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93104

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SCHOLARSHIP EXEMPLAR

NEW ZEALAND QUALIFICATIONS AUTHORITY
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Scholarship 2022
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.

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Question	Score
ONE	
TWO	
THREE	
TOTAL	

ASSESSOR'S USE ONLY

wildfire effects ST LT
2 volcano effects ST LT
Human management, inadvertent action

QUESTION ONE: WILDFIRE EFFECTS

Discuss the effect wildfires have on the climate, both short term and long term. Contrast this to a moderate volcanic eruption such as Mount Pinatubo.

Analyse how wildfires and volcanic eruptions can be affected by human interactions, including management of the environment and impacts of human populations.

Both wildfires and moderate volcanic eruptions can substantially effect the local and global climates, in the short term and in the long term. Both release aerosols which have a negative feedback albedo effect, reducing global temperatures. Yet, each natural disaster has its own unique effects on climate that can substantially shape the world stage. Moreover, wildfires and volcanic eruptions can be both managed and ~~inadvertently~~ propagated by human interactions.

Firstly, before we can identify the key short-term and long term effects of wildfires, one must understand how they are formed. A 'fire storm', as it is called, must start with an initial ignition. This could include agricultural clearing of the land by deliberately lighting fires, such is currently going on in the Amazon rainforest in Brazil. There are a vast range of sources of initial ignition, but as long as the fire then begins to spread ~~spreads~~ uncontrolled, the 'fire storm' cycle can begin. The heated smoke rises through the troposphere due to convection. As the smoke plumes reach a high enough altitude, they reach dew point temperature. Thus, they cool and eventually condense on hygroscopic nuclei or aerosols (particulates in the atmosphere). This ultimately

Also, these pyroCbs are warm but they are not moist, thus no rain occurs to extinguish the fires.

~~minute~~ ~~Also, the pyroCbs do not fall readily, thus rain is stagnated~~ allowing further propagation of wildfires.

forms pyrocumulonimbus clouds (pyroCbs), which are large ~~clouds~~ thunderstorm clouds. Due to the electrically charged nature of the clouds, lightning occurs, which then creates new fires. Thus, a perpetually negative feedback cycle is created. This is a negative feedback (global cooling effect) because of the albedo effect. The top of the ~~thunder~~ pyroCbs are white, which have a high albedo, close to 1. Thus, this reflects much of the solar radiation coming from the Sun. Hence, less heat enters the lower atmosphere, and global temperatures decrease. This has a global long term effect as the smoke vortexes can travel through the atmosphere and take a long ~~term~~ time to dissipate, for instance in the case of the Australia pyroCbs outbreak it took longer than a year. Another effect of the pyroCbs from wildfires is the infusing of the stratosphere with black carbon clouds and CO_2. This would oppose the aforementioned albedo effect, and stimulate a greenhouse effect. However, the albedo effect must be more significant/influential than the greenhouse effect. Moreover, wildfires release SO_2 which reacts with water to form H_2SO_4, sulfuric acid ~~($SO_2 + H_2O \rightleftharpoons H_2SO_3$)~~ ($SO_2 + O_2 \rightleftharpoons SO_3$), ($SO_3 + H_2O \rightleftharpoons H_2SO_4$). This causes short term acid rain which reduces the pH of the soil preventing growth of plants. ~~Overall, wildfires can~~ Wildfires also have significant long term effects on the local environment, it dehydrates the ground and hardens the surface, which interferes with the hydrosphere, ~~pre~~ hindering infiltration. Overall, wildfires have significant effects on both local and global climates in both the short-term and long term.

Next, moderate volcanic eruptions also substantially effect local ad global climate, in both the short term and long term. Again, before understanding the effects of volcanic eruptions, it is integral to point out the formation of such eruptions. Volcanic eruptions can occur in three main ways: at constructive margins (sea-floor spreading); at subduction zones; and at hotspots. Also, eruptions can be magmatic or phreatomagmatic, with the latter involving water and being more dangerous. In all cases, magma rises from the mantle and penetrates through the surface. However, the nature of the magma is essential to understand the specific effects of the volcanic eruption. Magma can be basaltic, andesitic or rhyolitic, ~~with~~ in order of increasing violence (due to increasing ~~increased~~ viscosity / trapped gases). Thus, for the purposes of "moderate" volcanic eruptions, we will focus on basaltic and andesitic eruptions, which form shield volcanoes and composite cones respectively. Eruptions release tephra, which at its smallest form is volcanic ash. The ash rises and is spread across the globe by stratospheric winds. Similar to pyroclasts, these aerosols have an albedo effect which outweighs their greenhouse effect. Thus, upon reflecting sunlight, global temperatures decrease. However, unlike wildfires, volcanic eruptions do not create a self-sustaining cycle, they tend to be more spontaneous. Such a cooling effect, nevertheless, is a long term global effect, as seen in the 1991 eruption of Mount Pinatubo when global temps. decreased by 1°C ove

