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Atmosphere

The Heat Budget

- The sun is the main source of energy for the Earth, and the solar energy we receive from it drives the atmospheric system.
- Generally, the incoming solar radiation(insolation) is balanced by the outgoing terrestrial radiation(infra-red radiation).
- The balance between input and output is called the Global Heat Budget.
- Incoming solar radiation passes through the atmosphere and is transferred to the planets surface but: some is reflected by clouds, scattered by gas particles in the air and reflected by the Earth's surface.
- The reflection and scattering is called the albedo affect and accounts for a loss of around 30 per cent of the incoming solar radiation.
- In addition: some is absorbed by clouds and some is absorbed by dust, water vapour and other gases.
- To balance the input, long-wave radiation is emitted from the surface back into the atmosphere. A lot of it is absorbed by water vapour, carbon dioxide and other greenhouse gases and is then re-radiated.
- Latitudinal variations mean that some parts of the planet receive much more solar radiation than others. Between 35-35 degrees north and south there is an energy surplus because incoming solar radiation is greater than outgoing terrestrial radiation.
- From 35 degrees north to the north pole and 35 degrees south to the south pole, there is an energy deficit because incoming radiation is less than outgoing terrestrial radiation.
- The variations around the Earth of energy surplus and energy deficit are greatest between the intense heating in the tropics and the intense cooling that takes place at the poles. This contrast between these two extremes is referred to as the global temperature gradient and is caused by the following:
- The curvature of the Earth means that the surface of the planet slopes further away from the sun with increasing distance from the Equator. Beams of incoming solar radiation will be concentrated on a smaller area at the equator, giving higher temperatures than at the poles, where they are more spread out.

- The curvature of the Earth also means that these beams pass through more atmosphere at the poles than at the Equator. They will be affected by more absorption and albedo from clouds, water vapour and gases, so temperatures will be lower.
- Between the tropics of Cancer and Capricorn, the sun is high overhead during the day all year round. Insolation is more focused and temperatures higher than at the poles, where the sun's rays hit the surface at a much lower angle.
- For six months of the year, the poles are covered in darkness, receive little or no incoming solar radiation and have very low temperatures.
- Effects of the surface albedo are also a contributing factor. At the poles white snow, and ice reflect much of the solar radiation back into space. In contrast at the equator, there is much more absorption by dense, dark tropical vegetation.
- Finally, the global differences in energy surplus and deficit would result in a severe energy imbalance, with the tropics becoming gradually warmer and the poles gradually colder. To keep balance, energy is transferred from areas of surplus to deficit in two different ways: Atmospheric Circulation (80%) and Oceanic Circulation (20%)

Energy Transfer

- Atmospheric Circulation - The three cell model attempts to explain global energy transfer through a series of interconnected cells that move air at high altitudes and have associated surface wind belts:
- Warm air rises at the equator and travels north and south in the upper atmosphere before cooling and descending at around 30°N and 30°S. The movement forms the Hadley cell.
- At the poles, cold dense polar air sinks and moves towards lower latitudes at the surface, warming as it travels and rising again at the polar front. This movement forms the polar cell.
- The ferrel Cell lies between the Hadley and Polar cells. It is controlled by the two other cells and gains energy from them. Warm air from the tropics is fed to higher latitudes through the ferrel cell, and cold air is transferred back to the sub-tropics.
- Because the Hadley and Polar Cells are controlled by Heat and cold, they are thermally direct. The Ferrel Cell is thermally indirect because it is controlled by the two other cells.
- As warm air rises in the Hadley Cell rises at the Equator, an area of low pressure forms at the Earth's surface. Huge cumulonimbus form and give rise to heavy convectional rainfall. The air spreads North and south and sinks at the sub-tropical

high pressure areas, This sinking air is very dry and gives clear skies and little or no precipitation, and it is in these areas that the hot deserts - the sahara are found.

