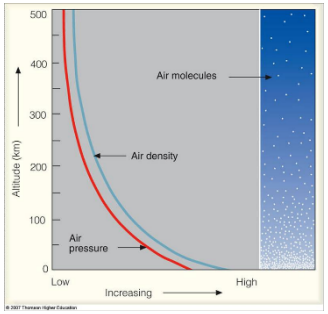
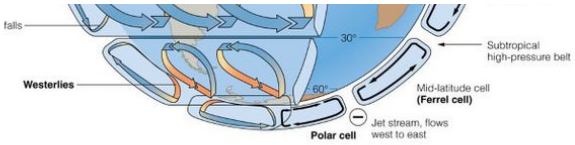
# Assessment Schedule – 2023

## Earth and Space Science: Demonstrate understanding of processes in the atmosphere system (91414)

### Evidence Statement

| Q | Evidence | Achievement | Merit | Excellence |
|---|---|---|---|---|
| ONE | The troposphere is the layer closest to Earth and contains 80% of the mass of the atmosphere, while the stratosphere contains less than 10%. The atmosphere consists of gases including nitrogen (78%), oxygen (21%), argon and trace amounts of carbon dioxide, methane, water vapour and other gases. Due to gravity, atmospheric particles are pulled towards Earth, leading to highest density (density = mass / volume) near the Earth's surface, decreasing with increasing altitude. This means that oxygen concentration reduces with increasing altitude.<br>  <br><br>https: / / physics.stackexchange.com / questions / 105489 / stratospheric-ship<br>Similarly, atmospheric pressure is highest at the surface as a column of air contains more particles at the Earth's surface than at altitude. Pressure is defined as force ÷ area. Thus, the troposphere will have higher air pressure and density than the stratosphere. This means that there is less drag on the plane, and it can therefore travel faster in the stratosphere. However, the thinner air may result in less oxygen available for the engines.<br>Weather occurs in the troposphere where water vapour (and aerosols) is abundant to form clouds. Jet aircraft can expect turbulent conditions related to weather and wind gusts in this layer, due to surface being source of heat and differential heating causing pressure gradients and air flow.<br>In comparison, the stratosphere has significantly less water vapour, and as the heat source is above (ozone / UV), there is very little vertical air movement, but much greater horizontal air movement, resulting in a much smoother, and potentially faster flight. This makes flights in the stratosphere less turbulent, as planes can travel above the clouds / weather.<br>Additionally, jet aircraft may from time to time use the jet streams near the tropopause to reduce flight times when flying from west to east. These are present as subpolar and subtropical jet streams in both hemispheres. Jet streams form near the tropopause, typically between sinking cold air masses and rising warmer air masses in adjacent cells, causing a strong movement along the polar and subtropical fronts to form jet streams. Because of the direction of Earth's spin, these streams move from west to east, and can reach high speeds, drastically reducing flight times when the plane is moving in the same direction. | Describes with understanding:<br>• composition of atmosphere, incl. oxygen and nitrogen<br>• difference in composition (water and ozone or ~90% and 10% mass)<br>• air density OR pressure<br>• density and / or pressure decreases with increasing altitude / lower in stratosphere<br>• weather occurs in troposphere / absent in stratosphere<br>• temperature decreases with altitude in the troposphere<br>• higher in the atmosphere air resistance / drag is lower<br>• troposphere heated from below (IR / GHG / conduction)<br>• stratosphere temp increases with altitude as heated from above (UV / ozone)<br>• flights faster / easier in jet stream if same direction. | Explains:<br>• why density / pressure is higher in the troposphere / closer to surface (or opposite)<br>• why available oxygen decreases with increasing altitude<br>• why troposphere has weather (inc. clouds) / turbulence / vertical air movement (due to uneven global heating / heated from below)<br>• why stratosphere is more stable (temp. increases with altitude) and has stronger winds<br>• how lower density reduces drag / air resistance, making travel faster at higher altitudes<br>• how jet streams are used from west to east and not east to west to reduce flight time due to rotation of the Earth. | Explains comprehensively:<br>• comparison of layers (density, pressure and composition)<br>• formation of weather systems (uneven global heating / heated from below) and air stability (heated from above) linked to preference for flying high<br>• why flying higher is better (linked to one reason explained), BUT insufficient oxygen for combustion present at higher altitudes.<br>• weather occurs in troposphere / absent in stratosphere. |

