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91414



914140



NEW ZEALAND QUALIFICATIONS AUTHORITY  
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## Level 3 Earth and Space Science, 2019

### 91414 Demonstrate understanding of processes in the atmosphere system

2.00 p.m. Thursday 28 November 2019  
Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of processes in the atmosphere system.	Demonstrate in-depth understanding of processes in the atmosphere system.	Demonstrate comprehensive understanding of processes in the atmosphere system.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

**You should attempt ALL the questions in this booklet.**

If you need more room for any answer, use the extra space provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–15 in the correct order and that none of these pages is blank.

**YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.**

Merit

TOTAL

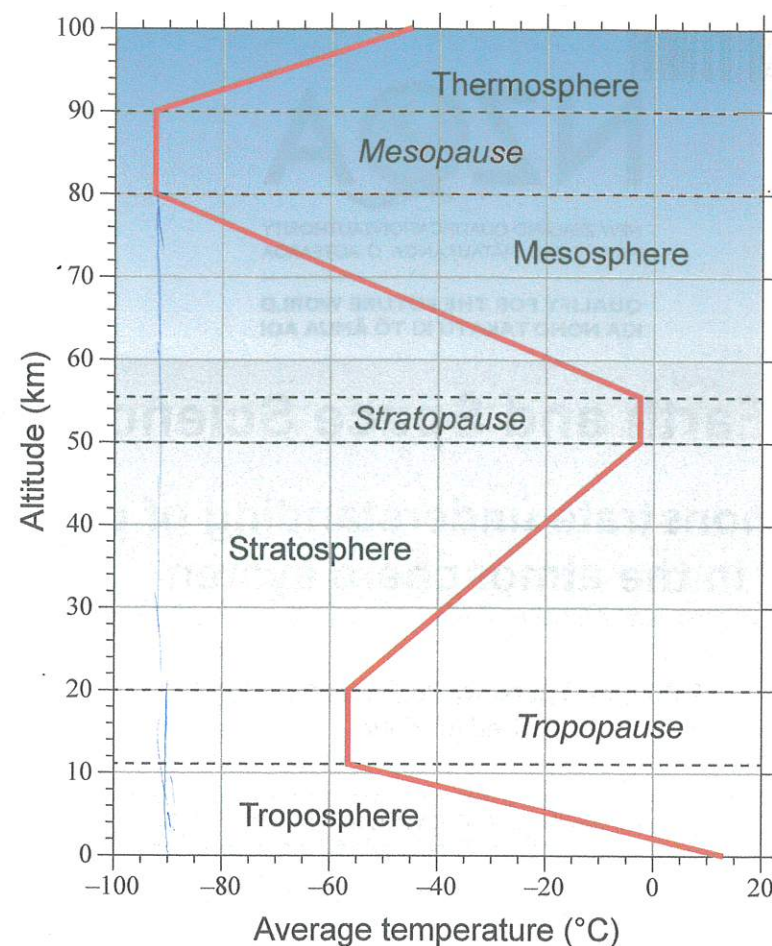
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# QUESTION ONE: TEMPERATURE WITHIN THE ATMOSPHERE

The graph below shows the **average** temperature gradient for the Earth's atmosphere.



Adapted from: [www.physicalgeography.net/fundamentals/images/atmslayers.gif](http://www.physicalgeography.net/fundamentals/images/atmslayers.gif)

Explain the temperature gradient graph.