- Rossby Waves and the Jet Stream - Recent evidence has shown that, instead of a Ferrel Cell, the upper atmosphere in the mid-latitudes consists of slowly travelling bands of high and low pressure in a horizontal wave-like motions called the Rossby Waves. Like rivers, Rossby waves can form meander loops which transfer cold air from the High to Low latitudes and warm air in the opposite direction. The waves have associated jet streams - narrow bands of very fast-flowing air - that influence mid-latitude anticyclones and depressions.
- Surface Wind Patterns - A the Earth's surface, the effects of the three-cell model are seen in the high-pressure areas at the poles and the low-pressure areas at the equator and in the mid-latitudes. In theory, surface winds should blow directly from high-pressure areas to low-pressure areas. The rotation of the Earth, however, produces the Coriolis Force, which deflects winds to the right of their direction of travel in the Northern Hemisphere and to the left in the Southern-Hemisphere.
- Pressure Differences, combined with the Coriolis, produce distinct global wind patterns: 1. Winds blow from the sub-tropical high-pressure areas to the Equator, forming the North-east and south East trade winds. 2. The mid-latitude westerlies flow polewards from the sub-tropical high-pressure areas and have associated series of anticyclones and depressions. They are impeded by land masses in the Northern Hemisphere and are stronger in the south. 3. The polar easterlies flow from the polar high-pressure areas to mid-latitudes flows.
- However, the idealised pattern of Global surface winds break down in reality because of localised conditions cut as the Monsoon over india and the influence of the Himalayan mountains. It is still useful as an indication of the general Pattern.
- Oceanic Circulation - Energy is also transferred around the planet by mean currents such as the North Atlantic Drift, which brings warmer waters to the western coasts of the UK and influences its mild climate. Elsewhere, cold currents off the coasts of Peru and Namibia create dry onshore winds and help to form deserts.
- Ocean Currents are driven by Thermaholine Circulation- heat and salt determining the density of the water. The cold water at the poles is denser because it contains more salt so it sinks and flows towards the Equator in deep ocean basins. Warmer, less dense surface currents flow polewards from the Equator. The resulting worldwide circulation system is known as the Atlantic Conveyor.
- The pattern of ocean Currents is similiar to that of Atmospheric Circulation, but deflection by land masses results in huge, circular loops of water called gyres. These flow clockwise in the Northern Hemisphere and anticlockwise in the South. The west

wind drift is not impeded by land masses and flows from west to East around the Globe.

- Other Factors responsible for these patterns include: the prevailing wind pattern - surface winds cause friction with the water surface and influence the direction of surface currents, deflection by coriolis, directing currents to the right in the Northern Hemisphere and Let in the south, the cold, slow moving deap-sea currents which have an effect on the surface patterns.
- The phenomana known al El Niño- periodic warming and cooling of the tropical Pacific Ocean - also have an influence on Global Weather Patterns, causing extreme events such as Heavy rainfall and flooding in normally very dry deserts.

Climate Change

- The enhanced greenhouse affect - Greenhouse gases in the atmosphere - including Carbon Dioxide, methane, nitrous oxide, halocarbons and water vapour - keep global temperatures around 30° C warmer than they would otherwise be. They are produced naturally but are added to by human activity. This causes the enhanced greenhouse effect which most scientists believe is behind climate change.
- Physical Causes of temperature change include:
- Volcanic Eruptions - These emit huge amounts of dust into the atmosphere. This is distributed by global winds, forms a blanket shielding the Earth from incoming solar radiation and leads to a decrease in temperature.
- Increased sunspot activity - leads to greater output of solar radiation ad increased temperatures, such as those in the warm 1940s. Climate change sceptics have said that this process is responsible for temperature increases over the last 40 years - but, in fact, the sun has cooled slightly since 1970.
- Milankovitch cycles - are slight variations in the Earth's orbit around the sun Every 41,000 years, there is a change in the tilt of the Earth's axis, which can bring more sunlight to polar regions. Over a period of 100,000 years, the orbit stretches, increasing and decreasing incoming solar radiation over long periods of time.
- Changes in Oceanic circulation - influence global change although, in the short term, this may be limited by El Niño effects.
- Human causes include:
- Fossil Fuels - Coal, Oil and natural gas were formed over millions of years but are being burned much more quickly. Since intense burning has started with the Industrial Revolution, the amount of CO_2 in the atmosphere has increased around 30 %

