



# DP IB Environmental Systems & Societies (ESS): SL



Your notes

## Climate Change: Causes & Impacts

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## What is the Difference Between Weather & Climate?

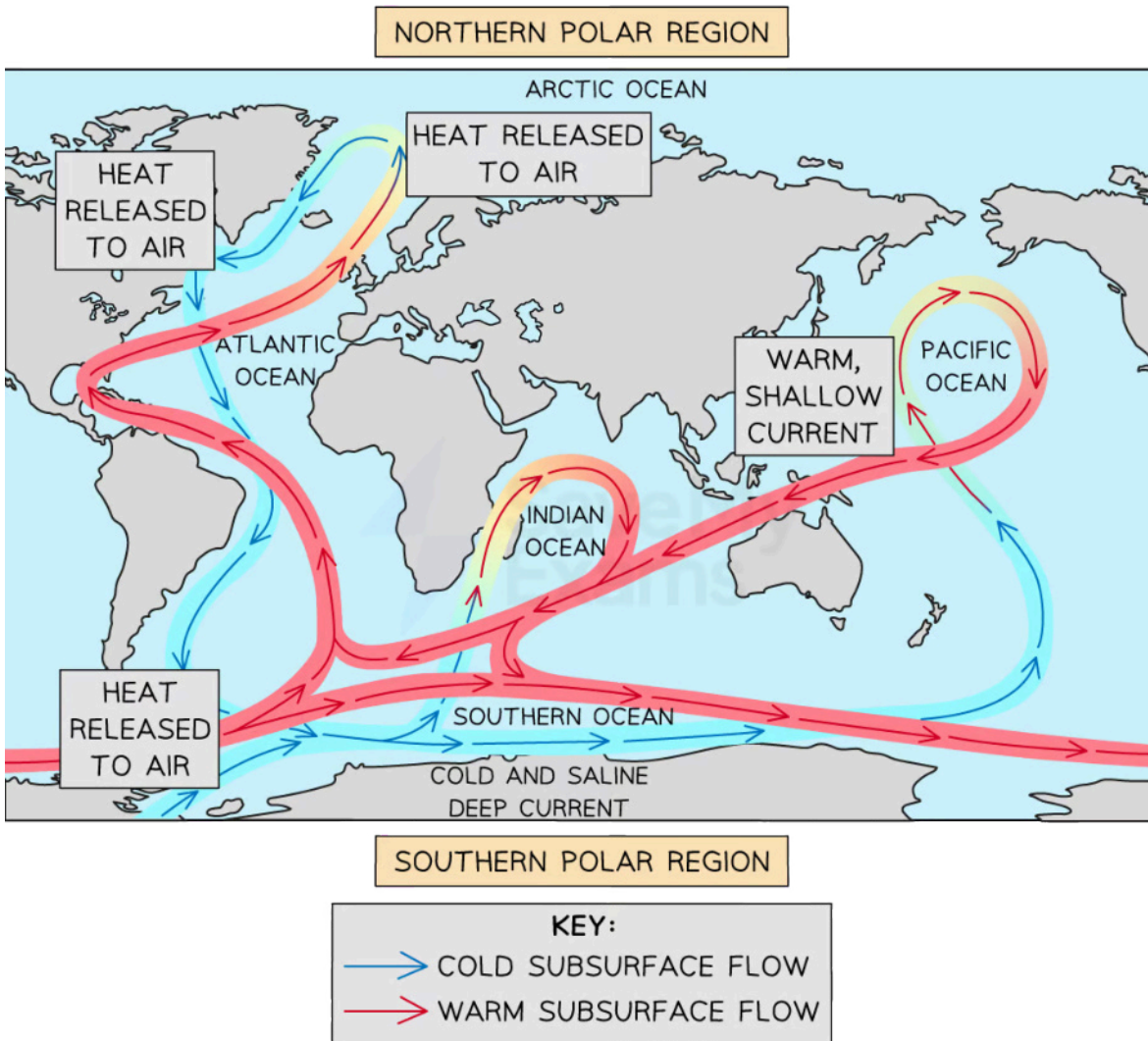
### Weather & Climate

- Climate refers to the **long-term** average of weather conditions in a particular region or location
  - It describes the **overall** patterns, trends, and variations in temperature, precipitation, humidity, wind, and other atmospheric factors over a significant period (typically 30 years or more)
  - Climate is influenced by various factors such as solar radiation, atmospheric circulation patterns, ocean currents, land features, and greenhouse gas concentrations
- Weather, on the other hand, refers to the **current state** of the atmosphere at a **specific time and place**
  - It includes **short-term** variations in temperature, humidity, cloud cover, precipitation, wind speed, and other atmospheric conditions
  - Weather conditions can change rapidly and are often described in terms of temperature, humidity, precipitation type, wind direction, and speed
- While climate provides a broader perspective on long-term atmospheric behaviour, weather is more concerned with immediate atmospheric conditions and forecasts
  - Understanding the difference between climate and weather is crucial for analysing long-term climate trends, predicting short-term weather events, and assessing the impacts of climate change on weather patterns