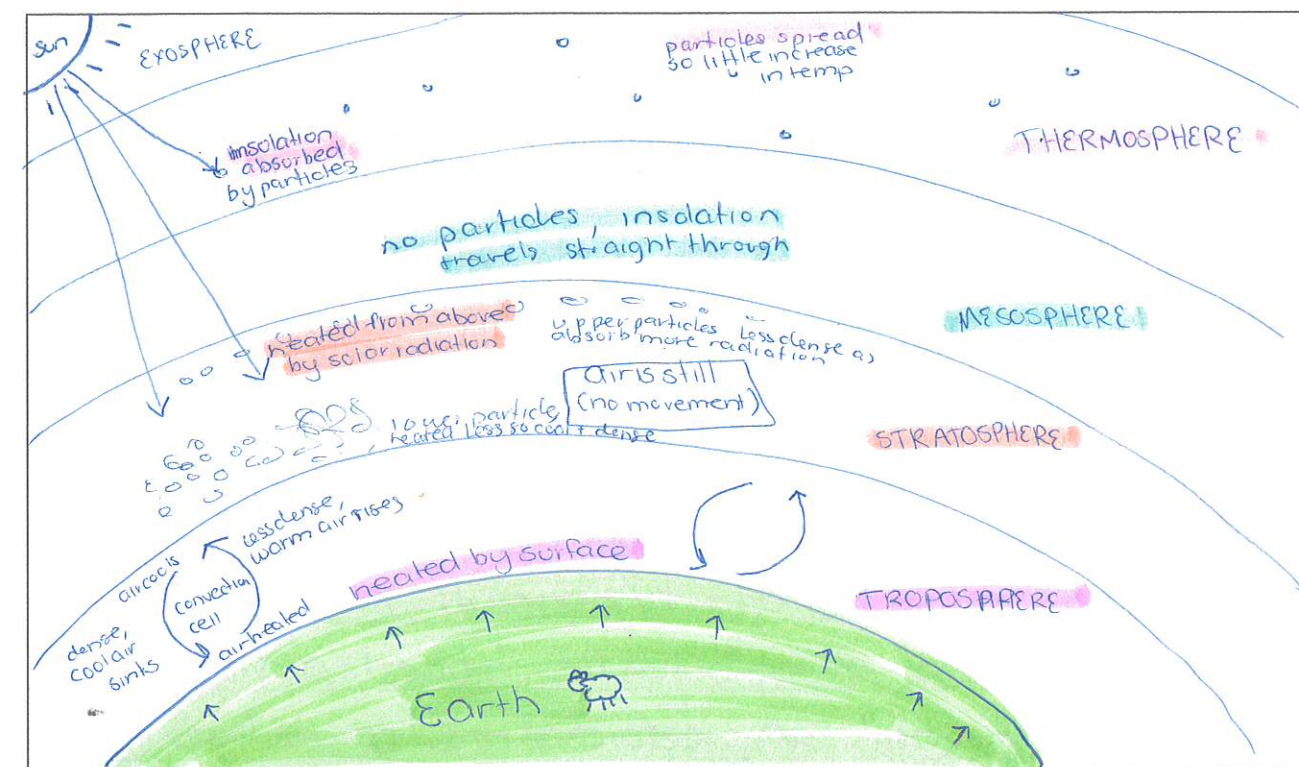
In your answer, you should consider:

- the heat source of each layer, and the type of radiation involved
- reasons for the temperature changes shown
- the effect of changes in latitude and seasons on the height of the troposphere.

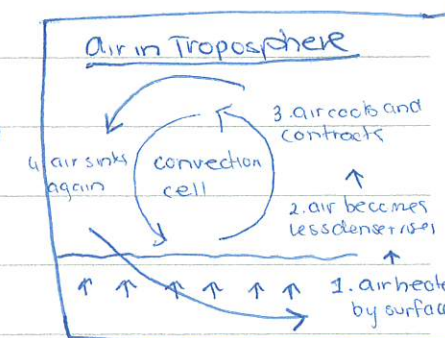
You may use a diagram to help support your answer.

The Earth's atmosphere is divided into different layers with increasing altitude.

