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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2025
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: VOLCANOES UNDER THE ICE

In 2014, a team of scientists discovered an active volcanic heat source beneath the Pine Island Glacier in west Antarctica. The team was studying ice melt and heat transport when they unexpectedly detected high concentrations of a gas from the mantle that indicates volcanic activity.

Figure 1: Antarctica showing Pine Island Glacier

Adapted from: www.earthdoc.org/content/papers/10.3997/2214-4609.2020geo108?crawler=true

Pine Island Glacier is the fastest moving and fastest melting glacier in Antarctica, reducing in thickness by more than 1 metre per year, corresponding to the loss of tens of gigatonnes of ice. The heat from the active volcanic source is about 25 times greater than that of a typical dormant volcano, and it is contributing to the glacier's rapid melting.

However, the team clarified that this volcanic activity is not the primary cause of the glacier's instability. Decades of research indicate that the primary factor is the heat from ocean currents, which is linked to changes in the climate and atmospheric conditions around Antarctica. While the volcanic heat source is a newly recognised contributor, the primary driver of the glacier's melting remains climate change and its effects on ocean circulation.

Volcanic activity beneath ice caps is known as subglacial volcanism. A subglacial volcano, also known as a glaciovolcano, erupts beneath a glacier or ice sheet. The result of the eruption is dependent on the size and magma type of the volcano, as well as how thick the ice is on top of it.

The last known volcanic eruption in the region of Pine Island Glacier was 2200 years ago. The date of the eruption was measured by using ice cores, looking at how deep the widespread layer of volcanic ash and tephra produced was buried under the snow and ice.

Figure 2: Types of subglacial volcanism

Adapted from: https://www.researchgate.net/publication/306203133_Glaciovolcanism

Discoveries in 2018 have revealed that beneath the Antarctic ice sheet, numerous volcanoes exist, including 91 previously unknown in west Antarctica, suggesting the region could be one of the largest volcanic areas on Earth. Many of these volcanoes are dormant, but their presence raises questions about their potential influence on ice melt and global sea levels. These volcanoes are primarily located along the West Antarctic Rift System, which lies between the East and West Antarctic plates, and is an area of significant tectonic extension. This tectonic activity is similar to rifting zones in other parts of the world, where tectonic plates pull apart, allowing magma to rise through the crust. As with many rift zones, the volcanism is primarily basaltic, although more evolved and complex magmas may also occur, depending on the local tectonics and magma differentiation processes.

As ice caps melt due to climate change, and the weight of the ice becomes lighter, the pressure on the Earth's crust decreases, potentially leading to increased volcanic activity. This phenomenon was observed at the end of the last ice age, where melting ice caps and glacial erosion led to a significant increase in volcanic eruptions. This is currently observed in places affected by the withdrawal of ice caps, such as Greenland and Alaska.

