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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2024
Earth and Space Science

RESOURCE BOOKLET

Refer to this booklet to answer the questions for Scholarship Earth and Space Science.

Check that this booklet has pages 2–7 in the correct order and that none of these pages is blank.

YOU MAY KEEP THIS BOOKLET AT THE END OF THE EXAMINATION.

QUESTION ONE: RIVERS IN THE SKY

Atmospheric rivers are long, relatively narrow areas of the atmosphere that carry a large amount of water vapour. They are responsible for most of the movement of water in the atmosphere from the Equator towards the poles. The number of atmospheric rivers peaks at a latitude of 41 degrees south. This latitude runs through the bottom of the North Island, Te Ika-a-Māui, and the top of the South Island, Te Waipounamu.

Figure 1: Historic atmospheric river in August 2022 that caused significant flooding and damage

Source: https://niwa.co.nz/news/exceptional-august-atmospheric-river-sets-record

Atmospheric rivers are measured on the integrated vapour transport scale, which is a mixture of the flow of the atmospheric rivers and the amount of vapour stored in the air. 1250 kg m^{-1} s^{-1} is considered “exceptional”. However, in 2022, the highest August reading was 1749 kg m^{-1} s^{-1}.

Atmospheric rivers in New Zealand can be divided into those that originate from the north and those from the south. Those that originate from the north are affected by the subtropical region of the Tasman Sea and by the western Pacific Ocean – they tend to hit land in the North Island. The integrated vapour transport value of the southern atmospheric rivers depends mostly on the strength of the westerly winds across the Southern Ocean, which are associated with the Ferrel cell; these tend to hit the South Island.

Two places of note that are affected by atmospheric rivers are the western side of New Zealand’s largest city, Auckland, and the western side of the South Island.

Table 1: Comparison of Auckland and the West Coast

	West Auckland	**West Coast**
Size	578 km^2	23 000 km^2
Population (2022)	315 000	32 700
Population density	545 / km^2	1.41 / km^2
Length of mountain range	25 km	500 km
Highest peak	Te Toiokawharu is 474 metres, with other multiple peaks exceeding 300 metres.	Aoraki / Mount Cook is 3724 metres and is the highest peak in New Zealand.

El Niño and La Niña are two phases of the cycle called the El Niño Southern Oscillation, ENSO. El Niño is defined by a warming of the eastern Pacific Ocean, off the coast of South America, as the trade winds weaken or reverse. La Niña is the opposite of El Niño, with warmer temperatures caused by stronger trade winds.

