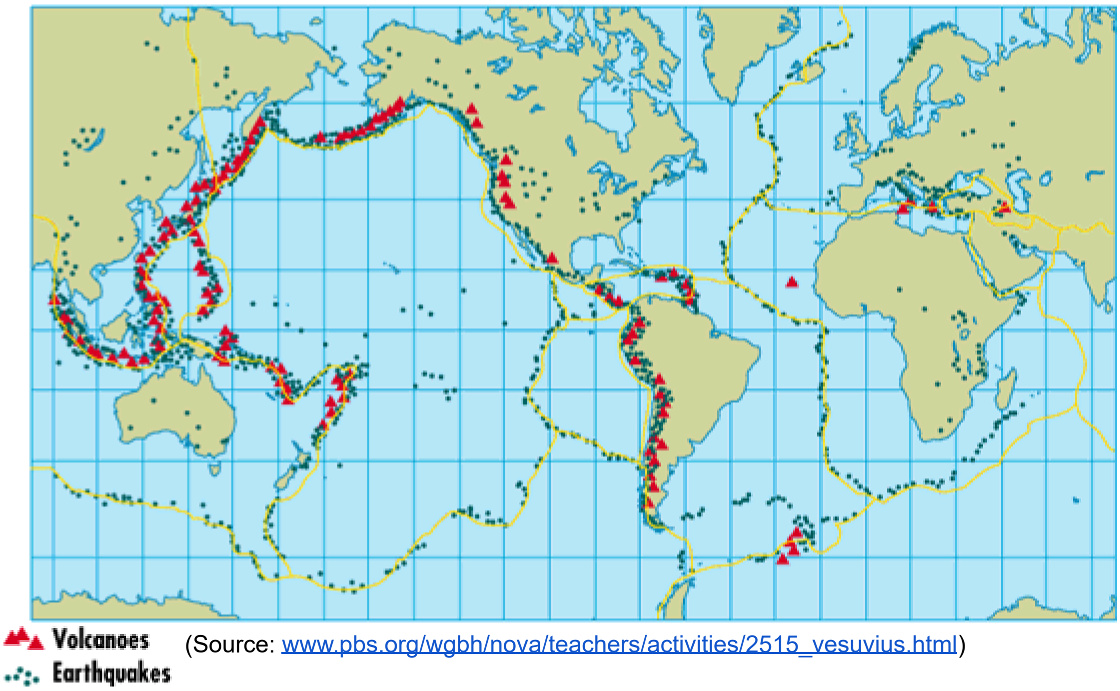
Tectonic hazards are hazards caused by **the movement of tectonic plates**. These hazards usually occur on **plate boundaries**, which is where **two tectonic plates meet each other**.

The global pattern of tectonic hazards are very clear on **tectonic plate maps**.



(Source:www.geologyin.com)

Global Distribution of Volcanoes and Earthquakes



(Source: www.pbs.org/wgbh/nova/teachers/activities/2515_vesuvius.html)

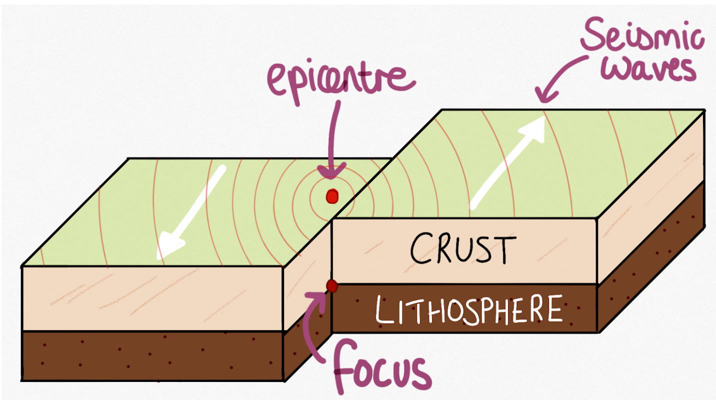
It can be seen that, on average, **volcanoes and earthquakes occur on plate boundaries**. Volcanoes occur on **convergent boundaries** (aside from when **two continental plates move towards each other**) and **divergent boundaries**. Earthquakes occur on **all types of boundaries** (divergent, convergent, or conservative).

Plates do not perfectly fit into each other, meaning they do not move in **fluid** motions. At all boundaries, plates can become stuck due to the **friction between plates**.

You can try this by moving **one palm** of your hand **against the other**, and it is clear that at some points there is more friction between irregularities and bumps, causing the hands to become stuck slightly.

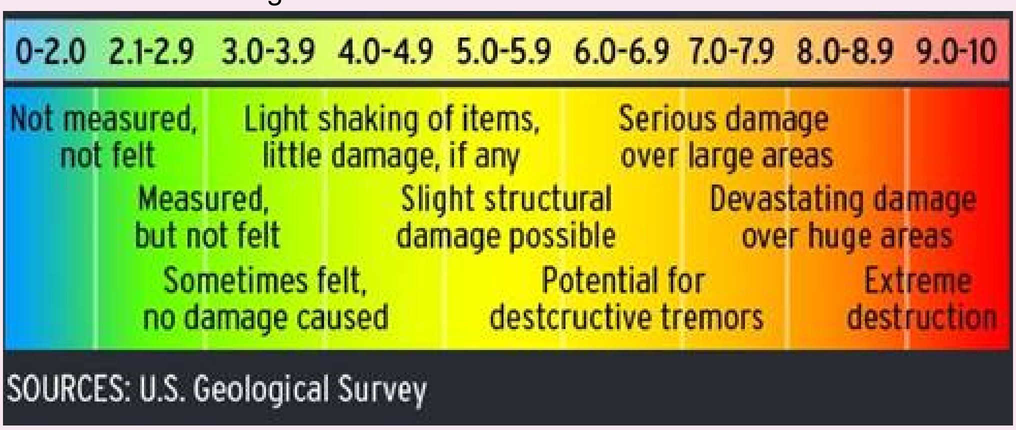
When the plates are stuck, the **convection currents** in the asthenosphere continue to push, which builds the pressure. It builds so much that it cannot be sustained and the plates eventually **give way**. All of this pressure is released in a sudden movement, causing a **jolting motion** in the plates This jolt is responsible for **seismic** movement spreading throughout the ground in the form of **seismic waves** (or shock waves).

The **focus** is the point underground where the earthquake originates from. The **epicentre** is the area above ground that is **directly above** the focus.



Magnitude

Seismicity is measures using the **logarithmic Richter Scale** which is a measure of the strength of seismic waves.



