SUPERVISOR'S USE ONLY

S

93104

931040

Draw a cross through the box (☒) if you have NOT written in this booklet

OUTSTANDING SCHOLARSHIP

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2025
Earth and Space Science

Time allowed: Three hours
Total score: 24

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 answer ALL the questions in this booklet.

Pull out Resource Booklet 93104R from the centre of 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 (). This area may be cut off when the booklet is marked.

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

QUESTION ONE: VOLCANOES UNDER THE ICE

Explore the stages and features of a glaciovolcanic eruption. As there is considerable ongoing ice loss in the region, consider the long- and short-term implications for volcanism in Antarctica.

There is a divergent plate boundary between the East and West Antarctic plates. As the plates diverge, the pressure in the lithosphere decreases ~~between~~ beneath the newly formed gap in the crust. This decompression causes adiabatic melting of the largely basaltic mantle rock. This magma is less dense than the surrounding rock, and thus it rises through the crustal gap and related fissures. The magma contains dissolved gases such as CO_2 and SO_2, which due to the pressure, ~~The most stage of the eruption~~ are retained within the magma, prior to breaching the crust.

There is certainly still variability in the magma that rises. ~~Basaltic~~ Mafic and ultra-mafic minerals have the lowest melting points, compared to felsic minerals, so partial melting can occur, leaving the felsic, rhyolitic magma in the mantle.* However, if the decompression from the divergence is high enough, the felsic minerals can also melt, producing a comparitively more andesitic magma than under different conditions.

*under high pressure conditions

Once the magma breaches the surface, the eruption characteristics vary depending on the ice and magma type. In a basaltic eruption, dissolved gases can leave more easily, as the basaltic lava is ~~more~~ not very viscous. This means there may not be an initially explosive eruption in the case of basaltic magma. However an effusive eruption like this would still melt ~~the~~ glacial ice on the surface, in which case, water is likely to enter the magma conduit, and instantly turning into steam, and expanding. ~~This~~ Thus, a phreatomagmatic eruption could occur, blowing parts of the ice away from the conduit. ~~In pate~~ If such an ~~erupse~~ eruption were to occur under thick ice, perhaps the surface ice would remain mostly intact, only, surrounding ice may cave in towards the conduit. ~~By this point~~ After subsequent phreatomagmatic eruptions, a cone would have formed out of tuff (hardened, ash like rock). Thus, a volcano is formed, which may continue to erupt ~~with~~ by fire fountaining, or with more phreatomagmatic eruptions. The consequent flow of ice, may actual start to exert more pressure on the rising magma, restricting any further eruptions entirely. ~~In the case of thinner ice, the same would occur initially~~

In the case of thinner ice, phreatomagmatic eruptions would occur initially, but the ice is likely to ~~become~~ be cleared, exposing the conduit to the air. In such case, the tuff cone could grow larger, with more apparent fire fountaining and the formation of a more permanent scoria cone. Furthermore, the clearing of ice means there is less pressure on the conduit, ensuring such a volcano can fire fountain for longer. Perhaps a shield volcano can form in the long term, ~~due to the~~

In both cases, the sub-glacial volcano differs greatly than those on land. On land, basaltic eruptions would form shield volcanoes, with low inclines and dense basalt rock as a result of effusive eruptions and the lava's low viscosity. Whereas, sub-glacial volcanoes are likely to have steeper inclines built out of vesicular rocks like scoria and tuff, stemming from the phreatomagmatic eruptions.

Also, in the case the ~~magma~~ pressure above the conduit is particularly low (such as with thin ice layers), the magma may be more andesitic. Phreatomagmatic eruptions would also occur, but subsequent fire fountaining is unlikely as andesitic magma is more viscous. Instead more explosive eruptions would be seen as gases escape, followed by effusive eruptions. Eventually, a taller stratovolcano could be formed, such as Erebus. These volcanoes are more likely to be active as they are not affected by the pressure of overlying ice, as in the case of some basaltic eruptions.

