

No part of the candidate's evidence in this exemplar material may be presented in an external assessment for the purpose of gaining an NZQA qualification or award.

SUPERVISOR'S USE ONLY

S

93104



931040

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

☐

+

SCHOLARSHIP EXEMPLAR



Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2024 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.

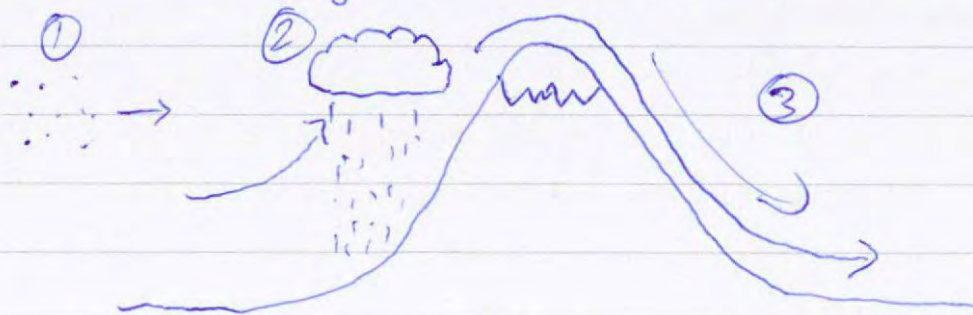
YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

QUESTION ONE: RIVERS IN THE SKY

Evaluate the effects of atmospheric rivers on the North and South Islands by considering two regions – west Auckland, and the West Coast of the South Island.

Furthermore, explore how atmospheric rivers would be affected by the El Niño Southern Oscillation (ENSO), and discuss some measures that could be taken in the way we use land to minimise the effects of atmospheric rivers.

In both instances (West Auckland and the west coast), significant precipitation would be caused. This is largely due to the areas of high elevation. As the atmospheric rivers come over each region, they are forced upwards by the physical mountain ranges; the Waitakeres in West Auckland and the southern alps on the West coast. As this moist air is forced upwards into the upper troposphere, the temperature decreases, causing the ~~mo~~ moist air to reach its dew point and condense. As the air condenses, it precipitates on the side of the mountains, which in both cases is the Western side of the ranges. Following this, the remaining air ~~also~~ warms due to the latent heat, where it then flows over the eastern side of the mountains as 'Foehn winds'. ~~Although this occurs for both instances~~



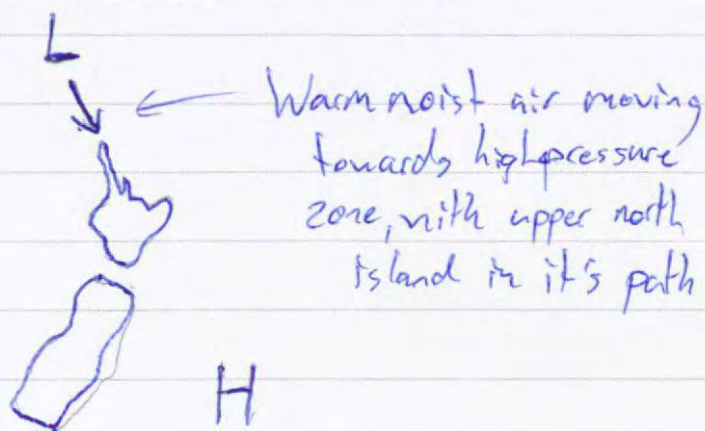
- ① Moist air from atmospheric river approaches range
- ② Air is forced upwards where it cools and condenses, causing rain
- ③ Leftover warm air flows down the other side of the range

Although both locations cause orographic rainfall, the significance varies. Firstly, the southern alps are much higher than the Waitakeres,

thus, more air is likely to condense going over the southern alps than the Waitakere as the temperature reaches a lower point (because there is a linear negative relationship between elevation and temperature in the troposphere). Therefore, the severity of the rain is likely higher on the West coast. However, in the case of West Auckland, there is a higher population density, from which we can imply a higher concentration of aerosols in the air (like dust and smog). Aerosols are required for water to condense as it needs something to condense onto, which is usually the large aerosol particles. Thus, in the case of the West coast, the ~~air~~^{vapour} condenses easier, potentially causing more rain. In either case, the rain can weather the and saturate the ground, potentially leading to landslides. ~~Beyond the severity of the atmospheric conditions, the positioning of the settlements also influences the effect in the ranges.~~