### Oceanic Circulatory Systems



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**Oceanic circulatory systems transport heat and energy around the world, affecting weather and climate**

- Weather and climate are strongly influenced by **oceanic circulatory systems**, which play a vital role in regulating temperature, moisture distribution, and atmospheric dynamics
  - These circulatory systems, such as **ocean currents** and **upwelling**, have significant impacts on both regional and global scales
- Ocean currents, driven by factors like wind, temperature, and salinity gradients, **redistribute heat** across the Earth's surface



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- Warm ocean currents carry **heat** from the tropics **towards higher latitudes**, moderating temperatures in coastal areas and influencing regional climates
- Cold ocean currents transport **cold water** from polar regions **towards lower latitudes**, resulting in cooler coastal temperatures and affecting the formation of coastal fog and marine ecosystems
- Upwelling occurs when cold, nutrient-rich water rises to the **surface**, primarily driven by **wind** that moves surface waters out the way, allowing deeper waters to rise up to replace them
  - Upwelling brings deep, **nutrient-rich** waters to the surface, supporting abundant marine life and contributing to the productivity of fisheries in coastal areas
- El Niño and La Niña events, part of the El Niño–Southern Oscillation (ENSO) cycle, have significant impacts on global weather patterns
  - El Niño events involve the warming of the central and eastern equatorial Pacific Ocean, causing shifts in atmospheric circulation and leading to droughts, floods, and other extreme weather events in various parts of the world
  - La Niña events, on the other hand, involve cooler-than-average sea surface temperatures and can result in contrasting weather patterns
- The **Gulf Stream**, a strong warm ocean current in the Atlantic Ocean, plays a critical role in shaping weather and climate in the **North Atlantic region**
  - It helps transport warm water and influences the temperature and moisture content of the air, affecting weather patterns and storm development
- Oceanic circulatory systems also influence the distribution of moisture in the atmosphere
  - Evaporation from warm ocean surfaces adds moisture to the air, which can lead to the formation of clouds, precipitation, and the development of storm systems
- Changes in oceanic circulatory systems, such as alterations in current strength or shifts in their paths, can have significant implications for regional and global climates
  - These changes can result from natural variability, as well as long-term climate change driven by factors like greenhouse gas emissions

## Atmospheric Circulatory Systems

- Weather and climate are also significantly influenced by **atmospheric circulatory systems**, which result in the movement of air masses, distribution of heat, and the formation of weather patterns
  - These circulatory systems, such as global wind patterns, jet streams, and local wind systems, impact both daily weather conditions and long-term climate trends

***Heat energy flow and surface winds can be explained using the tricellular model of atmospheric circulation***

- Global wind patterns, such as the **Hadley, Ferrel, and Polar cells**, are large-scale circulations driven by the uneven heating of the Earth's surface
  - These wind patterns help transport heat from the equator towards the poles, influencing the distribution of **temperature** and **pressure** on a global scale
- The jet streams are narrow, fast-flowing bands of winds in the upper troposphere and lower stratosphere
  - They form as a result of the temperature differences between air masses and play a significant role in shaping weather patterns
- **Local wind systems**, such as sea breezes, land breezes, and mountain-valley breezes, are influenced by differential heating and cooling of land and water surfaces
  - These winds can affect local weather conditions, especially in coastal and mountainous regions
- The **Coriolis effect**, caused by the Earth's rotation, influences the direction of winds and the formation of atmospheric circulation patterns
  - It deflects air masses in the Northern Hemisphere to the right and in the Southern Hemisphere to the left, resulting in the characteristic curving paths of winds
- Understanding the interactions between atmospheric circulatory systems and weather/climate is crucial for meteorologists, climatologists, and weather forecasters
  - By studying these circulatory systems, scientists can better predict and understand weather phenomena, assess climate patterns, and investigate the impacts of climate change on global and regional scales



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## What are Greenhouse Gases?