The troposphere is the lowest layer, from the surface of the Earth to about 11 km above the surface. This layer is heated by the Earth's surface, as infrared radiation is emitted by the Earth back into the atmosphere. As a result, temperature ~~increases~~ decreases with increasing



altitude, from around  $13^{\circ}\text{C}$  to  $-55^{\circ}\text{C}$  at the highest point. Temperature decreases with increasing altitude because the troposphere is heated by the Earth's surface. Air above the surface is warmed by convection/radiation from the lithosphere. This air, as it gains heat energy, gains kinetic energy and the particles move more, spread out, and the air becomes less dense. As a result, the less dense air rises. As it rises away from the heat source, the air cools, contracts and sinks where it is reheated to rise again. Therefore, the ~~more dense~~ air is ~~are~~ constantly circulated so the cooler, less dense air is at the top of this layer, where temperatures are around  $-55^{\circ}\text{C}$ . In the tropopause, temperatures are constant ( $\sim -55^{\circ}\text{C}$ ).



There is more space for your answer to this question on the following pages.

The stratosphere extends from



around 20k to 50km above the Earth's surface. With increasing altitude, temperatures also increase. <sup>(from  $-55^{\circ}\text{C}$  to  $-5^{\circ}\text{C}$ )</sup> This is because the stratosphere is heated from above by insolation. Therefore, the ~~air~~ ~~at~~ the highest point of the stratosphere is heated, gaining kinetic energy, and so particles move and the air is less dense. As this warm, less dense air is already the highest layer in the stratosphere, and it can't rise above the stratopause, there is no vertical movement/mixing of air. As a result, temperature increases with increasing altitude as the highest points of air absorb the most insolation before it reaches the lower regions of air. In the stratopause, temperatures remain constant ( $\sim -5^{\circ}\text{C}$ ).

In the mesosphere, the temperatures once again decrease with increasing altitude, from around  $-5^{\circ}\text{C}$  to  $-90^{\circ}\text{C}$ . This is because the mesosphere contains no particles, such as gas particles or dust, that may absorb heat. Therefore, the temperature decreases rapidly as no solar radiation is absorbed by this layer.

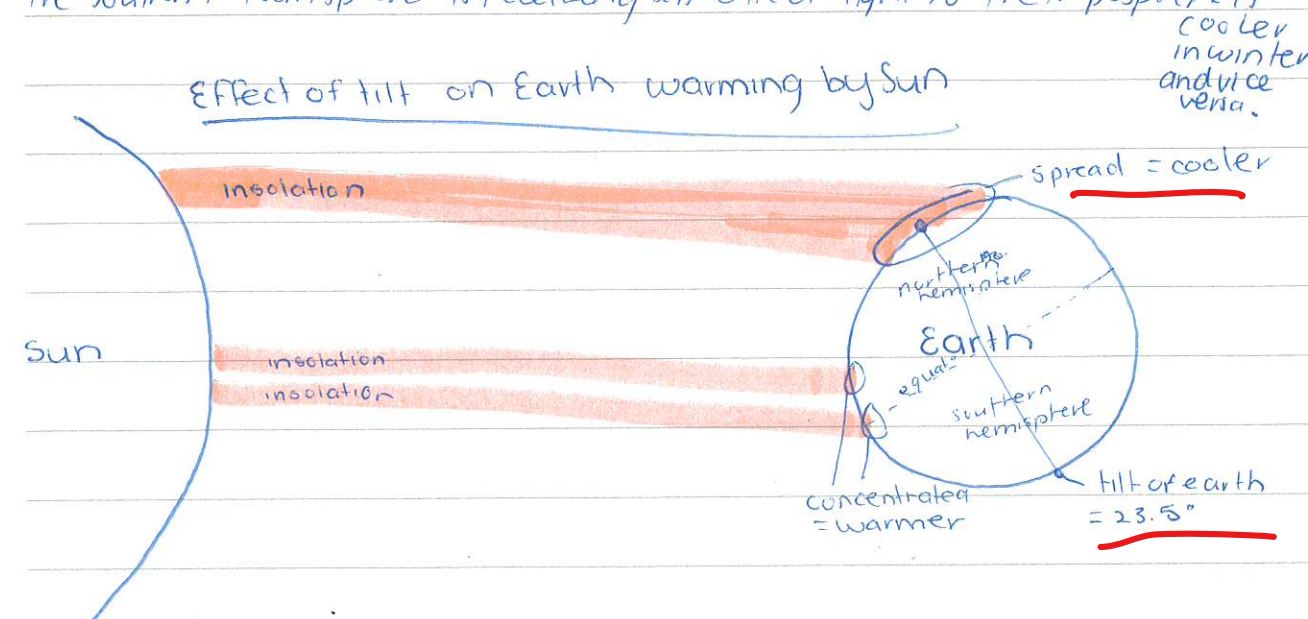
The mesosphere extends from 55km above the Earth's surface to 80km. In the mesopause, temperatures remain constant ~~at~~ (around  $-90^{\circ}\text{C}$ ).

