S

93104R

Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Scholarship 2023
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.

Resource for

QUESTION ONE: PHYTOPLANKTON AND THE CARBON CYCLE.

Figure 1: Phytoplankton and the movement of carbon in the ocean

Source: https://upload.wikimedia.org/wikipedia/commons/2/24/Marine_carbon_cycle.jpg

The global carbon budget is a measurement of how much carbon is entering and leaving the atmosphere. This is important to track so that climate change models can be as accurate as possible, as these models are often used to inform the development of environmental policy to combat climate change.

One of the largest interactions that removes carbon from the atmosphere is when carbon dioxide is dissolved into the ocean, where it can then be incorporated into marine food webs.

Phytoplankton are microscopic, photosynthetic organisms that are found in the sunlit layers at the top of the ocean, and they form the basis for most marine food webs. Phytoplankton undergo photosynthesis to change water from the ocean and carbon dioxide dissolved within it to make glucose, with oxygen as a by-product. It is the glucose that enters the food webs.

$$\text{carbon dioxide} + \text{water (with light energy)} \rightarrow \text{glucose} + \text{oxygen}$$

Despite having 100 times less overall mass than plants on land, phytoplankton as a whole undergo a similar amount of photosynthesis per year. Phytoplankton consume 10 times more carbon dioxide than humans are releasing annually from the burning of fossil fuels.

Phytoplankton production can be limited by a number of factors, such as sunlight hours, and temperature, as well as availability of reactants for photosynthesis and other body-building blocks. Iron, for example, is a limiting factor in the Southern Ocean. It usually comes from dust-blown winds from land masses; these are less common in the Southern Hemisphere.

Phytoplankton are consumed by zooplankton or they die naturally and can be decomposed by bacteria for energy via respiration. Alternatively, their carbon-rich bodies can sink into the deep ocean, and can be stored either as limestone or in deep sea currents.

Figure 2: Phytoplankton in the carbon cycle
Source: https://www.sciencelearn.org.nz/resources/689-the-ocean-and-the-carbon-cycle

The amount of carbon entering the deep ocean varies from 1% of total phytoplankton fixation in some places, to 50% in highly productive areas that have algal blooms. Algal blooms occur when conditions lead to very high levels of algae in the water, which includes phytoplankton. When the populations are very high, it can cause a build-up of toxins or a lack of oxygen in the water.

Whales have been of interest recently, as they consume tons of phytoplankton and zooplankton per day. Whales' waste is enriched in nutrients that are ideal for phytoplankton. When whales die, they move a large amount of matter to the ocean floor, as their bodies are too large to break down completely before sinking to the sea floor.

Two significant factors affecting today's oceans are the warming of the oceans and ocean acidification. Both of these factors contribute to a change in phytoplankton composition, number, and species. This also affects the productivity of the phytoplankton and therefore the food webs of which they form the basis.

Research has shown that smaller species of phytoplankton are favoured when there is a decrease in pH and an increase of temperature. Warmer oceans also may lead to the interactions in the food webs occurring faster with a quicker movement from organic carbon in forms such as glucose, to inorganic in the form of carbon dioxide.

Figure 3: A phytoplankton bloom in the waters east of New Zealand
Source: https://earthobservatory.nasa.gov/images/40924/spring-bloom-in-new-zealand-waters

Resource for
QUESTION TWO: SLOW-SLIP EVENTS

Since 2002, slow-slip events have been detected in New Zealand. These occur when the Australian and Pacific Plates are moving past each other at a rate of millimetres over weeks or months. Slow-slip events can generate earthquakes of magnitude 6 or greater. However, the energy is released over a much longer period of time, and over a much larger area. Typically, these slow-slip events occur at least once or twice a year.

Figure 1
Adapted from: https://www.geonet.org.nz/about/earthquake/sse

Figure 1 diagram shows a cross-section of New Zealand's subduction boundary. The locked plate section is where the Pacific Plate and Australian Plate are "locked" together due to friction on the fault. However, the slow-slip zone is where the plates are moving past each other over days to months, and relieve the built-up tectonic stress from when the plates were locked together.

