SL IB Geography

Your notes

5.1 Ocean: Atmosphere Interactions

Contents

5.1.1 Ocean Currents

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Distribution of Ocean Currents

- Ocean currents move the water in our oceans around the world
- There are two major types of ocean currents:
  - **Surface** currents – the currents that flow over the surface of the ocean
  - **Deep** currents – the currents deeper in the ocean, around 300 meters deep

Surface currents

- Wind is one of the main drivers of **surface current** distribution
- The wind is caused by the Atmospheric Circulation:
  - Surface currents follow common wind belt paths, such as Trade Winds, the Westerlies and the Polar easterlies
- The Coriolis Effect causes a **deflection** of the **atmosphere** as it rotates. This means that wind patterns vary:
  - The wind deflects to the **west** in the Southern Hemisphere and **east** in the Northern Hemisphere
  - Ocean currents flow in the deflection direction – currents will spiral clockwise in the Northern Hemisphere and anti-clockwise in the Southern Hemisphere
  - These swirling currents are called **gyres** and occur on either side of the equator
  - In a **low-pressure system** (where storms form), ocean currents spiral in the opposite direction (clockwise in the southern hemisphere and anticlockwise in the northern hemisphere)

Image showing the deflection of wind from the Coriolis Effect

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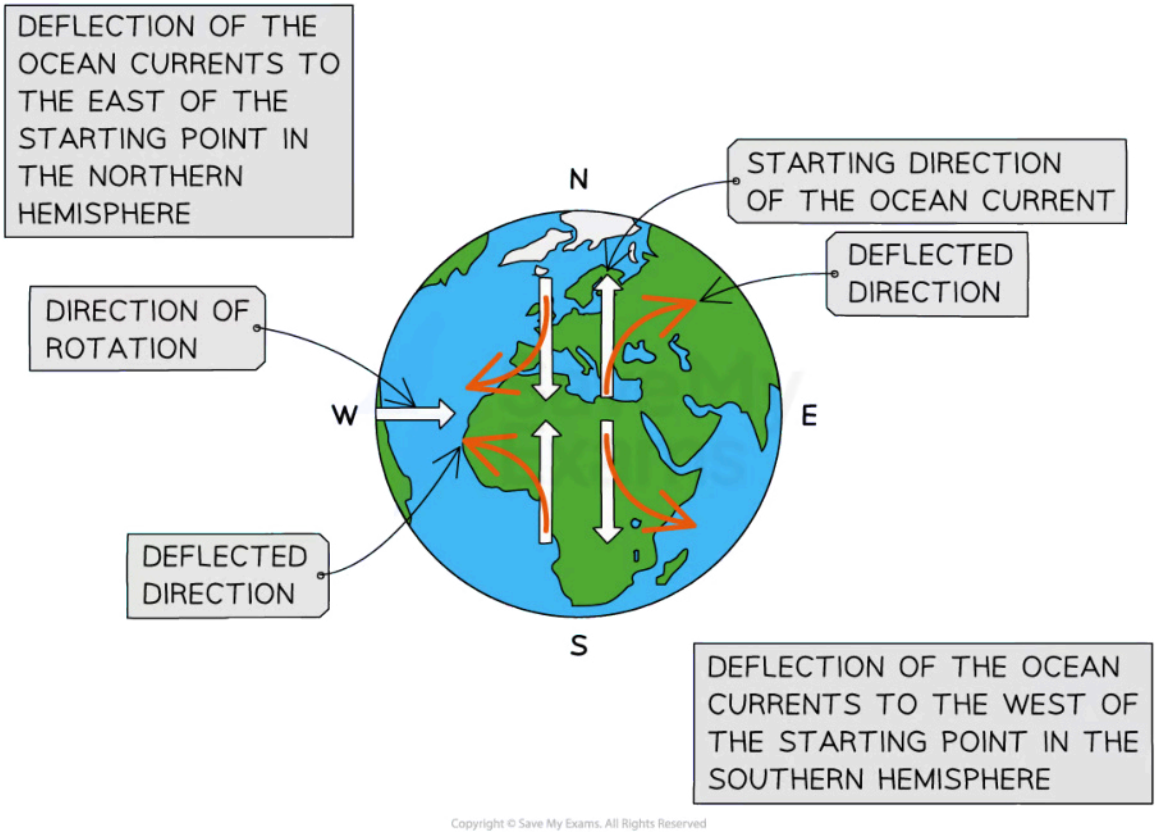

Image showing the deflection of wind from the Coriolis Effect

- **Ocean topography,** e.g. ocean basins or other landmasses, can also affect surface currents
- The main drivers of **deeper** ocean currents are **temperature** and **salinity**

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Importance of Oceanic Conveyor Belts

- The **Oceanic Conveyor Belt**, powered by **Thermohaline Circulation,** drives the movement of deeper currents:
  - The Oceanic Conveyor Belt moves waters from the north to the south of the world and all the way back again, just like a conveyor belt
- Ocean water moves in a **cyclical** pattern. Warmer waters flow downwards, and colder waters flow upwards
- **Heat** and **salinity** control Thermohaline Circulation:
  - Heat and Salinity affect water **density**
  - Cold water is more dense than warm water
  - The higher the salinity, the denser the water
- Starting in polar areas, the cold and salty (dense) water sinks
- Surface water then replaces this sinking water
- This process repeats, forming the deep currents
- These currents then make their way around the world, into areas where the water will heat up again
- This warmer (less dense) water returns to the surface, moving further around the world and eventually reaching the point where the process started
- The cycle repeats
- One full loop of the Oceanic Conveyor Belt could take anywhere between **100 and 1000 years**