~~It appears~~ In every case, the overlying pressure of the ice is a determining factor. Evidently, most sub-glacial volcanoes are present ~~on~~ around Marie Byrd Land. This could indicate that the ice (and pressure) is thinner, allowing decompression melting to occur more easily. This could be because warm ocean currents hit the coast, melting the surface ice faster than elsewhere.

It could also be extrapolated that ~~th~~ perhaps the area between the Transarctic mountains and Marie Byrd land has substantially ~~the~~ thicker ice, ~~allowing~~ ~~an~~ exerting pressure on the lithosphere and forcing magma to rise up through fissure around the periphery of the ice mass, causing said pattern of volcanism.

~~It could~~ Clearly, most volcanoes are dormant, suggesting they formed a while ago. This may have been during ~~an~~ a stronger interglacial period, where ice was thinner overall, or non-existent, allowing the formation to occur easier. This is particularly possible for the transarctic range, because glacial cover may have inhibited such substantial growth compared to the volcanoes ~~through~~ throughout Marie Byrd land.

There are many consequences of such volcanism. Firstly, the water melted in ~~an~~ a sub-glacial tends to drain along the bottom. This water could act as a lubricant, accelerating glacier movement, and subsequent marine/land termination. This could offset the surface mass balance of the ice sheet (net ice loss/gain) ~~which~~ into the negatives further than if climate change was the only driver. This could result in rising sea levels, and a reduction of thermohaline downwelling as the brine gets diluted by fresh water.

This increased glacial movement could be quite disruptive for Antarctic. The surrounding waters could be cooled by the

QUESTION TWO: WARMING OCEAN

Explore how shifts in the Subtropical Front have led to the warming of the ocean by the Chatham Rise. In your answer, consider oceanic and atmospheric processes. Furthermore, discuss what effects a continuation of the shift in the Subtropical Front would have on the marine biodiversity and fisheries on the Chatham Rise.

Surface currents are primarily fuelled by winds ~~also~~ and the left-deflection in the southern hemisphere resulting from the coriolis force. ~~The~~ New Zealand receives ocean water primarily from two currents. Firstly, ~~subtropical~~ warm equatorial ~~currents~~ easterly currents ~~move~~ dip down from the equator due to the gravitational effect of the equatorial ~~the~~ bulge, and the coriolis effect. This means, New Zealand is hit by reasonably warm ~~water~~ sub-tropical currents, particularly from the north-east. Secondly New Zealand receives cooler, less saline water ~~from~~ from the westerly-driven Antarctic circumpolar current. This water is more nutrient rich as it often contains dissolved micro and macro nutrients like iron and CO_2, originating from glaciers and the thermohaline current. This current tends to approach from the south

~~The~~ The cold water from the ACC is denser, so when the two currents meet, on the east coast the warm waters from the north do not tend to continue moving southward. This subtropical front, is thus largely determined by how far north ACC waters move.

Global warming has greatly accelerated the warming of air at the equator. ~~Moreover~~ Each air particle is more energetic, so when it rises, it is able to move farther South before losing it's energy and 'sinking' back to the surface. Typically, in the Hadley Cell, air rises at 0°, and sinks at about 30°S. However, with this added energy, the Hadley cell expands horizontally, and vertically. Consequently, the high pressure zone may extend further south, potentially bringing dryer, calmer weather to New Zealand. This expansion also has the domino effect of shrinking the Ferrel cell, which is an open system, and is thus dependant on the Hadley and Polar ~~Pol~~ cell's positions.

The Ferrel cell is what forms the westerly winds. ~~As~~ ~~air~~ As part of the Ferrel cell, air sinks at 30°, and rushes towards the polar front low pressure zone at 60° along the surface. These surface winds deflect left, forming strong westerly winds. If the 30° high pressure zone moves south, so will the westerly winds, and ~~This~~ consequently, so will the ACC. By moving the ACC further south, less of that cool nutrient rich water will dip northwards towards Chatham rise, and those areas will simply increase in temperature, as is anticipated in Tasmania as well. Ultimately, the sub-tropical front will then shift further south, allowing the warmer, sub-tropical waters to travel further southward, as there is no longer that density gradient blocking it.