Beyond the severity of the atmospheric conditions, the positioning of relevant settlements also influences the effect of the atmospheric rivers. The West Coast settlements are located on the western side of the alps and therefore receive the blunt force of the orographic rainfall and subsequent landslides. Whereas the majority of West Auckland's population is situated on the eastern side of the mountain, and thus is only subject to the Foehn winds and not the rain (and subsequent hazards) itself. Thus, considering potential variations in severity, the West coast is likely to be affected the most by atmospheric rivers in general, although "exceptional" cases can also have detrimental effects on West Auckland too.

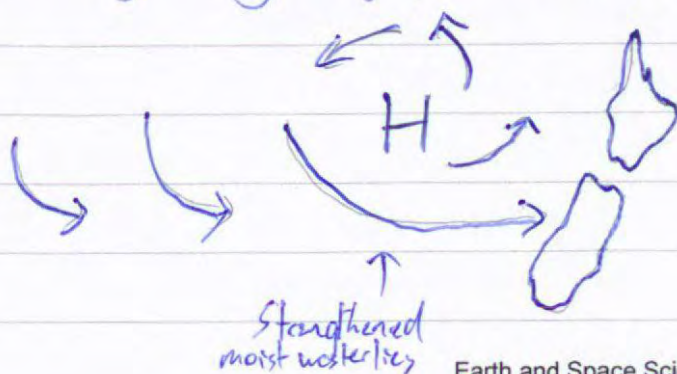
In terms of La Niña, Auckland and the upper north island ~~area~~ would experience more severe atmospheric rivers. During La Niña, the ~~are~~ easterly trade winds at the equator are stronger, strengthening the equatorial low pressure zone in the western Pacific. This strengthening forces the high pressure zone (of the Ferrel zone) at ~~40°~~ 30°S to the south east of New Zealand because the pressure gradient force ~~force is much higher~~ is much higher, meaning the air is pushed further. ~~Consequently, the low pressure zones are associated with extreme wet weather because it contains~~ Low pressure zones have a higher temperature (hence why the air rises), which means it carries more moisture. Therefore, because the western Pacific low pressure zone has strengthened, it means it holds significantly ^{more moisture} ~~warmer~~. Due to the pressure gradient force, this moist air moves south, ~~where~~ forming a strong atmospheric river that hits the upper north island, as seen below.



Consequently, during La Niña years, Anchut is as erographic
outfall occurs. Often times this river actually comes from the

North east, meaning the orographic rainfall will occur on the city side of the Waitakeres. Therefore, not only is the rain more severe (due to the increase in moisture), but it actually hits Auckland ~~precipitates~~ to disastrous effect. On the other hand, the high pressure zone in the southeast which has a low amount of moisture (as it is cooler) means that the rest of the country including the west coast experiences minor drought, especially since the usual ^{moist} westerlies are weakened by the reversal of the pressure gradient.

El Niño is when the trade winds weaken or reverse, weakening the strength of the Western Pacific low pressure zone, which means less moisture. For this reason, the high pressure zone at 30°S strengthens as the pressure gradient force isn't as strong. The high pressure zone moves slightly to the west and engulfs much of the country. Because the high pressure zone is dryer with an inability to hold much moisture, most of the country records a drought. However, as the zone now sits on the west coast, the geostrophic flow from the west is strengthened as it circles around the high pressure zone due to the pressure gradient force and the Coriolis effect. These westerlies pick up water from southern Australia and being carried by the high pressure zone, hit the west coast of the South Island, causing heavy orographic rainfall, as seen below.



QUESTION TWO: NEW ZEALAND'S GEOLOGICAL HISTORY

Explore why the geological history of New Zealand is different between the North Island and the South Island, considering tectonic and volcanic evidence.

Using extrapolation, discuss how the plate boundary in both islands might change in the future. ^{spreading}

The geological history of the two islands is largely governed by their differing plate boundaries, and volcanism.