Map showing thermohaline circulation process

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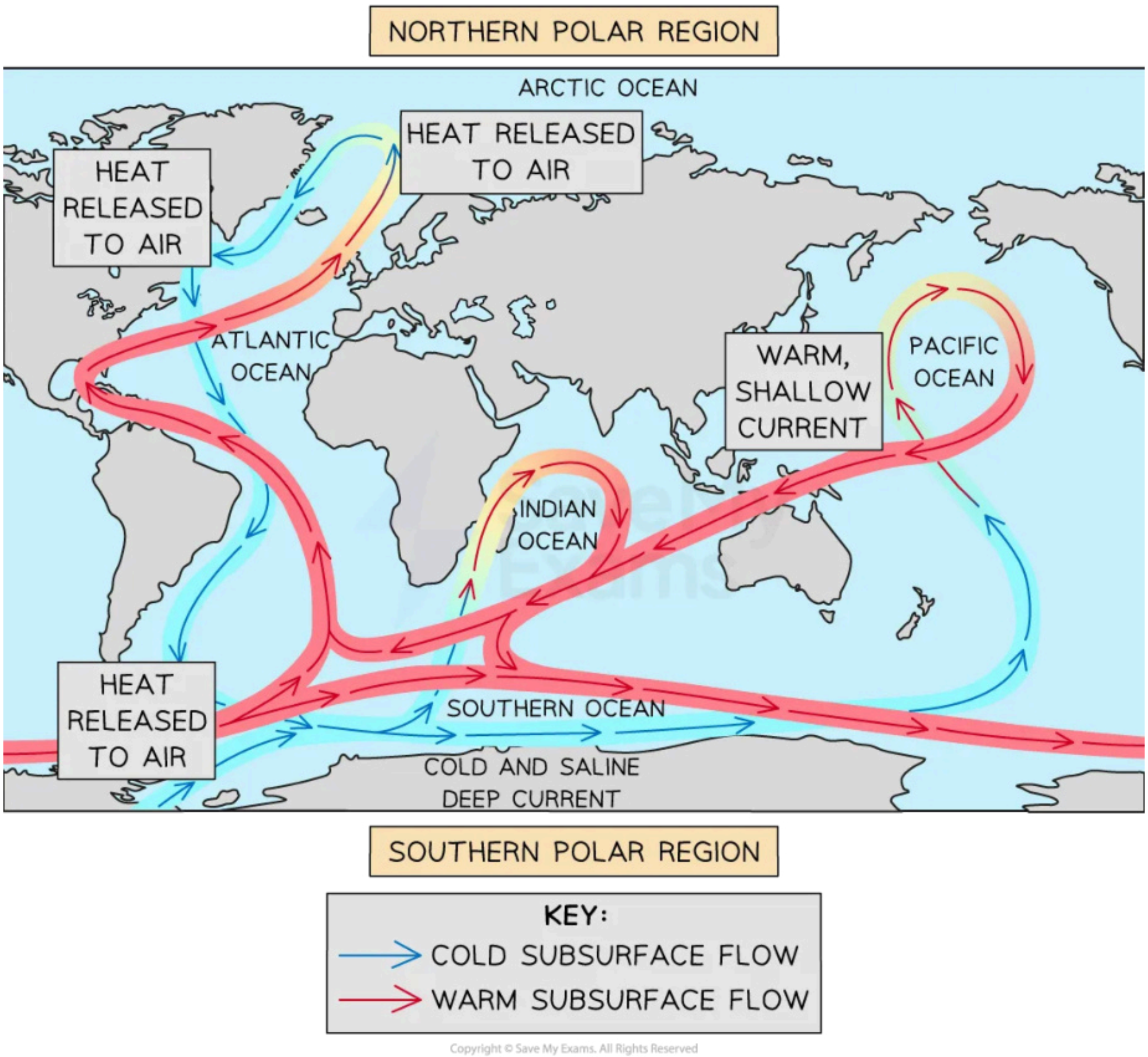

Image of the Thermohaline Circulation process

- Without the Oceanic Conveyor Belts, **average temperatures** across the world would drop
- Weather events like **Hurricanes** would become more common
- Marine life, like fisheries, would be severely affected

Nutrient & Energy Transfers in Ocean Currents

- The Coriolis Effect can cause **upwelling**:
  - The wind and atmospheric deflection cause the water on the surface of the ocean to blow away
  - **Upwelling** occurs when deep ocean currents rise upwards to replace surface waters
  - Upwelling brings nutrient-dense waters to the surface, which is perfect for species like plankton. This provides a food source for other marine life
  - Upwelling at the coast can provide a perfect climate for fishing industries