Slow-slip events are occurring at regular intervals. One particular example occurred off the east coast near Pōrangahau in 2006, 2011, and 2016. Scientists predicted that there would be another event in 2021, so placed instruments to measure it. A two-week event started and the land was detected to move 2 cm eastward. It also coincided with a cluster of about 60 small earthquakes recorded north of Gisborne, the largest being magnitude 4.2.

Further connections between slow-slip events and earthquakes have been discovered. As shown in Figure 2, slow-slip events occurred after the 2016 Kaikōura earthquake, as well as the Marlborough afterslip, which was an event that started post-earthquake. Note that the East Coast slow-slip is 600 km away from the Kaikōura epicentre. Geologists believe that a Kāpiti slow-slip event that started in 2013 caused the 6.2 magnitude Eketāhuna earthquake in 2014.

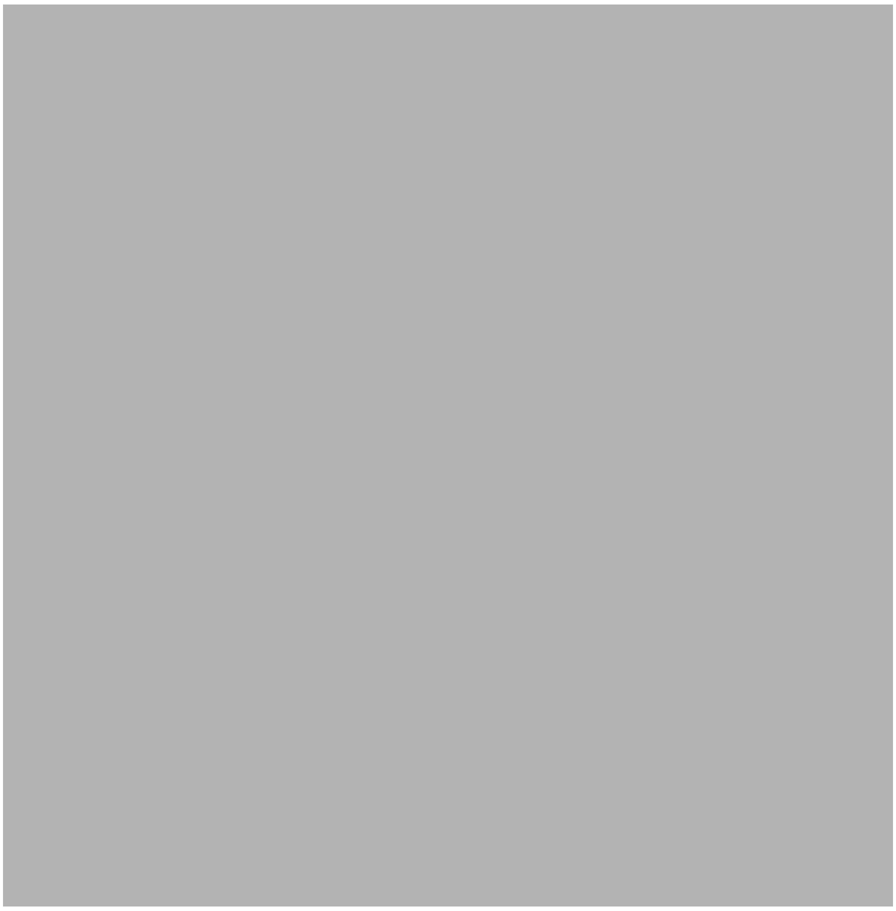

Figure 2

Adapted from: https://www.geonet.org.nz/news/6nkv7fmNXyAeQsKGgeowkc

Studying slow-slip events

Slow-slip events can be studied at the Hikurangi Subduction Zone. However, these slow-slip events can’t be detected by seismometers, so GPS stations have been placed on land to help measure the amount of displacement during an event. Their locations are shown in Figure 3.

