DP IB Environmental Systems & Societies (ESS): SL

Your notes

Introduction to the Atmosphere

Contents

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The Atmosphere as a Dynamic System

- The atmosphere is primarily composed of **nitrogen** (about 78%) and **oxygen** (about 21%)
- These two gases make up the majority of the atmosphere and play vital roles in supporting life on Earth
- In addition to nitrogen and oxygen, the atmosphere contains smaller amounts of other gases, including carbon dioxide, argon, water vapour, and various trace gases
  - Carbon dioxide, although present in relatively low concentrations (around 0.04%), is essential for maintaining the **greenhouse effect**, which helps regulate the Earth's temperature, and is essential for **photosynthesis**
  - Argon is an inert gas that does not participate in chemical reactions but contributes to the overall composition of the atmosphere
  - Water vapour is a variable component that plays a crucial role in the Earth's **weather patterns**, the formation of **clouds** and **precipitation**, and **photosynthesis**
  - Trace gases, such as methane, ozone, and nitrous oxide, are present in even smaller quantities but can have significant impacts on climate and atmospheric chemistry

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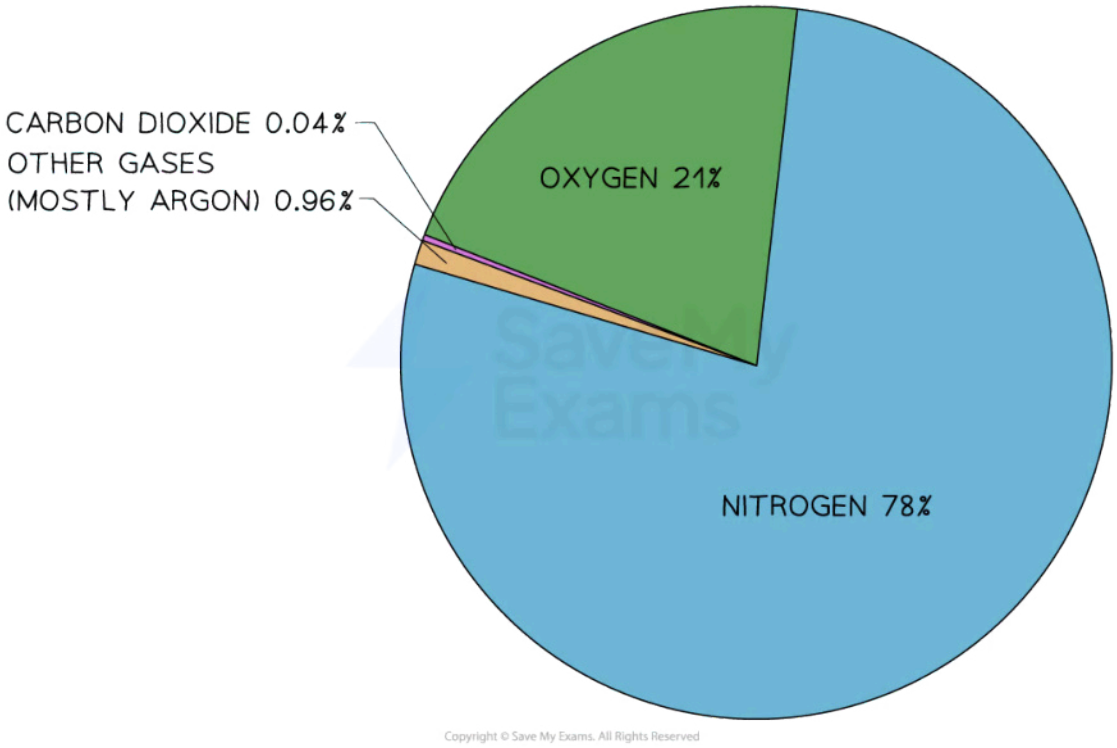

The gaseous composition of the Earth's atmosphere

Atmospheric Layers

- The atmosphere is **stratified** into different layers based on **temperature changes**
  - The inner layers of the atmosphere, where most interactions related to living systems occur, are the **troposphere** and the **stratosphere**
- The troposphere is the **lowest** layer of the atmosphere, extending from the Earth's surface up to about **10 kilometres**
  - It is where weather phenomena, such as cloud formation, precipitation, and the mixing of gases, primarily occur
  - The troposphere contains the highest concentration of water vapour, carbon dioxide, and other trace gases that are important for the functioning of living systems and the regulation of climate
- Above the troposphere is the stratosphere, which extends from approximately **10 kilometres to 50 kilometres** above the Earth's surface