| NØ | N1 | N2 | A3 | A4 | M5 | M6 | E7 | E8 |
|---|---|---|---|---|---|---|---|---|
| No response; no relevant evidence. | ONE point from Achievement | TWO points from Achievement. | THREE points from Achievement. | FOUR points from Achievement. | ONE point from Merit. | TWO points from Merit. | ONE point from Excellence. | TWO points from Excellence. |

| Q | Evidence | Achievement | Merit | Excellence |
|---|---|---|---|---|
| TWO | Sea spray aerosols are minute particles that are released into the atmosphere when waves break and are then transported by winds. The winds across the Southern Ocean near 50°S are strong, causing more waves, and high sea spray aerosol concentrations.<br>  <br><br>www.quora.com / What-is-the-tri-cellular-model-of-atmospheric-circulation<br>The atmospheric circulation cell at 50°S is the pressure-driven Ferrel cell. The cell forms when warm air from the Hadley cell cools and descends at 30°S, causing an area of high pressure at the surface.<br>Air flows away from the HP towards the Equator and 60°S. Air flowing towards 60°S warms through conduction as it travels over the surface, until it meets colder air from the polar cell. The warmer, less dense air rises at 60°S, leaving an area of low pressure at surface, and circulates back towards 30°S, near the tropopause, where it descends and completes the Ferrel cell circulation. The surface flow between 30°S and 60°S forms the westerly wind belt. Air does not flow in a straight line, due to the Coriolis effect (apparent deflection of air due to the curvature of the Earth). Instead, it is deflected to the left in the Southern Hemisphere, causing strong winds from the west near 50°S.<br>Sea spray aerosols act as condensation nuclei for the formation of clouds. They provide a surface for condensing water vapour molecules to attach to, and eventually lead to the formation of liquid droplets as they grow. Condensation is the process where water vapour turns into liquid by releasing latent heat to the atmosphere.<br>For clouds to form, there is also a requirement for sufficient water vapour to be present, and for the temperature of air to fall below the dew point (saturation point at a certain temperature). Evaporation is the state change from liquid water to gas when water absorbs latent heat. As the westerlies travel across the open ocean, the air will accumulate water evaporating from the ocean's surface.<br>Both aerosols and water vapour are transported towards New Zealand by strong westerlies. Once the humid, aerosol-laden air reaches land, it is forced to rise by (the Southern Alps and other) mountain ranges. As the air rises, it cools adiabatically until it reaches dew point, the temperature to which air must be cooled to become saturated with water. Once dew point is reached, condensation on aerosols is possible, and clouds form. Precipitation happens when the droplets reach sufficient mass and fall to the Earth due to gravity. | Describes with understanding:<br>• definition of sea spray aerosols<br>• warm / less dense air rises at 60°S **or** cold dense air sinks at 30°S<br>• low pressure at 60°S **and** high pressure at 30°S<br>• winds curve to left in Southern Hemisphere due to Coriolis<br>• aerosols act as condensation nuclei<br>• water vapour required for cloud formation<br>• dew point temperature should be reached for clouds to form / condensation<br>• evaporation state change from liquid to vapour / gas OR condensation is opposite<br>• air flow from HP to LP causes wind<br>• one correct statement about Ferrell cell. | Explains:<br>• formation of the Ferrel cell<br>• direction of westerlies the result of Ferrel cell surface flow and Coriolis effect<br>• how the high concentration of aerosols is produced in this area, due to strong winds<br>• how aerosols and water vapour interaction leads to cloud formation<br>• air forced up by mountains is cooled (dew point) causing condensation<br>• condensation processes with energy and phase changes. | Explains comprehensively:<br>• the formation of the Ferrel cell and westerlies with reference to pressure, temperature, density, and Coriolis effect<br>• cloud formation as result of aerosols, evaporation, condensation, and (adiabatic) cooling to dew point<br>• sea spray aerosols and water vapour transported long distances by westerlies, as these winds are strong and uninterrupted AND causes high concentrations of aerosols and evaporation rates. |