In the thermosphere, the temperatures begin to rise again slowly, from around  $-90^{\circ}\text{C}$  to  $-45^{\circ}\text{C}$ . In this layer of the atmosphere there are gas and dust particles (e.g. space debris) that are present to absorb incoming solar radiation, so the temperatures

increase again. However, it is still very cold in the ~~thermo~~ thermosphere as the particles are so spread that the heat absorbed can hardly be felt. Therefore, temperatures do not exceed  $-40^{\circ}\text{C}$ .

In the troposphere, temperatures can vary dramatically depending on season and latitude, not only height. In the equatorial latitudes, solar radiation is much more concentrated due to the angle of the Earth to the sun ( $23.5^{\circ}$  tilt), so this region receives more direct heat energy and the troposphere is much warmer, as the surface is warmer, and so emits more radiation.

At the polar latitudes ( $60^{\circ}$ - $90^{\circ}$ ), insolation is much more dispersed due to this angle, and so the surface is warmed less, so emits less heat energy and the troposphere is much cooler (see diagram). <sup>(see extra paper)</sup> Also, in summer months in the Northern Hemisphere (diagram), this hemisphere is tilted towards the sun, so receives more higher concentrations of light for longer periods of time, so the tropopause is warmer. During this time, the Southern Hemisphere is receiving less direct light so the troposphere is





## QUESTION TWO: THE ROARING FORTIES AND THE WEST COAST OF NEW ZEALAND

Sailors call the latitudes between  $40^\circ$  and  $50^\circ$  south the 'Roaring Forties'. New Zealand lies in the 'Roaring Forties', represented by the green band on the map below.