The **Modified Mercalli Intensity Scale** is also used, which is a rate of the destruction caused (originally the Mercalli scale when developed in 1884, but the name was changed after 1931 when it was modified). Unlike the Richter scale,

	the Mercalli scale has a definite end at 12 (XII as it is in roman numerals). The Mercalli scale is **subjective**, meaning sometimes it is disputed as it is dependent on human development being present rather than the strength of the seismic waves. **Modified Mercalli Intensity Scale** I – Instrumental: detected only by instruments II – Very feeble: noticed only by people at rest III – Slight: felt by people at rest; Like passing of a truck IV – Moderate: generally perceptible by people in motion; Loose objects disturbed V – Rather strong: dishes broken, bells rung, pendulum clocks stopped; People awakened VI – Strong: felt by all, some people frightened; Damage slight, some plaster cracked VII – Very strong: noticed by people in autos; Damage to poor construction VIII – Destructive: chimneys fall, much damage in substantial buildings, heavy furniture overturned IX – Ruinous: great damage to substantial structures; Ground cracked, pipes broken X – Disastrous: many buildings destroyed XI – Very disastrous: few structures left standing XII – Catastrophic: total destruction (Source: https://missnickles.wordpress.com/earth-science/) The magnitude of the earthquake is also dependent on the **depth of focus**. Conservative boundaries have the **shallowest** boundaries, meaning they are closer to the epicentre and the seismic waves are stronger. convergent boundaries usually have deeper focuses, meaning the seismic waves are spread over a larger area before they reach the epicentre. This is dependent on the earthquake.
Frequency	Earthquakes are frequent around the world and occur **every day** at boundaries. Hundreds of smaller magnitude earthquakes that cannot be felt by humans occur every day, whereas the larger earthquakes are less frequent.
Regularity	Earthquakes follow no pattern and are **random** so there is irregularity between events.
Predictability	Earthquakes are almost impossible to predict. **Microquakes** may give some indication but the magnitude cannot be predicted as how strong they are is **random**.

Hazards caused by earthquakes:

- **Shockwaves** (seismic waves) - When two plates move side by side, friction builds up and pressure increases; this pressure is stored as **potential energy**, it cannot move so it just builds up. When the pressure becomes too much, the plates eventually move.

  All of the energy that has been built up must go somewhere, so it is transferred into **kinetic energy**, which is released and vibrates throughout the ground. The further away from the focus, the weaker the shockwaves, as the energy is transferred into the surroundings.

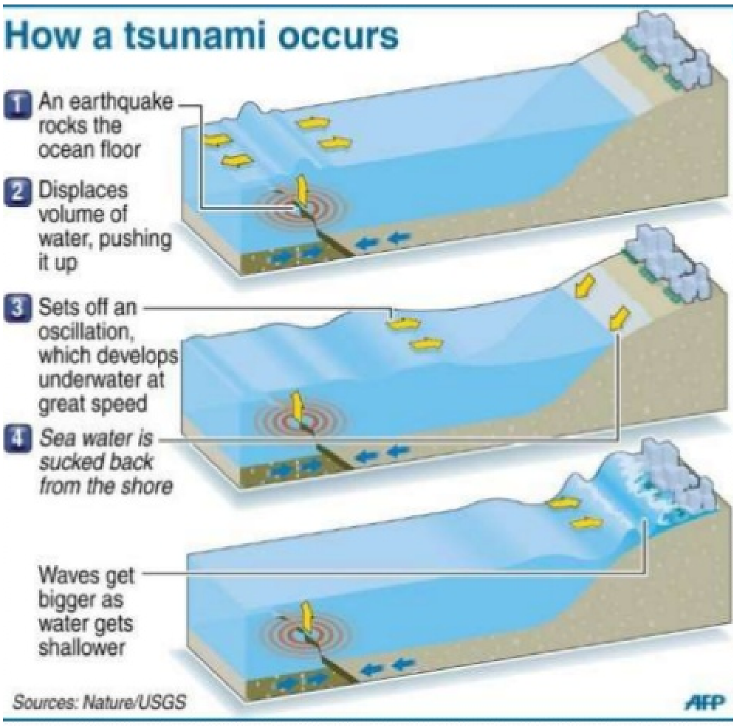
  This shaking alone causes many hazards, such as buildings and infrastructure collapsing.

- **Tsunamis**

When an oceanic crust is jolted during an earthquake, all of the water above this plate is **displaced**.

The water travels fast but with a low **amplitude** (height).

As it gets closer to the coast, the water becomes **shallower**, forcing the waves to become **compressed into a smaller area**.
This causes the waves to **slow down and gain height**, creating a wall of water that is on average 10 feet high, but can reach 100 feet.



- **Liquefaction** - When soil is saturated, the vibrations of an earthquake cause it to act like a liquid. Soil becomes weaker and more likely to **subside** when it has large weight on it.

Image: Liquefaction in Christchurch, New Zealand. Source:Stuff.co.nz

- **Landslides and avalanches** - Movement in **soil or snow** will cause it to become unstable. This can cause huge areas to **give way**, sending large amounts of debris or snow to tumble downhill. This can damage infrastructure and buildings, damage the environment, and poses a **huge threat to life**.

(Source: blogs.agu.org/landslideblog)

EFFECT	TYPE OF SEISMIC HAZARD: Environmental	Economic	Social	Political
Primary	- Earthquake can cause **fault lines** which destroy the environment - Liquefaction	- Businesses destroyed - Immediate payout for response	- Buildings **collapse**, killing/injuring people and **trapping** them - Homes destroyed	- Government buildings destroyed
Secondary	- **Radioactive materials** and other dangerous substances leaked from power plants - Saltwater from tsunamis flood **freshwater** ecosystems - Soil **salinisation**	- **Economic decline** as businesses are destroyed (tax breaks etc.) - High **cost of rebuilding** and insurance payout - Sources of income lost	- Gas pipes **rupture**, starting fires which can kill - Water supplies are contaminated as pipes burst, spreading **disease** and causing floods - Tsunamis which lead to **damaging flooding**	- Political unrest from food shortages or water shortages - Borrowing money for international aid - Can be initial chaos and '**lawlessness**' e.g. looting

RESPONSE AND RISK MANAGEMENT TO SEISMIC HAZARDS

PREVENTION

The majority of seismic hazards cannot be prevented. Earthquakes and tsunamis will occur regardless.

Liquefaction of soils can be prevented through soil stabilisation (gravel columns can be put in the ground).

Avalanches can be prevented through controlled explosions.

PREPAREDNESS

Earthquake prone areas (such as Japan) have extensive awareness strategies and education in place e.g. Drop, Cover, Hold On.

Earthquake warning systems and tsunami warning systems after an earthquake.

Evacuation plans and training.

MITIGATION

Search and rescue, immediate emergency aid, evacuation (short term).

Demolishing older, unsafe buildings.

Tsunami wave breaks and sea walls.

ADAPTATION

Move away from area at risk.

Capitalise on opportunities, such as encouraging tourism.

Insurance if living in places of risk.

Changing lifestyle choices e.g. moving valuable items so they cannot fall.

Building specially designed 'earthquake proof' buildings.