- The stratosphere contains the **ozone layer**, a region with a higher concentration of ozone molecules that **absorb** and **block** most of the Sun's **harmful ultraviolet (UV) radiation**
- This layer is crucial for protecting life on Earth from excessive UV radiation and has important implications for the health of ecosystems

- The reactions occurring in the inner layers of the atmosphere, particularly the troposphere and the stratosphere, are crucial for maintaining the balance of gases, regulating climate patterns, and **supporting life**
  - Within the troposphere, chemical reactions involving pollutants, greenhouse gases, and atmospheric particles can impact air quality and climate
  - In the stratosphere, chemical reactions involving ozone play a vital role in maintaining the ozone layer and protecting the Earth from harmful UV radiation


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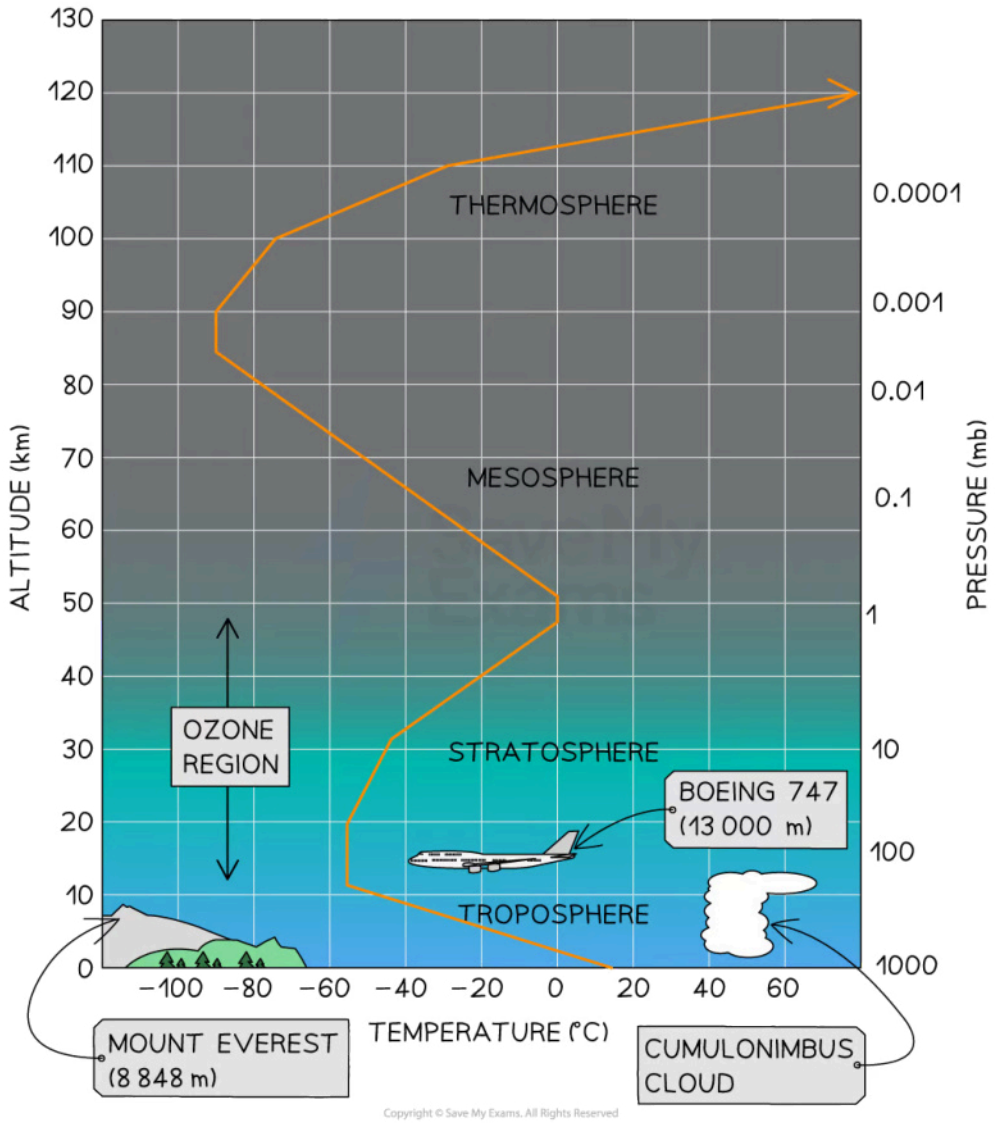