Furthermore, the shrinking of the Ferrel cell means the pressure gradient from the high pressure band to 60° will be greater, leading to stronger winds, and a faster ACC. This would encourage the ACC to simply keep moving past NZ and the Chatham rise, further limiting the flow of cold water to the CR.

It is also possible, that the thermohaline current upwelled ~~near the~~ by Chatham rise, as the bathymetry forced the deep sea current upwards. Yet due to the global warming and waning levels of sea ice formation in the Antarctic, the THC is slowing down. Thus, in that sense, another potential source of cold water is getting cut off, allowing the subtropical front to move further south.

La Nina increases the strength of the north-easterly ~~ocean~~ warm current, as the trade winds increase in strength. During these periods, the warm water would be pushed even further south, but arguably to a less significant degree compared to the movement of the westerlies.

Furthermore, because the ~~more~~ mid-latitudes are being warmed faster ~~than~~ than higher latitudes, because of the earth's curvature, a very steep temperature gradient is also forming. This further inhibits mixing along the sub-tropical front, ~~limiting nutrient supply~~ as the density difference is greater. This further inhibits mixing and the Chatham rise's access to nutrients.

It is also interesting that the Chatham rise has become increasingly isothermal and iso-saline. This is likely because more rigorous weather and appearance of low pressure systems stemming from global warming is increasing the level of mixing, so waters are mixed deeper. This can also be attributed to the lack of cold currents.

These changes have multiple effects on the chatham rise ecosystems. Firstly, ~~the lack of~~ nutrients like ~~the~~ iron and dissolved CO_2 are essentially ~~for~~ for photosynthesis to occur. With reduced supply, ~~the~~ primary production would decrease, and the waters would become increasingly anoxic. Subsequently, zooplankton and animals would lose an important source of carbon, endangering certain species more than others.

Furthermore, the warmer waters reduce the amount of CO_2 that can be dissolved through the physical pump, further limiting ~~the~~ primary productions and marine biodiversity.

That being said, the more anoxic ~~waters~~ and less stratified waters may lead to a negative feedback loop where more efficient microbial recycling of phosphorus by ~~~~ microorganisms on the sea floor could ~~~~ dampen the loss of primary production. This is because there would no longer be a strong thermocline blocking the upwelling of nutrients to the euphotic zone, allowing more phosphorus recycling. ~~~~

Overall, it's likely in the short term fisheries would suffer, with fewer

QUESTION THREE: SEASONS IN OUR SOLAR SYSTEM

Analyse how seasons on Mars, Uranus, and Neptune would be different to those on Earth by comparing eccentricity, length of orbit, distance from the Sun, and axial tilt. Additionally, evaluate the role that solar radiation plays in the planets' seasons.

Earth is closest to the sun compared to ~~All~~ Mars, Uranus and Neptune, with Earth sitting 150 million km away (1AU). ~~Comparatively~~ Mars is around 1.55AU away (on average), Uranus is around 19AU away on average, and Neptune is around 30AU away on average. Consequently, Earth receives the most solar radiation, at 1362Wm^{-2}, and each planet receives exponentially less the further away it is as the sun's energy disperses according to the inverse square law.

~~This is important, as the relative difference between seasons is dependent on the relative difference in energy received. This, Earth Season's are~~

Seasons are ~~dependent~~ defined by how surface insolation on a planet changes in regards to the planet's location thr ~~the~~ its orbit. ~~That the~~ If the planet has a significant axial tilt, each hemisphere will receive varying levels of insolation, as the sun's light will hit the surface at an angle. If the planet has an elliptical orbit, this will influence insolation received, as at the Perihelion, the planet will be closest to the sun and receive more insolation. The opposite is true for the aphelion. These characteristics can define when and how seasons on a planet change.