# Greenhouse Gases

## What are Greenhouse Gases?

- **Human activities** are significantly contributing to the increase in greenhouse gases in the atmosphere, leading to various impacts on the Earth's climate system
  - Increased levels of carbon dioxide, methane, and water vapour result from human activities such as burning fossil fuels, deforestation, and industrial processes

## Sources of Greenhouse Gases

- **Carbon dioxide:**
  - Main sources include the combustion of fossil fuels for energy generation, transportation, and industrial processes
  - Deforestation and land-use changes, such as clearing forests for agriculture or urbanisation, contribute to CO<sub>2</sub> emissions indirectly by reducing the planet's capacity to absorb carbon dioxide through photosynthesis
- **Methane:**
  - Produced by natural processes like the decomposition of organic matter in wetlands, forests, and oceans
  - Human activities such as agriculture (particularly rice cultivation and livestock farming), coal mining, oil and gas extraction, and waste management (landfills) contribute to methane emissions
- **Water vapour:**
  - Water vapour is the most abundant greenhouse gas in the atmosphere and its concentration is primarily determined by temperature and humidity levels
  - While human activities do not directly emit water vapour as a greenhouse gas, they can indirectly influence its levels through activities that affect temperature and moisture, such as deforestation, land-use changes, and the burning of fossil fuels that release other greenhouse gases



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Photo by [Steve Douglas](#) on [Unsplash](#)

*Rice paddies produce methane due to the anaerobic conditions created by flooded cultivation, which promote the growth of methane-producing microorganisms that decompose organic matter in the soil*

## Effects of Greenhouse Gases

- These greenhouse gases **trap heat** in the atmosphere, causing the Earth's temperature to rise, leading to **global warming**
  - The increase in **mean global temperature** has wide-ranging effects, including melting ice caps and glaciers, shifts in precipitation patterns, and changes in ecosystem dynamics
  - The higher concentration of greenhouse gases is contributing to the intensification of **extreme weather events** such as hurricanes, droughts, heatwaves, and heavy rainfall
- **Long-term changes in climate and weather patterns** occur as a result of the altered energy balance in the Earth's atmosphere and oceans
- Rising greenhouse gas levels also contribute to the thermal expansion of seawater and the melting of land-based ice, resulting in **sea level rise**

- The combination of increased global temperatures and rising sea levels poses significant risks to coastal communities, low-lying regions, and ecosystems
- It is essential to mitigate greenhouse gas emissions and implement strategies to adapt to the changing climate to minimise the potential impacts on the planet and human societies

## The Enhanced Greenhouse Effect

- The enhanced greenhouse effect is **different** from the natural greenhouse effect because it is primarily driven by **human activities** that release excessive amounts of greenhouse gases into the atmosphere, leading to an intensified trapping of heat and subsequent global warming
- While the natural greenhouse effect is a necessary process that helps regulate the Earth's temperature by trapping some heat to maintain a **habitable climate**, the enhanced greenhouse effect disrupts this balance as a result of greenhouse gas concentrations being artificially increased beyond natural levels