The north island is largely governed by the convergent boundary between the continental Australian plate and the oceanic Pacific plate. The Pacific plate has a higher concentration of iron, and is therefore basaltic, making it much denser than the continental crust which is richer in lighter ~~elements~~ compounds like silicon dioxide. For this reason, the oceanic/denser Pacific plate, subducts beneath the less dense continental Australian plate. This occurs from the southern tip to the north eastern coast of the north island. As the oceanic plate subducts, water is dragged down with it. ^{Ke into the asthenosphere} This water is volatile and when mixed with the hot rock/magma of the asthenosphere, further rock melts, forming significant amounts of magma. Because this magma is ^{less dense} ~~denser~~ than the asthenosphere and lithosphere, it rises through fissures and such to the surface. Once the magma reaches the crust surface, volcanoes are formed as the magma hardens. Often the spreading of magma occurs for millions of years until a volcano is formed, the type of which depending on the magma composition. ~~Initially, when the Pacific subduction zone was further west,~~ Around 23 million years ago, when the convergent boundary was further east (aligned with northland), magma breasted the surface beneath the Pacific ocean. ~~Again, when the mag~~ When the magma cooled with

the water, it cooled quickly generating steam. The pressure of the steam created an explosive phreatomagmatic eruption, which destroyed the newly formed igneous rock, forming ash, and launched it into the sky. Over subsequent millions of years, continuous eruptions formed a cinder cone volcano from the built up ash, draining the magma vent of water. Similar events occurred with Kaipara as this subduction zone extends for hundreds of kilometres, along volcanoes to form essentially anywhere along it, creating volcano arcs. By 19 mya, this subduction zone had again moved east, causing volcano arcs to form where the Cocomandel now is, only the arc was much larger and contained less phreatomagmatic eruptions, ~~Cocomandel volcanoes~~ leading to the formation of stratovolcanoes* that eventually collapsed into calderas once the magma chambers are emptied. Furthermore, by 2 mya, the subduction zone had moved southeast again which is generally where it currently sits. Here, ~~the~~ even more stratovolcanoes were formed, some of which also collapsing into calderas, which were consequently filled with water, creating lakes (i.e. Lake Taupo). Generally these three instances of volcanism are products of a convergent plate boundary with subduction that has moved over the past 30 million years.

*In comparison with the presence of vesicular magma

Furthermore, the north island has shown instances of hot-spot volcanism. Hot spots are particularly hot parts of the mantle, which due to the lower density, rise to the crust. Hot spot volcanism can cause any type of volcano, but they are often seen in groups or lines. This is because while the hot spot stays in place, the Australian plates move over it, leading the magma to breach at numerous different places relative to the plate. This leads to groups

and/or lines of volcanoes forming in the opposite direction to the plates motion. This is evident through the high concentration of volcanoes in Auckland and the chain of undersea volcanoes along the west coast of Northland.

It's important to consider the millions of years of weathering, erosion and occasionally collapse that this is applicable to all of these formations. Many of these formations are very different to what they used to be due to factors like erosion changing the landform, yet it is still clear the original landforms still generally apply.

The South Island does not have an entirely convergent boundary, but rather an oblique (which is not entirely parallel) transform boundary. This means that the plates move parallel to each other, shifting many of the landforms either north east or south west from where they originally formed. This fault runs along the west coast of the South Island. I mention it is oblique because some convergence has occurred to form the Southern Alps. The Alps are not volcanic, because the converging crusts are both continental, they have equal densities; thus when they converge no subduction occurs, rather they uplifted each other forming mountains. Because subduction does not occur, no magma reaches the surface, and therefore no volcanoes form. Simultaneously, these mountains are being displaced due to the transformative nature of this boundary. ~~Because~~ The eastern side is moving south west, while the western side is moving north east and thus evidence like the presence of schist in the northwest ^{and southeast} of the South Island proves this transformation.

Similar to northland however, the west coast of the south island shows evidence of hot spot volcanism through the dandenong and bays peninsula volcanoes being in line without the presence of ~~an~~ subduction.

Therefore, the north island was largely formed through convergent boundary and hot spot volcanism, while the south island was largely formed through ~~transform~~ oblique transformation boundaries (forming mountains) with some slight hot spot volcanism, hence why the south island has ~~few~~ few volcanoes and the north island has no major mountain ranges.