This is significantly more than the wildfire effect in Australia. Thus, we can conclude that volcanic eruptions release more ash, aerosols and pumice.

two years. A key aspect of geological study is to ensure validity and rigour of correlations/results. Thus, this volcanic cooling effect is further strengthened by the evidence of cold weather after the Laki, Tambora and Krakatoa eruptions. ~~However~~ Notably, the term 'long term' effect is relative, if you think of it in the context of Earth's age, the cooling effect does certainly seem to be short-term. This is because the aerosols eventually fall onto the surface or (less likely) escape the Earth's atmosphere. Moreover, similar to wildfires, volcanic eruptions release vast amounts of SO_2, which eventually form H_2SO_4 acid rain. Again, this has an extended impact on local soils, but, due to the cycling nature of the water cycle, in the broader long-term, the soil would revert to normal eventually. Thus, Shifting away from similarities, volcanic eruptions also ~~are~~ ~~caused~~ are accompanied by ~~vast~~ earthquakes (as the magma moves up towards the surface) and has a more vast range of effects including lahars, pyroclastic flows and lava flows. Thus, moderate volcanic eruptions can be seen to have ~~relatively~~ ~~moderately~~ fairly broader effects than wildfires, but in the context of global cooling, the events are quite similar.

Finally, both wildfires and volcanic eruptions can be affected (both prevented and propagated) by human interactions. In terms of prevention, wildfires can be limited by separating forests with roads or tram lines, so that ~~ground surface cannot spread~~ the fire cannot spread on the gravel. However, this does not directly challenge

cont'd on back pg. 14

* Higher than expected, C uptake in mature native
  ↳ why?
  ↳ Importance?
* Importance of new monitoring sites
* Future initiatives

QUESTION TWO: AN UNEXPECTED BALANCE

Carbon dioxide (CO_2) and methane (CH_4) are the greenhouse gases with the largest worldwide focus. There is much research on the emission and absorption of the greenhouse gases carbon dioxide and methane.

Discuss possible reasons why New Zealand has higher than expected carbon absorption from intact mature native forest, and its importance. Analyse why the placement of the new monitoring stations is important for the study of New Zealand's carbon balance, and any future initiatives that might come from these placements.

The carbon cycle is one of the three key cycles on the planet. It is closely linked with both the rock and water cycle, and is immediately pressing in today's context, given the currently-occuring climate change crisis. New Zealand's mature native forests appear to be acting as strong carbon "sinks", and CarbonMapNZ is beginning a process which will perhaps lead to a world-first country's carbon profile.

NZ's native mature forests are absorbing up to 60% more CO_2 than previously calculated. Evidently, the trees are functioning as biological pumps and are carrying out photosynthesis, which consists of the removal of CO_2 and H_2O from the atmosphere to make O_2 and organic nutrients ($6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$). What is interesting is that much of this is occuring in 'mature' forests rather than younger forests, which traditionally tend to have faster rates of growth (and thus would carry out more photosynthesis). However, NZ's native mature forests still seem to be carrying on with higher-than-expected photosynthesis. This could be explained by the structure of NZ natives, that may allow more sunlight to penetrate the under the canopy layer. Thus, more plant in the sub-canopy

can grow and carry out photosynthesis. However, a more significant factor could be the significant tectonic activity in NZ. This creates earthquakes and volcanoes, which constantly replenish trees. Thus, more growth needs to occur and thus more photosynthesis can occur. Another explanation is that it could be due to the species of plants that may just carry out prolonged photosynthesis. This notion of 'different' plants is supported by the fact that CO_2 absorption does not shut down completely during Winter in NZ like it does in the Northern Hemisphere. Furthermore, the native plants are specifically suited to the temperate climate of NZ, which recieves a fair amount of rainfall all year round with relatively consistent temperates, due to being close to the sea (which has a high specific heat capacity). Not to mention, NZ's native forests have a strong humus cycle with constantly replenished nutrients due to the joint action of all three cycles.

