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NZQA

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Earth & Space Science 2023

91413 Demonstrate understanding of processes in the ocean system

Credits: Four

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

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (DO NOT WRITE IN THIS AREA DO NOT WRITE). This area will be cut off when the booklet is marked.

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

Excellence

TOTAL 20

QUESTION ONE: CARBON DIOXIDE ABSORPTION AT THE POLES

Figure 1: Global ice area since 1979

Source: https://tamino.wordpress.com/2011/01/14/monckton-skewers-truth/

Deep ocean currents store carbon dioxide and reduce its concentration in the atmosphere. However, polar ice has been reducing as a result of climate change, and melting polar ice may disrupt the ocean currents that enable this removal of carbon dioxide.

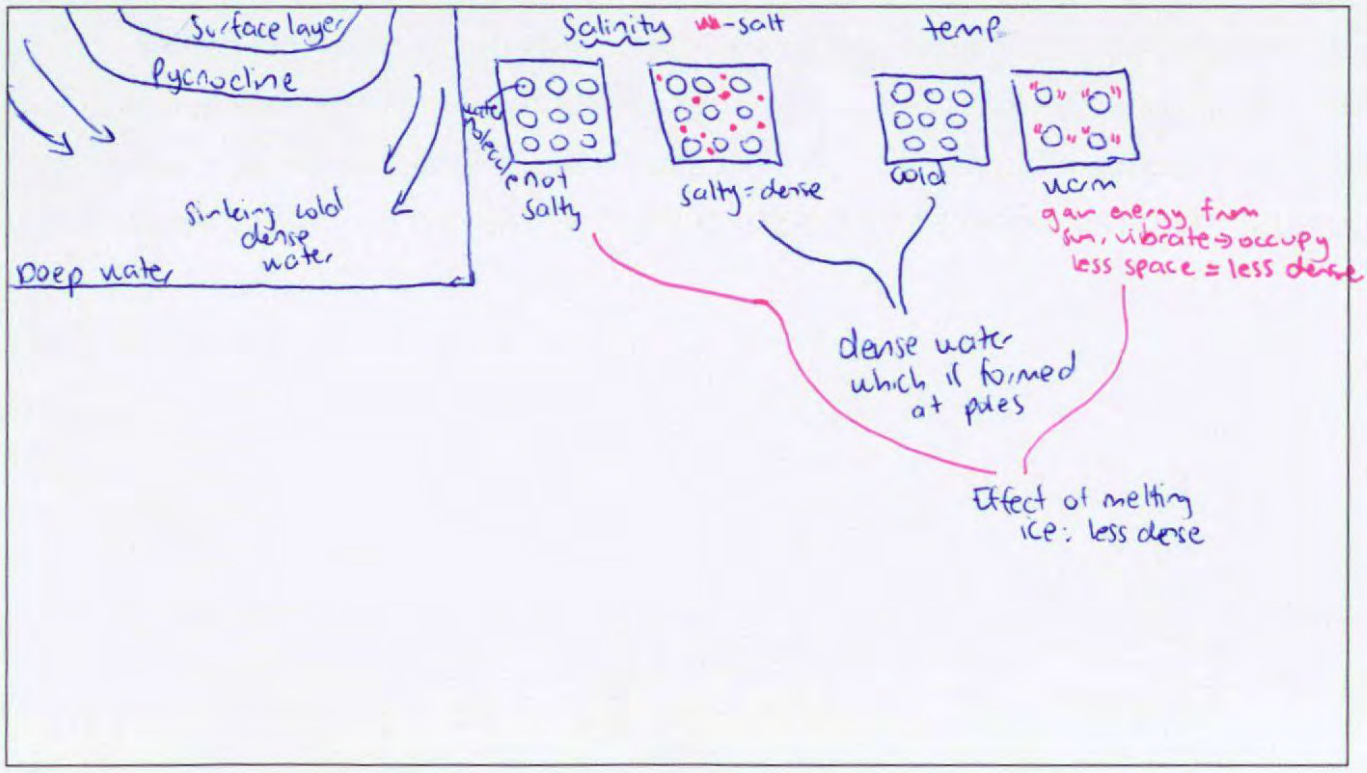
Explain the significance of melting polar ice in the removal of atmospheric carbon dioxide.