Approximate atmospheric temperatures and pressures up to an altitude of about 120 km – note the warmer temperatures in the troposphere, below the zone of maximum ozone concentration (in the stratosphere)

Atmospheric Systems

- The atmosphere is a **dynamic system** that plays a crucial role in the Earth's climate and weather patterns
  - As with other systems, the atmospheric system is made up of storages, flows, inputs and outputs
- **Storages**:

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- The atmosphere acts as a storage for **gases**, including greenhouse gases like carbon dioxide and methane, which contribute to the greenhouse effect and influence the Earth's temperature
- These gases are present in different concentrations and can vary over time due to natural and human activities

- **Flows**:
  - Within the atmosphere, there are constant flows of gases and particles, driven by processes such as air currents, weather patterns, and atmospheric circulation
  - These flows contribute to the movement and redistribution of gases and other substances within the atmosphere
- **Inputs**:
  - The atmosphere receives inputs from various sources
  - Natural inputs include gases emitted from **volcanic eruptions**, gaseous emissions from **plants** and other **living organisms**, and **dust** particles from **desert regions**
  - Anthropogenic inputs, resulting from **human activities**, include the release of greenhouse gases, air pollutants from industrial processes, and aerosols from combustion and other human-made sources

Photo by Michal Pech on Unsplash

Human activities such as emissions from industrial chimneys create inputs into atmospheric systems

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- **Outputs**:
  - The atmosphere also has outputs through different processes
  - It releases gases through natural processes like **respiration** and **photosynthesis**
  - Additionally, **pollutants** and aerosols can be removed from the atmosphere through **precipitation**, **dry deposition**, and chemical reactions
- **Exchanges and interactions with other Earth systems**:
  - The atmosphere interacts with other components of the Earth system, including the **biosphere** (plants, animals, and microorganisms), **hydrosphere** (oceans, lakes, and rivers), and **lithosphere** (landmasses and rocks)
  - It exchanges gases and particles with these systems through various mechanisms - for example, the exchange of carbon dioxide occurs through photosynthesis by plants and respiration by organisms
  - These interactions involve the exchange of gases, energy, and particles, shaping climate patterns, weather events, and overall Earth system dynamics

Changes through Geological Time

- The composition of the atmosphere has changed significantly over geological time
  - For example, during the **early stages** of Earth's history, the atmosphere had **high levels of carbon dioxide** and **lacked oxygen**
  - Over millions of years, photosynthetic organisms evolved and began to release oxygen as a byproduct, leading to the **oxygenation of the atmosphere**
  - Additionally, geological processes such as **volcanic activity** and meteorite impacts have influenced the atmospheric composition throughout Earth's history

Clouds

Photo by Jason Blackeye on Unsplash

Clouds form when warm, moist air rises and cools, causing water vapour to condense into tiny water droplets or ice crystals

- The majority of clouds form in the **troposphere**
- This layer is characterised by **decreasing temperature with increasing altitude**, creating conditions favourable for the **cooling** and **condensation** of water vapour

Albedo Effect of Clouds

- Clouds play a crucial role in the planet's **albedo effect**
  - Albedo refers to the **reflectivity** of a surface, indicating how much **solar radiation** is reflected back into space
  - Clouds have a high albedo, reflecting a significant portion of incoming sunlight back into space
  - This reflection of solar radiation helps **cool** the **Earth's surface** and lower the amount of energy absorbed by the planet, offsetting some of the warming effects caused by the greenhouse gases

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- In this way, the albedo effect from clouds contributes to the regulation of global average temperature