Now, the importance of this increased carbon absorbance, as a 'sink', is significant. Photosynthesis removes CO_2 from the atmosphere and stores them in plants which then decompose and release some CO_2 back to the atmosphere, whilst some are stored in millions of years underground as fossil fuels. The decreased partial pressure of CO_2 in the atmosphere is significant because CO_2 is a greenhouse gas. This means that it traps rises through the troposphere and traps the suns light heat, in what is

called the greenhouse effect. This blanket of CO_2 is decreased with increased photosynthesis. Thus, the positive feedback (increasing temperate) of the greenhouse effect is reduced. Hence, Climate change is decelleated and sea levels slow in their rising. Furthermore, removing CO_2 from the atmosphere and storing it in 'sinks' on land also prevents ocean acidification. A physical pump in the ocean-atmosphere interface exists, where CO_2 dissolves in sea water. CO_2 then reacts with water to form Carbonic acid ($CO_2 + H_2O \rightleftharpoons H_2CO_3$), which dissociates into hydrogen Carbonate ions ($H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$) and carbonate ions ($HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$). The increase in concentration of the hydrogen ions decreases the pH of the water and adversely impacts ocean life, including coral. Also, coral and photoplankton deposits of $CaCO_3$ react with the H^+ ions to release this sink of CO_2 which then can re-enter the atmosphere. Thus, any decrease in atmospheric CO_2 is important in terms of both Climate change and Ocean acidification.

1% CO_2
91% HCO_3^-
8% CO_3^{2-}
respectively.

The implementation of the new monitoring sites in the four landscapes which are most important to NZ's Carbon balance — native forests, exotic forests, farmland and cities — is a strong step towards mapping our carbon profile. As aforementioned, native forests absorb more than expected amounts of carbon. This can be compared with exotic forests and if there are significant differences, efforts to plant more natives can be encouraged as opposed to planting exotic plants. Furthermore, farmland is

a significant industry in NZ. The new stations, for instance the one at Winchmore, will provide ~~trap~~ evidence on the impact of dairy farming and meat farming on CH_4 emissions predominantly. Once key evidence is ascertained, changes to the amount of farming and more significantly the type of farming (intensive vs. extensive) can be made. Perhaps, legislature can be implemented which states for every hectare of farmland, a particular amount of native forest must be planted. Finally, to counteract the effects. the measuring of CO_2 emissions in cities is significant as there is heavy use of burning fossil fuels in transportation and industry. Data can be collected and decisions can be made around cleaner types of transport and industry. As touched upon earlier, there are a variety of future initiatives that can be implemented including but not limited to, planting more natives, having legislature surrounding farming, enforcing cleaner ~~the~~ urban transport, etc. Overall, these new sites will allow NZ to grasp a more informed understanding of our carbon profile, which will help us make beneficial ~~sufficient~~ decisions to ensure the sustainability of the future.

In summation, NZ natives seem to be a key way forward for increasing carbon absorbance and consequently decreasing ~~the~~ the effects of climate change and ocean acidification. Then, with the implementation of new monitory sites, we as a country can better understand our carbon profile and make informed decisions.

Albedo ; surface + Shape of orbit
Neptune effect / hot + cold

QUESTION THREE: KUIPER BELT OBJECTS

The size and composition of the larger Kuiper Belt objects have been determined using changes in their albedos during their orbit.

Discuss how changes in albedo can be used to analyse the Kuiper Belt objects' surfaces and the shapes of their orbits. Furthermore, discuss the effect that Neptune has on the orbits of hot and cold classical Kuiper Belt objects.

The Kuiper Belt is a region of icy objects beyond the orbit of Neptune. Such a distance is roughly 30-55 AU from the Sun, and thus roughly 29-54 AU from Earth. Because of this significant distance, it is difficult to ascertain details about KBO's (Kuiper Belt Objects) sizes, compositions and shapes of orbits. However, utilising their albedos as well as the effect Neptune has on them, some educated inferences can be made.

Before understudy the use of the albedo effect, it is vital to understand the formation of KBOs. They are remnants of the protoplanetary disc beyond the frost line during the formation of the Solar system 4.6 billion years ago. KBOs include dwarf planets such as Pluto, Eris and Makemake. Thus, it can be appreciated that some icy planetissimals did come together via accretion, however they never became large enough to increase gravitational forces and become a planet, by clearing their area and joining with more planetissimals. This can be explained by the vast distances between planetissimals in the Kuiper Belt, after all, it does have a width of 25AU. On a further note, it can be perhaps concluded that Neptunes gravity interfered

This is because of the vast distance between the Sun, the source of light, and the Kuiper Belt, a lot of the intensity/luminosity is lost with increased distance, similar to a flash light.