Diagram showing the process of upwelling

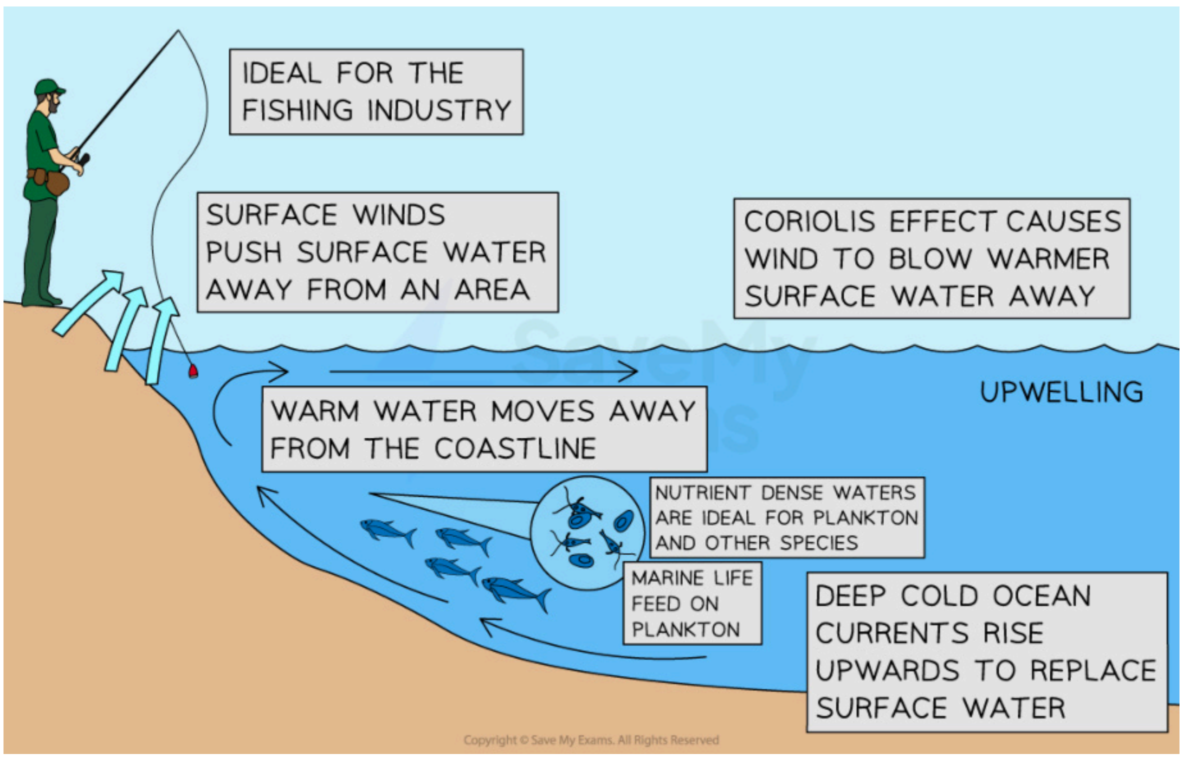

Image showing the process of upwelling in transferring nutrient-dense waters

- **Oceanic Conveyor Belts** are important for nutrient and carbon dioxide cycles:
  - Surface waters are not nutrient- or carbon-dioxide-rich
  - As they move through the conveyor belt, they become enriched with nutrients and carbon dioxide
- **Solar radiation** hits the Earth unequally. Ocean currents are important for distributing warmer and colder waters around the globe:
  - **Heat energy** transfers around the world as warmer water from the equator moves towards the poles and vice versa
  - Ocean currents play a major role in controlling our **climate** and **weather**

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5.1.2 Atmospheric & Oceanic Interactions

El Niño and La Niña

- During normal conditions, Trade Winds blow in a westerly direction:
  - Warm water moves from the South Americas towards the Asian continent
- Through upwelling, colder water rises to the top of the oceans to replace this warm water
- El Niño and La Niña interrupt these normal conditions

Image showing normal conditions (without El Niño and La Niña)

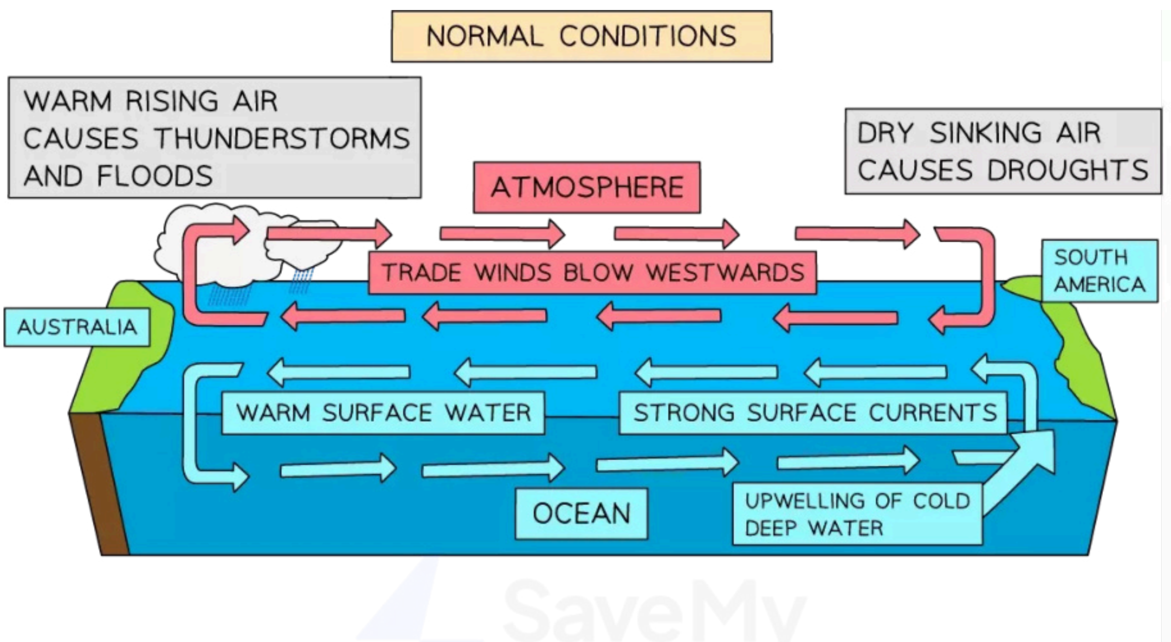


Image showing normal conditions (without El Niño and La Niña)

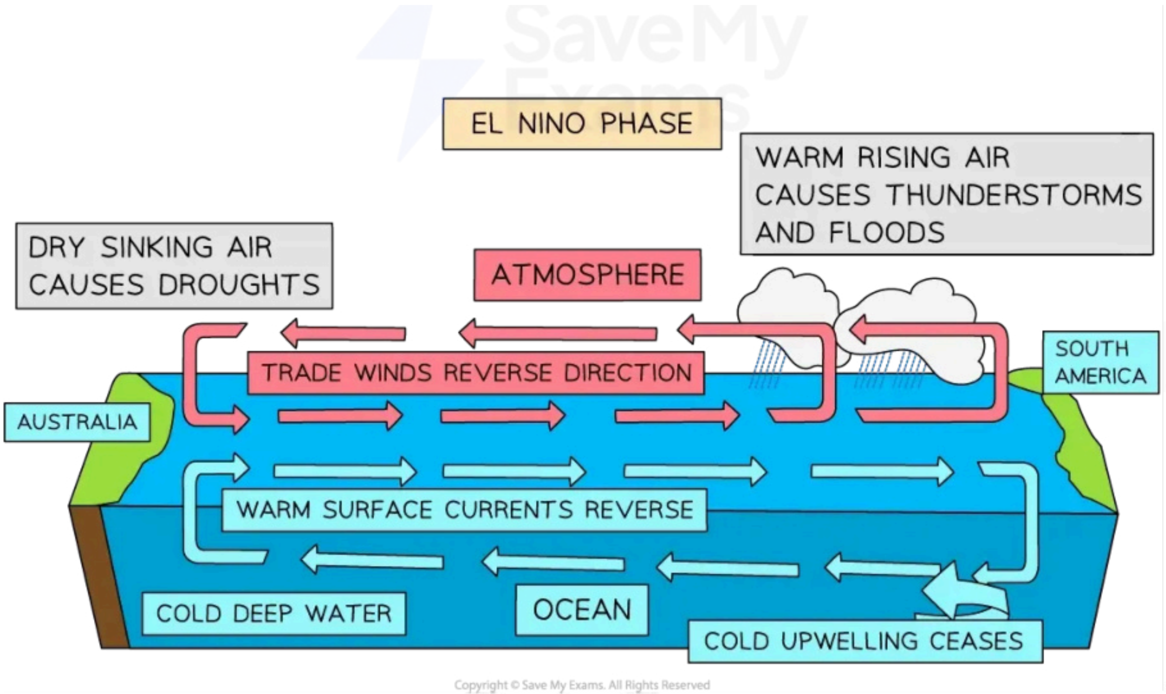
El Niño-Southern Oscillation (ENSO) and La Niña