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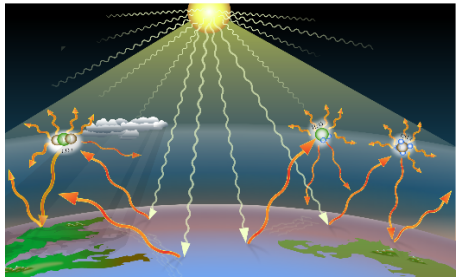
| Q | Evidence | Achievement | Merit | Excellence |
|---|---|---|---|---|
| THREE | The greenhouse effect is the natural phenomena responsible for the Earth's warm troposphere. Short-wave radiation from the sun is transmitted through the atmosphere, and is absorbed by land and ocean surfaces. The surfaces emit long-wave radiation in the form of infrared wavelengths. Greenhouse gases in the atmosphere absorb long wave (IR) radiation from the Earth's surface and re-emit it into the atmosphere, causing an increase of temperature in the troposphere. Greenhouse gases (GHGs) include water vapour, $CO_2$, ozone, methane, and nitrous oxide.<br>Human activities have increased the concentrations of some greenhouse gases in the atmosphere above natural levels e.g., carbon dioxide, $CO_2$, and methane, $CH_4$. Processes that emit these compounds include combustion of fossil fuels for transport and / or electricity generation, cement manufacturing, deforestation, land clearing, and agriculture (crops and animals).<br>  <br>1https: / / en.wikipedia.org / wiki / Greenhouse_gas<br>An increase in GHGs causes an increase in atmospheric temperature, as more outgoing IR radiation is absorbed by the gases, and less emitted into space. The Earth's energy balance is changed, as the atmosphere retains more heat, causing an increase in average global temperatures.<br>Albedo is a measure of reflectivity of a surface (reflecting radiation). Surface ice in glaciers, ice sheets, and snow regulate global temperature, because its high albedo reflects most incoming short-wave radiation back into space. This prevents absorption of short-wave and re-emission of long-wave radiation by the surface. As surface ice reduces, the planet's albedo decreases, meaning more short-wave radiation is absorbed by darker oceans and land surface and re-emitted as IR (heat). The data supports this, as an increase of 0.7 °C since 1994 has coincided with a loss of surface ice of more than 28 trillion tons.<br>The increase in greenhouse gases and atmospheric temperature causes more melting of surface ice, and reduces the albedo of the planet. The increased absorption of incoming solar radiation by oceans and land causes a positive climate feedback loop, as it leads to an increase in long wave radiation (heat) emitted from the surface, increasing atmospheric temperature. In turn, this leads to more melting of ice and further increases in global temperatures. | Describes with understanding:<br>• GHE responsible for warm atmosphere<br>• short-wave radiation from sun absorbed by land and / or ocean<br>• GHGs able to absorb heat / IR and re-emit it<br>• human activities increased GHG above natural levels<br>• increased GHG lead to increased average global temperatures<br>• surface ice has a high albedo / reflects incoming short-wave radiation<br>• as surface ice declines, average temperatures increase<br>• as temperatures increase, more surface ice will melt. | Explains:<br>• the GHE (incoming high energy / short wavelength radiation heats Earth, outgoing long wavelength / IR absorbed by GHGs)<br>• effect of melting surface ice on UV absorption due to lowering albedo<br>• impact of human activities on the greenhouse effect / energy balance<br>• surface ice albedo and effect on reducing global temperature (or opposite)<br>• loss of surface ice due to increasing GHG and temperature. | Explains comprehensively:<br>• how humans enhance the GHE with reference to human activities and relevant GHGs, short-wave and long-wave radiation<br>• how surface ice contributes to regulating average global temperature, with reference to albedo and comparison with land / ocean surface<br>• melting ice due to enhanced GHE leading to more energy absorption<br>• / lower albedo and **faster** warming of the atmosphere. |

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## Cut Scores

| Not Achieved | Achievement | Achievement with Merit | Achievement with Excellence |
|---|---|---|---|
| 0 – 7 | 8 – 13 | 14 – 18 | 19 – 24 |