VOLCANOES

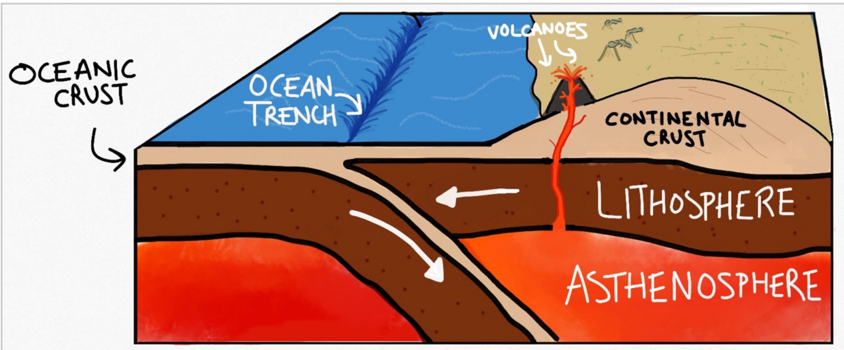
Volcanoes occur on plate boundaries where **plates melt** and **lava erupts** through a plate. Alternatively, they may occur on hotspots too.

Volcanoes on convergent plate boundaries

Volcanic eruptions on **convergent plate boundaries** are usually **explosive** due to the **high pressure** the magma is under. **Composite volcanoes**, made from **ash and lava**, are formed from these eruptions. These volcanoes form in different ways dependent on the **type of plate boundary**:

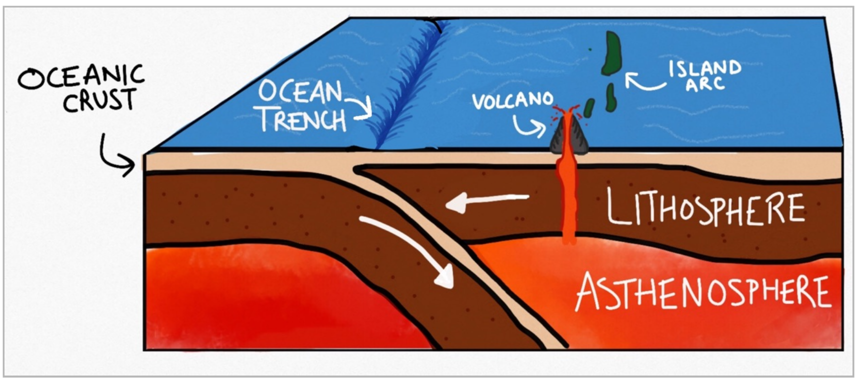
Continental and Oceanic

- Denser oceanic plate **subducts** below the continental.
- The plate subducting leaves a deep **ocean trench**.
- **Fold mountains** occur when sediment is pushed upwards during subduction.
- The oceanic crust is melted as it subducts into the asthenosphere.
- The extra magma created causes **pressure** to build up.
- Pressurised magma forces through weak areas in the continental plate.
- Explosive, high pressure volcanoes erupt through the continental plate, known as **composite volcanoes**.



Oceanic and Oceanic:

- Heavier plate **subducts** leaving an ocean trench. Fold mountains will also occur.
- Built up pressure causes **underwater volcanoes** bursting through oceanic plate.
- Lava cools and creates new land called **island arcs**.

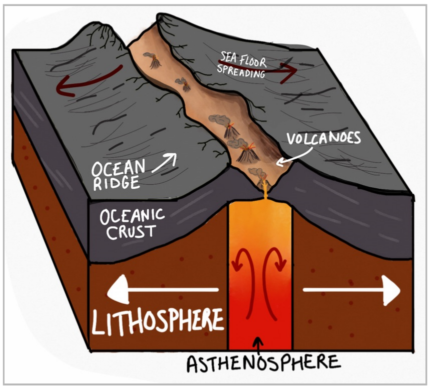


Volcanoes on divergent plate boundaries

Volcanic eruptions on **divergent plate boundaries** are usually **effusive** as the magma is under less pressure, so the **lava** flows more freely. **Shield volcanoes**, made from **mainly lava**, are formed from these eruptions. These volcanoes form in different ways dependent on the **type of plate boundary**:

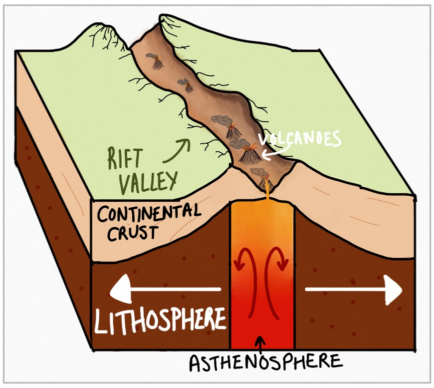
Oceanic and oceanic:

- Magma rises in between the **gap left by the two plates separating**, forming new land when it cools.
- Less explosive underwater volcanoes formed as magma rises.
- **New land** forming on the ocean floor by lava filling the gaps is known as **sea floor spreading** (as the floor spreads and gets wider).



Continental to continental:

- Any land in the middle of the separation is forced apart, causing a **rift valley**.
- Volcanoes form where the magma rises.
- Eventually the gap will most likely fill with water and separate completely from the main island.
- The lifted areas of rocks are known as **horsts** whereas the valley itself is known as a **graben**.



Volcanoes on Hotspots

Hotspots are areas of volcanic activity that are **not related to plate boundaries**. Hot **magma plumes** from the mantle rise and **burn through** weaker parts of the crust. This can create **volcanoes and islands**. The plume stays in the same place but the **plates continue to move**, which sometimes causes a **chain of islands** (such as Hawaii).

Hazards caused by volcanoes:

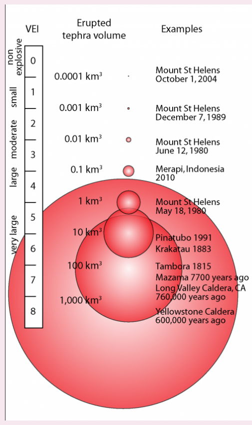
- **Lava flows** - lava can flow quickly or slowly depending on its **viscosity**. Silica makes lava **viscous** and slow, which is common in **explosive** eruptions.
- **Lahars** - caused by a number of reasons, usually by melting ice at high latitudes

Image: Lahar in the Tambour River, Guatemala. Courtesy of @ConredGuatemala / twitter

- **Mudflows** - different to lahars, which are **volcanic material**, mudflows may be triggered by the **violent shaking** that an eruption brings, or **meltwater** from the volcanic heat.
- Glacial floods (**jökulhlaups**) - when temperatures are high from lava, glaciers or ice sheets at high temperatures quickly melt and a large amount of water is discharged
- **Tephra** - any type of rock that is ejected by a volcano
- **Toxic gases** - released during some eruptions, even CO_2 can be toxic as it can replace oxygen as it is heavier
- **Acid rain** - caused when gases such as **sulfur dioxide** are released into the atmosphere
- **Volcanic landslides** - High velocity flows of debris caused when the **energy** from the eruption blows apart rocks and other material, sending it down the volcanic slope
- **Nuées ardentes**/pyroclastic flows - clouds of burning hot ash and gas that collapses down a volcano at **high speeds**. Average speeds of around 60 mph but can reach 430 mph.


