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TOP SCHOLAR



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.

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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.

The effects of the atmospheric rivers on the North and South Islands are varied and can be best illustrated by the regions of West Auckland and West Coast. Figure 1 shows how the largest amount of water vapour in the atmospheric river at above $1250 \text{ kgm}^{-1}\text{s}^{-1}$ travelled above the ~~mass~~ North, and western North Island, with the river thinning out to between $1000 - 500 \text{ kgm}^{-1}\text{s}^{-1}$ over the ~~stretched~~ West Coast of the South Island. More ~~less~~ water vapour in the air means that air pressure is greater and so ~~to~~ ^{atmosphere} the pressure on the ~~ground~~ to release the water vapour stored in these areas as precipitation. This however does not directly mean that the North Island receives more ~~or~~ rainfall than the South Island just because more water is travelling above as an exceptional atmospheric river. West Auckland has a short (25km) mountain range ~~about~~ with a very low height (max. 474m). This ~~is~~ short, shallow mountain range ~~is unlikely to~~ does not present a major obstacle for the atmospheric river and ~~therefore~~ means that despite high likelihood of releasing precipitation over the North Island, it is able to more quickly travel over it. Whereas the exceptionally tall and long (max. 3724m, 800km length) South Island mountain range presents a more significant hindrance to the flow of the atmosphere

river above it, and so despite less likelihood of bursting it will travel more slowly as it is ~~somehow~~ trapped by the ~~atmosphere~~ ~~now~~ at Southern Alps. The contrasting combinations of less time, more precipitation likelihood and more time, lower likelihood produce the end result that both areas ~~have a higher~~ receive significant rainfall from the atmospheric rivers.

The El Niño Southern Oscillation will affect NZ's atmospheric rivers. During La Niña, the North-easterly winds ~~to~~ ~~or~~ ~~the~~ predominate over the westerly winds, leading to a change in atmospheric river flow over the West Coast. With the atmospheric river travelling north-easterly rather than westerly, thereby causing the southern alps to 'trap' the river on the ~~other~~ side of the alps in Canterbury, rather than on the West Coast. This causes increased precipitation ~~on the~~ mostly winter but also ~~some~~ ^{slightly} in summer on the east coast of the South Island and therefore decreased precipitation and thus drought on the West Coast of the South Island (see figure 2). While in the North Island, the prevalence of North-easterly winds ~~forces~~ the atmospheric rivers ~~more~~ ~~desert~~ ~~are~~ ~~lower~~ regions more across the ~~relatively~~ Northern North eastern North Island resulting in the observed increase in precipitation in these areas, as well as on West Auckland.

While during an El Niño season, the opposite effect will emerge. The strong westerly winds in the summer forces the desert regions of the atmospheric river

Over the West Coast of the South Island producing increased ~~floods~~ rain and thus flooding in the West Coast, and thus less rain and flooding, and more drought on the east coast of the South Island on the other side of the Southern Alps. During the winter, the atmospheric river will result in more rain as again the drier, more water vapour stretch of the atmospheric river will travel over the South Island and will therefore produce more rain on the West Coast. Whereas in the North Island, the summer's increased strength westerly winds will result in movement of the atmospheric river such that the Northern areas, including West Auckland, will receive less precipitation and thus more drought, as too with the eastern coast. While, the winter's increased southerlies will bring not only colder temperatures but also slightly decreased North Island rainfall.

Atmospheric rivers bring challenging rain and drought conditions and the effect of these challenges can be minimised by use of appropriate land management strategies. Monocultural agriculture ~~means~~ that has replaced native bush in many areas of NZ. This has increased vulnerability to the effects of any ~~such~~ extreme effects of the atmospheric river system.