In your answer, you should consider:

- the causes of downwelling at the poles →
- the physical ocean carbon pump at high latitudes
- the significance of melting ice to the polar ocean surface.

You do not need to discuss carbon chemistry or thermohaline circulation.

An annotated diagram may assist your answer.



The deep thermohaline currents are derived primarily from the sinking of cold, dense, salty water in the poles (Antarctic and Artic). These currents are vital in taking the carbon from the atmosphere to the bottom of the ocean storing it for thousands of years thus having an overall cooling effect, however with increasing ~~ton~~ atmospheric temperatures from climate change The poles are losing their ability to downwell due to the fact the ice sheets are melting, and reflect the solar radiation thus waters are becoming less dense.

As equatorial warm waters move towards the poles they lose heat energy to the atmosphere as because of the Earth's tilt, the poles have a little direct solar radiation (concentration is spread over a larger surface). Therefore the waters are continually cold as little variation in heating throughout the year. This makes the water dense. Adding to this the water is very salty. This is because of the cold strong wind currents blowing across the surface thus causing evaporation. As evaporation only takes water it leaves the sea water more salty. Adding to this ice formation is vital in the development of downwelling as as ice forms, only freshwater freezes leaving behind a salty brine which makes the water become very dense. Typically the more dense water sinks below the less dense layer and these attributes contribute to very dense water thus this creates a downwell of the cold dense, salty water. ~~The physical pump~~ Since carbon dioxide dissolves better in carbon dioxide the poles are high concentrated in dissolved carbon dioxide which quickly

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

becomes carbonic acid (H_2CO_3). Therefore as a result this downwelling is significant in taking the carbon with it so it can be stored. This carbon can become stored as sedimentation at the bottom of the ocean or become part of the thermohaline current (or Antarctic circumpolar current etc.) which takes 1000's of years to resurface. This means the surface waters at the poles can keep ~~disso~~ ~~going~~ gaining CO_2 from the atmosphere as it is quickly taken down to bottom of the ocean. The ice formation is incredibly important as it allows these waters to be downwelled because of its formation of saline waters below the ice. However with its reduction it is losing its ability to reflect (albedo) and cool the surrounding waters while maintaining the high salinity that drives the thermohaline current containing the carbon for years. As the ice melts it begins to dilute the salinity of the surface water. Additionally with less ice, the pole waters absorb more of the solar radiation. Therefore the result is warmer, less saline water. This means the water is less dense as it is not dense enough to sink therefore does not get downwelled adequately thus less carbon is taken from the atmosphere with this current to store it away. Like mentioned before ~~colder~~ carbon dioxide is more soluble in colder waters however if the pole waters are warming due to lack of ice reflecting less of the solar radiation then the waters become warmer so less atmospheric carbon is dissolved increasing the amount of carbon dioxide in the atmosphere. If the waters are warmed then these can't be downwelled to be replaced with the warm equatorial waters therefore the long term result is the thermohaline current (deep cold current) stops. This current is the one which stores the once atmospheric carbon in the deep ocean creating a sink having an overall positive effect on the atmospheric carbon concentration. However the problem

is the poles drive this current but it is losing its ability to downwell because of the melting ice creating less dense, while allow less carbon (atms) to be dissolved warm, less saline water. Ultimately the melting of the ice caps in the poles reduces the amount of carbon from the atmosphere the ocean can dissolve (take in) then losing its ability to downwell it in the physical carbon pump and store it for thousands of years to keep the atmospheric level under check therefore ~~the~~ this concentration will significantly increase having a wider effect on Earth's climate. The fact that the warm waters can no longer dissolve as much carbon as it would if it were cold has the biggest effecton ~~atmospheric~~ the removal of atmospheric carbon dioxide as the ice at the poles continues to melt.

~~*~~ Carbon is highly soluble in water, therefore the ocean becomes a large sink for it (physical pump) and is especially concentrated in the colder regions: the poles as is more soluble in colder waters. This make the poles vital in decreasing the amount of carbon dioxide from the atmosphere and keeping the Earth's climate cool.