Nuée ardente au Karymsky
Photo : Jean-Pierre Kloster

Magnitude	**Vulcanicity** is measured using the **Volcanic Explosivity Index(VEI)**. The more powerful, the more **explosive**. The scale is logarithmic from VEI 2 and onwards. Multiple features are considered when calculating the VEI, including how much tephra is erupted, how long it lasts, how high the tephra is ejected etc. Intense high magnitude eruptions are **explosive** whereas calmer, lower magnitude eruptions are **effusive**. (Source: https://volcanoes.usgs.gov/vsc/glossary/vei.html)
Frequency	Frequency of eruptions varies per volcano. Volcanoes are classed as either **active, dormant or extinct.** An estimated **50-60 volcanoes erupt each month**, meaning volcanic eruptions are always frequent (and some volcanoes erupt constantly). Usually, a higher frequency eruption means the eruptions are **effusive** whereas low frequency means the eruptions are **explosive.**
Regularity	Volcanic eruptions are regular in that the eruptions on **each type of boundary** are similar (e.g. eruptions on convergent boundaries will regularly be explosive) Sometimes eruptions may be irregular and not fit patterns.
Predictability	Regularity of eruptions can help estimate when eruptions will take place (i.e. every 10 years). Seismic activity, gases releasing, elevation etc. can all indicate an imminent eruption, but there is no **definite** predictions to a volcanic eruption.



	TYPE OF VOLCANIC HAZARD			
EFFECT	**Environmental**	**Economic**	**Social**	**Political**
Primary	- **Ecosystems damaged** through various volcanic hazards - Wildlife killed	- **Businesses** and industries destroyed or disrupted	- People **killed** - **Homes destroyed** from lava/pyroclastic flows	- **Government buildings** and other important areas destroyed or disrupted
Secondary	- Water acidified by **acid rain** - Volcanic gases contribute to **greenhouse effect** (global warming)	- **Jobs lost** - Profit from **tourism** industry	- **Fires** can start which puts lives at risk - **Mudflows** or **floods** - Trauma - Homelessness	- **Conflicts** concerning government response, food shortages, insurance etc.

Hazards can be responded to by **preventing** them directly, being **prepared** for the next hazard, **mitigating** the effects, or completely **adapting** your lifestyle to limit the hazard's effects.

RESPONSE AND RISK MANAGEMENT TO VOLCANIC HAZARDS

PREVENTION

Volcanic eruptions cannot be prevented.

Only the risk to people can be prevented by not allowing people near volcanic hazards (e.g. preventing building around volcanoes).

PREPAREDNESS

Monitoring increases the notice of volcanic eruptions, meaning warnings can be given out.

Education on volcanoes in areas of risk so people know what to do if there is a volcanic eruption.

Evacuation procedures planned.

Training response teams.

MITIGATION

Direct intervention to the volcano, e.g. concrete blocks to steer lava away from areas at risk.

Strengthening buildings that are at risk of mudflows or ash pileup.

Evacuation and exclusion zones.

Mitigating effects on health by having emergency aid and rescue.

ADAPTATION

Move away from area at risk.

Capitalise on opportunities, such as encouraging tourism.

Change profession so it is less likely to be affected by volcanic hazards.

Mass Movement Hazards

Mass movement is the large scale movement of materials on a hillslope, caused when the **stress exerted** exceeds the **internal strength of the hillslope**, causing **instability**.

Mass movement on a slope will always be **downhill** due to the force of gravity. These movements can happen over a **range of timescales**, and also depend on the **moisture in the hillslope material**, which is shown in the diagram below:

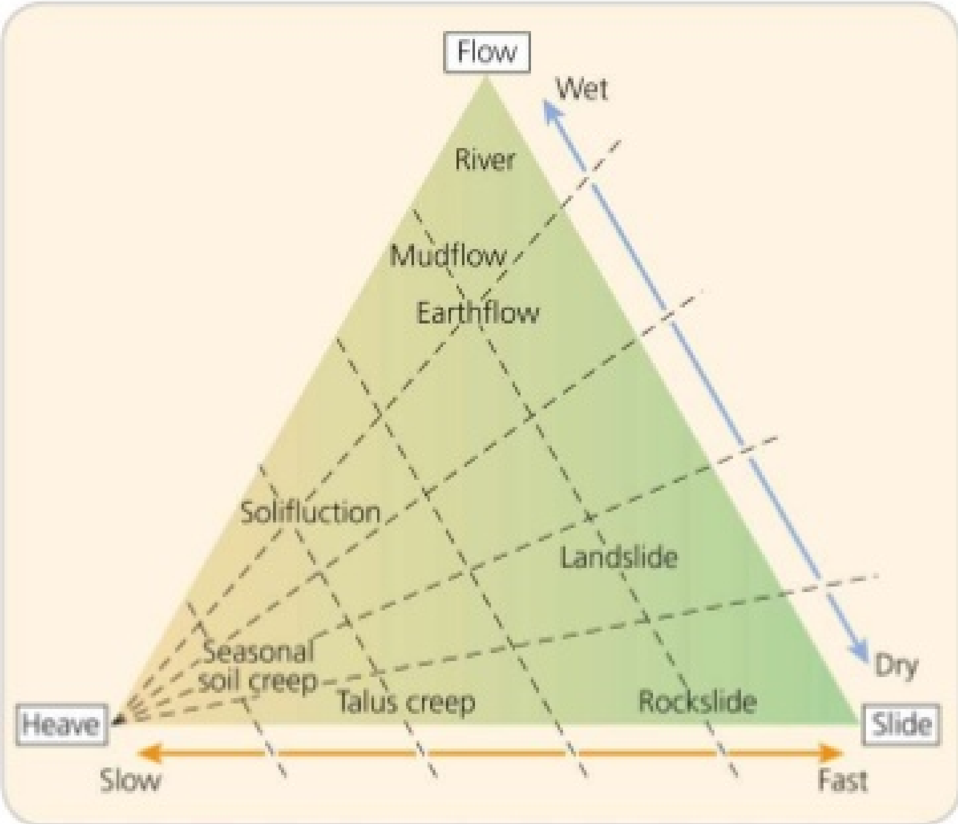


Figure 3.21 A classification of mass movements

Causes	Mass movement processes occur due to **slope instability**, causing the slope to give way. Slope instability is generally caused by either (or a combination of both): an **increase in external stress on the slope**, or a **decrease in the internal strength of a slope**. For example: ● The slope may become **too saturated**, causing the material to **give way**, e.g. mudslides. ● Weathering and erosion can **weaken** the internal strength until it can no longer bear the load on the slope, e.g. freeze-thaw processes can cause large rocks to fall off a slope (rockfalls). ● **Seismic waves** may cause mass movement processes, triggering rockslides, landslides, mudflows and other processes. ● Multiple human activities can **add stress** to a slope or **remove its strength** (e.g. deforestation can remove tree roots, which causes soil to be less cohesive and therefore at risk of mass movement).

Predictability	Mass movement processes can be **predicted and monitored** through different **technologies**. ● Precipitation levels can be measured through a rain gauge or precipitation radars, which can show the **risk** of a mass movement processes that are triggered by heavy rainfall. ● Soil moisture content can be measured through different technologies (such as a **time-domain reflectometer**). ● Changes in the surface of a slope can be detected using **radar technology**, and other systems such as an **inclinometer**, which measures the incline of a slope. ● **Seismometers** measure seismic waves going through the ground, which can indicate whether there is a risk of a mass movement process being **triggered**. Using **past data**, **predetermined indicators**, and other means, scientists can predict whether or not there is a possibility of a mass movement event through these technologies.