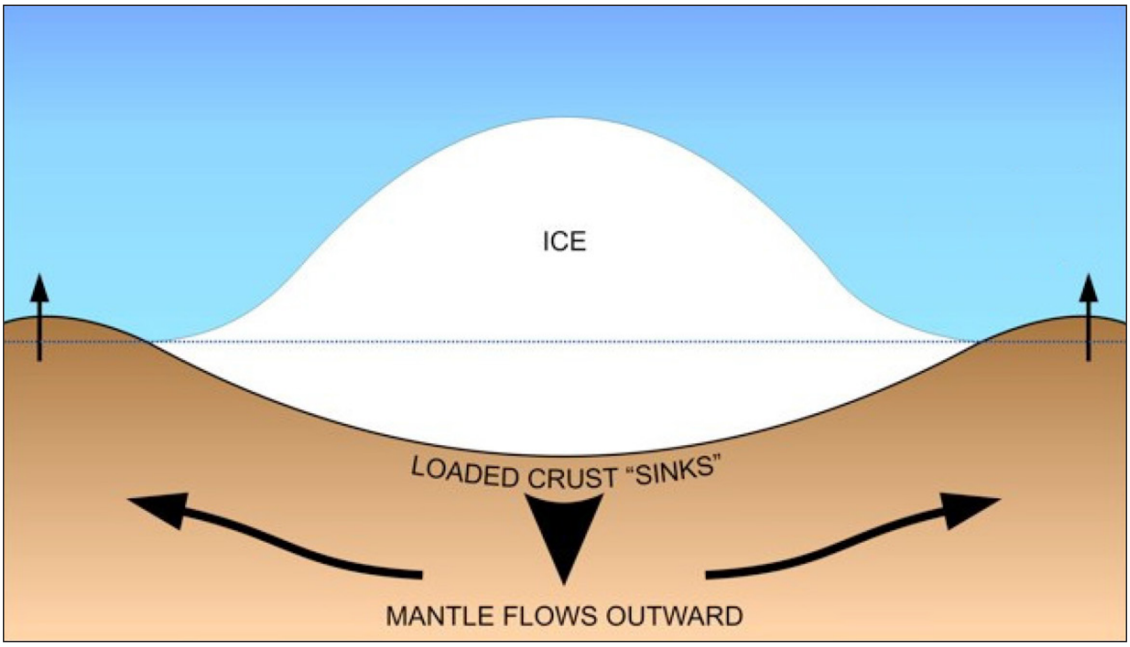

Figure 3: Effects when Earth's surface is loaded by a heavy ice sheet

Adapted from: https://nap.nationalacademies.org/read/26377/chapter/5

QUESTION TWO: WARMING OCEAN

The Chatham Rise is a submerged plateau that extends from the east of the South Island, and it is unique in its topography. It allows for cold, nutrient-rich fresh water from the Antarctic to mix with warm, iron-rich, sub-tropical water, and this provides the perfect conditions for marine organisms like phytoplankton. Furthermore, it is a cornerstone location for Aotearoa New Zealand’s fisheries, with the area accounting for about 60% of the nation’s total fish catch.

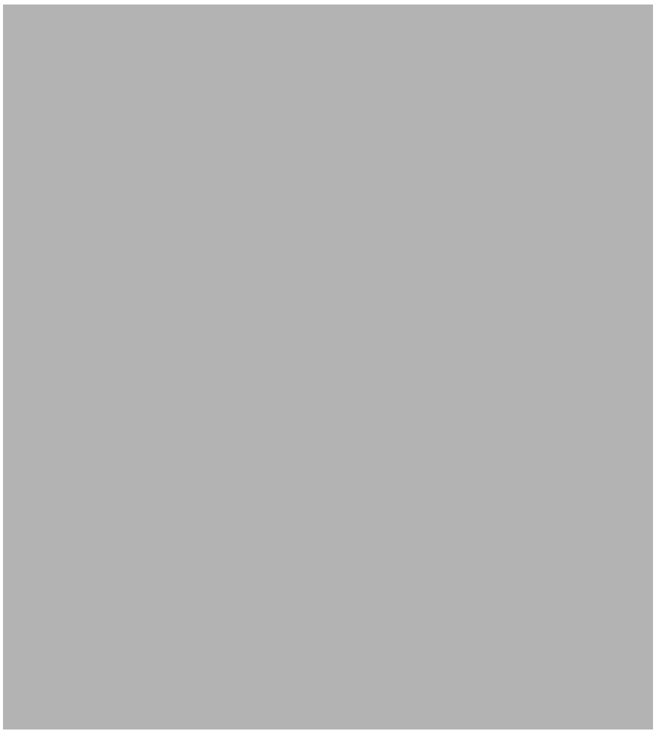

Figure 1: Topographic map of Zealandia showing the Chatham Rise

Source: https://en.wikipedia.org/wiki/Chatham_Rise

This mixing of cold, fresh water from the Southern Ocean with the warm, salty water from the subtropics is called the Subtropical Front. This front goes from west to east (along the Chatham Rise). This area has experienced periods of warming before returning to normal temperatures; however, since 2006 it has not stopped warming.