QUESTION TWO: MARINE HEATWAVES

When the surface ocean temperature is unusually high for a period of time, scientists consider this to be a marine heatwave. These events cause habitat destruction due to coral bleaching, seagrass destruction, and loss of kelp forests, as well as the death of fish and other marine species.

Figure 2: 2021–2022 marine heatwave in Fiordland, southwest New Zealand

Adapted from: www.odt.co.nz/regions/southland/bleaching-fiordland-sea-sponges-may-be-largest-its-kind

In recent years, the coastal waters around New Zealand have experienced some of the most extreme and persistent marine heatwaves on record, with Fiordland reaching 6 °C higher than previously recorded maximum temperatures. The warm water was likely caused by a mixture of climate change and the prolonged La Niña conditions.

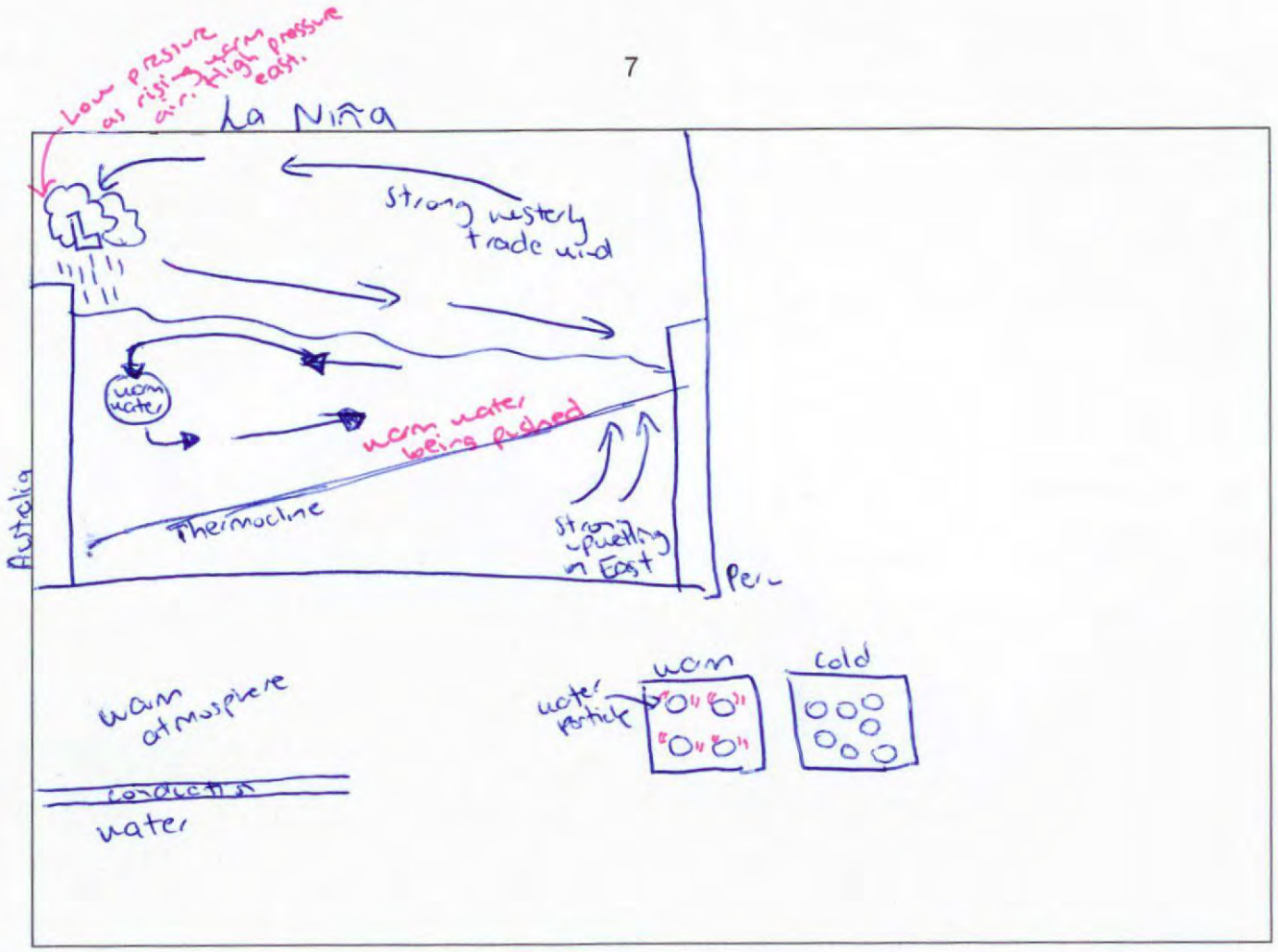
Discuss how climate change and La Niña may contribute to the increasing frequency and severity of marine heatwaves around New Zealand.