~~Now~~ Large fields of grass absorb less moisture than an ~~more~~ intact native forest, and due to the less deep root systems do not anchor ~~the~~ and hold together

the ground as effectively. This means that when
 the atmosphere ever produces extensive rainfall, the fields
 become waterlogged and unstable, resulting in ~~the~~ dangerous
 and extensive slips (landslides) which can impact lines, livelihoods
 and infrastructure, as can be seen in past rainfall events, especially
 in the West Coast of the South Island or the East Coast
 or the North Island. Therefore, to prevent this flooding
 and slippage, ^{more} the land, especially in hillside areas must be
 reverted to native bush which is ~~less~~ able to
 better deal with extensive flooding. Likewise, in urban environments
 where the paved surfaces ~~do not~~ absorb no water or merely
 funnel it to exposed areas (such as people's houses), and
 grassy ~~field~~ parks and sidewalks become quickly waterlogged, more
 areas of bush need to be established to deal with
 the big floodwaters. During ~~the~~ drought, monoculture's excessive
 water requirements ~~mean that resources quickly become~~
~~emptied~~ ~~which means that water~~ ~~is~~ mean
 that water insecurity is quick to emerge. This can be
 resolved by ~~either~~ decrease in farming or simply an
 increase in its efficiency, through use of ~~water~~ drought resistant
 crops and grasses which will have low water demands.
 Once again, replanting of forest will help resolve the challenges
 because ~~new~~ trees are able to hold store water in their
 roots than grassy one and so ~~can~~ have more extensive water
 resources remaining ~~than~~ during times of scarcity than do grassy fields.
~~This means that even in drought~~

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.

The ~~geological~~^{volcanic} and tectonic evidence demonstrates the differing geological histories of North and South Island. The volcanic evidence of each island is very different. The North Island shows extensive volcanic activity in the past. Figure 3 shows a chain of undersea volcanoes 20 million years ago off the coast of Auckland Northland Island that existed during this time. These volcanoes are to the west of the modern New Zealand Northland - Auckland area and are evidence of past subduction of the Pacific plate beneath the Australian plate. As the dense oceanic crust of the Pacific plate sinks under the buoyant, less dense continental crust of the Australian plate, the subducted crust is heated by the magma in the mantle that it encounters as it is pushed deeper and deeper. This crust is heated to become magma. This produces a plume which rises up and builds up pressure against the continental Australian plate crust as more plate crust is subducted and melted to magma. Eventually, the pressure builds so much that it causes an eruption, producing a volcano. The chain attests to the movement of the plate boundary, producing subduction and thus volcanoes as continental crust is subducted by oceanic crust. Figure 4 illustrates the movement south of the boundary. 23-15 mya, the Waitakere Volcano was active and further south and east around 18 mya the Coromandel volcanic zone became active, ceasing at 2 mya.

as the boundary continued moving south-east. The more recently active Taupo Volcanic Zone and Whakaraui / White Island attest to the continuation of this movement, as more ~~and~~ subduction zones emerged from a movement of the plate boundary. ~~Meanwhile the Kermadec trench also indicates the movement of these plates as~~

whereas

In the South Island, less volcanism is observed. This is because the South Island's plate boundaries are boundaries of continental and continental crusts rather than continental and oceanic ^{as in the North Island} crusts. This means that both plates crusts are buoyant and so neither ~~is able~~ sinks below and subducts the other, and so no subduction volcanoes can emerge. The alpine fault is a ~~fault line~~ plate boundary where the plates ~~this~~ slide past one another. This is indicated by the matching rock belts in ~~West~~ Nelson in the North ^{east} and Fiordland in the South west which could have only emerged by lateral movement of the fault line. ~~North east~~ This lateral movement, ~~and~~ causes uplift of the land surrounding due to pressure and strain on the land caused by the slow grinding movement of plates past one another. The uplifting produced the southern Alps 15mya and their height of around 4km attests to the plate movement described above. The volcanoes that are observed are likely hotspot volcanoes rather than subduction volcanoes as they occur relatively close together and relatively far from the fault line. The movement of the fault line ~~is~~ north-east ~~and~~ would have caused the movement of the hotspot

north-east as well as the southernmost ~~Quenean~~ ^{Paganini} volcano was active 16-10 mya and the Banks ^{Paganini} volcano which is north of Ouedes ~~is~~ was active before 6 mya. The shield rather than andesitic nature of these volcanoes further attests that they are hotspot volcanoes because ~~there~~ the andesitic type (observed in the Comand volcano zone) is more likely to be from ~~the~~ subduction volcanoes than are shield volcanoes which emerge rapidly from hotspot volcanoes.