The National Institute of Water and Atmospheric Research (NIWA) has been monitoring the ocean around the Chatham Rise using measurements from satellites and Argo floats. Argo floats are robotic instruments that move up and down through the water, and can drift with the ocean currents. It was found that there was warm and salty water all the way to the bottom of the seafloor, where there once was cold and less salty water.

Warming in this region is influenced by both global climate change and atmospheric processes specific to the Southern Hemisphere, which influence the location of the Subtropical Front.

The oceans in mid-latitudes have warmed more than the oceans further south, resulting in a stronger temperature gradient across the Southern Ocean. Additionally, westerly winds over the Southern Ocean have strengthened. These mechanisms have accelerated the surface flows in the Southern Ocean, which move from west to east. Stronger westerlies have also affected the currents that bring warm subtropical waters to the ocean around New Zealand.

The westerly winds have also moved south towards higher latitudes. The net effect is movement of the Subtropical Front to the south, causing an increase in ocean temperatures on the Chatham Rise.

Ocean warming is also occurring off Tasmania, with temperatures having risen by 1.5 degrees Celsius, which is more than twice the global average rate.

Another factor influencing the Chatham Rise is the El Niño-Southern Oscillation (ENSO), a natural climate cycle that affects global weather and ocean patterns. During La Niña events, warmer waters from the central and eastern Pacific shift toward New Zealand, intensifying the rise in sea temperatures.

Overall, there are significant challenges for the Chatham Rise. These environmental changes could lead to a decline in fish populations, threatening New Zealand’s fishing industry and altering the balance of its marine ecosystems. As global temperatures continue to rise, understanding these oceanic and atmospheric processes will be critical for managing New Zealand’s marine resources and ensuring the sustainability of its fisheries.

Figure 2: Argo float

Source: https://niwa.co.nz/newsunprecedented-ocean-change-may-impact-key-nz-fisheries