In your answer, you should consider:

- how the surface layer of the ocean is heated
- the effects of climate change on surface water temperature
- the effect of La Niña on the surface water temperature around New Zealand.

An annotated diagram may assist your answer.

Climate change and La Niña have a huge impact on the surface temperature of New Zealad's coastline by allowing more sola radiation to be absorbed and by increasing the trade winds from the east, bringing large masses of warm water to New Zealad.



The surface layer of the ocean is the top layer of the ocean therefore is affected by the climates and which absorbs the majority of the solar radiation. (This is how it is heated) The solar radiation reaches about 2-3m of it and mixing from waves and wind, ~~or~~ distribute the heat energy down to a depth of 25-30m. Climate change is impacting the warmth of the atmosphere. Therefore as the water warms by conduction from the atmosphere directly above it, the surface layer begins to warm. Additionally in the summer months when the solar radiation is the highest, with the gradual decrease (depletion) of the ozone layer this radiation will become stronger acting on the surface water, making it increase in temperature. With the continual warming and the ~~extensive~~ intensive solar radiation becoming more common then the chance of marine heat waves becomes higher and more frequent, slowly increasing the surface water's temperature as

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

it gains more heat. Overall the effect of climate change on NZ's coastal sea surface temperatures ~~are~~ is warming due to increased intensity of solar radiation reaching the surface and warmer atmosphere conducting heat which is probably why Fiordland received surface temps 6°C higher than previously recorded to this layer,

The 'La Niña' occurs when the prevailing easterly trade winds are intensified. During this period the strong wind current creates friction between the atmosphere and the surface, therefore the warmer eastern pacific waters are pushed in a great magnitude to the western pacific (New Zealand). therefore increasing the ocean surface temperature This occurs roughly every 3-5 years and last for roughly 2-3months however with climate change these periods are becoming prolonged intensifying the amount of warm waters the NZ coast receives and the frequency of marine heatwaves. ~~Additionally surface waters~~ ~~equate~~ primarily because the trade winds are becoming more frequently stronger. When La Niña hits it has a warming effect on both the water and the atmosphere as warm water rises heating the atmosphere by default warming the sea temperatures from their normal level thus creating a marine heatwave.

Therefore in New Zealand the surface water ~~becomes~~ are becoming increasingly warm because of the increase in climate change and prolonged La Niña events which push warm waters to NZ's east coast by the intensifying of the westerly direction trade winds. This therefore means the surface waters are becoming warmer more frequently, ~~and as~~ the surface layer mixes the heat energy to certain depths through waves and winds, it causes more frequent, severe ~~the~~ marine heatwaves in NZ. This will hugely devastate NZ's marine ecosystem by causing stress on the organisms and create (also deeper as most warm water = deep mixed surface layer) a more pronounced thermocline as there is greater stratification

between the deep layer and surface layer thus coastal upwelling is decreased, so ~~less nutrients~~ the nutrient rich water cannot be received by the surface water. When the water is nutrient poor there is not enough resources to live off therefore fish die especially because phytoplankton cannot thrive in these conditions. Overall a negative impact on habitats causing destruction.

Therefore when these two combine the sea temperatures spike as the both enhance the heat of NZ's surface temp therefore can be classified as marine heatwaves. And because these separately are becoming greater and more frequent the combined effect is devastating, each alone can increase the frequency and severity of marine heatwaves, particularly because climate change is becoming greater and La Nina events becoming more common due to the changing in Earth's climatic system.