	TYPE OF MASS MOVEMENT HAZARD			
EFFECT	**Environmental**	**Economic**	**Social**	**Political**
Primary	- **Ecosystems damaged** through destroyed slope - **Wildlife** killed - Damage to environment	- **Businesses** and industries destroyed or disrupted	- People **killed** or injured - **Homes** destroyed - **Roads blocked** - **Infrastructure destroyed**	- **Government buildings** and other important areas destroyed or disrupted
Secondary	- Debris and mud can **block waterways** and cause other environmental issues	- **Jobs lost** - Money needed to **rebuild and clean up** - **Investments** into slope stability	- **Power outages, gas leaks etc.** caused by broken infrastructure. - **Blocked** roads - Trauma - Homelessness	- **Conflicts or disagreements** concerning government response

RESPONSE AND RISK MANAGEMENT TO MASS MOVEMENT HAZARDS

PREVENTION

Reinforcement of the slope for example:

Rock bolting

Afforestation

Pinning/nailing

Netting

Grading

These methods can also be considered **mitigation** depending on how successful they are.

PREPAREDNESS

Evacuation plans and response plans in place.

Early warning systems using monitoring techniques, so that strategies can be put in place if there are indications of mass movement. For example, seismometers.

MITIGATION

Search and rescue, immediate emergency aid, evacuation (short term).

Steel netting to catch rockfalls, debris etc.

Hazard mapping (identifying areas of low, medium, and high risk) can be used to allocate areas for building, monitoring etc.

ADAPTATION

Move away from area at risk.

Insurance if living in places of risk.

Limit activities that make slopes more unstable such as agriculture, logging, ski tourism, mining, construction etc.

Atmospheric Hazards

Large Scale Tropical Disturbances

A **tropical storm** is a **low pressure**, spinning storm with high winds and torrential rain.

Hurricane Florence from the International Space Station

There are certain **conditions** for a tropical storm to form and develop:

- **Temperature:** Ocean temperatures must be around **26 - 27°C** and at least 60 metres deep. Warm water provides the storm with **energy**.
- **Air pressure:** Must be in areas of **unstable air pressure** - usually where areas of high pressure and low pressure meet (**convergence**) - 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, but no less than **5° on either side**. 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.
- **A trigger:** a pre-existing thunderstorm, a spot of very high sea surface temperature, an area of low pressure and many other factors can act as a **trigger** for a storm to develop, which will only further develop when the **other conditions are present**.

Formation

1. **Warm, moist air rises**, leaving an area of **low pressure below**. This causes warm air from surrounding areas of higher pressure 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 **cools**, condensing into **thunderstorm clouds**.

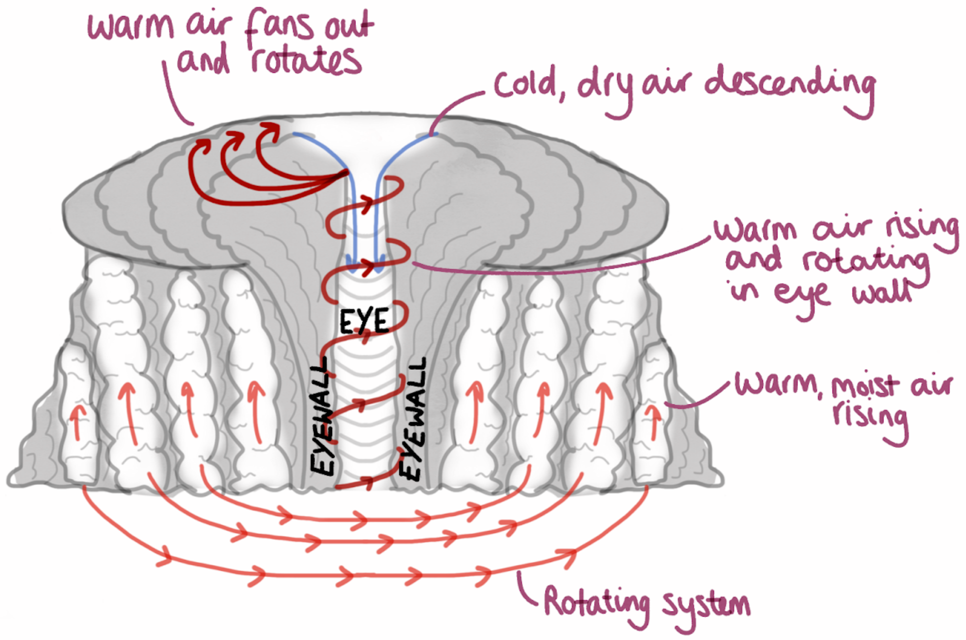
3. The whole system is spinning due to the **Coriolis effect**. In the **southern** hemisphere, the storms spin **clockwise**; in the **northern**, **anticlockwise**.

4. The **constant additions of energy** from the warm air causes the storm to spin faster and generate higher wind speeds.Furthermore, the **difference in pressure** between the **low pressure centre** and the higher pressure surroundings causes air to be **sucked in towards the centre**, enhancing the high winds. At **39 mph** the storm can be classed as a **tropical storm**.

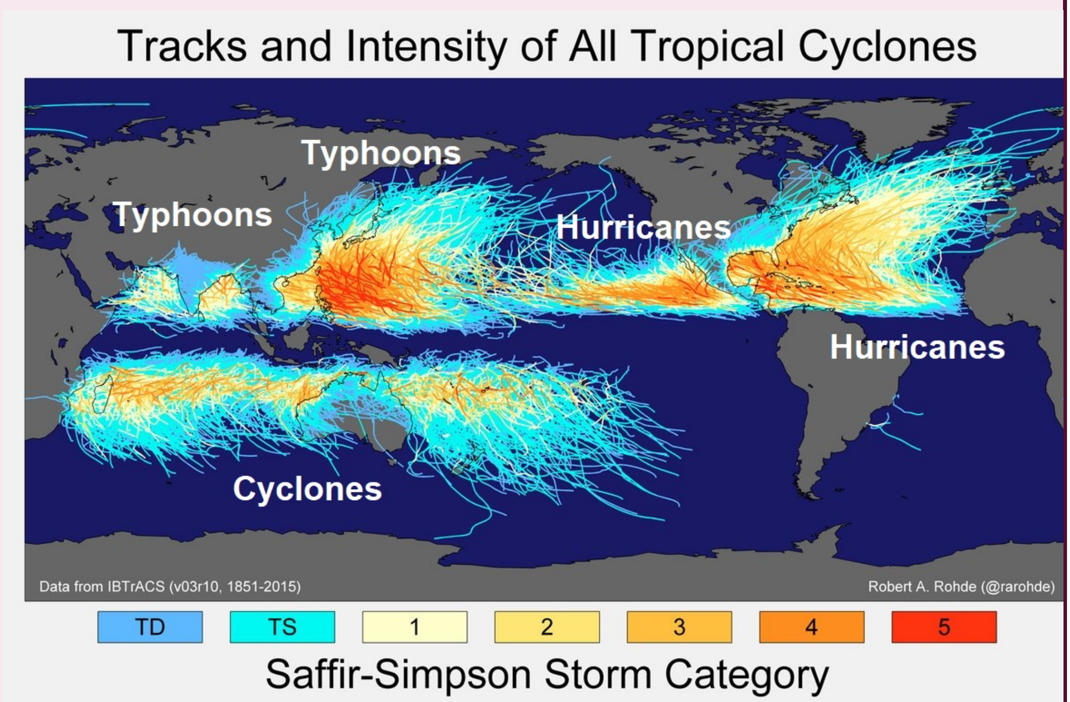
5. The **eye** of the storm is in the centre. This is an area spanning around **30 miles wide** that is of **extremely low pressure** (can be 15% lower pressure than areas outside of the storm). Cool, dry air (cool from the higher altitudes and the moisture has been transferred into the system) descends in the eye, causing the weather to be relatively **calm and cloud free**. The more intense the storm, the clearer the eye.