Mars has an axial tilt of 24.9°, which is only slightly higher than Earth's tilt of 23.4°. This means that during roughly half of Mars's orbit, one hemisphere will experience winter, as the insolation is spread over more area. However, the other hemisphere would experience summer. ~~Du~~ Because the axial ~~ax~~ tilt is larger, the seasons are ~~likely~~ could be more extreme ~~& [illegible]~~ than ~~[illegible]~~ Earth's as the relative gain and loss of insolation is greater. Therefore, martian summer's would be warmer, and winter's would be colder relative to Mars's own equinox. ~~Of course, Mars is generally~~ While Mars is colder because it receives ~~less insolation~~ only 586 Wm^{-2} of insolation, ~~[illegible]~~ it is a relative measure. It could also be true that the seasons are actually less extreme than Earth's due to the lower insolation, and thus there is only a marginal effect tied to the axial tilt. However, ~~because~~ it is hard to determine and weigh whether insolation or axial tilt is more significant.

Mars also has the highest orbital eccentricity of all the planets. This means that the southern summer occurs when Mars is closest, vice versa. This means the southern summer receives greater insolation than the ~~[illegible]~~ northern summer, and the southern winter receives less insolation than the northern winter. Thus, while seasons are relatively identical in each hemisphere on Earth, Mars' vary because of it's ~~higher [illegible]~~ more elliptical orbit. This could potentially support the argument that ~~a~~ southern hemisphere summers and winter's are relatively more extreme than on Earth.

Uranus is much further than Mars. Uranus receives only 3.7 Wm^{-2} of insolation, which is actually significant considering Uranus has very little primordial internal energy. ~~[illegible]~~ Being a Jovian planet, seasons can be identified by changes in atmosphere and convection patterns, whereas seasons are much less apparent.

Uranus is unique because it has an axial tilt of 97.8°, meaning it's poles face away from and towards the sun. This means that the poles receive insolation for the entirety of Uranus' days at each solstice. Consequently the difference between winter and summer at each pole is the most extreme compared to Earth, and all planets, as the poles either receive no insolation, or all of it at each solstice. However, despite this, no atmospheric activity was visible while Uranus moved between each equinox and through the southern summer equinox. It could perhaps be that because the pole received insolation nearly all the time, gas towards the core would rise slowly, but never condense to form any visible clouds. This is because the lack of internal heat means there is little ~~[illegible]~~ temperature difference the core and outer layers. Thus, since insolation has not changed, neither does the temperature of rising gas. Furthermore, perhaps, the rising gas convects in the upper layers to the opposite pole due to the high pressure and temperature gradient. Therefore, maybe on the opposite side, atmospheric seasonal activity could be seen. This could demonstrate such extreme hemispherical weather. Because ~~[illegible]~~ Earth's axial tilt is so much smaller, no ~~[illegible]~~ comparably substantial hemispherical differences are seen.

Also because of this difference, Uranus would have no polar vortex. On Earth, the pressure gradient between the poles and the equator strengthens a polar vortex, which is responsible for maintaining a polar jet stream and polar temperatures throughout the seasons. It can also lead to unpredictable weather, as stratospheric warming breaks down the vortex, causing the jet stream to dip further south, or reach further north. This can bring extreme weather ~~not~~ that doesn't correlate with the season. Because no such gradient or vortex can form on Uranus its possible Uranus's climate and seasons are more predictable and less chaotic.

~~Neptune is the farthest planet from the sun and receives the least solar insolation of $1.5 Wm^{-2}$~~

Similar to Mars, Uranus also has a more elliptical orbit than earth. Consequently, the patterns of convection and temperature ~~is not the same for each~~ with each season is not the same for each hemispheres, unlike earth.