QUESTION THREE: THE MOST PLASTIC-POLLUTED ISLAND ON EARTH

Henderson Island is a tiny uninhabited island in the Pitcairn Islands, and lies within the South Pacific Gyre. Beaches on Henderson Island contain an estimated 38 million items of plastic debris. On the island, researchers have found plastic rubbish from South America, Australia, and even as far away as Europe.

Figure 3: Ocean currents around Henderson Island and plastic rubbish on its beaches

Source: www.weforum.org/agenda/2017/05/the-untouched-south-pacific-island-choking-on-38-million-bits-of-plastic/

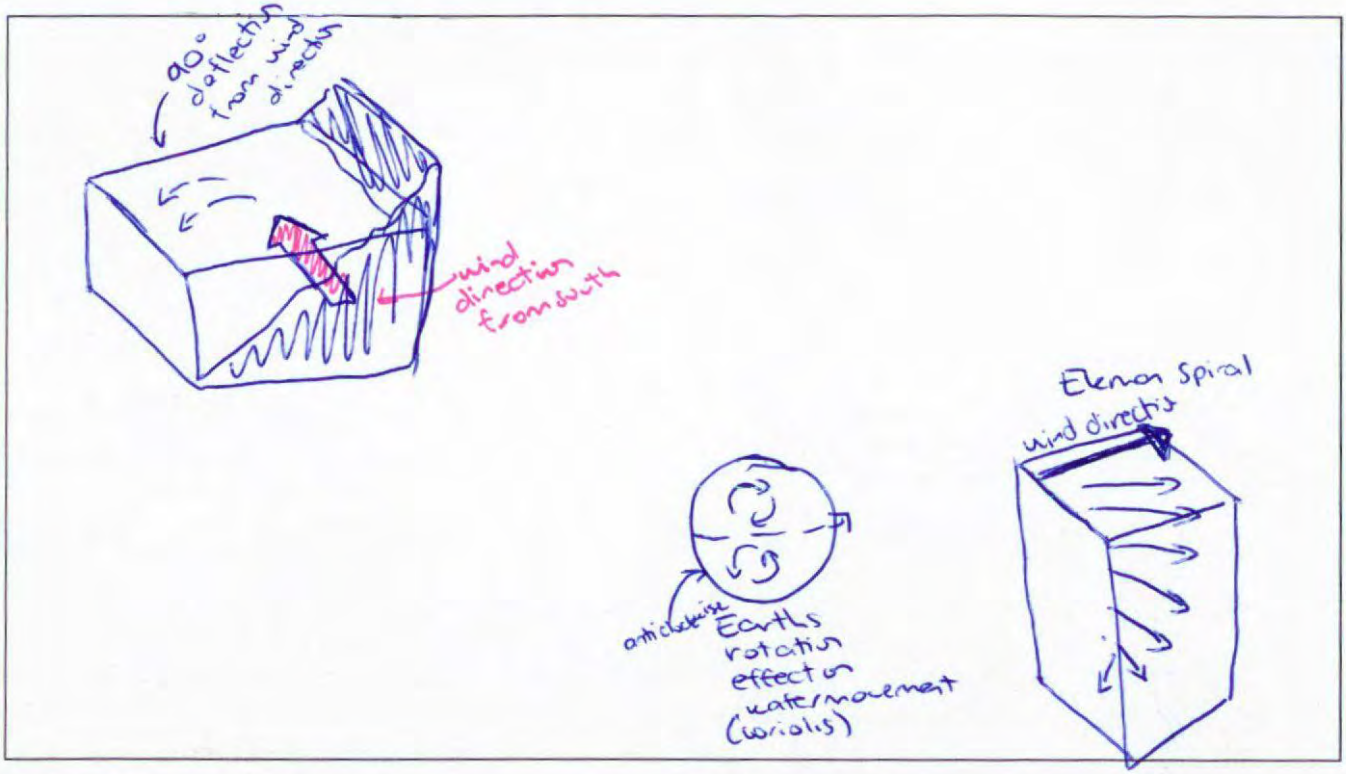
Discuss how surface ocean circulation has led to such a large accumulation of plastic debris on Henderson Island.