- **El Niño Southern Oscillation (ENSO)** is the change in warm water movement in the central-equatorial Pacific Ocean
- It affects atmospheric circulation, resulting in global temperature and rainfall changes
- The **Southern Oscillation** refers to changes in **atmospheric pressure** in the tropical Pacific
- There are three periods of **ENSO**:
  - Neutral
  - El Niño
  - La Niña
- In the **neutral phase**, air sinks at the Eastern Pacific, whilst warm and moist air rises at the Western Pacific

- **El Niño** is the **weakening** of **trade winds**, causing warm air to rise in the Eastern Pacific, and cooler air to sink in the Western Pacific
  - Warm surface water moves in an easterly direction towards the American continent
  - The Pacific jet stream moves further **south**
  - El Niño occurs when ocean temperatures rise **0.5°C** above average
  - May occur every 2–7 years
  - As ocean temperatures **rise**, e.g. off the Peru coast, **thermal expansion** occurs, resulting in **sea level rise**. As air rises and pressure is low, more **rainfall** occurs
  - As ocean temperatures **cool** e.g. off the Australian coast, rainfall reduces, resulting in **drier** conditions
- **La Niña** is the opposite of El Niño
- During La Niña, **trade winds** are very **strong**, and even more warm water moves towards Asia
  - The **Pacific jet stream** moves further **north**
  - Occurs when ocean temperatures are below average
  - Occurs every 3–5 years
  - Results in higher rainfall over Indonesia, and less rainfall over the central tropical Pacific Ocean
  - **Upwelling** causes cold water to move to the surface
- Each period of El Niño or La Niña can last between **9–12 months**
- El Niño is more common that La Niña

Images showing the process of El Niño and La Niña

Your notes


EL NINO PHASE
WARM RISING AIR CAUSES THUNDERSTORMS AND FLOODS
DRY SINKING AIR CAUSES DROUGHTS
ATMOSPHERE
TRADE WINDS REVERSE DIRECTION
SOUTH AMERICA
AUSTRALIA
WARM SURFACE CURRENTS REVERSE
COLD DEEP WATER
OCEAN
COLD UPWELLING CEASES
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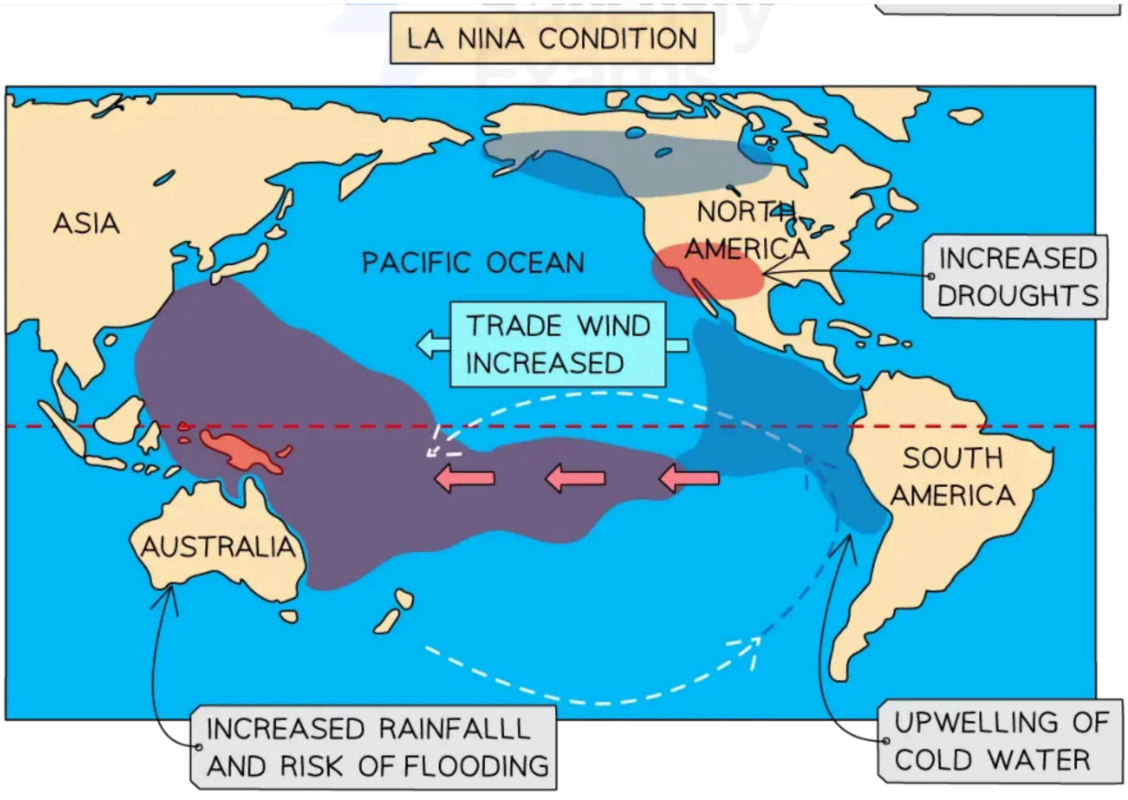
LA NINA CONDITION
ASIA
PACIFIC OCEAN
NORTH AMERICA
INCREASED DROUGHTS
TRADE WIND INCREASED
SOUTH AMERICA
AUSTRALIA
INCREASED RAINFALLL AND RISK OF FLOODING
UPWELLING OF COLD WATER
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Images showing the process of El Niño and La Niña

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Impacts of El Niño and La Niña

Effects of El Niño and La Niña

- El Niño and La Niña affect the climate, environment and the economy
- El Niño and La Niña can bring positives and negatives
- Climate change could worsen the effects of El Niño

Table showing the climatic, environmental and economic effects of El Niño and La Niña

Period	Climatic	Environmental	Economic
El Niño	Weather in the US and Canada is dry and warm Some areas of the world have higher rainfall, which can cause flooding, e.g. South America In India, El Niño can negatively affect the monsoon season, reducing rainfall and causing **droughts** Northern European winters are drier and colder Southern European winters are wetter UK summers are dry and hot Australia and Indonesia can experience heavy droughts	Changes in climate patterns can affect ecosystems and wildlife **Coral bleaching** can occur, which affects marine life	Damage to infrastructure occurs due to flooding, wind, rainfall, and fires Poor weather conditions can cause agricultural supply chain issues and increase costs **Food insecurity** increases, particularly in subsistence agriculture

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La Niña	Southern US experiences drier weather North-western US and Canada experience higher rainfall and flooding Winters are colder in the north and warmer in the south **Hurricanes** are more intense in areas like the Caribbean The **monsoon** season in India is more intense The UK is much wetter Australia and Indonesia can experience higher rainfall	Waters are nutrient-dense from upwelling, benefitting ecosystems and the marine food chain	In India, the intense monsoon season is a boost for agriculture and the economy Damage from intense flooding is costly in areas like Australia In South America, the fishing industry booms due to upwelling of nutrient-dense waters

Your notes

Examiner Tip

Always remember to use a case study/example to back up the points you make in your answers. You'll get higher marks for providing evidence.