From previous geological history, we can make a few assumptions about the future. Firstly we can assume the subduction zone will continue to move towards the southeast as it has the past 30 million years as it formed three substantial volcanic zones. This is likely due to a divergent plate boundary west of the Australian plate that pushes the whole plate east. Secondly we can assume the two plates will continue to transform along the ~~eastern~~ alpine fault as it has the past 16 million years. This also must occur to satisfy the Australian plates eastward movement, as it transforms north east along the alpine fault. Lastly, we can assume that more volcanoes will continue to form as a result of hot spot volcanism and the moving plates. The bays peninsula volcanoes ~~formed~~ went extinct 6 million years ago, meaning the hot spot moved from beneath it. Therefore, we could see a volcano form ~~wherever~~ ^{wherever} the hot spot is now.

QUESTION THREE: THE TOI 270 SYSTEM

Analyse and compare the formation of the TOI 270 system to the formation of our own solar system.

Explore the possibility of having basic forms of life on the planets in the TOI 270 system, considering surface temperature, composition, likelihood of an atmosphere, and interaction with the star they orbit.

All solar systems begin with a nebula; a concentrated collection of dust and debris. This ~~debris~~ dust collects forming globules held by electrostatic forces of attraction, which then form larger globules. Eventually one globule forms large enough to apply a gravitational force to surrounding particles, accelerating its growth. As the particles fall in to this mass, the gravitational potential energy is converted to kinetic energy, which at this scale acts as heat. At this point, the mass is thin and transparent, and thus any infrared heat released simply leaves the mass without exerting an outward pressure. This means there is no hydrostatic equilibrium, and thus the mass contracts ~~until~~ under gravity until the mass becomes opaque. When this occurs, heat can be contained and ~~is reflected~~ ^{is retained}. In successful cases, ~~this~~ the outward pressure exerted by this heat exceeds the gravitational force, and thus it grows. In the case of a red dwarf, this pressure isn't massive, so its growth is limited ~~by~~ before the hydrostatic balance is achieved and it stops growing. In the case of our sun, ~~the~~ it grew larger due to a greater outward pressure. Once the mass is formed, it begins to spin, and the centrifugal force causes a bulge of matter at its equator. This ~~then~~ ^{then} marks the formation of a protostar and its protoplanetary disc. Because red dwarfs are smaller, their initial protoplanetary disc is smaller. Within this disc is where planets of refractory material ^{elements} ~~matter~~ that ~~condense~~ ^{are} is vaporised at high temperatures, like metals) are formed. Earth like

systems were formed from this disc due to them being made out of refractory elements. Beyond this disc, gas giants are formed, where elements like helium freeze, forming gas giants such as ~~the~~ TOI 270c and TOI 270d. The same pattern is apparent with planets like ~~Mercury, Venus~~ in our system, with gas giants forming further away. Because the protoplanetary disc of the red dwarf is smaller than the one our sun would have had, it means that earthlike planets form much closer to their respective star which is the main consideration ~~with~~ in regards to life. Of course ~~the~~ once these planets form and the disc dissolves, the ~~red dwarf~~ ~~with~~ ~~star~~ protostar will undergo hydrogen fusion to form a ~~main sequence~~ star. as a result of immense gravity, turning the protostar into its respective main sequence star, which in this case is a small, cool red dwarf.

Because TOI 270B formed so close to the star, it is extremely hot, reaching a temperature of 254°C . This is ideal in some ways, as it means elements and compounds like nitrogen and carbon dioxide can remain gaseous as to form an atmosphere. However, water is not liquid ~~at~~ at 254°C , which is a substantial step in instating a carbon cycle that is a requirement for life. On Earth, water acts as a carbon sink; CO_2 dissolves in liquid H_2O , removing CO_2 from the atmosphere while CO_2 also reacts with rain to form H_2CO_3 that chemically weathers rocks to form ^{solid} carbonates. ~~Therefore~~ ^{Therefore}, assuming there is ~~over~~ a carbon source, such as volcanoes, the atmosphere will continuously fill up with CO_2^* . The same occurred with Venus, ~~which~~ ~~as~~ also lacked substantial liquid water. ~~This creates a positive feedback~~ This lack of proper carbon

sink also means that the temperature will further increase. This is because CO_2 is a greenhouse gas that traps heat radiating off a surface; thus ~~before~~ within a couple million years, the temperatures may have increased to an even more extreme level. The presence of a fair CO_2 balance is vital to sustain life because some life needs to respire which requires oxygen, while ~~others~~ ^{some life} photosynthesises to produce oxygen. Yet the ~~unbalanced~~ CO_2 issue likely means that it is too substantial for life to reverse, especially without other carbon sinks. Either way, the temperature is too hot for water (which is also required for ^{life} ~~light~~) and the CO_2 would likely form clouds that reflect necessary light (for photosynthesis) away from the surface. ~~That is~~ The other planets ~~likely~~ don't have the issue of an unbalanced carbon source because of the lack ~~of this balance~~ of volcanism and such on gas giants, but that also means there is no carbon for photosynthesis, and thus, neither of those gas giants could potentially have life.