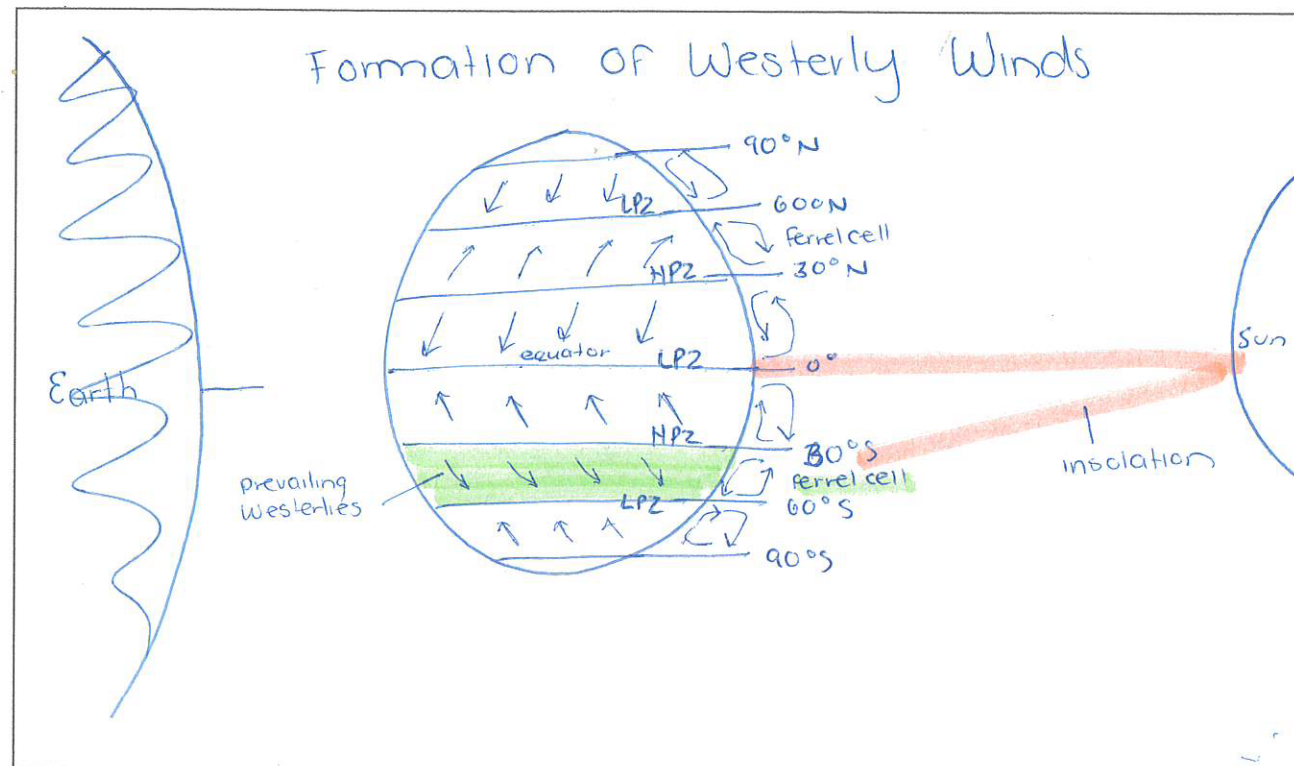
Source: [http://www.thesuperfins.com/wp-content/uploads/2017/02/001-the-Roaring-Forties-TheSuperFins.com\\_.jpg](http://www.thesuperfins.com/wp-content/uploads/2017/02/001-the-Roaring-Forties-TheSuperFins.com_.jpg)

Explain how the westerly winds of the 'roaring forties' are formed, AND how these contribute to the high annual precipitation rates found on the west coast of the South Island of New Zealand.

In your answer, you should consider:

- the role of solar heating and air pressure on wind formation
- the role of the Coriolis effect on the westerly wind belt
- the role of the Southern Alps in the South Island on precipitation rates.

You may use a diagram to help support your answer.



The westerly winds (prevailing westerlies) form between  $40^\circ$  and  $50^\circ$  south of the equator, and are also known as the 'Roaring Forties'.

These winds form due to differential heating of the Earth by the sun. Between  $30^\circ$  and  $60^\circ$  latitude, an open convection cell called a 'Ferrel cell' forms as air rises.

At the equator, more direct insolation is received and is concentrated. The air at the surface is warmed, becomes less dense and rises. As it reaches the tropopause, it spreads out north and south, cools and sinks at around  $30^\circ$  latitude north and south where it returns along the surface towards the equator to even the air pressure. A low pressure zone forms at the equator, and a high pressure zone forms at  $30^\circ$  latitude north and south. Between  $60^\circ$  and  $90^\circ$ , a similar process occurs as air rises at  $60^\circ$  where it is heated more, spreads to  $90^\circ$  at the tropopause, sinks and returns to  $60^\circ$  latitude north and south to even the air pressure. Between these two convection cells, a 'Ferrel' cell forms between  $30^\circ$  and  $60^\circ$  north and south. This cell forms as the air mimics the neighbouring cells causing it to rise at  $60^\circ$  latitude N and S, spread at the tropopause and contract and sink at  $30^\circ$  latitude N and S, where it returns poleward to  $60^\circ$  latitude to even the air pressure. As a result, an open convection cell forms with a high pressure zone at  $30^\circ$ - $40^\circ$  latitude and a low pressure zone at  $50^\circ$ - $60^\circ$  latitude.

as it becomes less dense as air at the surface is heated and particles gain kinetic energy.

There is more space for your answer to this question on the following pages.