With the formation of a large planet, similar to how Jupiter's gravity interfered during the formation of the Asteroid belt between Mars and Jupiter. However, ~~this is likely~~ in the context of Neptune and the Kuiper Belt, this is likely to be a relatively small factor. Now, once understanding that the KBOs are icey bodies which are fairly large (100km across), we can understand the relevance of utilising albedo to draw conclusions, given the vast distances. Now, the albedo scale has to be modified from Earth for the Kuiper Belt. An icey surface on Earth has an albedo of approximately 0.5–0.7, which is significantly higher than the average albedo of 0.05 of KBOs. Thus, to understand the composition of the KBOs, one would need to scale down the Earth albedo scale by a factor of roughly 10. Moving onto changes in albedo as a KBO orbits the sun, one can draw conclusions about the orbits. For instance, Eris has a atmosphere which freezes and condenses during its orbit. This would allign with when the orbit is close to the Sun and further from the sun. Because the state (phases) of the atmosphere changes during the orbit, one can conclude that Eris has an elliptical orbit rather than a circular orbit, as the distance from the heating effect of the sun continuously changes. Furthermore, Movemanve develops an atmosphere during its orbit which suggests that it has an elliptical orbit as at some points it will be closer to the Sun and the solid surface will temporarily be converted into a gaseous atmosphere. As for determining the composition of the surface, one the albedo of these state (phase) changes allows us to detect this.

can utilise the differences in boiling and melting points of particular molecules ~~and~~ in conjunction with the albedo. For instance, the carbon monoxide ~~will convert into a~~ on Pluto will become a solid before methane as Pluto moves 'further' away from the Sun in its elliptical orbit. The exact times at which there are significant shifts in albedo reflect a phase change, which can then be placed next to a relative temperature ~~to help~~ scale, to help identify the identities of the molecules making up the compositions of KBOs.

Moving on, Neptune's gravity effects the orbits of KBOs relatively significantly. KBOs whose paths come near to Neptune (based on position in space as well as relative time of orbits) will be affected by its gravity. These are called "hot" Classical KBOs and have elliptical and tilted orbits. This is because they orbit not only about the Sun but about a shared gravitational centre between themselves, Neptune and the Sun. Although Neptune's gravitational force is much lower in magnitude than the Sun's, because it is a ~~much~~ lesser distance from the KBOs, it is rendered strong enough to create a noticeable change. On the contrary, "cold" classical KBOs have relatively circular orbits that are more or less in the plane of the planets. This is because they have little interaction with Neptune's gravity. Now, it would be easy enough for them to just be further away in the

Kuipe Belt, such that Neptunes gravitational force effect weakens, whilst the Sun's remains relatively strong. However, "all classical KBOs have a similar average distance from the Sun of between about 40 and 50 AU." This suggests that Neptunes weakened influence is not due to further distance between the KBO and Neptune in a 1D line, but rather the distance between the "cold" KBO's and Neptune in a 2D plane. This means that the lengths of the orbits of the KBO's and Neptune, in terms of time, could be similar and they are at opposite sides of the plane at any given time. Thus, the only significant impact on the "cold" KBO would be the Sun, hence resulting in a relatively circular, non-tilted orbit path.

Overall, in spite of the vast distance between Earth and the Kuipe Belt, we are still able to draw conclusions utilising the effects of albedo and Neptune's gravity.

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

QUESTION NUMBER

1. the "fire storm" cycle, in which lightning strikes caused by pyroCbs cause new fires. Thus, it looks like significant wildfires can be most effectively prevented in the initiation stage of the cycle. This means finding alternatives to clearing land for farming, or rather shift to more intensive as opposed to extensive land use. Furthermore, education and awareness is a key factor. For instance, scattered all over NZ are signs which tell people the relative fire risk for that day. As mentioned earlier, humans do often ~~start~~ start fires, mainly when clearing land, etc. Now, for volcanic eruptions, we cannot control the movement of tectonic plates, however we can limit the effects of volcanic eruptions on humans by early detection, etc. Overall, volcanic eruptions both seem to be ~~the hardest~~ harder to prevent ~~or even inadvertently cause by human~~ the effects of. interactions. This fact tied in with the fact that they have more significant global cooling effects as well as a broader range of short term and long term effects, renders the volcanic eruptions a more significant threat.

Overall, volcanic eruptions are the more significant threat to global ~~climate~~ climate, ~~however~~ however, we can control the spread of wildfires more. Thus, it is up to us to at least try and control wildfires, ~~so as not make the situation~~ so that the overall global climate impact can be minimised.

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QUESTION NUMBER

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QUESTION NUMBER

93104

Subject	Earth and Space Science Scholarship	***Standard***	93104	***Total score***	15

Q	***Score***	***Annotation***
1	5	The candidate has been awarded a 5 rather than a 6 because they have done a good compare and contrast between the wildfire and volcanic eruption effects. However, they have not explored how human interactions can affect these phenomena in enough detail to be awarded a 6.
2	4	The candidate has attempted to discuss the possible reasons for the higher carbon dioxide absorption, but this is not enough to receive a 5 on this question. The monitoring discussion is comprehensive which is why it is a 4.
3	6	This question provides evidence towards 6 rather than a 7 for outstanding because the candidate explains how Kuiper Belt Objects orbit can be affected by distance from the Sun and how Neptune's gravity affects their orbit. However the candidate does not discuss how the albedo changes with orbit.