Furthermore, the presence of heavy solar flares from the close-proximity red dwarf means that a magnetic field would be required to protect the planet. A magnetic field implies a liquid core that moves, which also implies ~~convection~~ subsurface convection currents and tectonic movement and volcanism. Therefore, in the early years of this system, life must either sustain lethal solar flares or an unbalanced carbon cycle as a result of volcanism (caused by the liquid core). Perhaps in following billions of years, the star will stop spinning

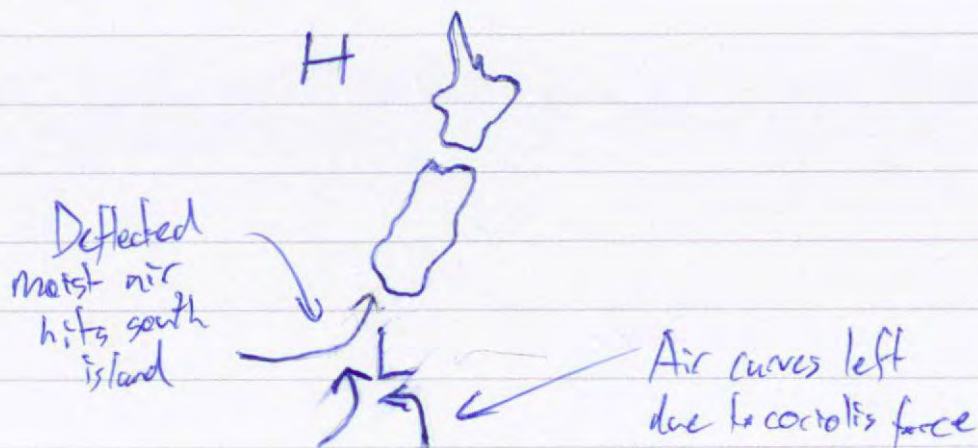
as a result of its magnetic field. This would reduce the frequency of solar radiation flares while also cooling down the star. A cooler star with less radiation could mean a much more habitable TOI 270B, as it may cool enough for liquid water to form. This would introduce a carbon sink, removing CO_2 from the atmosphere and its clouds, allowing life to form.

Extra space if required.

Write the question number(s) if applicable.

QUESTION
NUMBER

(ONE) Therefore, generally during the summer, the west coast receives the force of a moist westerly atmospheric river, causing higher rainfall. In Winter however, the high pressure zone moves further north, allowing the low pressure zones at 60°S to move further north too, as the axial tilt has meant that the lower latitudes are colder during Winter, and therefore air sinks at a latitude further north. This means that the atmospheric rivers now flow from the moist southern low pressure zones, ~~which~~ reducing the effect of the drought and bringing more precipitation to the south island, as seen below.



The variation in the effects is hard to combat, but some main solutions are as follows. Firstly don't build ~~bridges~~ ^{infrastructure} in floodplains; water collects in floodplains, causing damage to infrastructure during heavy rain. Secondly, reduce air pollution as to decrease the ~~air~~ aerosols that allow water vapour to condense. Finally, heavily monitor the presence of ENSO, as to properly prepare for strengthened atmospheric rivers.

Scholarship

Subject: Earth and Space Science

Standard: 93104

Total score: 15

Q	Score	Marker commentary
1	5	Candidate explains how ENSO can interact with atmospheric rivers and the effects on the north and South Island. However, this explanation lacks detail.
2	6	Candidate has written a good response on New Zealand's geological history. A few errors exist and candidate has not developed the future of the plate boundary enough for an outstanding response.
3	4	Candidates' response contains some errors which demonstrate a lack of understanding of feature and characteristics of exoplanets.