Recently, pressure sensors have been put on the seafloor to detect vertical movement of the seafloor. This is because the pressure at the seafloor changes in response to changes in the height of the water column above it. If the seafloor subsides, the height of the water column above the seafloor sensors increases, and it is recorded as an increase in pressure. The opposite is true for the uplift of the seafloor. Generally, if a slow-slip event occurred directly beneath these sensors, the seafloor could be expected to rise as a result, while registering on the sensors as a decrease in pressure. Further, the data showed that slow-slip events were happening further away from New Zealand.

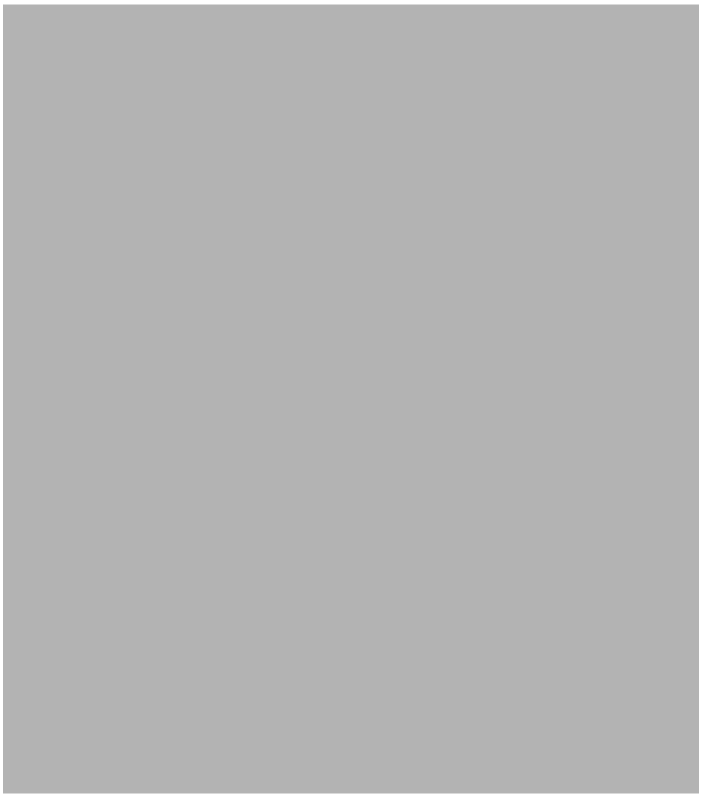

Figure 3: Location of GPS stations

Adapted from:
www.geonet.org.nz/earthquake/sse/manawatu
https://www.geonet.org.nz/earthquake/sse/hikurangi

Resource for
QUESTION THREE: JUPITER'S ATMOSPHERIC CELLS

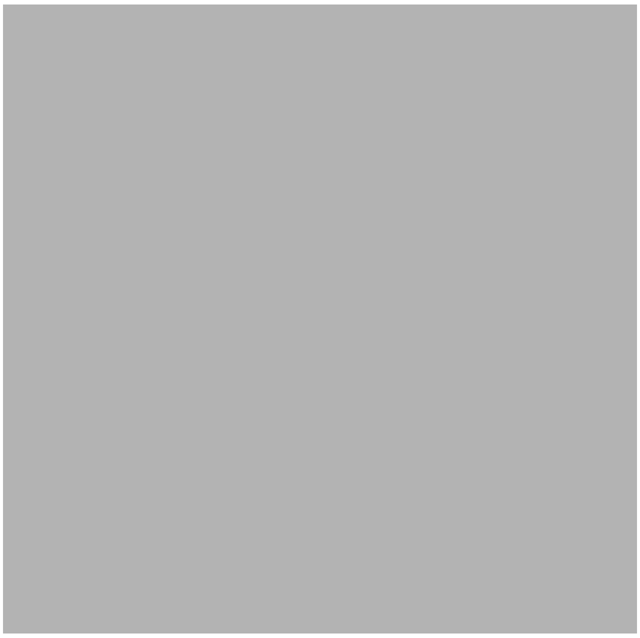

Figure 1

Source: https://www.nasa.gov/image-feature/hubble-spots-jupiter-s-great-red-spot

Jupiter is the largest planet in the solar system. It lacks a true surface; instead it is a planet of swirling gas and liquid. Jupiter's diameter is 11 times bigger than Earth's and it has 1321 times Earth's volume. Jupiter is also the most massive planet, being over 317 times the mass of Earth.