Examples of geographic impacts of El Niño and La Niña

- **1997–1998 El Niño**
- One of the strongest El Niño periods recorded
- At the beginning of 1997, trade winds weakened and reversed in the west/central equatorial Pacific, resulting in warm sea temperatures
  - Droughts hit **Indonesia** and the **Philippines**:
    - These droughts resulted in agriculture shortages in Indonesia
    - Food prices increased dramatically
    - Intense forest fires affected Indonesia, causing dangerous smog levels
  - **Peru** experienced intense flooding and rainfall:
    - The area of Tumbes in Peru had 16 times more rainfall over the year than usual
    - Caused massive infrastructure damage e.g. homes, health centres, roads, bridges
    - Damaged crops and killed livestock, causing a hike in food prices
    - Disease outbreaks e.g. malaria and diarrhoea
  - Drastic differences in **US weather**:
    - The US West Coast and the South had high rainfall and flooding
    - Storms battered this area, resulting in loss of life
    - Economic damage from cyclones e.g. crops and infrastructure
    - Hit tourism and recreation industries

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    - The US Midwest experienced hot weather – this year became "the year without a winter", one of the warmest winters recorded
- **2010–2012 La Niña**
- At the beginning of 2010, there were visible signs of El Niño, before eventually moving to a neutral phase
- In July, La Niña began, with colder ocean temperatures at the central/eastern tropical Pacific
  - **Australia**:
    - Record rainfall across Australia, bringing severe flooding across parts of the country
    - Damaged crops
    - Flooding of mines
    - Cyclones e.g. Cyclone Yasi
    - South-west Australia experienced one of the driest years ever recorded
    - Prices of commodities exported from places like Australia rose around the world
  - Heavy rainfall landed in **Colombia**:
    - Resulted in flash flooding and landslides
    - Resulted in deaths and injuries
    - Damage to infrastructure e.g. sanitation systems
    - Damage to livelihoods caused displacement in Colombia
    - Displacement resulted in increased conflicts
    - Disease spread e.g. diarrhoea, dengue, malaria, skin infections and even risk of rabies
  - Intense droughts hit **East Africa**:
    - A humanitarian emergency was declared in the Horn of Africa as food insecurity increased
    - Food and fuel prices rose
    - Livestock died from lack of water, reducing local farmer's incomes

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5.1.3 Hurricanes

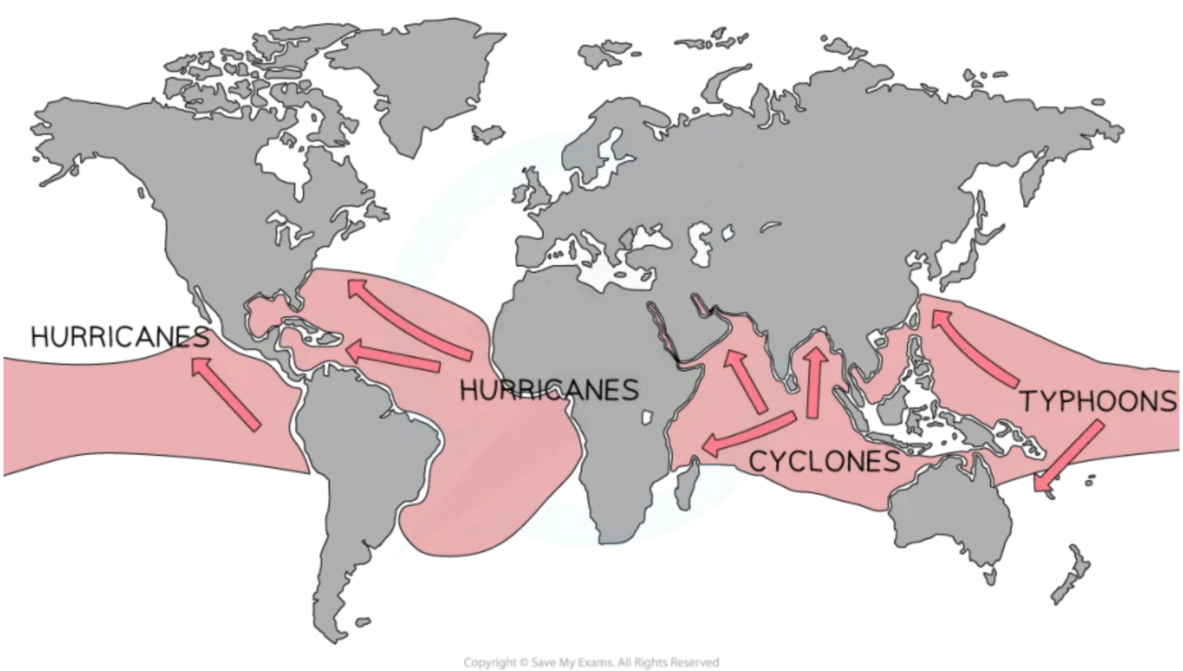
Distribution of Hurricanes

- "Hurricane" is one of the names given to **tropical storms**:
  - Other names used for tropical storms include **cyclones** and **typhoons**
  - Storm names vary depending on the **location** in which they form
- Hurricanes form over waters in **tropical** or **subtropical regions**:
  - Hurricanes usually form in the Atlantic Ocean, the middle or northeast of the Pacific Ocean, the Caribbean Sea and the Gulf of Mexico
  - Hurricanes form in these regions as the waters are warmer
- Hurricanes tend to occur over the months of **June – November**
- The Pacific Ocean has the largest number of hurricanes per year
- More hurricanes occur in the northern hemisphere than in the southern hemisphere

Examiner Tip

Make sure you are aware of how climate change could impact the intensity of hurricanes. What happens if waters further from the equator start to get warmer?