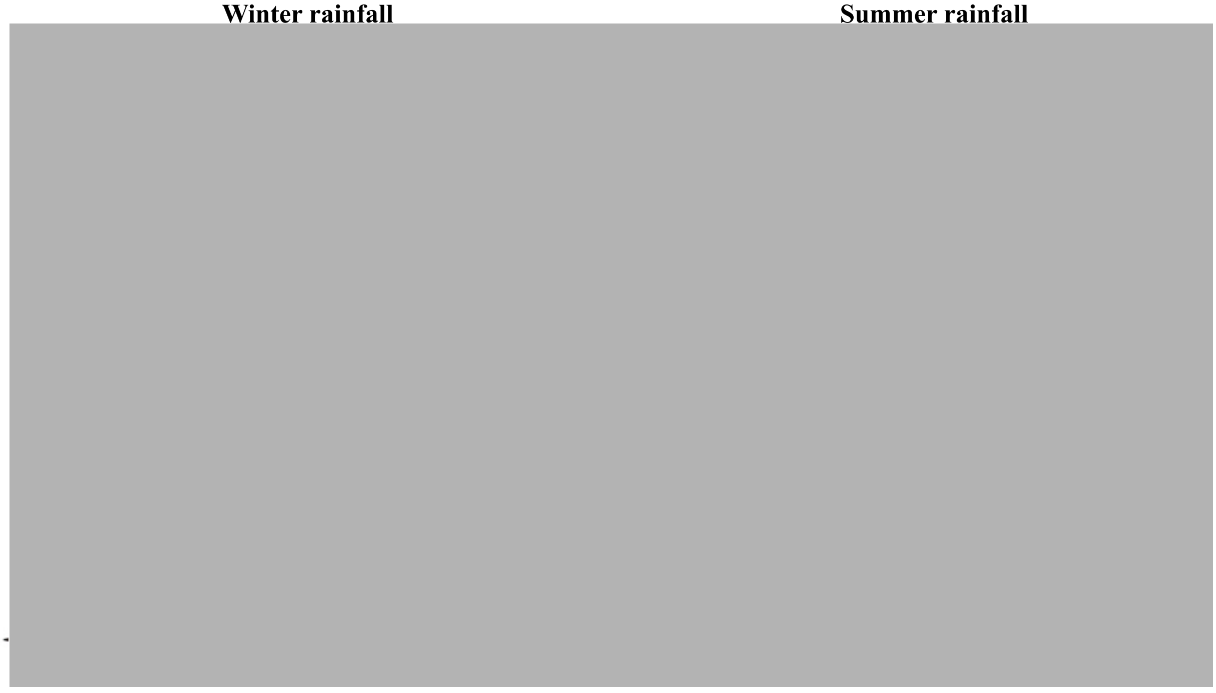
New Zealand is affected by the two phases of ENSO in different ways. During El Niño, New Zealand tends to experience stronger winds from the west in summer, and in winter the wind is more likely to come from the south, causing lower temperatures across the country. During La Niña, north-easterly winds are prevalent, which brings moist air to north-eastern areas. The south-west of the South Island can be prone to drought during La Niña.

Figure 2: La Niña conditions

Source: www.interest.co.nz/rural-news/108216/we-look-we-have-la-ni%C3%B1a-weather-pattern-settling-and-not-all-bad-new-zealand

Figure 3: Winter and summer rainfall during La Niña

Winter rainfall **Summer rainfall**



Adapted from: https://niwa.co.nz/el-nino-and-la-nina

QUESTION TWO: NEW ZEALAND’S GEOLOGICAL HISTORY

Aotearoa New Zealand has been changing and re-shaping since it broke away from Gondwanaland over 85 million years ago. Its current major geological features are: the Taupō volcanic zone, the Auckland volcanic field, the Southern Alps, and the chain of underwater volcanoes alongside the Kermadec Trench.

Figure 1: New Zealand continent and plate boundary

Source: https://teara.govt.nz/en/map/4398/plate-boundary-through-new-zealand

In the North Island, the Tāupo volcanic zone did not start forming until about 2 million years ago. Before that, the volcanism was centred in other parts of the North Island. The remnants of the eastern side of the Waitākere volcano is what forms the Waitākere ranges in Auckland. The Waitākere volcano was active between 23 and 15 million years ago and was 5 to 6 times the size of Ruapehu, Ngauruhoe, and Tongariro combined.

Figure 2: Formation of the Waitākere volcano

Source: https://www.researchgate.net/publication/256670097_Land_sea_and_sky

The Waitākere volcano formed at the southern end of two lines of undersea volcanoes. These two lines of volcanoes formed about 20 million years ago when the plate boundary was closer to the Northland region, as shown in Figure 3. This is an indication that the plate boundary has moved.

Figure 3: Undersea volcanoes 20 million years ago

Figure 4: North Island volcanic fields

Adapted from: https://www.researchgate.net/publication/256670097_Land_sea_and_sky

Adapted from: www.gns.cri.nz/our-science/natural-hazards-and-risks/volcanoes/volcano-types

Further evidence of the North Island's past volcanic activity is found in the Coromandel Peninsula, where the Coromandel volcanic zone began forming around 18 million years ago. The Coromandel volcanic zone consists of andesitic volcanoes, and there is a caldera in the middle of the Coromandel Ranges, the formation of which dates to between 9 and 7 million years. The volcanic activity in this region decreased between 4.7 and 4.2 million years ago, and it experienced basaltic eruptions only for the last 2 million years of its eruptive period before ceasing 2 million years ago. The activity shifted to the south and east of the Coromandel Peninsula.