The planet produces more thermal energy than it receives from the Sun. This may be due to the energy released as Jupiter slowly cools down. Despite its distance from the Sun, due to its size, Jupiter receives more solar energy than Earth.

Jupiter also rotates more quickly than Earth. Earth rotates once every 24 hours, whereas Jupiter rotates once every 9.925 Earth hours. This means that Jupiter rotates about 2.5 times faster than Earth.

Viewed from a telescope, Jupiter has striking stripes and the famous Great Red Spot.

Unlike Earth, Jupiter has around 20 bands. The banding on Jupiter is due to wind that moves very quickly in opposite directions. These move much faster than Earth's wind belts. Earth has atmospheric cells that move in similar ways to the bands of Jupiter, but has only six.

On Jupiter, the light bands, called zones, represent rising gas, whereas the dark bands are called belts, and represent sinking gas. The Great Red Spot is a very significant storm that has been in existence for the past 500 years, which is much longer than other storms on Jupiter. The massive storm's crimson-coloured clouds spin anticlockwise at speeds that exceed 650 kilometres per hour, and it is bigger than Earth itself.

Juno, a spacecraft sent to survey Jupiter, has taken measurements of Jupiter's bands. These indicate that the bands are like jetstreams, and they extend 3000 kilometres into the planet's atmosphere. This would mean that they are moving around 1% of Jupiter's mass. Jupiter has eight Ferrel-like cells in the north and eight in the south.

Figure 2: Atmospheric circulation cells on Earth and Jupiter

Source: https://www.jpl.nasa.gov/images/pia24965-atmospheric-circulation-cells-on-earth-and-jupiter

The coloured bands in Jupiter's atmosphere are associated with vertical convective motion. Upwelling warm gas results in the lighter-coloured zones; the darker bands lie above lower-pressure regions, where cooler gas is sinking back down through the atmosphere.

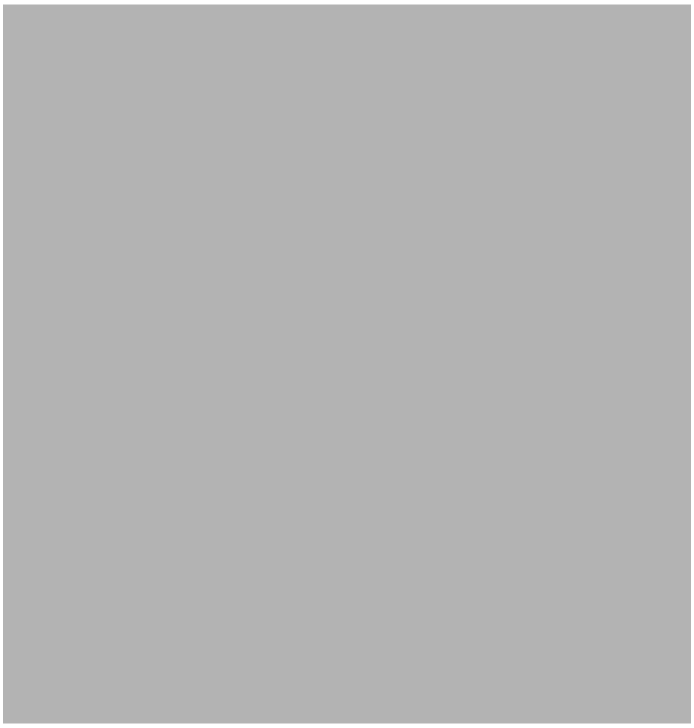

Figure 3

Adapted from: https://lifeng.lamost.org/courses/astrotoday/CHAISSON/AT311/HTML/AT31102.HTM

93104R