- Clouds also act as a feedback mechanism in the climate system
  - In addition, low clouds have a net cooling effect by reflecting more sunlight, while high clouds can have a net warming effect by trapping more outgoing infrared radiation
  - The balance between different cloud types and their altitude can influence the overall albedo effect and temperature regulation
- Changes in cloud cover and properties can lead to variations in the albedo effect and impact global average temperature
  - Factors such as aerosol pollution, changes in atmospheric circulation patterns, and climate change can influence cloud formation, distribution, and properties, affecting the net radiative forcing and temperature patterns on a regional and global scale


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Human Impact on Atmospheric Composition

- Human activities impact the atmospheric composition through altering inputs and outputs of the system
- Changes in the concentrations of atmospheric gases such as ozone, carbon dioxide and water vapour have significant effects on ecosystems

Human Activities Impacting the Atmosphere

Atmospheric component affected by human activity	Activities affecting atmospheric component	Effects on ecosystems
Ozone	Release of ozone-depleting substances (e.g. CFCs used in aerosols, gas-blown plastics, pesticides, flame retardants and refrigerants) reduces the amount of atmospheric ozone	Increases UV radiation reaching the Earth's surface, harming organisms, including phytoplankton, plants, and humans
Carbon dioxide	Burning fossil fuels, deforestation and industrial processes all increase atmospheric carbon dioxide	Enhances the greenhouse effect, leading to global warming and climate change, affecting ecosystems and biodiversity
Water vapour	Land use changes, agriculture and industrial processes can disturb atmospheric water vapour concentrations	Alters precipitation patterns, contributing to droughts or excessive rainfall in certain regions, impacting ecosystems, agriculture, and water availability
Methane	Agriculture (livestock and rice production), fossil fuel extraction and use, and waste management (landfill sites) can increase atmospheric methane	Enhances the greenhouse effect, leading to global warming and climate change, affecting ecosystems, melting permafrost (resulting in positive feedback) and ice caps, and contributing to sea-level rise

Nitrous oxide	Agriculture (fertiliser use, animal waste), combustion processes (e.g. in vehicle engines) and industrial activities all increase atmospheric nitrous oxide	Contributes to global warming and climate change, and affects air quality
Aerosols	Aerosols (e.g. fine particles, such as soot and dust, as well as gases like sulfur dioxide and nitrogen oxides) are produced by industrial processes, biomass burning and vehicle emissions	Alters radiative properties of atmosphere, affects air quality, and can influence cloud formation and precipitation patterns, impacting ecosystems and human health (fine particulate matter can be inhaled by humans and animals, leading to respiratory problems and other health issues) - atmospheric sulfur dioxide and nitrogen oxides lead to acid rain formation


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- It is important to recognise that the impacts of these human activities on atmospheric composition are **interconnected** and can have **cascading effects** on ecosystems, biodiversity, and human well-being
- The table above provides a simplified overview of some key **human-induced changes** in atmospheric composition and their general effects on ecosystems