The air returning poleward in the southern hemisphere in this ~~cell~~ Ferrel cell is deflected by the Coriolis effect to the ~~east~~ right. The Coriolis effect is the effect of the rotation of the Earth. As it spins, the air is deflected in an ~~easterly direction~~ to the right so is known as a westerly wind as it comes from the west to the east as it travels poleward.

As a result, the westerly winds are formed. These winds are strong and warm, and pick up a lot of moisture from the open and vast ocean (Pacific).

Due to the Pacific ocean being so vast, ~~there~~ the winds pick up a lot of moisture. Also, the waves and ripples caused by the wind increase the surface area of the water - feeding the winds to make them stronger as they receive heat energy from the ocean //

When these westerly winds reach the Southern Alps of New Zealand, orographic rainfall occurs. //

### OROGRAPHIC RAINFALL

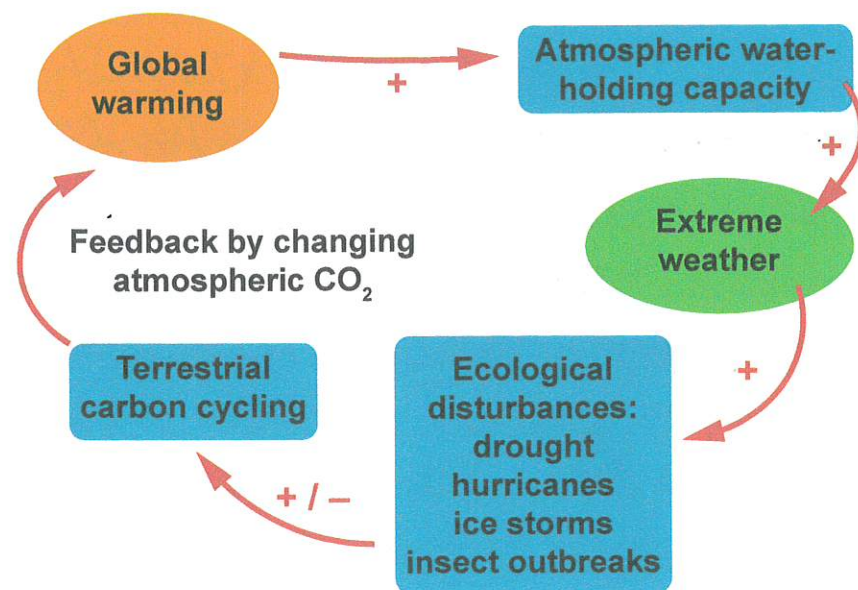


This occurs as warm, moist ~~air~~ <sup>wind</sup> reaches the southern Alps, air is forced to rise and as it rises above land it cools and contracts. This causes the water vapour to also condense, forming cumulonimbus clouds which create heavy, ~~steady consistent~~ <sup>consistent</sup> rainfall. The air, now dry, moves to the leeward side of the Alps, forming wispy clouds and a rain shadow (Foehn effect). Therefore, the west coast of New Zealand experiences high annual precipitation rates as there is consistent rainfall from orographic uplift of the Alps, and the westerly winds //



### QUESTION THREE: THE CARBON AND WATER CYCLES

The carbon and water cycles are closely linked, and help to regulate the Earth's temperature. One example of this is shown in the diagram below.