Neptune is farthest from the sun, and receives the least insolation, of $1.5 Wm^{-2}$. Due to the inverse square law, it is expected such low insolation would not trigger observable differences on Neptune with each season. However, like Uranus, Neptune lacks significant internal heat. This means

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

QUESTION NUMBER

1) melting glaciers, inhibiting primary production ~~Furthermore, the melt would also the~~ exposing ~~the~~ However, this may be balanced by the ~~flow~~ ~~an~~ increased sub-glacial flow of nutrients, particularly those gases originating from the eruptions. These things would be particularly short-term, as in a warming world, easterly currents should bring energy back to the area, and may actually result in algael bloom when combined with the added nutrients.

~~In the long term, eruptions and the exposure of volcanoes when~~ In the long term, the albedo of the antarctic region may decrease as ash is produced and land is exposed. This would contribute to polar amplification, helping reinforce the ice-albedo positive feedback loop, which in turn would promote volcanism as the ~~pr~~ ~~reas~~ pressure exerted by ice decreases.

Global warming is leading to more prevalent glacial melt as well. As the ice melts, volcanism will occur more easily due to the decrease in pressure. This is particularly important for coastal areas where warm currents move beneath glacier's, melting them at an accelerated rate. Thus, in the long

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

QUESTION NUMBER

term we would expect to see more volcanoes forming in the coastal areas such as the Pine Island glacier and the Marie Byrd land, ~~In the short~~ term, ~~the~~ with a greater portion of them being strato volcanoes.

In the short term, as pressure decreases, we may expect to see these dormant volcanoes become active again.

It can depend however. Land terminating glacial melt may add more water to some conduits, permanently inhibiting volcanism. However, marine terminating glaciers are likely to increase the amount of volcanism.

2) marine populations. However, over a longer period, marine biodiversity may ~~[illegible]~~, ~~[illegible]~~ dampen the effect. In fact, the warmer temperatures can be good ~~[illegible]~~ for primary production, but not when there is a nutrient shortage.

3) the insolation is the only energy received by gases, prompting convection in areas that are others devoid of atmospheric activity. This may also relate to Neptune's atmospheric composition; neptune would have higher amounts of methane, which has a very low boiling/melting point. ~~[illegible]~~ So even though Neptune is very cold, the methane

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

QUESTION NUMBER

rays only need a little energy in order for convection to start at summer solstice, even in conjunction with what little internal heat there is. We know something like this must occur as it has been observed that ~~[illegible]~~ white clouds form ~~[illegible]~~ in the southern hemisphere as Neptune approaches summer solstice. ~~[illegible] the difference~~ However, it's unlikely the temperature gradient between hemisphere's is larger than that of Earth's at each solstice, as insolation is still low. Thus, seasons likely aren't extremely different.

Neptune actually has a more circular orbit than Earth, and this would mean the northern winters would be more similar to southern winters, compared to earth. The same ~~[illegible]~~ can be said for summer too.

~~[illegible]~~ The length of the seasons also changes with length of orbit. The longer the orbit, the longer each season lasts. Consequently, the length of seasons increases as the distance from the sun increases.

Overall, insolation is central to seasons, but cannot be used to generalise what seasons are like. The solar system demonstrates that atmospheric composition and internal heat also contributes to seasonal trends, even if it's artificial.

Outstanding Scholarship

Subject: Earth and Space Science

Standard: 93104

Total score: 20

Q	Score	Marker commentary
1	7	Candidate has shown a good integration and progression of ideas when discussing the stages and features of a glaciovolcanic eruption. Furthermore, they explored the potential short- and long-term impacts of increased volcanism. However, the detail was not enough to be awarded an 8.
2	6	Candidate has written a well-structured answer that details oceanic and atmospheric processes around New Zealand and how these would be impacted by warming waters at the Chatham Rise. However, they are lacking an in-depth exploration in how the shifting subtropical front would impact the marine biodiversity around the Chatham Rise which is why they are not awarded a 7.
3	7	Candidate has done a detailed analysis about how seasons would be different on Mars particularly mentioning the effect that eccentricity has on Mars’s seasons. While they have analysed the differences between Uranus and Neptune, more detail was required to be awarded an 8.