- Deforestation - especially burning tropical rainforests, adds to the concentration of CO_2, but, more importantly, decreases the amount used by plants in photosynthesis.
- Methane - Produces 21 times as much greenhouse warming as CO_2. It comes from decaying vegetation (especially in rice paddy fields), increasing flatulent cattle and waste in landfill sites. Nitrous oxide comes mainly from agricultural fertilisers and pesticides. Sources of these gases are increasing rapidly in line with global population increases.
- Halocarbons - They are up to 13,000 times more potent than CO_2. They come from solvents and fridges but were banned internationally in 1989.
- Consequences of Climate Change include:
- Sea levels rising, leading to coastal flooding and som island nations becoming uninhabitable.
- An increase in extreme weather events such as European Heatwaves, Australian Forest Fires and severe hurricanes in the USA.
- The disappearance of the polar ice cap.
- The extinction of up to a third of all species by 2100.
- Tropical diseases such as Malaria moving into temperate latitudes.
- Climate wars fought over precious food and water.
- Bleaching of Coral Reefs.
- Changing agricultural patterns, for instance, potatoes giving way to maize in Scotland.

West Africa and the ITCZ

- West Africa has a tropical climate with temperatures greater than 23°C all year round. The climate between the Equator and 10°N and S is equatorial. Further north and south, the climate is tropical continental, often called Savanna. Beyond the Savanna lies the hot desert climate.
- Large masses of air settle over parts of the Earth’s surface and take on the characteristics of the areas where they form. When the air masses move, in the form of surface winds, they carry characteristics of their source areas. There are two main air masses affecting the weather and climate of West Africa:
- Tropical Continental - The cT air mass is formed over the sahara desert, and its associated winds are the north-east trades, known locally as Harmattan. These bring extremely hot temperatures, a very low relative humidity between 10 and 17 %, no rainfall and poor visibility because of the large amount of dust they carry.

- Tropical Maritime - Formed over the ocean south of the Equator, the south-east trade winds from the mT air mass are deflected by Coriolis as they pass over the Equator to become South-west Monsoon. These winds are hot, having formed in a tropical area, but humidity is high (from 62 to 82%). Associated rainfall varies from showers to intense thunderstorms.
- Areas where different winds meet are called zones of convergence.
- The zone where the North-east trade winds and the south-west monsoon meet over West Africa is called the inter-tropical convergence zone. The ITCZ is a zone of low pressure where air rises. South of the ITCZ, a wide band of different types of rainfall forms over several hundred kilometres.
- The ITCZ is not stationary but travels north and south of the Equator following the overhead sun and the thermal equator - the area of most intense heating of the Earth's surface by the sun.
- In July (the northern hemisphere summer), the thermal equator is at its most northerly extent, around 20°N, because the tilt of the Earth means that the sahara is receiving maximum incoming solar radiation.
- It then migrates south towards the Tropic of Capricorn until the peak of the southern hemisphere summer in January. However, part of the ITCZ remains at around 8°N over West Africa because of the differential heating of the oceans and the land surface.
- The position of the ITCZ determines the rainfall pattern over West Africa. In January, it is located near the southern coast of West Africa, and places such as Lagos in Nigeria receive light rainfall. Areas North of the ITCZ are affected by the bot, dry winds of the cT air mass and experience there dry season.
- As the ITCZ migrates north, large cumulonimbus clouds follow to the south and bring thunderstorms over Lagos and further inland. South of the Thunderstorms, rainfall will decrease once more, leading to a dip in monthly totals. As the ITCZ reaches its northernmost point in July, all areas south of around 20°N have their wet season.
- The ITCZ then Migrates south, and northern areas become dry once more. Southern coastal areas in West Africa will experience a returning band of thunderstorms and high rainfall, leading to a second rainfall peak. These areas, which are always south of the ITCZ, do not have a dry season.