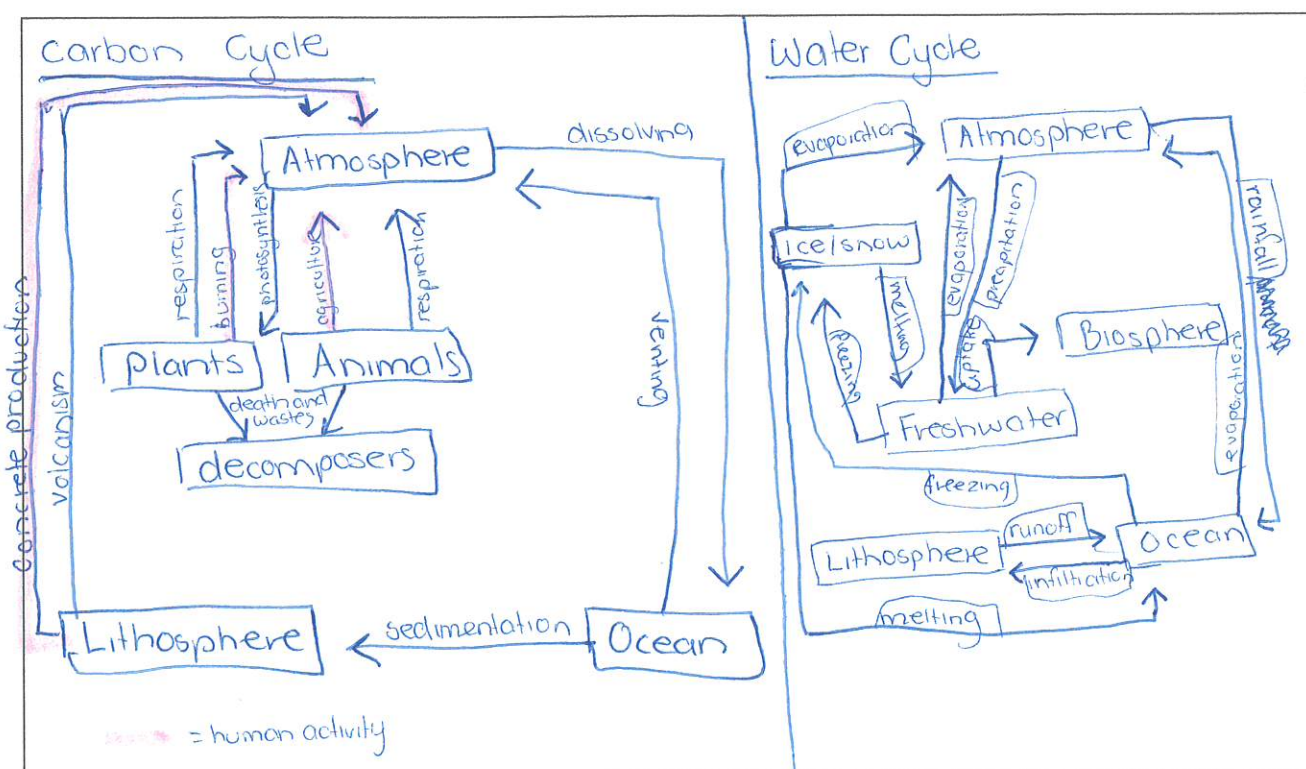
Adapted from: <https://iopscience.iop.org/article/10.1088/1748-9326/10/7/070201/pdf>

Explain how changes to the carbon AND water cycles can **influence** climate change.

In your answer, you should consider:

- how the Earth's temperature affects the water cycle
- the role of the carbon cycle in the Earth's temperature regulation
- how human activities have changed the carbon and water cycles.

You may use a diagram to help support your answer.



The water cycle explains how water is transported and stored around the Earth in its three states; liquid, solid, and gaseous water.

When water is heated, it ~~changes state~~ or cooled, it changes state. For example, evaporation of the ocean water or freshwater occurs as surface water is heated by insolation, gaining heat and kinetic energy so it becomes less dense as particles spread out. Water rises into the air, with rising air in convection cells, as water vapour (gaseous state). This water then cools as it rises, condenses to form clouds in the atmosphere and falls back to these reservoirs as rainfall / precipitation. In <sup>low</sup> ~~cold~~ temperature, water ~~more~~ particles may contract and freeze into ice/snow where it is stored until it melts again with higher temperatures causing particles to move and change into liquid state again. Therefore, where it is much cooler in the polar latitudes, water is stored as ice and snow and there is a lot of rainfall in mid/equatorial latitudes.