6. 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 winds reach **74 mph**, it becomes a hurricane/cyclone/typhoon.

A cross section of a tropical storm is thought to look something like this:



7. When the tropical storm reaches a coast, the **low pressure and high winds** will cause a large amount of sea water to be **taken into the system** and then released as a high wave called a **storm surge**.
8. When the storm reaches **land**, it no longer has a **supply of energy** (warm, moist air from the sea) and the eye eventually **collapses**. Heavy rain can persist for days.

Spatial Distribution	
Magnitude	Measured on the **Saffir-Simpson Scale** (A scale of 1-5) based on wind speed and thus power of the storm.

Frequency

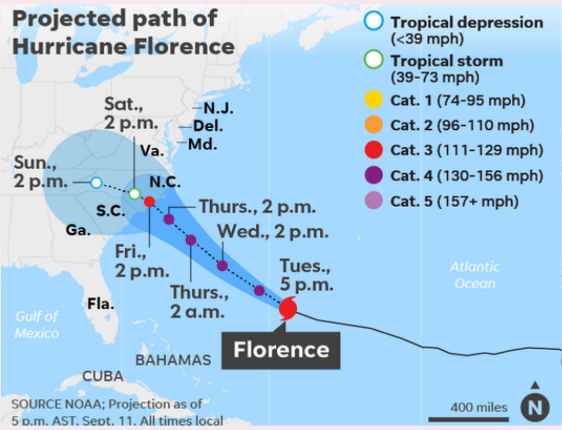
Tropical storms form in the Northern Hemisphere from June-November, and the Southern Hemisphere from November-April. The majority of tropical storms do not develop into strong storms and do not reach land. Tropical storms that are **higher magnitude** and reaching land are thought to be increasing in frequency.

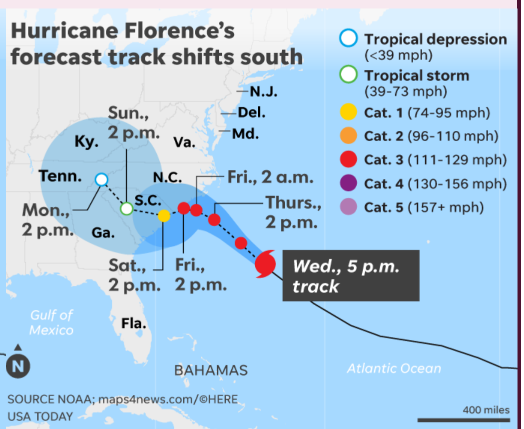
Regularity

Tropical storms are **irregular** because although they occur in the **same areas**, their path does not follow a set route - the route taken is **dependent on the storm** and the climatic conditions.

Predictability

Tropical storms form **away from land** meaning **satellite tracking** of cloud formations and movement can be tracked and the general route can be predicted. These projected path of Hurricane Florence estimates to the hour when the hurricane will hit. The first picture tracks 5 days in advance, the second picture is the day after. Note how the tracking changes within 24 hours.





The closer the hurricane gets, the easier it is to predict. Storm surges can also be predicted based on the pressure and intensity of the storm.

From past storms and climatic trends, the **probability** of a storm hitting an area can also be predicted. Scientists have predicted how many years it will take for a tropical storm to hit certain areas.

Hazards caused by tropical storms:

- **High winds** - over **300km/h** and therefore very strong. Hurricane winds are strong enough to blow a house down, and also blow heavy debris at high speeds, which can obviously cause damage and injure anyone who comes into contact.
- **Flooding** - coastal/river flooding from **storm surges** and **heavy rain**. River flooding also sends more floodwater to other places, which can cause areas outside of the tropical storm's path to flood also.
- **Landslides** - due to soil becoming **heavy** when wet with high levels of rain
- **Storm surges** - Large **rise in sea levels** caused by low pressure and high winds, pushing water towards the coast

	TYPE OF STORM HAZARD			
EFFECT	**Environmental**	**Economic**	**Social**	**Political**
Primary	- Beaches **eroded** -Sand displaced - Coastal **habitats** such as coral reefs are destroyed	- Businesses destroyed - **Agricultural land** damaged	- **Drowning** - **Debris** carried by high winds can injure or kill - Buildings destroyed	- Government buildings destroyed
Secondary	- River flooding/ **salt water** contamination - **Animals displaced** from flooding e.g. alligators -Water sources **changing course** from blockages	- **Rebuilding** and **insurance** payout - Sources of income lost - Economic decline from sources of income destroyed	- Homelessness - **Polluted water** supplies spread disease - Food shortages from damaged land	- Issues paying back international aid - Pressure for government to do more about **global warming**

RESPONSE AND RISK MANAGEMENT TO STORM HAZARDS

PREVENTION

In current climates and weather conditions, tropical storms cannot be avoided.

Strategies to mitigate climate change could prevent higher category storms.

PREPAREDNESS

Awareness through education of what to do during a tropical storm.

Evacuation plans and training.

Satellite image tracking to manage the areas that are at risk.

Storm warning systems and television broadcasts tracking the storm.

MITIGATION

Search and rescue, immediate emergency aid, evacuation (short term).

Strengthening the home through door barricades, roof strengthening etc.

Clearing loose debris before storms.

ADAPTATION

Move away from area at risk.