Distribution of tropical storms



Distribution of tropical storms

Formation of Hurricanes

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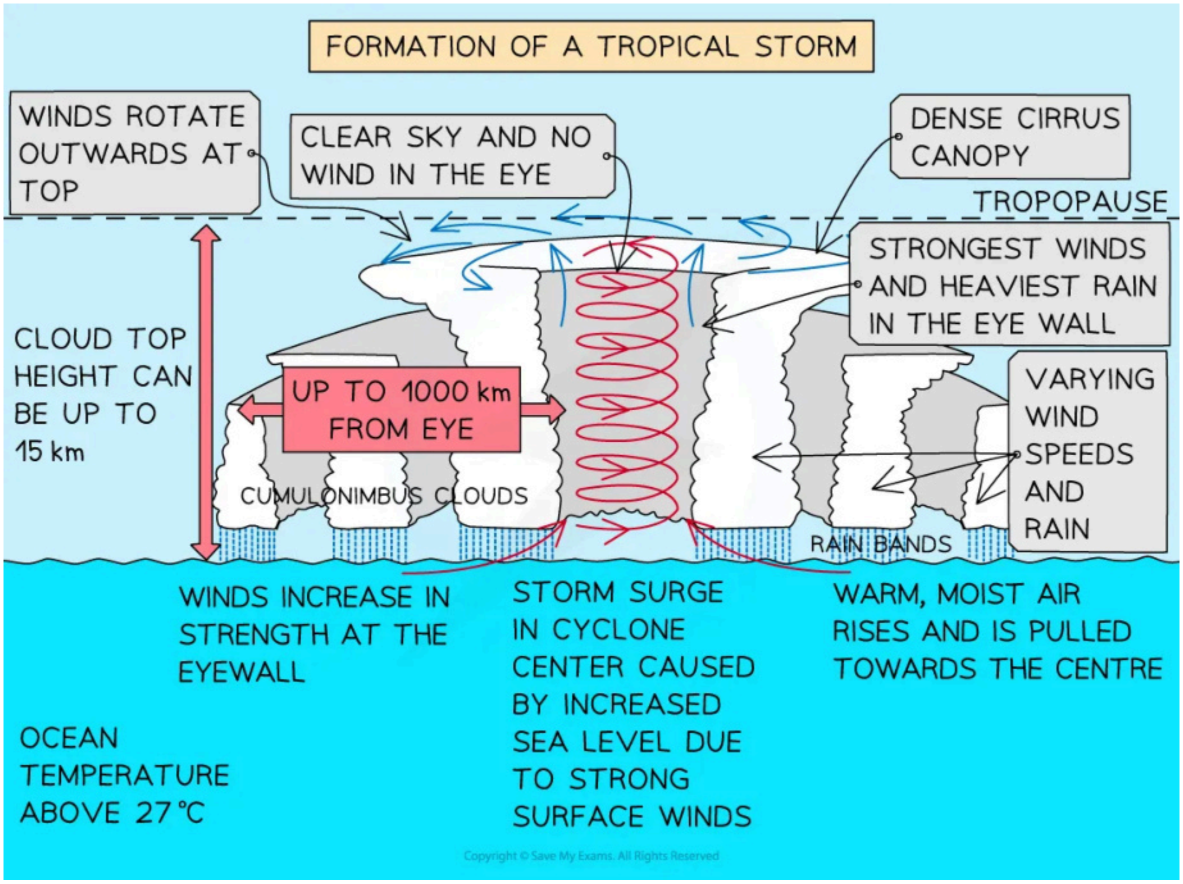
- Hurricanes are **low-air-pressure systems** formed over oceans
- Hurricanes need **warmer waters** to form (minimum 27 degrees Celcius)
- Warm and moist air above the ocean rises upwards, leaving behind a pocket of low pressure underneath
- **Cooler air** moves into this low-pressure area, heats up and rises
- This air **cools and condenses** as it rises and releases heat energy, forming clouds and storms
- The Coriolis Effect causes a spinning action. Storms in a low-pressure system will spin clockwise in the southern hemisphere and anti-clockwise in the northern hemisphere
- As this process intensifies with more heat energy, winds will increase and the spinning will worsen
- Wind with low wind shear helps storm clouds rise straight upwards
- The centre of a hurricane is the **eye**:
  - This is a large area of low-pressure air that is colder and drier
  - It results in a **calm** centre inside the storm
- When hurricanes reach land or move over colder waters, they will **lose energy** and slow down
- The Saffir-Simpson scale shows the intensity of hurricanes, by measuring wind speed

Formation of a hurricane

Your notes



Formation of a hurricane

Examiner Tip

Remember, hurricanes need a perfect balance of several conditions to form. Just because the water is warm, doesn't mean a hurricane will develop. It requires a combination of different factors.

Impact of Hurricanes

- Hurricane paths are hard to **predict**. This makes it more difficult to **prepare** for and **manage** hurricanes
- Hurricane winds can rip up trees, cause airborne debris and damage infrastructure, e.g. homes, power lines etc.
- Hurricanes can cause a rise in the water level, resulting in **storm surges**. This can cause dramatic coastal flooding as the wind moves the water inland
- Flooding can occur **inland** as a result of heavy rainfall after the hurricane
- Hurricanes can affect boats and offshore oil/gas stations out on the ocean

Case Study: Hurricane Katrina

Case Study – Hurricane Katrina

- Hurricane Katrina was a **category 5** hurricane that hit the Gulf Coast in 2005
- It formed over the Atlantic Ocean, building up to be one of the most deadly hurricanes in history
- It battered the areas of Florida, Mississippi and Louisiana, among others

The path of Hurricane Katrina as it hit the southwest coast of the US

The path of Hurricane Katrina as it hit the southwest coast of the US

Impacts of Hurricane Katrina

- Roughly **1833** people died with millions of people left homeless
- Damages cost roughly **$300 billion**
- New Orleans was the worst hit area:
  - **Storm surges** caused intense flooding
  - **Levees** and **floodwalls** were not strong enough to deal with the Category 5 storm
  - This **failure** of flooding protection resulted in the dramatic loss of life
- **Coastal erosion** destroyed beaches
- Land and forests were destroyed, impacting habitats and ecosystems
- Residents were left stranded, causing **tensions.** This resulted in increased crime e.g. looting
- People did not have any electricity for up to a week
- **Tourism** was severely affected
- The hurricane affected the **agriculture** and **oil/gas industry**, negatively affecting the **economy**