The Kermadec and Puysegur trenches are also evidence of the ~~plate~~ tectonic activity of the 2 islands. Both trenches formed from the opening of a rift in the land due to divergent movement of nearby plates. The divergent movement of the plates in the Kermadec trench caused a movement together of the plates at the more southern subduction boundary responsible for the North Island's volcanic activity as well as the uplift of the North Island out of the sea as the continental crust of the Australian plate rose above the sinking oceanic crust of the Pacific plate. Whereas the divergent plate movement ~~obs~~ that created the Puysegur trench forced the angled ~~thrust~~ lateral movement of the alpine fault which enabled the uplift of the South Island or especially the Southern Alps.

The differences in ~~geological~~ geological history of North and South Island are due to a

The ~~future~~ movement of the plate boundaries in both islands ~~past with me~~ will likely change in future. At present, the North Island

different type of plate boundary observed in each. The North Island's subduction plate boundary ~~is~~ evidenced by ^{an} ~~the~~ volcanism ~~the~~ going South-east on the accompanying uplift of the island, is due to the meeting of an ^{oceanic} ~~oceanic~~ ^{crust} ~~crust~~ section of the Pacific plate with a continental crust section of the Australian plate. Whereas the uplift of the Southern Alps and the north-easterly movement of a volcanic hotspot ~~was~~ evidenced that the South Island had a lateral movement plate boundary where continental crust ~~of two~~ sections of both the Pacific and Australian plate moved past one another.

The future of these boundaries is unclear. As the Alpine Fault continues to move northwards ^{east} it will cause an associated movement of the Southern Alps in this direction as more land is uplifted along this boundary. This movement will eventually result in a reconnection of the islands as the Alpine Fault moves north-eastwards into the Cook Strait. Meanwhile the south-eastern movement of the North Island's fault will cause the production of more increased volcanism off the east coast of the North Island, ultimately resulting in more uplift of the land as the continental crust section of the Australian plate mounts the oceanic crust section of the Pacific plate, producing more islands. ~~there~~ a decrease in the depth off this coast and through the volcanism producing more islands (the Whakaari, (Cape Māui in North))

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.

The TOI 270 system ~~will~~ and our own solar system will have formed by very similar processes. Both will have started with a nebula, whereby cosmic dust is compacted ~~and condensed~~ to create significant heat, ~~and~~ This is followed by the protostar stage where ~~the~~ elements formed in the core of the star are emitted ~~into space~~ as protoplanetary dust. This dust aggregates to form planetismals, with the ~~rocky~~ metallic planetismals forming before the gaseous ones. These planetismals will then aggregate ~~together~~ to form planets, once again rocky, metallic planets forming before gaseous ones. ~~Then~~ In our solar system Mercury, Venus, Earth and Mars form before Saturn, Jupiter, Neptune and Uranus. Whereas in TOI 270 the 270b planet forms before 270c and 270d. ~~Then~~ Each protostar continued to ~~condense~~ ~~on~~ compact and become denser, increasing temperatures. However the mass of 270's star is only ~~46%~~ of the sun's mass and as a result ~~the mass a red dwarf rather than red giant~~. Both stars The sun of our solar system is a main sequence red star with ~~the~~ ^{nuclear} fusion of H and He occurring at its core. Whereas TOI 270's star ~~is~~ with a mass ~~of~~ ^{40%} less than our sun's mass is ~~incapable of nuclear fusion~~. This means that it is a red dwarf with ~~or~~ temperatures ~~2/3~~ of the sun's, which correspondingly behaves differently to

star

the sun. The much smaller mass of the star as well as the lower ~~than~~ temperatures mean that ~~the possibility of life on~~ it has ^{fewer} planets orbiting, as the gravitational pull is less significant and less mass was released during the protostar stage. These planets are able to be closer than the sun's planets because they need to be closer to feel the gravitational pull but also because the ~~lower~~ lower temperatures mean that they can be closer without burning up.