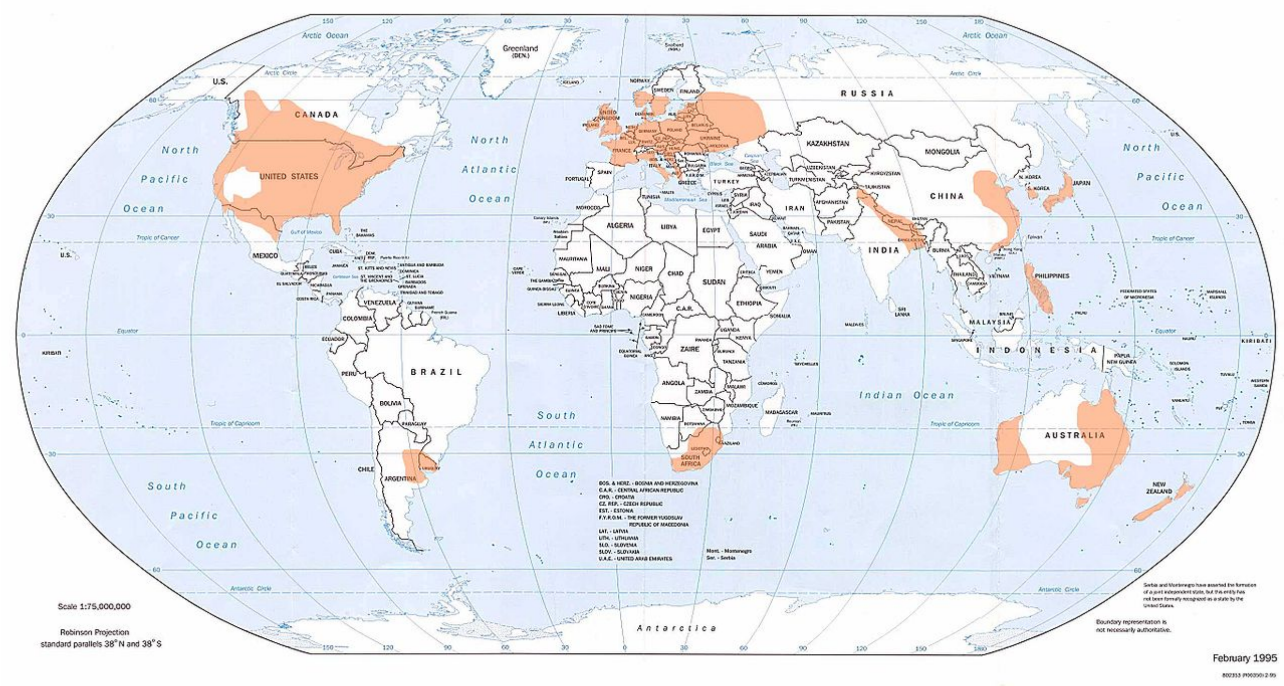
Design buildings to withstand high winds and flood damage.

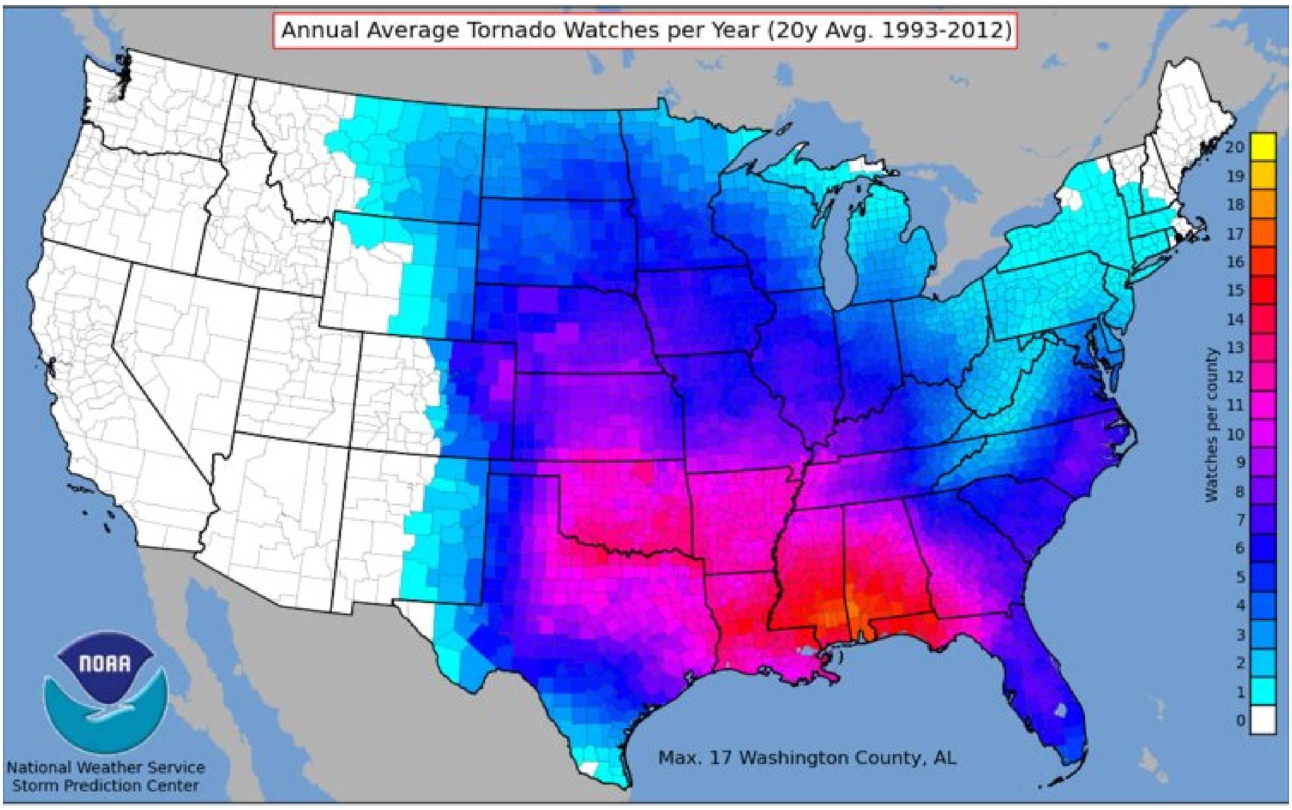
Flood defenses such as houses on stilts, coastal walls, river levees etc.

Small Scale Atmospheric Disturbances

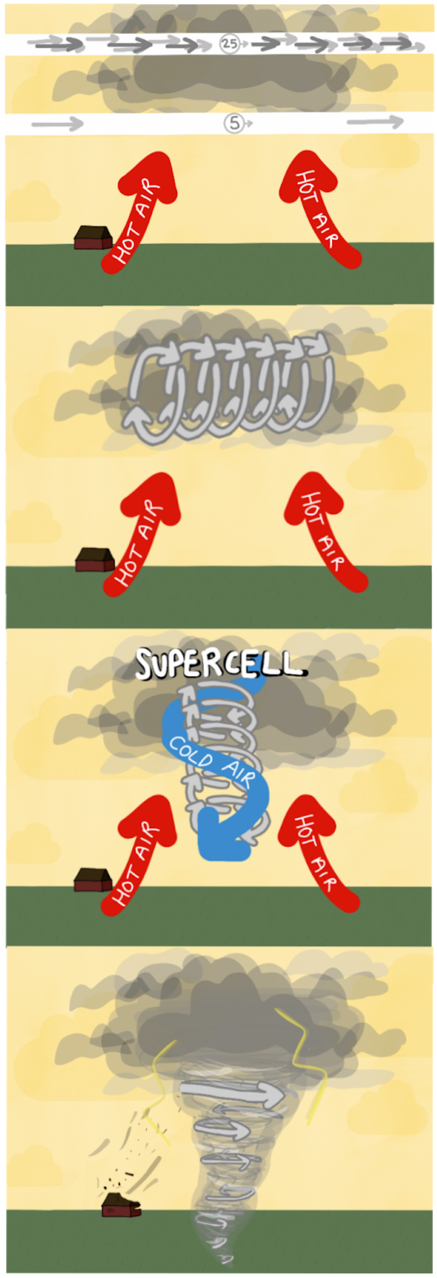
A **tornado** is a **violently rotating** moving vortex of air.