Responses to Hurricane Katrina

- **Evacuation** during Hurricane Katrina was poorly planned:
  - Many underprivileged people were left stranded
- The US government provided $50 billion, whilst other countries sent aid relief
- The Superdome (stadium) became a space for people to find shelter and food:
  - There were issues with food availability and unsanitary conditions
- Eventually, repairs were made to the levees and floodwalls, however, it took many months until the water was gone
- Many people living back in New Orleans cannot get home insurance or have to pay very high premiums as a result of hurricane risk

Your notes

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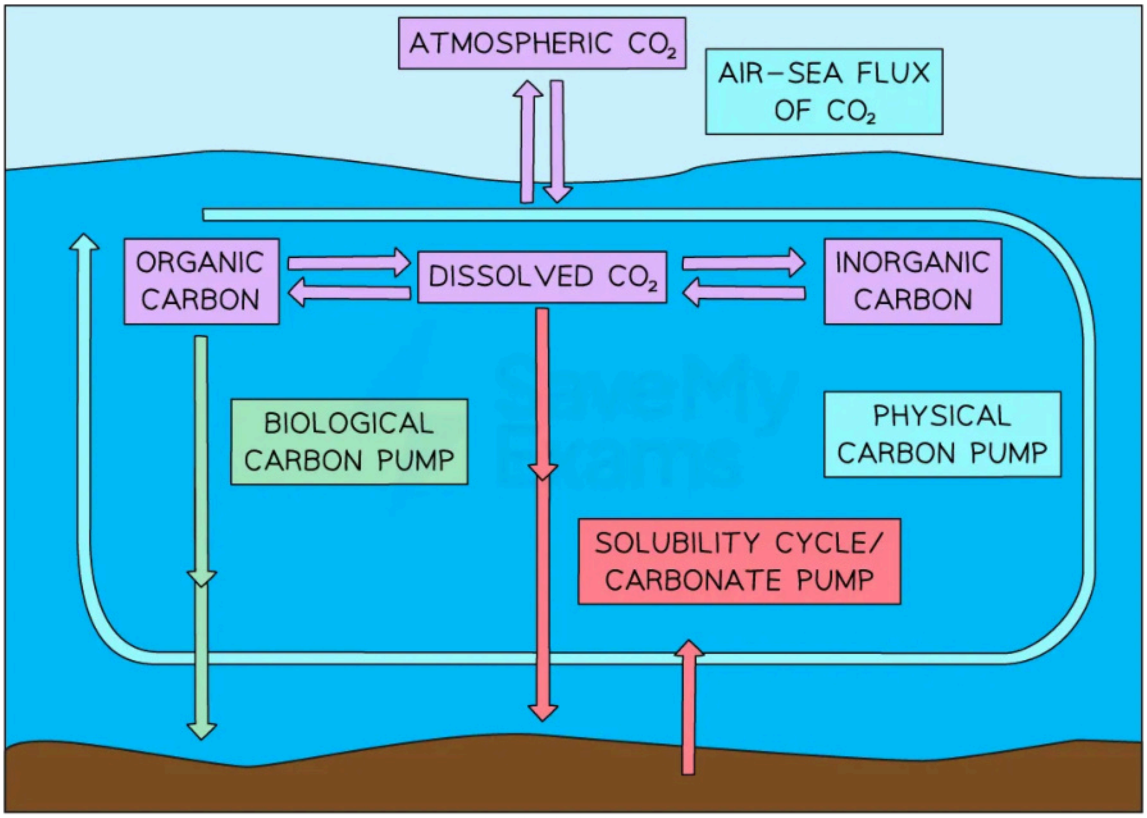
5.1.4 Oceans & Carbon Dioxide