There is some possibility of life in the TOI 270 system. The closest planet, 270b would be most likely unsuitable. The very high surface temperatures of around 254°C due to proximity and tidal locking mean that the planet would be unable to have ~~constant~~ liquid water or methane, which is currently seen as a requirement for life. Liquid media are required for as solvents to enable the dissolution and formation of the more complex molecules that are required even for the most basic forms of life. Additionally, high surface temperatures ~~such as these~~ of 254°C would ~~prevent~~ make life extremely difficult even if there were a liquid media. ~~The~~ Any life form would ~~be~~ need to be similar to the earth's extremophile bacteria ~~and~~ and archaea which are ~~not~~ evolutionarily simple and chemically structurally simple yet are nonetheless able to occupy extreme environments such as hydrothermal vents. ~~Also~~ ~~the~~ whereas the potential composition of 270b could ~~make~~ it ^{more} suitable, A

~~solid~~ rocky composition is presently seen as a requirement for life, as no lifeforms with ~~any~~ purely in gas have been discovered. ~~of the theory~~ A rocky surface is also necessary for ~~leakage~~ containment of any liquid, in cracks, ~~in~~ craters etc., as well as anchoring of any basic stationary organisms. Such 270b would need a very thick atmosphere to have life. ~~Due~~ Due to its large mass, ~~(1.25 x earth)~~, it is likely to be able to attract sufficient gases to surround it and protect the surface from external ~~harm~~ and trap any gases produced by and required for life on the planet, such as O_2 , H_2O and CO_2 . However, an atmosphere that is too thick may ~~prevent any~~ lead to even hotter surface temperatures and trapping of any noxious gases produced by any tectonic or volcanic activity on 270b. The planet is also very close to its ~~parent~~ star and is tidally locked which is responsible in part for high surface temperatures. However the proximity also ~~makes it~~ endangers it to the effects of its star. The red dwarf produces high radiation flares and emission of X-ray and UV rays. These would be extremely damaging to life on 270b as these would result in temperature ~~fluctuations~~ spikes but also result in damage to any genetic code required for development of even basic life by earthly Darwinian principles. A strong magnetic core and atmosphere may shield the planet from some of the effects but they cannot completely protect it from ~~the~~ all damage. These

factors ~~to~~ put together overall make life on 270b unlikely, however life could be associated with the other 2.

270c and 270d are both gas giants. Their gaseous nature immediately prevents any life on their surfaces, however their large sizes (2.4 and 2.4x earth respectively) mean that they will have sufficient gravitational pull to have moons orbiting them, and these will be candidates for life. They will not be likely to have life on 270c due to its extreme proximity to the star (0.05 Au) & producing very high temperatures (1800°) which make ~~to~~ life and the needed liquid medium impossible. The proximity of course also means ^{high} exposure to the radiation effects of the star which ~~prevents any~~ cause mutations to any genetic code, preventing development of life. The small mass of any such moons means that it cannot have a sufficiently thick atmosphere, or strong enough magnetic core, to protect against these effects. However, 270d is much further from the star (0.07 Au) and this means that it has lower temperatures (570°) and also lower exposure to radiation effects. This means that liquid water may be possible on any ~~or~~ moons of 270d. The temperatures of these moons will be similar to the planet's 570° ~~and~~ as any heating via tidal flexing will be small as the planet has a smaller gravitational pull than to earth's tidal flexing planets, and could be counteracted by albedo, reflecting some of the sunlight.

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

QUESTION
NUMBER

2 As the Alp moves farther into the future
beyond, the boundary may change