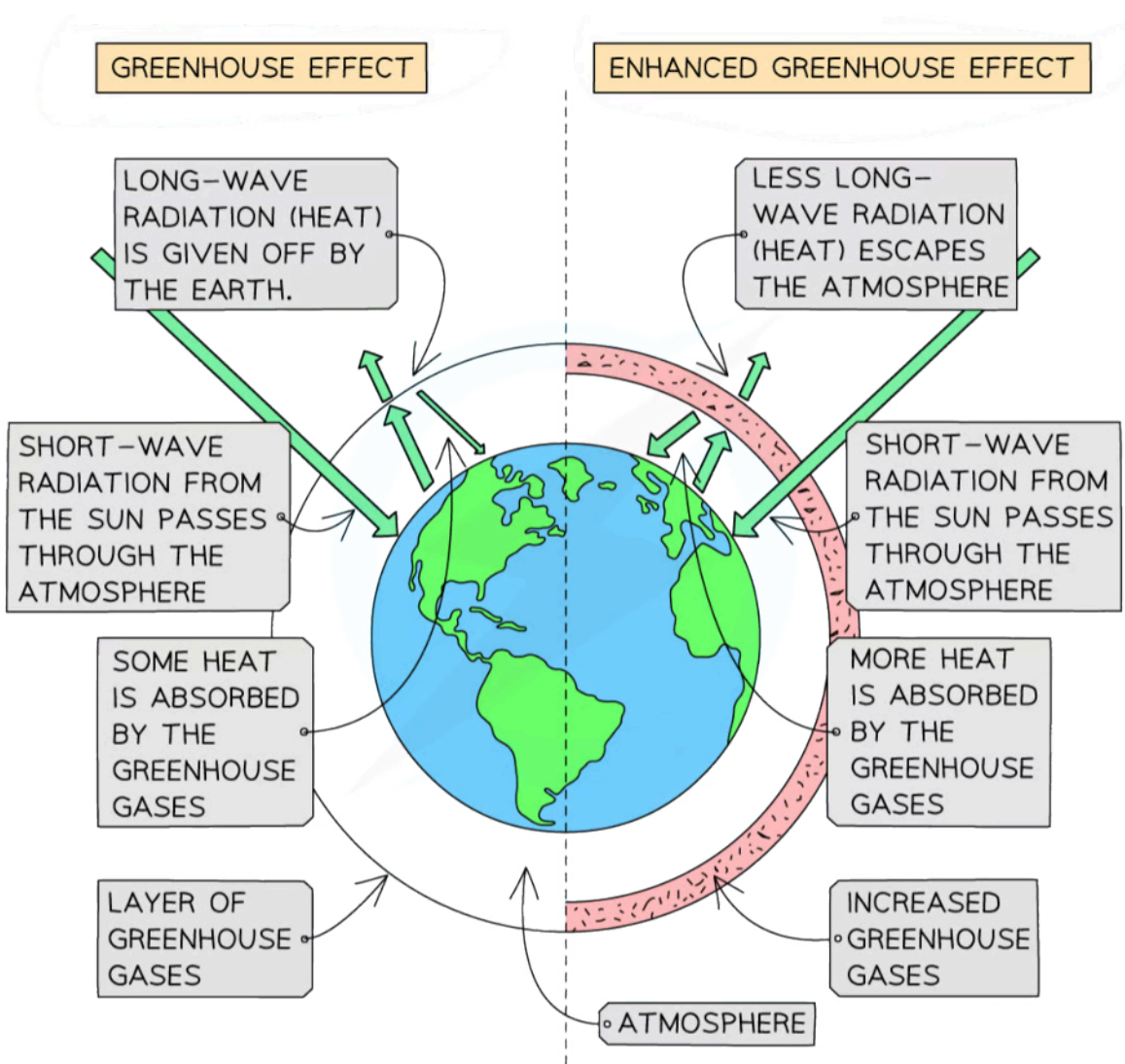


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**Human activities lead to the emission of greenhouse gases that enhance the natural greenhouse effect, contributing to global warming**



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## Positive & Negative Impacts of Climate Change

### Climate Change: Impacts

- Climate change is a global phenomenon, but its impacts can **vary significantly** from one location to another
- There are many potential impacts of climate change, some of which can be perceived as either **adverse** or **beneficial**:

### Changes in Water Availability

- Climate change can lead to alterations in precipitation patterns, resulting in changes in water availability
- Some regions may experience increased rainfall and flooding, while others may face more frequent and severe droughts, impacting water resources for agriculture, drinking water, and ecosystems

### Distribution of Biomes and Crop Growing Areas

- As temperatures and precipitation patterns shift, the distribution of biomes and suitable areas for **agriculture** can change
- Some regions may experience **expansion** of **favourable conditions** for crops and ecosystems, while others may face the **loss** or shifting of suitable habitats, impacting food production and biodiversity

### Loss of Biodiversity and Ecosystem Services

- Climate change can disrupt ecosystems, leading to the loss of biodiversity and the services they provide
- Changes in temperature, rainfall, and habitats can affect species' survival, migration patterns, and interactions, resulting in shifts in ecosystem functioning and potential declines in ecosystem services

### Coastal Flooding

- Rising sea levels, attributed to climate change, can lead to coastal flooding and increased vulnerability to storm surges
- This can result in the loss of land, infrastructure, and displacement of coastal communities

### Ocean Acidification

- Increasing levels of carbon dioxide in the atmosphere lead to the absorption of more carbon dioxide by the oceans, resulting in ocean acidification

- This can have detrimental effects on marine life, including coral reefs, shellfish, and other organisms that rely on calcium carbonate for their shells and skeletons

## Damage to Human Health

- Climate change can impact human health in various ways
- Heatwaves, extreme weather events, changes in disease vectors (e.g. mosquitos), and reduced air quality can all have negative health consequences, including heat-related illnesses, respiratory problems, and the **spread of infectious diseases**



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Photo by [Nguyen Kiet](#) on [Unsplash](#)

***Coastal flooding is becoming increasingly common as a consequence of the rising sea levels caused by global warming***