Tornadoes are found in **many areas across the world**, especially within the **middle latitudes**. Tornadoes occur most frequently in the USA, and these tornadoes are usually the most violent.





When the sun heats the ground, the **hot air** rises and then condenses into clouds. There must be an environment where **higher** winds are **stronger and faster** than the winds **lower down** for the formation to continue.



The **stronger, faster wind** may start to **roll underneath** the weaker wind, which creates a rolling horizontal **cylinder** of wind.

As the **powerful, hot updraughts of air** continue to rise, they can cause the horizontal cylinder to be forced upwards into a **rotating vertical column of air**. At this point, the storm is known as a **supercell**.

Cool, dry downdraughts of air **pull** the rotating air downwards, causing the spinning vortex to spin faster and become tighter.

If the rotating vortex of air reaches the **ground**, it is then classed as a **tornado**. Although the majority of tornadoes are small and short, some can be **extremely strong and violent**. Winds can exceed **200mph**, destroying the majority of things in its path until it eventually loses energy.

This video from the **Met Office** provides an overview of the formation with helpful illustrations.

Magnitude

The **Enhanced Fujita Scale** is used in some countries to rate the **intensity of a tornado** based on the **damage it causes**. EF0 is the lowest rating, whereas EF5 is the highest rating. The EF scale contains **28 damage indicators**, which are used to make a judgement on the level of damage.

Enhanced Fujita Scale

EF0	65–85 mph	Light damage
EF1	86–110 mph	Moderate damage
EF2	111–135 mph	Considerable damage
EF3	136–165 mph	Severe damage
EF4	166–200 mph	Devastating damage
EF5	>200 mph	Incredible damage

Frequency	Tornadoes occur **most frequently in the USA;** there are an average of 1200 tornadoes each year in the US, compared to 100 in Canada, and 300 in Europe. They are most frequent in spring, and rare in winter.
Predictability	Although predicting tornadoes is not 100% accurate, there are ways to **monitor** tornadoes and spot **warning signs**. ● **Favourable conditions** for a tornado to develop can be monitored, e.g. **intense thunderstorms**. ● **Warning signs** may be **sighted**, such as **funnel clouds**, or a **rear flank downdraft** (the movement of cold air downwards). ● Radars and weather systems can spot signs of a tornado forming, or if a tornado is already **on the ground**. A **Doppler Radar** detects a large rotating updraft (called a **mesocyclone**) in a **supercell** based on its shape.

Hazards caused by tornadoes:

- **High winds** - over **200km/h** and therefore very strong. Tornado winds are strong enough to blow a house down, pick up automobiles, and also blow heavy debris at high speeds, which can obviously cause damage and injure anyone who comes into contact.
- **Precipitation** - flooding due to extremely **heavy rain**. This can lead to other issues, such as landslides. Hail often develops in a supercell, which can grow to be **large enough to smash windows and cause serious injury**. Hail developed in supercells can be ¾ of an inch or larger in diameter.
- **Pressure imbalance** - there is a **huge pressure imbalance** between inside the tornado (**very low pressure**) and its surroundings. If a tornado is passing through a **house**, the difference in pressure inside the house compared to outside **alone** is enough to **rip off a roof** and much worse.

	TYPE OF TORNADO HAZARD			
EFFECT	**Environmental**	**Economic**	**Social**	**Political**
Primary	- Destruction of habitats from high winds and rain - Wildlife killed or injured	- Businesses destroyed - **Agricultural land** damaged	- **Debris** carried by high winds can injure or kill - Homes and other buildings destroyed	- Government buildings destroyed
Secondary	- Flooding from **heavy rain** - **Landslides** or other natural structural failures due to tornado and its storm - **Animals displaced** due to destroyed habitats	- **Rebuilding** and **insurance** payout - Sources of income lost - Economic decline from sources of income destroyed	- Widespread power failure - Psychological trauma as a result - Homelessness - Risk of injury due to destroyed house (e.g. electrical injury)	- Issues paying back international aid - Pressure on government to provide aid etc.

RESPONSE AND RISK MANAGEMENT TO TORNADO HAZARDS

PREVENTION	PREPAREDNESS	MITIGATION	ADAPTATION
There are no known ways to prevent a tornado from occurring as of yet. Risk to life can be prevented entirely by not living in tornado prone areas.	Tornado warning systems in place (e.g. tornado **watches** and tornado **warnings**) Evacuation plans, drills and training. Back-up generators, supplies etc ready in case of a tornado.	Search and rescue, immediate emergency aid, evacuation (short term). Turning off gas, electricity, and water to limit risk after a tornado. Stronger power lines to reduce power outages.	Move away from area at risk. Insurance if living in places of risk. Building infrastructure and buildings to withstand tornadoes, e.g. with reinforced roofs. Purpose built tornado shelters or storm cellars.

Hazard Perception

People have different **viewpoints** of how **dangerous** hazards are and what **risk** they pose. These perceptions are dependent on **lifestyle factors** which include **economic** and **cultural** elements. Note that these are the economic and cultural factors of **individual people** rather than an entire population's views.

Wealth - The financial situation of a person will affect how they **perceive** hazards. Wealthier people may perceive a hazard to be **smaller** as they are less **vulnerable** (e.g. they have the ability to evacuate with transport access, build stronger houses etc.). However, wealthier people may also view a risk as **greater** as there is more risk of **property damage** and **financial loss** than someone less wealthy. This is, of course, dependent on the person.

Experience - Someone who has **experienced more hazards** may be more likely to understand the **full effects** of a hazard. There are also studies suggesting that people who have experienced hazards are likely to have an **optimistic** and **unrealistic** outlook on future hazards, almost like a **'lightning never strikes the same place twice'** mentality. R. Kates describes this in his journal: **Natural Hazard in Human Ecological Perspective: Hypotheses and Models, 1971.**

Education - A person who is more educated about hazards may understand their full **effects** on people and how **devastating** they can be and have been in the past. Those who are less educated may not understand the full extent of a hazard and may not evacuate etc.

Religion and beliefs - Some may view hazards as put there by **God** for a reason, or being part of the **natural cycle of life** etc. so may not perceive them to be negative. In contrast, those who believe strongly in **environmental conservation** may perceive hazards to be a huge risk to the natural environment, especially hazards that are becoming more frequent due to global warming.

Mobility - Those who have **limited access** to escape a hazard may perceive hazards to be greater threats than they are. Whether they are in a **secluded location**, or if they are impaired with a **disability** or **illness**, those who cannot easily leave an area quickly may feel more at risk.