~~Carbon cycle~~  
The carbon cycle is the transport and storage of carbon around the Earth. Carbon plays a large role in regulating the Earth's temperatures as carbon particles can absorb insolation

There is more space for your answer to this question on the following page.



radiation to warm the Earth and the atmosphere. Carbon is cycled in many ways, such as being absorbed by green plants and phytoplankton for photosynthesis, or released by living organisms through respiration<sup>as CO<sub>2</sub></sup>. As carbon is released into the atmosphere through processes such as respiration or venting (ocean → atmosphere), it has a warming effect on the Earth as an increase in particles means more radiation is absorbed (and, therefore, heat energy). When carbon is taken up, out of the atmosphere, through processes such as photosynthesis ~~the~~ or dissolving (atmosphere → ocean), it has a cooling effect on the Earth as there are less ~~or~~ carbon particles to absorb less radiation and heat energy. As a result, the constant cycling of carbon regulates the Earth's temperatures - keeping them moderate for living organisms.

Human activities, however, have dramatically changed the carbon and water cycles. For example, activities such as agriculture, burning of trees (deforestation), and concrete production all release more carbon (as carbon dioxide) into the atmosphere. Deforestation results in less trees to take up CO<sub>2</sub> for photosynthesis, and so more CO<sub>2</sub> remains in the atmosphere. ~~As a~~ Agriculture and concrete production also release more CO<sub>2</sub> into the atmosphere through more animals' respiration and releasing CO<sub>2</sub>, and increase in machinery burning fossil fuels that release CO<sub>2</sub> into the atmosphere. As more CO<sub>2</sub>

is released into the atmosphere through these activities, the Earth is warmed more as more particles absorb more insolation / radiation. As a result temperatures of the ocean increase. This has a negative effect on the carbon cycle, as carbon is dissolved best in cool ~~the~~ ocean because the particles have less kinetic energy so remain suspended. As ocean temperatures rise due to absorbing heat energy from the warming atmosphere, less carbon can be dissolved. This disrupts the carbon cycle as even more carbon remains in the atmosphere and is cycled ~~and~~ less. This creates even more of a warming effect on the planet as even more particles remain in the atmosphere to absorb radiation.

This affects the water cycle as more water is evaporated ~~causes~~ due to higher temperatures, resulting in extreme weather like flooding and hurricanes in some regions, and drought in other regions as the temperatures are less regulated. Also, more ice melts due to increasing sea levels, resulting in rising sea levels and ultimately this all leads to ~~climate~~ influences climate change as the temperature rises and disrupts the carbon and water cycles.



Extra paper if required.  
Write the question number(s) if applicable.

QUESTION  
NUMBER

1\* Also, the atmosphere is thicker at the polar latitudes, so less insolation reaches the surface to warm it. On top of this, the poles have a higher albedo (due to ice and snow) so more insolation is reflected than absorbed. As a result, the surface absorbs less insolation at the poles than the equatorial latitudes, and so emits less infrared radiation to warm the troposphere. As a result, the troposphere ~~area~~ has lower temperatures at polar latitudes. ↑

Extra paper if required.  
Write the question number(s) if applicable.

QUESTION  
NUMBER

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## ESS 91414 Annotated exemplars 2019

Subject	ESS	Standard	91414	Total score	17
Q	Grade score	Annotation			
1	A4	Has explained how the troposphere is heated. The stratosphere temperature is not linked to ozone for an Achievement point. The uneven heating is linked to differences in latitudes and tilt is linked to season for three Achievement points. Has not clearly linked the last two points to the height of the troposphere for them to be Merit points.			
2	M6	Has explained how the winds are formed in terms of pressure (1 Merit point) and circulation cell formation (second Merit point) and has explained orographic rainfall for three Merit points. Coriolis effect is not explained in terms of the westerly wind formation for a third Merit point.			
3	E7	The student has integrated the explanations of all Merit points with the minor omission of explaining the greenhouse effect in temperature regulation to give a comprehensive discussion of the role of the carbon cycle in temperature regulation, and how changes to the carbon and water cycles can influence climate change.			

Confirmation of check	Y / N
This exemplar has been checked for similarities with current online exemplars.	Y