Greenhouse Effect

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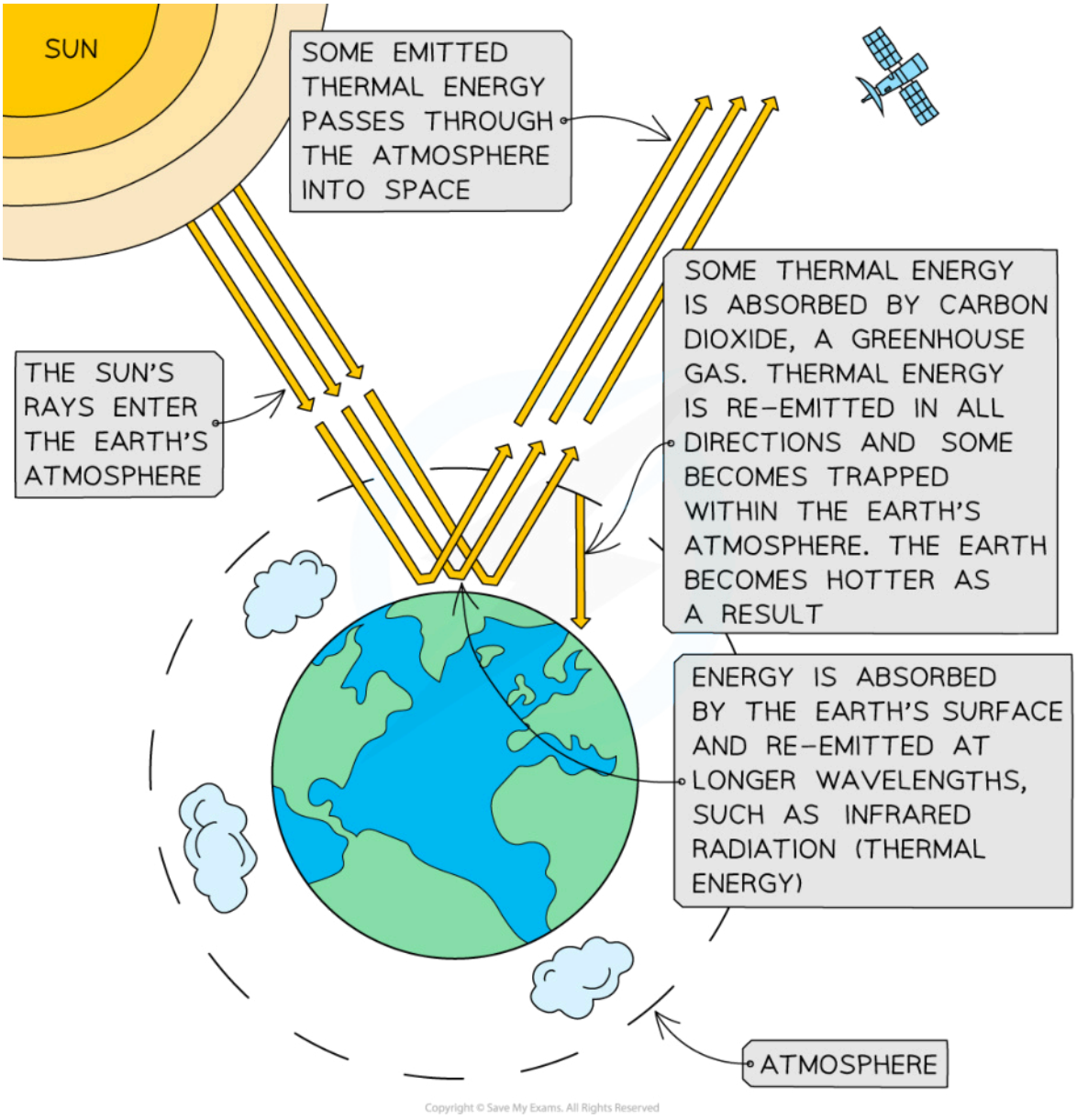
The Greenhouse Effect

What is the Greenhouse Effect?

- The Sun emits energy in the form of solar radiation (including visible light and ultraviolet rays) that enters the Earth's atmosphere
  - Some thermal energy is **reflected** from the Earth's surface
  - Most thermal energy is **absorbed** and **re-emitted** back from the Earth's surface
- This energy **passes through the atmosphere** where some thermal energy passes straight through and is emitted into **space**
- But some thermal energy is **absorbed** by **greenhouse gases** such as carbon dioxide, methane and water vapour, and is re-emitted in all directions
  - These gases act like a blanket, allowing sunlight to pass through but preventing a significant amount of the infrared radiation from escaping back into space
- This reduces the thermal energy lost into space and **traps** it within the Earth's atmosphere, keeping the Earth warm
- This process is known as the **greenhouse effect**
  - The greenhouse effect is a naturally occurring phenomenon
  - The greenhouse effect is important to ensure that Earth is warm enough for **life**
  - If it were not for the **insulating effect** of greenhouse gases, Earth would see similar **dramatic temperature fluctuations** to its neighbouring planets
  - Without the greenhouse effect, the average temperature would be much **colder**, making the planet **uninhabitable**



Greenhouse gases absorb the radiation that is re-emitted from the Earth's surface, trapping it in the atmosphere

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Examiner Tips and Tricks

Don't get confused - the greenhouse effect is a natural process and is necessary for life on Earth. The **accelerated** or **enhanced** greenhouse effect refers to the changes in the greenhouse effect (mostly due to human activity) that are commonly referred to as global warming. This is discussed further in 7.2.2!

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