- It's important to note that while some regions may experience certain benefits from climate change, such as increased agricultural productivity or longer growing seasons, the overall negative impacts tend to **outweigh** the positive ones
- **Adapting to** and **mitigating** climate change is crucial to minimise the potential adverse effects and protect ecosystems, biodiversity, human well-being, and the overall stability of the planet



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## Negative and Positive Feedback Mechanisms

- Both negative and positive **feedback mechanisms** are associated with climate change and may involve very long time lags
- Negative feedback mechanisms in climate change refer to processes that **counteract** or **reverse** the initial change, helping to stabilise the climate system
  - For example, as temperatures increase, the enhanced evaporation may lead to increased cloud cover, which can reflect more sunlight back into space, thus cooling the Earth's surface
  - Another negative feedback mechanism involves the absorption of carbon dioxide by oceans and vegetation, which helps regulate its concentration in the atmosphere
- Positive feedback mechanisms in climate change **amplify** or **intensify** the initial change, leading to further global warming
  - For example, as temperatures rise, the melting of ice caps and glaciers reduces the Earth's albedo, causing more sunlight to be absorbed and increasing warming
  - Another positive feedback mechanism involves the release of methane from thawing permafrost, which further enhances the greenhouse effect
- Time lags refer to the **delay** between a **cause** and its **effect** in the climate system, which can span decades or even centuries
  - For example, the release of carbon dioxide from burning fossil fuels may have immediate warming effects, but the full impact on global temperatures may take years to manifest due to thermal inertia in the oceans (the slow speed at which oceans actually warm up) and slow feedback processes
  - Similarly, changes in land use, such as deforestation, can have long-term consequences for climate as it takes time for ecosystems to respond and feedback to develop
- These feedback mechanisms and time lags make the climate system **complex** and **challenging to predict** accurately, contributing to uncertainties in climate projections
- Understanding and quantifying these feedback mechanisms and time lags is crucial for accurately assessing the potential impacts of climate change and developing effective mitigation and adaptation strategies



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## Causes of Climate Change

### Climate Change: Issues



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*An ozonesonde balloon is launched by NOAA (National Oceanic and Atmospheric Administration) – the ozonesonde itself is a lightweight instrument, carried up by the balloon, that measures ozone and standard meteorological quantities such as pressure, temperature and humidity, which can then be used as data inputs for climate modelling. The balloon will ascend to altitudes of about 115,000 feet (35 km) before it bursts.*

- One of the main **issues** surrounding climate change is how to properly identify who or what is responsible for **causing** it
- The causes of climate change is a **highly debated** issue, primarily due to **climate change denialism** (from the powerful corporations that stand to gain most from continued use of fossil fuels), conflicting environmental value systems and the complexity of global climate models
- These factors contribute to **uncertainty** and varying perspectives on the topic

### Conflicting Environmental Value Systems

- Climate change involves a range of social, economic, and ethical considerations, leading to different environmental value systems
- Various stakeholders hold diverse beliefs, priorities, and interests regarding the environment, economy, and societal well-being, influencing their positions on climate change
- Disagreements arise from **differing views** on the role of human activities, the extent of responsibility, and the appropriate actions to address climate change



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## Complexity of Global Climate Models

- Climate models are sophisticated **computer simulations** that integrate numerous factors and processes to project future climate scenarios
- These models take into account the incredibly complex interactions between the atmosphere, oceans, land surface, ice, and all other components of the Earth system
- Like any model, however, even the world's best climate simulators still come with a significant level of uncertainty

## Uncertainty in Predictions

- Climate models provide **projections** rather than precise predictions, as they aim to capture the **range of potential future climate outcomes**
- Uncertainties arise from the complexity of the climate system, limitations in observational data, and challenges in accurately simulating all relevant processes
- Different models and scenarios yield a range of possible outcomes, contributing to uncertainties in predicting the precise magnitude, timing, and regional patterns of climate change
- Communicating and managing uncertainty is a critical aspect of climate change discussions to ensure informed decision-making

## Impact on Public Perception and Policy

- Conflicting environmental value systems and uncertainties in climate predictions can **influence public perception** and **policy decisions**
- Debates may arise from differing interpretations of scientific evidence, risk perceptions, economic considerations, and political ideologies
- The scientific community continues to refine climate models and improve their accuracy, but the inherent complexity of the climate system makes predicting specific outcomes challenging
- Addressing these challenges requires **interdisciplinary collaboration**, transparent communication of uncertainties, and open dialogue among stakeholders
- Recognising the conflicting environmental value systems and uncertainties associated with climate change is crucial for fostering constructive discussions, informed decision-making, and taking effective climate action