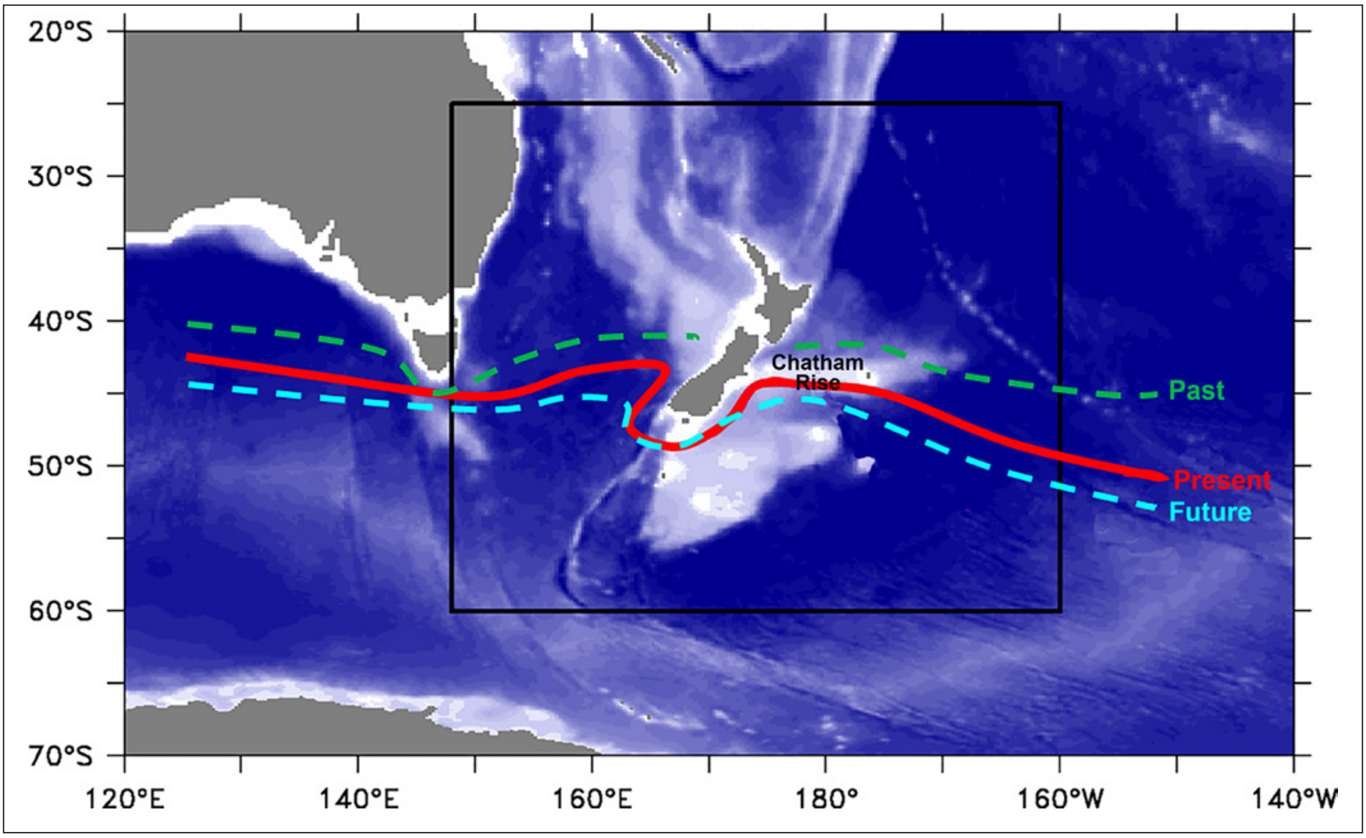

Figure 3: Current Subtropical Front (red line) and predicted Subtropical Front (blue line)

Adapted from: https://niwa.co.nz/climate-and-weather/stormy-seas-project

Figure 4: Changing sea surface temperatures around New Zealand

Source: https://snippets.energyts.com/snippets/20160421/story13.html

QUESTION THREE: SEASONS IN OUR SOLAR SYSTEM

Seasons on planets in our Solar System are characterised by changes to the temperature, climate, and weather over time. They are affected by a range of factors: the distance of the planet from the Sun, the length of orbit, axial tilt of the planet, and the orbital eccentricity of the planet.

Perihelion is when the planet is closest to the Sun and aphelion is when the planet is furthest from the Sun in its orbit. Eccentricity is a measure of how circular or elliptical an orbit is; as the value of the eccentricity increases, the degree of ellipticity increases. A value of zero for the eccentricity represents a perfectly circular orbit. The amount of solar radiation that a planet's atmosphere receives is measured in Watts per square metre (W/m^2). 1 AU is 150 million kilometres.

Table 1: Planet characteristics

Planet	Distance from the Sun (AU)	Length of orbit (years)	Axial tilt	Eccentricity of orbit	Perihelion (AU)	Aphelion (AU)	Amount of solar radiation received (W/m^2)
Earth	1.0	1.0	23.4°	0.0167	0.98	1.01	1362
Mars	1.52	1.88	24.9°	0.0935	1.4	1.67	586
Uranus	19.2	84.1	97.8°	0.0459	18.3	20.1	3.7
Neptune	30.1	165	28.3°	0.0097	29.8	30.3	1.5

Figure 1: Martian seasons

Adapted from: www.britannica.com/place/Mars-planet/Basic-astronomical-data

In 1986, the space probe *Voyager 2* was able to observe Uranus's south pole facing the Sun, and also no activity in its atmosphere. In 2007, the Sun was observed to be shining over Uranus's equator, which meant it experienced a day/night cycle associated with the 17-hour rotational period for Uranus.

Figure 2: Seasons on Uranus

Adapted from: https://earthsky.org/space/seasons-of-uranus-strange-sideways-world/

Over a period of six years, scientists were able to observe an increase in the amount and brightness of the clouds in Neptune's southern hemisphere. They believed this showed the planet entering spring.

Figure 3: Changing seasons on Neptune

Adapted from: https://hubblesite.org/contents/news-releases/2003/news-2003-17.html