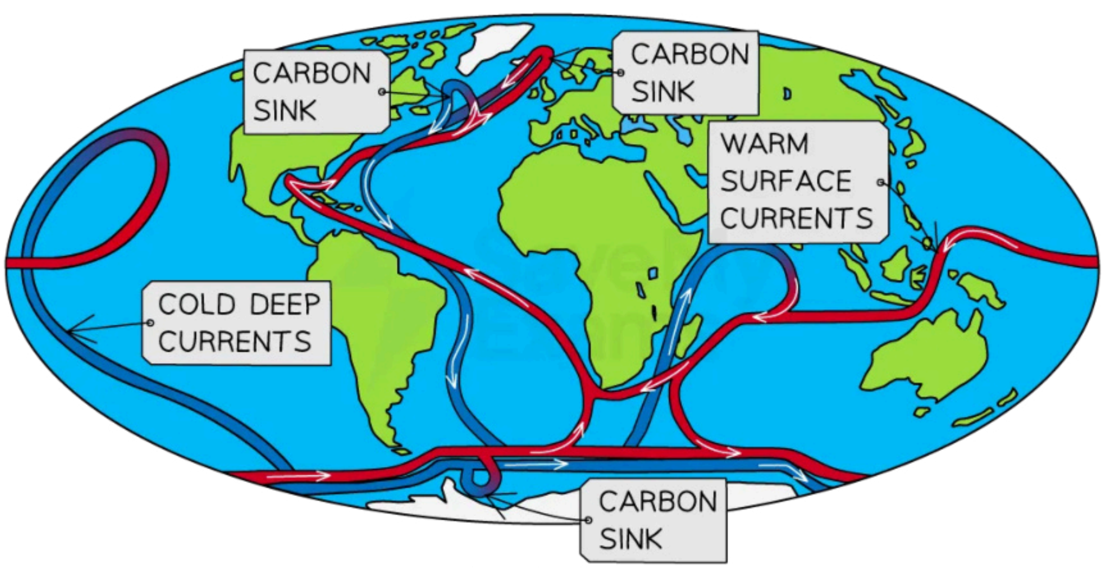
Oceans as a Carbon Dioxide Store

- Oceans contain large amounts of dissolved carbon
- They are **carbon sinks** or **reservoirs** for carbon **storage**
- Oceans **capture** and **absorb** carbon dioxide from the atmosphere:
  - This is the process of **carbon sequestration**
- Carbon moves from surface ocean layers to deeper ocean layers through:
  - **Biological Carbon Pump**
    - Tiny **phytoplankton** living in the upper layers need to **photosynthesise**. They absorb carbon dioxide during this process
    - Phytoplankton act as a source of food for other marine life. Carbon moves through the marine **food chain** into the different layers of the ocean
    - Species like plankton also **sequester** carbon dioxide and use it for their skeletons or shells
  - **Carbonate Pump**
    - After organisms die, skeletons or shells can dissolve into the water, **enriching** deep ocean currents with carbon
    - Decaying organisms can also release carbon dioxide
    - As animals breathe, carbon is also released into oceans
    - Dead organisms can build up and eventually compress on the seafloor and turn into limestone sediment
  - **Ocean Circulation** (**physical pump**) increases the amount of carbon that can be stored in oceans:
    - **Thermohaline circulation** moves surface and deep ocean currents around the world in a cyclical pattern
    - Dissolved carbon moves around oceans through this circulation
    - Water density brings carbon-rich waters deep down into ocean stores in a process called **downwelling**

Diagram illustrating carbon cycling at a 'sere' (lithosere) level

Your notes





Carbon cycling at a 'sere' (lithosere) level

Your notes

- Oceans are important for the future and for climate change, as they absorb vast amounts of carbon dioxide
- However, warmer waters cannot absorb as much carbon dioxide as colder waters. As ocean temperatures rise, this could worsen climate change by reducing the efficiency of the oceans as a carbon sink

Oceans as a Source of Carbon Dioxide

- Oceans are not only a store but also a **source** of carbon dioxide
- The process of **upwelling** can bring carbon-rich waters to the surface; this carbon can then make its way back into the atmosphere
- Disruption to the **thermohaline circulation** would cause large amounts of carbon to move upwards from deep ocean layers to the surface:
    - The ocean would become a greater **source** of carbon dioxide than a carbon **sink**
    - This could be **catastrophic** for the climate
- As **climate change** worsens, oceans may become a larger **source** of carbon dioxide:
    - As **sea ice melts**, ocean waters can mix more freely, bringing up those carbon-rich waters from the depths of the ocean
    - **Gasses** are released more easily when ocean waters are warmer

Examiner Tip

There is much more evidence for oceans as a store of carbon dioxide, however, it's really important to think about the future and climate change and the effects this could have on the ocean becoming a source of carbon dioxide!

Impacts of Ocean Acidification on Coral Reefs

- As a result of burning **fossil fuels**, more carbon dioxide enters the atmosphere
- Oceans also absorb lots more carbon dioxide
- This increase in carbon dioxide increases the **acidity** of ocean waters
- This is the process of **ocean acidification**
  - **Coral reefs** need to produce **calcium carbonate** to grow
  - Each coral organism (polyp) secretes a skeleton of calcium carbonate; these form the reef
  - As the ocean acidifies, coral reefs struggle to produce this calcium carbonate
  - This means that coral reef skeletons **cannot grow** as quickly; they become much **weaker** and are more likely to break
- Coral reefs are a vital food source and shelter for marine life
  - As coral reefs start to degrade, this threatens the marine wildlife that is dependent on coral reefs for survival
  - Coral reefs are also important for humans as they:
    - Are useful for protecting coastlines from erosion and storms
    - Are a hotspot for fishing industries
    - Bring tourism to local areas
    - Produce extracts that are used in medicine

Image showing the process and effects of ocean acidification

Your notes

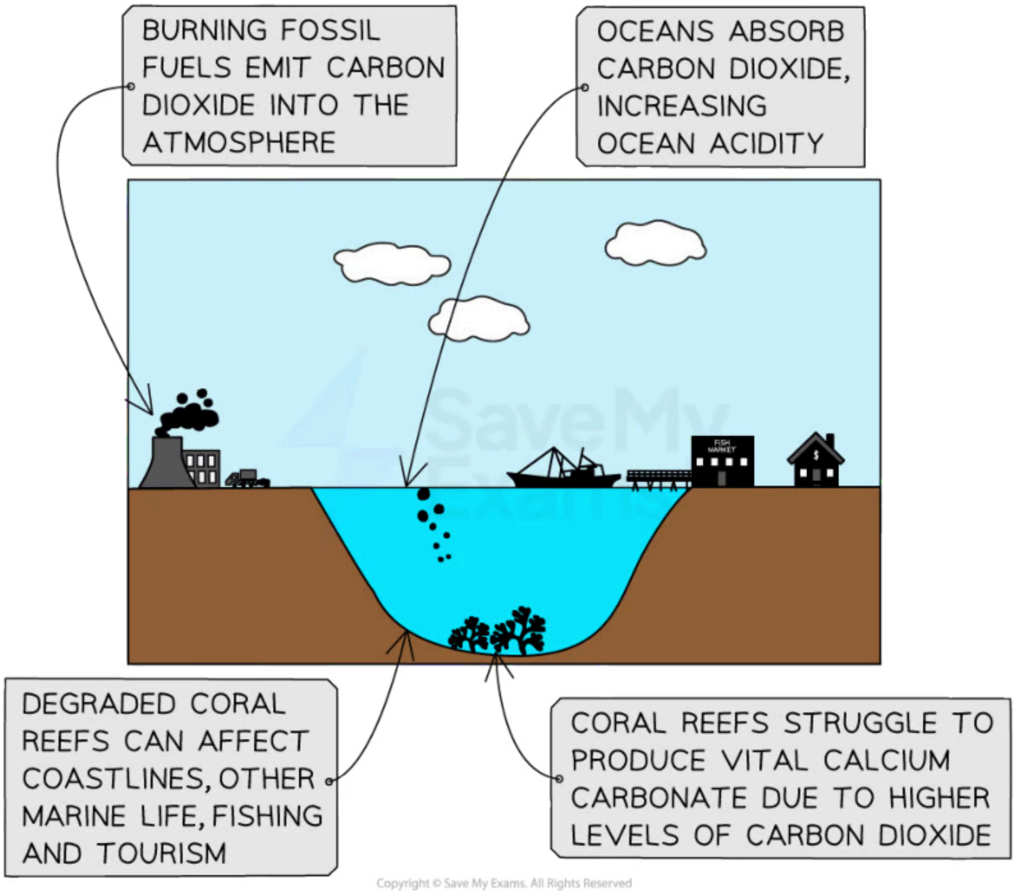


Image showing the process and effects of ocean acidification