The South Island has a different geological history to the North Island. Between 23 and 10 million years ago, the western side of the Alpine Fault was moving north-east relative to the eastern side at a rate of between 1–10 cm per year. This has resulted in about 450 km of displacement along the Alpine Fault. There are rock belts in Nelson that match reasonably well with those to the south in Fiordland. The Southern Alps began forming around 15 million years ago, and are now almost 4000 m high.

Finally, there are extinct volcanoes in the South Island. One of these is the Dunedin volcano, which was active between 16 and 10 millions years ago, and is a shield volcano. The other location is Banks Peninsula, which consists of two extinct volcanoes that stopped erupting 6 million years ago.

QUESTION THREE: THE TOI 270 SYSTEM

Figure 1: TOI 270 system

Source: https://exoplanets.nasa.gov/what-is-an-exoplanet/planet-types/super-earth/

An exoplanet is a planet outside of our solar system that likely orbits another star in our galaxy. In 2019, NASA's Transiting Exoplanet Survey Satellite (TESS) discovered a super-Earth and two mini-Neptunes orbiting a red dwarf star that was about 73 light-years away in the southern constellation of Pictor. The red dwarf star, TOI 270, is approximately 40% smaller than our Sun in both size and mass, with a surface temperature about one-third cooler than our Sun's.

Most of the planets orbiting red dwarf stars are tidally locked, which astrobiologists acknowledge is an obstacle to habitability. Additionally, red dwarf stars are known to begin their existence with millions of years of intense flaring before calming down.

Figure 2: Red dwarf star with solar flares coming off it

Source: www.nasa.gov/image-article/flaring-red-dwarf-star/

Red dwarf stars are the smallest, coolest stars in the main sequence and can survive for a very long time. The smaller the red dwarf, the longer it will continue to undergo fusion, so a very small 0.1 M_{sol} red dwarf will live for 10 trillion years. However, just because they are small does not mean that they are safe or simple.

A red dwarf star spins rapidly for the first couple of billion years of its life. These younger, faster spinning stars produce X-ray and UV emissions in giant flares that can occur every couple of hours.

The spin churns up and charges the inside of the star, which then generates a magnetic field. Gases close to the surface of the star are trapped by the field and heated to extreme temperatures, which then in turn releases the high radiation flares. In a somewhat ironic twist, the magnetic field produces angular momentum, which gradually slows the star's spin, and it can then settle into trillions of years of stability.

Table 1: Planets in the TOI 270 system

	TOI 270b	**TOI 270c**	**TOI 270d**
Distance of orbit from star (AU)	0.03	0.05	0.07
Planet radius	1.25 × Earth	2.4 × Earth	2.1 × Earth
Relative mass to Earth	2.09	6.15	4.78
Orbit	3.4 days	5.7 days	11.4 days
Temperature	254 °C	150 °C	57 °C

The innermost planet, TOI 270b, is likely to be a super-Earth, up to twice the size of Earth and made of gas, rock, or a combination of both. The other two planets, TOI 270c and TOI 270d are mini-Neptunes, bigger again than a super-Earth, and made wholly or partly of gas.

Table 2: Planets in the solar system

	Mercury	**Earth**	**Neptune**
Distance of orbit from star (AU)	0.4 (69 million km)	1 (150 million km)	30 (4.5 billion km)
Relative size to Earth	0.3	1	4
Relative mass to Earth	0.05	1	17
Orbit	88 days	365 days	165 years
Temperature	430 °C to –180 °C	15 °C	–200 °C

As the most common type of star, it is estimated that there may be up to 60 billion red dwarf stars in our galaxy that could have Earth-like planets, such as super-Earths. A super-Earth is up to twice the size of Earth and made of gas, rock, or a combination of both.

A factor that is considered to be the best sign for habitability on exoplanets is the presence of liquid water. An atmosphere is generally accepted to be required for liquid water to be present to stop water freezing or evaporating. Our Earth has a rotating liquid core that forms a magnetic field, which shields the atmosphere from radiation from the Sun.