In your answer, you should consider:

- how the South Pacific Gyre is formed
- how the Antarctic Circumpolar Current is formed
- how plastic debris travels thousands of kilometres from around the globe to accumulate on Henderson Island.

An annotated diagram may assist your answer.

The ocean surface currents combine to create large circular currents called 'Gyres'. These are a formed by a combination of surface currents, trade winds, coriolis effect, and gravity solar radiation. The south Pacific gyre has become significant in drifting debris onto Henderson Island which is located in the centre of the huge oceanic gyre.



The top of the gyre is formed by the prevailing easterly trade winds. This causes the water to flow in a westerly direction, a friction transfers energy to the water. This water is soon deflected down in a southerly direction because of the coriolis effect. The small island landmasses also cause the ekman trasport where the net movement of water is deflected to a right angle to the direction of wind because of the coriolis effect and it being exaggerated further into the water column. As it continues south it reaches and joins the Antarctic Circumpolar current which is a prevailing westerly trade wind. This creates the bottom of the gyre as the surface current are directed to moves back to the west coast of South America. As it reaches the SA coast, the water is deflected back up the coast being directed by the landmass while the ekman spiral and coriolis once again influence the current curving it around to once meet up with the westerly directon trade wind, to complete the gyre.

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As the water moves alongside the equator (top of the gyre) the water warms because of the direct concentration of sunlight at this low latitude. As it warms the waters expand through thermal expansion, creating a mounding effect. Gravity then acts on it allowing it to flow downhill near the poles where it becomes trapped in the circular current motion of the gyre.

The Coriolis effect is the apparent deflection of objects due to the earths rotation. This means water flows anticlockwise in the Southern Hemisphere and ~~anti~~clockwise in the Northern Hemisphere therefore why the South Pacific Gyre goes anti-clockwise. This coriolis effect also explains why the westerly moving trade winds are deflected 45° to the left in a more south-easterly direction and the Antartic Circumpolar current is deflected 45° in a more ~~south~~ north-westerly direction.

The combined effect is the formation of a vortex where the water flows inwards to create a calm centre. Debris left by ships ~~on~~ at all depths of the ocean and as part of coastal runoff and dumping becomes transported into the ocean currents. This debris soon makes it into the currents forming the South Pacific gyre and finally makes it way into the calm centre which in this case is the Henderson Island within the Pitcairn Islands. This debris can come from all over the globe where it becomes trapped in these ~~large~~ large ~~circular~~ currents in the South Pacific when the coriolis effect influences it into a gyre where it eventually dumps the debris on the Island. The gyre can collect debris

Including from South America and Australia.

running in currents near the equator from right down to the Southern Pole, ~~where~~ ultimately the whole southern hemisphere worth of debris can make its way into the South Pacific Gyre thus onto the small Island ~~of~~ Henderson Island, all because of the circular movement of the gyre created by strong trade winds in the pacific and the influence of the coriolis effect, gravity, ekman transport, friction and landmass.

→ The Antarctic Circumpolar Current is made by this trade wind and is actually a cold deep current being part of the thermohaline current. It is formed by the sinking, cold, dense salty waters.

Extra space if required.
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QUESTION NUMBER

91413

Excellence

Subject: Earth & Space Science

Standard: 91413

Total score: 20

Q	Grade score	Marker commentary
One	E7	The candidate explains the formation of brine and the effect this has on density and downwelling. Explanation does not include the influence of temperature and density. However, they have a comprehensive discussion of the effect of climate change on melting sea ice, and the resulting impact on carbon dioxide dissolving and downwelling which meets the Excellence for the E7 criteria.
Two	E7	The candidate explains how climate change warming the atmosphere leads to the warming of the surface layer of the ocean. The explanation does not extend this idea into the resulting increase in marine heat waves and ENSO for the Excellence for the E8 criteria. A strong discussion of the causes of La Nina and how this results in moving warmed surface waters towards New Zealand's coastline, and the effect that has helped them gain the E7.
Three	M6	The candidate provides a strong explanation of the formation of ocean surface currents, and how they form into gyres because of Coriolis, landmasses and the ACC. However, they did not explain the linking of surface currents to debris transport to the same level.